OS-299 (10-22)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.penndot.pa.gov

TRANSMITTAL LETTER

PUBLICATION:

Publication 222

DATE:

3/3/2025

SUBJECT:

March 2025 Edition, Publication 222 – Geotechnical Investigation Manual

INFORMATION AND SPECIAL INSTRUCTIONS:

Publication 222 (Geotechnical Investigation Manual), March 2025 Edition is to be issued with this letter.

The issuance is effective immediately for all projects not yet in the preliminary design phase. To promote time-neutrality and cost-neutrality of this issuance, any Department project that is currently at or beyond the geotechnical development phase (i.e., bidding and contracting of geotechnical drilling) may be completed under the November 2022 Edition of Publication 222 specifications. PennDOT Form URL links have been revised and updated throughout in this edition. No new policy or procedural changes have been completed.

CANCEL AND DESTROY THE FOLLOWING:

Publication 222, November 2022 Edition

ADDITIONAL COPIES ARE AVAILABLE FROM:

☒ PennDOT website - www.penndot.pa.gov
Click on Forms, Publications & Maps

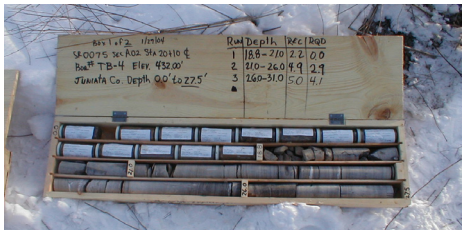
APPROVED FOR ISSUANCE BY:

Digitally signed by Jonathan A. Eboli, P.E.
Date: 2025.03.06 07:47:12 -05'00'

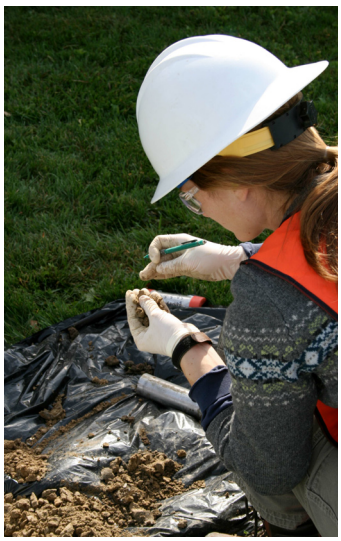
Jonathan A. Eboli, P.E.
Chief Executive, Highway Administration

Digitally signed by bevemiller
Date: 2025.03.05 16:31:31 -05'00'

Beverly L. Miller, P.E.
Chief Geotechnical Engineer
Bureau of Construction and Materials



Geotechnical Investigation Manual



pennsylvania
DEPARTMENT OF TRANSPORTATION
www.penndot.pa.gov

PUB-222 (3-25)

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

PUBLICATION 222 –2025
GEOTECHNICAL INVESTIGATION MANUAL

TABLE OF CONTENTS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

PUBLICATION 222 –2025
GEOTECHNICAL INVESTIGATION MANUAL

PURPOSE AND SCOPE

A geotechnical subsurface investigation serves to identify and delineate subsurface materials and conditions relative to the design of proposed highway facilities. The purpose of this publication is to present the criterion that pertains to the Drilling Contractors working for the Department or the Department's consultant; and to present criteria defining the requirements and responsibilities of the geotechnical inspection forces.

This publication provides the specifications, forms, and instructions relative to the following subsurface investigation topics:

1. Drilling Contractor prequalification
2. Drilling Contractor performance evaluation
3. Drilling Inspector requirements (certification, performance, and responsibilities)
4. Subsurface Boring, Sampling, and Testing Contract (SBSTC) administration
5. SBSTC Standard Specifications
6. Drilling Inspector Guidance Documents (Appendices)

Complete administration of the geotechnical subsurface investigation (boring, sampling and testing) portion of a project is obtained by combining the information in this Publication and Publication 293, Geotechnical Engineering Manual. These publications cover the administration requirements, policies, and procedures of the planning and execution of subsurface explorations.

Maintenance and updates of this publication are the responsibility of the Construction and Materials Division. Users may submit questions or suggest modifications or additions to the current edition to GeoPub222@pa.gov.

CHAPTER 1 – DRILLING CONTRACTOR PREQUALIFICATION

1.1 PREQUALIFICATION PROCEDURE

The objective of the prequalification process is to provide a mechanism to identify the pool of Prequalified Geotechnical Drilling Contractors meeting the minimum requirements to bid on subsurface investigation contracts under this publication. Prequalification promotes timely project development with a quality end product. The following procedure, in conjunction with Figure 1.2-1, will be used in prequalifying Drilling Contractors for Department projects:

1. The prequalification criteria is outlined in Chapter 1.2.

2. The prospective Drilling Contractor must complete the application package and submit to GeoPub222@pa.gov. Please allow two to three business days for a response. If the file is over 10MB, scan at a lower resolution or break down the submission into multiple emails.

   The application package must include Form TR-432, Drilling Contractor Prequalification Request, with any supplemental documentation, and a copy of valid documentation that verifies the current name and ownership of your company. The documentation should include the name of the owner(s), partner(s), managing member(s) or equivalent of the organization. Examples of acceptable documents may include:

   - Article of Incorporation
   - Business certificate or license
   - Certificate of Formation
   - Charter document
   - Doing-Business-As document
   - Legislation excerpt showing the establishment/creation of your organization

   Any parent company or wholly owned subsidiary arrangements must be fully disclosed to the Department as part of the application package.

3. The Central Office Geotechnical Section will review the application, render a decision, and inform the applicant when the determination has been made to prequalify the Drilling Contractor.

4. The applicant may appeal the decision made by the Central Office Geotechnical Section. Appeals must be made in writing to the Chief Geotechnical Engineer (CGE). The appeal must clearly provide the basis for the appeal and include any supporting information and documentation. The appeal must be submitted within 30 days of the original notification of application status.

1.2 CRITERIA FOR PREQUALIFICATION OF DRILLING CONTRACTORS

The minimum requirements necessary to be considered for prequalification in the various drilling classifications is indicated in Table 1.2-1.

Table 1.2-1 – Criteria for Drilling Contractor Prequalification

CRITERIA ITEM (1)	CLASS B (2)	CLASS A (3)	CLASS S (4)	CLASS E1 (10)	CLASS E2 (10)
	General BST	General BST	Specialized BST	Environmental BST	Environmental BST
a. Number of years in business (5)	3	5	5	3 (11), 1 (12)	3 (11), 1 (13)
b. Number of Projects last 5-years (5)	10	20	20	10 (11), 1 (12)	10 (11), 1 (13)
c. LF of drilling past 2-years (5)	14,000	21,000	(17)	14,000 (11), 1,400 (12)	14,000 (11), 1,400 (12) 1,000 (13)
d. Number/LF of SPT soil samples during past 2-years (5)	2,400/ 3,600	3,600/ 5,400	(17)	2,400/ 3,600 (11), 240/360 (12)	2,400/ 3,600 (11), 240/360 (12), 80/120 (13)
e. LF of rock coring during past 2-years (5)	2,000	3,000	2000	2,000 (11)	2,000 (11)
f. Number of full-time operational drill rigs (6)	2	3	2	2	2
g. Number of employees (7)	3	7	5	3 (14), 2 (15)	3 (14), 2 (15)
h. Specialized drilling or field-testing experience	No	No	Yes (17)	No	No
i. Fulltime office manager	No	Yes	Yes	Yes	Yes
j. Project completion record (8) (9)	100%	100%	100%	100%	100%
k. Number of GMWs installed (16)	0	0	0	5 (12)	2 (13)

Abbreviations: BST = Boring Sampling and Testing LF = Linear Feet
GMW = Groundwater Monitoring Well

Notes: 1. Table presents minimum requirements; any exceptions must be approved by the Department in writing.

2. Class B - Capable of providing typical boring, sampling and testing, including Standard Penetration Testing (SPT), disturbed and undisturbed soil sampling, auger sampling, rock coring, and installation of piezometers and slope inclinometers. No full-time office manager required.

3. Class A - Same capabilities as Class B, but requires a greater level of experience and a full-time office manager.

4. Class S - Special Class capable of specialized drilling, testing or sampling generally not available from Class A or Class B Drilling Contractors; however, any entity applying for Class S must be prequalified as a Class A or B Driller, or can meet Class A or B requirements. See Note (17) for specialized drilling requirements.

5. Experience of employees with other drilling companies may factor into consideration for some required criteria during the review process, so long as adequate detailed documentation for the indicated experience is provided. However, such experience, if accepted, cannot serve as a complete substitution for Items (a.) and (b.), but may be given greater consideration for Items (c.), (d.) and (e.). Documentation of satisfactory completion for Items (a.) and (b.) may be required in some situations. If employee experience is accepted, the Drilling Contractor will be temporarily classified for a probationary period of two (2) years prior to being placed on the permanent list.

6. Provide a detailed list of equipment and accessories. Rigs and equipment must be owned by the drilling contractor and work efficiently. If applicable, specialized equipment to perform specialized BST (Class S) should be listed separately.

7. Provide resumes for drillers and full-time office manager, each indicating number of years of relevant experience in the drilling industry and their qualifications.

8. Provide a project list of completed projects for the past two years. Completion is defined as completing a project in a timely manner to the satisfaction of the owner. Completion history includes both Environmental and General drilling projects.

9. Provide a minimum of two letters of reference from other state agencies or private firms that indicate satisfactory performance.

10. Class E1 and E2 - Experience must include drilling under Health and Safety Plans (HASP) prepared as required in 29 CFR 1910.120 (OSHA) Hazardous Waste Operations and Emergency Response. Class E1 must include experience drilling under personnel protection Levels D and C. Class E2 must include experience drilling under personal protection Levels D, C, and B.

11. May be tabulated from any projects completed by the firm during this period.

12. Must include only projects completed under a HASP.

13. Must include only projects completed under a HASP using Level B with positive pressure, full-face piece self-contained breathing apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA personnel protection, approved by the National Institute for Occupational Safety and Health (NIOSH).

14. Total employees with or without OSHA health and safety training.

15. Individuals must possess mandatory 40-hour OSHA training in health and safety for hazardous waste operations and emergency response with current certificate. This must include enrollment in a medical surveillance program as specified in 29 CFR 1910.120 (OSHA) Hazardous Waste Operations and Emergency Response.

16. Groundwater monitoring wells (GMWs) are to collect geological data, groundwater data, chemical data on soil and water, and provide for long-term monitoring capabilities.

17. Specialized drilling or field testing experience includes work such as Horizontal Drilling (HZD), Inclined Drilling (IND), Air-Rotary Drilling (ARD), Off-Shore Drilling requiring a barge (OSD), Cone Penetration Testing (CPT), Dilatometer Testing (DMT), Pressure Meter Testing (PMT), Vane Shear Testing (VST), Borehole Geophysical Testing (BGT), or other testing. Specialized BST prequalification's can be obtained with approval and will be limited to the specific area(s) of expertise for which the Drilling Contractor can demonstrate satisfactory experience. Provide sufficient documentation meeting both requirements for the specialized BST in which you are applying:

Class S Minimum Requirements		
SPECIALIZED BST	**NUMBER OF TESTS OR LINEAR FEET OF DRILLING**	**NUMBER OF PROJECTS**
Horizontal Drilling (HZD)	1500 LF	3
Inclined Drilling (IND)	1500 LF	3
Air-Rotary Drilling (ARD)	3000 LF	3
Off-Shore Drilling (OSD)	1000 LF	3
Cone Penetration Testing (CPT)	750 LF	3
Dilatometer Testing (DMT)	10 Tests	2
Pressure Meter Testing (PMT)	10 Tests	2
Vane Shear Testing (VST)	10 Tests	2
Borehole Geophysical Testing (BGT)	Inquire	Inquire

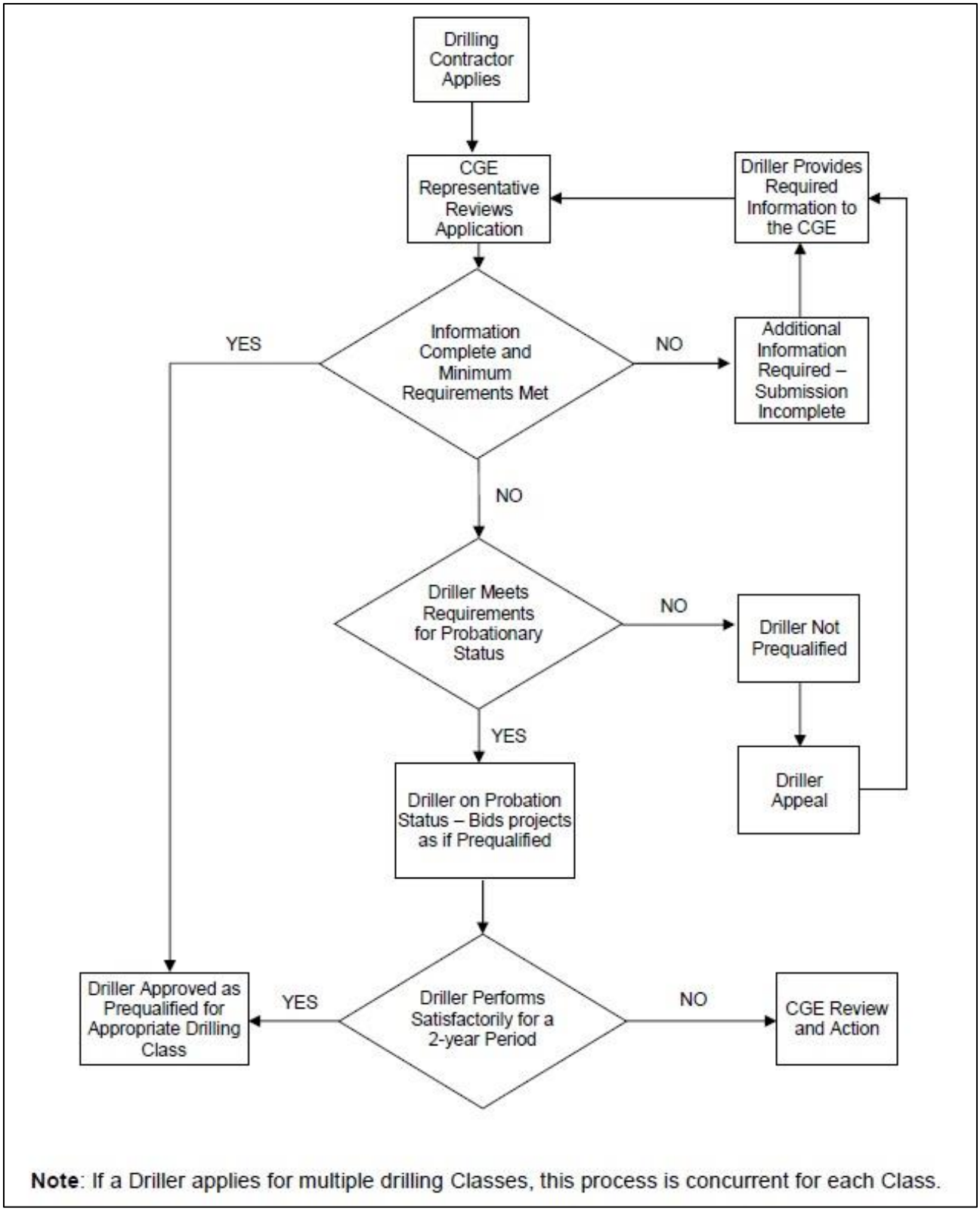


Figure 1.2-1 - Procedure Chart for Prequalification of Drilling Contractors

1.3 LIST OF PREQUALIFIED GEOTECHNICAL DRILLING CONTRACTORS

A current listing of Prequalified Geotechnical Drilling Contractors is maintained by the Central Office Geotechnical Section, and can be accessed at:

Prequalified Geotechnical Drilling Contractors

It is the responsibility of each Prequalified Geotechnical Drilling Contractor to ensure their contact information is kept up to date with the Department. The required contact information includes:

- Company name
- Mailing address
- Phone number
- Name of primary contact
- Email address of primary contact

Provide contact information updates to GeoPub222@pa.gov. If a Prequalified Geotechnical Drilling Contractor would like to prequalify for additional Classes, or to upgrade their current Class, a full submission including Form TR-432, Drilling Contractor Prequalification Request, must be provided with supporting documentation meeting all criteria as specified in Table 1.2-1 that provides the necessary supporting documentation for the additional class or upgrade. Provide submissions as specified in Chapter 1.1.

The Department will make periodic (bi-annual) notifications via email to all Prequalified Geotechnical Drilling Contractors. A response to the verification email is required within thirty days from the email date. For any Prequalified Geotechnical Drilling Contractor not responding to the email solicitation, a follow-up telephone call may be attempted by the Department. Any Prequalified Geotechnical Drilling Contractor that cannot be contacted will be removed from the prequalification list.

CHAPTER 2 – DRILLING CONTRACTOR PERFORMANCE EVALUATION

2.1 INSTRUCTIONS TO COMPLETE PERFORMANCE EVALUATION

The procedural flowchart for Drilling Contractor Performance Evaluation is presented Figure 2.1.3-1. The following sections discuss procedures for consultant and Department contracts and the rating procedure for required performance evaluations.

2.1.1 Consultant Contracts

1. The Project Geotechnical Manager (PGM) and project Certified Drilling Inspector(s) is responsible for preparing Form TR-433, Drilling Contractor Performance Evaluation. The PGM must be a P.E. or P.G. licensed in the Commonwealth of Pennsylvania. Note: the term "Engineer" refers to the corporation/company responsible on behalf of the Department for geotechnical work.
2. The PGM will discuss the Drilling Contractor's work performance with the District Geotechnical Engineer (DGE) prior to completing the Performance Evaluation.
3. The Consultant will send copies of the evaluation to the Drilling Contractor and the DGE for their review.
4. If the evaluation results in a satisfactory rating, copies of the evaluation must be submitted to the DGE. The DGE will send the evaluation to the CO Geotechnical Section.
5. If the evaluation results in an unsatisfactory rating and the DGE rejects the rating due to insufficient documentation, the Consultant will be notified of the deficiencies and must provide the required documentation and resubmit. If the DGE concurs with the unsatisfactory rating, it will be submitted to the Central Office (CO) Geotechnical Section for review.
6. If the rating is rejected by the CO Geotechnical Section, it will be returned to the DGE and Consultant with the deficiencies identified. Deficiencies must be addressed, and the evaluation must be resubmitted. If the CO Geotechnical Section approves the rating it will be returned to the DGE and Consultant with the necessary action defined.
7. Send information for the CO Geotechnical Section to GeoPub222@pa.gov. Please allow two to three business days for a response.

2.1.2 Department Contracts

1. The DGE and project Certified Drilling Inspector(s) will complete Form TR-433, Drilling Contractor Performance Evaluation.
2. The DGE will send a copy of the evaluation to the Drilling Contractor for their review.
3. Copies of the evaluation must be submitted to the CO Geotechnical Section. If the rating is rejected by the CO Geotechnical Section, it will be returned to the DGE

with the deficiencies identified. Deficiencies must be addressed and the evaluation resubmitted. If the CO Geotechnical Section approves the rating it will be returned to the DGE with the necessary action defined.

4. Send information for the CO Geotechnical Section to GeoPub222@pa.gov. Please allow two to three business days for a response.

2.1.3 Rating Procedure

- Record the exact company name of the Drilling Contractor and Drilling Inspector's organization.
- Describe the drilling project as specifically as possible
- If multiple drill crews are assigned to a project and the crew performance is notably different, each unit (drill crew) is to be rated separately.
- Assign a point value to all rating factors according to Table 2.1.3-1.
- Equipment, Safety, Procedure and Management Units: Calculate the 'Applicable Points', 'Earned Points' and 'Rating' for each unit using formulas shown on the evaluation form.
- For contracts extending one year or more, rate the Drilling Contractor at least once per year.
- In some cases, rating a Drilling Contractor prior to the completion of the contract would be appropriate. (e.g., a lengthy contract in which the Contractor is performing poorly) In such cases, mark the report at the top as "Interim Evaluation."

Table 2.1.3-1 - Key to Rating System Point Values

Bonus points	+1, +2	Drilling Contractor always performs this operation consistently throughout the project.
-	0	Drilling Contractor performs this operation correctly for the remainder of the project after verbal directive to correct a deficiency.
Penalty points	-1, -2, -3	Drilling Contractor continues to perform this operation incorrectly after verbally directed to correct a deficiency.
-	N/A	This factor not applicable to the project.

IMPORTANT:
Drilling Inspectors must provide daily documentation of drilling operations using Form TR-436, Drilling Inspector's Daily Report

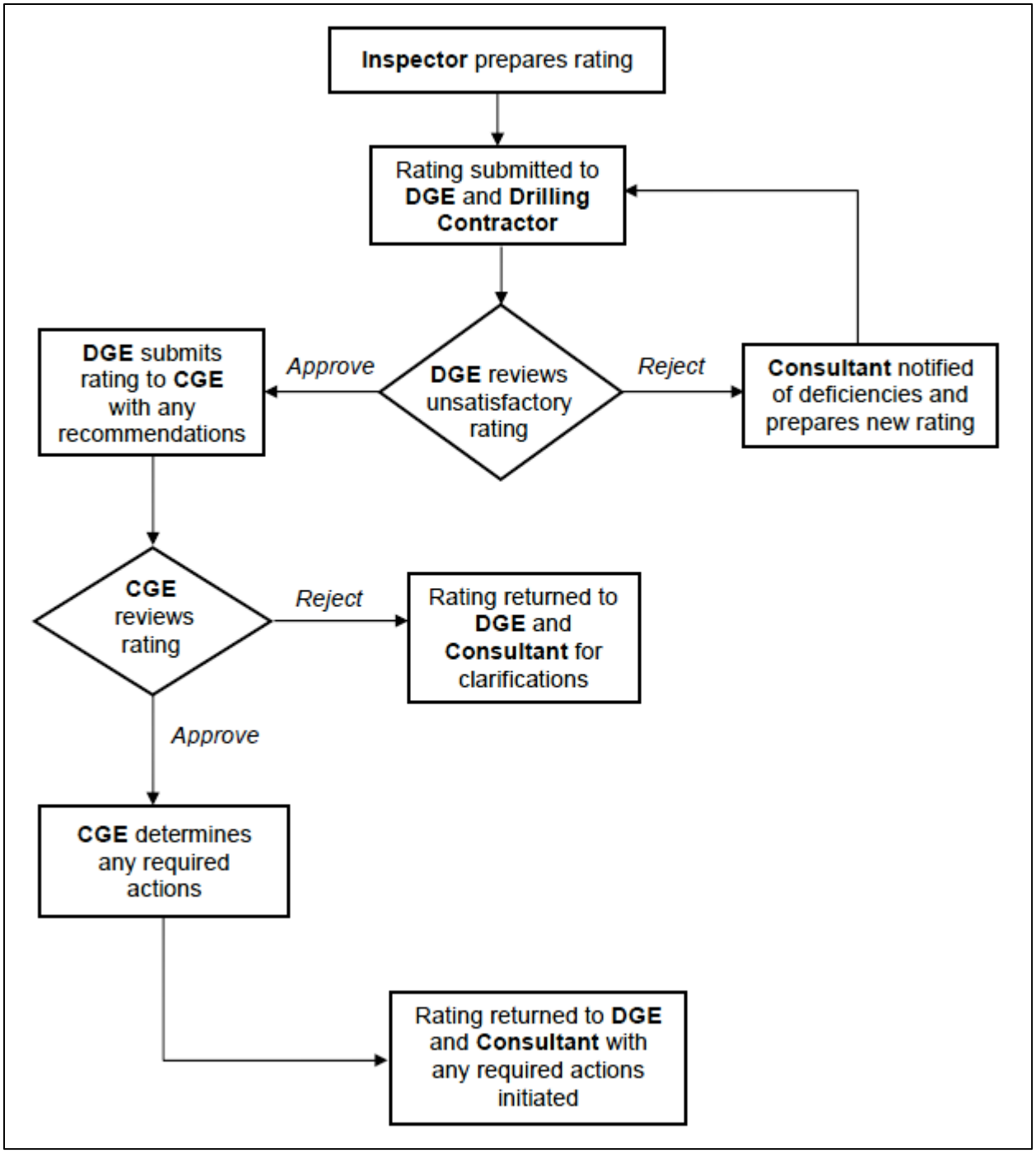


Figure 2.1.3-1 – Drilling Contractor Evaluation Procedural Flowchart

2.2 REMOVAL OF DRILLING CONTRACTOR FROM PREQUALIFIED LIST

The Department will maintain a performance evaluation record for each Drilling Contractor based on the information received from the District and Consultant offices. Any unsatisfactory rating received on any of the four contractor rating factors (Equipment, Procedure, Safety or Management) will be reviewed by the CO Geotechnical Section. During the review process, the Drilling Contractor must provide an explanation to the CO Geotechnical Section as

to the reason for the unsatisfactory rating and must demonstrate a plan for upgrading the rating to a satisfactory level.

Upon review, the CO Geotechnical Section will decide if the Drilling Contractor is to be placed on "Notice" status. A "Notice" status is to be a minimum duration of one year. During this period, the Drilling Contractor is allowed to bid on Department work. To be removed from "Notice" status, the Drilling Contractor must successfully work at least one Department project while on "Notice". This work must demonstrate that the Drilling Contractor has corrected any previous deficiencies related to the "Unsatisfactory" performance rating. This work must earn a "Satisfactory" performance rating and include a minimum of 50 ft. of SPT soil sampling and 50 ft. of rock coring. If a Drilling Contractor receives an unsatisfactory rating while on "Notice", the CO Geotechnical Section will review the rating to decide if the Drilling Contractor should be removed from the prequalified list. In the event a Drilling Contractor is removed from the prequalified list, the company will not be allowed to apply for prequalification for a time period deemed appropriate by the CGE, but not exceeding three years.

CHAPTER 3 – DRILLING INSPECTION REQUIREMENTS

3.1 MINIMUM REQUIREMENTS FOR DRILLING INSPECTION

All inspection will be the responsibility of the Project Geotechnical Manager (P.E. or P.G.). One full-time, Certified Drilling Inspector must be assigned to each operating drill rig with one full-time, drilling operator. It is not reasonable to expect a Drilling Inspector to visually monitor and accurately log the operation of two or more drilling rigs that are operating simultaneously.

Projects drilled under Department contracts will be inspected by District personnel or the District's representative. District Drilling Inspectors must be certified Drilling Inspectors. District employees needing to become certified must be tested and certified by the CO Geotechnical Section, or through other arrangements (such as testing by a neighboring District) as approved by the CGE.

Projects drilled under Consultant design contracts will normally be inspected by Consultant personnel. Consultant projects can be inspected by Department forces provided the Department Drilling Inspector is certified and the DGE is a licensed P.E. or P.G. in the Commonwealth. In addition, the DGE must review the core boxes and check and initial the Final Engineer's Log as shown in Chapter 3.6.6.

For projects where the geotechnical Consultant (or a subsidiary company thereof) is also a Drilling Contractor, the Consultant may be allowed to provide the project drilling services and to inspect the work performed by their own Driller. Reference Chapter 4.5 for more clarification on the requirements for this case.

The following minimum qualifications must be met by all Drilling Inspectors:

- Speaks, writes, reads and understands the English language fluently.
- Has prior drilling inspection experience on a minimum of three (3) drilling projects (Department or private) in Pennsylvania and surrounding states (refer to Appendix J for acceptable project locations) in the past two years, with minimum logging experience of 200 ft. of Standard Penetration Testing and 100 ft. of rock coring meeting Department requirements. Inspection credit is not given for auger advance footage during non-continuous sampling, such as augering through a soil zone for accessing top-of-rock, auger advances for 3-ft or 5-ft interval SPT sampling, or augering through pavement/asphalt. Minor amounts of augering can be counted when it is part of continuous sampling, such as when an obstruction or a 50/xx zone is encountered.
- Is knowledgeable of general drilling practices and the following references:
  - Publication 213 (Temporary Traffic Control Guidelines)
  - Publication 222 (Geotechnical Investigation Manual)
  - Publication 293 (Geotechnical Engineering Manual)
  - A copy of the boring contract for the project

  - A rock identification text (e.g., the *Audubon Society Field Guide to North American Rocks and Minerals*, the *Smithsonian Handbook of Rocks and Minerals*, other reference suitable for identification of PA rocks)
- Be able to: traverse rough, steep terrain; cope with inclement weather conditions; deal with potential natural hazards such as snakes, ticks, bees and poison ivy; work safely in the vicinity of live traffic and open bodies of water.
- Understands the general geotechnical design principles involved in the anticipated construction, and the anticipated laboratory testing.
- Successfully passed all parts of the Department's Drilling Inspector Examination and possess a valid drilling inspector certification issued by the Department.

Any Drilling Inspector who does not demonstrate adequate proficiency or dependability at the project site or engages in activities contrary to the best interest of the Department, as determined by the DGE, will be subject to immediate removal from the project. A qualified replacement will be required before work will be allowed to resume. The DGE must complete Form TR-437, Drilling Inspector Performance Evaluation, and submit copies to the removed Drilling Inspector and the CO Geotechnical Section within three working days of the dismissal.

3.2 CERTIFICATION POLICIES AND PROCEDURES

The purpose of this process is to provide a mechanism to certify drilling inspectors. The goal of this process is to provide qualified, knowledgeable drilling inspectors for overseeing drilling operations on Department projects. **Having a Certified PennDOT Drilling Inspector performing the required inspection duties does not release the consultant from the responsibility of providing accurate subsurface interpretations.** A certification procedural flowchart is presented in Figure 3.2-1. Submit Form TR-434, Drilling Inspector Examination Application, to apply.

- All Consultant drilling inspection forces must be certified by meeting the requirements of this publication and passing the standardized Drilling Inspector Examination.
- For minimum drilling inspector qualifications, reference Chapter 3.1.
- Certified Drilling Inspectors are subject to an orientation session prior to the start of drilling operations on any project at the discretion of the DGE. Inspectors are also subject to a quality-assurance performance review during drilling operations.
- Applications for project-specific drilling inspection certification must be submitted to the District where the project is located.
- Applications not related to a specific project (general state-wide certification) will be scheduled (time and date) at the convenience of the DGE at any one of the eleven Districts.
- Follow the Procedural Flowchart in Figure 3.2-1 to apply for the examination.
- Provide an application to the DGE at least thirty (30) days prior to start of drilling operations.
- The application submission must include the following:
  - Form TR-434, Drilling Inspector Examination Application

- Resume
- Project Listing. Provide a list of at least three projects inspected (project name and location), with a tabulation of SPT footage (200-ft min), auger footage, and rock coring (100-ft min) per boring that you inspected.
- Boring Logs. Provide copies of Inspector's Field Logs and Final Engineer's Logs used to tabulate the SPT, auger, and rock coring footage from each project that were inspected by the candidate.

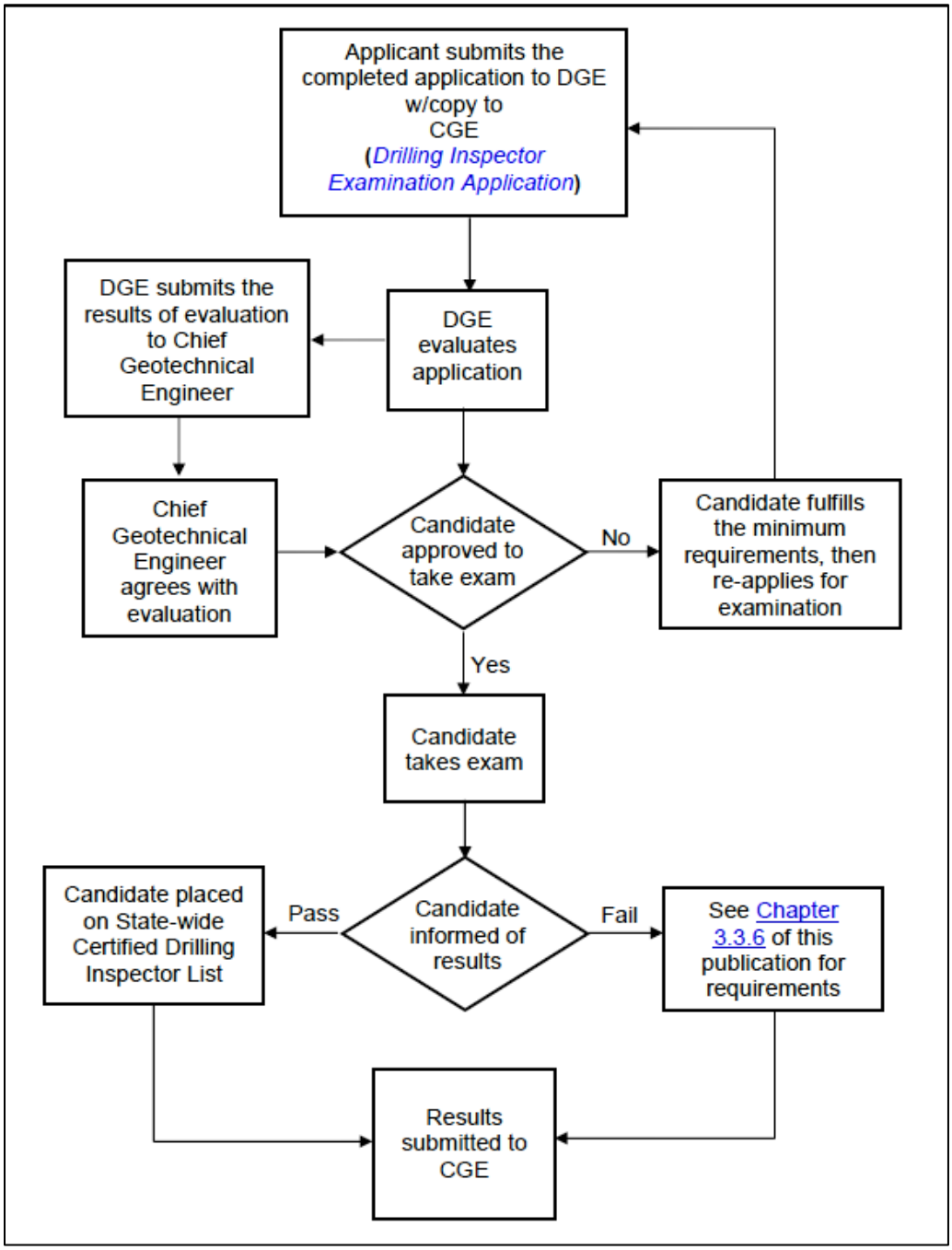


Figure 3.2-1 – Drilling Inspector Certification Procedural Flowchart

3.3 CERTIFICATION EXAM REQUIREMENTS AND GUIDELINES

3.3.1 Written Examination (Part-1 and Part-2)

Part-1 and Part-2 of the written examination is open-book and divided into two subject areas, Drilling Operations, Duties, and Technical Knowledge (Part-1) and Traffic Control (Part-2). There is a 110-minute time limit for the written test. Part-1 consists of 34 questions and covers all required duties and knowledge including geology, soil and rock identification, drilling operations, logging of borings, inspection duties, and Department guidelines/requirements. Part-2 consists of 8 questions and covers temporary traffic control procedures and requirements.

3.3.2 Rock and Soil Sample Identification Examination (Part-3)

Part-3 of the examination is an identification of rock and soil. The exam is also open-book and consists of a minimum of six soil identifications and 15 rock identifications. Districts can vary and may consist of additional samples (4 maximum). The candidate is allotted 85-minute time limit for the standard 21 sample test, with 5 additional minutes allotted for any additional sample. Physical descriptions are based on Publication 222 requirements. All candidates must be able to perform the following:

- Use of Publication 222
- Use the AASHTO and Unified (USCS) soil classification systems, and cross reference as necessary
- Identify different rock and soil types found in Pennsylvania
- Distinguish between siltstone, claystone, and shale
- Distinguish between carbonate and non-carbonate rocks
- Distinguish between sedimentary, igneous, and metamorphic rocks
- Distinguish between clay, silt, sand, and gravel

3.3.3 Required References, Identification, and Tools

The following materials will be required when sitting for the Drilling Inspector Examination. None of the materials below will be supplied by the Department to take the exam. **Failure to bring any of the materials below will result in failure of the exam and will require the candidate to follow re-examination procedures.**

- Technical references as listed under the third bullet in Chapter 3.1, other pertinent geologic references.
- Driver’s license
- Black pen, pencil, eraser, calculator
- 10% HCl acid solution, pocketknife, hand lens, common hardwood dowel (not oak), copper pipe or penny, common steel nail, steel file, plate glass (recommend ¼” thick)

3.3.4 Examination Rules

The following examination rules apply:

- Communication with any other applicant or source (including via telephone or laptop) during the examination is prohibited, except with the DGE or their designate. Prohibited communications will result in immediate failure of the exam.
- Required examination references, publications, or other required items will not be supplied at the test site as referenced in Chapter 3.3.3. The required references must be available as hard copies. Failure to bring required examination materials will result in their forfeit of the exam. These candidates must reapply to take the exam.
- Sharing of examination items or references between applicants is not allowed.
- Examination materials or answers may not be removed from the test site in any form.

3.3.5 Pass/Fail Requirements

To be placed on the Certified PennDOT Drilling Inspectors list, candidates must demonstrate overall aptitude by meeting minimum scoring requirements for both the Written and Sample Identification portions of the examination.

- For Part-1 of the exam, a minimum score of **70%** is required to pass.
- For Part-2 of the exam, a minimum **6** correct responses out of a total of **8** are required. If less than six of the questions are completed successfully, the candidate fails the entire exam, regardless of the overall exam score.
- For Part-3 of the exam, an overall minimum score of **70%** is required to pass. Also, the applicant must score at least **66%** on only the soil samples, regardless of the overall score for Part-3, to pass the exam.
- If a passing score is not achieved in any one part of the exam, the candidate must retake the entire exam (Part-1, Part-2, and Part-3). A procedural flowchart for Pass/Fail requirements is presented in Figure 3.2-1.

3.3.6 Failure of Examinations

The following requirements must be completed prior to re-application by the Drilling Inspector:

- Work on three documented drilling inspection projects completed after the failed exam.
- At least one of the three projects must be on a Department project as an apprentice. Apprenticeship is at no additional cost to the Department. Total footage requirements are as defined in Chapter 3.1. Indicate what project was completed as an apprentice in the project listing documentation of the application.

- Central Office Geotechnical Section maintains the right to waive requirements for specific situations determined on a case-by-case basis. This may include total footage requirements or accepting apprenticeship on a non-Department project (i.e., PA Turnpike or Port Authority project). Waivers are dependent upon demonstrated and documented corrective action taken by the applicant and/or their employer.

3.3.7 Examination Results

The DGE must proceed with examination results, as follows,

- The DGE must inform the CO Geotechnical Section of examination results via email within three working days of the exam. The DGE will submit the full exam and results to the CO Geotechnical Section via GeoPub222@pa.gov.
- Upon review of the examination results, the Central Office Geotechnical Section will notify the District of the findings. At this point, the DGE will notify the candidate of the exam results. When a candidate meets all requirements, and passes the examination, the CO Geotechnical Section will email a certificate to the successful candidate(s). The certification number and contact information of the newly certified Drilling Inspector will be included on the current listing of all Certified PennDOT Drilling Inspectors maintained by the CO Geotechnical Section.
- Form TR-435, Drilling Inspector Post-Examination Checklist, must be completed to indicate any areas of weakness exhibited on the exam. The checklist must be completed by the DGE whether the candidate passes or fails and emailed to the candidate. This list should be reviewed by the candidate in preparation for inspection duties or reapplication. The DGE will also copy/include the CO Geotechnical Section on the email.

3.3.8 List of Certified PennDOT Drilling Inspectors

A current listing of all Certified PennDOT Drilling Inspectors is maintained by the CO Geotechnical Section, and can be accessed at:

Certified PennDOT Drilling Inspectors

Once certified, the Drilling Inspector is responsible to promptly notify the Department any necessary update to their personal contact information by email to GeoPub222@pa.gov. Refer to the published Certified PennDOT Drilling Inspectors list for contact information to verify and report personal contact information changes.

The Department will make periodic (bi-annual) notifications via email to all Certified PennDOT Drilling Inspectors. A response to the verification email is required within thirty days from the email date. Any Certified PennDOT Drilling Inspector that cannot be contacted or does not respond will be removed from the certification list and placed on the Probationary List for a period of one year before being de-certified. Only

those Drilling Inspectors that are listed on the published Certified PennDOT Drilling Inspectors list are considered to hold a current and valid certification.

3.4 DUTIES OF INSPECTION FORCES

The general duties of a Drilling Inspector include:

- Verify the testing and sampling procedures are performed correctly.
- Ensure the depth of each sample is known and recorded correctly.
- Describe soil and rock samples correctly.

3.4.1 Prior To the Start of Drilling Operations

The PGM is responsible to notify the DGE of the planned start-date of drilling and to forward to the DGE a copy of the Drilling Contractor's submission providing applicable information required by Sections 104.01, 104.03, 104.08, and 104.09. The Drilling Inspector is responsible to:

- Have a copy of the "Intent to Enter" letter available at the site and confirm that arrangements for property access were made. Document all information that was discussed between the property owner(s) and the driller. Be prepared to provide the Department with written documentation of this contact
- Determine the apparent adequacy of the Drilling Contractor's drilling equipment. If any equipment appears faulty or questionable, the Drilling Inspector should discuss this with the driller and the PGM, if warranted
- Determine the adequacy of the Drilling Contractor's equipment for temporary maintenance and protection of traffic
- Determine if the Drilling Contractor has contacted all utilities and that all utilities are clearly marked in the field
- Visually confirm all plan locations of borings, test pits, and instruments are clearly staked according to plans or instructions given by PGM. Notify the PGM if any discrepancies are found or suspected. Note if any locations appear to be within 100 ft. of any domestic water supply wells or spring boxes and if so, confirm that the Drilling Contractor has the proper provisions as specified in Section 218
- Conduct field view of the site and understand what work is to be done. Note any environmental sensitive areas and if any temporary traffic control will be needed
- Study all documents, reports, and any other previous borings that were done at the site or nearby sites.
- Have a list of emergency telephone numbers, hospitals, and maps available at the site.
- Study the drilling contract and all attachments. If applicable, obtain and review the site-specific Health and Safety Plan (HASP)
- Be familiar with the subsurface investigation plan
- Understand the information to be gathered, its purpose in design and use for lab testing

3.4.2 During Drilling Operations

The PGM is responsible to keep the DGE promptly informed of any issues or problems. The Drilling Inspector's responsibilities include:

- Complete Form TR-436, Drilling Inspector's Daily Report
- Keep daily drilling quantity records/summaries, and review quantities with the driller each day work is completed
- Label all samples and core boxes and log all test borings and test pits as specified in Chapter 3.6
- Ensure that the operations are performed according to the terms of the work and all relevant publications and guidelines. Promptly report and document in detail any unexpected findings or problems to the PGM
- Be attentive and follow safe work practices at all times. During field work, wear appropriate safety apparel at all times including hard hat, high-visibility safety vest or shirt, and leather work boots
- Document instrument installations, including, but not limited to, types, locations, installation procedures and any problems encountered during installation
- Record any instructions given to the Drilling Contractor including date, time, to whom, and the driller's response and whether actual work was performed as per the instructions
- Maintain any records required by this publication or the DGE
- Record in detail any events or situations that may later result in litigation or a claim against the Department including emergency situations where an injury or fatality has occurred. Immediately notify the DGE of any injuries or fatalities.
- Confirm and have the Drilling Contractor make necessary field adjustments of the work zone traffic control set-up using Publication 213
- Act as a responsible representative of the Department at all times
- Document and assist to resolve any issues with the driller, motorists, and/or property owners during field operations. Communicate clearly. Be professional and courteous
- Have the following available at the jobsite:
    - All required technical references as listed in Chapter 3.1 and other pertinent geologic references
    - Driver's license
    - Black pen, pencil, eraser, calculator
    - 10% HCl acid solution
    - Pocket knife, hand lens, common hardwood dowel (not oak), copper pipe or penny, common steel nail, steel file,
    - PennDOT Drilling Inspector Certification Number

3.4.3 Drilling Inspector's Daily Report

Complete Form TR-436, Drilling Inspector's Daily Report. The Inspector will maintain and update daily a record for each drill rig, of the work completed including footage of drilling in

soil and rock. The record will document the quantity of each pay item listed in the Form of Proposal (Form TR-444, Form of Proposal) completed during the day. The record will also indicate, for each day, the driller's name, the helper's name and the hours worked. The record must document any verbal directives and the resulting corrective action performed by the driller. The record must note in detail any unusual events or conditions (e.g., petroleum odors or saturation thereof, damaging underground utilities, any situations that may later result in litigation or a claim against the Department) and their resolution and/or action taken. Failure to supply proper documentation may result in the Department taking necessary corrective actions upon the Inspector, including De-Certification. The Inspector and the Driller must review and sign the record daily to indicate agreement of the documentation and to indicate agreement with the quantities listed as complete. Also, note any disagreement with either the documentation or the listed quantities. One copy of the record will be made available to the PGM at the end of each workday, or weekly if agreed to by the PGM.

3.5 EVALUATION OF DRILLING INSPECTORS

3.5.1 Evaluation Procedure

All Drilling Inspectors should be formally evaluated by the Department (or a qualified representative of Department staff) on every project for performance of inspection duties using Form TR-437, Drilling Inspector Performance Evaluation. Evaluations can be based on delivered product. For better quality assurance, it is **strongly recommended** that evaluations be based on an actual site visit during the drilling operations, when possible. It is expected that the DGE (or a qualified representative of Department staff) complete a minimum of 10 evaluations of drilling inspectors throughout the calendar year. If a Drilling Inspector is removed during operations due to unacceptable performance, Form TR-437, Drilling Inspector Performance Evaluation, must be completed by the DGE as specified in Chapter 3.1. A copy of all completed performance evaluation forms must be forwarded by email to the CO Geotechnical Section at GeoPub222@pa.gov.

3.5.2 Recommended Actions by the DGE

Item number six on Form TR-437, Drilling Inspector Performance Evaluation, requires the DGE to recommend one of the following based on the Drilling Inspector’s performance.

- **Certification -** Drilling Inspector performance is ‘Satisfactory’ to ‘Excellent’ and individual should remain a Certified PennDOT Drilling Inspector.
- **Probationary Certification -** An overall performance of ‘Unsatisfactory’ can result in a certified inspector to be placed on probationary certification status. An Inspector placed on probationary certification remains on the statewide approved list; however, an additional documented ‘Unsatisfactory’ or ‘Unacceptable’ performance during probation may result in de-certification. The minimum duration of probationary certification is one year. In addition, the Inspector must inspect at least one project and receive a ‘Satisfactory’ or better performance rating to be removed from probationary status.

- **De-Certification -** The CGE may revoke a Drilling Inspector's certification if blatantly uncooperative, unsafe, or incompetent performance is thoroughly documented and receives an 'Unacceptable' rating. De-certification may also occur if the Drilling Inspector receives an 'Unsatisfactory' or 'Unacceptable' rating while on probationary status. The individual may apply for re-certification after a one year waiting period and the performance issue(s) prompting the de-certification have been resolved to the satisfaction of the CGE.

The CGE may take independent actions if the situation warrants. Prior to a CGE making a final determination of 'Probationary Certification' or 'De-Certification,' the Drilling Inspector will be provided with written notice of the CGE's intent to make such a determination and be provided with an opportunity to meet with the CGE and present any mitigating evidence or facts relevant to the CGE's determination. The CGE's written determination will be considered the Department's final determination and will only be appealable to the Secretary, as specified in the Administrative Agency Law, 2 Pa. C.S. § 101 seq. The CO Geotechnical Section will notify all DGE's of any Drilling Inspector who has been placed on probationary status, or who has been de-certified.

3.6 INSPECTOR'S FIELD LOGS AND FINAL ENGINEER'S LOGS

The Drilling Inspector is required to log all borings in the field, observing and recording information as the boring is being completed. The Inspector's Field Logs are to be submitted daily or weekly as required by the PGM or DGE. Log a boring by recording the field observations needed to complete the standard format "Final Engineer's Log", including information identified in Chapter 3.6.1 and Chapter 3.6.2. Log a test pit by recording the information required on the final standard format "Engineer's Test Pit Log" including the applicable information identified in Chapter 3.6.1 and Chapter 3.6.2. Describe soil samples and rock core samples conforming to the requirements of this publication, and record on standard hand-written field logs or PDA-generated field logs.

3.6.1 Information required on the Inspector's Field Log

- Project identification, including ECMS#, state route or local designation, section, district, and county
- Identification number for the test boring or test pit. Use the following acceptable naming conventions:

Table 3.6.1-1 – Boring Naming Convention[1]

Type of Boring	Abbreviation
Roadway/Other Boring	RB
Structure Boring	SB
Sign Structure	SS
Noise Wall	NW
Retaining Wall/MSE Boring	RW
Test Pit	TP

Notes: 1. For multiple borings of a structure or wall, include collated numbering following each abbreviation (i.e., SB1-01, SB1-02, SB1-03, SB2-01, RW1-01, RW1-02, RW1-03, RW2-01).

- Original ground elevation at the top of the test boring to the nearest 0.1 foot/feet
- Date and time at which the boring was started and completed as well as the date and time the boring was grouted
- Name of the drilling company, drill operator, and type of drill rig used
- Drilling Inspector name and PennDOT certification number (for District and Consultant inspection)
- Location of test boring relative to project reference line (e.g., segment/offset, station/offset from centerline) or other suitable references given by the PGM. Include the geodetic coordinates or state plane coordinates, whichever is known
- SPT hammer type (automatic, safety, or donut). Record the measured hammer efficiency rating (ER) and calibration date, if known
- Casing type, diameter, and depth (if used)
- Size of hammer and free fall used to advance casing (if used)
- Depth, type, number, relative moisture content and recovery of each soil sample
- Drilling method used to advance the boring in soil. Use the following hole types:

Table 3.6.1-2 – Type of hole to Advance the Boring in Soil

Hole Type	
Auger with Shelby Tube	Interval SPT - Rock Core
Continuous SPT	Auger
Continuous SPT - Rock Core	Auger - Disturbed Sample
Interval SPT	Auger - Rock Core

- Rock coring method used to advance the boring in rock. Include type and size of core barrel. Include the condition of the core bit, if known. Use the following rock coring methods:

Table 3.6.1-3 – Type of Rock Coring Method

Rock Coring Method[1]	
Double Tube Wire-Line - HQ	Triple Tube Wire-Line - HQ
Double Tube Wire-Line - HX	Triple Tube Wire-Line - HX
Double Tube Wire-Line - NQ	Triple Tube Wire-Line - NQ
Double Tube Wire-Line - NX	Triple Tube Wire-Line - NX
Double Tube Split-Inner Brl - HQ	Triple Tube Split-Inner Brl - HQ
Double Tube Split-Inner Brl - HX	Triple Tube Split-Inner Brl - HX
Double Tube Split-Inner Brl - NQ	Triple Tube Split-Inner Brl - NQ
Double Tube Split-Inner Brl - NX	Triple Tube Split-Inner Brl - NX

Notes: 1. Refer to Section 204 for approval of alternate rock coring methods.

Table 3.6.1-4 – Dimensions of Core Sizes

Size	Hole (outside) Diameter	Core (inside) Diameter
HQ	3.791 inches	2.500 inches
HX	3.650 inches	2.406 inches
NQ	2.980 inches	1.874 inches
NX	2.980 inches	2.154 inches

- Change in drilling method and reasons for such changes
- Hammer blows to advance split-barrel sampler 6 inches. If sampler advances less than 6 inches after 50 blows, record the depth of penetration for 50 blows (e.g., 50 / 0.2 ft.)
- Unconfined compressive strength of fine-grained cohesive soils based on Pocket Penetrometer and/or Torvane tests
- Depth, type, number, total recovery length of core recovered, and Rock Quality Designation (RQD) recovery length for each run of rock core
- Description and identification of each soil and rock stratum as specified in Chapters 3.6.3, 3.6.4, and 3.6.5.
- Depth to top and bottom of profile for each distinctive interval, layer or horizon in soil, rock, and anomalous zones
- Depth to groundwater level, measured immediately after completion of drilling (0-hour), and 24-hours after completion of drilling. Determine using an electronic water level meter.
- Depths at which field tests are made and results of the tests (if available)
- Difficulties in drilling such as obstructions, caving, boulders, rising of sand into bottom of boring, etc. If there are potential or likely causes for unexpected drilling results (e.g., lower than anticipated recovery, tool advancement problems, no recovery), indicate any potential causes that exist and may result in the observed conditions
- Depth of loss and return of circulating water. Also, note any increase in usage of drilling water

3.6.2 Information required on the Final Engineer's Log

The Final Engineer's Log must be in the appropriate format. The Final Engineer's log is comprised mostly of the information taken from the Inspector's Field Log but may also contain appropriate information from the laboratory testing results and Form TR-442, Driller's Boring Log, as determined by the PGM of record.

All Final Engineer's Logs must be sealed by a Professional Engineer (P.E.) or Professional Geologist (P.G.) currently licensed in the Commonwealth of Pennsylvania. A P.E. or P.G. who has completed the drilling inspection on a project may check their own work so long as they are cross checking all completed borings for accuracy and boring to boring consistency. Furthermore, if two different drilling inspectors are on the same project, the borings must be

checked for boring to boring consistency; in other words, similar borings with minor differences in description. The log must be sealed by the individual checking and approving the log. The purpose of the seal is to attest to the accuracy of information provided on the log as can be verified by inspection of core boxes and review of information provided by the Drilling Inspector. Since much of the information is collected through visual observation and field diagnostic procedures, it is not intended to imply sealing of the log assures 100 percent accuracy of the information presented. Rather, the seal attests the information on the log is consistent with materials and information contained in the core boxes representing the specific bore hole, and the reasonable accuracy of material (soil and rock) descriptions and identifications. The term reasonable accuracy reflects the realities of the variable nature of subsurface materials, the range of characteristics within specific soil and rock material types, the limitations of field identifications/classifications, and the inherent subjectivity in documenting field observations.

In addition to the information recorded on the Inspector's Field Log, the Final Engineer's Log is to include the following:

- Depth and Elevation at top of rock to the nearest 0.1 ft., if applicable
- Coordinates of the boring: The Drilling Inspector is to record the horizontal coordinate of each boring. This information will be provided by the project designer and will be in both of the following formats:

  State Plane Coordinates: _ _ _ _ _ _._ _ _ _ _N _ _ _ _ _ _._ _ _ _ _E
  Geodetic Coordinates: N _ _ º _ _ ' _ _._ _ " W _ _ º _ _ ' _ _._ _ "

  Because this information is commonly provided as Geodetic Coordinates (latitude and longitude), the links below will aid in the conversion of the Geodetic Coordinates into State Plane Coordinates (northing and easting). Coordinates of all borings are to be provided by the project designer and must be recorded on the final boring logs. This is required to enable standardized electronic data entry and to facilitate the long-term retracement of boring locations.

  NOAA State Plane Coordinate Utilities Online
  NOAA Geodetic Software
  US Army Corps of Engineers Corpscon Software

- Graphic column that gives a visual depiction of different soil and rock types encountered in the boring. Use the patterns shown in Figure 3.6.8-1(a), (b), and (c) and also accent shading as specified in Chapter 3.6.9.
- A graphical depiction of sample RQD percentage, SPT (N) value, soil recovery (percent), and rock recovery (percent) versus depth of boring
- Indicate when laboratory testing has been performed by using capital letters to designate the laboratory AASHTO/USCS soil classification. The laboratory classification must be applied to all adjacent materials (directly above and below the laboratory sample depth) that are equivalent (visually, textually, and behaviorally the same). For example, lab classified material from 12.0 – 13.5 ft. must be applied to entire soil strata, 10.5 – 15 ft. if the adjacent materials are

equivalent. Any other soil strata in the boring that are not adjacent, but are equivalent (visually, textually, and behaviorally the same) to the laboratory classified soil strata, must be revised to the appropriate visual classification. A sample boring of a field and laboratory classification is provided in Figure 3.6.2-1. The field classification of the soil stratum from 6.0 – 9.0 ft. is visually identical to the soil stratum from 10.5 – 15.0 ft. The laboratory sample was collected from 12.0 - 13.5 ft. and classified as A-4. The original field classification of the soil stratum from 6.0 – 9.0 ft. must be revised to the appropriate visual classification (in this case, a-4).

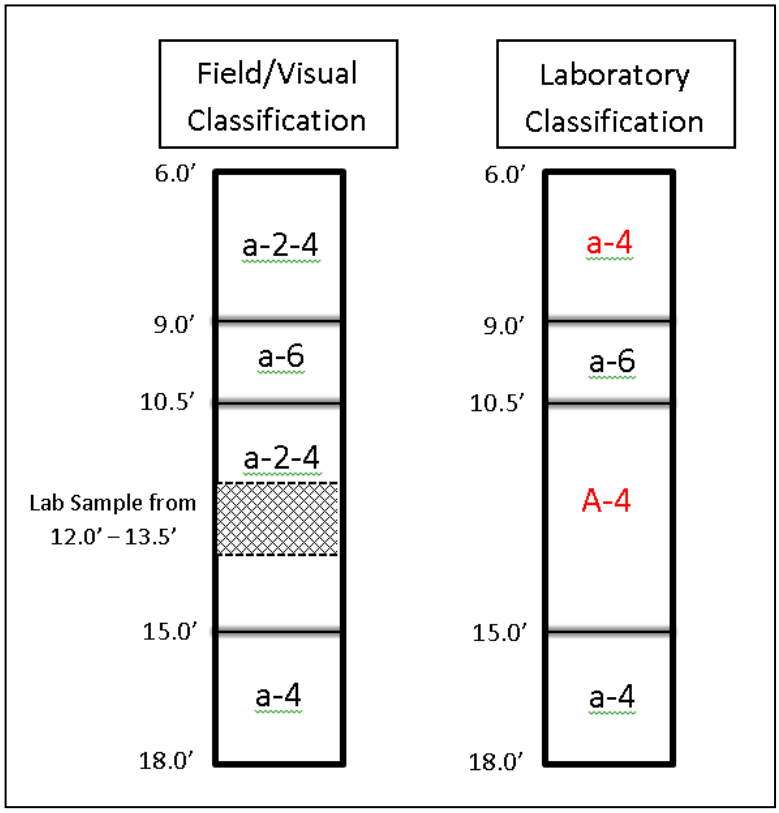


Figure 3.6.2-1 – Field Classification Corrections based on Laboratory Testing Results

- SPT Hammer Efficiency. SPT Hammer energy efficiency can be measured conforming to ASTM D4633. The Department requires the Drilling Contractor to provide measured hammer efficiency (ER_m) values for Donut hammers. The Department is currently not requiring measured ER_m values for Automatic hammers or Safety hammers; however, this information is to be recorded on the log if available from the driller. If actual calibration data is not available, an assumed hammer efficiency value (ER_a) will be recorded on the Final Engineer's Log and noted as such. The corrected N-value will be calculated and recorded on the Final Engineer's Log using the following equation:

$$N_{60} = \frac{ER * N_{unc}}{0.60}$$

where:

N_{60} = corrected N-value (rounded down to the nearest whole number)
ER = hammer efficiency (measured or assumed – see table below for assumed values)
N_{unc} = uncorrected N-value, number of hammer blows on the bottom 12 inches of penetration

Assumed hammer efficiency values (ER_a) based on hammer type will be according to Table 3.6.2-1. Note that for an assumed Safety hammer efficiency, no correction is necessary since the correction equation yields a value of 1.0.

Table 3.6.2-1 – Assumed Hammer Efficiency Based on Hammer Type

Hammer Type	Assumed Efficiency (ER_a)
Automatic	0.80
Safety	0.60
Donut	0.45

3.6.3 Standard Descriptors for Soil Samples

Soil is defined as unconsolidated material derived from physical, chemical and biological degradation of rock that can normally be excavated by manual methods alone and that can be satisfactorily penetrated and sampled by standard soil boring and sampling techniques. The Drilling Inspector must describe the applicable characteristics of texture, state, moisture, structure, gradation, particle shape, plasticity, color, and depositional environment for each soil stratum encountered using the identification procedure described in this section. This procedure is adapted from the Burmister Soil Description System and will be used to develop the written descriptions on the log, as well as aid in estimating the USCS (Unified) and AASHTO visual classifications recorded on the log.

The field description and classifications are meant to supplement the more formal laboratory AASHTO soil classification tests that are typically directed by the PGM at a later time. Field estimations of USCS and AASHTO classifications are to be recorded in lower-case lettering (e.g., sm, a-2-4), while laboratory classifications are to be recorded in capital lettering (e.g., SM, A-2-4). A complete full-word description is to be written in the description column. In cases where space is limited in the field, the abbreviations shown in this section may be useful to record the soil descriptions. Care must be taken that all abbreviated descriptions remain clear and easily understood. Use descriptive abbreviations only when necessary. Guidelines for the determination and formatting of soil descriptions are as follows:

Record the following description sequence on the Field and Final Engineer's Log to describe soil stratification:

(a) Soil Constituents and Fractions
(b) Soil Composition Modifier (if applicable)
(c) Soil State: Consistency or Relative Density
    1. Consistency (fine-grained soils)
    2. Relative Density (coarse-grained/granular soils)
(d) Soil Moisture Range
(e) Soil Structure (if applicable)
(f) Soil Gradation Description
(g) Soil Particle Shape (coarse-grained/granular soils)
(h) Soil Plasticity (fine-grained soils)
(i) Soil Color Range (modifier and hue as applicable)
(j) Depositional Environment (if applicable)
(k) Visual Classification (AASHTO and USCS)
(l) General Boring Remarks
(m) General Soil Descriptions

Each primary descriptor is defined in detail in the following sub-sections. The sequence is followed as shown in Chapter 3.6.3.14; however, depending upon the specific material and type, some description elements may have multiple parts (e.g., soil constituents) and some elements may only apply to certain material types (e.g., plasticity).

3.6.3.1 Soil Constituents and Fractions

List the primary constituent(s) name, then any secondary constituent(s) in order of decreasing relative amount using fraction descriptor. Constituents are visually identified following Table 3.6.3.1-1. Please note that this is a soil description, not a soil classification. Particle size breakdown follows AASHTO classification system. When descriptions are written, capitalize the entire primary constituent for both coarse-grained and fine-grained soil. Capitalize the first letter of secondary constituents. Do not capitalize any other standard descriptors. Place any supplemental descriptor(s) within parentheses, and locate in the description sequence where most appropriate, usually following the standard descriptors. There may be occasions, whereby definition (greater than 35%), a primary constituent cannot be identified. This could be the case when there are 3 or more constituents, and it cannot be visually discerned that one of those constituents makes up more than 35% of the material. In such cases, it is acceptable to identify a soil sample with only secondary constituents using Table 3.6.3.1-2 and the relative amount descriptor, "some" for each soil constituent. Only the first letter of secondary constituents must be capitalized. Coarse-grained and fine-grained constituents are described as follows:

1. **Coarse-grained Constituents:** Sand-size and larger particles are primarily identified according to Table 3.6.3.1-1. Additional information for fine-grained constituents can be found in Table 3.6.3.1-3. To visually assess grain size, refer to Figure 3.6.3.1-1.

Table 3.6.3.1-1 – Descriptors for Grain Material based on Grain Size

Constituent	Primary Descriptor	Grain Sizes	
		inches	sieve
Coarse-Grained	Boulders	≥ 12	-
	Cobbles	≤ 12 to > 3	-
	Coarse Gravel	≤ 3 to > 1	≤ 3 to > 1 inches
	Medium Gravel	≤ 1 to > 3/8	≤ 1 to > 3/8 inches
	Fine Gravel	≤ 3/8 to > 5/64	≤ 3/8 inch to > #10
	Coarse Sand	-	≤ #10 to > #40
	Fine Sand	-	≤ #40 to > #200
Fine-Grained	Silt	-	≤ #200
	Clay	-	≤ #200

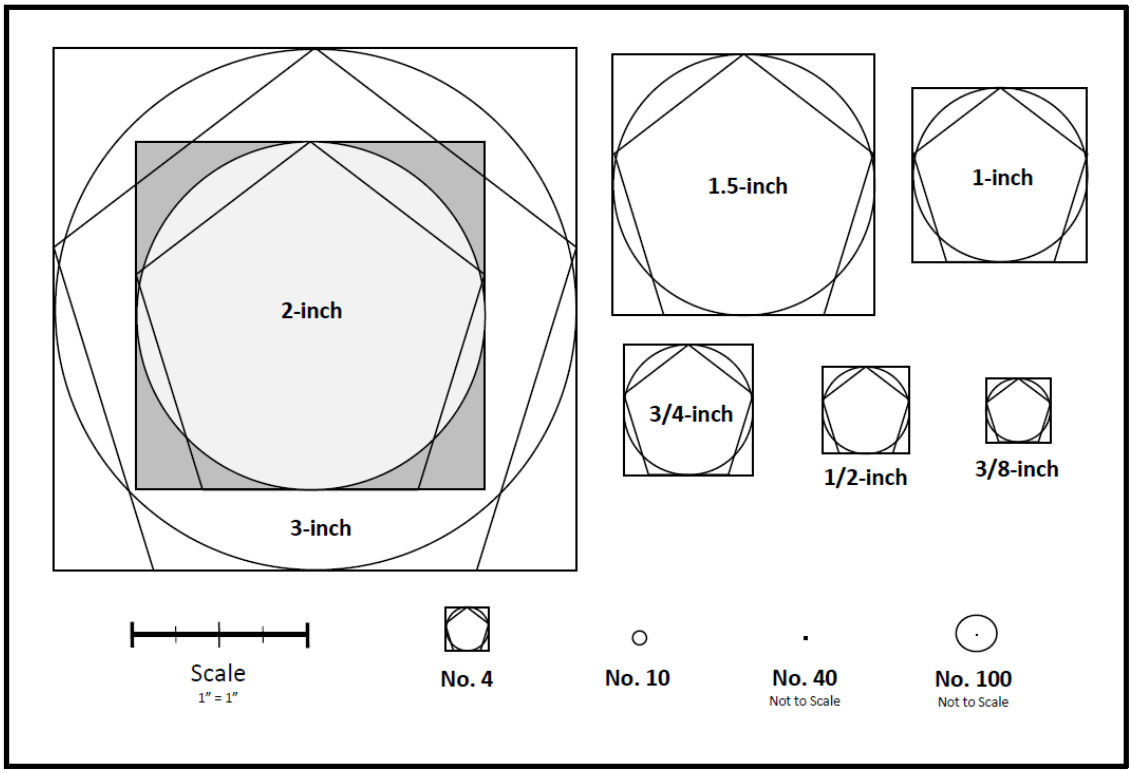


Figure 3.6.3.1-1 – Visual Estimation of Grain Sizes

2. **Fine-grained Constituents**: Identify the fine-grained constituents by observing their behavior, since particle sizes are too small to observe with the unaided eye. Silt particles are sized between 0.075 mm and 0.002 mm. Clay particles are sized below 0.002 mm. Use Table 3.6.3.1-2 to aid in identifying and estimating the relative amounts of fine-grained constituents. Materials that exhibit more plastic behavior contain high proportions of clay, while lower plastic materials would have more silt. Fine-grained materials that behave as exhibited and have the

characteristics of perfectly, non-plastic soils are identified as silts, while very high plastic materials that have a slick or smooth texture are identified as clays. Fine-grained materials that feel both gritty and slippery, or feel gritty but exhibit plastic behavior (e.g., are highly moldable, sticky, can be rolled into a thin ribbon) are a combination of silt and clay. The relative amount of silt and clay is estimated based upon an assessment of the various physical characteristics indicated in Table 3.6.3.1-3. Diagnostic methods for fine-grained soils are described in Appendix L.

When applicable, it may be appropriate to describe some materials more accurately by a specific name, such as “PEAT,” “TOPSOIL,” “ORGANICS,” “SHELL FRAGMENTS,” “SLAG,” etc. When these materials are encountered, address them as specified in Chapter 3.6.3.13. Additionally, the soil type “MECHANICALLY BROKEN ROCK” (BR) may be encountered that will describe rock broken up by the impact from SPT sampling or other mechanical means. When mechanically broken rock is designated as a soil type, no other primary or secondary constituents should be included, regardless of particle size. It is intended that mechanically broken rock describe a condition when SPT is conducted in zones transitioning into bedrock where lower quality rock is encountered. It is not desired to describe this material in the condition it is retrieved in the split-barrel sampler, but rather to represent the source of the material so that misleading representations and conclusions as to the nature of the material do not result. Also, the soil type “No Recovery” (NREC) can be used in circumstances where there is no recovery of a material.

After identifying the various soil constituents in the sample, the relative amount of each constituent must be estimated. This is determined visually (in conjunction with the simple field tests). Use Figure 3.6.3.1-2 to assist in the visual determination of the amount of secondary constituents (to the nearest 5%) then select the appropriate “relative amount” descriptor to describe and record, as shown in Table 3.6.3.1-2. Please note that the main constituents may only be joined by “and”. Additional fractional amounts will be included by adding “trace”, “little”, and “some” in front of the soil fraction depending on their relative amounts.

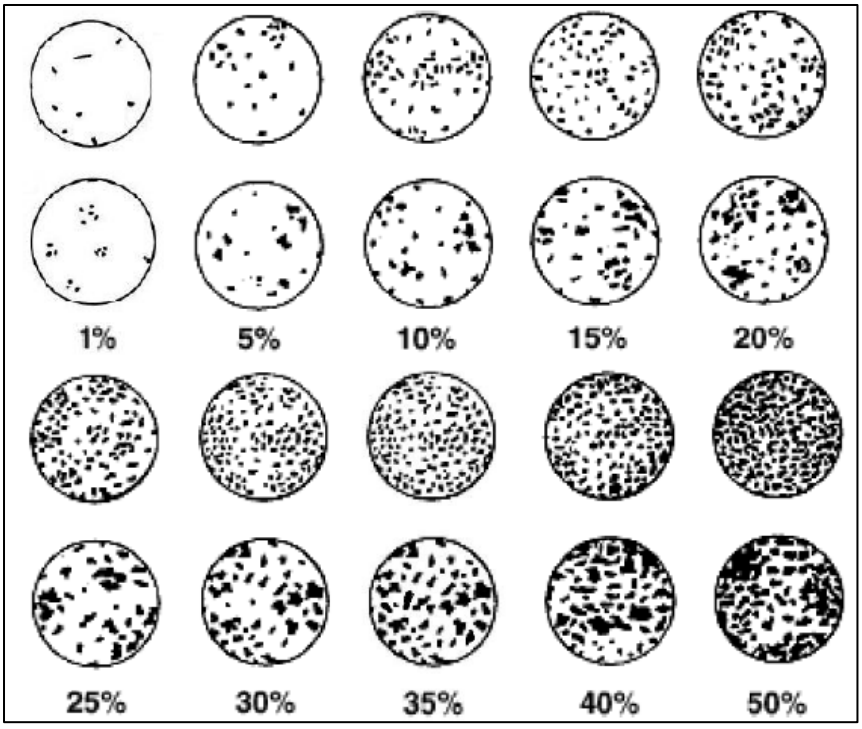


Figure 3.6.3.1-2 – Visual Estimation of Coarse Fragments

Because visual observation and field diagnostic procedures limit the accuracy to which relative amounts of fine-grained soil constituents are present in a sample (silt versus clay fractions), certain field visual descriptions of soil are not acceptable. For example, a soil description of "Silt, some Sand, trace Clay" is not a reasonable or acceptable description. This description indicates the material contains less than 10 percent clay, but greater than 35 percent silt. It is not possible to visually discern clay versus silt particles in such a wide variant, and field diagnostic procedures do not allow a refined assessment of clay and silt content. Therefore, it is neither practical nor possible to define such large differences (less than 10 percent to greater than 35 percent) in relative amounts of silt and clay content in a soil sample. Some additional incorrect examples include: "Clay, little silt, trace sand;" "Silt, little clay, trace sand;" "Sand and Silt, trace clay;" or any description where the relative amounts of silt and clay are substantial (more than one fraction descriptor range apart).

Table 3.6.3.1-2 – Soil Fraction Descriptors

Descriptor (Abbrev.)	**Relative Amount** (based on total sample volume)
Trace (**Tr**)	Content < 10%
Little (**Lt**)	Content ≥ 10 to < 20%
Some (**Sm**)	Content ≥ 20 to < 35%
And (**An**)	Content ≥ 35%

To further clarify, estimated relative amounts of silt and clay (if present) should still be provided, but must be described in relative amounts that are viable based on the limits of visual, textual, and field diagnostic procedures. Descriptions such as, but not limited to, “Silt and Clay, little sand,” “Clay, some silt, little sand,” “Sand, some silt, little clay,” “Sand, little silt, trace clay,” are all potential examples of descriptions based on limitations of field diagnostic procedures. Descriptions of simply “Silt” or “Clay,” exclusive of the other, and with or without coarse grain constituents, are also acceptable for visual description if the fine-grained portion of the sample exhibits extreme non-plastic (silt) or extreme plastic (clay) behavior.

A jar test (which is a semi-quantitative and inexact procedure) can be used to help quantify relative amounts of coarse- and fine-grained materials. Conduct the test by filling a standard glass sample jar 1/3 full of a representative sample of soil. Fill the jar with water until it 2/3 full. Seal the jar and shake vigorously until the sediments break apart and are separated into individual particles. Place the jar on a flat surface and leave undisturbed to allow the sediments to settle naturally. Coarse-grain sediments will fall out of suspension first, followed by fine sands, silts, and clay sized particles. This method can further enhance estimation of relative amounts of soil particle size constituents; however, caution should be used because of the following limitations:

1. Finer constituents would be deposited in a more flocculent consistency thereby making it appear that they constitute a greater percentage of the sample than they actually do.
2. This method will not allow a highly accurate estimation of relative amounts of fine silts and clays given that the upper zone (where the fine silts and clays settle) of the settled sample does not allow visual discerning between the two materials. The same can be said for very fine sands and coarser silts.

Again, noting the limitations indicated above, caution must be observed in using this method to estimate grain size distribution. Also, note that it is not practical to conduct a jar test on every sample due to either restriction in time or the need for a representative sample to conduct laboratory testing.

Table 3.6.3.1-3 – Descriptors for Fine-Grained Materials Based on Behavior

Fine-Grained Constituent	Plasticity Description/ Abbreviation	Estimated Plasticity Index (PI)	Smallest Thread Diameter	Physical Behavior							
				Thread Characteristics	Workability to reach Plastic Limit	Moldability	Dilatancy	Adhesion	Appearance and or Texture	Drying Time	Dry Residue
Predominately Silt (Silt ↑ More Silt ↑)	Non-plastic (Np)	0% - 2%	Ball cracks	Dries rapidly when rolling; a 1/8-inch thread cannot be rolled at any water content	Not applicable, thread cannot be rolled	Does not mold well	Moist soil ball sheds water when shaken giving a glossy appearance	Non-sticky	Rough or gritty texture, dull smear btw. thumb and forefinger	Rapid	Very powdery residue when dry
	Low Plastic Fines (Lp)	3% - 10%	1/4 to 1/8 -inch	Feels powdery when drying out during rolling; The thread can barely be rolled; the thread is weak and soft	Thread can barely be rolled	Moldable under small range of water content	Moist soil ball retains water or sheds water slowly when shaken	Slightly sticky	Rough to smooth texture, dull smear btw. thumb and forefinger	Moderate	Powdery residue when dry
Predominately Clay (More Clay ↓ Clay)	Medium Plastic Fines (Mp)	>10% - 20%	1/16 -inch	The thread cannot be rerolled after reaching plastic limit; the thread has medium stiffness	Short working time to reach plastic limit	Very moldable		Moderately sticky	Smooth texture, dull to shiny smear btw. thumb and forefinger	Slow	Generally little powdery residue when dry
	High Plastic Fines (Hp)	>20%	1/32 -inch	The thread can be rerolled after reaching the plastic limit; the thread has very high stiffness	Very long working time to reach plastic limit	Very moldable over a wide range of water content	Moist soil ball retains water when shaken	Very sticky	Slick texture, very shiny or waxy appearance	Very slow	Very little powdery residue when dry

3.6.3.2 Soil Composition Modifier

Special modifiers are used for some soils in which particular combinations of texture and mineralogy require distinct emphasis. If applicable, describe the soil composition according to Table 3.6.3.2-1.

Table 3.6.3.2-1 – Composition Modifiers

Descriptor	Abbreviation
Contains ash and cinders	Ash
Contains bituminous concrete fragments	Bcf
Contains brick fragments	Cbf
Contains cement concrete fragments	Ccf
Contains organics	Org
Contains rock fragments	Rfg
Contains slag	Slg
Micaceous	Mic

3.6.3.3 Soil State: Consistency or Relative Density

The description of the relative density or soil consistency is based largely on the penetration resistance properties, as follows:

1. **Consistency:** Describe the consistency of cohesive, fine-grained soils according to the Table 3.6.3.3-1 based on SPT N-values, or estimated unconfined compressive strength from either pocket penetrometer tests or torvane tests. On the Final Engineer's Log, the descriptor for consistency must be based upon pocket penetrometer or torvane tests when available, or the corrected (N_{60}) N-value when pocket penetrometer or torvane tests are unavailable. Refer to Appendix I for corrected (N_{60}) N-values for various hammer types at assumed efficiencies.

   The **pocket penetrometer** test is conducted to estimate the unconfined compressive strength of a cohesive soil. Conduct the test on the sample within the split-barrel and according to the pocket penetrometer manufacturer's directions. The test is conducted using the following general instructions:

   i. To begin the test, remove protective cap and push the indicator ring so that it reads zero (0).
   ii. Slowly insert piston at a constant rate until engraved mark on the side of the piston (approximately ¼ inch travel) is level with soil.
   iii. Observe and record the reading (typically in tsf). If the specific device used registers in different units, the observed reading must be converted to tsf for the Final Engineer's Log. Repeat.
   iv. For weak soils, use 1-inch adaptor foot/feet, multiply reading by 0.0625.

The **torvane** test is conducted to estimate the undrained shear strength of a cohesive soil. Conduct the test according to the torvane manufacturer's directions. The test is conducted using the following general instructions:

i. To begin the test, push the indicator to the zero stop.
ii. Select a reasonably flat surface, extending well beyond the vane size used. It is important that the area tested is not a locally raised area. The test location must be well supported by the surrounding soil. The soil surrounding the test area must be of the same general condition and consistency of the test area.
iii. Use a larger torvane for weaker soils and a smaller vane size as the soil stiffens. Multiple vane sizes should be used to compare results.
iv. Press pocket vane shear tester into soil to depth of blade; maintain constant vertical pressure while turning knob clockwise at a rate to develop failure within 5 to 10 seconds.
v. After failure develops, release remaining spring tension slowly. Pointer will indicate maximum shear value until manually reset.

Since the undrained shear strength of a cohesive soil (c_u) is related to the unconfined compressive strength of a cohesive soil (q_u), $c_u = 0.5\ q_u$, either test can be used to help validate estimates of unconfined compressive strength to SPT N-values.

Table 3.6.3.3-1 – Consistency of Cohesive Fine-grained Soils[1]

Descriptor	**Abbreviation**	**Typical Consistency**	**Est. Unconfined Compressive Strength** Tons/Sq. Ft. (MPa)	**SPT-N_{60}** (blows per ft.)
Very Soft	Vsf	Extruded between your fingers when squeezed	≤ 0.25 (≤ 0.025)	≤2
Soft	Sf	Molded by light finger pressure	≥ 0.25 - 0.5 (0.025 - 0.05)	3-4
Medium	Md	Molded by strong finger pressure	> 0.5 – 1.0 (0.05 – 0.1)	5-8
Stiff	St	Readily indented by thumbs but penetrated with great effort	> 1.0 - 2.0 (0.1 – 0.2)	9-15
Very Stiff	Vst	Readily indented by thumbnail	> 2.0 – 4.0 (0.2 – 0.4)	16-30
Hard	Hd	Indented with difficulty by thumbnail	> 4.0 (> 0.4)	≥31

Notes: 1. SPT values alone are not a reliable means for estimating Unconfined Compressive Strengths of cohesive soils. Pocket penetrometer or Torvane tests should be performed in the field to assist the Engineer in assessing the strength of cohesive soil deposits.

2. **Relative Density**: Describe the relative density of granular soils based on standard penetration resistance from Standard Penetration Tests (SPT), according

to Table 3.6.3.3-2. On the Final Engineer's Log, the descriptor for relative density must be based upon corrected (N_{60}) N-values. Refer to Appendix I for corrected (N_{60}) N-values for various hammer types at assumed efficiencies.

Table 3.6.3.3-2 – Relative Density of Granular Coarse-grained Soils

Descriptor	Abbreviation	SPT-N_{60} (blows per ft.)
Very Loose	Vls	≤4
Loose	Ls	5-10
Medium Dense	Md	11-30
Dense	Dn	31-50
Very Dense	Vdn	≥50

3.6.3.4 Soil Moisture Range

Describe the amount of moisture present in each soil sample using the descriptors and corresponding defined appearance in Table 3.6.3.4-1. The amount of moisture within a given soil can have a dramatic effect on its engineering properties. Knowing how the moisture content of the soil column varies with depth can be very valuable to site assessment.

Table 3.6.3.4-1 – Standard Moisture Descriptors

Descriptor	Abbreviation	Appearance
Dry	Dr	Absence of moisture, dusty, completely dry to the touch
Damp	Dp	Slight moisture perceptible by touch, fine-grained soils are usually firm, granular soils usually have very little apparent cohesive binding
Moist	Ms	Sample visibly wet but no visible free water, sample cool to the touch, at or above optimum moisture, granular soil may exhibit slight apparent cohesive binding
Wet	Wt	Visible free water throughout sample, usually soil is below water table, contains significantly more moisture than moist soil, fine-grained soils usually soft or very soft, granular soils exhibit no apparent cohesive binding

3.6.3.5 Soil Structure

Inspect the soil samples to determine if any of the textural-structural features listed in Table 3.6.3.5-1 are evident. Record structure descriptors on the logs as applicable.

Table 3.6.3.5-1 – Soil Structure Descriptors

Descriptor	Abbreviation	Description
Blocky	Bl	Cohesive soil that can be broken down into small angular blocks that resist further breakdown
Fissured	Fi	Soil tends to break along definite planes of fracture with little resistance to fracturing
Heterogeneous	He	Composed of dissimilar parts throughout
Homogeneous	Ho	Similar color and texture throughout
Laminated	La	Alternating very thin layers of varying material or colors with the layers less than ¼" thick
Lensed	Le	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Saprolitic	Sa	Soil composed of completely weathered rock that retains the fabric and appearance of the original rock but with only a trace of the original bond strength
Slickensided	Sl	Contains shear planes that appear striated, polished and/or glossy
Stratified	St	Alternating thin layers of varying material or color with layers at least or greater than ¼" thick
Varved	Va	Layered soil having a repetitive structure of contrasting color (often alternating between fine sand and silt or clay), resulting from variations in annual seasonal deposition

3.6.3.6 Soil Gradation Description

Inspect the soil samples to determine the character of the gradation and record descriptor on the log as required. Gradation describes the distribution of different size groups within a soil sample. Refer to Figure 3.6.3.6-1 for a distribution photograph and Table 3.6.3.6-1 for a detailed description of soil gradation. **Well graded** sand has all sizes of material present from the No. 10 sieve to the No. 200 sieve. **Poorly graded** sand may be **uniformly graded** or **gap graded**. If soil is uniformly graded, most of its particles are about the same size. An example of this is a sieve analysis for sand in which the No. 20 sieve size is almost exclusively present. If a soil is gap-graded, at least one particle size is missing. An example of gap-graded sand is one in which a sieve analysis reveals that No. 40 size material is missing while all other sand sizes are present.

Table 3.6.3.6-1 – Soil Gradation Descriptors

Descriptor	Abbreviation	Description
Well Graded	Wg	Having a good distribution of particles sizes
Poorly Graded	Pg	Lacking good representation of particle sizes within the maximum to minimum particle size range of the material. Use this term when the gradation is not well distributed, but sufficiently different from a uniform or gap graded material.
Uniformly Graded	Ug	Particles are nearly all the same size (or fall within a tight range of sizes)
Gap Graded	Gg	Gradation is missing a band or range of particle sizes

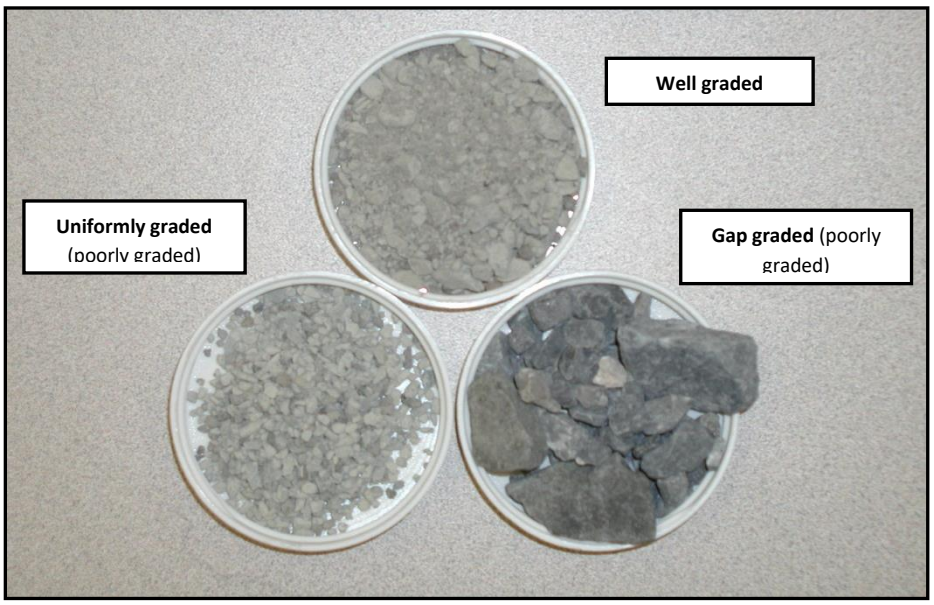


Figure 3.6.3.6-1 – Soil Gradation Distribution

3.6.3.7 Soil Particle Shape

Inspect the soil samples to determine the shape of the gravel and coarse sand particles. The description of the particle shape is based largely on the close examination of the individual grains and is only appropriate for coarse-grained soil or more accurately the coarse fraction of a soil. The grain shape affects the stability of the soil because of the increased resistance to displacement that is found in the more irregular particles. According to Figure 3.6.3.7-1, record the descriptor on the log as required using Table 3.6.3.7-1.

Table 3.6.3.7-1 – Soil Shape Descriptors

Descriptor	Abbreviation	Description
Angular	An	Particles have irregular shape with crisp angular edges
Sub Angular	Sa	Particles have irregular shape with weathered or rounded angular edges
Sub Rounded	Sr	Particles have an irregular shape with well rounded edges
Rounded	Ro	Particle has a generally smooth rounded shape
Elongated	El	Particle length is more than three times particle width
Flat	Fl	Particle width is more than three times particle thickness
Flat and Elongated	Fe	Criteria for both flat and elongated are met

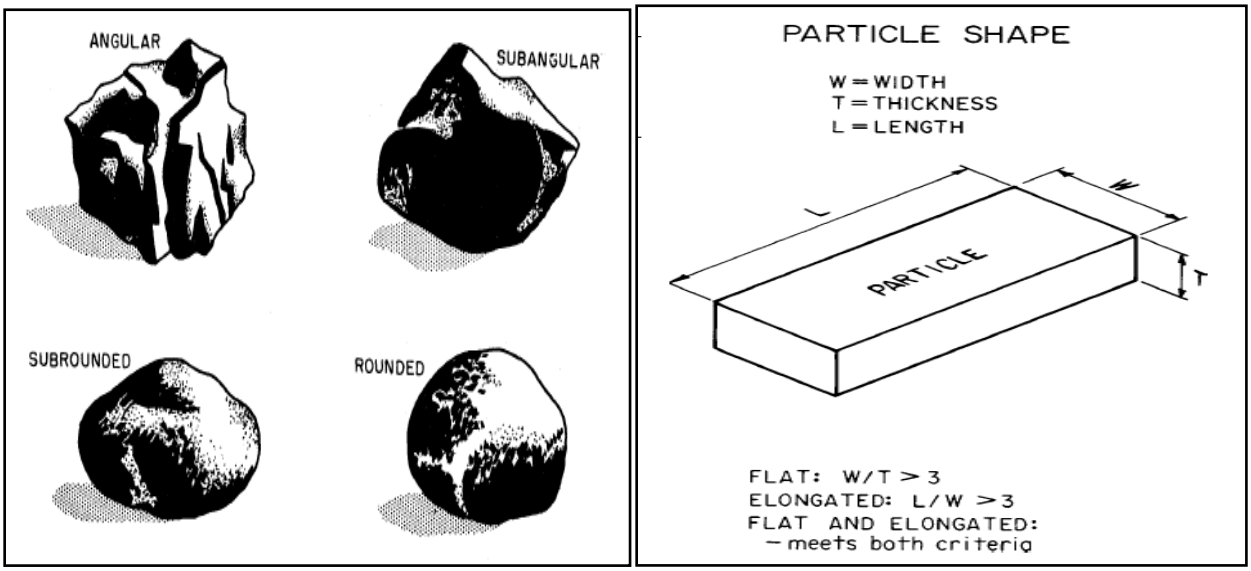


Figure 3.6.3.7-1 – Soil Particle Bulky Grain Shapes and Criteria

3.6.3.8 Soil Plasticity

Determine the plasticity of fine-grained soils using the field diagnostic procedures described in Appendix L. The primary part of information in field classification of silts and clays, is the level of stickiness, or cohesion present in the soil. Use Table 3.6.3.1-3 to assess the soil plasticity and record the proper descriptor.

3.6.3.9 Soil Color Range

Describe the basic color of each soil and modify if necessary, by adjectives such as light, dark, mottled, or banded. Use the standard colors shown in Table 3.6.3.9-1. The table provides the standard colors and their abbreviations for both soil and rock.

Color is useful for correlating strata between borings, and for interpreting the relative amounts of organic matter in the mineral soil for classifying soils. Light soils (e.g., white, light gray, yellow) are typically low in organic matter; medium soils (brown) are moderate in organic matter content; and dark soils (e.g., black, dark brown, dark red) are often high in organics.

Table 3.6.3.9-1 – Standard Color Descriptors

Standard Soil and Rock Colors and Abbreviations							
Black	Bk	Blue	Bu	Brown	Bn	Gray	Ga
Green	Gn	Olive	Ol	Orange	Or	Pink	Pk
Purple	Pr	Red	Rd	Silver	Sv	Tan	Tn
		White	Wh	Yellow	Yl		

In addition to a basic color, there can be variations in color that further help delineate, describe, identify and correlate soil types. These variations are covered with two additional color descriptors: hue and color modifier. The hue helps further define the color of a soil sample by allowing the description of a secondary color description that better defines the color of a soil sample that is not a pure one color material, or the mineralogy provides a mix of colors. Separate the hue from the color with a hyphen. The color modifier allows further color definition in terms of the shade (lightness or darkness of a color) and color structure (mottled or banded). Mottling is the appearance of uneven spots of a distinctly different color or shade, while banding indicates distinct, repeating, changes in color, usually the result of some regular depositional variation. Table 3.6.3.9-2 provides the standard soil and rock hues used to further define the color of a material, while Table 3.6.3.9-3 provides the standard color modifiers.

Table 3.6.3.9-2 – Standard Hue Descriptors

Standard Soil and Rock Hues and Abbreviations									
Blue	Bu	Brown	Bn	Gray	Ga	Green	Gn	Red	Rd
Olive	Ol	Orange	Or	Pink	Pk	Purple	Pr	Yellow	Yl

Table 3.6.3.9-3 – Standard Color Modifiers

Standard Soil and Rock Color Modifiers and Abbreviations		
Light	Lt	Lighter side of color range
Dark	Dk	Darker side of color range
Mottled	Mt	Irregularly marked with spots of different colors
Banded	Bd	Distinct alternating light and dark shades, or alternating colors

3.6.3.10 Depositional Environment

Describe the sedimentary depositional environment to express in what way the soil was deposited using the descriptors in Table 3.6.3.10-1. Soils derive their engineering behavior mostly because of the geologic depositional environment that controls their development.

Residual deposits cover a major portion of the Commonwealth as seen in the map of Surficial Materials of Pennsylvania in Appendix F and reflect the composition of the parent bedrock. Glacial deposits predominate in the northeastern and northwestern sections of the Commonwealth as seen in the map of Glacial Deposits of Pennsylvania in Appendix F.

Table 3.6.3.10-1 – Types of Soil Deposit

Descriptor	Abbreviation	Description
Aeolian	Ae	Soil deposited by wind
Alluvium	Al	Soil deposited by flowing water
Colluvium	Co	Soil deposited by gravity
Glacial Outwash	Go	Soil deposited from glacial meltwater
Glacial Till	Gt	Soil deposited from unsorted glacial settlement
Residuum	Re	Insoluble material remaining from weathered rock
Fill	Fl	Human-made deposit

3.6.3.11 Visual Soil AASHTO/USCS Classification

The Drilling Inspector must visually estimate in the field the AASHTO and Unified soil classifications on each soil strata encountered, and record the corresponding abbreviations, using lower-case letters, onto the Inspector's Field Log. The visual classification must be conducted according to the guidelines for field classifications of soils presented in Appendix D. The results of any laboratory testing completed to formally determine the soil classifications must also be recorded on the Final Engineer's Log and identified as such by using capitalized abbreviations. Laboratory classifications must reflect not just the specific sample that was tested from a zone of split-barrel samples, but the full length of any continuous run of material in a hole that is visually representative of the tested sample, provided that the test sample was obtained from the continuous run of material. Laboratory classifications cannot be applied to similar materials from other depths in a hole that are separated by a visually different material, or to similar materials in other bore holes (regardless of the proximity of the hole, depth of sample, or similarity of the material). However, lab classification can be used to revise an original field/visual classification of material in the same borehole or adjacent boreholes where the material is visually, texturally, and behaviorally equivalent to the lab classified material. Refer to Figure 3.6.2-1 and Chapter 3.6.2 for additional clarification.

3.6.3.12 General Boring Remarks

Provide important information relating to the drilling operations and any other information that may give assistance in defining the subsurface conditions in soil. If applicable, the remark(s) should be recorded at the nearest depth to which it was referred to on the boring log. Types of examples of possible remarks include, but are not limited to, the purpose for offsetting the location or change in elevation of a boring, multiple drilling inspectors, any installed instrumentation or bag sample locations, spoon/auger refusal, poor recovery, no recovery, loss of soil sample, tool drops, and basis for unsampled advancement.

3.6.3.13 General Soil Descriptions

If applicable, include descriptive terms regarding the structure, origin, or other important characteristic of the sample at the end of the constituent description. Place terms within parentheses and record the specified depth. Types of examples could include organic matter (e.g., peat deposits, compost, manure), slag, shell fragments, foreign smells/odors, striking colors, type of fill (embankment, uncontrolled, or subbase), signs of heat (combustion), or presence of large objects (e.g., concrete blocks, foundations, boulders).

3.6.3.14 Examples of Field Soil Descriptions

The following are examples for soil description sequence to be used on the Field and Final Engineer's Log to describe soil stratification:

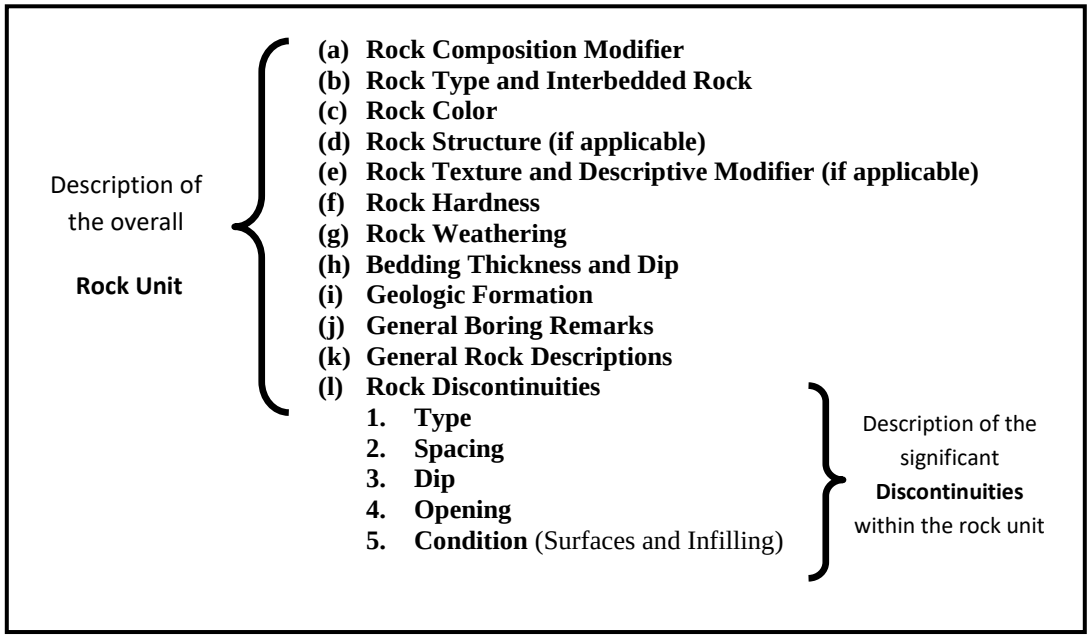
- fine SAND, some Silt, trace Gravel, medium dense, moist, poorly graded, rounded, brown, fill, a-2-4/sm
- SILT and CLAY, some Gravel, trace Sand, soft to medium, moist to wet, well graded, sub angular, high plastic fines, mottled yellow and light gray, glacial outwash, a-6/cl, (trace roots), (with sandstone fragments)
- fine SAND, some Clay, medium dense, moist, poorly graded, dark gray, fill, a-2-6/sc, (trace shell fragments)
- coarse GRAVEL, some Silt, loose, dry, uniformly graded, elongated, red-brown, glacial till, a-2-5/gm,
- fine SAND, some Gravel, little Silt, dense, moist, homogeneous, well graded, rounded, light brown, residuum, a-2-4/sm, (slight petroleum odor)
- fine GRAVEL and SAND, little Silt, trace Clay, micaceous, medium dense, damp, homogeneous, well graded, angular to sub-rounded, non-plastic, light brown to red-brown, fill, a-1-b/sw, (occasional fragments of brick and concrete)
- SILT, some fine Sand; stiff to soft, moist, poorly graded, low plastic, orange-brown to tan, alluvium, a-4/ml
- coarse GRAVEL and SILT, some Cobbles, contains cement concrete fragments, loose, damp, blocky, gap graded, angular to rounded, light gray-blue and tan, fill, a-4/gm, (striking red color)

3.6.4 Standard Descriptors for Rock Core

Rock is defined as an indurated mass of mineral aggregates that cannot normally be excavated by manual methods alone and that cannot be satisfactorily penetrated and sampled by standard soil boring and sampling techniques. Describe the characteristics for each rock stratum encountered according to the sequence shown in Figure 3.6.4-1. The general (overall) rock deposit is described first, followed by the characteristics of any discontinuities of significance. For example, avoid giving a wide-ranging description for a rock unit as "very hard to soft", rather, define the dominant character or the rock as "hard" with the subsequent description of the discontinuities or weathered zones as "soft". Detailed guidance for describing discontinuities is found in Chapter 3.6.5.

A complete full-word description is to be written in the description column. Abbreviations for various descriptors have been established for field use to aid in recording descriptions when space is limited. Use descriptive abbreviations only when necessary. When measurements are taken for a property such as RQD, the numerical values should always be recorded in the columns provided.

Figure 3.6.4-1 – Standard Rock Core Description Sequence



3.6.4.1 Rock Composition Modifier

To describe the lithology of the granular sediments and rocks in greater detail, the rock type (e.g., Shale) is often preceded by a major composition modifier (e.g., carbonaceous). Use major descriptive modifiers to describe mineral types that are present in the majority of the rock using Table 3.6.4.1-1. Capitalize the entire rock type and, if applicable, the interbedded rock type. Do not capitalize any other standard descriptors. Place any supplemental descriptor(s) within parentheses, and locate in the description sequence where most appropriate, usually following the standard descriptors.

Table 3.6.4.1-1 – Rock Composition Modifier

Descriptor	Abbreviation	Description
Arenaceous	Are	Containing sand or sand particles
Argillaceous	Arg	Pertaining to a sedimentary rock that contains an appreciable amount of clay
Calcareous	Cal	Containing calcite; in particular, rock in which grains are cemented with calcite
Carbonaceous	Car	Rich in carbon or organic matter
Dolomitic	Dol	Containing an appreciable amount of magnesium carbonate
Ferruginous	Fer	Containing iron oxides

Descriptor	Abbreviation	Description
Fossiliferous	Fos	Containing fossils; usually applied to rocks in which the fossils are abundant
Micaceous	Mic	Group of silicate minerals exhibiting perfect basal cleavage, which commonly forms flakes, scales, or sheets.
Pyritic	Pyr	Containing the mineral pyrite (iron disulfide – "fool's gold"); may only be visible with a hand lens.

3.6.4.2 Rock Type and Interbedded Rock

Identify the rock type encountered. The rock types listed in Table 3.6.4.2-1 should cover nearly all rock types that may be encountered in Pennsylvania. If a rock type is encountered that is not listed, indicate the specific rock type, its origin and then use the "Sedimentary – Other" graphic symbol for any sedimentary rock types not listed, and use the generic "Metamorphic" or "Igneous" graphic symbols for any metamorphic or igneous rocks identified but not listed. For interbedded rock, provide the secondary rock such that the term "interbedded with" is used (e.g., SANDSTONE interbedded with SHALE).

Table 3.6.4.2-1 – General Rock Types in Pennsylvania

Rock Type	Abbreviation	Rock Origin	Graphic Symbol
Amphibolite	Am	Metamorphic	Metamorphic
Anorthosite (Gabbro)	An	Igneous	Igneous
Anthracite Coal	Co-A	Sedimentary	Coal
Argillite	Ar	Sedimentary	Argillite
Bituminous Concrete	BC	Human-Made	Asphalt Concrete
Basalt/Metabasalt	Ba	Igneous	Igneous
Bituminous Coal	Co-B	Sedimentary	Coal
Breccia	Br	Sedimentary	Conglomerate
Cement Concrete	CC	Human-Made	Cement Concrete
Chert	Ch	Sedimentary	Sedimentary - Other
Claystone	Cl	Sedimentary	Claystone
Coal	Co	Sedimentary	Coal
Conglomerate	Cn	Sedimentary	Conglomerate
Diabase (Gabbro)	Di	Igneous	Igneous
Dolomite	Do	Sedimentary	Limestone
Flint Clay	FlC	Sedimentary	Sedimentary - Other
Gabbro	Ga	Igneous	Igneous
Gneiss	Gn	Metamorphic	Metamorphic
Granite/Granodiorite	Gr	Igneous	Igneous
Hornfels	Hr	Metamorphic	Metamorphic
Igneous rock type not identified in this listing		Igneous	Igneous
Limestone	Lm	Sedimentary	Limestone
Marble	Mr	Metamorphic	Metamorphic
Masonry	MA	Human-Made	Cement Concrete

Rock Type	Abbreviation	Rock Origin	Graphic Symbol
Metamorphic rock type not identified in this listing		Metamorphic	Metamorphic
No Recovery	NREC	N/A	No Recovery
Orthoquartzite (Sandstone)	Or	Sedimentary	Sandstone
Pegmatite	Pg	Igneous	Igneous
Phyllite	Ph	Metamorphic	Metamorphic
Quartzite	Qr	Metamorphic	Metamorphic
Rhyolite/Metarhyolite	Rh	Igneous	Igneous
Sandstone	Sa	Sedimentary	Sandstone
Schist	Sch	Metamorphic	Metamorphic
Sedimentary rock type not identified in this listing		Sedimentary	Sedimentary - Other
Serpentinite	Sr	Metamorphic	Metamorphic
Shale	Sh	Sedimentary	Shale
Siltstone	Si	Sedimentary	Siltstone
Slate	Sl	Metamorphic	Metamorphic
Unsampled	Uns	N/A	Unsampled
Void	Vd	N/A	Void

When not provided as a rock composition modifier (Chapter 3.6.4), varieties of specific rock types such as variants of schist (e.g., garnet schist, etc.) would be described as the general rock type (i.e., schist) with the specific variant defined in the remarks section of the description.

3.6.4.3 Rock Color

Describe the rock color using the basic colors shown in Table 3.6.3.9-1 for each rock type, and modify if necessary by hue color shown in Table 3.6.3.9-2 and color modifiers in Table 3.6.3.9-3. Color is very noticeable and an obvious characteristic of a rock, but it is also the most difficult to interpret. Most rock colors are the result of iron staining, partially decayed organic matter, and/or mineral content.

3.6.4.4 Rock Structure

Determine the rock structure by identifying specific rock characteristics such as grain size, shape, cavities, foliation, secondary minerals, layering or banding, color of planar zones, and wearing of the rock surface. Also, observe the applicable rock origin type. This would include rocks that are sedimentary, igneous, or metamorphic in nature. If applicable, apply Table 3.6.4.4-1 to determine the correct term to describe the rock structure.

Table 3.6.4.4-1 – Rock Structure Descriptors

Descriptor	Abbreviation	Rock Origin	Description
Amygdaloidal	Amg	Igneous	Vesicle that has been filled with secondary minerals

Descriptor	Abbreviation	Rock Origin	Description
Concretions	Ccr	Sedimentary	Hard, compact masses formed by the precipitation of minerals
Cross Bedded	Crb	Sedimentary	Original depositional layering is inclined
Fissile	Fsl	Sedimentary	Splits easily along planes of weakness into thin sheets
Flow-Banding	Flb	Igneous	Bands or layers formed during original molten rock flow
Foliated	Fol	Metamorphic	Thin layering from alignment of constituent mineral grains
Gneissic Foliation	Gnf	Metamorphic	Planar zones of dark and light colored minerals
Graded Bedding	Grb	Sedimentary	Change in grain size from the base of the bed to the top; typically, coarser sediments at base
Nodules	Nd	Sedimentary	Solid mineral replacement body generally rounded in shape
Non-Foliated	Nfo	Metamorphic	Absence of foliation
Oolitic	Olt	Sedimentary	Containing small round calcareous grains
Schistose	Sct	Metamorphic	Containing parallel arrangement of platy or prismatic minerals
Shaley	Sha	Sedimentary	Exhibiting shaley structure, fissility, or thin partings.
Slaty Cleavage	Scl	Metamorphic	Cleavage into thin layers or plates, like those of slate
Slickensided	Slk	All Rock Origins	Exhibiting polished, striated surface along which movement of rock has occurred
Vesicular	Vsc	Igneous	Containing small cavities called vesicles that formed when gases escaped from lava
Weakly Foliated	Wfo	Metamorphic	Exhibiting weak or less distinct foliation

3.6.4.5 Rock Texture and Descriptive Modifier

If applicable, describe the rock texture and add any rock descriptive modifiers. Texture refers to the sizes and shapes of grains, the relationships between neighboring grains, and the orientation of grains within a rock. Identify these distinguished characteristics and origin of the rock for use in Table 3.6.4.5-1 to describe the rock texture. Use descriptive modifiers to designate the appearance or how it was formed using Table 3.6.4.5-2.

Table 3.6.4.5-1 - Rock Texture Descriptors

Descriptor	Abbreviation	Rock Origin	Description
Aphanitic	Aph	Igneous	Contains crystals so fine that individual minerals cannot be distinguished with naked eye
Coarse-Grained	Cgr	Sedimentary	Consist of predominately coarse-grained particles
Crystalline	Crs	All Rock Origins	Consisting of or containing crystals
Fine-Grained	Fgr	Sedimentary	Consist of predominately fine-grained particles
Glassy	Gls	Igneous	Resembling glass in smoothness and shininess
Pegmatic	Peg	Igneous	Containing very coarse grains greater than 3 cm in length
Phaneritic	Pha	Igneous	Contains crystals roughly equal in size and individual minerals can be distinguished with naked eye
Phenocrystic	Phe	Igneous	Contains large conspicuous crystals
Pitted	Ptd	All Rock Origins	Contains numerous very small voids
Porphyritic	Prt	Igneous	Contains relatively large isolated crystals in fine texture matrix
Porphyroblastic	Pbl	Metamorphic	Contains large crystals embedded in a finer-grained matrix
Vitreous	Vit	All Rock Origins	Resembling glass, but with a vitreous (pearly) luster
Vuggy	Vug	All Rock Origins	Containing voids usually with a mineral lining of different composition

Table 3.6.4.5-2 – Rock Descriptive Modifiers

Descriptor	Abbreviation	Rock Origin	Description
Dull Luster	Dls	All Rock Origins	Dull earthy appearance
Evaporites	Evp	Sedimentary	Formed from evaporation of lake or sea water
Friable	Frb	All Rock Origins	Easily broken or crumbled
Glassy Luster	Gls	All Rock Origins	Having a glassy appearance
Metallic Luster	Mls	All Rock Origins	Having a surface appearance similar to or resembling metal
Mineral Veins	Mnv	Sedimentary	Having fractures that have been filled with mineral material (quartz)

Descriptor	Abbreviation	Rock Origin	Description
Pearly Luster	Pls	All Rock Origins	Having a surface appearance similar to or resembling a pearl
Waxy Luster	Wls	All Rock Origins	Having a surface appearance similar to or resembling wax

3.6.4.6 Rock Hardness

Describe the apparent hardness of the rock core according to the diagnostic correlations given in Table 3.6.4.6-1. The term "hardness" is generally understood as being the resistance of a material against abrasion of a body made of another material. Hardness is a function of the mineralogy of the rock, the strength, and the state of weathering. A rock consisting of hard minerals that are well connected with little weathering, will exhibit a high degree of hardness, while the same rock mass in a weathered state with weak cementing may diagnostically have a low degree of hardness. Hardness is used to help differentiate and describe rock.

Table 3.6.4.6-1 – Rock Hardness Descriptors

Descriptor (Abbrev.)	Test Criteria for Hand Specimen	Typical PA Rock Type	Approx. Mohs Hardness Scale	Materials in Hardness Range
Very Soft (**Vs**)	Scratched by a wood dowel or fingernail	Gypsum, evaporites, some shale	1 – 2	PVC, fingernail
Soft (**Sf**)	Scratched by rubbing against the surface of a copper pipe or fitting, but not scratched by a wood dowel or fingernail	Schist, shale, most limestone	3 – 3.5	copper pipe
Medium Hard (**Mh**)	Scratched by rubbing against the surface of a common steel nail, but not scratched by rubbing against the surface of a copper pipe or fitting	Siltstone, sandstone, some limestone	5 – 5.5	common nail, glass
Hard (**Hd**)	Scratched by rubbing against a hardened steel file, but not scratched by rubbing against the surface of a common steel nail	Some sandstone, chert, granite, gneiss	7.5 - 8	hardened steel, porcelain
Very Hard (**Vh**)	Not scratched by rubbing against a hardened steel file	Some hornfels	> 8	corundum

3.6.4.7 Rock Weathering

Describe the degree of weathering of the overall rock unit (deposit) according to the criteria given in Table 3.6.4.7-1. Concentrate on the apparent degree of decomposition of the rock relative to that of the comparable fresh parent rock. Do not confuse hardness with weathering. While weathering tends to reduce hardness, a once hard rock type that has been weathered (such as weathered siltstone) may exhibit similar hardness as a weaker, un-weathered

soft rock type (such as fresh claystone). Consider the deterioration of the sample in describing the weathered condition of the rock. Weathered rock masses generally have lower strength relative to a fresh mass of the same rock type.

Table 3.6.4.7-1 – Rock Weathering Descriptors

Descriptor (Abbrev.)	Criteria
Fresh (**Fw**)	No visible decomposition, discoloration, or oxidation.
Slightly Weathered (**Sw**)	Slight decomposition, discoloration, or oxidation **impacting < 20 % of the rock mass.**
Weathered (**Ww**)	Significant decomposition, discoloration, or oxidation **impacting 20 to 40 % of the rock mass.** Weaker minerals decomposed. Apparent strength less than fresh parent rock.
Moderately Weathered (**Mw**)	Moderate decomposition, discoloration, or oxidation **impacting 40 to 60 % of the rock mass.** Noticeable loss of strength relative to fresh parent rock.
Highly Weathered (**Hw**)	Major decomposition, discoloration, or oxidation **impacting > 60 % of the rock mass.** Rock is significantly weakened relative to its un-weathered state. Less weathered components may be present in rock mass.

3.6.4.8 Bedding Thickness and Dip

Observe and record the bedding thickness according to Table 3.6.4.8-1 and determine the dip angle according to Table 3.6.4.8-2 for sedimentary rock formations. If bedding is not apparent or indistinct, note as such. In the case of foliated metamorphic rock formations, knowing the orientation of foliations (alignment of platy or elongate minerals) may be very useful in understanding the structural character of a rock formation. Use Bedding/Discontinuity Dip description to characterize the orientation of foliation.

Table 3.6.4.8-1 – Rock Bedding

Bedding Thickness (Abbrev.)	Description
Indistinct Bedding (**Inb**)	Bedding structure not clearly defined
Laminated Bedding (**Lmb**)	Bedding thickness < 1/4 inch
Thin Bedding (**Tnb**)	Bedding thickness 1/4 to 1 inch
Narrow Bedding (**Nrb**)	Bedding thickness 1 to 3 inches
Moderate Bedding (**Mob**)	Bedding thickness 3 to 9 inches
Medium Bedding (**Meb**)	Bedding thickness 9 to 24 inches
Thick Bedding (**Tkb**)	Bedding thickness 2 to 6 feet
Massive Bedding (**Mab**)	Bedding thickness > 6 feet

Table 3.6.4.8-2 – Bedding/Discontinuity Dip Descriptors

Bedding/Discontinuity Dip (Abbrev.)	Description
Flat Dip (**Fld**)	Beds/Discontinuities dipping < 5 degrees
Shallow Dip (**Sld**)	Beds/Discontinuities dipping from 5 to 15 degrees
Moderate Dip (**Mdd**)	Beds/Discontinuities dipping from 15 to 30 degrees
Steep Dip (**Std**)	Beds/Discontinuities dipping from 30 to 45 degrees
Very Steep Dip (**Vsd**)	Beds/Discontinuities dipping from 45 to 60 degrees
Sheer Dip (**Srd**)	Beds/Discontinuities dipping > 60 degrees

3.6.4.9 Geologic Formation

Research the location of the project site in Pennsylvania and refer to Appendix E and Map 1, Publication to determine and record the geologic formation, abbreviation, and period/epoch. Map 1, Publication is a 1:250,000-scale map of the bedrock geology of Pennsylvania compiled by T.M. Berg and others. A current geologic map of Pennsylvania can be found on the website of the Department of Conservation and Natural Resources (DCNR) and can be accessed through Map 1, Publication. This information is for general project information and must be provided for each boring. The information is not required to be listed on field or Final Engineer's Logs.

3.6.4.10 General Boring Remarks

Provide important information relating to the drilling operations and any other information that may give assistance in defining the subsurface conditions in rock. If applicable, the remark(s) should be recorded at the nearest depth to which it was referred to on the boring log. Types of examples of possible remarks include, but are not limited to, estimated top of rock location, loss of rock sample, no recovery, the depth of loss and return of circulating water or an increase in usage of drilling water, changes in color of drill return water, tool drops, drilling advancement rate, plugging during drilling, loss of fluid, rolled or recut pieces of core, and any other inconsistencies while coring.

3.6.4.11 General Rock Descriptions

If applicable, include descriptive terms regarding the structure, origin, or other important characteristic of the sample not already captured at the end of the rock description. These will be captured as general descriptions at a specified depth. Place terms within parentheses, and locate in the description sequence where most appropriate, usually following the standard descriptors. Some typical examples might be: foreign smells, striking colors, signs of heat (combustion), or presence or absence of large objects (e.g., concrete blocks, foundations), voids, mined-out coal seams, soil seams, infilling, limestone caverns, jointing, brokenness, highly weathered rock zones, solution cavities, etc.

3.6.4.12 Rock Discontinuities

Describe discontinuities according to Chapter 3.6.5.

3.6.4.13 Examples of Field Rock Descriptions

The following are examples for rock core description sequence to be used on the Field and Final Engineer's Log to describe the rock unit:

- fossiliferous BRECCIA, dark red-brown, very soft, fresh, medium bedding, steep dip, fracture zone, narrowly spaced discontinuity, sheer dip, narrow joint opening, (1/8-in thick, filled with calcite, very soft)
- micaceous SCHIST, brown with mottled yellow-brown, foliated, soft, highly weathered, jointed, medium spaced discontinuity, sheer dip, wide joint opening
- CLAYSTONE, gray and red-brown, metallic luster, soft, slightly weathered, moderate bedding, moderate dip, fracture zone, medium spaced discontinuity, sheer dip, (no infill)
- SILTSTONE, red-brown, medium hard, slightly weathered, medium bedding, flat dip, random fractures, widely spaced discontinuity, sheer dip, tight joints
- SANDSTONE interbedded with SHALE, gray and dark gray, hard to very hard, fresh, thin bedding, shallow dip, jointed, widely spaced discontinuity, shallow dip, tight joints
- dolomitic LIMESTONE, gray to blue-gray, vuggy, mineral veins, medium hard, slightly weathered to moderately weathered, moderate bedding, steep dip, bedding joint, moderately spaced discontinuity, moderate dip, narrow joint opening (slickensided)
- BASALT/METABASALT, black to green-black, flow banding, aphanitic, dull luster, hard, fresh, fracture zone, narrowly spaced discontinuity, sheer dip, tight joints

3.6.5 Standard Descriptors for Rock Core Discontinuities

The Drilling Inspector must observe and record descriptions of the following applicable characteristics of major or significant discontinuities in the rock core: **type, spacing, dip, opening,** and **condition**. The **condition** description may include characteristics of the **surface** roughness as well as the soil **infilling** thickness, constituents, and hardness. The Drilling Inspector must adequately describe these features using the descriptions outlined in this section. For additional guidance pertaining to describing rock cores, see Publication 293, Geotechnical Engineering Manual, and the U.S. Department of the Interior, Bureau of Reclamation (USBR), Engineering Geology Field Manual, 2001.

Identifying and describing the structure of rock masses is an important part of the test boring inspection and Final Engineer's Log. Rock bedding or discontinuities often create planes or surfaces within the rock mass that have considerably different engineering properties than the intact parent rock specimens tested in the laboratory. Accordingly, discontinuities can control the properties and behavior of rock masses.

The following are definitions of terms describing rock structure:

- **Bedding/Foliation**: For the purposes of the boring log description, bedding planes define the interface of rock deposits having notable or significant differences in character. The contacts between rock bodies of different lithology's

are considered bedding planes and described separately from other types of rock discontinuities discussed below. Bedding description is to be in accordance with Table 3.6.4.8-2. Structural foliations (such as cleavage), which are planar or layered are characteristics of metamorphic rocks, that can be structurally similar to the bedding features in sedimentary rocks.

- **Discontinuity**: For the purposes of the boring log description, a discontinuity is a collective term used for joints, fractures, shears, and faults.
- **Fracture**: A term used to describe an irregular or non-planar break in geologic material, excluding shears and shear zones. Additional fracture terminology is provided in Figure 3.6.5.1-1.
- **Shear**: A structural break where differential movement has taken place along a surface is termed a shear. Shearing is sometimes characterized by a slickenside or gouge. Often, the shear direction, amount of displacement, and continuity may not be known because of limited exposures or observations.
- **Fault**: A shear with significant discontinuity that can be correlated between observations is a fault. Faults demonstrate high spatial continuity, and therefore occur over significant portions of given sites, foundation areas, or regions. The observed fault feature may be a segment of a fault or fault zone, as defined in the literature. The designation of a shear as a fault or fault zone is a site-specific determination.
- **Shear/Fault Zone**: A shear or fault that exhibits significant width when measured perpendicular to the plane of the shear or fault. The zone may consist of multiple slickensides, gouge, striations, breccia, or many related faults or shears together with fractured and crushed rock between the shears or faults, or any combination of these.
- **Soil Infilling**: Soil material that has migrated into an open rock joint or discontinuity. The deposit is most likely caused by the movement of water.

3.6.5.1 Discontinuity Type

Use a single description, or range of descriptors, to describe the discontinuities observed over the length of the reported fracture density. Refer to Figure 3.6.5.1-1 for detailed criteria concerning discontinuity types.

In addition, other specific discontinuity types may be described including: a valley stress relief joint, (Vsrj) which is a near vertical fracture, parallel to the valley wall due to unloading of rock from a mass removal; an incipient joint, (Inj) which is a fracture that does not continue through the core when visually inspected, but is more evident when the core is wetted and dried; and a shear fracture, (Shf) which is a fracture surface characterized by a polished surface or slickensides.

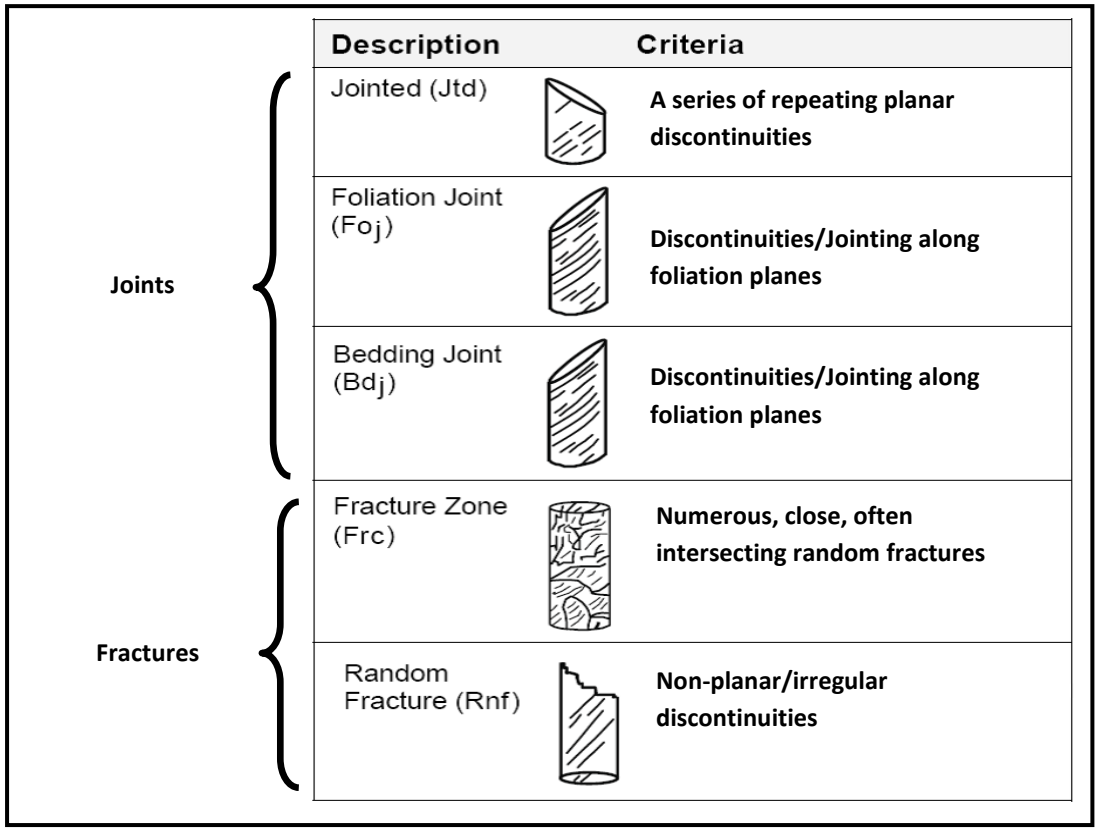


Figure 3.6.5.1-1 – Standard Core Log Descriptors for Discontinuity Types

3.6.5.2 Discontinuity Spacing

Measure the spacing between each discontinuity and record the measured values. Select a spacing descriptor that best describes the spacing according to Table 3.6.5.2-1. For accurate understanding of what constitutes a discontinuity, refer to the definitions given in the beginning of this section.

Table 3.6.5.2-1 – Discontinuity Spacing Descriptors

Spacing	Abbreviation	Description
Laminated	Lmd	Discontinuity spacing < ¼ inch
Narrow	Nrd	Discontinuity spacing from > ¼ inch up to 1 inch
Close	Cld	Discontinuity spacing > 1 inch up to 3 inches
Moderate	Mod	Discontinuity spacing > 3 inches up to 9 inches
Medium	Med	Discontinuity spacing > 9 inches up to 2 feet
Wide	Wdd	Discontinuity spacing > 2 feet up to 6 feet
Massive	Mad	Discontinuity spacing > 6 feet

When a significant joint set can be distinguished (parallel or sub-parallel joints), true spacing will be measured as shown on Figure 3.6.5.2-1, and a representative description of the spacing must also be recorded. If apparent spacing is given, label as such. When complex jointing patterns are encountered, long written descriptions can be avoided by writing succinct

descriptions that are supplemented with core sketches and/or photographs. Joint spacing affects block size and geometry in the rock mass. Spacing is a required input for several rock mass classification systems.

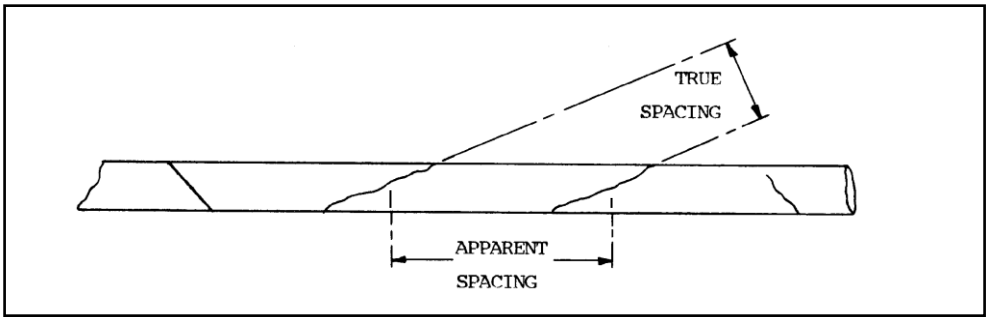


Figure 3.6.5.2-1 – Comparison of True and Apparent Spacing

For each run of rock core, the total core recovery (REC), percent recovery, and rock quality designation (RQD) must be recorded. Core recovery and RQD are important indicators related to the discontinuity spacing. Core recovery and RQD should be measured along the core centerline as shown in Figure 3.6.5.2-2. The RQD for each core run is determined by summing the total length of those pieces of core that are 4 inches in length or longer, and then dividing that length by the total length of core run and multiplying by 100 percent.

$$RQD = \left(\frac{\Sigma\ Pieces\ \geq 4"}{length\ of\ core\ run}\right) * 100$$

If the core is broken by handling or by the drilling process (e.g., machine or mechanical breaks, the fracture surfaces are fresh, irregular breaks rather than joint surfaces), the fresh broken pieces are fitted together and are counted as one piece. Therefore, machine or mechanical breaks are ignored. The Drilling Inspector should mark mechanical or irregular rock breaks by drawing three parallel lines across the break to indicate as such.

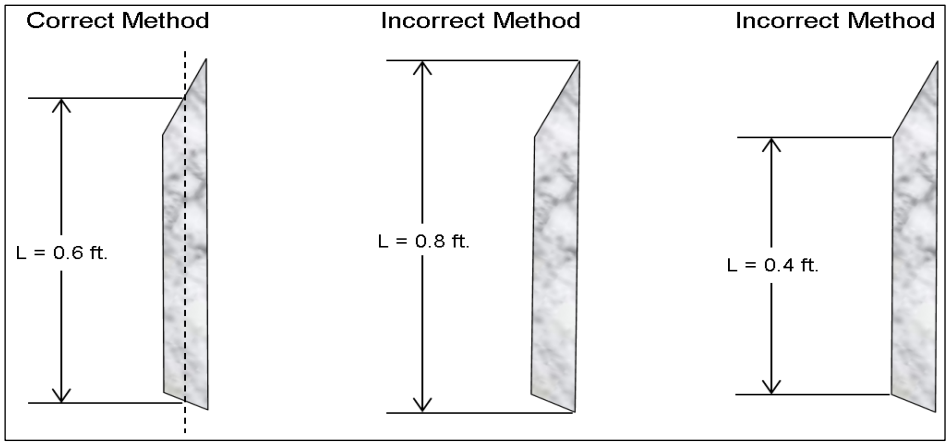


Figure 3.6.5.2-2 – Length Measurement of Core Recovery and RQD

The RQD for pieces of rock core that are moderately to highly weathered, contain pores, are chemical altered, or are friable should be included in the calculation. Any non-indurated sample such as a clay or soil seam encountered during drilling that exceeds 4-inches in length should not be included in the calculation of RQD.

3.6.5.3 Discontinuity Dip

Use the standards as indicated in Figure 3.6.5.3-1 and Table 3.6.4.8-2 to describe the magnitude of dip of discontinuities. If possible, measure strike and dip in bedrock exposures or from oriented core, report discontinuity dip in vertical core, and measure angle from core axis for angled borings. Report an average angle only if moderate variations are observed. Provide both a range and average if large variations in orientation are apparent. Observation of the magnitude of discontinuity dip made with non-oriented core is useful for anticipating various difficulties that may arise from advancing piles or shafts in rock masses that contain discontinuities that are oriented close to vertical.

Procedure for orienting and measuring rock core from vertical and angle borings:

Vertical Boring: The true dip magnitude is determined by the maximum angle measured between the discontinuity and the plane at the top of each core run that is perpendicular to the core axis. This angle is the steepest possible plunge along the plane, and is recorded as true dip (TD), e.g., TD = 35 degrees. Note the dip-direction or strike cannot be determined from a non-oriented vertical core.

Angled Boring: The true dip magnitude and dip direction or strike direction of a discontinuity cannot be directly measured from a non-oriented angled boring. Measure the angle of the discontinuity relative to the plane at the top of each core run that is perpendicular to the core axis. Report the dip of the discontinuity as a relative dip (RD) RD = 30 degrees. Where angle borings are completed for specific project investigation needs, indicate the boring angle from vertical, and the azimuthal bearing of the boring.

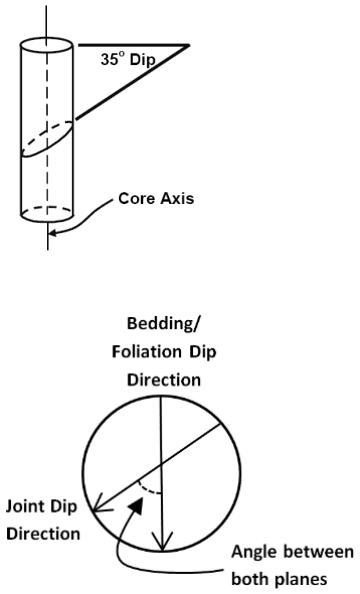


Figure 3.6.5.3-1 – Measurement of Discontinuity Dip Magnitude

3.6.5.4 Discontinuity Opening

Measure the opening of each discontinuity and record the measured value. Select a descriptor that best describes the opening according to Table 3.6.5.4-1. Descriptions for discontinuity openings may involve a single descriptor or can describe a range of joint openings (e.g., large to narrow joint opening, narrow to tight joint opening, wide to open joint opening, etc.). For an accurate understanding of what constitutes a discontinuity, refer to the definitions in Chapter 3.6.5.

Table 3.6.5.4-1 – Discontinuity Opening Descriptors

Descriptor	Abbreviation	Description
Tight Joints	Tjo	No open space at discontinuities - fits together tight, but not a fresh break
Narrow Joint Opening	Njo	Open spacing up to 1/8 inch - aligned well but may have some evidence of weathering along discontinuity planes
Open Joints	Ojo	Open space > 1/8 inch up to 3/8 inch – usually weathering along discontinuity planes
Large Joint Opening	Ljo	Open space > 3/8 inch up to 1 inch – often significant weathering along discontinuity planes
Wide Joint Opening	Wjo	Open space > 1 inch – may have significant weathering or may have infilling

3.6.5.5 Discontinuity Condition

Record a detailed description of an individual discontinuity only if the feature is known or suspected to be significant and persistent within the rock mass of interest. If a significant discontinuity surface and/or soil infilling are present, describe its physical characteristics. Surfaces or fillings of similar character can be described and recorded as one general description for multiple discontinuities in a run, portion of run, or defined physical length. Characteristics such as roughness, thickness, texture, and hardness of the surfaces/infill are important in evaluating the shear strength of persistent discontinuities, and in modeling the deformability and stability of large-scale rock masses. Surface characteristics are less important only when low-strength materials (soils) comprise fracture fillings that would likely control the behavior of the rock mass.

For any significant discontinuity or similar group of discontinuities, record a description of any of the following notable characteristics that apply:

1. Describe the discontinuity **surfaces** as rough, smooth, or polished. The roughness (small-scale asperities) of fracture surfaces is critical for evaluating shear strengths. Roughness descriptors such as “striated” or “slickensided” should be used whenever observed. For oriented core or outcrops, the orientation of striations or slickensides should be recorded. The rake of striations or slickensides should be recorded when observed in core from vertical drill holes that have not been oriented.
2. Describe the discontinuity **infill** thickness, constituents, and hardness. Soil or crystalline mineral material can provide a significant tensile and shear strength to the discontinuity. The presence or absence of coatings or fillings, and characteristics of the filling material, may be as significant as fracture spatial relationships or planarity. Strength and permeability of fractures may be affected by fillings. Be mindful that infill may be present in situ only to be washed away in the drilling process and not recovered. Color changes in the returned drill fluid can give an indication of washed infill, while a sudden tool drop of the drill steel may indicate an open void has been encountered. If soil infilling is recovered, describe as outlined below:

- **Infill Thickness**: Measure and record the thickness in inches. If no thickness is noted, discontinuity surfaces will be understood to be "tight" or labeled as such (no infill or void).
- **Infill Constituents**: Descriptors for infill texture is the same as those described in Chapter 3.6.3 for soils and Chapter 3.6.4 for intact rock.
- **Infill Hardness**: Descriptors for infill consistency or density are the same as those described for soils, Table 3.6.3.3-1 and Table 3.6.3.3-2. Describe the discontinuity healing (or re-cementation) condition, if evident. Discontinuity healing can be observed when there is a color contrast with the bordering intact rock. Features referred to as "veins" are often healed discontinuities. In addition to an observation of the amount of the discontinuity that has been healed, the healing material should be observed and recorded. The amount and material of the healing is relevant to the estimation of discontinuity shear strength, discontinuity hydraulic conductivity, and to the ease with which the rock can be excavated (e.g., open excavation, drilled shaft, borehole).

3.6.6 Standard Final Engineer's Log

The Department has made available PennDOT-specific gINT libraries, templates, and examples to the Districts and Business Partners. Detailed information for obtaining gINT software and PennDOT's gINT data template and library, and for integrating gINT into the project development process can be accessed electronically on the PennDOT gINT Webpage. gINT Software with PennDOT's gINT data template and library are required to be used to prepare geotechnical reports. With the adoption of gINT software, the Final Engineer's Log and Engineer's Test Pit Log is strictly standardized to facilitate efficient electronic data capture and reporting. Project files associated with gINT software will have the appropriate file naming convention, MPMS_#####_District_XX (e.g., MPMS_42195_District_02).

The Inspector's Field Logs are not strictly standardized. However, to record the required drilling data and material information in the field, the Drilling Inspector may use Form TR-438, Inspector's Field Log (recommended), or another similar log. Inspector's Field Logs can be formatted as portrait or landscape; handwritten or PDA-generated; or almost any format that the PGM and DGE determine to be clear and efficient to the data collection and preparation of the final logs. If data is entered electronically in the field using the gINT Field Data Collection Tool, this data can be imported into a gINT project file to create the electronic version of an Inspector's Field Log.

As needed or when required by the PGM or DGE, use Form TR-438A, Supplemental Notes and Sketches (or alternate), to record supplemental information about the boring operations, sampling, or decommissioning of boreholes. PennDOT's optional Borehole Grouting Log report can be produced using gINT software with PennDOT's gINT library, or an independent Borehole Grouting Log may be used. When submitting independent or PennDOT's gINT Borehole Grouting Log, the electronic file containing the report is to be properly labeled (i.e., Borehole Grouting Log MPMS_#####), and must be submitted per Chapter 4.11. The Supplemental Notes and Sketches form is not available in the gINT software or in the gINT Field Data Collection Tool. The use of the supplemental sketch sheet is encouraged to record details that would otherwise be difficult to clearly describe using only written descriptions. Lengthy or

unclear written descriptions can sometimes be avoided using a simple sketch. Recording details concerning oriented test borings, unusual rock core features, or site conditions can often be more clearly described using a supplemental drawing. Form TR-438A, Supplemental Notes and Sketches, may be submitted electronically per Chapter 4.11.

3.6.7 Standard Engineer's Test Pit Log

The following information must be provided on the Engineer's Test Pit Log:

- Professional Engineer or Professional Geologist seal, signed and dated, of the project geotechnical manager (PGM) of record, attesting to the accuracy of all information on the log.
- Project identification, including ECMS#, state route or local designation, section, district, and county
- Test pit identification number
- Coordinates, state plane (northing and easting) and geodetic (latitude and longitude)
- Date of excavation and backfill
- Name of Certified Drilling Inspector (DGS's or PGM's Representative)
- Elevation of top of test pit
- Ease of excavation using Table 3.6.7-1

Table 3.6.7-1 – Ease of Excavation Descriptors

Descriptor	By Equipment/Material
Easy	Small sized excavator (between 11 - 19 tons using a 2-ft. bucket) * excavates a full bucket of material consistently with little resistance; generally associated with very loose to loose or very soft to soft deposits
Moderate	Small sized excavator (between 11 - 19 tons using a 2-ft. bucket) * excavates full to half of a bucket of material consistently with greater resistance or need to loosen some material; generally associated with medium dense to dense or medium to stiff deposits
Difficult	Small sized excavator (between 11 - 19 tons using a 2-ft. bucket) * excavates material with much more resistance and more loosening of material; generally associated with very dense or very stiff to hard deposits

Notes: 1. Excavator and bucket size may vary. Adjust accordingly based on material present.

- Location of the test pit relative to project reference line (e.g., segment, offset, offset from centerline) or other suitable reference points
- Type of and size of excavation equipment used
- Pit dimensions including depth, width, and length
- Seepage amount and elevation
- Depth to top and bottom of profile for each soil type
- Caving of sides and at what depth using Table 3.6.7-2

Table 3.6.7-2 – Caving Descriptors

Descriptor	Description
Stable	Test pit walls (sides) exhibit little or no signs of caving
Moderate	Test pit walls (sides) exhibit occasional calving (like breaking of iceberg face) or sloughing at various depths or locations
Unstable	Test pit walls (sides) exhibit caving in large amounts; significant sloughing, caving, bulging, spalling, or slope failure occurring throughout excavation

- Depth, type, and condition of rock (if encountered)
- Bag number and depth of bag samples
- Pocket penetrometer or Torvane test results
- Description and identification of each soil and rock stratum (if encountered) as specified in Chapters 3.6.3, 3.6.4, and 3.6.5.
- Include any relevant information such as presence of boulders, reason for stopping excavation (e.g., caving sides, difficult excavation, limit of reach of backhoe), moisture condition, and relative density and consistency of soils.
- Included with the log, provide digital photographs (minimum 8-megapixal resolution, .jpg format) of each test pit, with location information (project number, station, test pit number, depths, etc.) clearly identified in photograph. Enough photographs must be provided to clearly identify all details.

Use the standard Engineer's Test Pit Log provided with gINT software.

3.6.8 Graphic Symbols for Soil and Rock Deposits

Graphic representations are useful for showing the extent of different general deposit types. The symbology shown in Figure 3.6.8-1(a), (b), and (c) is to be used on the Final Engineer's Log and when graphical representations are to be shown on Soil Profile plan sheets, or cross-sectional stick-logs. Figure 3.6.8-2 aids in providing shortened nomenclature used in gINT for graphic symbols.

The graphic symbols developed for soil and rock are designed to be simple and intuitive, so that anyone familiar with the system can easily and rapidly identify a rock or soil type by the symbol. Particles for gravel, sand silt and clay are identified as indicated in the legend below. They are identified by size and shape.

Legend for Soil Symbols

Primary or Secondary Soil Symbols

▲ = Mechanically Broken Rock
⬟ or ⬠ = Gravel and/or Sand
● or ○ = Silt
▬ or ─ = Clay
ϒ or ϒ = Organics

Legends for Rock Symbols

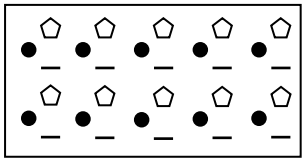
⬠ = Conglomerate/Breccia
○ = Sandstone
• = Siltstone
– = Claystone

Since granular materials (gravels and sands) are the largest particle sizes, the largest symbol is for gravel-sand. The gravel-sand symbol consists of a pentagon. This shape was selected to help differentiate it from fine-grained silts and clays, and to provide dual representation for Conglomerate and Breccia. These two rock types are very similar, the only difference being the particle shape. Conglomerates contain generally rounded particles, while Breccia's contain very angular particles. The pentagon shape is somewhat between a rounded and angular particle, allowing the use of one symbol to represent both Conglomerate and Breccia. The mechanically broken rock symbol is represented by a triangle to designate the angular shape of broken rock.

Silt is represented by an intermediate-sized circle. Clay is represented by flat line representing the very thin and flat, nearly two-dimensional, shape of a clay particle. Organics/Topsoil is represented by two curved lines and one straight line to represent vegetation (the source of organic material).

For the soil symbols, except for clay, when a grain symbol is shaded completely black it is to indicate that in a soil, that particle size is dominant. When clay is the dominant particle size, all other shapes lack the black shading. This provides for a simple and intuitive set of symbols for the various possible soil combinations.

When a soil symbol contains only one grain size symbol, the soil is comprised nearly exclusively of that grain size. The grain symbol will be accordingly shaded black. For mix grained soils, any grain size that is present in the matrix in visibly significant proportions (approximately 5 percent or greater), is represented in the soil symbol. Again, the predominant grain size will always be the one shaded black. As an example, a soil comprised primarily of silt but also having notable gravel, sand, and clay fractions may be identified as the following symbol:



A corresponding Final Engineer's Log description for this symbol may be "**SILT**, some **Sand,** some **Clay,** trace **Gravel**…"

pennsylvania
DEPARTMENT OF TRANSPORTATION

Graphic Symbols for Soil Deposits

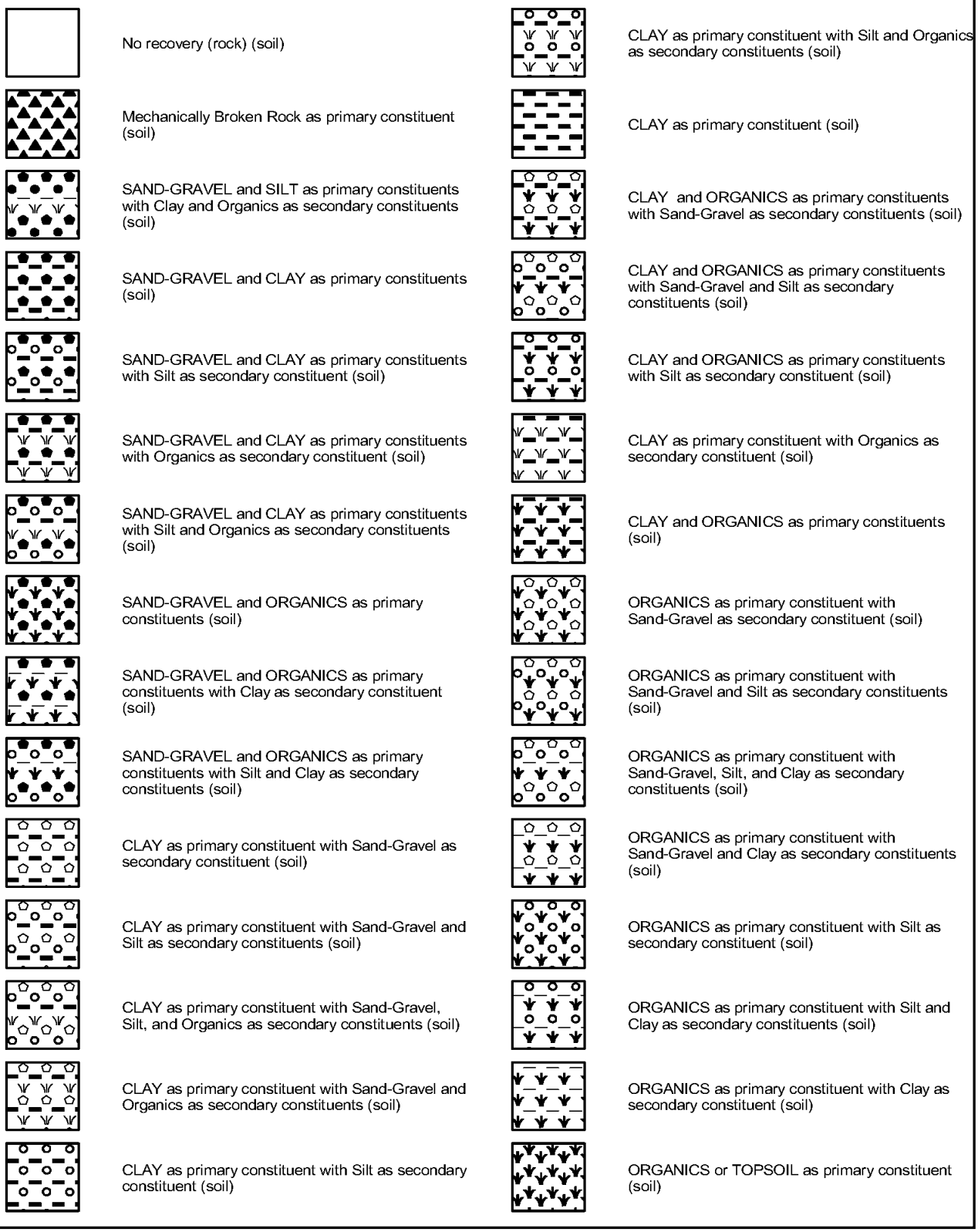


Figure 3.6.8-1(a) - Standard Graphic Symbols for Soil Deposits

pennsylvania
DEPARTMENT OF TRANSPORTATION

Graphic Symbols for Soil Deposits

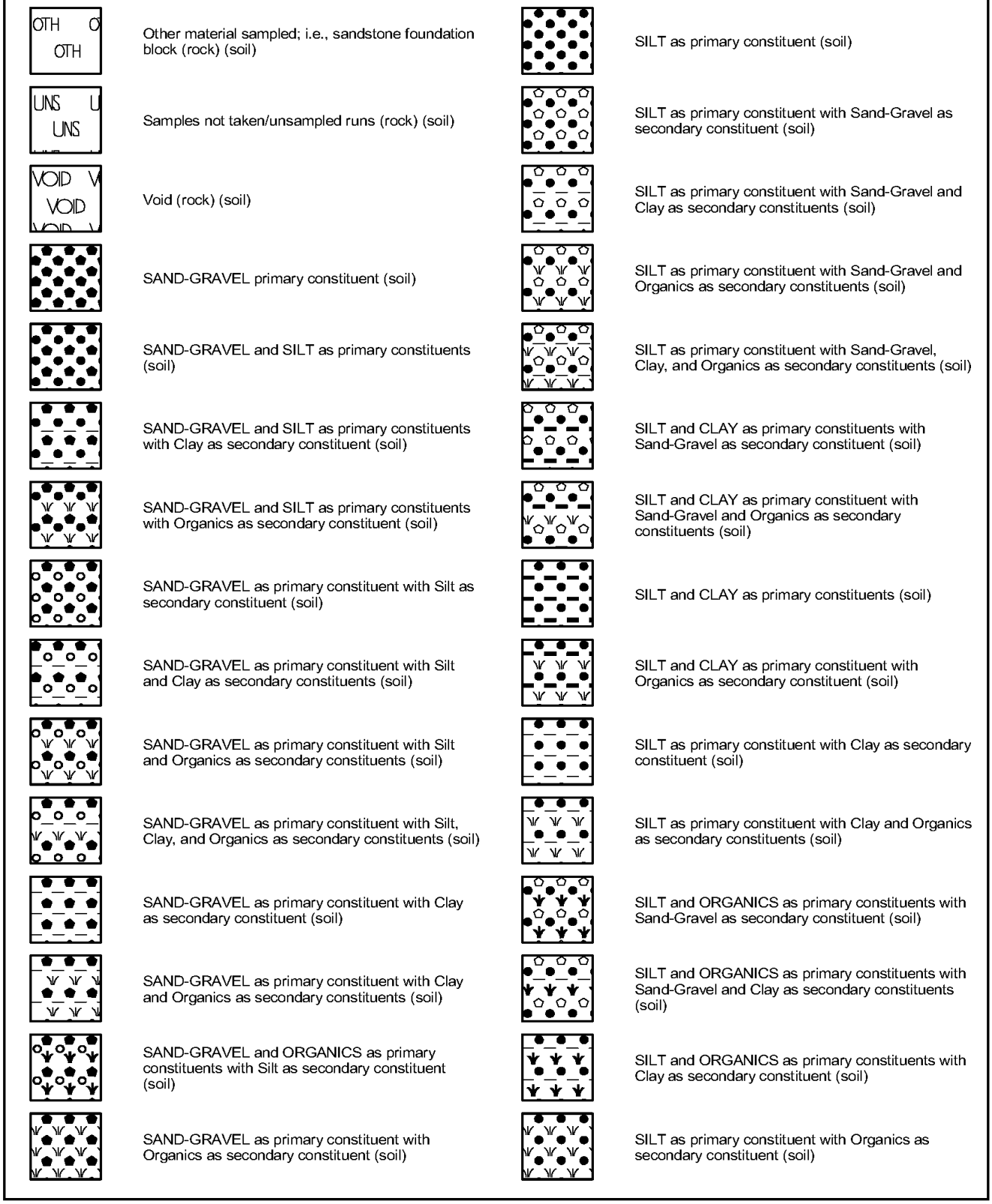
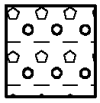


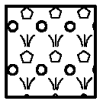
Figure 3.6.8-1(b) - Standard Graphic Symbols for Soil Deposits (Cont.)

pennsylvania
DEPARTMENT OF TRANSPORTATION

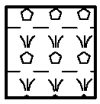
Graphic Symbols for Soil Deposits



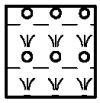
Mix Sand-Gravel, Silt and Clay with no primary constituent (soil)



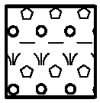
Mix SAND-GRAVEL with Silt and Organics with no primary constituent (soil)



Mix Sand-Gravel with Clay and Organics with no primary constituent (soil)



Mix Silt Clay and Organics with no primary constituent (soil)



Mix of Sand-Gravel, Silt, Clay and Organics with no primary consituent (soil)

Figure 3.6.8-1(c) - Standard Graphic Symbols for Soil Deposits (Cont.)

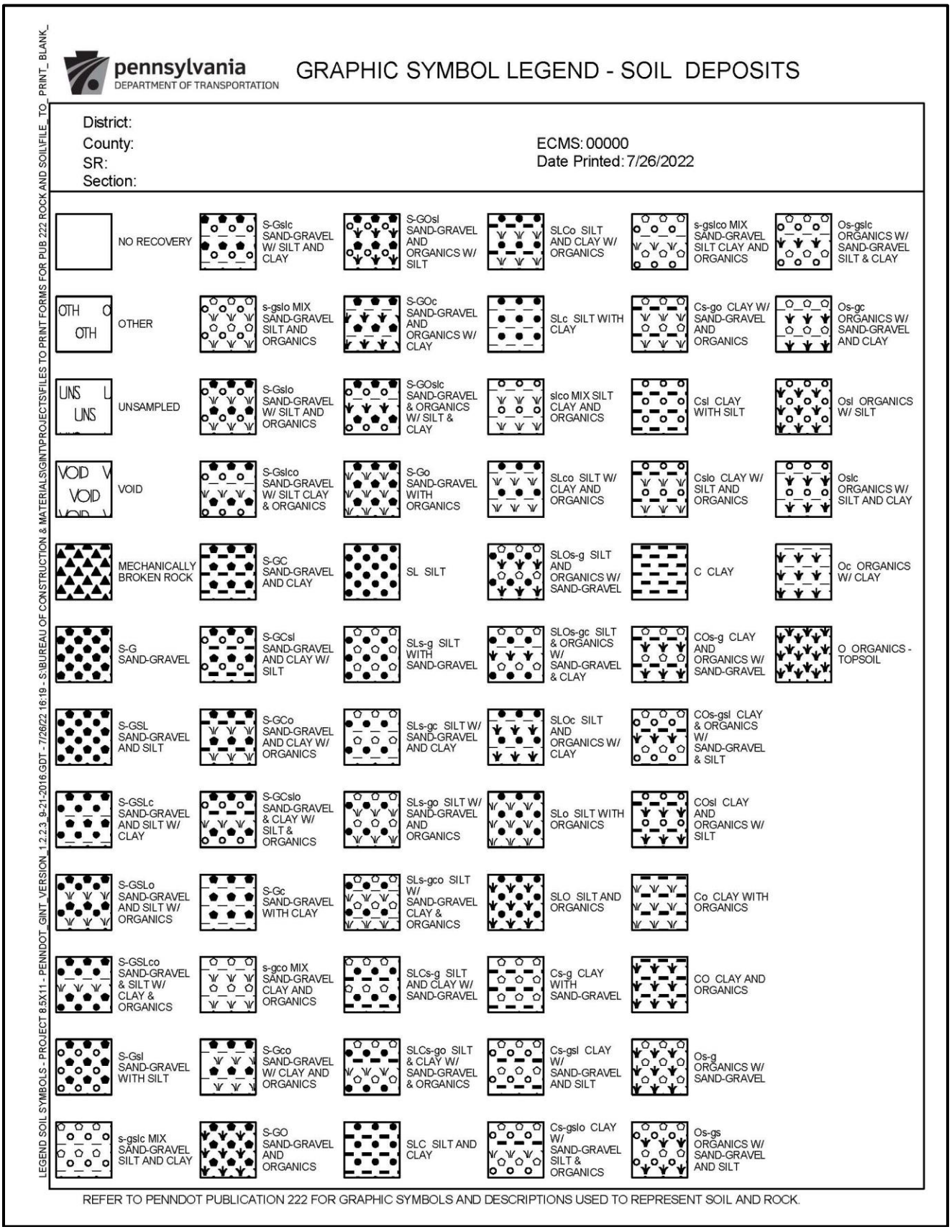


Figure 3.6.8-2 - Standard Graphic Symbols Legend for Soil Deposits

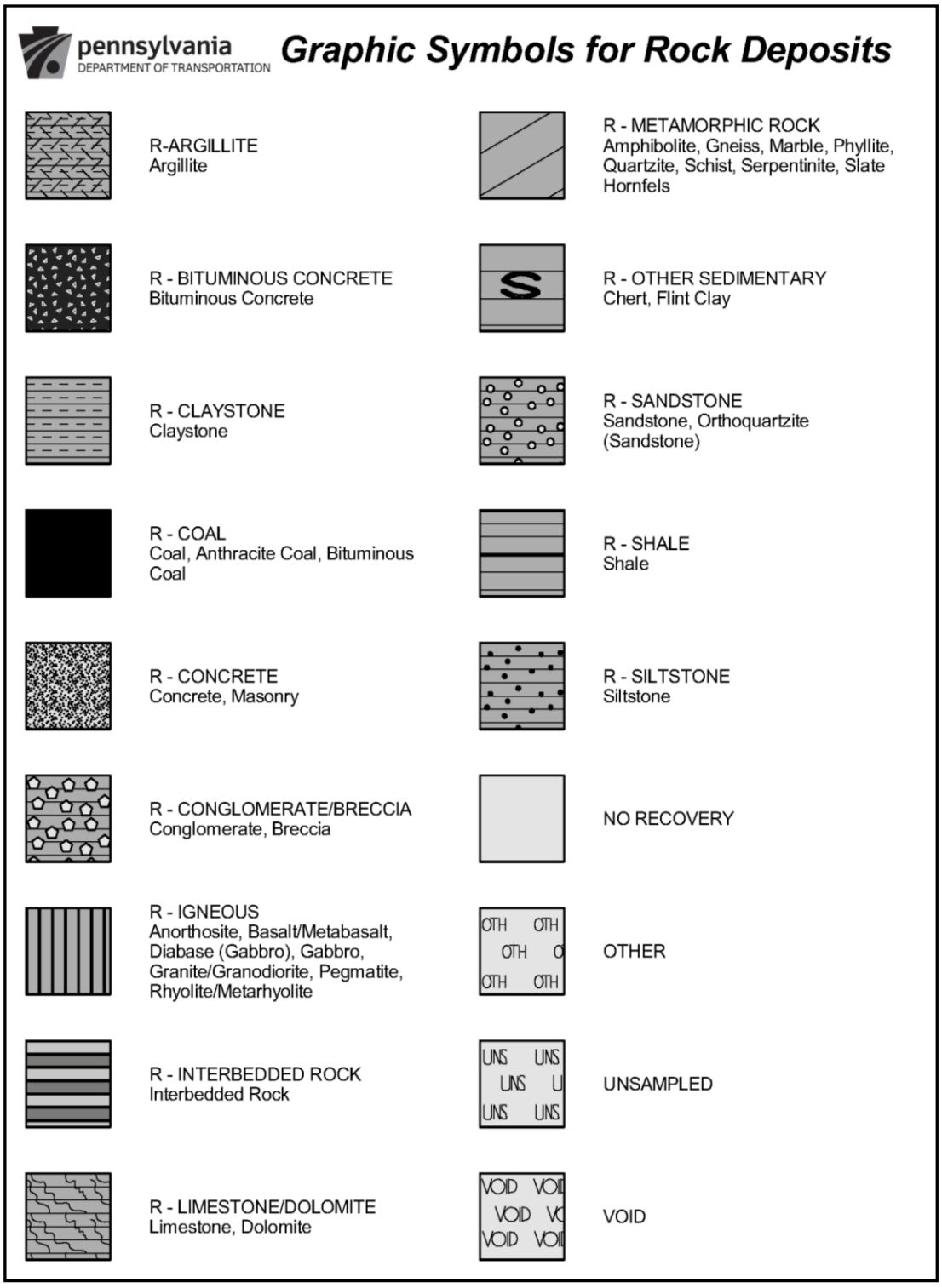


Figure 3.6.8-3 - Standard Graphic Symbols for Rock Deposits

All rock symbols (except for coal, concrete, and bituminous concrete) are shaded gray to differentiate them from soil. A blank symbol represents no recovery (in rock or soil). A symbol

with the letters “UNS” represents an unsampled run and a symbol with the word “VOID” represents a void within rock or soil.

All sedimentary rock types (again, the exception is coal) have a series of horizontal lines on a gray field. This indicates their origin from soil sediments, which are originally deposited in horizontal layers. The graphics with the symbol are set up similar to the soil symbols with some modifications as indicated in Figure 3.6.8-3. Coal is simply shaded black. Coarse-grained sedimentary rocks, conglomerate, and breccia’s contain the gravel and/or sand grain symbol. Sandstone, siltstone and claystone contain the silt and clay symbols respectively. Shale has many horizontal lines, representing its fissility or partings.

While limestone and dolomite are two different rock types (dolomite being, a mineral and containing magnesium in addition to calcium carbonate), they are both carbonate rocks that are functionally similar. For this reason, one symbol was selected to represent both rock types. Dolomite is more resistant to acid attack and solutioning, but both are ultimately a carbonate rock. Veining was added to the basic sedimentary symbol, representing the mineral veins often present in limestone.

A generic sedimentary symbol is used to indicate when one of the less common sedimentary rock types are encountered (e.g., argillite, chert). The symbol consists of the letter “S” imprinted on the basic sedimentary symbol of horizontal lines on a gray field. No differentiation is made between claystone and mudstone.

Igneous rocks are indicated by a series of vertical lines on the gray field. The vertical lines represent the origin of igneous rocks from the upward movement of magma into (plutonic) or through (volcanic - reaching the surface) the earth’s crust. Metamorphic rocks are represented by a series of diagonal lines on a gray field, representing their origin from either sedimentary of igneous rocks that have been altered by heat or pressure.

Concrete and bituminous concrete are both human-made materials that are represented separately. The concrete symbol contains dark outlined, triangular shapes of varying sizes that represent the composite material (concrete), which is composed of granular aggregate embedded in cement. The bituminous concrete symbol consists of white outlined, triangular shapes (representing the aggregate materials) accentuated in a black background to exemplify the distinctive black appearance of asphalt.

3.6.9 Graphics Shading for Soil and Rock

Graphic columns on the Final Engineers Log are enhanced with use of standard shaded background accents. The use of shading enhances the visual interpretation of soil versus rock materials. Grayscale enhancement is provided on electronic versions of logs, and required on printed computer-generated versions, when utilizing gINT software approved and distributed by the Department.

3.7 CORE BOX AND TEST PIT PHOTO LOGS

Included with the boring log, provide a 5-inch x 3.75-inch digital photograph of each open core box, with core samples, measurement device (e.g., tape measure, 6-foot ruler) placed

adjacent to each core box, and information on inside of lid clearly visible (project number, station, boring number, depths, etc.). Figure 3.7-1 shows an appropriate core box photograph, including proper spacing techniques, proper labeling of core box and soil samples, and correct orientation of the rock core (reference Chapter 3.8 and Section 214). Use an appropriate Core Box Photo Log for core box photos and an appropriate Test Pit Photo Log when necessary, both available in the gINT software. The following information must be provided:

- Project identification, including ECMS#, state route, section, district, and county
- Identification number for the test boring or test pit and box number
- Photographs that must meet one of the following specifications:
  - Photos taken in .jpg format with 8-megapixel resolution (minimum), with minimal compression (highest quality).
  - Photos taken in .png format with 8-megapixel resolution (minimum). The file must then be converted and saved in .jpg format.

Figure 3.7-1 – Sample Core Box Example

Project photo files associated with gINT software are to follow the appropriate file naming convention:

MPMS_#####_District_XX_Boring Number_Box_X_of_Y (e.g., MPMS_42195_ District_02_SB1-01_Box_1_of_3).

3.8 PACKAGING AND LABELING OF SAMPLES

The Drilling Inspector must place samples in the core box in the order shown in Figure 214-1. The Drilling Inspector must properly label all jar samples and all core boxes, according to

the requirements in this publication. It is standard practice to begin each boring with a new core sample box, or refurbished core box in good condition. Unless the DGE directs otherwise, when two borings have minor amounts of recovered sample (such as very shallow and/or low recovery borings) it is permissible to place samples from both borings in a single core box. The box labeling must clearly indicate that the box contains samples from multiple borings.

Do not remove any sample(s) from the original field box for laboratory testing until the completed core box photograph is taken. The DGE or PGM must give concurrence to the selection and removal of individual soil and rock samples needed for laboratory testing.

For **Split-Barrel Soil Samples**, place the most representative and least disturbed five-inch-long portion of each split-barrel soil sample in a glass sample jar. Place the sample in the jar such that the bottom-end of each five-inch sample is at the bottom of the jar. The jars supplied by the Drilling Contractor include pre-printed and self-adhered labels as shown on Figure 3.8-2, placed on the side and top of each jar to record the required information. Clearly, accurately, and permanently fill-in the required information on the lid and side of each jar. Place the jars in wooden core boxes, maintaining the correct sequence and orientation of the jars. The lid-end of the jar should always correspond with the top-end of the selected soil sample and should be placed in the core box with that orientation.

For **Undisturbed Soil Samples**, clearly, accurately and permanently mark the side of the sample tube and the end caps as shown in Figure 3.8-3. Metal or plastic tube caps are to be used. Unless specified otherwise by contract or directed by the PGM or DGE, undisturbed samples must be packaged and transported conforming to ASTM D4220, and delivered to the testing laboratory no later than one week after the sample is originally taken. Samples are to be handled, stored and shipped in the same orientation in which they were sampled. Samples are to be protected from bumping, dropping, rolling, etc. by properly packaging and cushioning. For all modes of transporting samples, the loading, transport, and unloading of sample containers should be monitored by the Drilling Inspector or other qualified person such as the PGM, geologist, or soils technician.

For **Rock Core Samples**, place rock cores in the sequence of recovery in well-constructed wooden core boxes as specified in Section 214.02(a). Fill boxes from left-to-right, top-to-bottom. Orient and align the predominant discontinuity set such as bedding or jointing so they are observed at their steepest angle as depicted in Figure 3.7-1. Fill in the information in the stenciled areas on the box lid and sides as shown in Figure 3.8-1. Place wooden block spacers at the end of each core run and between rows and mark the depth from the surface of the boring to the top and bottom of the drill run on the wood blocks. When voids are encountered, place a wood block showing the depth to, and length of, void encountered at the approximate location of the void in the core run. When necessary to maintain proper confinement of the samples, use screws or nails to permanently fasten blocks in place. Screws can be toed-in at an angle through a box partition or side of box.

Upon completion of each boring, clearly, accurately and permanently mark the top, front side, and both ends of the core box as shown in Figure 3.8-1. The left end of each core box must be painted with white or light-colored paint. Use a permanent black marker to print the information

on the box. Permanently mark the inside of the core box lid with the core run information including run number, top and bottom depths of run, recovery length, and rock quality designation (RQD). When core boxes need stacked, ensure the core boxes are stacked four wide by up to eight high on each pallet and orienting in an alternating direction so that each level of four core boxes is perpendicular to the next level of four core boxes.

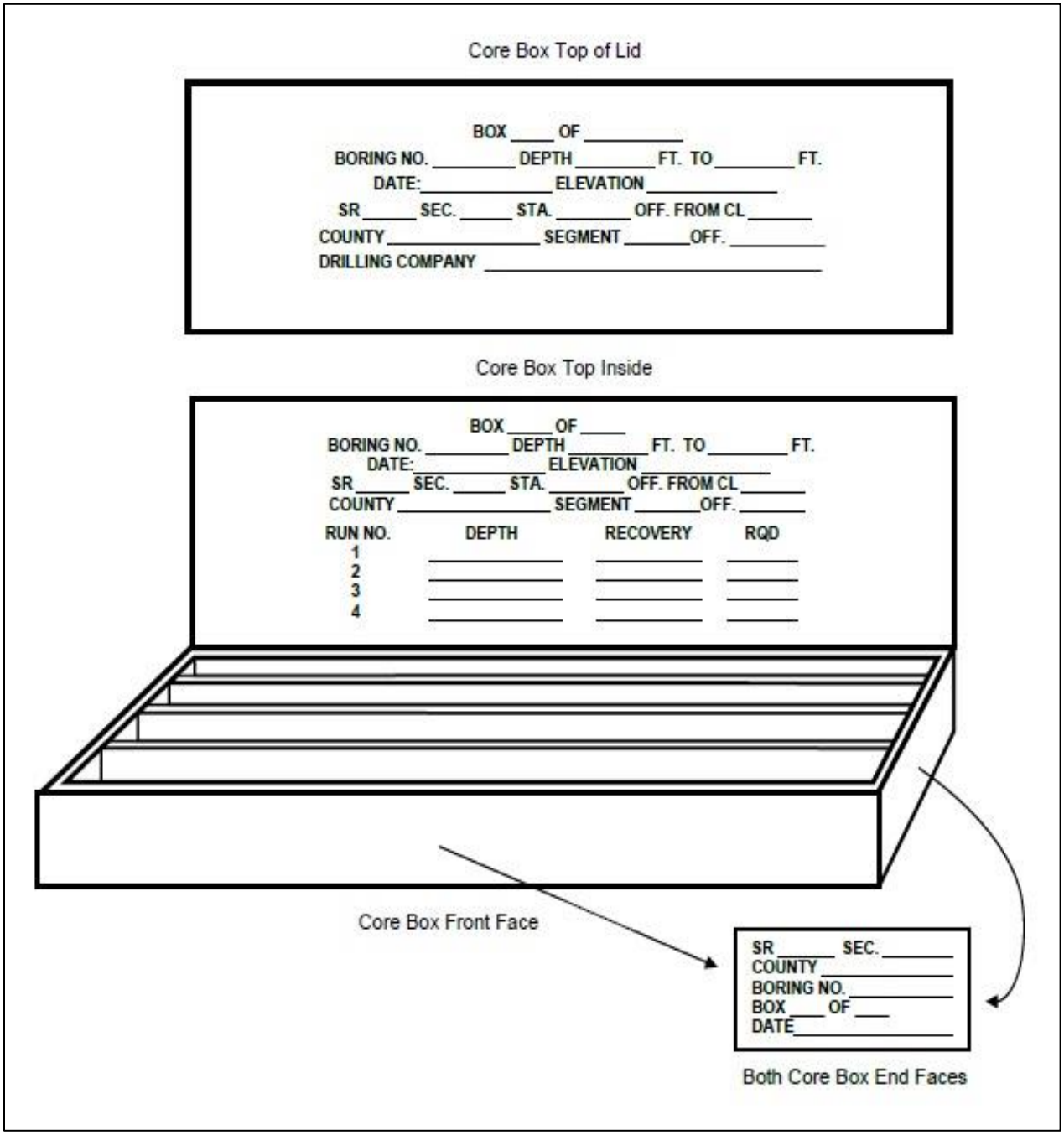


Figure 3.8-1 – Core Box Design and Labeling

SR _____ SEC. _____ COUNTY _____

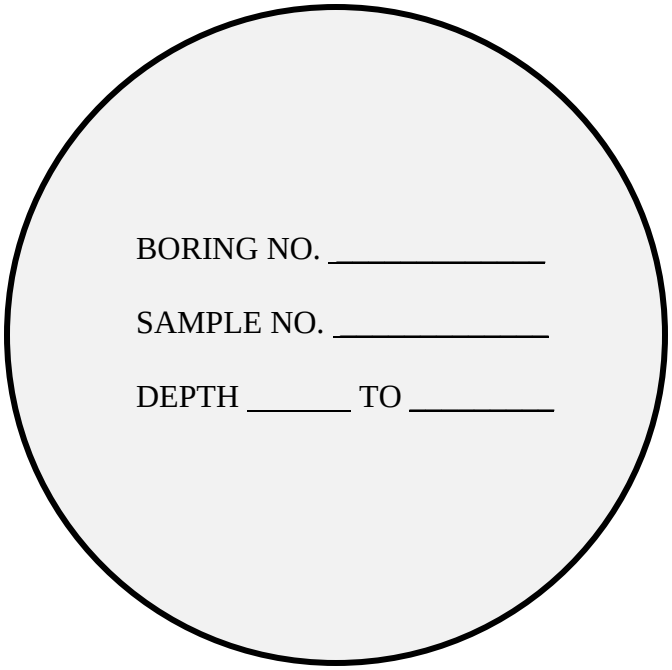
STA. _____ OFFSET FROM CL _____

BORING NO. _____ SAMPLE NO. _____

DEPTH FROM _____ TO _____ RECOVERY _____

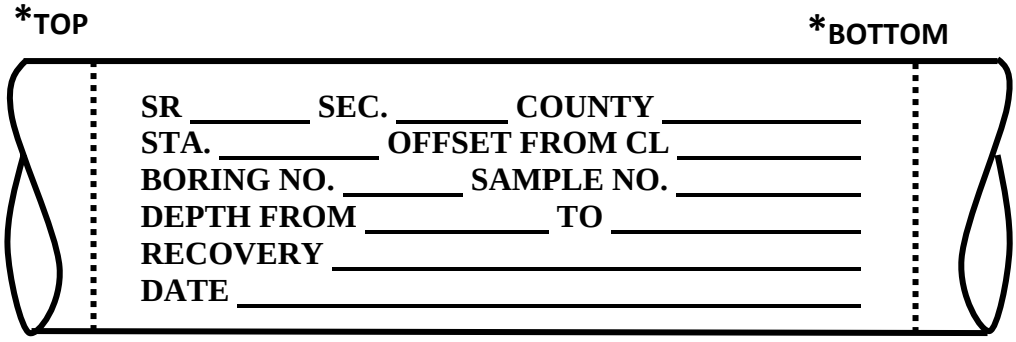
BLOWS/ 0.5 FT _____ DATE _____

(Side of Jar)



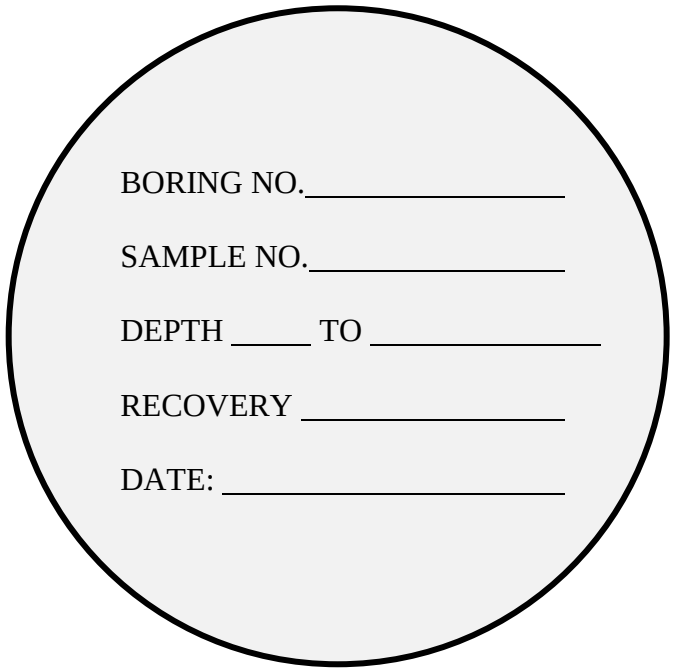
(Top of Jar)

Figure 3.8-2 – Sample Jar Labeling



(Side of Tube)

*INDICATE TOP AND BOTTOM OF SAMPLE WITH
A LABELED LINE ON THE OUTSIDE OF THE TUBE.



(Cap of Tube)

Figure 3.8-3 – Undisturbed Sample Tube Labeling

3.9 SAMPLE QUANTITY AND QUALITY

Drilling Inspectors who examine, package, and transport soil, rock, and water samples have an important role in ensuring the quality of the laboratory test results. When performing field investigations, the Drilling Inspector must be familiar with the procedures contained within this Publication and should also review applicable AASHTO and ASTM standards, such as the following:

AASHTO R13 - Practice for Conducting Geotechnical Subsurface Investigations
ASTM D653 - Terminology Relating to Soil, Rock, and Contained Fluids
ASTM D1452 - Practice for Soil Exploration and Sampling by Auger Boring
ASTM D1586 - Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587 - Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D3550 - Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
ASTM D4220 - Practices for Preserving and Transporting Soil Samples
ASTM D5434 - Guide for Field Logging of Subsurface Explorations of Soil and Rock
ASTM D6032 - Test Method for Determining Rock Quality Designation (RQD) of Rock Core
ASTM D6151 - Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

Prior to drilling, the Drilling Inspector must seek clear instruction from the PGM as to the number and type of laboratory tests that are anticipated for a given project. The PGM typically makes the final selection of samples for lab testing once drilling is complete. For this reason, it is important that adequate quantity of materials have been recovered during the drilling operations.

During drilling, the Drilling Inspector and Drilling Contractor share in the responsibility to obtain the sufficient quality and quantity of sample material needed for testing. There are a variety of standard laboratory tests for soil and rock materials. To assist in this, Table 3.9-1, Table 3.9-2, and Table 3.9-3 list guidelines for sample requirements for some of the more common individual laboratory tests. The minimum sample size needed to properly prepare a lab specimen of soil can be dependent upon the gradation of the soil. Depending upon the actual gradation of the soil, a larger or smaller quantity of material than is listed may actually be needed to prepare the specimen. If the Drilling Contractor cannot retrieve the amount of material listed, or if conditions differ than what was anticipated, the Drilling Inspector must contact the PGM for additional guidance on obtaining adequate sample quantities. Refer to Figure 3.9-1 for proper bag sampling of soil for MTL (Materials Testing Laboratory) samples.

After drilling, the Drilling Inspector must conduct a quality check of their field notes and observations once back in the office. Sample descriptions and identifications will be reviewed and revised as necessary to ensure that they are following the procedures presented in this section. Descriptors of sample properties that are subject to change due to time or environment, such as moisture or RQD, must not be revised. Samples that are to be stored for

laboratory testing or other purposes must be inventoried to ensure correct labeling and accounting.

Table 3.9-1 – Soil Sample Sizes for Individual Laboratory Tests

Soil Test or Property	Standard	Sample Type and Quantity[1, 2]	Additional Comments
Moisture Content	AASHTO T265	1 jar for max. particle size of 0.5 inch 3 jars for max. particle size of 2 inches	Place in air-tight jar or plastic bag.
Unit Weight	ASTM D7263	1 jar or 3-inch piece of Shelby tube or block sample (minimum 3 cubic inches). Sample must be intact with minimal disturbance.	Sample must have sufficient cohesion to maintain shape. Jar or plastic bag must be airtight to maintain natural soil moisture.
Specific Gravity	AASHTO T100	1 jar	
Particle Size Analysis	AASHTO T88	1 lb. (2 jars) for max. particle size of 0.375 inch. 4.5 lb. max. particle size of 1 in. 9 lb. for max. particle size of 2 in. 11 lb. for max particle size of 3 in.	If inadequate sample is available for 1 inch and larger material, it is acceptable to use a minimum of 3 jars.
Liquid Limit, Plastic Limit, Plasticity Index	AASHTO T89 (Liquid Limit) AASHTO T90 (Plastic Limit)	1 jar when sample is primarily fine-grained. 2 to 3 jars when sample contains coarse material.	Minimum of 0.2 lb. passing the No. 40 (0.425mm) sieve when both T-89 and T-90 performed.
Consolidation	AASHTO 216	Approx. 4 inch of Shelby tube. Undisturbed sample required.	Min diameter. = 2 in. Min. height = 0.5 in., and min. diameter to height ratio of 2.5.
Unconfined Compression	AASHTO T208	Can be run on disturbed or undisturbed samples. 2 Shelby tubes needed. Typically, 3 samples (approx. 6 inches each) required for test. Soil must have sufficient cohesion to maintain shape. For disturbed/remolded sample, approx. 10 lb. sample required for test (additional sample needed if sample contains coarse material).[3]	Min. sample diameter = 1.3 in., length to diameter ratio of 2 to 2.5. One Shelby tube generally does not contain sufficient testable sample.
Direct Shear	AASHTO T236	Can be run on disturbed or undisturbed samples. Portion (approx. 6 inches) of Shelby tube. Typically, 3 samples (approx. 2 inches each) required for test. For disturbed/remolded sample, approx. 3 lb. sample required for test (additional sample needed if sample contains coarse material).	Min. sample diameter/width = 2.0 in. Min. diameter/width to thickness ratio is 2:1. Sample height must be at least 6 times max. grain diameter. Typical shear device uses 1 inch sample height.

Soil Test or Property	Standard	Sample Type and Quantity[1, 2]	Additional Comments
Triaxial Compression (Unconsolidated Undrained Shear)	AASHTO T296	Can be run on disturbed or undisturbed samples. 2 Shelby tubes needed. Typically, 3 samples (approx. 6 inches' high each) required for test. Soil must have sufficient cohesion to maintain shape. For disturbed/remolded sample, approx. 25 lb. sample required for test (additional sample needed if sample contains coarse material).[3]	Min. diameter = 1.3 inch and height to diameter ratio between 2 and 2.5. Largest particle size must be smaller than 1/6 sample diameter. One Shelby tube generally does not contain sufficient testable sample.
Triaxial Compression (Consolidated Undrained Shear)	AASHTO T297	Can be run on disturbed or undisturbed samples. 2 Shelby tubes needed. Typically, 3 samples (approx. 6 inches' high each) required for test. Soil must have sufficient cohesion to maintain shape. For disturbed/remolded sample, approx. 25 lb. sample required for test (additional sample needed if sample contains coarse material).[3]	Min. diameter = 1.3 inch and height to diameter ratio between 2 and 2.5. Largest particle size must be smaller than 1/6 sample diameter. One Shelby tube generally does not contain sufficient testable sample.
California Bearing Ratio (CBR)	AASHTO T193	2 bags (100 lbs. total).[3]	100 lbs. is preferred for three 1-point molds on fine-grained material (i.e., all material passing the 3/8-inch sieve molded to optimum moisture/maximum dry density).[4]
Moisture-Density Relations (Compaction)	PTM 106	1 bag (50 lbs.) recommended. Minimum of 12 lbs. of material finer than 3/8-inch sieve required.[3]	
Hydraulic Conductivity (Permeability)	ASTM D5084	Can be run on disturbed or undisturbed samples. Portion (approx. 6 inches) of Shelby tube. For disturbed/remolded sample, approx. 3 lb. sample required for test (additional sample needed if sample contains coarse material).	Min. sample height and diameter of 1 inch. Largest particle size must be smaller than 1/6 sample diameter and height. ASTM D2434 used for high permeability soils
Resistivity (soil)	AASHTO T288	5 jars (3.3 lbs.) of 2 mm or smaller particles.	If possible, obtain approx. 5 lb. bag sample to perform all 4 corrosion tests. Obtain additional material if sample contains particles greater than 2 mm. Keep sample in air-tight container and test as soon as possible.
pH (soil)	AASHTO T289	1 jar (0.2 lb.) of 2 mm or smaller material.	
Sulfate Ion (soil)	AASHTO T290	1 jar (0.55 lb.) of 2 mm or smaller material.	
Chloride Ion (soil)	AASHTO T291	1 jar (0.55 lb.) of 2 mm or smaller material.	
Organic Content ("Loss of Ignition" Method)	AASHTO T267	1 jar. Only small amount of material needed (i.e., 0.22 lb. of material passing 2 mm sieve).	Recommended to determine total organic content of soil.

Notes: 1. An equivalent amount of soil from an undisturbed sample (e.g., Shelby tube) can be used in place of a disturbed sample.

2. One jar of soil will typically weigh approximately 0.5 lbs. Assumes sample with a 1.375-inch diameter, 5 inches long and unit weight of 110 pcf.

3. When using remolded samples, it is preferred to use virgin material for each remolded sample. If adequate sample is not available, it is acceptable to re-use sample that was previously tested.

4. For three 1-point molds on coarse-grained material (i.e., some material retained on the 3/8-inch sieve molded to optimum moisture/maximum dry density), 400 lbs. is preferred.

Table 3.9-2 – Rock Sample Sizes for Individual Laboratory Tests

Rock Test or Property	Standard	Sample Type and Quantity	Additional comments
Unconfined Compression	ASTM D7012, Method C	4-inch min. piece of NQ diameter or larger rock core. Min diameter = 1.875 inch, length to diameter ratio between 2:1 and 2.5:1. Typically several pieces should be tested from a rock stratum.	If required core length is not available, it is permissible to use length to diameter ratio less than 2:1 and correction factor in ASTM D2938, 1979.[1] Use proper preparation and procedure.[2]
Point Load Strength	ASTM D5731	Minimum of 10 pieces of core with diameter between 1.2 and 3.3 inches, and length greater and 30% of diameter. Block and irregular samples can also be used. See test specification for sample size requirements for block and irregular samples.	Test is used as an index test for rock strength classification. It does not measure unconfined compressive strength. ASTM D7012, Method C should be used when adequate samples are available.
Fizz Rating	Sobek Method	See Chapter 10 of Publication 293 for testing and sample size requirements. Typically core samples from entire length of coring should be tested, not just core suspected of being potentially acidic.	These three tests are required for Acid-Base Accounting (ABA). Samples are pulverized in lab to pass the 0.25 mm sieve.
Neutralization Potential	Sobek Method (with Siderite Correction)		
Total Sulfur	ASTM D4239		
Slaking	ASTM D4644	Minimum 10 pieces of rock core. Each piece should weigh approx. 0.1 lb., which is equivalent to a piece of NQ core that is approx. 0.5-inch long.	Similar size pieces of rock fragments obtained from rock exposures (outcrops), test pits, etc. can also be used.
	PTM 122	See Chapter 15 of Publication 293 for testing and sample size requirements, and interpretation guidelines.	This test requires a sample of 100-200 grams, commonly a rock core sample 1- 1.5-inch(es) in length.

Notes: 1. $C=C_a/(0.88 + (0.24b/h))$, where C = computed compressive strength of an equivalent L/D = 2 specimen, C_a = measured compressive strength of the specimen tested, b = test core diameter, and h = test core height.

2. Do not follow ASTM D4543 for preparation of test specimens; however, do make sure the ends of the rock core specimen are cut with a wet saw aligned to provide top and bottom surfaces that are smooth and reasonably perpendicular to the axis of the core. Remove any protrusions or burrs that remain from the wet saw cuts prior to compressive testing. This can be done with a file, grinding wheel, or carefully trimming with a wet saw.

Table 3.9-3 – Water Sample Sizes for Individual Laboratory Tests

Water Test or Property	Standard	Sample Type and Quantity	Additional comments
Chloride	ASTM D512	Prior to obtaining samples, coordinate with laboratory that will be performing tests to determine required sample sizes, preservation and storage requirements, and time restrictions.	Lab that will perform tests should provide sample containers, buffering solutions etc.
Sulfate	ASTM D516		
pH	ASTM D1293		
Conductivity and Resistivity	ASTM D1125		

- Use cloth or burlap type bag with sufficient durability to prevent tears and spills. A 5-gallon bucket with a lid may also be used, or a similar durable container of adequate strength.
- Do not place more than 50 pounds of soil in one bag/suitable alternative container.
- When using large (18 inch x 30 inch) PennDOT canvas bags, a bag filled to the top of logo is approximately 50 pounds of soil.
- Tie bag tightly with string or a plastic zip-tie. Do not use duct tape.
- Use a plastic bag liner at least 3-mil thickness, unless otherwise directed.
- For moisture content samples, place soil in a zip-sealed plastic bag.
- Identify the sample by marking the bag with County, S.R. and Section number, Boring number, Station/Offset. Use permanent marker.
- When sending a bag sample to the MTL, attach a completed Form TR-447, Sample ID. Blank forms and sample bags can be obtained by contacting any of the DGE offices.

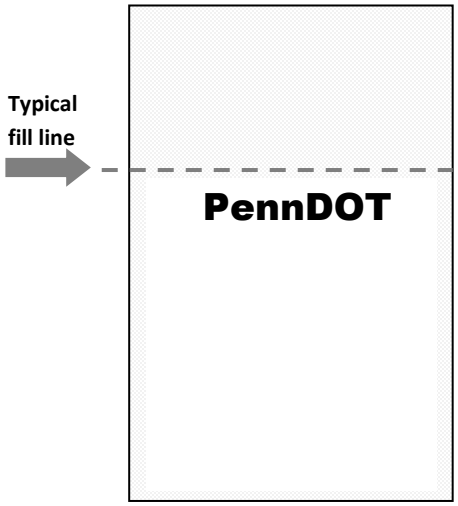


Figure 3.9-1 – Proper Bag Sampling of Soil for MTL Samples

3.10 BACKFILLING AND PLUGGING OF BORINGS

Drilling Inspectors must observe and document that borings are properly backfilled with grout as specified in Section 209 of the standard drilling specifications. Backfilling with cementitious grout serves to permanently stabilize and protect bore locations against environmental hazard such as; artesian flows, groundwater migration between separate aquifers, and vertical migration of possible contaminants into groundwater. Grouting also guards against the hazards of possible surface subsidence of the borehole. All borehole locations, even in remote areas, must be properly and securely backfilled.

CHAPTER 4 – SBSTC ADMINISTRATION

4.1 PRIORITIES AND OBJECTIVES

The PGM should remain aware of the overall objectives of the SBSTC, and make appropriate efforts to ensure that the following priorities and objectives are met:

1. **Proper Scope.** Obtain adequate information to establish all design parameters with sufficient reliability and to address all subsurface problems that may arise in design or construction.
2. **Proper Communication**. Ensure that the following Department personnel (as appropriate) are promptly informed of any conditions that may result in a change in the contract, or any unusual conditions that are encountered during exploration:

    - District Geotechnical Engineer
    - District Bridge Engineer (or Plans Engineer if no structure work is involved)
    - District Environmental Manager
    - Liaison Engineer or Project Manager

3. **Proper Documentation**. The subsurface conditions determined by the operations are fully and accurately described in the logs and records.

4.2 CONTRACT MANAGEMENT

Projects drilled under Department Contracts will be inspected by District personnel or the District's Representative.

Projects drilled under Consultant Design Contracts will normally be inspected by Consultant personnel. Consultant-designed projects can be inspected by Department forces provided the Department Drilling Inspector is Certified and the DGE is a licensed P.E. or P.G. in the Commonwealth. In addition, the DGE must review the core boxes and check and initial the Final Engineer’s Log.

For projects where the geotechnical Consultant (or a subsidiary company thereof) is also a Drilling Contractor, the Consultant may be allowed to provide the project drilling services and to inspect the work performed by their own Driller. See Chapter 4.5 for more clarification on the requirements for this case.

All inspection will be the responsibility of the PGM. One full-time, Certified Drilling Inspector will be assigned to each drill rig.

Any PGM or Drilling Inspector who does not demonstrate adequate proficiency or dependability at the project site or engages in activities contrary to the best interest of the Department, as determined by the DGE, will be subject to removal from the project. A qualified replacement will be required before work will be allowed to resume. The DGE must complete a written evaluation (Form TR-437, Drilling Inspector Performance Evaluation) of the Drilling

Inspector, within three working days of removal. Upon completion, the evaluation must be submitted to the removed Drilling Inspector, with a copy to the CGE.

4.3 PREPARATION OF PROPOSAL/CONTRACT

Prepare a draft subsurface investigation plan and submit to the DGE for approval. The plan must include the proposed types, depths and locations of all borings, and the preliminary laboratory testing plan.

A proposal/contract for undertaking the necessary field work must be prepared using the current SBSTC. Submit the proposal/contract to the DGE for review and acceptance as directed.

Preparation of the Proposal must include the following items:

(a) **Property Owners**. Send notice to all affected property owners as detailed in Section 103.11.
(b) **Railroad Right-of Way**. Consider entry onto railroad right of way as discussed in Section 103.12.
(c) **Underground Utilities.** The requirements for working near underground utilities are discussed in Section 103.10(a) of the Standard Specifications for SBST. In situations where a utility is struck or damaged, or where previous utility damage to the facility owner's line is discovered during drilling, the contractor/excavator is to comply with Pennsylvania's Underground Utility Line Protection Law Act 50 (P.L.852, No. 287 amended October 30, 2017). The contractor/excavator will notify the PGM/DGE of the utility strike or damage immediately. Once notified, the PGM/DGE must also file an Alleged Violation Report (AVR) to the Public Utility Commission through the PA One Call System for the AVR within ten business days after a utility strike or damage has occurred to a facility owner's line. A special provision to conduct this work must be prepared by the PGM/DGE and included in the contract.
(d) **Overhead Utilities**. The requirements for working near overhead utilities are discussed in Section 103.10(b) of the Standard Specifications for SBST. When any part of the drill rig, including drill steel, is proposed to be located within 20 ft. of overhead power lines, the PGM/DGE must contact the utility owner to determine the voltage in the line to ensure that the clearance distance requirement of Section 103.10(b) is met. In situations where clearance between overhead lines and drill equipment is less than required in Section 103.10(b), the PGM/DGE must coordinate this work with the appropriate utility company. Specific directions and necessary special provision(s) and pay item(s) to conduct this work must be prepared by the PGM/DGE and included in the contract.
(e) **Methane and Carbon Monoxide Gases.** The requirements for working where methane gas or carbon monoxide gas may be encountered are discussed in Section 103.09(c) of the Standard Specifications for SBST. In situations where it is suspected that methane or carbon monoxide gas may be encountered (i.e., where deep mines are likely to be encountered, where drilling in the vicinity of deep mines, where mineable coal seams may be encountered) the PGM/DGE must include specific direction for methane and carbon monoxide monitoring in the contract. Typically, monitoring requirements are included in the schedule of

drilling, and monitoring is incidental to the cost of drilling; however, special provisions or pay items may be warranted in certain situations where an atypical level of monitoring is needed. During the subsurface investigation, if an elevated concentration of methane or carbon monoxide is encountered that prevents drilling and grouting of boreholes, the PGM/DGE should be prepared to provide direction to the Drilling Contractor. The PGM/DGE may contact PA-DEP personnel, the CGE, and/or others for technical assistance.

(f) **Anticipating the Method of Advancing Soil Borings.** The PGM should consider if a specific method of advancing soil borings is required or preferred, based on the anticipated site conditions. Attachment I will typically indicate the anticipated method of hole advance for soil borings, "Advanced by means selected by Contractor." By doing this, the Drilling Contractor is responsible to select the most effective means/methods to accomplish the work. If the method does not work, the method will have to be modified. If, when preparing the contract, the PGM decides a specific method of boring advancement is needed, that method should be specified (e.g., hollow-stem auger, drive casing). Hollow-stem augers are the commonly preferred choice of boring advancement; however other options such as steel casing is occasionally employed. In some cases, augers cannot successfully advance – like cobbles/boulders, fills with obstructions, very dense tills, limestone ledges, cap rock above mine voids, etc.

(g) **Contract Documents**. Prepare the SBSTC documents according to the investigation plan approved by the Department. Prepare a plan of the foundation layout indicating the location of the test borings and other pertinent information.

(h) **Cost Estimate**. Prepare an Engineers Estimate of the cost of the work.

(i) **Letter of Interest**. Prepare a draft letter of interest advertising solicitation of bids for the subsurface investigation contract. Inform potential bidders in the letter that a reply is required by the date indicated in the letter of interest, and advise that all replies must be sent back to the email address indicated using the response form supplied in the email (Form TR-439, Drilling Contractor Letter-of-Interest Response). Potential bidders responding after this date are not allowed to bid on the contract. Except for cases as noted in Chapter 4.5, the letter is to be sent by email (in a blind copy or mail merge format) to all Drilling Contractors on the current list of PennDOT Prequalified Geotechnical Drilling Contractors. Include a copy of Form TR-439, Drilling Contractor Letter-of-Interest Response, and Letter of Interest with the email to each PennDOT Prequalified Geotechnical Drilling Contractor. Include the following in the letter:

- Provide the MPMS number for the proposed work.
- Provide the anticipated type of borings, samples, and field tests with approximate quantities.
- Provide the location of the holes (water or land).
- State whether Maintenance and Protection of Traffic drawings will be provided or required.
- State whether any boring or test pit locations are within 100 ft. of any domestic water supply well or spring box, and if so include the appropriate as required by Section 218.
- State whether the railroad requires safety training prior to entry on its right of way; anticipated dates for bid opening and Notice to Proceed;

- Attach a map that would allow anyone unfamiliar with the area to find the project.
- Describe any other pertinent information.

(j) **Cover Letter**. Prepare a draft of the letter to be used to transmit the SBSTC documents to the Drilling Contractors who respond to item (h). Include in the letter the county, state route, and section numbers of the project; the date, time and location of the mandatory pre-bid meeting (if required); the date, time and location of the bid opening; the MPMS number for the project (to be used for input into gINT); and a reminder to follow the instructions in the Instructions to Bidders.

(k) **Contract Documents.** Prepare and transmit the contract documents to the Drilling Contractors expressing interest. The cover letter and accompanying contract documents must be sent via certified mail, email (with read receipt verification), or hand delivered.

4.4 FACILITATION OF CONTRACT BIDDING

The PGM must ensure that the following requirements are completed during the bid process:

(a) **Pre-Bid Meeting**. Conduct the mandatory pre-bid meeting unless indicated otherwise by the DGE. At this time, all borings must be staked on the project. Pre-bid meeting minutes must be sent to all Drilling Contractors that attended the pre-bid meeting. Minutes are sent via email (with read receipt verification). Sufficient time must be given to allow Drilling Contractors to receive and review pre-bid meeting minutes prior to bidding date. Questions submitted by a Drilling Contractor after the pre-bid meeting minutes have been distributed must be responded to via email by replying with the question and answer to all Drilling Contractors that attended the pre-bid meeting. Questions can be submitted up to 3 business days before the bid opening. If a response is provided, it must be emailed one business day (no less than 24 hours) prior to bid opening. If a question arises that impacts the scope of the project, a time extension to submit bids may be required, or as directed by the DGE.

(b) **Bid Opening**. Attend the bid opening. At the discretion of the DGE, bid openings may occur virtually or in-person, and at the District office of which the project is located, or opened at the consultant Engineer's office, provided that the DGE, or representative approved by the DGE, is present. Use Form TR-441, SBSTC Bid Opening and Tabulation, for proper procedure, bid opening, and short bid tabulation. Check the bid documents for completeness, correctness of quantities, and cost tabulations. Tabulate the bid results. Determine the low bidder. Obtain concurrence on the acceptability of the low bidder from the District Office in writing or by email). In the case of a tie bid a coin toss between the tied bidders will determine the apparent low bidder. The company whose name begins with the letter the comes first in the alphabet will always be heads. Otherwise, the project must be re-bid.

(c) **Drilling Contractor Notification**. Notify all bidders of the results; send each a tabulation of the bids (i.e., the aggregate bid amount of all bids). Please note that a

tabulation summary may only be provided to the bidders of that contract. A detailed list of unit prices for each item will not be provided, nor is this part of the tabulation summary. Return all proposal guarantees except those of the two lowest bidders. Notify the lowest bidder to complete the forms in the bid package and furnish the required Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond), Additional Bond for labor and Material (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials), and insurance certificates. Notify the second lowest bidder that their proposal guarantee will be held until the lowest bidder completes the necessary paperwork.

(d) **Notice to Proceed**. Review the lowest bidder's submissions for completeness. The insurance certificate must name the Commonwealth of Pennsylvania as co-insured. When all submissions are complete, return the proposal guarantees and issue a Notice to Proceed. Notice to Proceed should clearly state the day on which the time charges will begin.

(e) **DGE Notification**. Provide the DGE a copy of all correspondence at the time it is sent out. Only one copy of the advertisement letter is needed. Furnish a copy of all pages in the bidding package in which the Drilling Contractor has filled in information, and copies of the bonds and insurance certificates.

(f) **Statewide Notification**. Contracts let by the Department must be advertised in either the *Engineering and Construction Management System (ECMS)*; or the *Supplier Relationship Management (SRM)* system, as appropriate.

(g) **CGE Notification**. Upon award of contract to successful bidder the PGM (Consultant for consultant contracts, DGE for department contracts) must submit a completed copy of Form TR-444, Form of Proposal, to the Central Office Geotechnical Section at GeoPub222@pa.gov. This includes work performed under provisions of Chapter 4.5. Include the completed copy of Form TR-439, Drilling Contractor Letter-of-Interest Response, for the successful bidder (or entity performing work). Also provide the Engineer's cost estimate if a simplified bid solicitation was used.

4.5 ACCELERATED ACQUISITION OF DRILLING AND TESTING SERVICES

4.5.1 Acquisition of Drilling and Sampling

Bid solicitation for drilling services during both Preliminary Engineering and Final Design may be simplified for consultant-designed projects where the Engineer's cost estimate for drilling is $45,000, or less. In such cases, the District has the option to direct the project geotechnical consultant to obtain drilling services as follows:

(a) The Consultant or sub-Consultant may perform the drilling services with their own forces if they (or their owned subsidiary doing the drilling) are a PennDOT Prequalified Geotechnical Drilling Contractor. In such cases, the DGE must conduct a quality assurance field review of the drilling operations and complete Form TR-437, Drilling Inspector Performance Evaluation, and Form TR-433, Drilling Contractor Performance Evaluation. The DGE must provide written concurrence to the Project Manager that the unit prices for drilling services are

reasonable and competitive. If concurrence on reasonable and competitive unit prices cannot be reached, then follow the method described in section "(b)" below.

(b) If the Consultant or sub-Consultant is not a PennDOT Prequalified Geotechnical Drilling Contractor, the drilling services may be provided by soliciting written quotes from at least three (3) PennDOT Prequalified Geotechnical Drilling Contractors. The DGE must consider the Drilling Contractors as viable and likely to submit a bid for the work. In this case, 'viable' is defined as a driller who regularly performs services for Department projects and is located geographically such that it is reasonable to expect that they could competitively provide the required services and would have an expectation of being interested in pursuing this work under normal procedures. At least two bids should be received to justify a choice of a firm. In rare cases where only one bid is received, written documentation must be on record showing at least two other viable firms were solicited but chose not to bid the work. The DGE must provide written concurrence of the bid award to the Project Manager and indicate that the low-bid unit prices are reasonable and competitive.

If the Engineer's cost estimate for drilling is **more than $45,000**, the Consultant must prepare and send a letter of interest advertising solicitation of bids for the subsurface investigation contract to all Drilling Contractors on the current list of PennDOT Prequalified Geotechnical Drilling Contractors. The Consultant (or the Consultant's subsidiary) may not bid on the contract or perform drilling services with their own forces.

In all cases, the drilling and field testing services provided must follow the technical and performance provisions of this publication.

4.5.2 Acquisition of Laboratory Testing

Laboratory testing of soil and rock materials collected during the subsurface investigation must be performed by an AASHTO Materials Reference Laboratory (AMRL) that is accredited for each test method to be conducted (except where AMRL does not certify a specified test method). Proof of accreditations must accompany any Price Proposal.

The laboratory test results must be reviewed and attested by a Professional Engineer registered in the state of Pennsylvania.

According to the PennDOT Policy and Procedures for the Administration of Consultant Agreements, Publication 93, Chapter 3.6.7, laboratory testing is considered a "non-professional service". The laboratory testing may be performed by the prime consultant's AMRL certified laboratory. A project Price Proposal must be submitted by the consultant and must include a schedule of unit prices (per test) for the laboratory tests proposed. The DGE will review the Price Proposal and provide written concurrence to the Project Manager indicating the proposed unit costs are fair and reasonable. If fair and reasonable unit costs are not evident, obtain three written quotes or documented telephone quotes to justify a choice of laboratory testing provider. Sample transport costs and administrative costs must be considered in the justification. Accordingly, it is usually most efficient (considering direct-costs and logistics) for the administering geotechnical consultant to perform the laboratory testing services with their own forces, provided they meet

the AMRL certification requirements. If needed, more than one laboratory may be used to perform the AMRL certified tests for a project.

4.6 DEPARTMENT-LET CONTRACTS

Drilling contracts executed directly by a PennDOT District or County office must use the appropriate processes to procure drilling services and follow the technical and performance provisions of this publication (including Attachment II). Purchasers and Project Managers should include a requirement in procurement documents that vendors providing drilling services must appear on the approved list in **Publication 222**.

The Department's Engineering and Construction Management System (ECMS) may be used for planned drilling services for design and construction projects. Examples include:

- geotechnical test boring, sampling and testing,
- pavement coring, sampling and testing
- bridge design and replacement
- highway design and construction

The appropriate Supplier Relationship Management (SRM) End User Procedure, based on annual purchasing thresholds, should be followed to obtain on-call drilling services. On-call drilling services may be used for work not covered by an ECMS contract. Examples include:

- emergency repairs to highways and bridges due to rockslides or landslides
- occasions when drilling is needed while performing maintenance operations
- drilling projects to be completed prior to establishment of a specific ECMS contract

When using SRM for drilling services, the SRM purchasing and bid documents must provide clear specifications regarding the scope of work and geographic coverage area. It is acceptable to have multiple SRM Contracts or POs (purchasing documents), if a clear distinction is made as to what work or geographic area is covered by each purchasing document; however, there must not be any overlap of work or geographic areas if multiple purchasing documents are in place. Duplicate purchasing documents with no discernible difference in how work is assigned to multiple vendors under the same or similar contract are not acceptable.

Districts and Counties should ensure compliance with Department *Procurement Directive 10-02* whenever drilling services are needed. If necessary, purchasers should contact the Bureau of Office Services, Procurement Help Desk at 717-346-9900 to discuss such contracts.
All drilling work completed under contract must be inspected by a Certified Drilling Inspector.

4.7 ENTRY ONTO RAILROAD RIGHT-OF-WAY

4.7.1 Temporary Railroad Right-Of-Entry Permit/Agreement

Entry onto Railroad right of way (property) may be required for construction activities as well as inspection, maintenance, survey, soil borings, engineering studies, etc. Therefore, in order to gain entry onto Railroad property a Department's contractor and/or their subcontractors or a

Department's consultant and/or their sub-consultants are required to enter into a temporary Railroad Right-of-Entry (ROE) permit/ agreement with the Railroad.

Because Railroad ROE permits/agreements have been determined to be a contract and they are not in compliance with the Commonwealth Attorneys Act, the Department **cannot** sign such documents. Only the Department's contractor or consultant who is performing the required work activities on the Railroad's property can sign a ROE permit/agreement. Refer to the latest edition of Publication 371, Chapter 7, Section 7.03, Entry onto Railroad Property.

4.7.2 Department Scope of Work Details and Method of Payment

The following activities may be required by the Department's District Grade Crossing Engineer/Administrator (DGCE/A), District Project Manager (DPM), or District Liaison Engineer (DLE) regarding scope of work details and method of payment for design consultant projects.

(a) The DGCE/A, DPE, or DLE will consult the Railroad to determine any special requirements that the Railroad may have in order for the Department's contractor or consultant to gain access onto Railroad property.
(b) Information obtained must include, but not be limited to, Railroad insurance requirements, ROE permit/agreement fees, copies of applicable permits, time required to process permit, required safety training, Railroad specifications, and if necessary, associated flagging costs and necessary arrangements for flagging protection.
(c) The DGCE/A, DPM, or DLE will ensure that all applicable Railroad ROE requirements are contained within the Department's scope of work/contract for the project.
(d) The scope of work must detail the method of payment for design consultant projects. If the method of payment is not included in the original consultant agreement, it must be processed as a supplement.
(e) For District in-house projects where geotechnical explorations are to be performed by Department personnel, the DPM, DLE, or DGE must notify the DGCE/A to obtain all necessary Railroad ROE requirements and procedures, and method of payment prior to entry onto Railroad Right-Of-Way. Note that the Department cannot sign Railroad ROE permits/agreements, but if the Railroad requires a permit/agreement to be entered into with the Department, consult with the Department's Office of Chief Counsel before proceeding further.
(f) The DPM, DLE, DGE, or DGCE/A will make provisions for reimbursement of Railroad costs based on Department guidelines and procedures.

4.7.3 Consultant/Contractor ROE Requirements and Method of Payment

The following activities may be required by the Department's consultant or contractor, including any sub-consultants or sub-contractors, (Applicant) in order to obtain a Temporary Railroad ROE permit/agreement and method of payment:

(a) Contact Railroad to determine any special requirements the Railroad may have.

(b) The consultant's technical and price proposal must address all procedures required by the Railroad in order to obtain the necessary Temporary Railroad ROE permit/agreement and method of payment for Railroad invoices, permit fees, etc. This will include, but not be limited to, ROE permit/agreement procedures with associated costs with Railroad turnaround time for processing permits/agreements, Railroad insurance, flagging costs, Railroad safety training, and required notifications to Railroad prior to entry onto Railroad right of way.
(c) Information for each individual entry by Applicant must be supplied to the Railroad as specified in their specification and/or permit requirements when applying for the ROE permit. Include scope of work, exact location of the entry, estimated cost of work to be performed on the railroad property, distance from the outermost track where the activities will take place, anticipated date of entry, number of people, and length of time.
(d) Applicant must obtain a copy of the Railroad's Temporary ROE permit/agreement. The Applicant must submit the completed and signed permit/agreement, with applicable supporting documentation and permit fees to the Railroad for execution. The Railroad must forward the executed ROE permit/agreement to the Applicant. The Railroad will advise the Applicant of any necessary modifications required based upon Railroad's policies and procedures.
(e) Prior to entry onto Railroad ROW an executed ROE permit/agreement must be in the possession of the Applicant.
(f) Railroad will submit invoices directly to the Applicant for services rendered and payment must be made by Applicant in accordance with Railroad's procedures.

4.7.4 Entry onto Railroad Right Of Way

Prior to entry onto the Railroad Right Of Way (ROW) for the geotechnical exploration the following activities are required:

(a) Determine an exact scheduled starting date and ending date for the entry onto Railroad ROW.
(b) Incorporate these dates in the letter seeking bidder interest and the proposal.
(c) Where District policy allows an alternative to a defined schedule, note the desired method of scheduling in the letter seeking bidder interest and in the proposal.
(d) Notify the District of the scheduled starting date at least thirty (30) days before the start date and provide the Railroad the required notice in accordance with Railroad's specifications and/or permit requirements.
(e) Comply with the Railroad's required safety training prior to entering.
(f) Maintain an independent record of personnel making entry, date of entry, purpose of entry, railroad personnel and equipment present and their activities, etc. review and countersign railroad time sheet(s) daily; do not countersign if there is a disagreement - notify the District. Forward a copy of the time sheet(s) to the District within fifteen (15) days of their receipt.

4.8 CONTRACT SPECIAL PROVISIONS

The standard specifications for SBST as shown in the test boring contract document must apply to all subsurface investigation work performed for the Department including work

performed under an *Engineering and Construction Management System (ECMS)* or *Supplier Relationship Management (SRM)* contract. If changes are required for a specific job, they must be handled in a similar manner to special provisions and included in Attachment II of the test boring contract. The attachment is referred to as Modifications and Additions to Standard Specifications for SBST. It is in this section that modifications to the specifications can be made (which might include changes of method of payment, deletion of sections, modification of work, etc.) to suit various situations that may arise.

4.9 DISPOSITION OF SOIL AND ROCK SAMPLES, AND PROJECT RECORDS

Upon completion of drilling operations (or periodically during the drilling operations for larger projects), arrange for the Drilling Contractor to deliver all samples and core boxes to the location designated in the SBSTC (Subchapter 5A, Article G). If the designated location is not the District's storage facility, arrange for delivery to the District facility, after work (logging and lab testing) with the materials has been completed. Any delivery to a District facility requires a seventy-two (72) hour notice, and must be accompanied with Form TR-440, Chain of Custody for Subsurface Boring Sample Boxes.

Sample specimens selected for laboratory testing will be removed from the core boxes prior to delivery to the District's long-term storage facility. Accessing specimens from core boxes that have already been placed in long-term storage should only be done under unusual circumstances and will require coordination with the DGE. In all cases, when a soil or rock sample is taken from a core box for testing, a durable spacer (e.g., glass sample jar, wood block) must be used to fill the space created. A written description of the sample and purpose for removal must be placed in the glass jar, or securely fastened to the spacer.

4.9.1 Disposition of Test Boring Samples and Boxes

Test boring samples from the Soil’s Investigation may be discarded after six (6) months have elapsed following the acceptance of the “Notification of Final Quantities and Contract Settlement Amount” by the Construction Contractor, provided the Construction Contractor has not notified the Department of any rejection, exception, or intention to file a claim relating to any matter. In the event of a claim, intent to file a claim, rejection, or exception either by the Construction Contractor or the Department, the samples must be kept until authorization is received from the Office of Chief Counsel to discard.

To dispose of test boring samples and core boxes following acceptance of “Notification of Final Quantities and Contract Settlement Amount,” the DGE may optionally contact the Drilling Contractor listed on the lid of the core box and arrange for all samples and core boxes (i.e., core boxes and contents) at the stored location to be picked up by the Drilling Contractor. If the Drilling Contractor does not respond within 30 days, or if the Drilling Contractor decides to respond in writing that they are relinquishing their claim to obtain and reuse the core boxes, the core boxes can be offered to all Drilling Contractors, or be discarded.

If offered to all Drilling Contractors, the first Drilling Contractor to respond to the email solicitation will be identified as the recipient and be able to retrieve the identified core boxes. The Drilling Contractor will pick up the core boxes containing the rock and soil samples; core boxes do not need to be emptied. The Drilling Contractor may reuse the core boxes according to

Section 214. The cost for disposal of the core box and its' contents is at the Drilling Contractor's expense at their facility.

4.9.2 Disposition of Paper Records

Paper records, including all logs; field and laboratory test results, and reports must be retained for seven (7) years from the date of final payment to the Construction Contractor, if it is a 100% State-funded project; for Federal-aid projects, seven (7) years from the date of final payment to the Construction Contractor or three (3) years from the date of final FHWA reimbursement, whichever is later. If a claim has been filed by the Construction Contractor or the Department, these records will be retained until directed by the Office of Chief Counsel.

4.10 WORK ORDERS AND DISPUTED WORK

Consult with the District Geotechnical and project Liaison Engineer (if applicable) prior to submitting a work order and when encountering a dispute on the type of work.

Submit work orders to the DGE or project Liaison Engineer, in letter form, explaining the reason for the work; quantity, type, unit prices, and money value for each item of work; include any sketch that may be necessary to explain or locate the work. Also, submit a letter from the Drilling Contractor agreeing to the quantity, type, unit prices, and money value for each item; include any other data that may be needed to justify the price. Both the work order and the Drilling Contractor's letter should mention any agreed to time extension. Do not inform the Drilling Contractor to proceed with the work until receiving written authorization from the District Executive.

Provide documentation of any disputed work.

4.11 SUBMISSIONS TO THE DEPARTMENT

The project Geotechnical Consultant is responsible to assure the delivery of the following information to the Department's DGE in which the project is located:

(a) **Inspector's Field Logs.** Provide a copy of the Inspector's Field Logs within forty-eight (48) hours of obtaining the last groundwater level reading. These may be hand-written or computer-generated logs.

(b) **PennDOT Final Engineer's Logs.** Provide the Final Engineer's Logs for test borings and test pits, within fourteen (14) days of completing the investigation. Electronic logs must be in PDF format via EFT link. Electronic logs and test results must be individually sealed by a P.E. or P.G., with signature and date, attesting to the accuracy of all information. The P.E. or P.G. must be the PGM of record and registered in the Commonwealth of Pennsylvania.

(c) **PennDOT gINT Project File.** Provide the PennDOT gINT Project file(s) for test borings and test pits, and all field and laboratory tests, within fourteen (14) days of completing the investigation. The PennDOT gINT Project file(s) must be prepared as specified in this publication and follow the project file naming convention specified in Chapter 3.6.6. The PennDOT gINT Project file(s) are to be uploaded via EFT link. To obtain the EFT link and login credentials, Business

Partners must go to PennDOT's gINT Web Page and join the gINT Subscription List. After completing the gINT Subscription Sign-up Form and the Commonwealth IT Resource Acceptable Use Policy Agreement – Commonwealth Contractor or Consultant, and submitting the forms to gINTSupport@pa.gov, business partners will receive the EFT link, instructions for uploading files to the EFT Link, and login credentials.

(d) **Sample Photographs**. Provide all core box and test pit photographs utilized in the PennDOT gINT Project file(s) within fourteen (14) days of completing the project, or earlier if requested by the DGE. Individually photograph each completed core box as specified in Chapter 3.7. Submit photo files in .jpg format via EFT link and follow the photograph naming convention as specified in Chapter 3.7.

(e) **PennDOT Form TR-440.** The Consultant is responsible to forward a signed copy of the completed form(s) TR-440, Chain of Custody for Subsurface Boring Sample Boxes and TR-440A, Tabulation Supplement, to the DGE within seven (7) days of delivery of boxes to the PennDOT storage facility.

(f) **Other Records.** Provide a copy of any correspondence, records, notes, tabular forms, etc. developed during the investigation, and any other information that the Department considers necessary for its records. Provide electronic files via EFT link.

The Consultant must submit the following electronic files via EFT link to the Central Office Geotechnical Section within fourteen (14) days of completion of the investigation, testing, or report:

(a) **PennDOT gINT Project File.** Include the PennDOT gINT Project file(s) for test borings and test pits.

(b) **Logs and Material Tests.** Include the Final Engineer's Logs and all field and laboratory tests in PDF format.

(c) **Sample Photographs**. Include all test pit and core box photographs. Files must be in .jpg format and follow the file naming convention and format per Chapter 3.7.

CHAPTER 5 – SBSTC DOCUMENTS

SUBCHAPTER 5A – INSTRUCTIONS TO BIDDERS

INSTRUCTIONS TO BIDDERS

SUBSURFACE BORING, SAMPLING, AND TESTING CONTRACT (SBSTC)

For

_____

_____

_____

Issued by

_____

_____

_____

Dated

_____

Article A – General

Section A-1 - The following instructions are for the information and guidance of Contractors submitting a proposal for the subject Subsurface Boring, Sampling and Testing Contract (SBSTC).

Section A-2 - Definitions. The term "PGM" referred to in the Contract Documents is the party issuing these Instructions to Bidders and is under contract with the Pennsylvania Department of Transportation (hereinafter referred to as the "Department") regarding the completion of the subject SBSTC. If issued by the Department, the Department will also be considered as the PGM. All other parties are as defined in the Standard Specifications for Subsurface Boring, Sampling, and Testing.

Section A-3 - The Contract Documents must consist of the Instructions to Bidders; Form TR-444, Form of Proposal; Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC); the Standard Specifications for Subsurface Boring, Sampling, and Testing; the Plan and Location of Borings; the Attachments; and all subsequent addenda and modifications. These documents are essential parts of this Contract and are intended to be complementary and to describe and provide for the complete Work. A requirement occurring in one document is as binding as though occurring in all.

In case of discrepancy, the document requiring the most demanding and costly alternative for the Contractor must be given priority when bidding.

Article B – Location of Borings

Section B-1 - The test boring locations for the subject Subsurface Boring, Sampling, and Testing Contract are indicated in the attached plans entitled, "Plan and Location of Borings, _____", prepared by _____ and dated _____.

Article C – Scope of Work

Section C-1 - The estimated work item quantities for this test boring program are set forth in Attachment I – Schedule of Proposed Borings, and in Form TR-444, Form of Proposal.

These quantities are estimates only. The quantities stipulated in Form TR-444, Form of Proposal, have been issued for the purpose of comparing bids and, as such, are subject to change by the PGM.

The approximate locations of the test borings are presented in the Plan and Location of Borings referenced in Article B above. The actual locations and depths of undisturbed soil samples, special field tests, and/or borehole instrumentation will be determined by the PGM during the course of the drilling operations.

Section C-2 - The Contractor will be required to provide no fewer than _____and no more than _____ fully equipped, operating and staffed drilling machines per work shift for work on this Contract with a minimum full-time crew of two persons per rig, including one qualified driller and one helper. The PGM and/or Contractor may request additional rigs if mutually agreeable. The maximum recall time will not exceed six (6) months.

Section C-3 - The original handwritten or electronic Form TR-442, Driller's Boring Log, for each boring must be submitted to the PGM at the completion of the boring.

Article D – Submission And Comparison of Proposals

Section D-1 - Submit two (2) copies (both copies with original signatures) of the executed Form TR-444, Form of Proposal, and Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC) to:

Commonwealth of Pennsylvania
Department of Transportation
District _____
_____
_____
_____

before _____ a.m., p.m. prevailing time, on _____. Proposals will be opened and read at _____ a.m., p.m. of the same day in the District Office of the Department. Seal the proposal in an envelope plainly marked with the Bidder's name and address, and as follows:

BID DOCUMENTS:

SUBSURFACE BORING, SAMPLING, AND TESTING CONTRACT FOR

_____

_____

_____

To be Opened: _____

At _____ a.m., p.m.

Section D-2 - Enclose a proposal guaranty of ten (10) percent of the PROPOSED TOTAL COST OF CONTRACT, but not less than $50.00, with the proposal as a guaranty that in the event the proposal is accepted and a Contract awarded, the Contract will be duly executed and its performance duly secured by the required Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond) and Additional Bond for Labor and Materials (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials). The proposal guaranty must be in the form of a Cashier's Check, a Treasurer's Check, a Certified Check, a Letter of Credit, or a Proposal Guaranty Bond with surety made out to _____, in the amount specified after the words "Amount of Proposal Guaranty" as shown in Form TR-444, Form of Proposal.

Where the bidder does not comply with their proposal and does not provide a Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond) and an Additional Bond for Labor and Materials (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials) within a period of thirty (30) calendar days, if award is made to them, the proceeds of the Cashier's, Treasurer's, or Certified check or Proposal Guaranty Bond submitted as a proposal guaranty with their proposal will be forfeited to the use of the PGM as liquidated damages. All proposal guarantees will be returned when the successful Contractor has executed a contract and has submitted a Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond) and an Additional Bond for Labor and Materials (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials).

Section D-3 - Execute and return with the proposal "Affidavit Accepting Provisions of the Workers' Compensation Act," which is described in Article I and is included as Attachment IV of these Instructions to Bidders.

Section D-4 - The bidder to whom the Contract is awarded will be required to execute a "Contract Bond" (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond), covering satisfactory performance of the work contracted, in the penal sum of 1/2 (50%) of the amount of the Contract, and an "Additional Bond for Labor and Materials" (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials), covering the prompt payment in full for utility services rendered and for all materials furnished and/or labor supplied or performed in the prosecution of the work, also in the penal sum of 1/2 (50%) of the amount of the Contract. Both bonds must also be executed by a corporate surety satisfactory to the PGM. The same surety must execute both bonds and should any surety upon such bonds become unsatisfactory to the PGM, the Contractor must promptly furnish such additional security as may be required from time to time to protect the interests of the PGM, the Department and of persons, firms or corporations supplying utility services, materials, and/or labor in the prosecution of the work contemplated by the Contract. The cost of these bonds will be entered as the Fee for Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond) and Additional Bond for Labor and Materials (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials) presented in Form TR-444, Form of Proposal.

Section D-5 - The PGM reserves the right to reject all bids, to waive technical defects and to accept or reject any part of any bid, if in the PGM's judgment, the PGM's and Department's best interests will be served thereby. In acting on proposals, cash discounts will not be considered.

Section D-6 - The proposal as made will be deemed an offer that may be accepted by the PGM at any time within sixty (60) days after bids are opened. When the proposal has been accepted by the PGM, the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC) will be executed by the PGM and the successful bidder must be the "Contractor." No other Contract Documents will be executed by the PGM.

Article E – Equal Employment Opportunity and Non-Discrimination

Section E-1 - The Contractor must abide by the requirements for equal employment opportunity and non-discrimination set forth in Publication 408, Appendix C, Designated Special Provisions 10, 11 and 12 (DSP 10, 11 & 12).

Article F – Identification of Samples and Documents

Section F-1 - All samples, reports and other documents obtained or prepared as a part of this Contract will include the following identification on the label, front cover, or title page in addition to other information required in the Standard Specifications for Subsurface Boring, Sampling and Testing:

_____

_____

Article G – Disposition of Samples

Section G-1 - The contractor is required to remove, at their expense, all samples and core boxes from the job site at the end of each work shift and provide storage until such time as they are delivered by the contractor to the designated locations. The storage facilities must conform to the requirements set forth in the Standard Specifications for Subsurface Boring, Sampling, and Testing, Section 214.

After completion of all test borings, the Contractor will be required to deliver, at their expense, all soil samples and rock core boxes to:

_____

_____

_____

Section G-2 - After completion of all test borings, and during the delivery procedures, each party responsible for identification and custody of the core boxes is required to fill out the appropriate section of Form TR-440, Chain of Custody for Subsurface Boring Sample Boxes.

The PGM will be responsible to provide this form electronically to the successful low bidder at the beginning of the project.

Article H – Mandatory Pre-Bid Meeting

Unless otherwise specified by the DGE, a drilling project requires a mandatory pre-bid field meeting. Only PennDOT Prequalified Geotechnical Drilling Contractors who attend the mandatory pre-bid meeting may bid on the project. When the pre-bid meeting requirement is waived by the DGE, any PennDOT Prequalified Geotechnical Drilling Contractor may bid on the project.

A representative of the PGM will be available to accompany the bidders on a field view of the project area on _____, at _____ a.m., p.m. prevailing time. The meeting location will be at _____. If you plan to attend this field view, please signify so by calling _____, at _____, before _____. Pre-bid minutes and agenda will be provided to the drillers in attendance, no later than five (5) working days before the bid opening. Pre-bid minutes will be an addendum to the Contract.

Article I – Insurance and Liability

Section I-1 - Limits of Coverage. The Contractor must procure and/or maintain at its expense the insurance coverage stipulated in the Standard Specifications for Subsurface Boring, Sampling, and Testing, all with limitations of not less than:

TYPE OF COVERAGE	LIMITS OF LIABILITY	REQUIRED MINIMUM COVERAGE
Bodily Injury	Aggregate	$1,000,000
Property Damage	Aggregate	$1,000,000
Automobile Liability (Bodily Injury)	Aggregate	$1,000,000
Automobile Liability (Property Damage)	Aggregate	$1,000,000
Worker's Compensation	As Required by Applicable Law	
Employer's Liability	Aggregate	$1,000,000
Umbrella Liability (Bodily Injury and Property Damage Combined)	Aggregate	$1,000,000

Section I-2 - Additional Insurers. The PGM, _____, and the Department must be named as additional insured under the above said Bodily Injury and Property Damage Insurance policies by endorsement thereto and such insurance must be primary to any other insurance maintained by the PGM or the Department.

Section I-3 - Worker's Compensation. Execute and return with the proposal the "Affidavit Accepting Provisions of the Workers' Compensation Act," which is included as Attachment IV to these Instructions to Bidders, to signify acceptance of the provisions of the Workers' Compensation Act.

Article J – Modifications to the Standard Specifications for Subsurface Boring, Sampling, And Testing

Section J-1 – Attachment II to these instructions defines specific modifications or additions to be included as part of the Standard Specifications for Subsurface Boring, Sampling, and Testing for this Contract.

Article K – Schedule for Work on Railroad Right-Of-Way

Section K-1 – Attachment III to these instructions explains the requirements for a defined schedule for work on Railroad Right-of-Way. Borings and drilling quantities to be completed within the Railroad Right-of-Way should be included with the defined schedule.

SUBCHAPTER 5B – CONTRACT ATTACHMENTS

ATTACHMENT I – Schedule of Proposed Borings

SR _____ Segment _____ County _____ Section _____ MPMS # _____

Sheet _____ of _____

BORING NO.	STATION	OFFSET FROM BL/CL (ft.)	ESTIMATED SURFACE ELEVATION (ft.)	SOIL BORING				ROCK DRILLING AND CORING	SPECIAL INSTALLATION	BOREHOLE TESTING	OTHER
				Sample Type (1)	Method of advancement (2)	Estimated quantity		Type and estimated quantity (ft.) (3)	Type and estimated quantity (ft.) (4)	Type and estimated quantity (ft.) (5)	(6)
						Sample (ea.)	Drilling (ft.)				

ATTACHMENT I – Schedule of Proposed Borings

SR _____ Segment _____ County _____ Section _____ MPMS # _____
Sheet _____ of _____

(1) SOIL BORING – Sample Type

SPT - SPT sampling, continuous, 1-3/8-inch diameter
SPT - 5 - SPT sampling, 5-ft intervals, 1-3/8-inch diameter
SPT -__ - SPT sampling, __-ft. intervals, 1-3/8-inch diameter
TW - Thin-wall Tube sampling, 3-inch diameter
BG - Bag sampling, auger boring
___ - _____

(2) SOIL BORING – Method of Advancement

NS - Advanced by means selected by Contractor
HS - Advanced by hollow-stem auger w/center plug
UN - Advanced un-sampled for rock coring
II - Advanced for installation of instrumentation
TT - Advanced for thin-wall tube sample
___ - _____

(3) ROCK DRILLING AND CORING

NX - NX or NQ rock coring
B - _____ -inch diameter rock coring
C - _____ -inch diameter destructive rock drilling
P - Pavement Core (6" diameter)
__ - _____

(4) SPECIAL INSTALLATIONS

PP - Piezometer pipe
PC - Protective casings
PS - PVC Sensing Sections
PT - Porous tube piezometer tips (indicate total)
IC - Inclinometer
VW - Vibrating wire piezometer
__ - _____

(5) BOREHOLE TESTING

CP - Cone penetration testing
CH - Constant head permeability testing
DR - Dilatometer testing
FP - Falling head permeability testing
HP - Hydraulic pressure testing
PR - Pressuremeter testing
T - Temperature measurement
VS - Vane shear testing
BC - Borehole camera investigation
__ - _____

(6) OTHER

TP - Test pit
TWS - Temporary water service
W - Boring drilled on water
E - Environmental precautions
WR - Wetland requirements
MPT - Maintenance and Protection of Traffic
G - Grouting by tremie
___ - _____

ATTACHMENT II – Modifications and Additions to Standard Specifications for SBSTC

If necessary, any project-specific modifications or additions to the standard specifications are located here.

ATTACHMENT III – Schedule for Work on Railroad Right-of-Way

The PGM and the Contractor recognize that they must complete work on Railroad right of way according to the defined schedule.

The Pennsylvania Department of Transportation will pay Railroad costs incurred by the Contractor due to work on Railroad right of way during the defined schedule. Those costs are limited to the entry fee, insurance, and protective services. The Department is not liable to compensate the Railroad for any damage caused by the Contractor's operations.

The Contractor will be liable for any Railroad costs incurred during work performed outside of the defined schedule. The two exceptions will be when the Contractor is prevented from working within the schedule due to the Railroad's operations, or when the Engineer increases the schedule by written notice to the Contractor. Costs incurred by the Contractor for work performed outside of the defined schedule will be deducted from the monies due the Contractor as Assessment Damages, not as a penalty.

The schedule defined below is the Contract Schedule unless the Contractor submits a revised schedule that is approved by the PGM and the Department. If necessary, the Contractor must submit the revised schedule with Form TR-444, Form of Proposal, and Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC). The revised schedule must meet the following requirements:

1. The Railroad must concur in writing with the revised schedule.
2. The total contract amount will have an absolute ending date of: _____
3. The maximum contract days cannot exceed: _____ days
4. The maximum days of work on Railroad right of way: _____ days

SCHEDULE FOR WORK ON RAILROAD RIGHT-OF-WAY	
Work begin date:	
Work end date:	
Days of the week that work is to be performed:	
Working hours each day:	to
Specific borings to be completed:	
Estimated total linear feet of borings to be completed:	

ATTACHMENT IV – Affidavit Accepting Provisions of the Workers' Compensation Act

State of _____

ss

County of _____

_____ _____

(*Name of officer, if corporation*) (*Title of officer, if corporation*)

_____ being duly sworn according to law deposes and says

(*Name of contractor*)

(they / it) ha__ accepted the provisions of the Workers' Compensation Act of 1915

of the Commonwealth of Pennsylvania, with its supplements and amendments, and have

insured (their) liability hereunder in accordance with the terms of said Act

with _____ its _____ Company.

_____

(*Company*)

By: _____(*Seal*) _____(*Seal*)

Sworn to and subscribed before me this _____ day of _____ A.D. 20 ___.

SUBCHAPTER 5C - FORM OF PROPOSAL

Reserved for Form TR-444, Form of Proposal

SUBCHAPTER 5D – CONTRACT AGREEMENTS

Reserved for PennDOT or Consultant Contract Agreements

As necessary, use Form TR-445A, PennDOT Subsurface Boring, Sampling, and Testing Contract, for PennDOT Contract Agreements, or Form TR-446A, Consultant Subsurface Boring, Sampling, and Testing Contract, for Consultant Contract Agreements

SUBCHAPTER 5E – STANDARD SPECIFICATIONS FOR SBSTC

STANDARD SPECIFICATIONS FOR SUBSURFACE BORING, SAMPLING, AND TESTING

TABLE OF CONTENTS

SECTION 100 - GENERAL PROVISIONS

SECTION 200 - TECHNICAL AND WORK PROVISIONS

SECTION 100 – GENERAL PROVISIONS

SECTION 101 – GENERAL INFORMATION AND DEFINITIONS

101.01 GENERAL

The following stipulations, requirements and descriptions of Work are hereby defined and described as the STANDARD SPECIFICATIONS FOR SUBSURFACE BORING, SAMPLING, AND TESTING, and all must apply to the Contract unless specifically waived in the Instructions to Bidders.

These specifications are generally written in the imperative mood. In sentences using the imperative mood, the subject, "the Contractor," is implied. Also, implied in this language are "must," "must be," or similar words and phrases. In the Technical sections, the subject may also be a Vendor, Fabricator, or Manufacturer, who may be supplying material, products, or equipment for use on the project. The word "will" generally pertains to decisions or actions of the Department and/or Project Geotechnical Manager (PGM).

In these specifications or on the drawings, the following words or similar words refer to actions of the Department and/or PGM, unless otherwise stated: "directed," "required," "allowed," "ordered," designated," "prescribed." Also, the words "approved," "accepted," "acceptable," "satisfactory," "considered," or words with similar intent, mean by or to the Department and/or PGM, subject in each case to the final determination of the Secretary, and subject to further review, as allowed by law or allowed elsewhere in these specifications.

In these specifications, reference to a subsection of the specifications includes all general requirements of the section of which the subsection is a part.

In these specifications, the words "or equal," referring to a product, material, or process, mean "equal as determined by the Department and/or PGM."

In these specifications, the words, "as indicated," or "indicated" mean "as indicated or indicated in the prepared Contract Documents."

101.02 POINTS NOT COVERED BY STANDARD SPECIFICATIONS

Any aspects of the work not clearly defined by these specifications will be governed by the rules of the best prevailing practice for that class of work.

101.03 DEFINITIONS

ADDITIONAL WORK – Work, of a type already provided by the contract and for which the contract has established a unit price.

APPLICANT – The Department's consultant or contractor, including any sub-consultants or sub-contractors.

AWARD – The Department's and/or PGM's written acceptance of a proposal.

BIDDER – Any individual, firm, partnership, corporation, or a joint venture, submitting a proposal for the work contemplated and acting either directly or through an authorized representative.

CONTRACT DOCUMENTS – Includes the Instructions to Bidders; Form TR-444, Form of Proposal; the Standard Specifications for Subsurface Boring, Sampling, and Testing; the Plan and Location of Borings; and the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC).

CONTRACT TIME –The duration specified in the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC), commencing with the date of Notice-to-Proceed, over which the work is to be completed.

CONTRACTOR – A person, persons, or corporation who has agreed to perform the work by their signature on the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC). Also, the Contractor's authorized representative at the site of the work.

CONTRACTOR'S REPRESENTATIVE – Individual authorized by the Contractor to be in charge of the work.

DEPARTMENT – Pennsylvania Department of Transportation.

ENGINEERING DISTRICT – Geographic division of the Department for the purposes of management, design, construction, and maintenance.

ENGINEER – The corporation/company responsible on behalf of the Department for geotechnical work. For purposes of the SBSTC, the authorized representative that has entered into the Contract with the Contractor.

EXTRA WORK – Work arising from additions to the list of contract work items and work having no quantity and/or price included in the contract, which is determined by the PGM to be necessary or desirable to complete the project.

FIELD SUPERVISOR – The individual authorized by the Contractor to be in charge for Work completed on-site.

IN WRITING – Communication between parties delivered or sent, and received, in the form of a written letter, email, or facsimile.

DRILLING INSPECTOR – Person representing the PGM during drilling at the site to make inspections of contract performance and of material furnished.

LOCAL TRAFFIC – Vehicular traffic that originates or stops within the project limits.

NOTICE-TO-PROCEED – Written notice, issued by the Engineer, to authorize the Contractor to commence work.

NOTICE-TO-PROCEED DATE – The date, established in writing by the Department, on which work is to begin.

POTABLE WATER – Water for human consumption that meets the biological and chemical standards of 25 PA Code § Chapter 109, Safe Drinking Water Act

PROJECT GEOTECHNICAL MANAGER (PGM) – The person responsible on behalf of the Department for geotechnical work. The PGM must be a P.E. or P.G. licensed in the Commonwealth of Pennsylvania.

PROPOSAL – The offer of a bidder, on Form TR-444, Form of Proposal, to perform the work at the prices bid or predetermined.

ROCK – Indurated mass of mineral aggregates that cannot normally be excavated by manual methods alone and that cannot be satisfactorily penetrated and sampled by standard soil boring and sampling techniques.

SECRETARY – The Secretary of Transportation or a Deputy Secretary of Transportation of Pennsylvania.

SOIL – Unconsolidated material derived from physical, chemical, and biological degradation of rock that can normally be excavated by manual methods alone and that can be satisfactorily penetrated and sampled by standard soil boring and sampling techniques.

SUBCONTRACTOR – Any individual, partnership, firm, corporation, or joint venture, who/which undertakes, with prior consent of the Department, part of the work under the terms of the contract, with and responsible to the prime Contractor by virtue of an agreement.

SURETY – A corporate body, which is bound with and for the Contractor, for the satisfactory performance of the Contractor's work and for the prompt payment in full for material, labor, equipment rentals, and utility services, as provided in the bonds.

TRAFFIC CONTROL PLAN – A developed method or scheme for safely and efficiently moving traffic through or around a highway work zone as specified in 67 Pa Code, Chapter 212.

WORK – The furnishing of all tools, equipment, materials, supplies, transportation, labor, supervision, logs, records, and all things necessary or incidental to compliance with the requirements of the Contract Documents.

SECTION 102 – BIDDING REQUIREMENTS AND CONDITIONS

102.01 INTERPRETATION OF ESTIMATES OF QUANTITIES

The estimates of quantities, shown in the Instructions to Bidders and Form TR-444, Form of Proposal, are approximate and are shown only as a basis for the calculation upon which the contract award is to be made. The Department and PGM do not assume any responsibility that the estimated quantities will actually be required, nor will the Contractor be allowed to plead misunderstanding or deception because of the quantity estimates or because of the character of the work, the location, or other conditions. The Department and/or PGM reserve the right to increase, to decrease, or to omit any of the quantities of work. An increase or decrease of the quantities of the items will not be sufficient grounds for granting an increase in the unit prices bid.

102.02 INSPECTION OF SITE BY BIDDER

It is expected that the bidder will visit the site to become thoroughly acquainted with local conditions relative to the prosecution of the work required by the Contract, such as handling and storage of materials and equipment, working conditions, availability of water and other supplies, transportation, access to individual boring locations, etc. Failure to make such inspection will not relieve the successful bidder of their responsibility for properly estimating the cost of satisfactorily performing all work required by the Contract Documents within the time set forth in the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC).

SECTION 103 – GENERAL CONTRACT CONDITIONS AND REQUIREMENTS

103.01 CONTRACT TIME

Complete all work within the time period specified in the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC). The contract time will be calculated in calendar days from the date of Notice to Proceed.

103.02 CONTRACT TIME ADJUSTMENT

If satisfactory completion requires additional work or extra work, or if unforeseen conditions (other than normal weather events) result in temporary suspension of the work as specified in Section 103.05, the contract time may be increased. Unforeseen conditions can include severe weather if documented justification substantiating major or unusually severe weather conditions (e.g., flooding, large amount of snow/ice) were abnormal for the period of time, could not have been reasonably anticipated, and had an adverse effect on the scheduled drilling. The basis of the increase will be the daily rate of progress previously anticipated by the PGM for additional work, a period mutually agreed to by the PGM and Contractor for extra work, or the period of suspension in the event of unforeseen conditions, as established by the PGM.

103.03 CHANGES IN SCOPE OF WORK

The PGM reserves the right to order, at any time during the progress of the work, additions to the list of contract work items, as may be necessary or desirable. Any such order will be in writing by the PGM. Also, should any item contained in the proposal and contract be found unnecessary for the proper completion of the work, a written order will be given to eliminate such item from the contract. Such changes will not invalidate the contract, nor release the surety. Payment for such work will be made under Section 105.03.

103.04 LIQUIDATED DAMAGES

Any work that remains uncompleted after the time specified in the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC) for project completion, the sum of $800 per Drilling Inspector per 8-hour day (plus $80/hour for any amount of time over 8-hours on that day), unless otherwise stated in the proposal, will be deducted from money due or to become due. This deduction will not be assessed as a penalty, but as liquidated damages. Liquidated damages are only calculated to recover losses incurred by the Department or fees paid by the Department. The liquidated damages minimum rate is compensation for salary, overhead, and expenses incurred for late delivery or untimely performance of the particular contract. A contract time extension may be made, at the discretion of the PGM, as applicable beyond the period specified in the contract, when the Contractor is not responsible for the delayed completion of the work. In such cases, the Contractor is liable for liquidated damages for delays commencing from the date on which the extended period expires.

In the event the Contractor is declared in default and the Contract is terminated as specified in the provisions of Section 103.06 liquidated damages will be charged as provided by

this section, and such amounts, if any, will be deducted from money due or to become due to the Contractor or the surety. If the total amount chargeable as liquidated damages exceeds the amount payable to the Contractor or the surety, the excess is to be paid to the PGM by the Contractor or the surety.

103.05 SUSPENSION OF WORK

Work may be suspended by the PGM, wholly or in part, for the following reasons:

- failure to carry out orders
- failure to perform any provisions of the contract
- unforeseen conditions not anticipated in estimating the contract time required for the completion of the work

Written notification will be given of the action to be undertaken and the reason for the actions. After receipt of notice of suspension, take all reasonable steps to minimize the further incurrence of costs or expenses under the Contract. Payment will be made for the work actually accomplished up to date of suspension, and accepted by the PGM, at the unit prices set forth in Form TR-444, Form of Proposal. Payment will also be made for any minimum and reasonable costs and expenses agreed to by the DGE, the PGM, and Contractor in writing that may be required to allow the maintenance of equipment in standby condition so that services may be resumed if conditions so warrant in the opinion of the DGE.

103.06 TERMINATION OF CONTRACT

(a) Termination Due to Delay, Neglect, or Default. The Contractor may be declared in default for the following reasons:

- failure to cooperate, meet schedules, or complete work within the time specified in the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC)
- failure to perform the work with sufficient labor, equipment, or material to ensure the completion of the specified work as specified in the contract terms
- unsatisfactory performance of the work
- failure or refusal to remove material or remove and replace any work rejected as defective or unsatisfactory
- insolvency or bankruptcy
- commission of any act of bankruptcy or insolvency
- assignment made for the benefit of creditors
- failure or refusal within ten (10) days after written notice by the PGM, to make payment or show cause why payment should not be made, of any amounts due for material furnished, labor supplied or performed, for equipment rentals, or for utility services rendered, as covered by the Additional Bond for Labor and Materials (Form TR-445C, PennDOT

Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials)

- failure to protect, to repair, or to make good any damage or injury to property
- work not carried on in an acceptable manner for any cause

The PGM, after giving ten (10) days written notice of default will have the power and authority, without violating the contract, to:

- declare the Contractor in default
- take the completion of the work out of the hands of the Contractor
- appropriate or use any or all materials assembled for the project
- enter into a contract or contracts with others for the completion of the work
- use such other methods that will be expedient for the completion of the contract in a satisfactory manner

(b) Termination for Convenience. With approval from the DGE, the PGM, after giving ten (10) days' written notice, will have the power and authority, without violating the contract, to cause termination of the contract for the convenience of the PGM and the Department.

(c) Payment. Subsequent to contract termination, payment will be made at the unit prices specified in Form TR-444, Form of Proposal, for work completed and accepted by the PGM. No other payment will be made.

(d) Disposition of Documents and Samples. In the event of termination for any reason, all finished or unfinished documents, all soil and rock samples, and other materials, at the option of the PGM become the property of the Department.

(e) Completion of Work Terminated Due to Default. In the event of default and contract termination, the PGM may have the work required under the contract completed in such manner as, in the PGM's judgment, will best serve the interests of the Department. The Contractor will be liable for and must pay to the PGM any excess in cost expended over and above the cost specified in Form TR-444, Form of Proposal, as well as any expenses caused the PGM and Department, by the failure of the Contractor to comply with the terms of the Contract.

103.07 LAWS, ORDINANCES, REGULATIONS AND PERMITS

Comply with all laws, ordinances, rules, and regulations of the Federal and State governments, or of any political subdivision thereof, which are applicable to the work to be performed under the Contract. Obtain all permits and licenses necessary to the prosecution of the work, except for work on railroad property, as specified in Section 103.12, at no additional cost to the PGM or Department.

103.08 PATENTS AND PERMITS

Pay all royalties and indemnify and save harmless the PGM and the Department from any claims for infringement by the reason of the use of any patented designs, device, material, or process to be performed or used under the Contract.

103.09 SAFE PRACTICES IN DRILLING

(a) Responsibility. Follow generally accepted drilling practices and be responsible for all matters dealing with safety in performing the work, including safety of all persons and property during performance of the work, employees and all employees of subcontractors that may perform work. This requirement will apply continuously regardless of time or place and will in no way be altered because the PGM gives general directions as to the location where samples should be taken. Additionally, the drilling contractor should not perform any work that the drill operator considers unsafe. In the event of any disputes, these must be addressed with the DGE. This does not relieve the contractor of the responsibility to thoroughly inspect the site, and come prepared to the job with equipment necessary to conduct work in a safe manner, as specified in Section 102.02. Pre-bid meetings are the primary mechanism that potentially unsafe drilling conditions that were not recognized by the PGM or the Department can be identified by drilling contractors. If a pre-bid meeting is not conducted, such conditions must be addressed by the contractor to the PGM prior to bid, or any costs associated with mitigating the unsafe conditions may be the responsibility of the contractor.

(b) Occupational Safety and Health Regulations. Comply at all times with applicable Federal, State, and local laws, provisions, and policies governing safety and health, including the Federal Construction Safety Act (Public Law 91-54), Federal Register Chapter XVII, Part 1910 “Occupational Safety and Health Standards” and Part 1926 “Occupational Safety and Health Regulations for Construction” of Title 29, Code of Federal Regulations, and subsequent publications updating these regulations.

(c) Deep Mine Safety Monitoring Equipment. Borings that intercept deep mines or coal may encounter methane gas and/or carbon monoxide gas during the drilling and grouting process. Provide a monitor for the measurement of methane, carbon monoxide, and oxygen. Provide a monitor with a minimum range of measurement as follows: methane from 100 ppm (0.01%) to 50,000 ppm (5.0%); carbon monoxide from 10 ppm (0.001%) to 1,000 ppm (0.10%). Provide an operating monitor at the location of each boring where deep mines are known or suspected of being encountered; where indicated in the contract; or as directed by the PGM. Obtain readings directly above the boring and within 12 inches of the boring opening. Maintain monitors in good operating condition, including calibration, for the life of the project. Have a monitor available to the PGM for inspection of the boring and any previously drilled holes on the project.

Repair or replace monitors within twenty-four (24) hours of notice from the PGM and /or DGE. Drilling of borings in deep mined areas will not be allowed if the monitor is not present and operating as specified.

If methane above 12,500 ppm (1.25%) or carbon monoxide above 10 ppm (0.001%) is detected immediately stop work and allow the boring to naturally vent. If after 24 hours or more methane above 12,500 ppm or carbon monoxide above 10 ppm is detected, employ industry standard methods to vent the borehole. Drilling may continue if venting reduces the methane to below 12,500 ppm and carbon monoxide below 10 ppm. If after venting for at least 24 hours the methane remains between 12,500 ppm and 25,000 ppm or carbon monoxide remains between 10 ppm and 30 ppm, grout the boring. If at any time methane above 25,000 ppm (2.5%) or carbon monoxide above 30 ppm (0.003%) is detected, evacuate the area, and contact the PGM.

(d) Environmental Drilling under Class E1 or E2. A site-specific Health and Safety Plan (HASP) will provide a health and safety program to cover specific work practices to assure employee health and safety. A generic HASP is provided as an Appendix to **Publication 222** to be used in developing the site-specific HASP. The written HASP is for systematic identification of known or suspected site hazards and identification of employee response to those hazards.

The HASP must communicate hazards to employees for their awareness and protection. Site characterization is a continuous process. After the completion of each phase of assessment, information is obtained and evaluated to define the potential hazards. All site personnel should be constantly alert for new information about site conditions. The contractor is responsible for compliance with the site-specific HASP. The contractor may develop their own HASP but it must equal or exceed the prior established site HASP. **The HASP must be reviewed and accepted by the Department's Environmental Manager prior to the commencement of work on the site.** Do not construe Department acceptance of Contractor submittals to imply approval of any particular method or sequence for conducting the work, or for addressing health and safety. The contractor is responsible for all employees and subcontractor's employees on the project site.

The contractor must provide OSHA certified personnel who have completed a 40-hour health and safety training course or current 8-hour refresher training. There must also be an established Medical Monitoring Program. Documentation of all health and safety training must be provided to the Department prior to initiating work on the project.

Periodic air monitoring of the breathing zone, borehole, and background must be performed during all work operations. The PGM's Health and Safety Officer is responsible for this monitoring and to initiate upgrade.

It is the responsibility of the contractor to inform their employees of all potential hazards related to this work as specified in 29 CRF 1910,1200 Hazard Communication Standard and is responsible for supplying all equipment and materials to perform the services specified in this document at Personal Protection Equipment (PPE) Levels D, C, or B. Unless specified otherwise, Level D PPE, as

discussed in the HASP, must be considered the minimum work level acceptable for those areas of the project site designated by the PGM.

(e) Encountering Contaminated Material. If the Drilling Contractor, Drilling Inspector, or PGM encounters potentially contaminated material not previously suspected, during any phase of the geotechnical investigations, the operation must be halted in a safe and controlled manner, and the PGM will immediately contact the DGE. The DGE should contact the District Environmental Manager.

In such cases, the drilling contractor is required to secure the site until appropriate personnel can enter the site to complete decontamination efforts. Securing the site includes containerizing all suspected contaminated materials including the suspected samples, fluids used to clean the sampling devices, and any materials (towels, gloves, etc.) used in the containment process. If securing these materials cannot be performed in a manner that provides reasonable safety to the drilling personnel, or the suspected contaminated material is causing physical distress (e.g., due to odors), then the area should be guarded at a safe distance until properly equipped personnel arrive to containerize the materials and secure the site.

Due to the potential for encountering contaminated material, the drilling contractor must have available for every project, at least one 55-gallon drum, incidental to the project, to containerize contaminated material for initial site securing. As many sites do not allow for safe and secure storage, the contractor must provide additional provisions for sitting a trailer, providing a fenced area, or other temporary measures to securely store the drum, as required. The method of storing the drum must provide secure, lockable, containment.

If necessary, containerized materials may be transported off-site prior to receipt of analyses. This material may be relocated to the closest appropriate Department maintenance facility, only as a last resort. This option must be coordinated with and approved by the Department. The responsible Department maintenance facility official must be notified before any potentially contaminated samples are transported to the facility. The PGM (Project Geotechnical Manager) or DGE, if an in-house project, will make the appropriate arrangements to contact a company allowed to transport the hazardous material as required. All geotechnical samples obtained from a suspected waste site will require proper labeling in addition to those specified in Section 214.

Under no circumstances should site workers perform activities they are not trained and capable of performing, or that compromise personal safety.

103.10 LOCATION OF UTILITIES AND UNDERGROUND STRUCTURES

The Contractor is responsible for knowing the location of all underground utilities, overhead utilities, pipes, cables, and underground structures that their employees could potentially encounter while on-site. It must be the Contractor's responsibility to perform the work under the safest possible conditions, and to employ the necessary precautions to avoid these features during completion of boring, sampling, and testing operations.

(a) Underground Utilities. If it is established that the location of a boring is such as to cause interference with an underground facility or structure, advise the PGM. At their discretion, the PGM may designate a new location for the boring or authorize its omission.

Before the work begins, comply with the Pennsylvania Underground Utility Line Protection Law, Act 287 of the General Assembly of Pennsylvania, 1974 as amended or superseded, which defines the procedures for notification to Public Utilities prior to excavation, drilling, or demolition work by use of powered equipment or explosives. The law requires the use of the PA One-Call System to locate all utilities. In addition, the Contractor must coordinate with the public or private landowners to locate non-public underground utilities such as buried electric lines, communication cables, drainage pipes, etc. The boring location(s) must be adequately offset where the hole location(s) conflicts with utilities and other structures in the project area including those not covered by the PA One-Call system (as indicated above). If necessary, Section 219 may be specified to locate underground utilities.

In the event of a utility strike, the contractor/excavator is to comply with Pennsylvania's Underground Utility Line Protection Law Act 50 (P.L.852, No. 287 amended October 30, 2017). The contractor/excavator must file an Alleged Violation Report (AVR) with the Public Utility Commission through the PA One Call System within ten business days after striking or damaging a facility owner's line. The contractor/excavator must notify the PGM/DGE immediately after a utility line is struck, damaged, or if previous damage is discovered so that the PGM/DGE can also file a required AVR.

Refer to Publication 10, DM-1, Section 8.6, for guidance for submitting the Alleged Violation Report. For specific requirements for completing an AVR or for directly contacting the PA One Call System, contact information is as follows:

PA One-Call Phone: dial **8-1-1**
or call **1-800-242-1776**
On-line: pa1call.org

(b) Overhead Utilities. To determine the required minimum distance to stay away from overhead power lines, the PGM will contact the utility company to determine voltage in the line. For voltage to ground of 50kV or less, the minimum clearance between overhead power lines and any part of the drill rig, including any drill steel, is 10 ft. For voltages to ground over 50kV, the minimum clearance distance is 10 ft. plus 4 inches for every 10kV over 50kV. For overhead lines not containing power (e.g., cable, telephone) the minimum clearance between the lines and any part of the drill rig, including drill steel, is 10 ft. In situations where clearance between overhead lines and drill equipment is less than required above, the requirements of 1910.333(b) and 1910.333(c), respectively, of the OSHA regulations must be followed. Any work in these conditions must be coordinated by the PGM with Contractor and the appropriate utility company(ies). The Contractor must arrange with the public utility to shield adjacent overhead power lines, as required, at no additional cost to the Department.

103.11 WORK ON PUBLIC AND PRIVATE PROPERTY

(a) Permission for Access. General permission to enter public or private property on which borings or test pits are located, or over which access is required, will be obtained by the PGM. The PGM will provide a copy of the "Notice of Intent to Enter" (NOITE) letter to the driller awarded the contract (at the time of awarding the bid). In addition to the NOITE letter, the PGM will contact property owners in person or by telephone at least 3 days but not more than 2 weeks prior to entering their property.

Obtain prior approval from the PGM before entering any property within the work area. Do not drill, construct an access route, or stage on any property where personal contact has not been made until given permission in writing from the Department. Any cost incurred, including but not limited to property damage, delays, or down time caused by entering any property without prior approval of the PGM, must be borne solely by the Contractor.

(b) Arrangements for Access. Prior to entering any property, make specific arrangements for property access (including schedule, access route, etc.) with the owners of properties on which borings are located or over which access is required to perform work. Property owner information (name, address, telephone number, etc.) will be provided by the PGM. Provide all the information discussed with the property owner to the Drilling Inspector. The Drilling Inspector will prepare and provide the Department with written documentation of this contact if requested.

If access is denied to any property for which general permission to enter has been obtained, notify the PGM in writing. The PGM will contact the DGE if access to any property is denied.

103.12 WORK ON RAILROAD RIGHT-OF-WAY

(a) Permit for Access. The PGM will acquire from the Applicant the permits, insurances, and railroad personnel necessary to gain access to Railroad right of way on which borings or test pits are located or over which access is required.

(b) Schedule for Access. The Permit for Access must describe all entries required, including entry by sub-contractors. The PGM will provide the following information in Attachment III to the Instructions to Bidders prior to entry onto Railroad right of way:

Schedule for Work to be done on the Railroad's Right-of-way

- Work to begin on:
- Work to end on:
- Days of week on which work is to be performed:
- Working time per day:
- Specific borings to be completed:
- Distance from each boring to centerline of nearest track:

- Estimated total linear feet to be completed:

Work must start on the day stated. The Department will be assessed charges for railroad personnel and equipment required to monitor the work from the day scheduled for work to begin. In the event work does not begin on the day scheduled, any costs billed by the railroad will be back charged to the Contractor.

(c) Assessment Damages. Contractor will be liable for any railroad costs incurred for work that is performed outside of the Schedule for Work defined in Attachment III. Exceptions will be granted only when the railroad's operations prevent work from being completed within the schedule, or when the PGM increases the schedule by written notice. Railroad costs that are incurred for work that is performed outside of the schedule will be deducted from the monies due, not as a penalty, but as Assessment Damages.

103.13 PROTECTION OF WORK, PERSONS AND PROPERTY

Provide and maintain any barricades, lights or other safety devices necessitated by hazardous conditions or required by local authority at no additional cost to the PGM or Department.

The Contractor must take all necessary precautions to prevent or minimize discharge of water on any roadway. Perform sweeping and salting operations of the work during drilling operations, as necessary, to prevent icy, wet, slippery, or dusty conditions that could pose undue hazards or inconvenience to property owners, pedestrians, or vehicular traffic, at no additional cost to the PGM or Department.

103.14 INJURY TO PERSONS AND DAMAGE TO PROPERTY

Promptly repair all physical damage to property resulting either directly or indirectly from the SBST operations. Every effort practical and reasonable must be made to prevent damage to property. This includes, but is not limited to, using plywood over lawn areas and soft ground, avoiding fences where possible, staying clear of structures and prepared landscaping, and minimizing trimming of trees.

If the Drilling Contractor, Drilling Inspector, or PGM encounters or is notified of any injury or fatality to persons, resulting either directly or indirectly from the SBST operations, the drilling operation must be halted in a safe and controlled manner, and the PGM will immediately contact the DGE. The DGE should contact the District Project Safety Officer and proceed as directed. Under no circumstances should site workers perform activities they are not trained and capable of performing, or that compromise personal safety. Work will resume only when directed by the DGE.

Upon completion of the work, furnish satisfactory evidence that all claims arising from injury to persons or damage to property resulting from the boring, sampling, and testing operations have been resolved. The acceptability of evidence that claims have been resolved will be determined by the PGM.

103.15 INSURANCE AND LIABILITY

(a) General. Obtain and pay for such insurance as will protect the Department and the PGM from claims under the Workers' Compensation Act and from any other claims for damages for personal injury including death, or for damages to property, both real and personal, which may arise from operations under the Contract, whether such operations be by the Contractor or by anyone directly or indirectly employed by the Contractor.

(b) Coverage. Effect and maintain for the duration of the Contract the following insurance in companies or through agents, with minimum limits of coverage as specified in the Instructions to Bidders, at no additional cost to the PGM or Department:

1) WORKER'S COMPENSATION INSURANCE including Employers' Liability Insurance in accordance with the laws of the Commonwealth of Pennsylvania.
2) GENERAL LIABILITY INSURANCE for Bodily Injury and Property Damage, including explosion, collapse, and underground hazards coverage.
3) AUTOMOBILE INSURANCE for Bodily Injury and Property Damage covering all automotive vehicles owned or hired by the Contractor and used on this Contract not otherwise so covered by insurance, and including automatic coverage for additions to the schedule of vehicles.

(c) Certificates of Insurance. Deliver to the PGM, before starting the work, certificates from insurance companies or their agents, in duplicate, stating that such insurance is in force and will not be canceled during the conduct of the work without thirty (30) days written notice to the PGM. The certificate of liability insurance will include as additional named insurers, the PGM and the Department, in respect to the work to be performed by the Contractor.

(d) Additional Taxes and Insurance. Report and pay all Old Age Benefit and Social Security Taxes and other insurance as required by State and Federal Laws.

(e) Reduction of Coverage. In the event that, during the course of the work, the above limits of coverage should be reduced for any reason, the PGM and/or the Department reserve the right to terminate the Contract without waiving any other rights it may have under the law. Such termination will be effected by giving written notice thereof to the Contractor, as specified in Section 103.06.

(f) Liability. In no event will the PGM or the Department, their officers, employees, or representatives be liable in any way for consequential damages of any kind. By signature on the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC), the PGM and the Department are released from any liability for damage to property howsoever caused in connection with the performance of the work to the extent coverage is in force for such damage under a physical damage insurance policy. If any of the physical damage insurance policies do not allow release of other persons or firms from liability

before a loss, obtain endorsement to such policies from the respective insurance carriers as may be necessary to affect a waiver of the right of subrogation by such insurance carriers against the PGM and the Department.

(g) Indemnification. Without limiting any other provision of the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC), fully indemnify, save harmless, and at the PGM's request, defend the PGM and its subsidiaries, affiliated companies, agents and employees, and the Department and its officers, agents and employees, from and against all suits, actions, legal proceedings, claims, demands, damages, costs and expenses of whatsoever kind or character, including but not limited to attorneys' fees and expenses, arising out of or because of:

1) Any liability or obligation in any manner caused or occasioned or claimed to be caused or occasioned by, any act, omission, fault, or negligence of the Contractor or anyone acting on their behalf, including but not limited to vendors, their sub-contractors and sub vendors, and the employees and agents of any of the foregoing, in connection with or incident to the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC) or the work to be performed hereunder.
2) Any injuries (including death) or damage to any person or entity employed by or acting on the Contractor's behalf under the Contract Agreement (Form TR-445A, PennDOT SBSTC, or Form TR-446A, Consultant SBSTC).

103.16 EQUAL OPPORTUNITY AND NON-DISCRIMINATION

In connection with the execution of the Contract, do not discriminate against any employee or applicant for employment because of race, religion, color, sex, or national origin consistent with the Commonwealth of Pennsylvania Nondiscrimination Clause. Take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, religion, color, sex, or national origin.

Comply with the Regulations of the U.S. Department of Transportation relative to non-discrimination in federally assisted programs of the Department of Transportation (Title 15, Code of Federal Regulations, Part 8(a)(b)(c)).

103.17 INTEREST OF PUBLIC OFFICIALS

No member, official, or employee of the Department or of another state or local public body during their tenure or for one year thereafter is allowed to have any interest, direct or indirect, in the Contract or the proceeds thereof.

103.18 INTEREST OF MEMBERS OF CONGRESS

No Member of or Delegate to the Congress of the United States is allowed to have any share or part of this Contract or to any benefit arising therefrom.

103.19 SUBLETTING OR ASSIGNMENT OF CONTRACTS

Do not sublet, sell, transfer, assign, or otherwise dispose of the contract or any portion or rights, title, or interest, without the written consent of the PGM.

If consent is given, subletting a portion of the contract will be allowed. However, do not sublet a portion equal to, or exceeding 50 percent (50%), of the original total contract price. "Specialty Items," as identified in the proposal, may be performed by subcontract. The cost of any specialty items performed by subcontract may be deducted from the original total contract price before computing the amount of work allowed to be performed by subcontract. Subcontracts or transfer of contract will not release Contractor liability under the contract and bonds.

103.20 DISSEMINATION OF INFORMATION

Any reports, information, data, etc., given to or prepared or assembled under this Contract may not be made available to any individual or organization without prior written approval of the Department.

103.21 PUBLICATION, REPRODUCTION AND USE OF MATERIAL

No material produced in whole or in part under this Contract will be subject to copyright in the United States or in any other country. The Department will have unrestricted authority to publish, disclose, distribute, and otherwise use, in whole or in part, any reports, data, or other materials prepared under this Contract.

103.22 AUDIT, INSPECTION OF RECORDS, AND OWNERSHIP OF MATERIALS

Allow the authorized representatives of the Commonwealth of Pennsylvania to inspect and audit all data and records relating to performance of work under the Contract. Retain records for a period of at least three (3) years after completion of the Contract. At the end of three (3) years, provide the records to the Department or obtain written permission from the Department to dispose of the records.

Provide free access of the duly authorized representatives of the Department at all reasonable times to such books and records and the right to examine and audit the same and to make such transcripts there from as necessary to allow inspection of all work data, documents, proceedings, and activities.

Documents, drawings, design data, and reports used or prepared in the performance of this Contract belong to and become the property of the Department in perpetuity.

103.23 CONTINGENT FEES

If requested by the PGM, provide a sworn affidavit certifying that no company or person other than a bona fide employee was retained to solicit or secure the Contract, and that no payment or agreement to pay has been made to any company or person other than a bona fide employee, any fee, gifts, or any other consideration contingent on or resulting from the award of the Contract.

103.24 GOVERNING LAW

The Contract will be governed by the laws of the Commonwealth of Pennsylvania, and applicable federal and local laws as they may from time to time be in effect.

103.25 MISCELLANEOUS PROVISIONS

(a) Construction Bidding. Neither the Contractor nor its member companies or their affiliated companies may bid on or perform any direct construction work in connection with this project.
(b) Clean Air Act of 1970. Comply with all orders, applicable standards or regulations issued pursuant to the Clean Air Act of 1970.

SECTION 104 – CONTROL AND PERFORMANCE OF WORK

104.01 SUPERVISION, PERSONNEL, AND MANNER OF PROSECUTION OF WORK

Designate in writing, at the beginning of work, a competent field supervisor or foreperson who will be present at the site of the work at all times and will be responsible for supervision and performance of the work. Directions given them by the PGM will be binding on the Contractor, and such directions will be confirmed in writing when so requested. Any driller who begins work under the Contract must continue to work on the project until its completion, unless the PGM requests their transfer in writing. A driller may not be transferred without the written approval of the PGM.

Prosecute the work in a manner that will promote rapidity in execution, secure safety of life and property and satisfy the objectives of the project as indicated.

104.02 INSPECTION OF WORK

Perform no work unless the representative of the PGM is present, unless the work is off the roadway and requires no traffic control, and does not involve work that must be witnessed and logged by the Drilling Inspector. In such case, prior written authorization from the PGM is required. Provide full opportunity at all times for inspection of the work by the PGM. Immediately remedy any work not completed as indicated to the satisfaction of the Contract Documents and the PGM at no additional cost to the PGM or Department.

104.03 WORK PLAN AND SCHEDULE

Submit a Work Plan in writing to the PGM a minimum of seven (7) calendar days prior to beginning the Work on-site. If for any reason the contractor is not working on a planned day, they must notify the PGM and Drilling Inspector with an adequate, advanced notification. The Work Plan must include, as a minimum:

(a) The name and telephone number of the Contractor's Representative and Field Supervisor
(b) The dates on which on-site Work will begin and end.
(c) The days-of-the-week and hours-of-the-day on which Work will be performed.
(d) Estimated dates during which major specialty tasks (such as installation of instruments or performance of field tests) will be performed.
(e) A list of any boring(s) that need to be moved to avoid interference with underground or overhead utilities (see Section 103.10)
(f) A Traffic Control Plan, if required (see Section 215.03)

104.04 LOCATION OF BORINGS AND SURVEY

The PGM will establish in the field suitable points, lines, marks, locations, and elevations as required to locate test borings and/or test pits. Where possible, borings are to be located a minimum of 100 ft. from domestic water supply wells. If borings must be located within the 100-ft. distance, then those locations should be indicated on the Plan and Location of Borings and

discussed at the pre-bid meeting. Do not drill any borings within a radius of 10 ft. from any domestic water supply well or spring box. Furnish, without additional compensation, such labor, temporary structures, and materials as may be required by the PGM to establish and maintain such points, lines, marks, locations, and elevations.

The approximate locations of the required borings and/or test pits are indicated on the Plan and Location of Borings. The exact location of the individual borings will be determined and staked by the pre-bid meeting. If boring locations have not been approved by the pre-bid meeting, then the borings will be placed as close as possible to the expected locations. These borings will be identified as approximate locations.

The final locations of some borings may be modified in the field by the PGM, depending upon topographic features and subsurface conditions encountered during progress of the work.

Borings on land may be offset from the designated location by the PGM to avoid surface obstructions or impractical working conditions. Test borings on water must be located within a radius of five (5) feet from the designated locations.

104.05 NUMBER AND DEPTH OF BORINGS

The number of borings required is indicated in the Instructions to Bidders and on the Plan and Location of Borings. The final number of borings may be increased or decreased at the discretion of the PGM, as specified in Section 103.03.

Extend all borings to the depths, elevations or conditions specified in the Instructions to Bidders, unless the PGM specifically directs otherwise in the field.

104.06 SEQUENCE OF BORINGS

The PGM reserves the right to designate the sequence in which borings will be made. Any such specific sequencing must be provided in Attachment II of the bid document.

104.07 ABANDONED BORINGS

No payment will be made for any boring that has been abandoned before reaching the depth, elevation, or condition specified on the Plan and Location of Borings and/or in the Instructions to Bidders, unless the PGM approves and accepts the borings as being completed.

Afford the PGM the opportunity to measure the depth of any boring and to inspect samples of materials recovered before abandonment and removal of casing and drilling equipment.

104.08 WATER FOR DRILLING OPERATIONS

Make necessary arrangements with appropriate private property owners or governmental agencies for use of water supplies while drilling. Any expense incurred including the cost of

hauling water therefore must be reflected in the Proposed Bid Prices Per Unit for borings presented in Form TR-444, Form of Proposal. No additional payment will be made by the PGM or the Department for water required for drilling operations.

Use only potable water for drilling water if drilling operations are conducted within 100 ft. of domestic water supply wells or spring boxes. Potable water should be supplied in a clean container free of debris and/or foreign matter.

Wetlands that can be used as a source of drilling water will be noted in Attachment II. The Department will provide a Wetland Usage Plan detailing access, procedure of water removal, and recharge and restoration of disturbed areas.

Areas that may be wetlands but are not noted as such cannot be used without Department approval. The Department must be notified prior to using such areas. The Department will determine whether the wetland can be used as a source of water. Revision to the above plan, as noted above, will be provided for areas determined to be wetlands from which water can be obtained. Allow sufficient time for the Department's review in the scheduling of operation so that the allowable contract time is not exceeded.

104.09 RESTORATION OF DISTURBED AREAS

Restore ground areas disturbed by personnel and equipment as nearly as possible to their original condition. Any agreement to modify the restoration to original condition is strictly an agreement between the Contractor and the property owner and is to be at no additional cost to the Department. Prior to starting the work, submit repair methods for PennDOT facilities to the Department. Exercise particular care in the restoration of property such as shrubs, lawns, fences, walls, gardens, and pavements that are damaged, and restore all property to its original or like-original condition before leaving the site. No additional payment will be made by the PGM or the Department for restoration of disturbed areas.

104.10 PROTECTION OF ENVIRONMENT

During all phases of work, the Contractor must conduct their operations to minimize:

1) The disturbance of trees and other forms of vegetation
2) The use of excavation equipment to construct access roads, sumps
3) Discharges into waterways.

The Contractor must restrict their activities to the immediate vicinity of the boring locations as much as practical. The Contractor must not excavate or bench into any existing hillside or embankment slope, except as necessary and approved by the Engineer.

The use of trees for winching, within the existing right of way, is discouraged but not prohibited. If winching using trees is necessary, use only trees of sufficient size to prevent uprooting or related damage. Protect tree limbs and bark from damage using rubber matting, etc. The use of guide rail posts to assist in winching is not allowed.

104.11 TREE CUTTING

When cutting or trimming of trees is necessary to access boring locations, provide competent personnel and use proper arboricultural practices, tools, and personal protective equipment (PPE) to perform the work safely and efficiently. Use proper PPE such as hand protection (29 CFR 1910.266 (d)(1)(iii)); hard hat, ANSI standards Z89.1-1989 or Z89.2-1971 (29 CFR 1910 Subpart I); safety glasses and face shields, ANSI Z87.1-1989 (29 CFR 1910.266(d)(1)(vii)(A)&(B)); hearing protection, leg protection, APA guidelines (29 CFR 1910.266 (d)(1)(iv)); safety footwear, Z41-1991 compliant, ASTM F1818 (29 CFR 1910.266 (d)(1)(v)); and first-aid kits (29 CFR 1910.266 (d)(2)(i)).

Conduct tree cutting operations from off the travel lanes. Promptly remove any tree trimming debris to maintain a safe work area. Clear roadway drainage ditches/swales of any debris associated with this work.

Unless otherwise specified or directed, trimmed tree limbs should be removed back to the branch collar. Trees on Department's right of way that require 2/3 or more of canopy removal must be removed to ground level. Removal to ground level must be no higher than three inches above the ground surface, cut parallel to the ground surface. Trees on private property that require 2/3 or more of canopy, can be removed completely at the property owner's discretion. If trees are required to be removed from maintained lawns, the stumps must be removed to a minimum 6 inches below existing ground level, debris removed, and backfilled with topsoil, seeded, and mulched.

Be mindful of the Department's right-of-way lines and any required work limits. If tree cutting work is required off the Department's right of way, contact affected property owners in writing informing them of the proposed work and offering them any resulting wood. Use Form M-689 for this purpose. Document any attempted property owner contacts, indicating the date, time, and type (personal or written). When a property owner agrees to retain the cut wood, obtain Form M-689 agreement, and submit a copy to the DGE. Cut wood to the agreed lengths and place on private property at the right-of-way line as specified in Department policy.

104.12 SITE CLEANUP

After completing field operations, promptly remove all equipment mobilized and material brought to the site and restore the site to its original condition, as described under Section 104.09. The work will not be considered complete until site cleanup has been completed and accepted by the PGM.

SECTION 105 – PAYMENT

105.01 GENERAL

Perform all work for the compensation set forth in Form TR-444, Form of Proposal, except as noted under Section 105.03. The compensation thus set forth includes the cost of all insurance, bonds, and other incidentals, as well as all taxes and premiums payable under Federal, State, and Local laws applicable to labor, materials, supplies furnished, or work performed.

The basis of measurement and payment is as set forth under the Technical Provisions of these Standard Specifications for Subsurface Boring, Sampling, and Testing, or as specified in Form TR-444, Form of Proposal, with the latter taking precedence.

105.02 UNIT PRICES

Except for lump sum prices that are fixed and invariable, the proposed bid price per unit specified in Form TR-444, Form of Proposal, will govern. The estimated quantities of these items are only approximate as indicated under Section 102.02. Depending on soil and rock conditions established during the actual boring operations in the field, the PGM reserves the right to increase or decrease the number of borings and total units of work. If the final quantities are greater or less than the estimated units listed in Form TR-444, Form of Proposal, additions to or deductions from the indicated proposed total price will be made based upon the proposed bid price per unit, except as noted in Section 103.03 for changes in scope of work, which will be paid for as specified in Section 105.03 as additional or extra work.

105.03 ADDITIONAL WORK AND EXTRA WORK

(a) Additional Work. This includes only the following:

- work of the type already provided for in the contract and
- work for which there is a contract price.

Perform all such work only when authorized in writing by the PGM, as stated in subparagraph (c). All additional work will be paid at the contract price and in the same manner as if it had been included in the original contract.

(b) Extra Work. This includes only the following:

- work arising from changes described in Section 103.03, which results in a significant increase or decrease in the cost of performing that work or
- work, having no quantity and/or price included in the contract, which is determined by the PGM to be necessary or desirable to complete the project.

Perform all such work only when authorized in writing by the PGM, as stated in subparagraph (c). All extra work will be paid only as stated in subparagraph (c).

(c) General. Additional work and extra work must be authorized in writing by the PGM prior to its performance. Compensation will be limited to the work authorized in writing and actually performed. Work performed prior to written authorization will be at the Contractor's risk.
A work order identifying the work to be done and the price to be paid will be processed prior to or during the performance of the work. To avoid interrupting the project, written authorization to perform work under this section will be in the form of a letter, email, or other writing from the PGM, issued within a reasonable length of time. The writing will set forth the work to be done and will state whether the work is to be paid as additional work and/or extra work.
If the work is to be paid as additional work, the PGM's writing will refer to the contract price for that work.
If the work is to be paid as extra work and is such that a reasonable price therefore can be negotiated, the PGM and Contractor will agree on a price and the PGM's writing will refer to the negotiated price for that work.
Payment for additional work and/or extra work is accepted as payment in full for all profit and for all equipment, labor, material, field overhead, home office and general administrative expenses, and every other expense incurred because of the additional and/or extra work.
No claims for additional compensation of any kind arising out of or relating to such work can be asserted against the PGM and/or Department.

(d) Disputes. In the event of a disagreement with the PGM as to whether work is original contract work or additional work, original contract work or extra work, or additional work or extra work the following must be done:

1) Notify the DGE immediately of such disagreement and confirm the disagreement in writing to the DGE within ten (10) days. Upon notification to the DGE of such disagreement, records will be kept daily of all labor, equipment and materials used in the disputed work. Review for accuracy and sign all such records at the end of each day or at the beginning of the next business day. Report to the DGE in writing within ten (10) days of such review all disagreements with such records. Failure to review and sign the records daily or to report in writing disagreements therewith will provide an irrefutable presumption that such records are accurate.
Disputes concerning all such work will be resolved by the District Executive and payment will be made on the basis determined by the District Executive.
2) In the event of a disagreement with the District Executive the party under contract with the Department must then have six (6) months to file their claim with the Board of Claims as provided in 72 P.S. 4651.

105.04 INVOICING

Submit monthly invoices to the PGM for work completed and accepted each month during the course of the Contract. Ten (10) percent of each invoice will be withheld pending

final completion and acceptance of the work and acceptance of all records required by the Contract Documents. Submit monthly and final invoices only for work completed and accepted by the PGM. Provide as a minimum, the following information in each invoice:

(a) Boring date, number, actual depth drilled in soil and in rock for each boring completed during the invoice period.
(b) Total units of each bid item completed and accepted during the invoice period together with the bid price per unit for each bid item and an extension of the total cost for each.
(c) The amount of payment requested, the amount retained (ten percent), and the net amount of payment.

In addition, provide in each invoice a cumulative total of the following as of the beginning and end of the invoice period:

(a) The completed and accepted units for each of the bid items.
(b) The amount of payment, the amount retained (ten percent), and the net amount of payment.

105.05 PAYMENT OF RETAINAGE

Upon completion and acceptance of the work by the PGM and acceptance of all documents and records, submit to the PGM satisfactory evidence that all claims arising from boring, sampling and testing operations under the Contract have been satisfactorily resolved. The ten (10) percent withheld from invoices will not be released until this evidence has been received by the PGM.

SECTION 200 – TECHNICAL PROVISIONS

SECTION 201 – MOBILIZATION

201.01 DESCRIPTION

This work consists of: movement to the site of all necessary personnel and equipment required to complete borings, including winches, bulldozers, trucks; set up of all equipment, tools, personnel and materials necessary to complete the work required by the Contract; removal of equipment, personnel and excess materials at the completion of the work; obtaining the required permits, insurance; restoration of disturbed areas, site cleanup; and any initial items required to start the work. When borings are scheduled to be conducted on water, Mobilization includes items such as stable working platforms, barges, boats, ramps, and any equipment, personnel, materials necessary solely to complete required boring(s) on bodies of water.

Movement between borings is not considered Mobilization but is to be included in the per-linear foot(feet) price for advancing the boring. Costs related to accessing boring locations such as vegetation clearing/removal, site leveling, and guiderail removal is not considered Mobilization but is to be included in the per-linear foot(feet) price for advancing the boring.

201.02 MEASUREMENT AND PAYMENT

Mobilization. Lump Sum.

Payment for the general Mobilization item will be made according to the following schedule:

A partial payment for Mobilization will be approved when the value of work completed and accepted is equal to 10% of the total contract bid amount less the Mobilization bid amount. That is, when: $ work completed = 0.10 x ($ total bid – $ mobilization bid). The partial payment will be determined as the **lesser of** the following:

- 70% of the Mobilization bid
- 8% of the Total contract bid

Upon satisfactory completion of all work, pay the remaining amount of the Mobilization item.

SECTION 202 – STANDARD SOIL BORING, SAMPLING AND TESTING

202.01 DESCRIPTION

This work consists of making soil borings to determine the true nature, arrangement and thickness of soil strata and any other materials as they exist in the ground; obtaining from each boring representative disturbed samples of the soil coming from each stratum as it exists in the ground; and performing standard penetration tests (SPT) at the depth of each representative disturbed sample; and advancing unsampled borings through soil.

202.02 PROCEDURES FOR ADVANCING BORINGS IN SOIL

(a) General. Advance borings in soil using the methods discussed below. The method used must be selected by the Contractor unless a specific method is indicated otherwise in the Contract. Methods other than those listed below may not be used unless approved by the PGM or DGE.

Regardless of the method used to advance the boring in soil, provide equipment with the minimum inside diameter (I.D.) necessary to allow required field testing, sampling, instrumentation installation, etc. Advance augers/casing to the depth or elevation required. Do not advance augers/casing to a depth greater than the depth at which testing or sampling is to be done.

Maintain all drilling equipment in good working order at all times throughout the duration of the work. If, in the opinion of the PGM, the equipment supplied is inadequate for proper completion of boring, sampling and testing operations, or installation of instrumentation, replace the equipment immediately with suitable equipment at no additional cost to the Department.

At all times during advancement of the boring through soil, maintain the water level inside the hole at or above the level of water outside of the hole. When necessary and particularly when drilling through very soft cohesive soil or cohesionless sand, maintain the hole full with water or at a level sufficiently higher than the groundwater level at all times before, between and after sampling operation to reduce the possibility of soil entering the hole (e.g., blow-in, sanding in, soil heave). Additional measures to prevent blow-in, including increasing the density of the drill water by adding bentonite or drilling mud to the water, may be necessary if approved by the PGM.

After completing each boring, including required groundwater level readings, backfill as specified in Section 209 or as otherwise indicated in the Contract or by the PGM. Do not backfill borings in a mine fire area until after completion of any temperature monitoring program.

(b) Advancement methods

1) Continuous Flight Hollow-Stem Augers. Continuous flight hollow-stem augers are only allowed to be used with a center (pilot) bit assembly (center rod, plug and bit) that prevents material from entering the augers as they are being advanced. Removal of material from inside the augers using water or any other method instead of a center bit assembly is not allowed. If while using a center bit assembly material enters the augers,

water or other methods may be used if approved by the PGM. The center bit assembly must be used at all times when advancing the borings to the required sampling or testing interval. Once the augers reach the required sampling or testing depth, the center bit assembly is removed to allow insertion of necessary sampling or testing equipment.

2) Threaded Flush-Joint Steel Casing. Steel casing must be threaded, flush joint and of sufficient strength to maintain an open hole. The casing may be advanced by drilling or driving. Once the casing is advanced to the sampling or testing depth, disturbed material inside the casing must be removed to the sampling or testing depth (i.e., bottom of casing). Various methods, which typically include the use of water, may be used to remove disturbed material from inside of the casing; however, bottom discharge wash bits are not permissible, nor are any other methods that disturb the soil at the top of the sampling or testing interval.
3) Solid Flight Helical Augers. Solid flight helical augers are allowed to be used to collect bulk soil samples, and to advance boring to the top of bedrock when sampling, testing or rock coring is NOT required, or as otherwise allowed by the PGM. Solid stem augers are not allowed to be used to advance a boring in soil when sampling, testing, rock coring, instrumentation installation, or any other procedure requiring an open hole is needed.
   See Section 216 for requirements for bulk soil sampling with solid flight augers. When solid flight augers are used to estimate top of bedrock, advance augers until refusal is encountered or as directed by the PGM.
4) Drilling Mud. Drilling mud, sometimes referred to as drilling slurry, may be used when approved by the District Geotechnical Engineer. Drilling mud is not allowed to be used when water or soil testing (environmental or electro-chemical) is to be performed on samples obtained from the boring, and it is not allowed when a piezometer (vibrating wire, open standpipe, etc.) will be placed/constructed in the boring. Drilling mud can be used with or without casing/hollow-stem augers and is typically comprised of a mixture of water and bentonite, a mixture of water and organic polymers (polymer mud), or a mixture of both bentonite and polymer mud with water. Only bentonite or other materials acceptable for use in aquifers that may be a source for a potable or domestic water supply are allowed for use as drilling fluids. No toxic or potentially harmful materials may be used as additives in drilling fluids. Drilling mud is commonly used to advance borings in deep/thick coastal plain deposits, to control running sands and artesian water conditions, and in squeezing/caving ground where lateral pressures are high due to weak soil strength.

(c) Artesian Conditions. An artesian condition is defined as an event where the in-situ pore pressures of a geologic formation force a flow of ground water above the existing ground surface. If artesian conditions are encountered while advancing the boring through soil or rock, cease advancement of the borehole and confine flow within drill tooling (i.e., augers or casing). Confine flow by extending the drill tooling above the ground surface. If there is flow around the

exterior of the drill tooling, use additional measures as necessary to confine flow within the drill tooling. Record on the boring log: the depth of borehole at the time that the artesian condition was encountered, the height of artesian head, and the relative turbidity (determined according to Figure 202-1). Contact the PGM immediately to determine if the boring must be advanced or stopped and grouted.

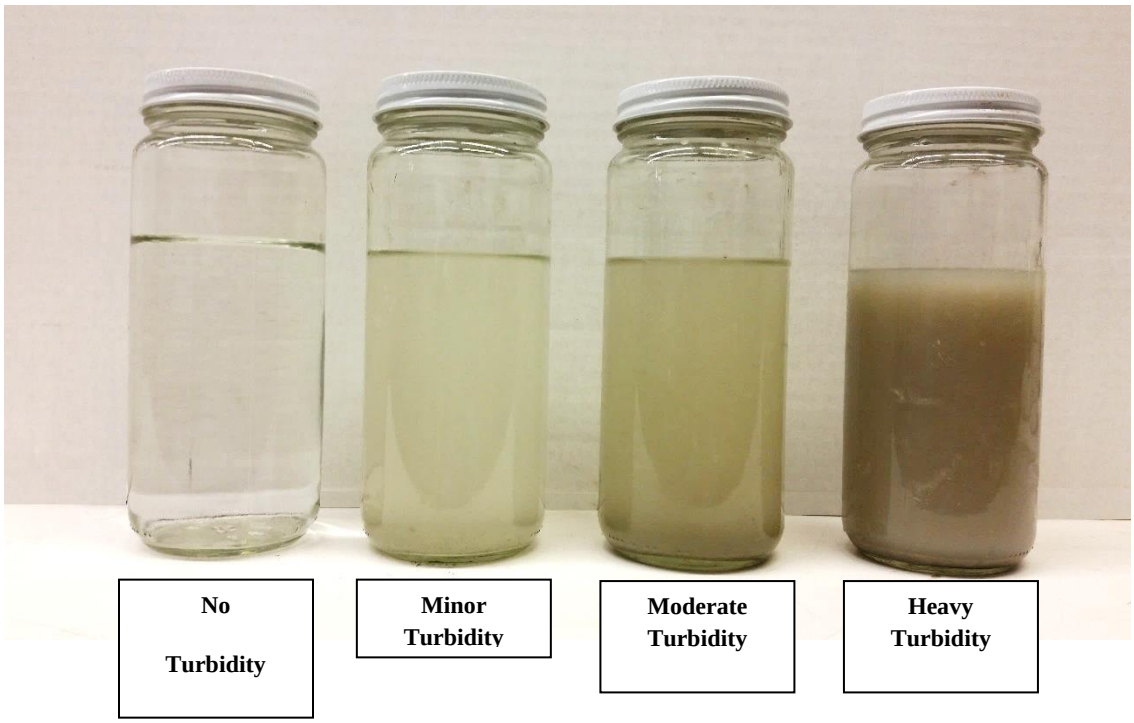


Figure 202-1 – Measurement of Turbidity

202.03 PROCEDURES FOR STANDARD SOIL SAMPLING AND TESTING

(a) General. Conduct penetration tests and obtain split-barrel samples conforming to ASTM D1586, except as modified in these specifications. Conduct continuous SPT unless specified otherwise, with the top of the first sample at the ground (soil) surface. For structure borings, provide continuous SPT to top of rock, unless otherwise directed by the DGE.

(b) Equipment. For equipment not specified herein, meet the requirements conforming to ASTM D1586.

1) Split-Barrel Sampling Device. Provide, for each drill rig, at least two, 2 inch outside diameter split-barrel samplers with inside diameters of 1-3/8 inch at least 24-inch long. Provide other diameter split-barrel samplers if specified. The inside of each split-barrel must be flush with the inside of the drive shoe. Other split-barrel samplers are allowed only with the prior written approval of the PGM.
The bottom of the sampler must be sharpened to form a cutting edge at its inside circumference. Maintain the beveled edge of the drive shoe in good condition and, if worn, reshape the edge to the requirements conforming to

ASTM D1586. Replace the drive shoe of the sampler if damaged in such a manner as to cause projections within the interior surface of the shoe. Provide a minimum of two drive shoes in good condition for each sampling device.

Furnish on the boring log a complete description of the sampler, giving inside and outside diameters and length of barrel.

Fasten the sampler to its drive pipe by a connection embodying a check valve arranged to allow the ready escape of water entrapped above the soil sample as the spoon is driven down into the soil, but which will close as the soil sample and sampler are withdrawn, thus preventing the development of hydraulic pressure on top of the soil sample. Confirm a check valve is used as required.

Install a spring-type sample retainer in the tip of the sampler when necessary to prevent loss of the sample. If the standard split-barrel sampler does not recover a soil sample on the second trial, as in granular soils, use a sampler with a flap valve or sand trap, or another approved device, to recover the sample. Do not use trap doors of the flap type protruding at any point into the inside diameter of the sampler without prior approval of the PGM.

2) Hammer. Provide a solid rigid metallic hammer having a mass of 140 pounds + or – 2 pounds, with a hammer drop system meeting the requirements conforming to ASTM D1586, which can apply blows at a rate of 20 to 40 blows/minute. Automatic, Safety, and Donut hammers are allowed. Automatic and Safety hammers are expected to have an efficiency rating (ER) of not less than 60%. If a Donut hammer is to be used, the Contractor must provide a hammer efficiency calibration of the hammer performed within the previous 12 months. Hammer efficiency calibration is to be measured conforming to ASTM D4633.

(c) Procedure. After cleaning the boring to remove all loose materials, remove the center bit assembly from the hollow stem auger. Gently lower the split-barrel sampler to the bottom of the hole. If, due to insufficient cleaning, the sampler remains more than six (6) inches above the specified sampling depth, remove the sampler and provide additional cleaning. Drive the sampler with the guided hammer into undisturbed soil below the bottom of the boring. Allow the hammer to fall freely through a height of 30 inches. The guide must be marked to facilitate easy measurement of the hammer drop. Observe and record the number of blows required to drive the sampler each 6-inch increment for a total penetration of 18 inches. **Do not overdrive the sampler.** Clearly record the number of blows for each 6 inches of penetration. Cumulative blows will not be accepted. Record the actual amount of penetration to the nearest 0.1 ft. Remove the sampler and advance the casing to the next scheduled sampling depth, or as directed by the PGM.

Drive the sampler with blows from the 140-pound hammer following the refusal criteria in Figure 202-2.

If a soil sample is lost or is found unsatisfactory as to size or condition, make a second attempt to obtain a satisfactory soil sample before advancing the boring to a lower elevation. Wash samples will not be accepted.

Immediately upon removal from the hole, carefully disassemble the sampler and record the soil description and amount of sample recovery. Remove the most representative and least disturbed portion of the sample, measuring 5 inches in length, and place into an air-tight glass jar of the dimensions specified in Section 214. Do not push or wedge additional material into the sample jar. Where a change in strata occurs within the spoon sampler, place a sample of each material in a separate jar. Record the depth of the change. Securely fasten the lid of each jar. If the length of sample recovered is insufficient to provide a sample 5 inches long, place the entire sample in the sample jar.

Describe soil samples and record borings, sampling and testing data as specified in Section 213. Package, ship, and store the samples as specified in the requirements of Section 214.

SPT Refusal Criteria and Action[5, 6]			
Condition	**Primary Action**	**Results**	**Consequential Action**
Condition A: SPT results of N = 50/0.1 ft. for one interval **OR** N ≥ 50/0.3 ft. for two consecutive intervals[4]	Attempt 2 ft. core run	Encounter rock with REC ≥ 80%	Begin continuous coring at 5 ft. runs
		Encounter rock with REC < 80% but ≥ 20%	Continue continuous coring at 3 ft. runs[1]
		Rock REC < 20%	Go to Condition B[2, 3]
Condition B	Attempt auger to next SPT elevation. Describe cuttings. Attempt SPT.[4]	Auger Refusal	Go to Primary Action in Condition A
		N = 50/0.1 ft. for one interval **OR** N ≥ 50/0.3 ft. for two consecutive SPT intervals	Go to Primary Action in Condition A
		N < 50/0.3 ft.	Continue SPT

Figure 202-2 – SPT Refusal Criteria

Notes: 1. If recoveries remain below 80% and encountering softer or weaker rock (e.g., claystone, shale, weak siltstone) or highly weathered rock, maintain continuous coring at 3 ft. runs. If harder and/or un-weathered or slightly weathered stronger rock is encountered, it may be best to switch to continuous 5 ft. core runs after two consecutive 3 ft. core runs.

2. When drilling conditions indicate the recovered material was encountered at the bottom of the core run, or there is clear indication that conditions are improving, a second 2 ft. core run may be attempted.

3. Unless site or project specific conditions or subsurface conditions indicate otherwise, if after a second cycle through Condition "A", rock core recoveries continue to remain less than 20%, switch to continuous coring at 3 ft. runs.

4. Do not describe SPT or auger cuttings recovered from weathered or weak rock as a soil or provide a soil classification. Describe consistent with the material encountered (e.g., shale fragments, highly weathered sandstone).

5. Whenever results from subsurface investigations (whether SPT or rock coring) indicate a change in subsurface conditions, follow the appropriate consequential action indicated above.

6. SPT = standard penetration test, N = SPT blow count, REC = Recovery

202.04 MEASUREMENT AND PAYMENT

(a) Soil Borings, NX-Diameter (minimum):
- (1) With Continuous SPT Sampling. Linear Foot.
- (2) With 5-ft Interval SPT Sampling. Linear Foot.
- (3) With _-ft. Interval SPT Sampling. Linear Foot.
- (4) Unsampled. Linear Foot.
- (5) Premium for Soil Borings on Water. Linear Foot.
- (6) Premium for Deep Continuous SPT Sampling (60-120 ft.). Linear Foot
- (7) Premium for Extra Deep Continuous SPT Sampling (>120 ft.). Linear Foot

(b) Soil Borings, -Diameter:
- (1) With Continuous SPT Sampling. Linear Foot.
- (2) With 5-ft Interval SPT Sampling. Linear Foot.
- (3) With _-ft. Interval SPT Sampling. Linear Foot.
- (4) Unsampled. Linear Foot.
- (5) Premium for Soil Borings on Water. Linear Foot.
- (6) Premium for Deep Continuous SPT Sampling (60-120 ft.). Linear Foot
- (7) Premium for Extra Deep Continuous SPT Sampling (>120 ft.). Linear Foot

Payment will be made at the proposed bid price per linear foot(feet) for the actual linear foot(feet) of soil borings completed and accepted by the PGM. Soil borings located on land will be measured from the ground surface to the depth at which rock was encountered, as determined by the PGM, and through any zone in which soil boring and sampling is resumed below a zone of rock drilling or coring. The PGM's identification of rock will be based on SPT refusal and successful initiation of rock coring procedures. Soil borings located on water will be measured from the bed of the body of water, with no payment for depth of water penetrated.

The payment per linear foot(feet) will be considered full payment for all costs associated with the soil boring and standard sampling and testing, including all required labor, equipment, and materials, and all logging, shipping, and storage of soil samples. The payment per linear

foot(feet) will also be considered full payment for confining flow within drill tooling when artesian conditions are encountered.

The premium per linear foot(feet) for borings on water will be paid in addition to the bid price per linear foot(feet) of similar land borings and will be considered full payment for all costs associated with performing the operation on a body of water, including all required specialized labor, equipment and materials.

The premium for soil borings on water will be paid for the borings noted as such in Attachment I.

The premium per linear foot(feet) for deep and extra-deep SPT sampling will be paid in addition to the unit bid price for Item Numbers 202.04(a)(3) and 202.04(b)(3), test borings with continuous SPT sampling. The premium is based on the depth of the soil boring and is a percentage of the contract bid unit price for standard depth Soil Borings with Continuous Split-Barrel Sampling. The premium schedule is indicated in Table 202-1. The total amount paid for the items specified above, at the depth intervals indicated in the schedule, is determined by multiplying the contract unit price bid for Soil Borings with Continuous SPT Sampling (on land) by the multiplier corresponding to the appropriate depth interval. No depth premium will be paid for borings bid as non-continuous SPT sampling.

Table 202-1 – Depth Premium Schedule for Continuous SPT Sampling

SPT DEPTH INTERVAL	DEPTH PREMIUM (max.)	MULTIPLIER[1]
Standard (0 to 60 ft.)	0%	none
Deep (60 to 120 ft.)	30%	0.3
Extra Deep (>120 ft.)	50%	0.5

Notes: 1. To determine the additional payment per linear foot(feet) for the Items and Depth Intervals indicated

SECTION 203 – UNDISTURBED SOIL SAMPLING

203.01 DESCRIPTION

This work consists of recovering undisturbed soil samples from soil borings.

203.02 EQUIPMENT

Use equipment conforming to ASTM D1587 or as directed by the PGM. Provide thin-walled tubes of 16-gauge seamless brass or hard aluminum, or 16- or 18-gauge seamless steel, with a minimum total length of 30 inches and with outside diameter of 3 inches, unless otherwise indicated by the PGM. Use only new, clean, un-corroded tubes removed from the manufactures' packaging at the job site. Used sample tubes are not allowed. All equipment will be subject to inspection and approval. Provide all sample tubes with a machine-prepared, sharp cutting edge having a flat bevel to the outside wall of the tube and drawn in to provide an inside clearance beyond the cutting edge of 0.015 inch $\pm$ 0.005 inch.

203.03 PROCEDURE

Obtain samples using the procedures conforming to ASTM D1587, unless otherwise specified herein or by the PGM.

(a) Location. Complete each standard soil boring as specified. Do not attempt undisturbed samples in these borings. Drill an unsampled soil boring as specified in Section 202.02(b) approximately three to five feet away from the standard soil boring to a depth specified by the PGM.

(b) Method. Recover undisturbed soil samples by means of thin-walled tube samplers. When the sampling depth is reached, remove all loose and disturbed materials. Clean out, in such a manner, that the soil immediately above the top of the sample is as nearly undisturbed as possible. Advance and clean out hole as specified in Section 202. Connect the sampling device to the drilling rod, lower slowly to the bottom of the hole, and advance into the soil for 6 inches less than the total length of the sampling tube. If obstructions, such as gravel particles, prevent the full penetration of the sampler, obtain undisturbed soil samples of a lesser length with approval of the PGM.

Advance thin-walled tubes in a continuous downward motion at a rate of 3 to 5 seconds/ft. using the rig hydraulics without rotation, or otherwise as specified, approved, or directed by the PGM. Do not drive the sampler unless the character of the soil is such that driving with the hammer is absolutely necessary and is approved by the PGM.

Allow the sample tube with its contained soil sample to remain in place for a minimum of 15 minutes. After this time period, rotate the drill rod through two complete revolutions to shear the soil immediately below the sample. Carefully remove the sample from the boring and detach from the sample rods. Do not extrude the sample from the tube.

Remove any disturbed material in the upper end of the tube and measure the sample recovery. Remove ½-inch to 2 inches of material from the lower end of

the tube for use in sample description. Completely fill the lower end of the tube, and at least 2 inches in the upper end of the tube immediately above the sample with a hot (melted) sealing wax consisting of paraffin wax, beeswax, microcrystalline wax, or some combination of these wax types. Tightly pack the remaining space in the upper end of the tube with paper, cloth, or other approved material. Close the ends of the tube with snug-fitting plastic caps and secure caps in place with adhesive or friction tape. Dip the ends of the tube in hot wax several times to provide an air-tight seal.

During sampling in very soft soils, if directed by the PGM, use a weighted drilling mud, to maintain a pressure on the soil as nearly equal as possible to that existing before the drilling operations.

(c) Records. Record each undisturbed sampling tube as specified in Section 213. The boring number for the sample must be the standard soil boring number with the addition of the suffix "A". A separate, complete boring log must be prepared for each boring made for obtaining samples, whether samples are successfully obtained. Package, ship, and store samples as specified in Section 103.

203.04 MEASUREMENT AND PAYMENT

(a) Thin-wall Tube Sampling of Soil, 3-Inch Diameter. Each.
(b) Thin-wall Tube Sampling of Soil, __-Inch Diameter. Each.

Payment will be made in addition to payment for linear feet of unsampled soil boring, at the proposed bid price per unit for each sample successfully removed and accepted by the PGM. Payment will not be made for drilling the interval of the undisturbed sample unless the interval is actually drilled for obtaining additional samples below the initial sample. The payment per sample will be considered full payment for all costs associated with obtaining the sample, including all required labor, equipment and materials, and all logging, packaging, shipping, and storage of samples. No payment will be made for damaged samples or uncollected samples due to Contractor negligence, error, or improper sampling technique. This determination will be made by the PGM. In the event of a failed sample attempt due to Contractor negligence, additional boring or a new unsampled hole may be required to attempt another undisturbed tube sample. No payment will be made for this additional unsampled soil boring.

SECTION 204 – ROCK DRILLING AND CORING

204.01 DESCRIPTION

This work consists of securing intact samples of rock from borings by diamond core drilling to determine the true nature, arrangement and thickness of rock strata and discontinuities as they exist in the ground, and of advancing unsampled borings through rock.

204.02 PROCEDURES FOR ADVANCING BORINGS IN ROCK

(a) General. Perform rock coring conforming to ASTM D2113, except as modified by these specifications, to obtain rock core of the size indicated where the soil boring has refused further penetration by split-barrel sampling. Drill each boring to the final boring depth indicated, or to the depths directed by the PGM. Sample soft or decomposed rock with a driven sampler as specified in Section 202 when possible.

(b) Equipment. If not specified herein, meet the requirements conforming to ASTM D2113.

1) Drill. Use a core drill having hydraulic feed-type mechanisms. Maintain the drill in an efficient and safe operating condition.
2) Core Barrel. Use a Series "M" swivel-type, double-tube core barrel with a diamond bit and a reaming shell, a double-tube wire-line core barrel with a diamond bit, or a triple tube core barrel with a diamond bit and a split metal or solid PVC inner barrel. Maintain the core barrel and bit in efficient operating condition and replace if damaged or worn. A solid or split inner barrel may be used in all borings, unless otherwise directed by the PGM.
3) Drill Rods. Provide drill rods having an inside diameter that will allow flow of drilling fluid through the rods in a quantity sufficient to provide an upward velocity of the fluid between the rod and the hole wall to remove the cuttings effectively. Do not drill with drill rods that are not straight.
4) When directed by the PGM, re-circulate all drill water. Use only potable water for drill water when drilling operations are within 100 ft. of any domestic water supply well or spring box.
5) Disposal of drill water must be conducted in an environmentally appropriate manner as directed by the PGM. Ensure that any potentially damaging or harmful materials are collected and disposed of in a manner that result in any impact to local environmental conditions.

(c) Procedure for Rock Coring. Make all test borings through appropriate size casing or hollow-stem augers installed to the bottom of soil borings. Advance the casing or hollow-stem augers to rock and seal into the rock surface to prevent seepage from or sloughing of soil overburden into the bore hole to be cored. Follow length of core runs as prescribed in Figure 202-2.
When coring rock, including shale, claystone, and coal, control the speed of the drill and the drilling pressure, amount and pressure of water, and length of run to

give the maximum possible recovery from the rock being drilled. Maximum length of first coring run is two (2) feet. Do not allow grinding of core. Maintain and observe pressure gauges to detect any blocking of core in the barrel, and at any suspicion that such is occurring, immediately cease drilling, remove the barrel from the hole and remove the core. Do not continue coring until care has been taken to see that the core barrel, bit, and other equipment are in satisfactory operating condition. If poor recovery is experienced due to failure to consider the above factors, redrill, and core the hole at no additional cost.

If soft or broken rock is encountered that cause broken pieces of rock to fall into the hole and cause unsatisfactory coring, or if voids of any type including mined-out coal seams or limestone caverns are encountered that endanger the continued downward progress of the boring, ream and case the hole with flush-joint casing to a point below the broken or open zone. Use a size of flush-joint casing that will allow securing of the specified core size. Repeat this procedure as many times as necessary to keep the hole clean. The use of standard wire line tools of the specified size is a preferred alternative procedure.

Make individual drill runs in the coring operation of not more than 5 ft. Where soft or broken rocks are encountered or anticipated, reduce the length of runs as indicated in Figure 202-2, or less as directed by the PGM, to reduce the core loss and keep core disturbance to a minimum. Make every effort to obtain maximum core recovery and record in the boring log all significant actions of the drill tools and reasons for loss of core.

Discontinue core drilling if, in the opinion of the PGM, observations of the drill tool indicate that softer materials have been encountered, and standard split-barrel sampling may be resumed. When drilling in carbonate formations, if soil filled voids are encountered, attempt a split-barrel sample to determine the nature of the material contained in the void.

Failure to comply with the foregoing procedures when ample warning of unusual subsurface conditions has been received in advance, will constitute justification for the PGM or DGE to require redrilling of any boring from which core recovery is unsatisfactory, at no additional cost. When, in the opinion of the PGM, the rock is in either a soft or broken condition, take precautions to keep the core intact as much as possible. Where used, dismantle the split inner barrel horizontally and remove the core with care.

Exercise particular care in recording water losses, artesian pressures, rod jerks, changes in rate of advancement or any other unusual coring experiences that will supplement the core record and further document the nature and extent of fracturing or voids. Mark fractures and their estimated widths in the core boxes and clearly indicate the location of voids.

Immediately upon removal of the core barrel from the hole, carefully remove the rock core sample from the barrel, place the rock in core boxes as specified in Section 214. Describe the rock samples, measure the rock recovery, and prepare the driller's log of each rock boring as specified in Section 213.

After completing each rock boring, install groundwater monitoring as specified in Section 208. After completion of groundwater monitoring, and when the hole is not required for long-term groundwater monitoring or instrumentation, backfill as specified in Section 209.

Package, ship, and prepare the rock core for storage as specified in Section 212 and Section 214.

(d) Procedure for Unsampled Rock Drilling. Where it is necessary to advance a rock boring without securing rock core, such as for installing piezometers, slope indicator casing or other field installations, or for performing field tests at a predetermined depth, advance the boring by methods as specified in Section 204.02(c), air rotary methods, or by using a tricone roller bit. When the hole is not required for long-term groundwater monitoring or instrumentation, backfill as specified in Section 209.

204.03 MEASUREMENT AND PAYMENT

(a) NX or NQ Rock Coring.	Linear Foot.
(b) _____ -Inch Diameter Rock Coring.	Linear Foot.
(c) _____ -Inch Diameter Unsampled Rock Drilling.	Linear Foot.
(d) Premium for Rock Drilling and Coring on Water.	Linear Foot.

Payment will be made at the proposed bid price per linear foot(feet) for the actual linear feet of rock coring completed and accepted by the PGM. Rock borings located on land will be measured from the depth at which rock was encountered, as determined by the PGM, to the bottom of the rock boring as determined by the PGM. Rock borings located on bodies of water or waterways will be measured in the same manner.

The payment per linear foot(feet) will be considered full payment for all costs associated with rock coring and drilling, including all required labor, equipment and materials, and all logging, packaging, shipping, and storage of rock core.

The premium per linear foot(feet) for rock drilling and coring on water will be paid in addition to the bid price per linear foot(feet) for rock drilling and coring of the same size on land, and will be considered full payment for all additional costs associated solely with performing the operations on a body of water or waterway, including all required specialized labor, equipment and materials.

The premium for rock drilling and coring on water will be paid for the borings noted as such in Attachment I.

SECTION 205 – CONCRETE/MASONRY DRILLING AND CORING

205.01 DESCRIPTION

This work consists of securing intact samples of Portland cement concrete/masonry from borings in pavements or structures by diamond core drilling, and of advancing unsampled borings through Portland cement concrete or masonry.

205.02 PROCEDURES FOR ADVANCING BORINGS IN CONCRETE/MASONRY

(a) General. Perform concrete or masonry coring conforming to ASTM C42, except as modified by these specifications to obtain concrete or masonry cores of the size and length indicated.
(b) Equipment. Use a diamond core drill to obtain the required concrete or masonry specimen.
(c) Procedure for Concrete/Masonry Coring. Obtain concrete or masonry core samples by the procedure as specified in Section 204.02(c) for rock coring or other methods approved by the PGM. After completing each boring, backfill as specified in Section 209.
(d) Procedure for Unsampled Concrete/Masonry Drilling. Where it is necessary to advance a boring through concrete or masonry without securing concrete or masonry core, such as for instrumentation installations or for performing field tests at a predetermined depth, advance the boring by methods as specified in Section 204.02(d). After completing each unsampled boring, backfill as specified in Section 209.

205.03 MEASUREMENT AND PAYMENT

(a) _____ -Inch Diameter Concrete/Masonry Coring. Linear Foot.(Each)
(b) _____ -Inch Diameter Unsampled Concrete/Masonry Drilling. Linear Foot.
(c) Premium for Concrete/Masonry Drilling and Coring on Water. Linear Foot.(Each)

Payment will be made at the proposed bid price per linear foot (feet) for the actual linear foot(feet) of borings through concrete or masonry completed and accepted by the PGM. Borings through concrete or masonry located on land will be measured from the top of concrete/masonry to the bottom of concrete/ masonry, as determined by the PGM. Borings through concrete/ masonry drilled from locations on bodies of water or waterways will be measured in the same manner.

The payment per linear foot(feet) will be considered full payment for all costs associated with concrete or masonry coring and drilling, including all required labor, equipment and materials, and all logging, packaging, shipping and storage of concrete or masonry core. The premium per linear foot(feet) for concrete/masonry drilling and coring on water will be paid in addition to the bid price per linear foot(feet) for concrete/masonry drilling and coring of the same size on land, and will be considered full payment for all additional costs associated solely with performing the operations on a body of water or waterway, including all required specialized

labor, equipment and materials. The premium for concrete/masonry drilling and coring on water will be paid for the borings noted as such in Attachment I.

SECTION 206 – STANDPIPE PIEZOMETERS

206.01 DESCRIPTION

This work consists of installing standpipe piezometer(s) to allow long-term monitoring of groundwater level.

206.02 PROCEDURE AND MATERIALS

Use the following procedures and materials to install a standpipe piezometer. A typical standpipe piezometer detail is shown in Figure 206-1.

(a) Prior to the start of work submit data sheets for all materials proposed to be used for approval by the PGM. Submit data sheets for porous piezometer tip, piezometer riser pipe, sand backfill, bentonite chips/pellets, and for any other materials proposed to be used. Do not begin work until approval has been given by the PGM.

(b) Drill the boring required to install standpipe piezometer at the location and depth indicated in Attachment I, or as directed by the PGM. Install standpipe piezometer in nominal 4-inch diameter borehole or larger. Borehole must be fully supported with steel casing or hollow stem augers during standpipe piezometer installation. The use of drilling mud for borehole support is not allowed.

(c) Clean the borehole of any loose, disturbed material.

(d) Place a 1-foot thick layer of sand in the bottom of the borehole. The sand must be well graded with a maximum particle size of 2 mm (No. 10 sieve) and no more than 5% by weight finer than 300 microns (No. 50 sieve).

(e) Install porous piezometer tip attached to piezometer riser pipe in the borehole with the porous piezometer tip placed on top of the sand backfill. The porous tip and each section of riser pipe will be inspected and approved before installation. Use flush threaded PVC drop pipe. Do not use solvent/cement to secure pipe. If necessary to secure the pipe, use a mechanical fastener that does not interfere with the function of the pipe or any instrumentation. Center the porous piezometer tip and piezometer riser pipe in the borehole. Extend the piezometer riser pipe to the top of the protective casing or as directed by the PGM. The porous piezometer tip must be 1-inch diameter (minimum) porous polyethylene and 24 inches (minimum) long. Porous polyethylene must have pore diameters of 50-100 microns (0.002 - 0.004 inch). The porous piezometer tip coupling/adapter must be sized to fit the piezometer riser pipe, and it must have a plug at the bottom. The piezometer riser pipe must be solid (not slotted or perforated) 1-inch diameter (minimum) Schedule 40, threaded-joint, flush-joint, PVC pipe. The connection between the porous tip and riser pipe must not be blocked or obstructed.

(f) Place additional sand around the porous piezometer tip. The sand must meet the requirements stated in (d) above and extend 2 ft. above the top of the porous piezometer tip.

(g) Use bentonite to seal the annulus above the porous piezometer tip. Place a 3-ft. thick layer of bentonite on top of the previously placed sand. The bentonite must

be dry, preformed compressed bentonite “chips” or “pellets”. Powdered bentonite may not be used.

(h) Fill the remaining annular space with neat cement grout. Use a minimum 1-inch outside diameter grout pipe and tremie grout as specified in Section 209.

(i) Provide a threaded protective cap with vent hole at the top of the piezometer riser pipe.

(j) It is the Contractor’s responsibility to remove casing without damaging the standpipe piezometer. The casing may be removed as piezometer backfilling (e.g., sand, bentonite, grout) progresses. However, the borehole must be supported (i.e., with either casing or piezometer backfill materials) at all times during installation and backfilling. Use a weighted tape or other methods during each stage of backfilling and casing removal to measure piezometer backfill level and ensure that the borehole is supported. If the Contractor does not complete piezometer installation in a satisfactory manner, and the cause is negligence or incorrect procedure on the part of the Contractor, an additional boring as required to provide the piezometer at the depth and location designated by the Engineer will be furnished at no additional cost to the Department.

(k) If artesian conditions are encountered during installation of the standpipe piezometer, extend casing and the piezometer riser pipe to a sufficient height above ground surface to contain the flow. After the standpipe piezometer installation is complete and the casing is removed, install a differential pressure gauge and valve at the top of the standpipe piezometer that can measure the piezometric pressure. The pressure gauge and valve must be installed no more than 2 ft. above ground surface. The pressure gauge must be a mechanical type with a pressure range of 0 to 10 psi and a dial gauge marked in 0.1 psi increments. A conceptual detail is provided in Figure 206-2, but the contractor is responsible for providing the final assembly, which must be approved by the PGM.

(l) Where indicated by the PGM, install a non-airtight protective steel or cast-iron casing with a 4-inch (minimum) diameter and locking or bolted cover over the completed piezometer. For a piezometer located in pavement, provide a flush-mount protective casing with a recessed lid with countersunk bolts. For above-ground installations, provide a hinged lid with hasp and lock. In all cases, extend the protective casing at least 24 inches below the ground surface, and backfill the full depth of the protective casing with neat cement grout as specified in Section 209.02(c).

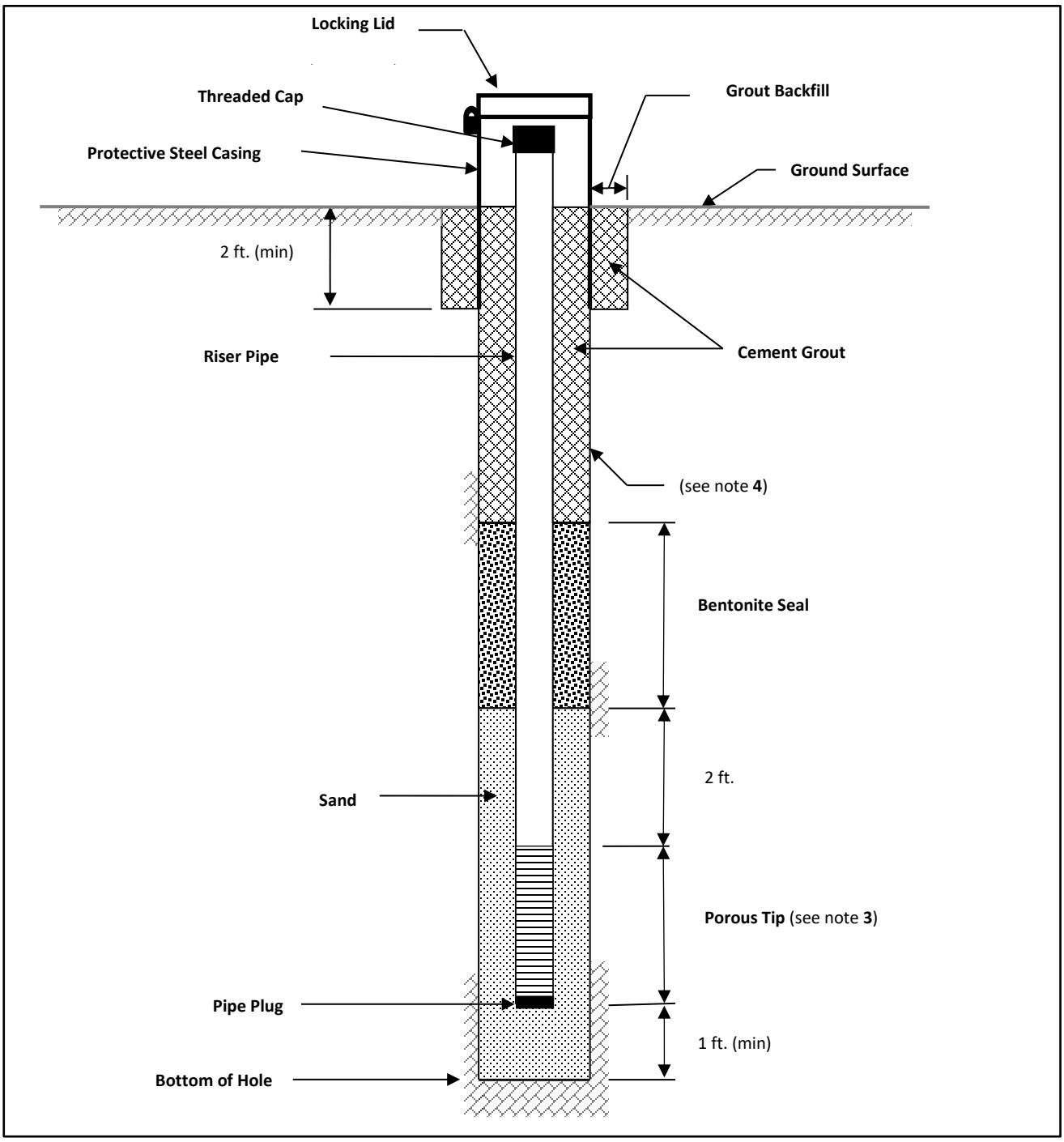


Figure 206-1 - Standpipe Piezometer (Typical) N.T.S.[1, 2]

Notes: 1. Types of hinges and hasps must be pre-approved by the PGM. Light-weight hinges or hasps will not be acceptable. All locks must have common keys.

2. 4-inch (min) steel pipe, extending 12-inches above the ground surface.

3. Bottom of porous tip (sensing section) to be determined by the PGM at completion of boring.

4. Minimum borehole diameter in soil must be 4-inches.

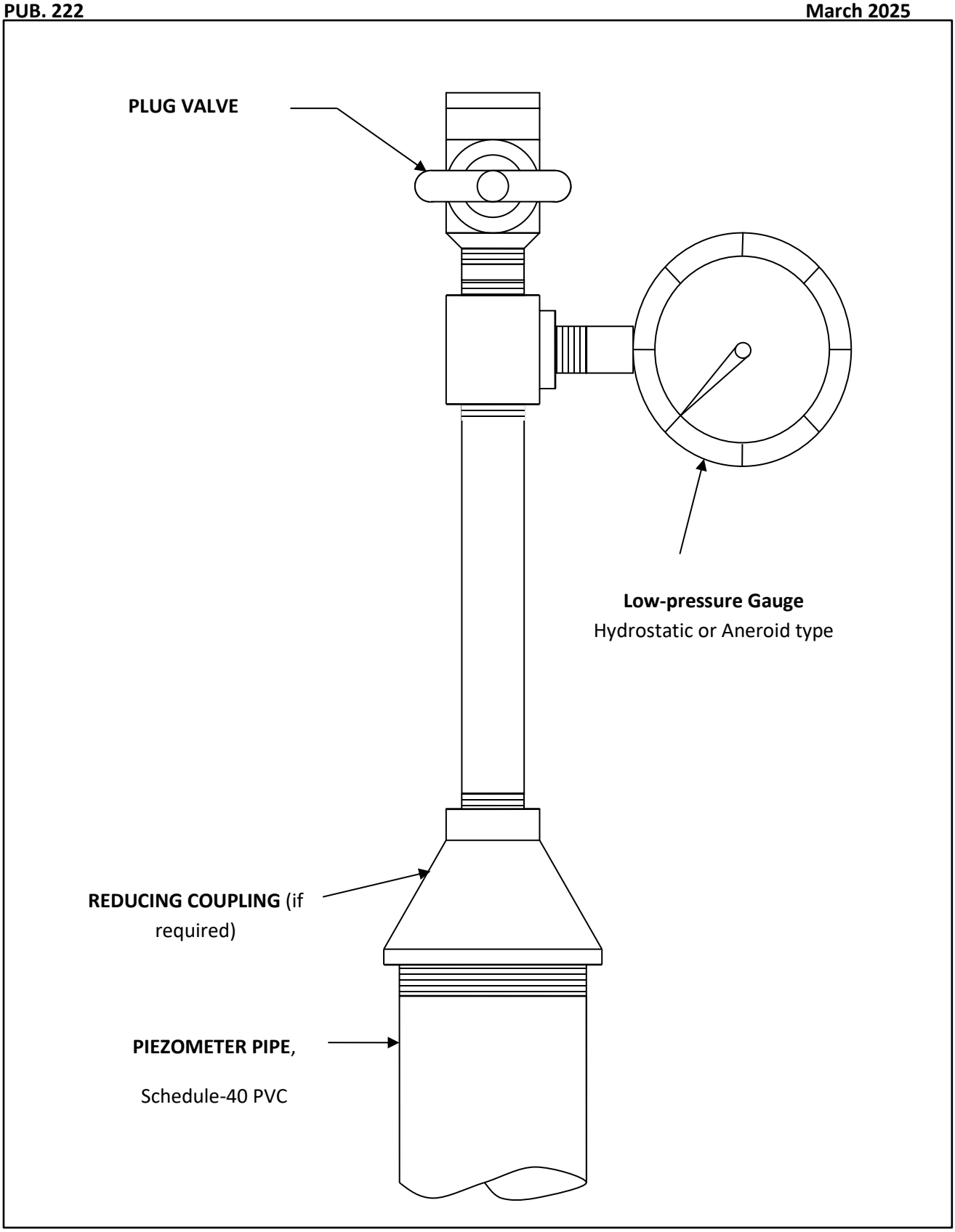


Figure 206-2 - Low-Pressure Artesian Monitoring Assembly (Typical) N.T.S.

206.03 MEASUREMENT AND PAYMENT

(a) Standpipe Piezometer	Linear Foot.
(b) Porous Piezometer Tip	Each.
(c) Protective Casing, Above-ground	Each.
(d) Protective Casing, Flush	Each.
(e) Low-Pressure Artesian Monitoring Assembly	Each.

Piezometer pipe will be measured from the top of the pipe to the top of the porous tip. The payment per linear foot(feet) for piezometer pipe installed and accepted will be considered full payment for all costs associated with installation of piezometer in the boring, including all required labor, equipment and materials, but excluding the costs associated with boring advancement, porous tip, piezometer pressure gauge, protective steel casing, and grouting the boring below the bottom of the piezometer, which will be paid for separately. The payment for non-shrink grout below the bottom of the piezometer will be as specified in Section 209.03 when additional borehole depth was directed by the PGM.

When installing standpipe piezometer, the cost for additional reaming the boring through bedrock to accommodate the PVC pipe, if required, will be incidental to the cost of PVC pipe.

For each above-ground casing installations, a Master Lock® No. 3 (or equivalent) padlock must be supplied with labeled keys to the PGM or DGE, and others as needed. The cost of each padlock will be considered incidental to the unit price of the Protective Casing.

SECTION 207 – INCLINOMETER CASINGS

207.01 DESCRIPTION

This work consists of installing inclinometer casing in a boring to allow monitoring of lateral movement of the ground.

207.02 PROCEDURE AND MATERIALS

Use the following procedures and materials to install inclinometer casing. A typical inclinometer casing detail is shown in Figure 207-1. For procedures and materials not specified herein, use the requirements conforming to ASTM D6230.

(a) MATERIAL APPROVAL - Prior to the start of work, submit data sheets for all materials proposed to be used for approval by the PGM. Submit data sheets for inclinometer casing, couplings, telescoping sections/couplings, top and bottom caps, grout valves/adapters and for any other material that is proposed to be used. Do not begin work until approval has been given by the PGM.

(b) BOREHOLE ADVANCEMENT - Drill the inclinometer boring at the location indicated in Attachment I, or as directed by the PGM. Drill as specified in Sections 202, 204, and/or 205 to the depth indicated or as directed by the PGM.

(c) Borehole size – Provide a nominal 4-inch or larger diameter borehole through soil, and nominal 3-inch or larger diameter borehole through rock.

(d) Borehole maintenance - Borehole through soil must be fully supported with augers, steel casing during inclinometer casing installation.

(e) borehole Cleaning - Remove any loose, disturbed material from the borehole before installation of the inclinometer casing. As directed, flush the borehole with clean water until the return water is clear.

(f) Casing INSTALLATION - Orient the casing such that one set of casing grooves is aligned with the expected direction of maximum lateral ground movement. Lower casing into the borehole, adding clean water inside the casing as needed to overcome buoyancy. Do not apply pressure to the top of the casing as this may alter the profile of the casing and cause it to “snake”. Do not twist the inclinometer casing from the top as this can cause the grooves of the inclinometer casing to spiral. Install the inclinometer casing to a minimum of 10 ft. into rock or 20 ft. below the zone of suspected movement, as directed by the PGM.

(g) Casing assembly - Provide ABS plastic inclinometer casing having a 2.75-inch outside diameter, four machined longitudinal grooves equally spaced around the inside circumference. Use self-aligning, flush casing with ABS plastic top and bottom caps. Connect casing sections using either integral/built-in couplings or flush ABS plastic couplings. Connect casing sections and top and bottom caps in accordance with manufacturer’s recommendations.

(h) Telescoping CASING sections - When indicated or directed by the PGM, provide ABS plastic telescoping sections/couplings that are compatible with the inclinometer casing to allow settlement or heave of the inclinometer casing. The number and location of telescoping sections/couplings will be provided by the PGM. Connect telescoping sections/couplings in accordance with manufacturer’s

recommendations. If vertically assembled, install telescoping sections fully extended, and if horizontally assembled, install telescoping sections fully compressed, unless conditions warrant otherwise. To prevent premature compression when using telescoping casing and couplings, do not allow the casing to rest on the bottom of the borehole until backfilling is complete, and grout has set (if applicable). If placing casing in a water-filled hole, it may be necessary to fill the casing with clean water to provide the necessary ballast to lower the casing.

(i) Grout adapter - The use of a fabricated grout valve placed at the bottom of the casing will be allowed. Flushing of the casing may be required if a ball-check type valve is used. When a grout adapter or grout valve is used at the bottom of the casing to grout the borehole, provide an adapter or valve that is compatible with the casing and that is recommended by the manufacturer. Connect adapter/valve in accordance with manufacturer's recommendations.

(j) Casing acceptance - After the inclinometer casing has been installed in the borehole but prior to backfilling, allow the PGM to inspect the inclinometer casing either visually and/or with a dummy probe or other device.

(k) CASING BACKFILL - Once the PGM has accepted the inclinometer casing, tremie grout the annular space between the borehole and inclinometer casing with cement grout. Whenever possible, backfill the installation before or during removal of the casing or hollow stem augers. Use one of the grout mixes as specified in Section 209.02(b). Grout through either the grout valve/adapter connected to a grout tube going down inside the inclinometer casing, or a minimum 1-inch diameter grout pipe placed at the bottom of the boring inserted outside the inclinometer casing. Place grout as specified in Section 209. Where the bottom of the inclinometer casing is more than 5 ft. above the bottom of the boring, backfill the lower portion of the boring by tremie grouting and allowing it to set at least twelve (12) hours, or backfill as approved or directed by the DGE. Use grout mixture as specified in Section 209.02(c). When groundwater measurements are required, use sand backfill (do not use grout backfill).

(l) auger/CASING REMOVAL - The Contractor is responsible to remove augers/casing without raising, twisting, or damaging the inclinometer casing. Do not twist or rotate the augers/casing to remove. Only use the direct-pull method. Backfilling/grouting and casing/auger removal must be conducted in a coordinated manner such that the borehole support is maintained, but backfill does not extend above the bottom of casing/auger (causing the inclinometer casing to be pulled up or twisted during auger/casing extraction). The augers/casing may be removed as grouting progresses, however, the open borehole in soil zones must be supported (i.e., with either augers/casing or grout) at all times during installation and backfilling. Use a weighted tape or other methods during grouting and auger/casing removal to measure inclinometer backfill level and ensure that the borehole is supported. If the Contractor does not complete inclinometer casing installation in a satisfactory manner, and the cause is negligence or incorrect procedure on the part of the Contractor, an additional boring as required to provide the inclinometer casing at the depth and location designated by the Engineer will be furnished at no additional cost to the Department.

(m) PROTECTIVE STEEL CASING - Install protective casing and locking cap as indicated or as directed by the PGM. If indicated or directed, install a steel or cast-iron protective casing over the completed inclinometer casing. Set the bottom of the protective casing at least 2 ft. below the ground surface, and backfill the full depth of the protective casing with grout as specified in Section 209.02. For above-ground installations, Figure 207-3, extend the 4-inch diameter (minimum) protective casing 2 ft. above the surrounding ground surface, and provide a lockable steel lid with lock and key. Installations above the ground surface must have the inclinometer casing extend a minimum of 2 inches above the top of the protective casing unless the protective casing has a minimum diameter of 10 inches. For installations in roadway or shoulder pavements, install a flush steel casing with well-fitting and secure steel lid. Install lid at grade level, and having a minimum diameter of 10 inches, and secured with bolts or equivalent means. Refer to Figure 207-3 for typical installation detail. In all cases, where a minimum 10-inch diameter protective casing is used, the top of the ABS plastic inclinometer casing must be a maximum of 2 inches below the top of the protective steel casing. The protective casing assembly must be able to withstand any external loads and traffic wheel loads without being dislodged or damaged.

207.03 MEASUREMENT AND PAYMENT

(a) Inclinometer casing	Linear foot(feet).
(b) Protective casing, above-ground	Each.
(c) Protective casing, flush	Each.

The payment per linear foot(feet) for inclinometer casing installed and accepted will be considered full payment for all costs associated with installation of inclinometer casing in the borehole, including all required labor, equipment and materials, but excluding the costs associated with boring advancement, protective casing and grouting the boring below the bottom of the inclinometer casing, which will be paid for separately. Inclinometer casing will be measured inside the casing from the top of the casing to the top of the bottom cap.

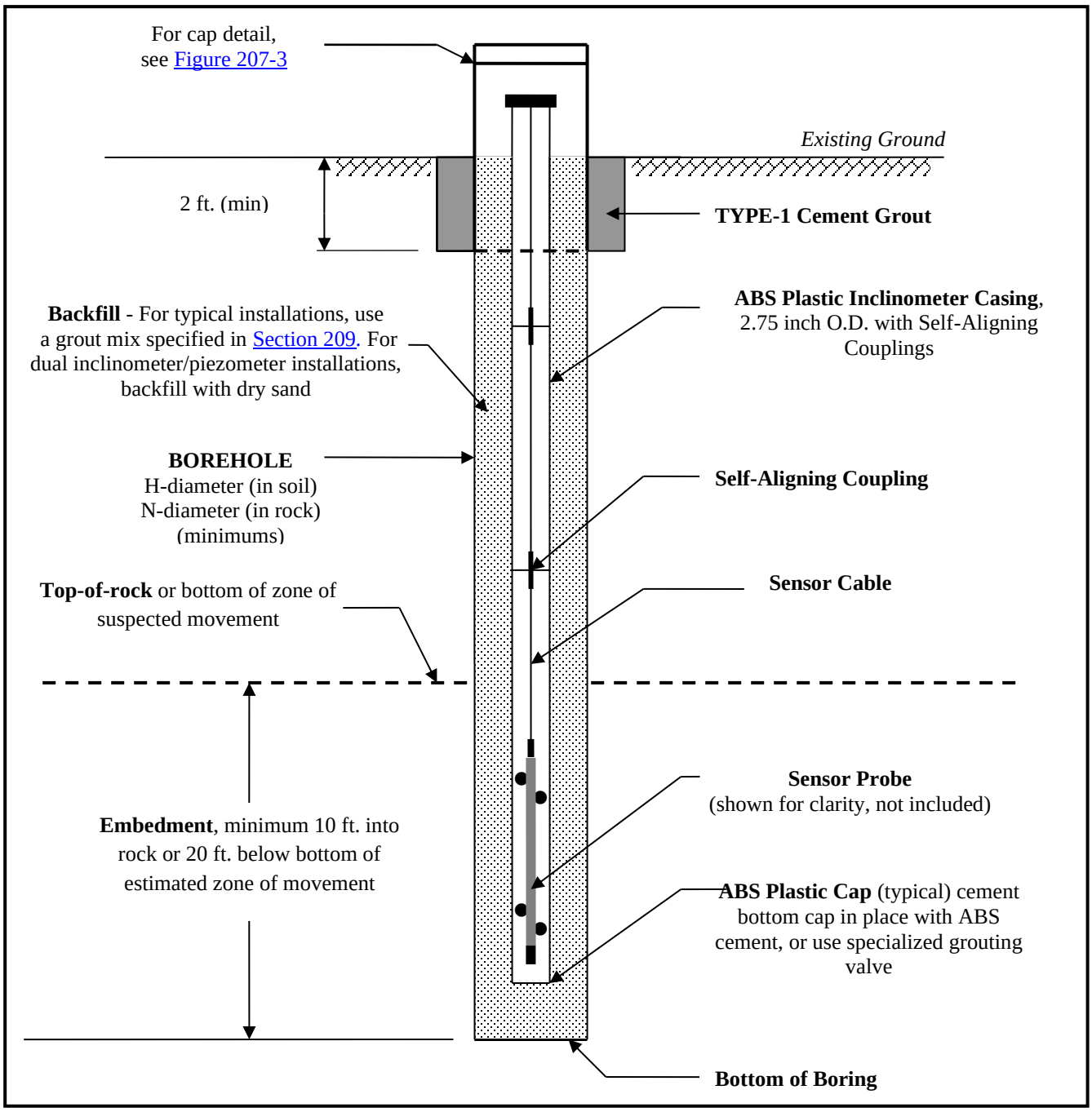


Figure 207-1 – Inclinometer Installation (Typical) N.T.S.

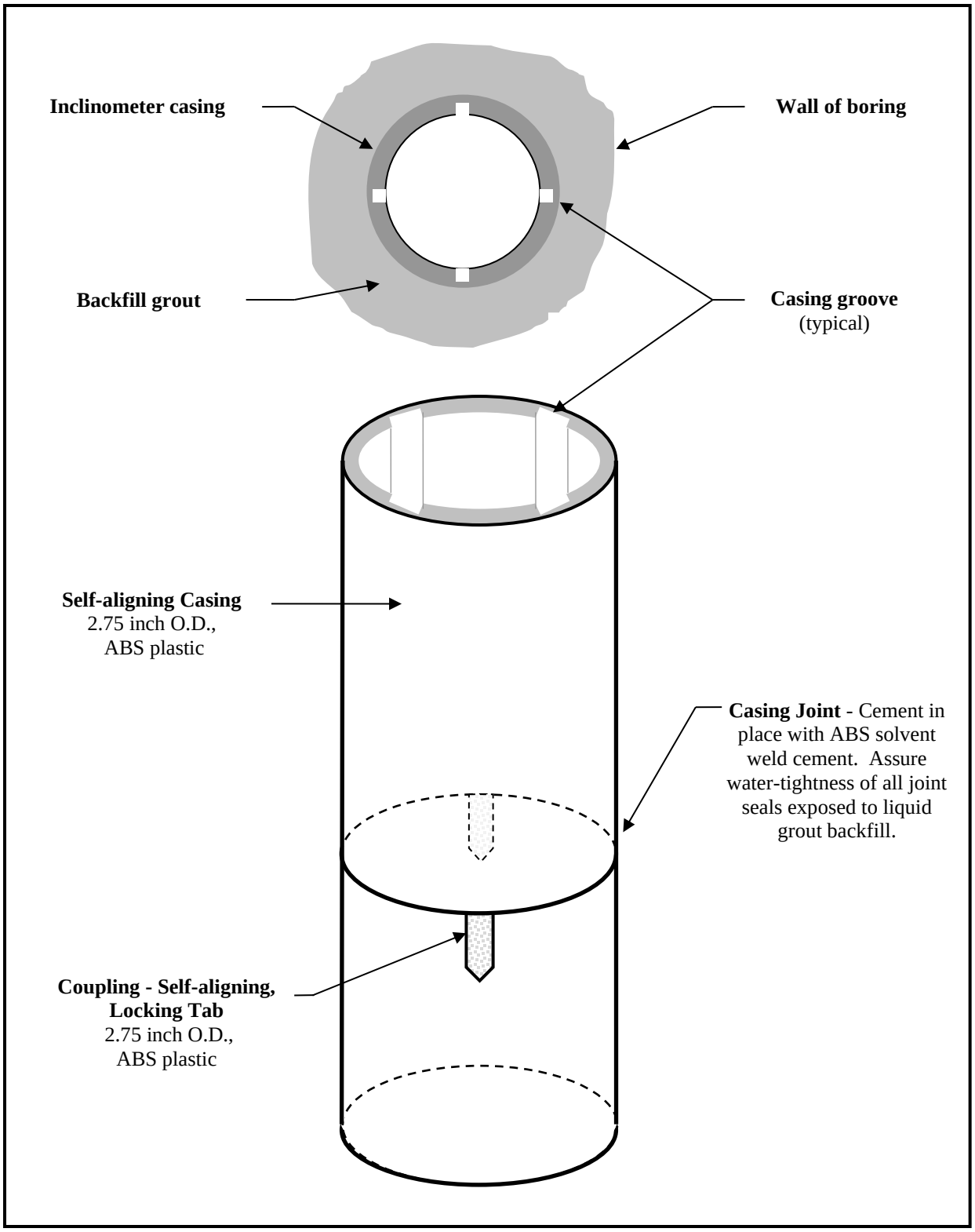


Figure 207-2 – General Inclinometer Coupling Installation N.T.S.

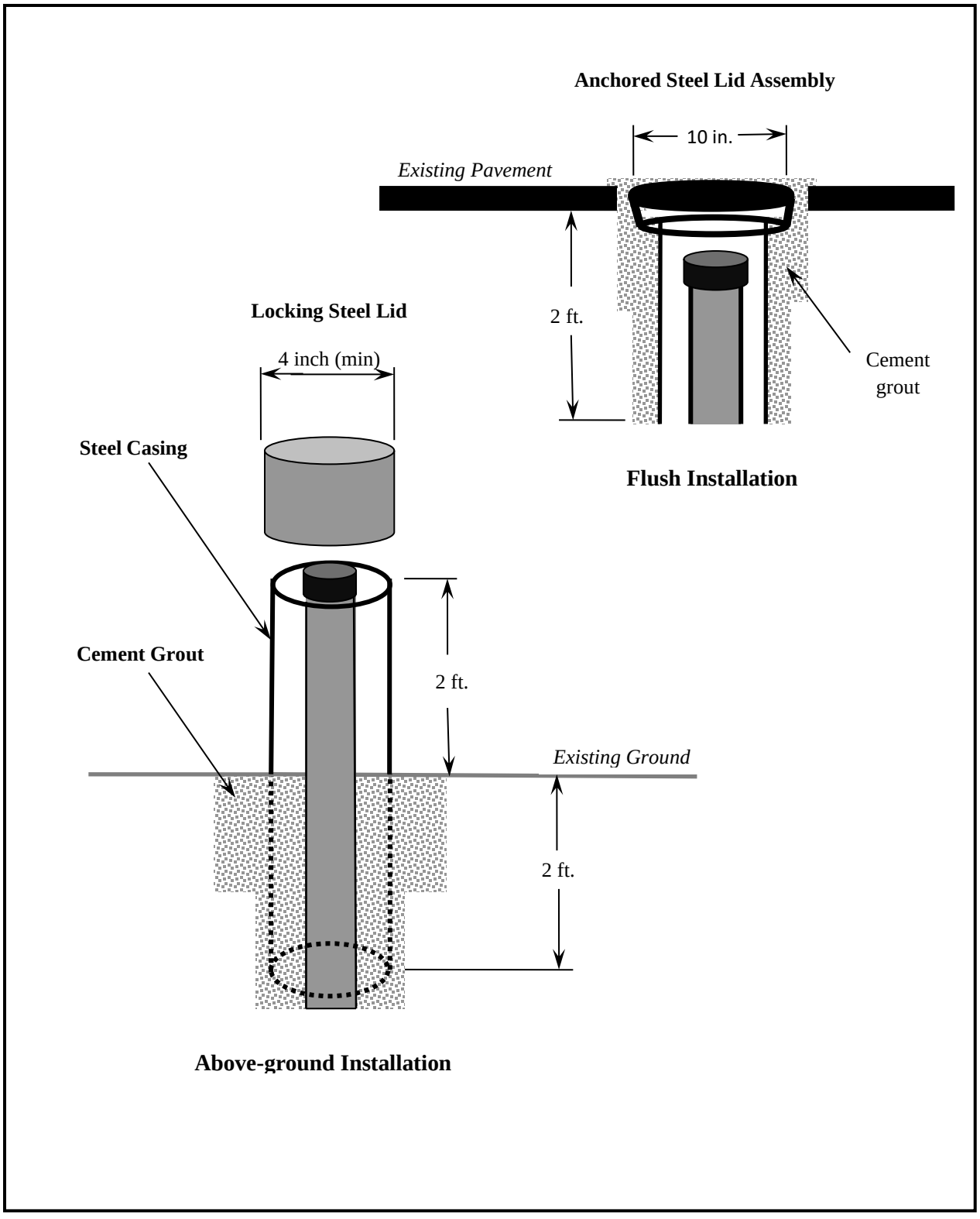


Figure 207-3 - Inclinometer Protective Casing (Typical) N.T.S.

SECTION 208 – GROUNDWATER OBSERVATIONS

208.01 DESCRIPTION

This work consists of observing and measuring groundwater during the subsurface boring, sampling, and testing operations.

208.02 PROCEDURES

Measure groundwater levels and record on the field logs for all completed borings. Measure groundwater levels to the nearest 0.1 ft. using an electronic water level indicator with an audible or visual signal. Record on the boring logs any unusual water conditions and depths at which there is a gain or loss of water, or return of water after a loss during boring operations. Record the depths at which water under excess pressure is observed. When water under excess pressure is observed, stop the drilling operation and extend the casing above the ground surface to contain the flow of water, or temporarily attach a low-pressure gauge at the top of the boring to allow measurement of water pressure. Measure and record the height of water above the ground surface or the water pressure at the top of the boring. Measure and record groundwater levels immediately after pulling casing or removing hollow-stem augers (0-hr reading); and twenty-four hours later (24-hr reading) to verify equilibrium and establish any change in the depth of groundwater.

Before pulling casing or removing hollow stem augers, install temporary 1-inch ID (minimum or larger if required for sampling purposes) PVC pipe to allow the measurement of groundwater levels. Provide a sensing section in the bottom 5 ft. consisting of PVC pipe having staggered 1/8-inch wide slots or 3/8-inch diameter holes that are cut at maximum 6-inch center-to-center spacing. This pipe will also be used to tremie grout the hole when closing the boring as specified in Section 209. Accordingly, do not place a permanent cap or plug on the bottom of the pipe.

If more than one (1) day is required to complete a boring, take groundwater readings at the end of each day's operation and immediately prior to the resuming of drilling operations and record on the drilling log in the remarks section.

If drilling mud was used to advance the boring, install temporary PVC casing at the completion of drilling. After installation of temporary casing, flush the hole with clean water to remove the drilling mud from the boring. Inject water at the bottom of the boring and continuing flushing until only clean water exits at the top of the boring to ensure all drilling mud is displaced. After flushing, record 0-hour and 24-hour groundwater levels. Note that drilling mud is not allowed to be used if any water sampling for testing, including electrochemical or environmental, is to be performed in the boring.

208.03 MEASUREMENT AND PAYMENT

No separate measurement or payment for this work.

SECTION 209 – BACKFILLING AND PLUGGING BORINGS

209.01 DESCRIPTION

This work consists of backfilling all completed borings that do not contain instruments (such as piezometers or inclinometer casing) and backfilling below the bottom of instruments.

209.02 PROCEDURES AND MATERIALS

(a) General. Temporarily cover or cap each boring that does not contain an instrument immediately upon completion of the boring. Permanently backfill with grout and plug each boring flush with the ground surface immediately after the final groundwater level has been obtained, or as directed by the Representative. Grout as specified in the appropriate procedure specified under Section 209.02(b)(c)(d), or (e).

(b) Use an appropriate Portland cement-based grout mix as indicated in Table 209-1 for backfilling, as agreed to by the Representative. When mixing grout, thoroughly mix the water and cement first, followed by any required bentonite. The liquid grout consistency should be as thick as possible, yet liquid enough to be pumpable. The ratios in the table below can be adjusted, if necessary, to allow pumping. The consistency of the grout should resemble thick cream or pancake batter. Place grout by pumping through a tremie grout pipe that extends to the bottom of the boring. Raise the grout pipe periodically during grouting, but maintain the tip of the pipe at a minimum depth of 5 ft. below the top of grout in the boring or at the bottom of the boring or casing, whichever is shallower, until grouting is complete.

Table 209-1 – Grout Mix Ratios

GROUT MIX	Typical Backfill Condition	Approx. Compressive Strength (PSI)	Approx. Grout Unit Weight (PCF)	Component	Amount
TYPE-1 Neat Cement	competent rock backfill, cap grout, casing annulus	200	115	Water Cement	6 gal 94 lbs
TYPE-2 Low Bentonite	Inclinometer backfill, soil or porous rock	150	105	Water Cement Bentonite	10 gal 94 lbs 5 lbs
TYPE-3 High Bentonite	soft soil or very porous rock	50	90	Water Cement Bentonite	30 gal 94 lbs 25 lbs

(c) Boring Through Soil and Rock. Backfill the boring to the ground surface using one of the grout mixes from Table 209-1. If an alternate grout mix is proposed to

be used, the mix design must be submitted in writing and approved by the DGE prior to use. Use TYPE-3 grout only with the approval of the DGE in instances of excessive grout loss. Grout loss is considered "excessive" when the volume of grout loss using non-bentonite grout exceeds 60% of the borehole volume (i.e., consider using TYPE-3 grout when a volume of grout equal to 160% of the nominal borehole volume does not successfully backfill the borehole). Once the grout backfill has been placed to the top of the borehole, monitor the level of grout in the borehole. If any grout settlement occurs within 24 hours, top-off with additional grout.

(d) Grouting of Protective Casing. Backfill around the outside of the protective casing with a TYPE-1 grout mix as shown in Table 209-1, or an alternative grout mix approved by the DGE.

(e) Boring Through Mine Voids(s) or Limestone Cavern(s). Install a grouting basket or plug in the boring immediately above the top of the mine or cavern and place a 5-foot plug of Type-A fine aggregate as specified in Publication 408, Section 703.1 on top of the basket or plug. Backfill the boring as specified in Section 209 (a) and (b).

(f) In the event multiple voids (mines or caverns) are penetrated by a boring, backfill the boring with grout in stages. In the first stage, backfill from the bottom of the boring to the bottom of the lowest void as described above. In the second stage, backfill the rock strata between the lowest void and the void above it by supporting a grout basket on a 1-1/4-inch (minimum) diameter pipe with the bottom of the pipe on the bottom of the lowest void and the grout basket located in the rock strata above the lowest void. With the grout basket in place, grout the portion of the boring between the two lowest voids as described above. If NX standard wire line equipment is used to core the rock, extract the NX casing to the top of the zone being backfilled in the second stage and maintain in place until the second stage of grouting is completed.

Allow each stage of grouting to set a minimum of twelve (12) hours before proceeding with the next stage. Perform the third and subsequent stages of grouting as specified for the second stage. Perform the final stage of grouting to the ground surface as specified above for a boring penetrating one mine or cavern.

(g) Boring Through Pavement, Sidewalk, Bridge Deck, Floor Slab or Wall. Backfill the boring with grout as specified in Section 209 (a) and (b) to the bottom or back of the pavement, sidewalk, floor slab or wall.

In concrete or asphalt pavements or slabs, plug the boring at the top with a non-ferrous, non-shrink, fast-setting cement-based grout of a strength and thickness equal to the original structure, pavement, or slab. Use grout that exhibits no shrinkage when tested conforming to ASTM C827/C 827M.

In plugging borings through bridge decks, provide temporary support or forming for the plug, acceptable to the DGE.

In concrete structures, grout the boring for the full depth of the boring with a non-ferrous, non-shrink, fast setting cement-based grout of a strength equal to the original structure, but not less than 3,000 pounds per square inch.

(h) Boring with Artesian Condition. Maintain drill tooling above ground surface to eliminate flow of water as specified in Section 202.02(c). Backfill as specified in Section 209 (a) and (b). Use Type-1 Grout Mix and add 4 pounds of bentonite per

94 pounds of cement. A mix with a low water to cement ratio, by weight, is needed to resist artesian pressures.

209.03 MEASUREMENT AND PAYMENT

(a) Grout Backfill in Soil or Rock.	Linear Foot
(b) Grouting Basket or Plug in Soil or Rock.	Each
(c) Non-Shrink Cement Grout in Concrete Structure.	Linear Foot
(d) Non-Shrink Cement Grout Plug in Concrete or Asphalt.	Each

Payment made for each listed item, completed and accepted, will be considered full payment for all costs associated with installing the indicated item, including all required labor, equipment, and material. Measurement will be made of the actual units installed and accepted. Measurement of sand-cement grout backfill will be from the top of the grout to the bottom of grout, from the top of the grout to the top of the grout basket, or plug in a boring penetrating a mine void or limestone cavern.

SECTION 210 – TEST PITS

210.01 DESCRIPTION

This work consists of providing and operating equipment suitable for excavating and backfilling test pits for subsurface exploration, sampling, and testing.

210.02 EQUIPMENT AND PROCEDURES

Provide excavation equipment, such as a backhoe or tracked excavator, capable of excavating to a depth of at least 10 ft. or as specified in the Instructions to Bidders and Form TR-444, Form of Proposal. Excavate the test pit consistent with the applicable OSHA requirements for safe, open excavations. Backfill the test pit in maximum 1-ft. lifts, compacting the fill material with the excavator bucket, or as required by contract special provision. The Contractor must not mobilize the excavation equipment unless directed by the PGM. Provide one qualified and experienced operator for each piece of excavation equipment. Provide equipment with sufficient capacity and power to perform the required work.

210.03 MEASUREMENT AND PAYMENT

(a) Test Pit, Mobilization.	Each.
(b) Test Pit, Excavation.	Hours.
(c) Test Pit, Standby.	Hours.

The Test Pit, Mobilization pay item will be considered full payment for all costs associated with the scheduling, delivery, and removal of the test pit excavation equipment from the site.

Payment per-hour for Test Pit, Excavation will be considered full payment for all costs associated with operating the excavator on-site, including the operator and all other required labor, equipment, and supplies. Measurement will be made of actual hours on site as required perform the work. No payment will be made for time lost due to equipment failure, or time work is performed that is unauthorized, unacceptable, or unnecessary to meet the required standard to excavate and backfill.

Payment for Test Pit, Standby will be made only when the PGM or representative determines/authorizes the use of Standby time is appropriate. Payment made for hours of Standby will be considered full payment for all costs associated with maintaining the indicated equipment and personnel on site and ready to commence or resume work. Measurement will be made of actual hours on site of each excavator with operator in an ordered or approved state of Standby to the nearest one-half hour. In no case will the Standby time plus work time per day exceed one normal 8-hour work shift unless designated in the Instructions to Bidders and Form TR-444, Form of Proposal.

SECTION 211 – STANDBY FOR BORINGS

211.01 DESCRIPTION

This work consists of maintaining test boring equipment and work forces on site in a state of readiness to commence or resume subsurface exploration, sampling and testing operations during a time period for which temporary suspension or interruption of such work (not including weather related events) has been ordered or approved.

211.02 PROCEDURE

Maintain equipment and work forces as directed on site in a state that will allow immediate commencement or resumption of exploration, sampling, and testing operations.

211.03 MEASUREMENT AND PAYMENT

(a) Standby, Borings on Land, Equipment and Work Crew. Hours
(b) Standby, Borings on Water, Equipment and Work Crew. Hours

Payment for Standby will only be made when the Project Geotechnical Manager (PGM) or representative determines/authorizes the use of Standby time is appropriate. Payment made for hours of Standby will be considered full payment for all costs associated with maintaining the indicated equipment and personnel on site and ready to commence or resume work. For borings on land and borings on water, equipment will include all materials and supplies necessary to make borings, obtain samples and perform testing specified.

Measurement will be made of actual hours on site of each drill rig with crew in an ordered or approved state of standby to the nearest one-half hour. In no case will the standby time plus work time per day exceed one normal 8-hour work shift unless designated in the Instructions to Bidders and Form TR-444, Form of Proposal. Standby time will not be allowed when the Contractor is performing specialized testing such as Vane Shear, Pressuremeter, Cone Penetrometer, Dilatometer, etc. When the PGM or representative performs testing that requires Contractor delay (such as a Borehole camera survey) Standby will be paid accordingly.

SECTION 212 – STORAGE AND PROTECTION OF CORE BOXES

212.01 DESCRIPTION

This work is the installation of durable coverings for core boxes to protect from the weather.

212.02 MATERIAL

(a) Provide tarpaulin (tarp) of the following specifications:

- Dimension = 10 foot by 10 foot, minimum
- Thickness = 11 mil, minimum
- Mass Density of fibers = 1000 denier, minimum
- Nylon reinforcing mesh-count = 14 by 14, minimum
- Edge grommet spacing = 24 inches, maximum
- UV protective coated silver lined polyethylene
- Silver lamination must be at least on one side of tarp
- Reinforced corners

(b) Provide polypropylene rope, 3/16-inch diameter, minimum.

212.03 PROCEDURE

Once core boxes are delivered to the storage site indicated in the contract, stack boxes on pallets in layers of alternating directional pattern. Stack boxes four wide and eight high on each pallet. Unless otherwise directed, limit stacking of pallets to a maximum of two high.

Cover stacks with tarp to protect the top and all four sides. Secure the tarp with minimum 3/16-inch diameter polypropylene rope, laced through the grommets, and fastened tightly.

Label the contents of the pallet(s) on the top and all four sides of the tarp. Print directly on the tarp with a permanent, waterproof, black marker. Print legibly and provide at a minimum the project SR and Section, boring numbers, and box numbers as indicated below:

SR _____ , Section _____.

Boring No. _____ Boxes _____ through _____.

Boring No. _____ Boxes _____ through _____.

Boring No. _____ Boxes _____ through _____.

212.04 MEASUREMENT AND PAYMENT

(a) Tarp. Each

All quantities of rope needed to secure the tarps is considered incidental to the tarp item.

SECTION 213 – RECORDS AND REPORTS

213.01 DESCRIPTION

This work consists of maintaining and confirming detailed records of the subsurface boring, sampling, and testing operations.

213.02 SYSTEM FOR DESCRIBING SOIL AND ROCK

(a) Soil Description. Describe the following characteristics of each soil stratum encountered:

- Texture – For coarse-grained soil, describe the primary or predominant texture of a as either a gravel size or a sand. For fine-grained soil, describe the primary or predominant texture as either silt or clay. Describe supplementary textures using the adjectives (e.g., gravelly, sandy, silty, clayey). Use all that apply, with the most prominent first and the least prominent last.
- Color - Describe the basic color of each soil, such as yellow, brown, tan, red, gray, or black and modify, if necessary, by adjectives such as light, dark, mottled, banded, or mixed.
- Moisture - Describe the amount of moisture present in each soil sample in terms of wet, moist, damp, or dry.

(b) Rock Description. Describe the following characteristics of each rock stratum encountered.

- Type - Identify the basic rock type encountered such as limestone, dolomite, calcite, shale, sandstone, siltstone, claystone, coal, conglomerate, chert, marble, slate, phyllite, quartzite, quartz schist, gneiss, diabase, and granite.
- Color - Describe the basic color of each rock type, such as brown, red, tan, gray, pink or black, and modify, if necessary, by adjectives such as light, dark, banded, or mixed
- Unusual Conditions or Difficulties – Note any additional information (such as changes in the color of drill return water, tool drops, drilling advancement rate, obstructions, caving, boulder, etc.).

213.03 BORING LOGS

Keep a continuous and current field record of the operation of each boring. Use Form TR-442, Driller's Boring Log, or an equivalent form approved by the PGM. Make the boring log available to the PGM at all times for review. Upon the completion of each boring, submit the original driller's log to the PGM. As a minimum, record the following information on each boring log:

(a) General Information:

1. The project identification, including route, section, and county.
2. The test boring identification number.
3. The date on which the boring was begun and the date on which the boring was completed.
4. The name of the Prequalified Geotechnical Drilling Contractor, driller, and helper.
5. The name of the PGM's field representative (Certified Drilling Inspector).
6. The elevation of the top of the test boring (if available).
7. The location of the test boring relative to project reference line (e.g., segment, offset and offset from centerline) or other suitable reference points.
8. The type of drill rig used.
9. The drilling method used to advance the boring in soil.
10. The inside and outside diameter and depth of any casing used.
11. The type and weight of hammer and free fall used to advance the split-barrel sampler, the number of rope turns on the cathead (1-3/4 or 2-1/4), and the diameter of the sampler. Note whether the hammer is automatic (high efficiency) or manual (standard, low efficiency).
12. Hammer Efficiency Rating (ER), if known.
13. The length of the split-barrel sampler.
14. The drilling method used to advance the boring in rock.
15. The type and size of core barrel used and bit designation.

(b) Specific Boring, Sampling and Testing Information:

1. The depth, type, number, and recovery of each soil sample. Number soil samples sequentially with an “S-” prefix.
2. The blows per 6 inches or less to advance the split-barrel sampler.
3. The length of core run and length of recovered core for each run of rock core. Number rock core runs sequentially with an “R-” prefix.
4. A description of each soil and rock stratum encountered, the depth to the top and bottom of each stratum, and discontinuities in each stratum.
5. Depth to groundwater level, elapsed time after completion of drilling and date on which observation was made.
6. Depths at which undisturbed samples are taken.
7. Difficulties in drilling (obstructions, caving, boulders, rising of sand into bottom of boring, etc.) including the basis for any loss of soil sample or rock core.
8. Depth of loss and/or return of circulating water and increase in usage of drilling water.
9. Any additional information (such as changes in the color of drill return water, tool drops, drilling advancement rate, etc.) that may be of assistance in defining or provide reasoning to the presence of strata changes, boulders, voids, fissures, or other subsurface conditions.

213.04 DAILY DRILLING QUANTITY SUMMARIES

The Contractor will maintain and update daily a record for each drill rig of the work completed including footage of drilling in soil and rock. The record will document the quantity of each pay item listed in Form TR-444, Form of Proposal, completed during the day and will be summarized weekly. The record will also indicate, for each day, the driller's name, the helper's name, and the hours worked. The Driller and Drilling Inspector must review and sign the record daily to indicate agreement with the quantities listed as complete and note any disagreement with the listed quantities. Provide data to the Drilling Inspector/PGM as needed to facilitate accurate documentation of the work on the record. One copy of the record will be made available to the Drilling Inspector/PGM at the end of each workday.

213.05 MEASUREMENT AND PAYMENT

No separate measurement or payment for this work.

SECTION 214 – PACKAGING, PROTECTING, AND SHIPPING OF SAMPLES

214.01 DESCRIPTION

This work consists of packaging, protecting, and shipping soil and rock samples in a manner that will facilitate sample identification and minimize the potential for sample disturbance or damage. This work also includes how to retrieve samples and core boxes upon notification of disposition.

214.02 PACKAGING OF SAMPLES

(a) Samples Core Boxes. Provide new or refurbished wooden core boxes as shown in Figure 214-1 for packaging, shipping, and storing of split-barrel soil samples and rock core samples. Boxes must be stenciled in black paint according to Figure 3.8-1. Construct the core boxes and partitions to restrain the sample jars and rock cores against shifting during transport. Assist, as necessary, to properly place core samples in the core boxes. Refurbished wooden core boxes must be sanded to remove any previous information, must not be painted, be in good condition, and are to be clean.
Unless the PGM or DGE directs otherwise, when two borings have minor amounts of recovered sample (e.g., very shallow borings, low recovery borings, etc.) it is permissible to place samples from both borings in a single core box.

(b) Sample Jars. Provide new glass sample jars approximately 5 inches high and approximately 2 inches inside diameter at the mouth, and with an inside diameter of not more than ¼-inch larger than that at the mouth. Provide the jars with a metal screw cap containing a rubber or waxed paper gasket. Provide self-adhesive, printed labels placed on the side of each jar to record the required information as shown in Figure 3.8-2.

214.03 PROTECTION AND SHIPMENT OF SAMPLES

(a) Split-Barrel Soil and Rock Core Samples. Provide suitable dry storage for all samples until completion of all required subsurface exploration sampling and testing contract work items. At the completion of work, carefully ship all samples to the location indicated in the Instructions to Bidders, or as directed by the PGM. No payment will be made for boring and sampling operations associated with samples that are damaged or missing because of Contractor negligence. When shipping, adhere to Section 212.03 regarding stacking of the boxes.

(b) Undisturbed Soil Samples. Unless specified otherwise by contract or directed by the PGM or DGE, undisturbed samples must be packaged and transported according to "Group D" sample procedures conforming to ASTM D4220. These procedures include protecting the undisturbed soil samples from vibration, impact, bumping, dropping, rolling, etc. by proper packaging and cushioning. Samples are to be handled, stored, and shipped in the same orientation in which they were taken. Protect samples from freezing or excessive heat. Metal or plastic tube caps must be provided and used to seal the sample tubes. Provide wood, metal, or other suitable type of shipping container that adequately cushions and insulates the undisturbed samples. Deliver or ship the undisturbed samples in a timely manner to the location indicated in the Instructions to Bidders, or as

directed by the PGM. For all modes of transporting samples, the loading, transport, and unloading of sample containers will be monitored by the Drilling Inspector or other qualified person such as the PGM, geologist, or soils technician. No payment will be made for boring and sampling operations associated with samples that are damaged or missing because of Contractor negligence.

214.04 DISCARDING OF SAMPLES

If notified by the DGE of available boxes, respond with one of the following,

(a) Coordinate within 30 days to pick up previously used wooden core boxes containing soil and rock samples. The specified core boxes can only be obtained by the drilling contractor listed on the core box lid.
(b) Relinquish your right to obtain and reuse the core boxes in writing. The core boxes will be offered to all Drilling Contractors on a first response basis of an email solicitation.

Core boxes are not to be emptied at any District facility, and at no additional cost to the Department. Failure to respond to the DGE's notice requesting core box pick up, or failure to pick up assigned core boxes within a 30 day timeframe, will result in the core boxes and contents being discarded, or offered up to the next drilling contractor responding to an email solicitation.

214.05 MEASUREMENT AND PAYMENT

No separate measurement or payment for this work.

BILL OF MATERIALS

MEMBER	QTY	DIMENSIONS	TYPICAL LUMBER
Lid	1	¾" x 11-½" x 48"	Lumber No. 2 Pine, Exterior Plywood
Bottom	1	¾" x 11-½" x 48"	Lumber No. 2 Pine, Exterior Plywood
Sides	2	¾" x 2-½" x 48"	Lumber No. 2 Pine, Exterior Plywood
Ends	2	¾" x 2-¼" x 10"	Lumber No. 2 Pine, Exterior Plywood
Partitions	3	¼" x 2" x 46-¾"	Lumber, Spruce or Hardboard

Note: All dimensions above are neat measure.
Pine Block Spacers (5-¾" x 2-3/16") are to be included with each box.

HARDWARE	QTY
2" Hook and Eyelet	1
Eyelet	1
½" x 2" Metal Hinge	2
Screw-type Nails	(As needed)
Hinge Screws	(As needed)

Specifications:
All lumber is to be No. 2 Pine or approved equal (except partitions).
End pieces and bottom are to be slotted to allow recessing of ends and bottoms of partitions.
Slots are to be of sufficient dimensions to provide rigidity to partitions and easy removal.
All lumber members are to be firmly secured by appropriately sized screw-type nails.
Metal hinges are to be recessed sufficiently to ensure closure of the lid and secured by appropriately sized wood screws.
Box dimensions must be sufficient to accommodate sample jars.

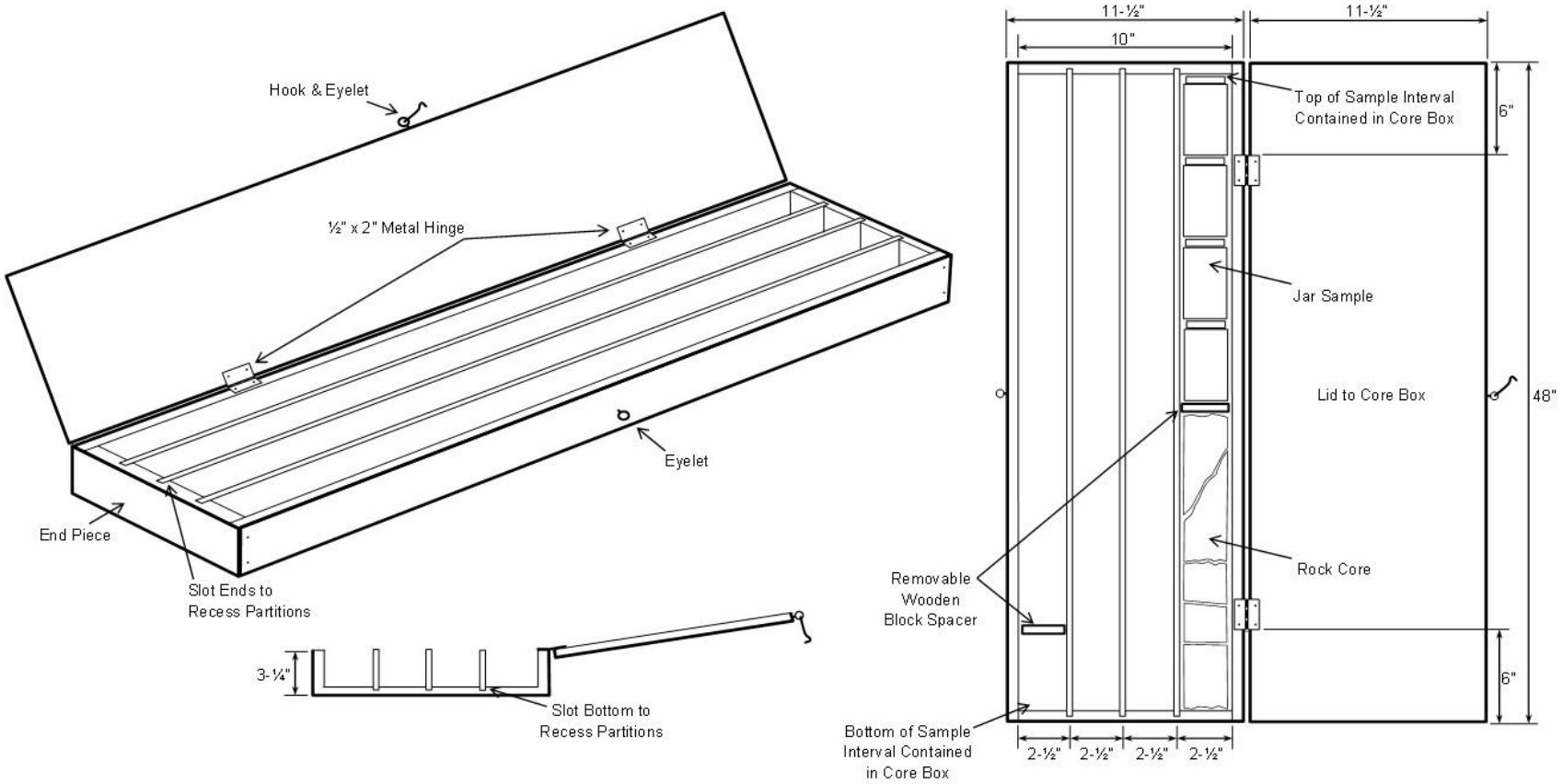


Figure 214-1 - NX Core Box Construction

SECTION 215 – MAINTENANCE AND PROTECTION OF TRAFFIC

215.01 DESCRIPTION

This work consists of maintaining and protecting traffic in and adjacent to the area where subsurface exploration, sampling, and testing operations are being performed.

215.02 MATERIAL

Furnish material and traffic control devices necessary for the maintenance and protection of traffic, and conforming to the Traffic Control Plan, the National Manual on Uniform Traffic Control Devices (MUTCD), Title 67 Pa. Code, Chapter 212, and Publication 213.

215.03 PROCEDURES

Comply with the requirements of Section 103.13 and 67 Pa. Code, Chapter 212.

Install and maintain the traffic control devices as required or directed. Schedule operations to allow movement of traffic with minimum interference. If traffic interruptions become too frequent, cease operations in the area concerned, as directed. Take satisfactory remedial action to correct the situation before continuing operations.

Provide personnel, equipment, and material as specified in Publication 408, Title 67 Pa. Code, Chapter 212, Publication 13(DM-2), Chapter 9, and Publication 213 to control traffic through work zones and to provide safety for the work force. Submit traffic control plan for approval.

215.04 MEASUREMENT AND PAYMENT

(a) Maintenance and Protection of Traffic. Lump Sum.

This item will be measured and paid for at the lump sum bid price upon completion of the project.

SECTION 216 – AUGER BORING FOR BULK SOIL SAMPLES

216.01 DESCRIPTION

This work consists of obtaining bulk soil samples for laboratory testing, using auger tools to advance the boring and obtain the required sample.

216.02 PROCEDURES FOR ADVANCING AUGER BORINGS

(a) General. Perform auger boring and sampling conforming to ASTM D1452, except where modified by this specification.

(b) Equipment. Use solid flight helical augers having a diameter from 6 inches to 16 inches, or other equipment as approved by the PGM.

(c) Procedure. Advance the augers to the top of the sampling depth specified by the PGM. Remove the augers and clean the flights as necessary to ensure a subsequent representative sample. Return the augers to the previous depth, advance the augers to the bottom of the sample depth indicated, remove the augers, and take the soil sample directly from the auger flights. Samples should consist of a minimum 50 pounds of soil and are to be placed in a plastic lined canvas sample bag. If required, continue the procedure to obtain additional samples from depths indicated or specified by the PGM.

Mark the sample bag with the S.R. number, Section number, Boring number, Station and Offset, and the exact depths at which the sample was obtained. Use a permanent marker when identifying the information on the sample bag. In addition, place a representative sample in a jar of the type as specified in Section 214.02(b) and store the jars in a sample box described in Figure 214-1.

Use of casing will be required if the boring collapses upon removal of the augers, below the groundwater elevation, or where specified by the PGM. The inside diameter of the casing must be larger than the diameter of the augers used. Advance the casing to the depth indicated, clean the casing using the auger (or other approved method), and reinsert the auger to take the sample as specified in the previous paragraph.

216.03 MEASUREMENT AND PAYMENT

(a) Auger Boring. Linear Foot

Linear feet payment includes all labor and materials involved with bagged bulk samples.

SECTION 217 – CONTRACTOR RECALL

217.01 DESCRIPTION

The Contractor may be subject to a recall in order to complete additional test borings or test pits after the original Contract work is completed, approved, and the Contractor has demobilized. The possible recall will be within six (6) months of demobilization. The Contractor will have three (3) weeks to mobilize once notified by the PGM.

217.02 PROCEDURE

It will be the responsibility of the Contractor to renew the Insurance certificate and verify that all utilities remain clear. The Contract Bond (Form TR-445B, PennDOT Contract Bond, or Form TR-446B, Consultant Contract Bond) and Additional Bond for Labor and Materials (Form TR-445C, PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Additional Bond for Labor and Materials) will be held by the PGM for the duration of the recall. All unit prices must remain in effect for the duration of the recall; however, the contractor recall item includes mobilization.

217.03 MEASUREMENT AND PAYMENT

(a) Recall, per Drill Rig. Lump Sum.

MPT for contractor recall will be prorated based upon the percent of total footage that required MPT in the original contract, so long as the level of MPT required during the contractor recall is consistent or similar to the requirements of MPT in the original contract boring. If MPT requirements are significantly more costly for recall borings, then MPT cost will have to be negotiated. No additional payment for mobilization will be made for contractor recall.

For Contractor recall requiring an additional Test Pit(s), the unit prices for Test Pit Mobilization, Item 210.03(a), and Test Pit Excavation, Item 210.03(b), will be applicable for payment for test pit work.

SECTION 218 – TEMPORARY POTABLE WATER SUPPLY

218.01 DESCRIPTION

Provide temporary potable water service to any impacted property owner when directed by the DGE or their Representative.

218.02 MATERIALS

Provide all necessary equipment such as supply truck, storage tank, piping, parts, connections, and valves to connect to the property owner's water supply system. Provide storage tank of sufficient volume. Protect storage tank from freezing and pressurize if necessary.

218.03 PROCEDURE

The PGM will immediately notify the Contractor of any property owner having a water supply potentially impacted by drilling. Within 8 hours of direction from the PGM, provide a sufficient quantity of potable bottled water to the affected property owner. Provide sufficient quantities of bottled water for each permanent resident in the impacted dwelling, sufficient defined as one gallon per day of drinking water for each individual and five gallons per day for cooking and personal hygiene per each impacted dwelling. Within 36 hours of direction from the PGM, install a functioning temporary water service and supply at least 100 gallons of water per day per resident affected. Maintain continuous operation of the temporary water system until directed by the PGM that adverse effects are abated or within the limits defined in the contract, whichever is sooner. Notify the PGM and the impacted property owner prior to connection and disconnection of the temporary water service. It is the responsibility of the Contractor to provide suitable/reliable temporary potable water service (i.e. supply) that replaces the impacted property owner's water supply well due to negative impacts from drilling operations.

218.04 MEASUREMENT AND PAYMENT

(a) Hookup and Disconnect of Temporary Potable Water Supply. Lump Sum

The lump sum payment includes all bottled water supplied, and the hookup and disconnect of the temporary supply.

(b) Temporary Potable Water Supply. Week

A unit payment will be made for each week (consecutive 7 days), and any remaining portion thereof, that the temporary pressurized water supply is connected and functioning. Payment includes all quantities of pressurized water supplied.

SECTION 219 – LOCATING UNDERGROUND UTILITIES

219.01 DESCRIPTION

This work consists of conducting a visual site assessment at prospective drilling sites to identify any location(s) and/or indicator(s) of privately owned utilities unidentified by the PA One-Call System.

219.02 MATERIALS

Provide all necessary equipment including, but not limited to, ground penetrating radar (GPR) and/or similar tools to best determine the location of privately owned utilities in a non-destructive manner.

219.03 PROCEDURE

Upon identifying the boring locations at the drilling site, conduct an initial visual site inspection to identify any location(s) and/or indicator(s) of privately owned underground utilities. Indicators that subsurface utilities may be present include, but are not limited to, fiber optic markers, junction boxes, manholes, mast arms, strain poles, light poles, invisible fences, septic systems, sprinkler systems, drainage pipes, gas or water lines, and/or other appurtenances. Direct coordination with the public or private landowner(s)/entity will be required to identify the limits of the underground utility in question. Contact the applicable Regional Traffic Management Center (RTMC) Manager to confirm whether or not fiber optic lines are present as part of the Intelligent Transportation System (ITS) initiative. Identify any areas where non-destructive/electronic location methods may be required to locate private underground utilities.

After the initial site inspection and coordination with the landowner(s)/entities/RTMC, contact and discuss any findings with the PGM. If areas where non-destructive/electronic location methods were identified, GPR, or another non-destructive method, may be allowed with the approval of the PGM. If necessary, the PGM may consider adequately offsetting the boring location(s) where a potential conflict exists with underground utilities.

If sign or roadway lighting systems are indicated through on-site and plan inspections, contract with a licensed electrical contractor qualified to provide cable location services. After contracting to have the cables located, the contractor will call the Electrical Maintenance Field Office to arrange for access to the power supply cabinet controlling the system. Permission would then be granted and documented. It is the responsibility of the contractor to properly reconnect and restore the system to its normal operating mode by verifying with the manager at the Electrical Field Office.

Vegetation clearing/removal is incidental to this work.

The Contractor is responsible for implementing the appropriate MPT as specified in Section 215.

In the event of a utility strike, reference Section 103.10(a).

219.04 MEASUREMENT AND PAYMENT

(a) Locating Underground Utilities. Hour

Locating crew and all associated equipment paid per hour.

SUBCHAPTER 5F – CONTRACT BONDS

Reserved for PennDOT or Consultant Contract Bonds

As necessary, use Form TR-445B, PennDOT Subsurface Boring, Sampling, and Testing Contract, for a PennDOT Contract Bond, or Form TR-446B, Consultant Subsurface Boring, Sampling, and Testing Contract, for a Consultant Contract Bond

SUBCHAPTER 5G – ADDITIONAL BOND FOR LABOR AND MATERIALS

Reserved for PennDOT or Consultant Additional Bond for Labor and Materials

As necessary, use Form TR-445C, PennDOT Subsurface Boring, Sampling, and Testing Contract, for PennDOT Additional Bond for Labor and Materials, or Form TR-446C, Consultant Subsurface Boring, Sampling, and Testing Contract, for Consultant Additional Bond for Labor and Materials

SUBCHAPTER 5H – CONTRACT APPENDICES

Contract appendices are developed on a project-specific basis and typically include necessary supplemental and supportive information such as:

- Project Location Map
- Boring Location Plan
- Proposed Detour Routes
- Required Maintenance and Protection of Traffic Figures

APPENDIX A – LIST OF ACRONYMS

AASHTO American Association of State Highway and Transportation Officials
ABS Acrylonitrile Butadiene Styrene
AMRL AASHTO Materials Reference Laboratory.
ANSI American National Standards Institute
APA Administrative Procedures Act
ARD Air-Rotary Drilling
ASTM American Society for Testing and Materials
BGT Borehole Geophysical Testing
BL Base Line
BST Boring, Sampling and Testing
CBR California Bearing Ratio
CD Consolidated Drained
CFR Code of Federal Regulations
CF Cubic Feet
CGE Chief Geotechnical Engineer
CGI Combustible Gas Indicator
CL Center Line
CPT Cone Penetration Testing
CU Consolidated Undrained
DCNR Department of Conservation and Natural Resources
DGCE/A District Grade Crossing Engineer/Administrator
DGE District Geotechnical Engineer
DLE District Liaison Engineer
DMT Dilatometer Testing
DPM District Project Manager
DPE District Project Engineer
DSP Designated Special Provisions
ECMS Engineering and Construction Management System
FHWA Federal Highway Administration
FID Flame Ionization Detector
ER Efficiency Rating
FTP File Transfer Protocol
gINT Geotechnical Integrator
GMW Groundwater Monitoring Well
HASP Health and Safety Plan
HVE Hydro-Vacuum Extraction
HZD Horizontal Drilling
IND Inclined Drilling
LEL Lower Explosive Limits
LF Linear Foot
MPMS Multi-modal Project Management System
MPT Maintenance and Protection of Traffic
MSDS Material Safety Data Sheet
MSHA Mine Safety and Health Administration

MTL Materials Testing Laboratory
MUTCD Manual on Uniform Traffic Control Devices
NEC National Electric Code
NESC National Electric Safety Code
NIOSH National Institute for Occupational Safety and Health
NOAA National Oceanic and Atmospheric Administration
NOITE Notice of Intent to Enter
NTS Not to Scale
OG Original Ground
OSD Off-Shore Drilling
OSHA Occupational Safety and Health Administration
PA-DEP Pennsylvania Department of Environmental Protection
PennDOT Pennsylvania Department of Transportation
PE Professional Engineer
PG Professional Geologist
PGM Project Geotechnical Manager
PID Photoionization Detector
PMT Pressuremeter Testing
PPE Personal Protective Equipment
PSO Project Site Officer
PTM Pennsylvania Testing Method
ROE Right of Entry
ROW Right of Way
RQD Rock Quality Designation
SBST Subsurface Boring, Sampling, and Testing
SBSTC Subsurface Boring, Sampling, and Testing Contract
SCBA Self Contained Breathing Apparatus
SPT Standard Penetration Testing
SR State Route
SRM Supplier Relationship Management
SSO Site Supervisor Officer
TWS Temporary Water Service
USBR United States Bureau of Reclamation
USCS Unified Soil Classification System
UU Unconsolidated Undrained
VST Vane Shear Testing
WR Wetland Requirement

APPENDIX B – GLOSSARY OF GEOLOGICAL AND GEOTECHNICAL TERMS

A-line – The line on the plasticity chart that divides clays from silts.

AASHTO Soil Classification System – A soil classification system, typically used for highway design and construction that classifies soils into eight groups (A-1 through A-8 and includes several subgroups).

Activity – The ratio between plasticity index and the percent by weight of clay. The activity value is related to clay particle size, the higher the activity, the smaller the particle size.

Adhesion – The shear resistance between soil and a structure (steel, concrete, timber).

Alluvial Fan – A sloping mass of sediment, often granular, deposited at a point along a river or stream where there is a decrease in gradient.

Alluvium – Accumulations of sediment (i.e., clay, silt, sand, gravel, other rock material) transported by flowing water and deposited in riverbeds, floodplains, lakes, shores, and alluvial fans at the base of mountain slopes.

Amygdaloidal – A volcanic rock texture containing mineral-filled, elliptically shaped vesicles.

Angle of Internal Friction – For a given soil, the angle on the graph of the shear stress versus normal effective stress at which shear failure occurs.

Angle of Repose – The steepest angle at which loose granular material remains stationary without sliding downslope.

Anisotropic – A mass of soil having different properties in different directions; refers to permeability or stress-strain characteristics.

Aphanitic – An Igneous rock texture containing crystals that are too small for individual minerals to be seen with unaided eye.

Aquiclude – An impermeable bed that hinders or prevents groundwater movement.

Aquifer – A rock or unconsolidated sedimentary unit or group of units that is capable of supplying water to wells in accessible quantities.

Argillaceous – Pertaining to a sedimentary rock that contains an appreciable amount of clay (e.g., argillaceous limestone).

Atterberg Limits – The water contents of a soil mass corresponding to the transition between a solid, semi-solid, plastic solid or liquid determined through laboratory testing to distinguish the plasticity of clay and silt particles.

Bearing – The horizontal angle between a line and a specified coordinate direction, usually north or south.

Bearing Capacity – A foundation load per unit area that a soil can support without shear failure.

Bedding – The arrangement of rock in layers, strata, or beds resulting from differences in texture, composition, or color to the original sediment; the most characteristic structure in sedimentary rocks.

Bedrock – Solid rock that underlies soil or other surficial material or is exposed locally at the surface.

Bentonite – Soft, plastic clay composed of sodium montmorillonite (clay minerals) derived from weathering of volcanic ash.

Calcareous – Refers to rock containing calcite; in particular, rock in which grains are cemented with calcite (e.g., calcareous shale).

California Bearing Ratio (CBR) Test – A laboratory test that is used to determine the suitability of a soil for use as a subbase in a pavement section.

Capillary Rise – The height at which water will rise above the water table due to negative pore water, pressure, or capillary action of the soil.

Carbonaceous – Rock or soil that is rich in carbon or organic matter.

Cementation – A process in which sedimentary rocks are lithified. As material precipitates from water that percolates through sediment, open spaces are filled, and particles are joined into a solid mass.

Clay minerals – Very tiny crystalline substances evolved primarily from chemical weathering of certain rock-forming minerals; very small colloidal size crystals (diameter less than 2 μm). Chemically, they are hydrous aluminosilicates plus other metallic ions.

Cleavage – Type of foliation characteristic of slates; parallel arrangement of fine-grained minerals giving the rock the tendency to split along definite, parallel, closely spaced planes. Slaty cleavage may be parallel with or at an angle to original bedding. Basal cleavage is exhibited on a horizontal plane of a mineral by way of its base and is exhibited by the mica group.

Coarse-Grained Soils – Sandy and gravelly soils containing particles larger than No. 200 sieve (0.075mm) according to the Unified Soil Classification System.

Coefficient of Consolidation –The rate at which the volume changes during primary consolidation.

Cohesion – A force that holds together like particles within a soil.

Cohesionless Soil – Granular soils (silt, sand, and gravel) that do not exhibit cohesion.

Cohesive soil – Clay type soils that exhibit cohesion.

Colluvium – Loose, heterogeneous, structureless, soil deposits or rock fragments transported by gravitational forces or mass wasting that usually collect at the base of a slope.

Compaction – Volume change in soils where air is expelled from the voids while the water content remains constant; may occur due to vibration and/or self-weight; achieved by rolling, tamping, or vibrating fill soils during construction.

Conchoidal Fracture – A type of fracture that produces a smooth curved surface; a diagnostic feature of quartz.

Concretion – A spherical, ellipsoidal, or irregularly shaped mineral mass precipitated from an aqueous solution in pores or cavities in sedimentary rock.

Cone Penetration Test – A penetration test in which a cone that has a 60 degree point is pushed into the ground at a continuous rate to measure resistance by correlating the depth penetrated with the force applied.

Confined Aquifer – An aquifer overlain by a confining layer of low permeability.

Consistency – The degree of adhesion between soil particles that can resist deformation or rupture.

Consolidation – Volume change in fine-grained soils due to the dissipation of excess pore pressure (reduction of water content) from static loads. The rate at which consolidation occurs is dependent upon the permeability of the soil.

Contact – A surface between two different types or ages of rocks (i.e., between two adjacent formations or members).

Contact Metamorphism – Changes in rock caused by heat from a nearby magma body.

Creep – The slow downhill movement of soil and regolith.

Cross-bedded – A sedimentary structure in which relatively thin layers or laminae are deposited at an inclined angle to the main bedding; formed by wind or water.

Cryptocrystalline – Comprised of submicroscopic crystals (e.g., Chert).

Crystalline – Consisting of crystals or fragments of crystals.

Debris Slide – A slide involving downslope movement of relatively dry unconsolidated material and rock debris; slide mass does not exhibit backward rotation as in a slump or rotational failure, but slides or rolls forward.

Degree of Saturation – The proportion of the volume of water to the total volume of voids for a given mass of soil.

Density – The ratio between the total mass and the total volume of a unit of soil or rock usually expressed as a unit weight.

Desiccation – The process of shrinkage or consolidation of the fine-grained soil produced by the increase of effective stresses in the grain skeleton and the development of capillary stresses in the pore water.

Dike – A tabular or sheet-like shaped intrusive igneous body that is often steeply inclined and cuts through the surrounding rock.

Dilatancy – An increase in the bulk volume during deformation caused by the change of a closely packed structure to an openly packed structure.

Dip – The angle between the horizontal plane and the structural surface (bedding, a joint, fault, foliation, or another planar feature). The direction of dip is at a right angle to the strike of the planar feature.

Direct Shear Test – A laboratory test used to determine the relationship of shear strength to consolidation stress. Shear strength values, cohesion, and the angle of internal friction are determined from the test.

Disappearing Stream – A stream that disappears into an underground channel and does not reappear in the same or even adjacent drainage basin. In areas underlain by carbonate bedrock, streams commonly disappear into sinkholes and follow channels through caves.

Discontinuity – A structural break (fractures, joints, planes of weakness, and shear zones or faults) in geological materials that controls the strength, deformation, and permeability of geologic materials and their engineering properties. Discontinuities are unhealed and have zero to low tensile strength.

Dissolution – The removal of rock material by solution leaving behind a space, cavity, or film of insoluble residue.

Dolomitic – Rock that contains an appreciable amount of magnesium carbonate $CaMg(CO_3)_2$ (e.g., dolomitic limestone).

Drawdown – The amount the water level in a well is lowered due to the removal of water.

Erosion – The processes that loosen sediment and move it from one place to another on the earth's surface by wind, water, ice, and/or gravity.

Evaporite – A sedimentary mineral formed of material deposited from solution by evaporation of water (e.g., gypsum, halite).

Excess Pore Pressure – The increment of pre-water pressures greater than hydro-static values, produced by consolidation stresses in compressive materials or by shear strain; dissipates during consolidation.

Exfoliation – A weathering process where concentric shells, slabs, or sheets, are successively broken loose and stripped away from a rock mass.

Expansive Clays – Clays that are sensitive to water causing them to swell or expand (e.g., montmorillonite).

Extrusive Rock – A rock formed from a mass of magma that flowed out on the surface of the earth.

Fault – A fracture in rock or other material across which there is a total loss of cohesion and along which there has been significant movement parallel to the surface of failure. In rock cores, a fault can sometimes be recognized by the displacement of mineral veins.

Feldspar – A general name for a common group of rock forming minerals of alkali-aluminum silicate composition (e.g., Na- plagioclase, Ca- plagioclase and K-feldspar).

Felsic – Light colored; also refers to feldspar and silica minerals in rocks.

Ferromagnesian Minerals – A variety of silicate minerals containing abundant iron and magnesium (e.g., olivine, amphibole, pyroxene, etc.).

Ferruginous – Rock and soil that contain iron oxide minerals (e.g., hematite).

Fine-Grained soils – Silt and clay soils containing particles smaller than No. 200 sieve (0.075 mm) according to the Unified Soil Classification System.

Fines Content (fraction) – Soil grains smaller than No. 200 sieve (0.075 mm).

Fissilty – The property of rock or minerals to split easily into thin layers along closely spaced, parallel surfaces (e.g., bedding planes in shale).

Fissured Clay – A clay having an internal network of narrow cracks or separations in which the width and depth tends to increase upon drying.

Flaggy – Having the tendency to part or split into layers suitable for flagstone, (0.4 to 2 in.) thick.

Flow Rate – The total volume of water flowing during a particular unit of time.

Foliation – The alignment of platy or elongate minerals that gives some metamorphic rocks a banded appearance; the result of heat and pressure the rock is subjected to during metamorphism. Three major types of foliation are recognized: slaty cleavage, schistosity, and gneissic layering.

Formation – A mappable body of rock of distinctive lithology or lithology's and unique stratigraphic position.

Fossiliferous – Describes rocks that usually contain an abundant number of fossils.

Fracture – Breakage in rock where no appreciable movement has taken place and may be parallel with or at an angle to banding, bedding, cleavage, foliation, or lamination (e.g. faults, joints). Shear and shear zones are excluded.

Fragipan – A dense layer of soil, containing silt and sand with no organic matter and very little clay; extremely hard and impermeable, which is primarily due to compaction.

Friable – Describes rocks that are easily crumbled or broken with manual pressure.

Gap Graded – A soil in which a band or range of particle sizes are not well represented or are missing.

Geologic Cross Section – A diagram showing the structure and arrangement of soils and or rock as they would appear in a vertical plane below the earth's surface.

Glacial Erratic – A large boulder carried by glacial ice to an area far removed from its point of origin.

Glacial Lake Clay – Clay rich sediments deposited in a pro-glacial lake environment. The lake deposits are mostly varves that are comprised of alternating layers of silt and clay.

Glacial Outwash – stratified sand and gravel size sediments washed out from a glacier by meltwater streams; deposits typically form terraces along the flanks of the Susquehanna River valley. The overall stratification is horizontal with individual strata showing crossbeds, ripples, and clast-supported imbrication.

Glacial Striations – Scratches and grooves in bedrock caused by glacial abrasion.

Glacial Till – An unsorted or poorly-sorted, unconsolidated glacial deposit; deposited by ice that contains a wide range of particle sizes from clay to boulder size with rounded and or angular fragments; unstratified to crudely stratified.

Glassy –Describes the texture of certain igneous rocks that contain no crystals; resembling glass in smoothness and shininess

Gneissic Foliation (gneissosity) – Type of foliation resulting from alternating layers of light and dark colored minerals.

Goethite – A yellowish, reddish to brownish black mineral of iron and hydroxide, the most common form of natural rust.

Gouge – Soft, uncemented, pulverized, clay-like material found along some faults.

Graded Bedding – Bedding that displays a gradual or progressive change in particle size (i.e., from coarse at the base to fine at the top).

Grain Size Distribution – Soil particle sizes that are determined from a representative sample of soil that is passed through a set of sieves of consecutive smaller openings (see sieve analysis).

Grains – A mineral or rock particle generally less than a few millimeters in diameter.

Gravel Bar – An elongate gravel deposit on a streambed or riverbed.

Groundmass – The matrix of relatively fine-grained material between phenocrysts in a porphyritic rock.

Hardness – A mineral's resistance to scratching and abrasion, determined on a comparative basis as described in this document. (Refer to Table 3.6.4.6-1)

Hematite, Hematitic – A common iron oxide mineral (the principle of iron ore).

Heterogeneous Soil – A mass of soil containing different engineering and index properties.

Homogeneous Soil – A mass of soil containing one characteristic that has the same engineering and index properties.

Hydraulic Conductivity – The capacity of a porous medium to transmit water. The rate at which fluid can move through a permeable medium depends on properties of the fluid and properties of the medium.

Hydraulic Gradient – Rate of change in total head per unit distance of flow in a given direction.

Hydrometer Test – A laboratory test used to determine the amount of distribution of finer particles (silts or clays) of a soil sample.

Igneous rock – Rock (including volcanic and plutonic rock) formed by cooling and solidification of molten silicate minerals (magma).

Imbrication – The orderly, overlapping arrangement of flattened or sub-spheroidal grains in the direction of flow.

Indurated – A property of a compact rock hardened by pressure, cementation, and especially heat.

Infiltration – The movement of surface water into rock or soil through cracks and pore spaces.

In-situ – In place; undisturbed, existing field conditions.

Instrumentation – Geotechnical instruments (e.g., inclinometer, piezometer, extensometer) used to monitor conditions such as deformations, pressures, loads, etc.

Interbedded – Describes layers of rock lying between beds or alternating with beds of a different rock type.

Intermittent stream – A stream through which water flows only part of the time.

Isotropic – A soil mass having the same properties in all directions; refers to permeability and stress strain characteristics.

Joint – A planar fracture in rock along which there is little to no visible movement or displacement parallel to the fracture.

Karst – The topography of a region that is underlain by limestone, dolomite, gypsum, or marble and can be affected by dissolution; characterized by surface depressions into which water is intercepted and diverted underground into caverns. (Karst features include caves, disappearing streams, closed depressions, and sinkholes).

Lamination – Very thin layering (may be a result of physical or chemical variations) in rock that is less than 0.25 in. and may be parallel with bedding or at an angle to bedding (cross laminations) in sedimentary rock.

Landslide – A relatively rapid type of movement (e.g., debris flow, debris slide, rockslide, and slump).

Limonite, Limonitic – An iron oxide mineral of variable composition; a common weathered product of other iron minerals.

Liquid Limit (LL) – The water content above which the soil will flow like a liquid, but below which will have a plastic consistency.

Lithification – The process (e.g., cementation, compaction, recrystallization) by which loose sediment becomes rock.

Lithology – The character of a rock described in terms of color, structure, mineral composition, grain size and arrangement of its component parts.

Luster – The reflection of light on a given mineral's surface classified by intensity or quality.

Mafic rock – An igneous rock containing more than 50% ferromagnesian minerals.

Magnesian – A rock or mineral containing an appreciable amount of magnesium.

Massive bedding – Thick bedded strata that are homogeneous and lacks significant internal structures; bedding thickness greater than 6 ft.

Matrix – The fine-grained portion of some sedimentary rocks (e.g., conglomerate, sandstone) in which the coarser particles are embedded. The matrix may not be cemented.

Member – A part, or subdivision of a formation in which the rocks are distinctly different from the rocks of the rest of the formation (e.g., Sherman Creek Member of the Catskill Formation).

Metamorphic Rock – Rock formed by the alteration of pre-existing rock deep within the earth by heat pressure, and or chemically active fluids.

Mica, Micaceous – A group of silicate minerals exhibiting perfect basal cleavage, which commonly forms flakes, scales, or sheets.

Mineral – A naturally occurring inorganic substance, usually having an internal crystal structure.

Mohs scale – A series of ten minerals used as a standard in determining hardness.

Moisture Content – The ratio between the mass of water and mass of soil solids.

N-Value – The number of blows required to drive a split-barrel sampler during a standard penetration test a distance of 12 inches after the initial penetration of 6 inches.

Nodule – A small, irregular, surfaced rock body that differs in composition from the rock that encompasses it; formed by the replacement of the original mineral matter (quartz in the form of flint or chert is the most common component). Most commonly occurs in limestone and dolomite.

Non-foliated – Metamorphic rocks that do not exhibit foliation

Normally Consolidated Soil – A soil whose pre-consolidation pressure equals the existing overburden pressure.

Oolite – A sedimentary rock (generally limestone) composed of ooliths (small round grains of calcium carbonate in concentric layers).

Organic Soils – Soils comprised of organic material, dark in color, and having an organic odor such as peat.

Quick Condition – The condition of a soil when effective stresses within the soil mass is zero; caused by an increase in seepage force transmitted to the soil that overcomes the gravitational force acting on the soil.

Overburden Soil – Overlying soil of a desirable soil or rock stratum.

Over Consolidated Soil – A soil whose pre-consolidation pressure is greater than the existing overburden pressure.

Parting – The surface of a rock mass along which the rock splits easily (e.g., bedding surface, fracture surface).

Peat – An accumulation of partly carbonized plant material containing approximately 60% carbon and 30% oxygen.

Pegmatitic – Describes igneous rocks dominated by crystals greater than 3 cm. in length.

Perched Water Table – A localized zone of saturation above the main water table created by an impermeable layer.

Permeability –The property of a soil or a porous or fractured rock for transmitting a fluid; measures the relative ease of flow under unequal pressure.

Phaneritic – An igneous rock texture in which the crystals are roughly equal in size and large enough so the individual minerals can be identified with the unaided eye.

Phenocryst – An obviously large crystal embedded in a matrix of finer-grained crystals

Piezometer – An instrument used to measure in-situ pore water pressures.

Pinnacle – A column of rock extending above the surrounding bedrock, completely or nearly so with regolith; commonly present in carbonate geologic settings.

Plagioclase – A series of sodium, calcium, aluminum, and silicate minerals in the feldspar group.

Plastic Limit (PL) – The moisture content in which the soil will have a plastic consistency.

Plasticity – The property of a soil that allows it to deform continuously; usually a mass of clay size particles. A plastic (cohesive) soil will hold its shape when molded, unlike a cohesionless soil (sand).

Plasticity Index (PI) – Range in water content between the liquid limit and the plastic limit, PI = LL-PL.

Poorly-graded Soil – Soil that contains either an excess or deficiency of certain particle sizes.

Pore Pressure – The pressure exerted by the fluid within the pores or voids in a porous material. In saturated soil, the pore pressure is the pore water pressure.

Porosity – The percentage of the bulk volume of a soil or rock that is occupied by void space.

Porphyritic – An igneous rock texture characterized by two distinctively different crystal sizes, larger crystals are called phenocrysts, and the matrix of the smaller crystals, are termed the groundmass.

Porphyroblast – A large crystal of a mineral such as garnet or staurolite set in a matrix of much, finer-grained minerals in a metamorphic rock.

Proctor Test – A laboratory test that provides results of maximum dry density and optimum moisture content of soils used to determine relative density in the field using in-place density tests.

Pyrite – An iron disulfide, pale yellowish brown to brass yellow and often tarnished with iron oxide with a hardness of 6 to 6.5; “fool’s gold”.

Red Beds – A sedimentary sequence that is predominantly red in color because of the presence of significant hematite.

Regolith – The layer of soil and loose rock fragments overlying the bedrock.

Residuum – Soil formed in place by weathering of the underlying rock on which it lies; no relict rock structure is present.

Rider Coal – A thin seam of coal overlying a thicker seam of coal.

Saprolite – Soil derived primarily from Igneous and Metamorphic parent rock; maintains structure of parent bedrock but with only a trace of the original bond strength; often micaeous; present throughout the Piedmont Physiographic Province.

Schistosity – Type of foliation characteristic of coarse-grained Metamorphic rocks; commonly produced by the parallel or sub parallel orientation of flaky or prismatic minerals such as micas or hornblende.

Sedimentary Rock – Rock formed from the weathered products of pre-existing rock that have been transported, deposited, and lithified.

Sensitivity – A measure of the change in ultimate strength of clays between undisturbed and disturbed samples.

Settlement – The gradual downward movement of a foundation due to the compression of soil below the foundation.

Shear strength – The internal resistance per unit area that the soil mass can offer to resist failure and sliding along any plane inside it.

Siderite – A brownish iron carbonate mineral; commonly found in nodules in shale from the Pennsylvania Appalachian Plateaus Province; an ore of iron.

Sieve Analysis Test – A laboratory test where a representative sample of soil is passed through a set of sieves of consecutively smaller openings to determine the sizes and amount of the separated soil particles.

Sill – A tabular igneous intrusion that parallels the planar structure of the surrounding rock.

Sinkhole – A shallow or deep depression formed by dissolution of carbonate rock and the collapse of overlying material into the cavity.

Site Investigation – Process of methodically sampling, characterizing, and testing soil and rock to delineate and evaluate subsurface materials and conditions relative to the design of proposed highway facilities.

Slickenlines – Parallel striations on a slickensided surface along which movement of rock has occurred.

Slickenside – A polished surface along which movement of rock has occurred; commonly producing slickenlines, which indicates direction of movement.

Slump – A type of mass movement in which material moves along a curved surface of rupture.

Sphalerite – A brown or black (may also be yellow or green) mineral of zinc and iron sulfide; an ore of zinc.

Specific Gravity (G_s) – The ratio between the density of the solid particles and the density of water at 4˚C.

Standard Penetration Test (SPT) – A field test that measures the resistance of the soil to penetration of a standard split-barrel sampler that is driven for three successive increments of six inches (1.5 ft. total) with a 140-pound hammer dropped from a height of 30 inches. The N-value is derived from this test.

Stiffness – A measure of the resistance offered by an elastic body to deformation.

Streak – The color of a mineral in its powdered form; usually obtained by rubbing the mineral against an unglazed porcelain tile to see the mark it makes.

Strike – The compass direction of the line of intersection created by a structural surface (dipping bed or fault) and a horizontal surface. Strike is always perpendicular to the direction of dip.

Talus – Rock fragments that accumulate at the base of a ridge, cliff or cut slope.

Texture – The size, shape, and arrangement of particles that make up a rock.

Toughness – The property of a soil that can absorb stress by plastic deformation.

Triaxial Stress Test – A laboratory shear strength test in which drainage conditions can be controlled (e.g., unconsolidated-undrained (UU), consolidated-undrained (CU), and consolidated-drained (CD)).

U-line – The line on the plasticity chart that marks the approximate upper limit of the relationship between the plasticity index and the liquid limit for natural soils.

Unconfined Compressive Strength Test – A laboratory test similar to the unconsolidated-undrained test performed on plastic soils, usually clay. From this test, the undrained shear strength is calculated as ½ of the unconfined compressive strength.

Underclay – A rootworked claystone occurring below a coal seam; sometimes called soft clay or plastic clay.

Unified Soil Classification System – A system of soil classification based on grain size (coarse-grained soils), liquid limit and plasticity (fine-grained soils).

Unit Weight (γ) – The weight of soil plus water per unit volume.

Vane Shear Test – A field test used to measure the shear strength of a soil that is low-strength, homogeneous, and cohesive.

Varved clays – Alternating thin layers of silt and clay, a pair of silt and clay layers is called a couplet and represents an annual cycle (summer-silt; winter-clay) of deposition in a glacial lake. The light layer usually comprises the coarser silt and fine sand. The darker layer is typically comprised of fine clay (see Glacial Lake Clay).

Vein – A fracture that has been filled with mineral material (e.g., quartz, calcite).

Vesicular – Describes igneous rocks that contain small cavities called vesicles, which form when gases escape from lava.

Visual Classification – A field test that is used to estimate soil characteristics (e.g., the range of particle sizes, plasticity of fine-grained soils).

Vitreous – Resembling glass, but with a vitreous (pearly) luster

Void Ratio – The ratio between the volume of voids and the volume of solids (soil grains).

Vuggy – Small cavity or hole in rock that often contains mineral linings that differ from the surrounding matrix (e.g., calcite vugs in limestone, dolomite, etc.).

Water content – The ratio between the mass of water and the mass of soil solids.

Well Graded Soil – A soil with a good representation of particle sizes over a wide range.

APPENDIX C – GENERIC HEALTH AND SAFETY PLAN FOR REMEDIAL INVESTIGATION ACTIVITIES

This is a generic Health and Safety Plan (HASP) that can be used by the Department as an example HASP outline for future review of project-specific HASP documents submitted by the contractor.

Included in the Health and Safety Plan are explicit requirements relative to the site such as, but not limited to: employee training; personal protective equipment projected for the site; medical surveillance particular to potential site exposure; frequency and types of air monitoring, personnel exposure to hazardous substances by zonation of the site operations according to areas of contamination and procedures for site emergencies; safe work practices and identification of medical assistance; decontamination procedures to minimize personnel contact with hazardous substances and equipment thereof; emergency response plan necessary to effectively handle anticipated emergencies prior to an actual emergency, (e.g., lines of authority, evacuation, critique, emergency equipment) confined space entry procedures; and spill containment procedures should transfer, transport, or disposal of hazardous material be deemed necessary.

HASP SIGN-OFF SHEET

The following personnel have read and fully understand the contents of the HASP.

Name	Date	Company	Signature

HASP TABLE OF CONTENTS

SECTION 1 – INTRODUCTION

This Health and Safety Plan has been prepared for _____ to be conducted by _____ _____ field personnel within _____ . The plan has been prepared as specified in 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response, Final Rule. The information included in this plan has been collected from all available sources pertaining to potential hazards within _____ .

1.1 Scope of Work

_____

_____

_____

_____

1.2 Site Description

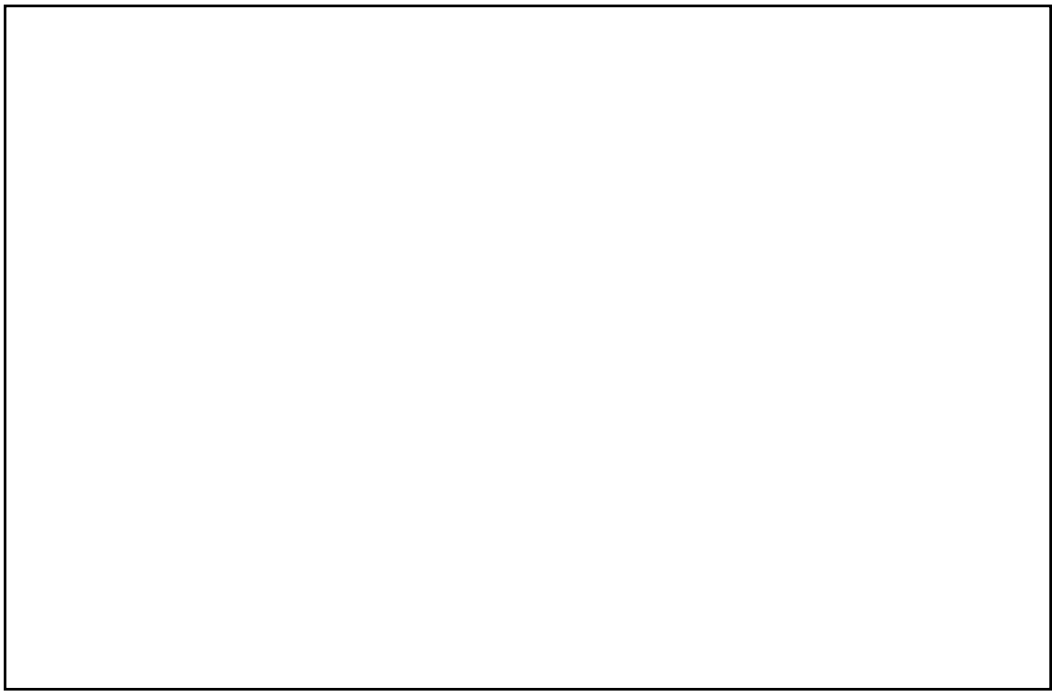
_____

_____

_____

_____

1.3 Site Map



1.4 Site Communications

_____

_____

_____

_____

1.5 Emergency Signal:

_____

_____

_____

_____

SECTION 2 - ORGANIZATIONAL STRUCTURE

The organizational structure section establishes the specific project chain-of-command and specifies the overall responsibilities of supervisors and employees. The site supervisor (SS) has the responsibility and authority to direct all site waste operations. The site health and safety officer (SSO) has the responsibility/authority to develop and implement the HASP to verify compliance with the plan. This organizational structure must be made available to all affected employees and must be reviewed and updated as necessary to reflect the current status of waste site operations.

Name	Title/Position	Company

SECTION 3 – SITE HEALTH AND SAFETY RISKS

The health and safety risks at the site included chemical hazards listed in Table ____ and physical health hazards involved with heavy sampling equipment.

_____

_____

_____

_____

_____

_____

Standard operating procedures listed in Appendix III include machinery and mechanized equipment safety. In addition to these procedures, the following guidelines will be observed during drilling operations.

1. Prior to drilling, adequate site preparation should be performed to accommodate the drill rig and supplies and provide a safe working environment.
2. Overhead and buried utilities must be located prior to start-up of drilling activities.
3. All on-site personnel should stand clear of the drill rig immediately prior to and during starting of the engine.
4. Organic vapor monitoring will be conducted continuously in the workers' breathing zone during drilling operations.
5. Immediately following the completion of drilling operations, the entire work area will be monitored to determine if vapor concentrations have returned to background levels. If elevated levels are detected, the source will be determined, and the appropriate action will be taken.

SECTION 4 – WORK ZONES AND SITE CONTROL

Various activities will be conducted throughout the project area in separate work locations. Each work location will have its own work zones. The exclusion zone is the area of anticipated contamination and will be designated as the specific reconnaissance, soil gas survey, sampling, or drilling area.

_____

_____

_____

_____

_____

_____

A decontamination station will be established for each work as needed. Support areas will be located in areas free of known contamination where administrative, communication, and other support activities can be freely conducted.

SECTION 5 – AIR MONITORING

AIR MONITORING EQUIPMENT

Air monitoring will be conducted during all on-site activities. A flame ionization detector (FID), photoionization detector (PID), and a combustible gas indicator/oxygen meter (CGI) will be utilized for air monitoring. In addition, Drager pump and colimetric tubes will be utilized on an as-needed basis.

The FID and PID will monitor for total organic vapors in exclusion zones. These instruments will be calibrated daily and operated by trained personnel only. Readings from these instruments will be used to set appropriate levels of protection for on-site personnel.

The CGI will be utilized to monitor combustible gas and oxygen levels in exclusion zones.

AIR MONITORING ACTION LEVELS

Lower Explosive Limits (LEL) Reading

- 10-25% LEL – Limit all activities in the area to prevent sparks; proceed with extreme caution.
- 25% LEL – All personnel will withdraw immediately to the contamination reduction area or another designated safe area.

Oxygen (0_2) Reading

- 19.5% 0_2 and below – Air supplied respiratory protective equipment (Level B) is needed (Note: LEL's are not valid in atmospheres with 0.5% 0_2)
- 25% 0_2 and above – All personnel withdraw immediately.

Inorganic/Organic Gases and Vapors

- Action level depends on TLV/PEL/REL. – Consult specific industry reference manual and Table _____.

CONDITIONS MODIFYING LEVELS OF PROTECTION

Level C

- 0-50 PPM above background on FID or PID – Other (describe)

Level B

- 50-500 PPM above background on FID or PID – 0_2 Less than 19.5%

SECTION 6 – PERSONAL PROTECTIVE EQUIPMENT PPE

Location	Activity	Level of Protection

PERSONAL PROTECTION EQUIPMENT (PPE)

Level D

- Hardhat
- Coveralls
- Safety boots
- Gloves (optional)
- Safety glasses (optional)

Level C

- Hardhat
- Air purifying respirator, full or half-face (with safety glasses) with appropriate cartridges
- Chemical resistant overalls
- Chemical resistant gloves, inner, and outer
- Chemical resistant safety boots with disposable boot covers

Level B

- Level B consists of Level C protective equipment plus use of pressure-demand, full face piece self-contained breathing apparatus (SCBA) or pressure-demand supplied air respirator with escape SCBA.

Levels of protection will be modified as site conditions warrant. These modifications will only be made with the approval of the Project Manager (PM) and the SSO (see Section 5 - Air Monitoring)

SECTION 7 – DECONTAMINATION

All personnel and equipment leaving exclusion zones will be thoroughly decontaminated. The following decontamination equipment will be available: plastic sheeting, collection containers, wash tubs soap, potable and deionized water, acid solvent, and scrub brushes.

All boots and gloves will be decontaminated using soap and water solution and scrub brushes. Outer boots, outer gloves, and chemical resistant suit will then be removed. When respirators are used, all respiratory equipment will be decontaminated and sanitized daily.

Sampling equipment decontamination consists of washing with soap and water solution, acid rinse (if needed), solvent rinse (if needed), and deionized water rinses to remove contaminants.

If heavy equipment is used, decontamination procedures will be implemented to prevent hazardous materials from leaving the site.

All decontamination fluids and all disposable clothing will be collected and disposed of in accordance with all applicable federal, state, and local regulations.

SECTION 8 – EMERGENCY RESPONSE

Location of Nearest Telephone:	
Medical Emergency:	
Ambulance:	
Hospital:	
Directions to Hospital:	

EMERGENCY TELEPHONE NUMBERS:

AGENCY	TELEPHONE

Emergency Signal:

Example:

Repeated intervals of three short beeps of an automobile horn will the signal for all on-site personnel to immediately report to the support area.

Emergency Evacuation:

The following emergency evacuation routes and regrouping areas are designated for use in emergency situations.

_____

_____

_____

_____

Decontamination following an emergency evacuation will be directed by the SS and the SSO. In all situations, when an on-site emergency results in evacuation of the site, personnel must not re-enter until:

1. Conditions created in the emergency have been corrected
2. Hazards have been reassessed
3. HASP has been reviewed

4. Site personnel have been briefed on any changes in the site safety plan.

Site Security and Control:

See Sections 4 and 9.

Emergency Equipment and PPE:

In case of an emergency, the following equipment will be maintained on site:

Basic emergency and first aid equipment will be available in the Support Zone or the Contamination Reduction Zone. Such equipment must include a first aid kit, emergency eyewash, fire extinguishers, and safety-related equipment.

Emergency Identification and Response:

Should any contaminants or suspected hazardous material by encountered on-site that were not identified in the Site Safety Plan, all further on-site activities will be suspended, and all on-site personnel evacuated at the discretion of the SS and the SSO.

Information to Report to Emergency Response Agency:

- Name of person reporting incident
- Location and telephone number of person reporting
- Nature of emergency, incident
- Name of person injured or exposed
- Data, time, and location of incident
- Action taken.

On-site personnel should report as much information as possible concerning the substance to the SS or the SSO. If the substance cannot be identified, the SS and SSO will use whatever resources are available to better characterize the unknown. The SS and SSO should also determine:

- appropriate control methods to prevent further spread/release of the hazard
- potential impacts of the substance to on-site personnel, the surrounding population, and the environment
- resources necessary to contain, stabilize, and cleanup/remove the hazard
- appropriate authorities to notify

Accidents:

The following standard emergency procedures will be used on-site personnel in the event of an accident. The PM or the SSO must be notified and will be responsible for ensuring that the appropriate procedures are followed.

1. Personnel injury in the Exclusion Zone: Upon notification of an injury in the Exclusion Zone, the designated emergency signal must be sounded. All site

personnel must assemble at the Support Zone (Contamination Reduction Zone). The rescue team will enter the Exclusion-Zone (if required) to remove the injured person. The SS and the SSO should evaluate the nature of the injury, and the affected person should be decontaminated to the extent possible prior to movement to the Support Zone. Appropriate first aid must be administered, and contact should be made for an ambulance and with the designated medical facility (if required). No persons can reenter the Exclusion Zone until the cause of the injury or symptoms are determined. The accident will be documented in the daily logbook.

2. Personnel injury in the Support Zone: Upon notification of an injury in the Support Zone, the SS and the SSO will assess the nature of the injury and take appropriate action. If the cause of the injury of loss of the injured person does not affect the performance of the site personnel, operations may continue. If the injury increases the risk to others, the designated emergency signal must be sounded and all site personnel must move to the Support Zone/Contamination Reduction Zone for further instructions. Activities on-site will stop until the added risk is removed or minimized.
3. Fire/Explosion: Upon notification of a fire or explosion on-site, the designated emergency signal must be sounded and all site personnel assembled at decontamination line. The Fire Department must be alerted and all personnel moved to a safe distance from the involved area.
4. Personal Protection Equipment Failure: If any site worker experiences a failure of alteration of protective equipment that affects protection factor, that person, their buddy must immediately leave the Exclusion Zone. Re-entry must not be allowed until the equipment has been repaired or replaced.
5. Other Equipment Failure: If any other equipment on-site does not operate properly, the SS and SSO must be notified and then determine the effect this failure on continuing operations on-site. If the failure affects the safety of personnel or prevents completion of the Work Plan tasks, all personnel must leave the Exclusion Zone until the situation is evaluated and appropriate actions taken.

Natural Disasters:

Earthquakes, Tornadoes, High Winds, Floods, and Thunderstorms: Should any of these events be forecasted or occur, all work activities should be stopped immediately, and all personnel should evacuate the site via designated routes.

Emergency Response Follow-Up:

Following activation of the Emergency Response Plan, _____ will submit a written report documenting the incident. The _____ field logbook will be maintained in such a manner that the report can be prepared from the logbook entries. The report may indicate that an update of this plan is necessary.

Emergency Response Pre-Planning:

Prior to commencing on-site work activities, the PM and the SSO will review the Emergency Response Plan with all site personnel.

SECTION 9 – SITE SECURITY

SECTION 10 – EMPLOYEE TRAINING AND MEDICAL SURVEILLANCE

All on-site personnel must meet the training and medical surveillance requirements established by the Occupational Safety and Health Administration (OSHA), which are listed in the Code of Federal Regulation, 29 CFR Part 1910.120 (e) training and (f) medical surveillance. Written training certificates and a physician's written opinion must be retained for all on-site personnel. All personnel will be given a site-specific briefing by the SSO prior to conducting on-site activities.

SECTION 11 – CONFINED SPACE ENTRY

Any confined space entry that may be required must first be authorized by the PM.
The basic requirements for entry into a confined space are to:

- Test the atmosphere prior to entry for oxygen and toxic and combustible levels of gases, or vapors. If the oxygen content is less than 19.5%, the personnel must wear supplied air respirators while in the area. If the toxic levels of chemicals are present, appropriate personal protective equipment will be necessary. If combustible gas levels are above 10% of the lower explosive limit, entry should be delayed until the level falls below 10%. Forced ventilation can be used to lower the concentration of toxic or combustible gasses and raise the oxygen content. However, what chemicals will be removed from the space and where they will go should be evaluated before starting ventilation.
- Establish a system to mark a confined space unsafe should tests indicate it is unsafe to enter. Markings are to remain in place until tests indicate entry is safe.
- Lockout, block, or otherwise deactivate all mechanical, electrical, liquid, and gas systems relating to the confined space that may create a hazard during entry if they are put in motion or otherwise activated.
- Develop emergency procedures for rescue inside the confined space. This included a person on standby outside the confined space to observe the worker and provide help in an emergency. Any rescue personnel entering the confined space will need, as a minimum, the same protective equipment that the person inside is using. A lifeline should be attached to any worker to aid in pulling them out.

SECTION 12 – CHEMICAL HAZARDS

Include copies of Material Safety Data Sheets for any potentially hazardous chemicals used in the drilling and sampling activities. Tabulate the various data sheet titles on the following table for quick reference.

Chemical IDENTITY *(as Used on Label and List)*	Used for

SECTION 13 – STANDARD OPERATING PROCEDURES

GENERAL SAFETY MEASURES

Personal Practices

- At the very least, hands and face must be thoroughly washed upon leaving the site and before eating, drinking, breaks, or any other off-site activity. During instances when outer garment decontamination procedures are in effect, entry team members must thoroughly shower as soon as possible following the removal of protective garments.
- Such activities as eating, drinking, chewing gum or tobacco, smoking or any other practice that increases the tendency for hand-to-mouth contact, must be prohibited within contaminated zone(s) and prior to washing hands, and face within the contamination reduction corridor or decontamination reduction corridor or decontamination line.
- The use of respiratory protective equipment must be in accordance with currently accepted policies and procedures governing such devices. Air purifying respirator cartridges should be changed at least once each workday on-site. Spent cartridges should be discarded before breaking for lunch and again at the end of each day's activities. As a recommended minimum, respirator or gas mask canisters should be discarded at the end of each day's activities. More frequent changes must occur at the first sign of breakthrough based on contaminant warning properties or when indicated by an end of service indicator. In all cases, only NIOSH/MSHA approved respirators must be used and no canisters must be used beyond their expiration dates.
- No excessive facial hair or any other obstruction, which interferes with a satisfactory fit of the mask-to-face piece seal, is allowed on personnel required to wear respiratory protective equipment. Similarly, the wearing of contact lenses is prohibited when wearing respiratory protective devices.
- The use of medicine and alcohol has the potential to mask the effects from exposure to toxic chemicals. Alcohol, caffeinated products, and certain medications can contribute and exacerbate the effects of heat stress. Prescribed drugs should not be taken by personnel during response activities when the potential for absorption, inhalation, or ingestion of toxic substances exists, unless specifically approved by a qualified physician. Similarly, over-the-counter medications should only be used with a physician's approval and in accordance with package limitations and warnings. The intake of alcoholic or caffeinated beverages should be avoided during response activities.
- Contact with surfaces known or suspected of being contaminated should be avoided during on-site activities. Whenever possible, avoid walking through puddles, mud, or discolored surfaces; kneeling on ground; leaning, sitting, or placing equipment, drums, containers, or vehicles on ground.

- Levels of protection must be established for a given site and must be based upon the best available information regarding known or suspected hazards associated with the site and the types of activities to be accomplished. Site activities must then be performed in accordance with those site-specific levels of protection. Changes in the

site-specific levels of protection should be made when the level of site-specific information improves sufficiently to warrant any change. When sufficient site-specific information is lacking or when the conditions of a site are unknown or in doubt, all site entries and on-site activities will be performed in Level B protection, as a minimum, until the knowledge of site-specific hazards has improved.

GENERAL HOUSEKEEPING

- All stairways, passageways, gangways, and access/ways will be kept free of materials, supplies, and obstruction at all times.
- Loose or light material will not be stored or left on roofs or floors that are not closed in unless it is safely secured.
- Tools, materials, extension cords, hoses, or debris will be located so as not to cause tripping or other hazards.
- Tools, materials, and equipment subject to displacement or falling will be adequately secured.
- All storage and construction sites will be kept free from the accumulation of combustible materials. Weeds and grass will be kept down.
- Rubbish, brush, long grass, or other combustible material will be kept from areas where flammable and combustible liquids are stored, handled, or processed.
- All spills of flammable and combustible liquids will be cleaned up immediately.

FIRE PREVENTION

General

- Fires and open flame devices will be controlled by a strict permitting system.
- Smoking will be prohibited in all areas where flammable, combustible, or similar hazardous materials are stored, except in those locations specifically provided for such purpose and approved by the appointed Project Safety Officer (PSO).
- All major motorized equipment will be equipped with a fire extinguisher of a type and make approved by the National Board of Fire Underwriters.

Access

- Fire lanes will be maintained free of obstruction to provide access to all areas.
- Material will be stockpiled or staged to minimize the spread of fire internally and to allow access for firefighting.
- Within 200 ft. of each portable tank or flammable/combustible liquid container stored outdoors, there will be a 13-ft. wide access way for fire control apparatus. Clearance will be maintained around lights and heating units to prevent ignition of combustible materials.

Flammable and Combustible Liquids

- All tanks, containers, and pumping equipment, portable or stationary, used for the storage of handling of flammable and combustible liquids will be list by UL or FM or approved by the Mine Safety and Health Administration (MSHA).
- All sources of ignition will be prohibited in areas where flammable liquids are stored, handled, or processed. Suitable NO SMOKING signs will be posted in all such areas.
- Flashlights and electric lanterns used during handling of flammable liquids will be the type listed by the Underwriters' Laboratories or other nationally recognized testing laboratory for use in such hazardous areas.
- Shipment storage and handling of all flammable liquids will be in containers approved for shipment of such materials and tagged or labeled in accordance with regulations of the U.S. Department of Transportation.
- Drums, barrels, and other flammable liquid containers will be tightly capped. Safety cans or other portable service containers of flammable liquids having a flashpoint at or below 73F will be painted red with a yellow band around the can and/or the name of the contents conspicuously painted or stenciled on the container in yellow.
- Dispensing systems will be electrically bonded and grounded.
- Storage tanks will be equipped with relief vents. Tank vents will not be located close to open flames, stacks, heating apparatus, or any other source of ignition. Water draw-off valves will be antifreeze type of insulted to prevent freezing.
- Areas in which flammable or combustible liquids are transferred, in quantities greater than 5 gallons from one tank or container to another will be separated from other operations by 26 ft. or by construction having a fire resistance of at least one (1) hour. Drainage or other means will be provided to control spills. Natural or mechanical ventilation will be provided to maintain the concentration of flammable vapor at or below 10 % of the lower flammable limit.
- All tanks, hoses, and containers of 5 gallons or less will be kept in metallic contact with flammable liquids while being transferred. Transfer of flammable liquids will not be attempted until containers are electrically interconnected (bonded) and, if necessary, grounded.
- Workers will be required to guard carefully against any part of their clothing becoming contaminated with flammable or combustible fluids. They will not be allowed to continue work when their clothing becomes so contaminated.

ELECTRICAL SAFETY

General

- All electrical wiring and equipment will be of a type listed by UL or Factory Mutual Engineering Corporation for the specific application.
- All installations will comply with the National Electrical Safety Code (NESC), National Electrical Code (NEC) or U.S. Coast Guard Regulations.
- All work will be by personnel familiar with code requirements and qualified for the class of work to be performed.

- Live parts of wiring or equipment will be guarded to protect all persons or objects from harm.
- Electric wire passing through work areas will be covered or elevated to protect it from damage by foot traffic, vehicles, sharp corners, projections, or pinching
- Before beginning work, the person in charge will ascertain by inquiry, direct observation, or by instruments, whether any part of an electric power circuit, exposed or concealed, is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact therewith. Whenever possible, de-energize all equipment and/or circuits before work is started. Additionally, all personnel should adhere to applicable clearance procedures and be protected by grounding.
- When it is necessary to work on energized lines and equipment, rubber gloves and other protective equipment or hotline tools meeting the provisions of the American National Standards Institute (ANSI) J-6 series will be used.
- Patched, oil soaked, worn, or frayed electric cords or cables will not be used.
- Extension cords or cables will not be fastened with stables hung from nails or suspended by bare wire.
- Portable and semi-portable electrical tools and equipment will be grounded by a multi-conductor cord having an identified grounding conductor and a multi-contact polarized plug-in receptacle.
- Semi-portable equipment, floodlights, and work lights will be grounded. The protective ground of such equipment will be maintained during moving unless supply circuits are de-energized.
- Driven rod electrodes will have a resistance to ground not to exceed 25 ohms.

Temporary Wiring

- Temporary wiring will be guarded, buried, or isolated by elevation to prevent accidental contact by workers or equipment.
- Flexible cord sets will be of a type listed by the UL. Flexible cord sets used on construction sites will contain the number of conductors required for the service plus an equipment ground wire. The cords will be Type ST, STO, SJT, SJTO, S, SO, SEO, W, or G.
- Exposed empty light sockets and broken bulbs will not be allowed.
- Portable electric lighting used in confined wet and/or hazardous locations such as drums, tanks, vessels, and grease pits will be operated at a maximum of 12 volts.

Operations Adjacent to Overhead Lines

- Overhead transmission and distribution lines will be carried on towers and poles that provides safe clearance over roadways and structures.
- Clearances will be adequate for the movement of vehicles and for the operation of construction equipment.
- Ladders, elevated work platforms, aerial lifts, drill rigs, or any other aerial extensions will be established so there is no possible of accidental contact with any electrical

transmission line or device, or lines and devices will be deactivated and certified as such.

HAND AND POWER TOOLS SAFETY

- All hand tools will be in good repair and used only for the purpose for which designed.
- Tools having defects that will impair their strength or render them unsafe will be removed from service.
- When work is being performed overhead, tools not in use will be secured or placed in holders.
- Throwing tools or materials from location to another, from one person to another, or dropping them to lower levels, will not be allowed.
- Only non-sparking tools will be used in locations where sources of ignition may cause a fire or explosion.
- Power tools will be inspected, tested, and determined to be in safe operating condition prior to use. Continued periodic inspections will be made to assure safe operating condition and proper maintenance.
- Rotating or reciprocating portable power tools will have a constant pressure switch that will shut off the power when the tool is released by the operator. A portable power tool may have a lock-on control provided turn-off can be accomplished by a single motion of the same finger or fingers that turned it on.
- Blends of hydraulic fluid used in powered tools will be chosen so that they retain their operating characteristics at the most extreme temperatures to which they will be exposed.
- Manufacturers' safe operating pressures for hydraulic hoses, valves, pipes, filters, and other fittings will not be exceeded.
- All hydraulic or pneumatic tools that are used on or around energized lines or equipment will have non-conducting hoses having adequate strength for the normal operating pressures.
- Loose and frayed clothing, loose long hair, dangling jewelry, rings, chains, and wrist watches will not be worn while working with any power tool or machine.
- All woodworking tools and machinery will meet applicable requirements of ANSI 01.1, Safety Code for Woodworking Machinery.

MACHINERY AND MECHANIZED EQUIPMENT SAFETY

- Train personnel in proper operating procedures.
- Install adequate on-site roads, signs, lights, and devices.
- Install appropriate equipment guards and engineering controls on tools and equipment. These include roll-over protective structures, seat belts, emergency shutoff in case of rollover, and backup warning lights and signals.
- Provide equipment such as cranes, derricks, and power shovels with signs saying, "unlawful to operate this equipment within 10 ft. of all power lines".
- Use equipment and tools that are intrinsically safe and not capable of sparking, and pneumatically and hydraulically driven equipment.

- Where portable electric tools and appliances can be used, (i.e., where there is no potential for flammable or explosive conditions), use three-wire grounded extension cords to prevent electric shocks.
- In hydraulic power tools, use fire-resistant fluid that can retain its operating characteristics at the most extreme temperatures.
- At the start of each workday inspect brakes, hydraulic lines, light signals, fire extinguishers, fluid levels, steering, and splash protection.
- Keep all non-essential people out of the work area.
- Prohibit loose-fitting clothing or loose long hair around moving machinery.
- Keep cabs free of all non-essential items and secure all loose items.
- Do not exceed the rated load capacity of a vehicle.
- Instruct equipment operators to report to their supervisor(s) any abnormalities such as equipment failure, oozing liquids, unusual odors, etc.
- When an equipment operator must negotiate in tight quarters, provide a second person to ensure adequate clearance.
- Have a signalperson direct backing as necessary.
- All on-site internal combustion engines should have spark arrestors that meet requirements for hazardous atmospheres. Refuel in safe areas. Do not fuel engines while vehicle is running. Prohibit ignition sources near a fuel area.
- Lower all blades and buckets to the ground and set parking brakes before shutting off the vehicle.
- Implement an ongoing maintenance program for all tools and equipment. Inspect all tools and moving equipment regularly to ensure that parts are secured and intact with no evidence of cracks or areas of weakness that the equipment turns smoothly with no evidence of wobble, and that is operating according to manufacturer's specifications. Promptly repair or replace any defective items. Keep maintenance and repair logs.
- Store tools in clean, secure areas so that they will not be damaged, lost, or stolen.
- Keep all heavy equipment that is used in the Exclusion Zone in that zone until the job is done. Completely decontaminate such equipment before moving it into the clean zone.

MEDICAL AND FIRST AID PROCEDURES

- Prior to start of work, arrangements will be made for medical facilities, ambulance service, and medical personnel to be available for prompt attention to the injured and consultation on occupational health.
- Communication and transportation to effectively care for injured workers will be provided.
- Where any part of the body may be exposed to toxic or corrosive materials drenching and/or flushing activities will be provided in the work area for immediate emergency use.
- On activities requiring a first aid station or an infirmary, the facilities and equipment will be determined by the proximity and quality of available medical services and will be in accordance with the recommendation of a licensed physician.
- Alternate facilities that provide the quantity and quality of services outlined in this operating practice may be utilized if approved.

POTABLE WATER AND SANITARY FACILTIES

General

- An adequate supply of drinking water will be supplied from sources approved by federal, state, or local health authorities. Drinking water will be dispensed by means which prevent contamination between source and the consumer.
- The common cup is prohibited. A sanitary container for the paper cups and a waste receptacle for the used cups will be provided. Containers for drinking water will be clearly marked as to contents and not used for other purposes.
- There will not be any cross-connection, open or potential, between a system furnishing potable water and a system furnishing non-potable water.

Washing Facilities

- Washing facilities will be provided as needed to maintain healthful and sanitary conditions. Each washing facility will be maintained in a sanitary condition and provided with water, soap, individual means of drying, and metal-covered receptacles for waste.

APPENDIX D – UNIFIED AND AASHTO SOIL CLASSIFICATION SYSTEM REFERENCES

AASHTO Classification of Soils and Soil-Aggregate Mixtures

(from AASHTO M145)

Classification of Soils and Soil-Aggregate Mixtures

General Classification	**Granular Materials** (35% or less passing No. 200 sieve)							**Silt-Clay Materials** (> 35% passing No. 200 sieve)			
Group Classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3 [a]	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6
Sieve Analysis (Percent Passing)**:**											
No.10	**50 max.**	--	--	--	--	--	--	--	--	--	--
No. 40	**30 max.**	**50 max.**	**51 min.**	--	--	--	--	--	--	--	--
No. 200	**15 max.**	**25 max.**	**10 max.**	**35 max.**	**35 max.**	**35 max.**	**35 max.**	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid Limit	--		--	**40 max.**	**41 min.**	**40 max.**	**41 min.**	40 max.	41 min.	40 max.	41 min.
Plasticity Index	**6 max.**		**N.P.**	**10 max.**	**10 max.**	**11 min.**	**11 min.**	10 max.	10 max.	11 min.	11 min. [b,c]
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel, and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good							Fair to Poor			

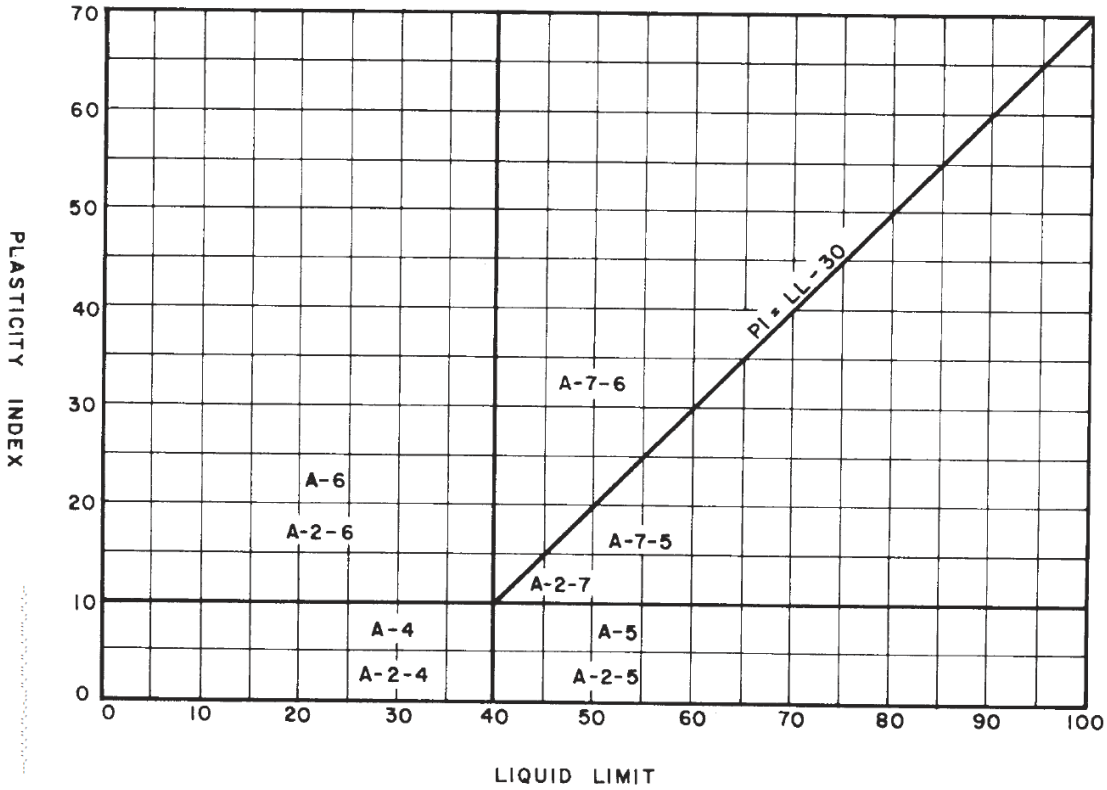
[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate the superiority of A-3 over A-2

[b] for A-7-5, PI $\leq$ LL - 30

[c] for A-7-6, PI > LL - 30

AASHTO Liquid Limit and Plasticity Index ranges for Silt-Clay Materials

(from AASHTO M145)



(Note: A-2 soils contain less than 35% finer than the No. 200 sieve.)

Comparison of AASHTO to UNIFIED Soil Classifications

Reference: Das, B.M. *Principles of Geotechnical Engineering*. Boston: PWS, 1994.

Soil group in AASHTO system	Comparable soil groups in UNIFIED system		
	Most Probable	Possible	Possible but Improbable
A-1-a	GW, GP	SW, SP	GM, SM
A-1-b	SW, SP, GM, SM	GP	--
A-3	SP	--	SW, GP
A-2-4	GM, SM	GC, SC	GW, GP, SW, SP
A-2-5	GM, SM	--	GW, GP, SW, SP
A-2-6	GC, SC	GM, SM	GW, GP, SW, SP
A-2-7	GM, GC, SM, SC	--	GW, GP, SW, SP
A-4	ML, OL	CL, SM, SC	GM, GC
A-5	OH, MH, ML, OL	--	SM, GM
A-6	CL	ML, OL, SC	GC, GM, SM
A-7-5	OH, MH	ML, OL, CH	GM, SM, GC, SC
A-7-6	CH, CL	ML, OL, SC	OH, MH, GC, GM, SM

UNIFIED Classification System
Soil Classification Charts

Reference: *ASTM D2487*

COARSE-GRAINED SOILS have <50% passing the No. 200 sieve				
			Group Abbreviation	**Group Name**
Gravels <50% of coarse fraction passing the No. 4 sieve	Clean Gravel (<5% fines)	-	**GW**	**Well-graded GRAVEL**
		-	**GP**	**Poorly-graded GRAVEL**
	Gravels with Fines (>12% fines)	fines classify as ML or MH	**GM**	**SILTY GRAVEL**
		fines classify as CL or CH	**GC**	**CLAYEY GRAVEL**
Sands ≥50% of coarse fraction passing the No. 4 sieve	Clean Sands (<5% fines)	-	**SW**	**Well-graded SAND**
		-	**SP**	**Poorly-graded SAND**
	Sands with Fines (>12% fines)	fines classify as ML or MH	**SM**	**SILTY SAND**
		fines classify as CL or CH	**SC**	**CLAYEY SAND**

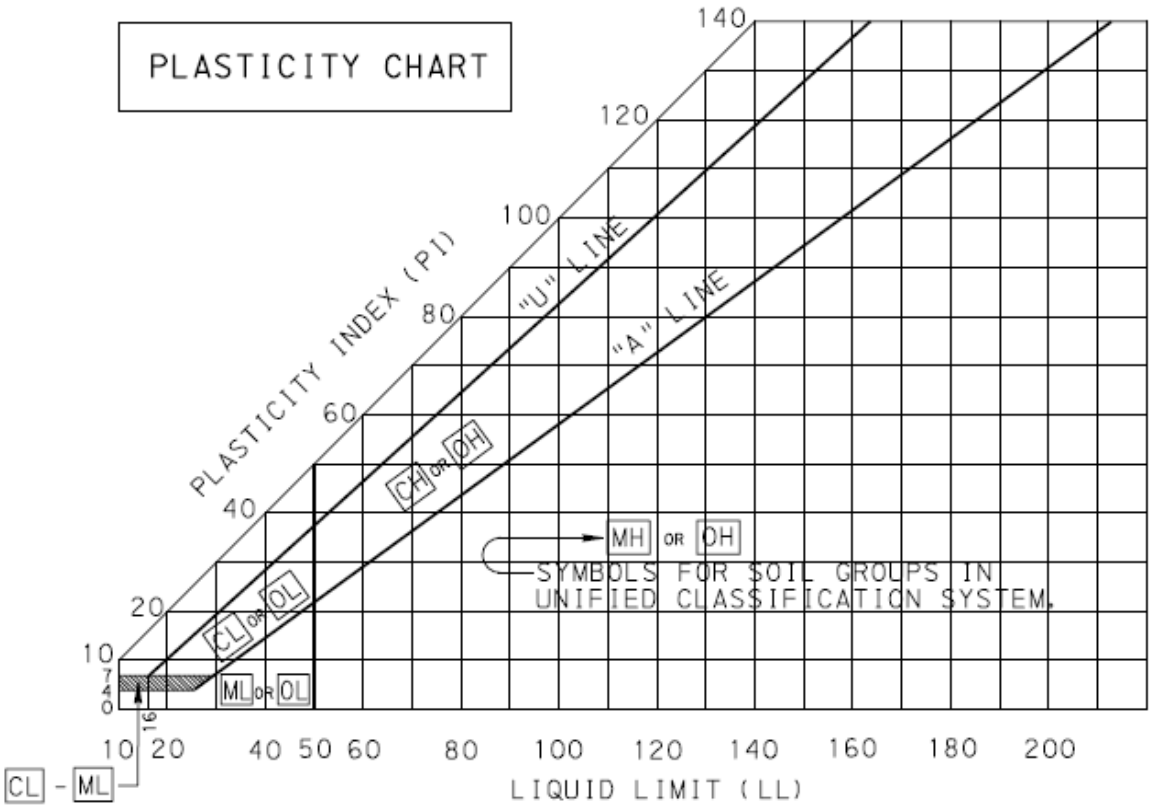
- In the UNIFIED system, a soil is considered coarse-grained if it contains fewer than 50% fines.
- Coarse-grained particles will not pass through a No.200 sieve.
- Gravel is material retained on the No.4 sieve.
- Sand is material passing the No.4 sieve but retained on the No. 200 sieve.
- Soil is classified as GRAVEL if the %-gravel is estimated to be greater than the %-sand.
- Soil is identified as SAND if the %-gravel is estimated to be equal to, or less than, the %-sand.

FINE-GRAINED SOILS have ≥50% passing the No. 200 sieve			
		Group Abbreviation	**Group Name**
Silts and Clays Liquid Limit <50	Inorganic	**CL**	**LEAN CLAY**
		ML	**SILT**
	Organic	**OL**	**ORGANIC SOIL**
Silts and Clays Liquid Limit ≥50	Inorganic	**CH**	**FAT CLAY**
		MH	**ELASTIC SILT**
	Organic	**OH**	**ORGANIC SOIL**

- In the UNIFIED system, a soil is considered to be fine-grained if it contains 50% or more fines.
- Particles that pass through a No. 200 sieve are identified as fine-grained.

HIGHLY ORGANIC SOILS		
	Group Abbreviation	**Group Name**
Primarily organic matter, dark in color, and organic odor	**PT**	**PEAT**

UNIFIED Liquid Limit and Plasticity Index ranges for Silt-Clay Materials



Equation of "A-Line": Horizontal at PI=4 to LL=25.5, then PI=0.73(LL-20)

Plastic soils plot above the A-Line on chart.

Non-plastic or slightly plastic soils plot below the A-Line on chart

Equation of "U-Line": Vertical at LL=16 to PI=7, then PI=0.9(LL-8)

The U-Line represents the approximate upper limit for natural soils.

Correct tests never plot above U-line.

Comparison of UNIFIED to AASHTO Soil Classifications

Reference: Das, B.M. *Principles of Geotechnical Engineering*. Boston: PWS, 1994.

Soil Group in UNIFIED System		Comparable soil groups in AASHTO system		
		Most Probable	Possible	Possible but Improbable
GW	Well graded gravel Well Graded gravel with sand	A-1-a	--	A-2-4 A-2-5 A-2-6 A-2-7
GP	Poorly graded gravel Poorly graded gravel with sand	A-1-a	A-1-b	A-3 A-2-4 A-2-5 A-2-6 A-2-7
GM	Silty gravel Silty gravel with sand	A-1-b A-2-4 A-2-5 A-2-7	A-2-6	A-4 A-1-a A-5 A-7-5 A-6 A-7-6
GC	Clayey gravel Clayey gravel with sand	A-2-6 A-2-7	A-2-4 A-6	A-4 A-7-5 A-7-6
SW	Well graded sand Well graded sand with gravel	A-1-b	A-1-a	A-3 A-2-4 A-2-5 A-2-6 A-2-7
SP	Poorly graded sand Poorly graded sand with gravel	A-3 A-1-b	A-1-a	A-2-4 A-2-5 A-2-6 A-2-7
SM	Silty sand Silty sand with gravel	A-1-b A-2-4 A-2-5 A-2-7	A-4 A-5 A-2-6	A-6 A-1-a A-7-5 A-7-6
SC	Clayey sand Clayey sand with gravel	A-2-6 A-2-7	A-4 A-6 A-2-4 A-7-6	A-7-5
ML	Inorganic silt (with sand or gravel)	A-4 A-5	A-6 A-7-5	--
CL	Inorganic clay (with sand or gravel)	A-6 A-7-6	A-4	--
OL	Organic silt Organic clay (with sand or gravel)	A-4 A-5	A-6 A-7-5 A-7-6	--
MH	Elastic silt	A-5 A-7-5	--	A-7-6
CH	Inorganic clay of high plasticity	A-7-6	A-7-5	--
OH	Organic silt Organic clay	A-5 A-7-5	--	A-7-6
PT	Peat, Muck, and Other highly organic soil	--	--	--

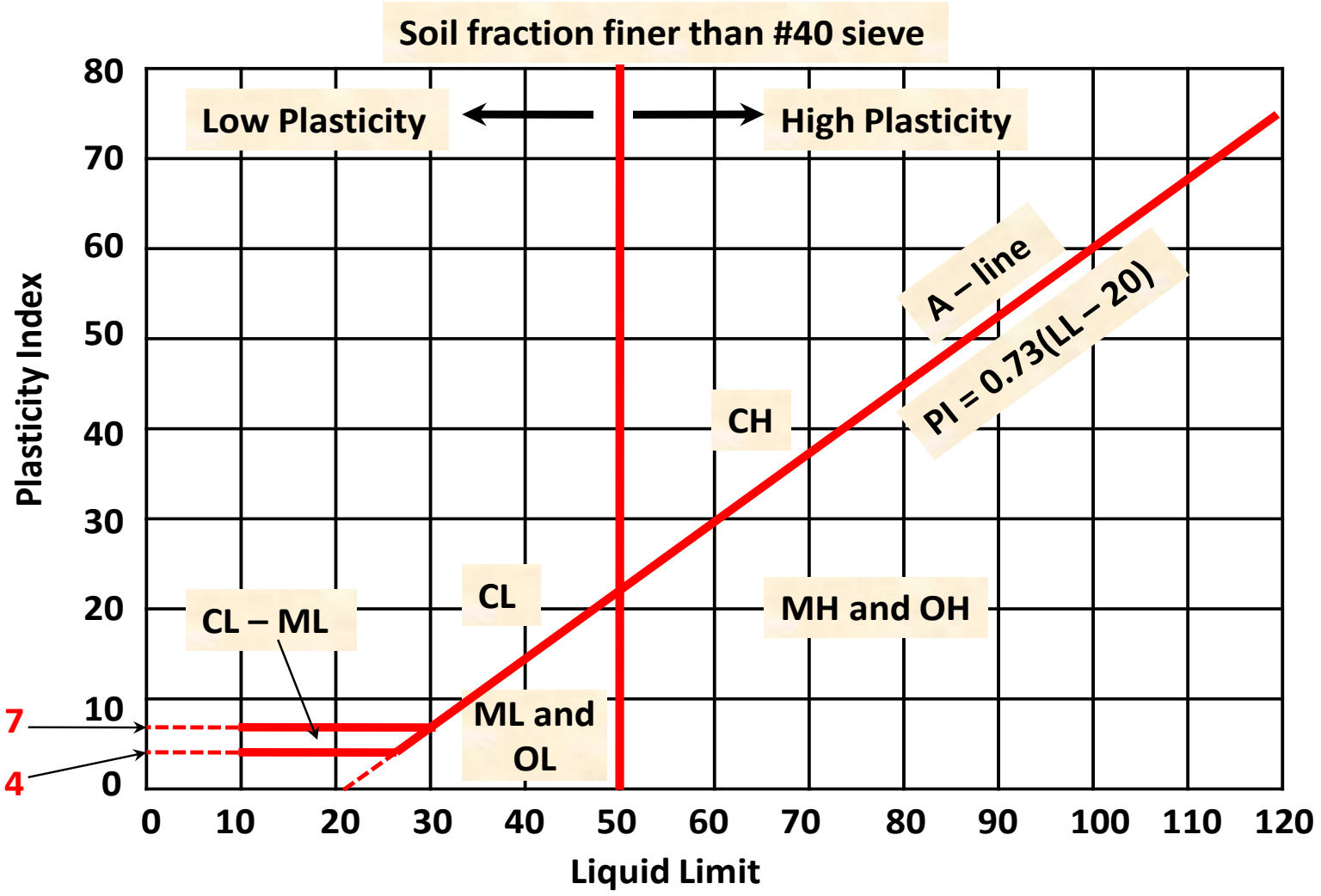
Unified Soil Classification System (USCS)

Criteria for Assigning Group Symbols and Group names Using Laboratory Tests				Soil Classification	
				Group Symbol	Group Name[B]
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well-graded gravel[F]
			Cu < 4 and/or 1 > Cc > 3[E]	GP	Poorly graded gravel[F]
		Gravels with fines More than 12 % fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sandls Less than 5 % fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			Cu < 6 and/or 1>Cc>3[E]	SP	Poorly graded sand[I]
		Sand with fines More than 12 % fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	Silts and Clays Liquid Limit less than 50	Inorganic	PI > 7 and plots on or above "A"line[J]	CL	Lean clay[K,L,M]
			PI < 4 and plots below "A"line[J]	ML	Silt[K,L,M]
		Organic	$\frac{\text{Liquidlimit - ovendried}}{\text{Liquidlimit - notdried}} < 0.75$	OL	Organic clay[K,L,M,N,O]
	Silts and Clays Liquid Limit 50 or more	Inorganic	PI plots on or above "A"line	CH	Fat clay[K,L,M]
			PI plots below "A"line	MH	Elastic silt[K,L,M]
		Organic	$\frac{\text{Liquidlimit - ovendried}}{\text{Liquidlimit - notdried}} < 0.75$	OH	Organic clay[K,L,M,P,O]
HIGLY ORGANIC SOILS		Primarily organic matter, dark color, and organic color		Pt	Peat

Unified Soil Classification - Notes

[A] Based on the material passing the 3-in (75-mm) sieve. **[B] If field sample cointained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.** **[C] Gravels with 5 to 12 % fines require dual symbols :** **GW-GM well graded gravel with silt** **GW-GC well graded gravel with clay** **GP-GM poorly graded gravel with silt** **GP-GC poorly graded gravel with clay** **[D] Sands with 5 to 12 % fines require dual symbols :** **SW-SM well graded gravel with silt** **SW-SC well graded gravel with clay** **SP-SM poorly graded gravel with silt** **SP-SC poorly graded gravel with clay**	**[E] Cu = D_{60} / D_{10}** $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ **[F] If soil contains ≥ 15% sand, add "with sand" to group name.** **[G] If fines classify as CL-ML, use symbol GC-GM, or SC-SM** **[H] If fines are organic, add "with organic fines" to group name.** **[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.** **[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.** **[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.** **[L] If soil contains ≥30 % plus No. 200, predominantly sand, add "sandy" to group name.**	**[M] If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.** **[N] PI ≥ 4 and plots on or above "A" line.** **[O] PI < 4 and or plots below "A" line.** **[P] PI plots on or above "A" line.** **[Q] PI plots below "A" line.**

Plasticity Chart for Unified Soil Classification System (USCS)



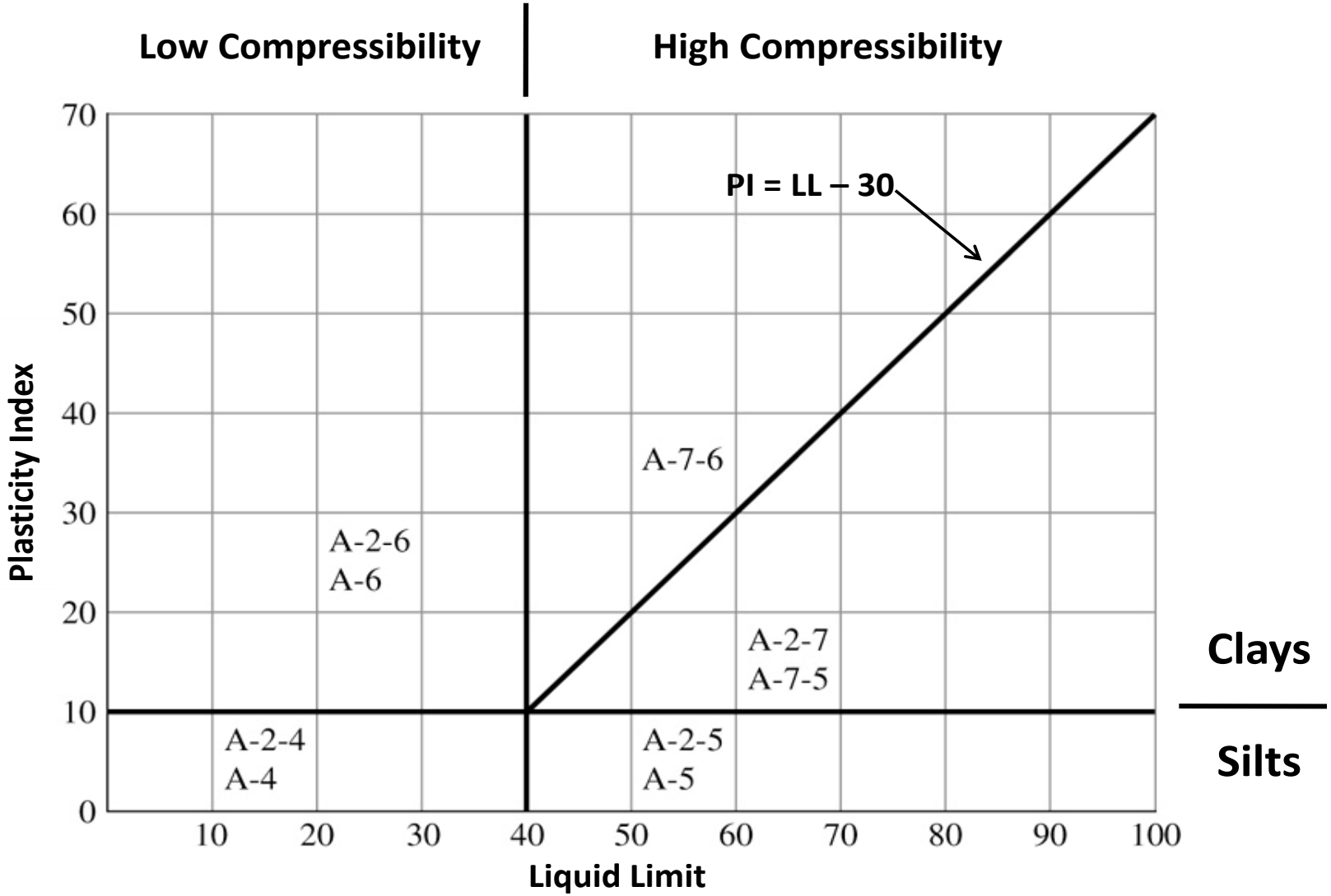
Note: M vs. O based on presence of organics

AASHTO Soil Classification

AASHTO Classification of Soils and Soil-Aggregate Mixtures											
General Classification	Granular Materials (35 Percent or Less Passing 0.075 mm (No. 200) Sieve)							Silt-Clay Materials (More than 35 Percent Passing 0.0075 mm (No. 200) Sieve)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, percent passing 2.00 mm (No. 10) 0.425 mm (No. 40) 0.075 mm (No. 200)	 ≤ 50 ≤ 30 ≤ 15	 - ≤ 50 ≤ 25	 - > 50 ≤ 10	 - - ≤ 35	 - - ≤ 35	 - - ≤ 35	 - - ≤ 35	 - - > 35	 - - > 35	 - - > 35	 - - > 35
Characteristics of fraction passing 0.425 mm (No. 40) sieve Liquid Limit Plasticity Index	 - ≤ 6		 N.P.	 ≤ 40 ≤ 10	 > 40 ≤ 10	 ≤ 40 > 10	 > 40 > 10	 ≤ 40 ≤ 10	 > 40 ≤ 10	 ≤ 40 > 10	 > 40 > 10
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

Notes:
Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30.
Plasticity index of A-7-6 subgroup is greater than LL minus 30. **See AASHTO Plasticity Chart**

AASHTO Plasticity Chart



APPENDIX E – PA GEOLOGIC FORMATIONS, ABBREVIATIONS, AND PERIOD/EPOCH

Geologic Formation	Abbreviation	Period/Epoch
Albite - Chlorite Schist	Xwc	Lower Paleozoic
Allegheny and Pottsville Groups, Undivided	IPap	Pennsylvanian
Allegheny Group	IPa	Pennsylvanian
Allentown Formation	Cal	Cambrian
Annville Formation	Oan	Ordovician
Anorthosite	Xa	Lower Paleozoic
Anorthsite	a	Precambrian
Antietam and Harpers Formations	Cah	Cambrian
Antietam Formation	Ca	Cambrian
Axemann Formation	Oa	Ordovician
Bald Eagle Formation	Obe	Ordovician
Beaverdam Run Member	Dcbr	Devonian
Beekmantown Group	Ob	Ordovician
Bellefonte and Axemann Formations	Oba	Ordovician
Bellefonte Formation	Obf	Ordovician
Benner Formation Through Loysburg Formation, Undivided	Obv/Obl	Ordovician
Berea Sandstone Through Riceville Formation, Undivided	MDbr	Mississippian and Devonian
Berra Sandstone Through Venango Formation, Undivided	MDbv	Mississippian and Devonian
Berry Run and Sawmill Run Members, Undivided	Dcbs	Devonian
Bloomsburg and Mifflintown Formations	Sbm	Silurian
Bloomsburg Formation	Sb	Silurian
Brallier and Harrell Formations, Undivided	Dbh	Devonian
Brunswick Formation	TRb	Triassic
Bryn Mawr Formation	Tbm	Tertiary
Buddys Run Member	Dcb	Devonian
Buffalo Springs Formation	Cbs	Cambrian
Burgoon Sandstone	Mb	Mississippian
Burgoon Sandstone Through Cuyahoga Group, Undifferentiated	Mbc	Mississippian
Buttermilk Falls Limestone Through Esopus Formation, Undivided	Dbe	Devonian
Casselman Formation	IPcc	Pennsylvanian
Catskill Formation	Dck	Devonian
Catskill Formation, Undivided	Dck	Devonian
Chadakoin Formation	Dch	Devonian
Chambersburg Formation	Oc	Ordovician
Chickies Formation	Cch	Cambrian
Clarion Formation	IPa	Pennsylvanian

Geologic Formation	Abbreviation	Period/Epoch
Clarks Ferry Member	Dccf	Devonian
Clinton Group	Sc	Silurian
Coburn Formation Through Nealmont Formation, Undivided	Ocn	Ordovician
Coburn, Nealmont, Benner and Loysburg Formations	Obv/Ocl	Ordovician
Cocalico Formation	Oco	Ordovician
Cockeysville Marble	Xc	Lower Paleozoic
Conemaugh Group	IPc	Pennsylvanian
Conestoga Formation	OCc	Ordovician and Cambrian
Corry Sandstone Through Riceville Formation, Undivided	MDcr	Mississippian and Devonian
Cuyahoga Group	Mc	Mississippian
Decker Formation Through Poxono Island Formation, Undivided	Sdp	Silurian
Diabase	TRd	Triassic
Duncanon Member	Dcd	Devonian
Elbrook Formation	Ce	Cambrian
Epler Formation	Oe	Ordovician
Felsic Gneiss, Hornblende - Bearing	fgh	Precambrian
Felsic Gneiss, Pyroxene - Bearing	fgp	Precambrian
Foreknobs Formation	Df	Devonian
Franklin Marble	fm	Precambrian
Freeport Formation	IPa	Pennsylvanian
Gabbroic Gneiss and Gabbro	gga	Precambrian
Gatesburg Formation	Cg	Cambrian
Gatesburg Formation - Lower Members	Cgl	Cambrian
Gatesburg Formation - Mines Member	Cgm	Cambrian
Gettysburg Conglomerate	TRgc	Triassic
Gettysburg Formation	TRg	Triassic
Girard Shale	Dg	Devonian
Glenshaw Formation	IPcg	Pennsylvanian
Granitic Gneiss	gn	Precambrian
Granitic Gneiss and Granite	Xgr	Lower Paleozoic
Granodiorite and Granodiorite Gneiss	ggd	Precambrian
Graphitic Gneiss	gg	Precambrian
Greene Formation	Pg	Permian
Greenstone Schist	vs	Precambrian
Hamburg Sequence Rocks - Andesite Intrusives	Ohe	Ordovician
Hamburg Sequence Rocks - Conspicuous Limestone	Ohl	Ordovician
Hamburg Sequence Rocks - Predominantly Graywacke	Ohg	Ordovician
Hamburg Sequence Rocks - Predominantly Phyllitic Shale	Oh	Ordovician
Hamburg Sequence Rocks - Shale and Graywacke	Ohsg	Ordovician
Hamilton Group	Dh	Devonian
Hammer Creek Conglomerate	TRhc	Triassic

Geologic Formation	Abbreviation	Period/Epoch
Hammer Creek Formation	TRh	Triassic
Hardyston Formation	Cha	Cambrian
Harpers Formation	Ch	Cambrian
Harpers Formation - Includes Montalto Member	Chm	Cambrian
Heidlersburg Member	TRgh	Triassic
Hershey and Myerstown Formations, Undivided	Ohm	Ordovician
Hershey, Myerstown and Annville Formations	Oha	Ordovician
Holocene	Qs	Quaternary
Hornblende Gneiss	hg	Precambrian
Huntley Mountain Formation	MDhm	Mississippian and Devonian
Irish Valley Member	Dclv	Devonian
Jacksonburg Formation	Ojk	Ordovician
Juniata and Bald Eagle Formations	Ojb	Ordovician
Juniata Formation	Oj	Ordovician
Keyser and Tonoloway Formations, Undivided	DSkt	Devonian and Silurian
Keyser Formation Through Clinton Group, Undivided	DSkc	Devonian and Silurian
Keyser Formation Through Mifflintown Formation, Undivided	DSkm	Devonian and Silurian
Kimberlite	Jk	Jurassic
Kinzers Formation	Ck	Cambrian
Kittanning Formation	IPa	Pennsylvanian
Ledger Formation	Cl	Cambrian
Leithsville Formation	Clv	Cambrian
Limestone Fanglomerate	TRfl	Triassic
Llewellyn Formation	IPl	Pennsylvanian
Lock Haven Formation	Dlh	Devonian
Lockatong Formation	TRl	Triassic
Long Run Member	Dclr	Devonian
Lower Cambrian Rocks, Undivided	Cul	Cambrian
Mafic Gneiss, Hornblende - Bearing	mgh	Precambrian
Mafic Gneiss, Hornblende - Bearing	Xmgh	Lower Paleozoic
Mafic Gneiss, Pyroxene - Bearing	mgp	Precambrian
Mafic Gneiss, Pyroxene - Bearing	Xmgp	Lower Paleozoic
Mahantango Formation	Dmh	Devonian
Marburg Schist	Xwm	Lower Paleozoic
Marcellus Formation	Dm	Devonian
Martinsburg Formation	Om	Ordovician
Martinsburg Formation w/ Argillaceous Limestone and Shale	Oml	Ordovician
Martinsburg Formation w/ Impure Sandstone (Graywacke) Interbeds	Omgs	Ordovician
Matavolcanics	Xwv	Lower Paleozoic
Mauch Chunk Formation	Mmc	Mississippian
Metabasalt	mb	Precambrian

Geologic Formation	Abbreviation	Period/Epoch
Metadiabase	md	Precambrian
Metadiabase	Od	Ordovician
Metagabbro	Xmg	Lower Paleozoic
Metarhyolite	mr	Precambrian
Millbach and Schafferstown Formations	Cms	Cambrian
Millbach Formation	Cms	Cambrian
Monongahela Group	IPm	Pennsylvanian
New Oxford Conglomerate	TRnc	Triassic
New Oxford Formation	TRn	Triassic
Nittany and Stonehedge/Larke Formations	Ons	Ordovician
Nittany Formation	On	Ordovician
Northeast Shale	Dne	Devonian
Old Port Formation, Ridgeley Member	Dor	Devonian
Old Port Formation: Shriver, Mandata, Corriganville and New Creek Members	Dosn	Devonian
Oligoclase - Mica Schist	Xw	Lower Paleozoic
Onondaga and Old Port Formations	Doo	Devonian
Onondaga Formation	Don	Devonian
Onondaga Formation Through Poxono Island Formation, Undivided	DSop	Devonian and Silurian
Ontelaunee Formation	Oo	Ordovician
Packerton Member	Dcp	Devonian
Patapsc Formation	Kp	Cretaceous
Peach Bottom Slate and Cardiff Conglomerate, Undivided	Xpb	Lower Paleozoic
Pegmatite	Xpg	Lower Paleozoic
Pensauken and Bridgeton Formations	Tpb	Tertiary
Peters Creek Schist	Xpc	Lower Paleozoic
Pinesburg Station Formation	Ops	Ordovician
Pleasant Hill Formation	Cph	Cambrian
Pocono and Rockwell Formation, Undivided	MDpr	Mississippian and Devonian
Pocono Formation	Mp	Mississippian
Poplar Gap Member	Dcpg	Devonian
Pottsville Group	IPp	Pennsylvanian
Quartz	TRfq	Triassic
Quartz Monzonite and Quartz Monzonite Gneiss	gqm	Precambrian
Reedsville Formation	Or	Ordovician
Richland Formation	Cr	Cambrian
Rickenbach Formation	Ori	Ordovician
Ridgeley Formation Through Coeymans Formation, Undivided	Dcr	Devonian
Rockdale Run Formation	Orr	Ordovician
Rockwell Formation	MDr	Mississippian and Devonian
Scherr Formation	Ds	Devonian
Serpentinite	Xs	Lower Paleozoic

Geologic Formation	Abbreviation	Period/Epoch
Setters Quartzite	Xsg	Lower Paleozoic
Shadygrove Formation	Csg	Cambrian
Shawangunk Formation	Ss	Silurian
Shenango Formation	Ms	Mississippian
Shenango Formation Through Cuyahoga, Undivided	Msc	Mississippian
Shenango Formation Through Oswayo Formation, Undivided	MDso	Mississippian and Devonian
Sherman Creek Member	Dcsc	Devonian
Snitz Creek and Buffalo Springs Formations	Csb	Cambrian
Snitz Creek Formation	Csc	Cambrian
Spechty Kope Formation	MDsk	Mississippian and Devonian
St. Paul Group	Osp	Ordovician
Stockton Conglomerate	TRsc	Triassic
Stockton Formation	TRs	Triassic
Stonehedge Formation	Os	Ordovician
Stonehedge/Larke Formation	Osl	Ordovician
Tomstown Formation	Ct	Cambrian
Towamensing Member	Dct	Devonian
Trenton Gravel	Qt	Quaternary
Trimmers Rock Formation	Dtr	Devonian
Tuscarora Formation	St	Silurian
Venango Formation	Dv	Devonian
Vintage Formation	Cv	Cambrian
Wakefield Marble	Www	Lower Paleozoic
Walcksville Member	Dcw	Devonian
Warrior Formation	Cw	Cambrian
Washington Formation	Pw	Permian
Wayneburg Formation	PIPw	Permian and Pennsylvanian
Waynesboro Formation	Cwb	Cambrian
Weverton and Loudoun Formations, Undivided	Cwl	Cambrian
Wills Creek Formation	Swc	Silurian
Wills Creek, Bloomsburg, and Mifflintown Formations	Swm	Silurian
Wissahickon Formation	Xw	Cambrian and Ordovician
Zooks Corner Formation	Czc	Cambrian
Zullinger Formation	Cz	Cambrian

APPENDIX F – GENERAL MAPS OF PENNSYLVANIA

See the attached maps downloadable from DCNR.

Geologic Map of Pennsylvania

Glacial Deposits of Pennsylvania

Surficial Materials of Pennsylvania

Physiographic Provinces of Pennsylvania

Distribution of Pennsylvania Coals

Limestone and Dolomite Distribution in Pennsylvania

Oil and Gas Fields of Pennsylvania

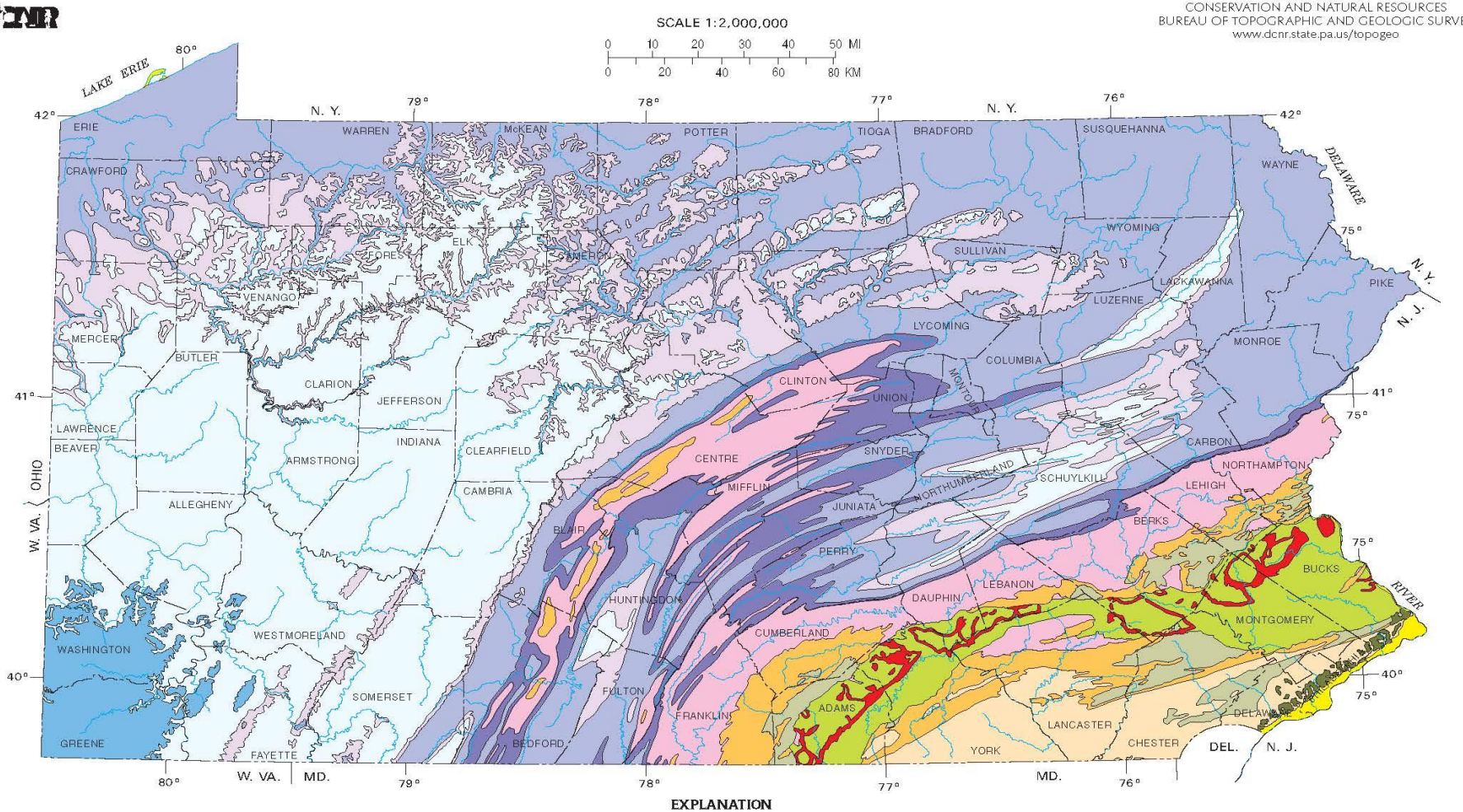
Geologic Units Containing Potential Significant Acid-Producing Sulfide Minerals

Additional maps related to Marcellus, Utica, and Devonian Shale are downloadable from MCOR.

MAP 7

GEOLOGIC MAP OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

QUATERNARY (0–1.8 mil. yrs.) Sand, gravel, and silt. *Sand and gravel.*	TERTIARY (1.8–65 mil. yrs.) Sand, gravel, silt, and clay. *Sand and gravel.*	* JURASSIC AND TRIASSIC (144–248 mil. yrs.) Red sandstone, shale, and conglomerate (green), intruded by diabase (red). *Building stone, iron.*	PERMIAN (248–290 mil. yrs.) Cyclic sequences of shale, sandstone, limestone, and coal. *Lime, clay.*	PENNSYLVANIAN (290–323 mil. yrs.) Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone. *Coal, clay, lime, building stone.*	MISSISSIPPIAN (323–354 mil. yrs.) Red and gray sandstone, shale, and limestone. *Flagstone, limestone, clay.*	DEVONIAN (354–417 mil. yrs.) Red sandstone, gray shale, black shale, limestone, and chert. *Flagstone, silica sand, clay, lime.*	SILURIAN (417–443 mil. yrs.) Red and gray sandstone, conglomerate, shale, and limestone. *Lime, building stone.*	ORDOVICIAN (443–490 mil. yrs.) Shale, limestone, dolomite, and sandstone. *Slate, limestone, zinc, clay.*	CAMBRIAN (490–570 mil. yrs.) Limestone, dolomite, sandstone, shale, quartzite, and phyllite. *Lime, building stone.*	LOWER PALEOZOIC (443–570 mil. yrs.) Metamorphic rocks (metasedimentary and meta-igneous): schist, gneiss, quartzite, serpentine, slate, and marble. *Building stone, talc.*	PRECAMBRIAN (older than 570 mil. yrs.) Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble. *Building stone, graphite, sericite.*

*Cretaceous rocks, which are present in small areas of southern Montgomery County, cannot be shown at the scale of this map.

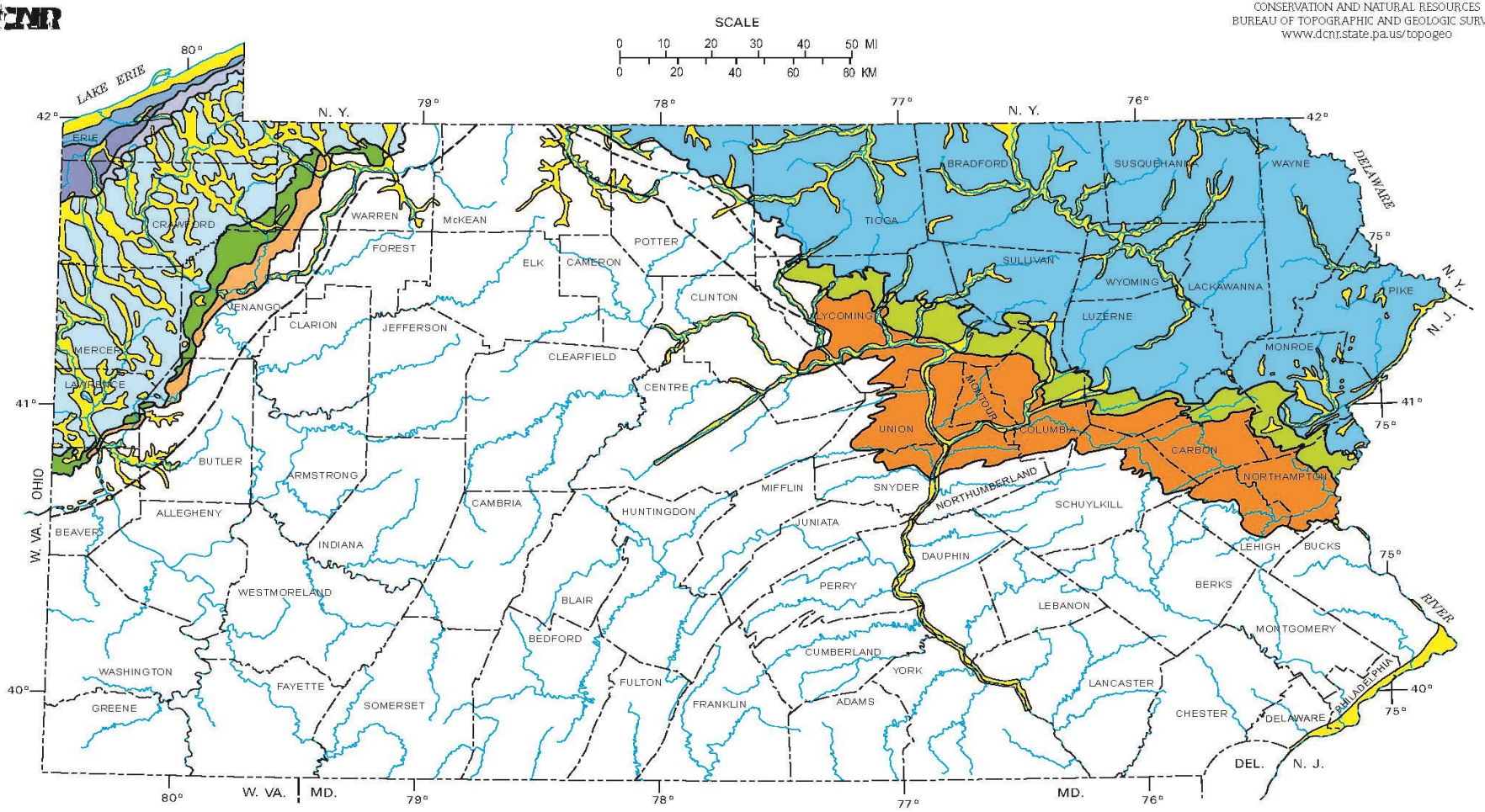
Prepared by Bureau of Topographic and Geologic Survey. Third Edition, 1990; Fourth Printing, Slightly Revised, 2007.

2200-MP-DCNR0498
Printed on Recycled Paper

MAP 59

GLACIAL DEPOSITS OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

RECENT TO LATE ILLINOIAN (0–198,000 yrs.)

STRATIFIED DRIFT

Sand and gravel in eskers, kames, kame terraces, and outwash, principally in valleys; silt and clay in lake deposits in formerly ice-dammed valleys; lake clays and beach sands and gravels along Lake Erie; thin (Recent) to thick (late Illinoian) soils.

WISCONSINAN (17,000–22,000 yrs.)

ASHTABULA TILL
HIRAM TILL
LAVERY TILL
KENT TILL

Thick, gray, clayey to silty to sandy till covering over 75 percent of the ground; topography is mainly gently undulating, but there is also some knob-and-kettle topography; thin soil.

OLEAN TILL

Moderately thick, gray to grayish-red, sandy till covering 25 to 50 percent of the ground; very thin till covers an additional 25 percent of the ground; topography reflects the underlying bedrock; thin soil.

LATE ILLINOIAN (132,000–198,000 yrs.)

TITUSVILLE TILL
UNNAMED TILLS

Thin, gray (Titusville) to brown and grayish-red (unnamed), clayey to sandy till covering 10 to 25 percent of the ground; topography reflects the underlying bedrock; moderately thick, well-developed soil.

PRE-ILLINOIAN (>770,000 yrs.)

MAPLEDALE TILL
UNNAMED TILLS

Thin, gray, clayey to silty till in patches covering up to 10 percent of the ground; topography reflects the underlying bedrock; thick, well-developed soil, commonly having a yellowish-red color.

SYMBOLS

Southern limit of glacial advance

Approximate limit of Illinoian advance

Approximate limit of pre-Illinoian advance

By W. D. Sevon and D. D. Braun.
Second Edition, 1997; Second Printing, 2000.

2200-MP-DCNR3027
Printed on Recyded Paper

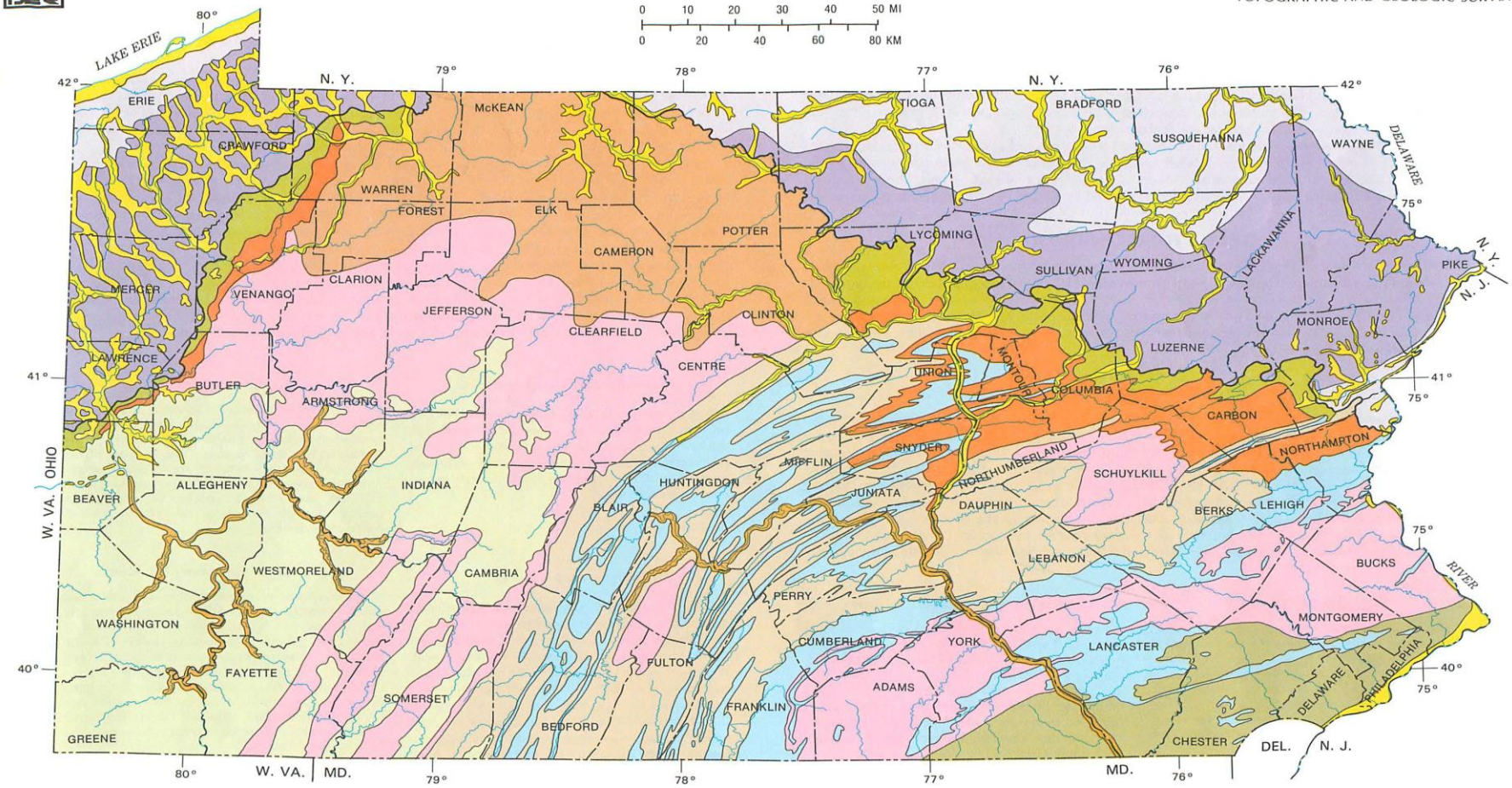
MAP 64

SURFICIAL MATERIALS OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF PARKS AND FORESTRY
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY

SCALE 1:2,000,000

0 10 20 30 40 50 MI
0 20 40 60 80 KM



EXPLANATION

(See reverse side for detailed explanation of map units)

GLACIAL DIAMICTS

- STRATIFIED SAND AND GRAVEL
- STREAM TERRACE DEPOSITS
- Silty glacial diamict
- Sandy glacial diamict
- Sandy to silty glacial diamict
- Sandy to clayey glacial diamict

RESIDUUM, COLLUVIUM, AND ALLUVIUM

- Plateaus and deep valleys
- Ridges and valleys
- Mixed topography and rocks
- Carbonate rocks
- Igneous and metamorphic rocks
- Residuum and landslides

SYMBOLS

- Approximate contact between surficial materials
- Late Wisconsinan glacial border

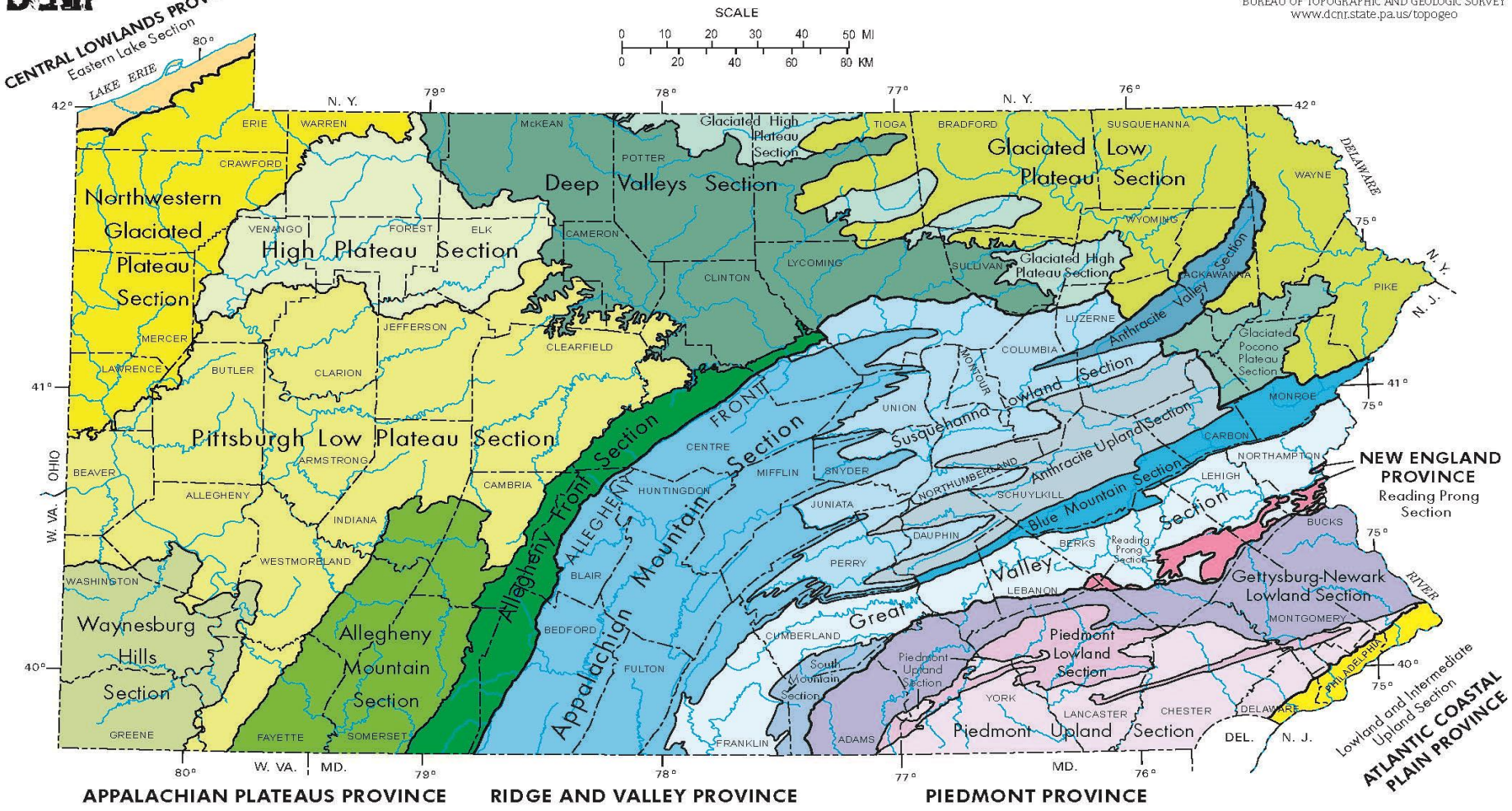
Compiled by W. D. Sevon

DER #381-3/92

MAP 13

PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

CENTRAL LOWLANDS PROVINCE: Eastern Lake Section

APPALACHIAN PLATEAUS PROVINCE: Northwestern Glaciated Plateau Section; High Plateau Section; Pittsburgh Low Plateau Section; Waynesburg Hills Section; Allegheny Mountain Section; Allegheny Front Section; Deep Valleys Section; Glaciated High Plateau Section; Glaciated Low Plateau Section; Glaciated Pocono Plateau Section

RIDGE AND VALLEY PROVINCE: Appalachian Mountain Section; Susquehanna Lowland Section; Anthracite Valley Section; Anthracite Upland Section; Blue Mountain Section; Great Valley Section; South Mountain Section

NEW ENGLAND PROVINCE: Reading Prong Section

PIEDMONT PROVINCE: Gettysburg-Newark Lowland Section; Piedmont Lowland Section; Piedmont Upland Section

ATLANTIC COASTAL PLAIN PROVINCE: Lowland and Intermediate Upland Section

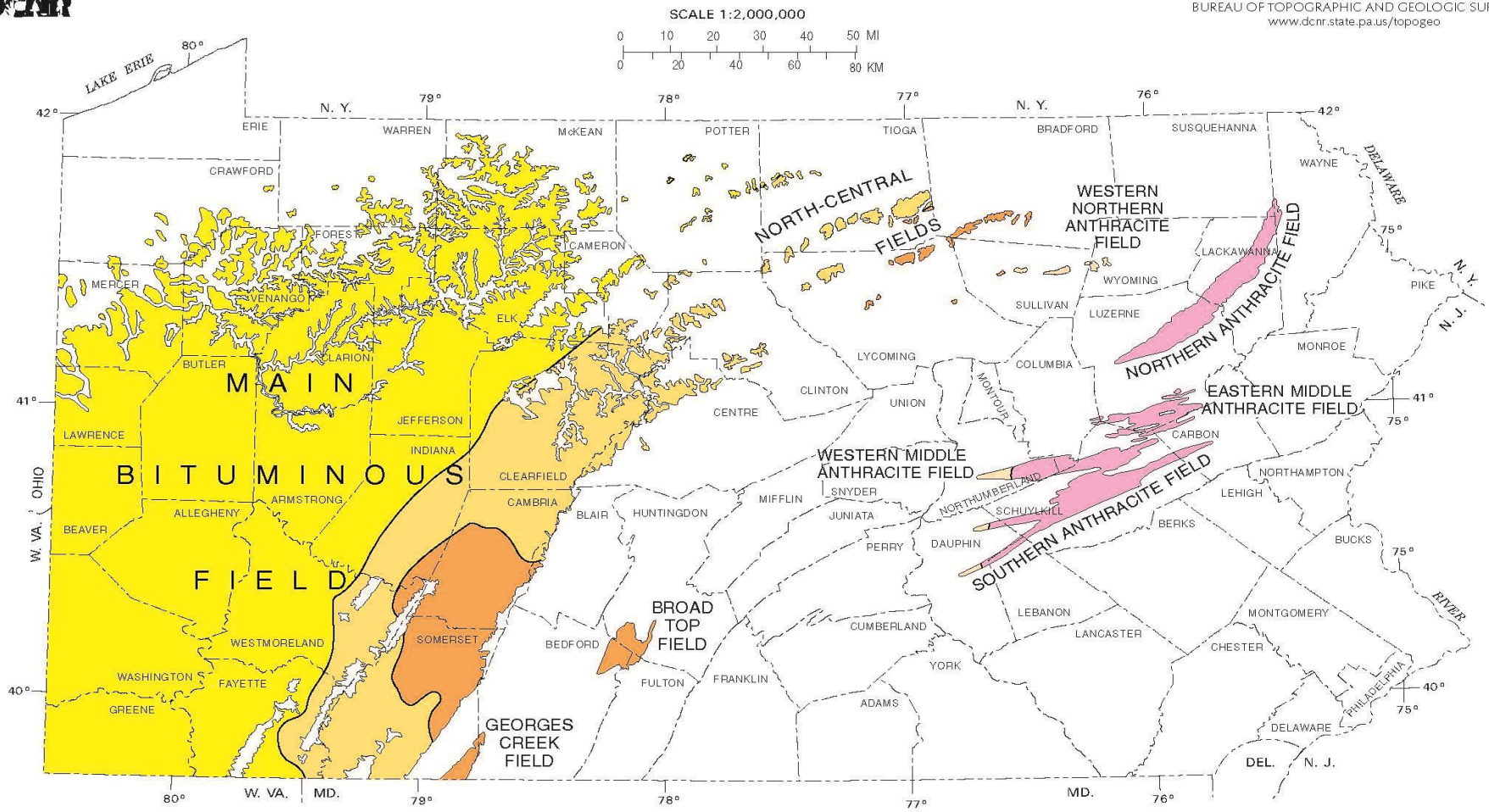
SYMBOLS
Approximate boundary between physiographic provinces
Approximate boundary between physiographic sections

Compiled by W. D. Sevon. Fourth Edition, 2000.

MAP 11

DISTRIBUTION OF PENNSYLVANIA COALS

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

BITUMINOUS FIELDS

- High-volatile bituminous coal
- Medium-volatile bituminous coal
- Low-volatile bituminous coal

ANTHRACITE FIELDS

- Semi-anthracite
- Anthracite

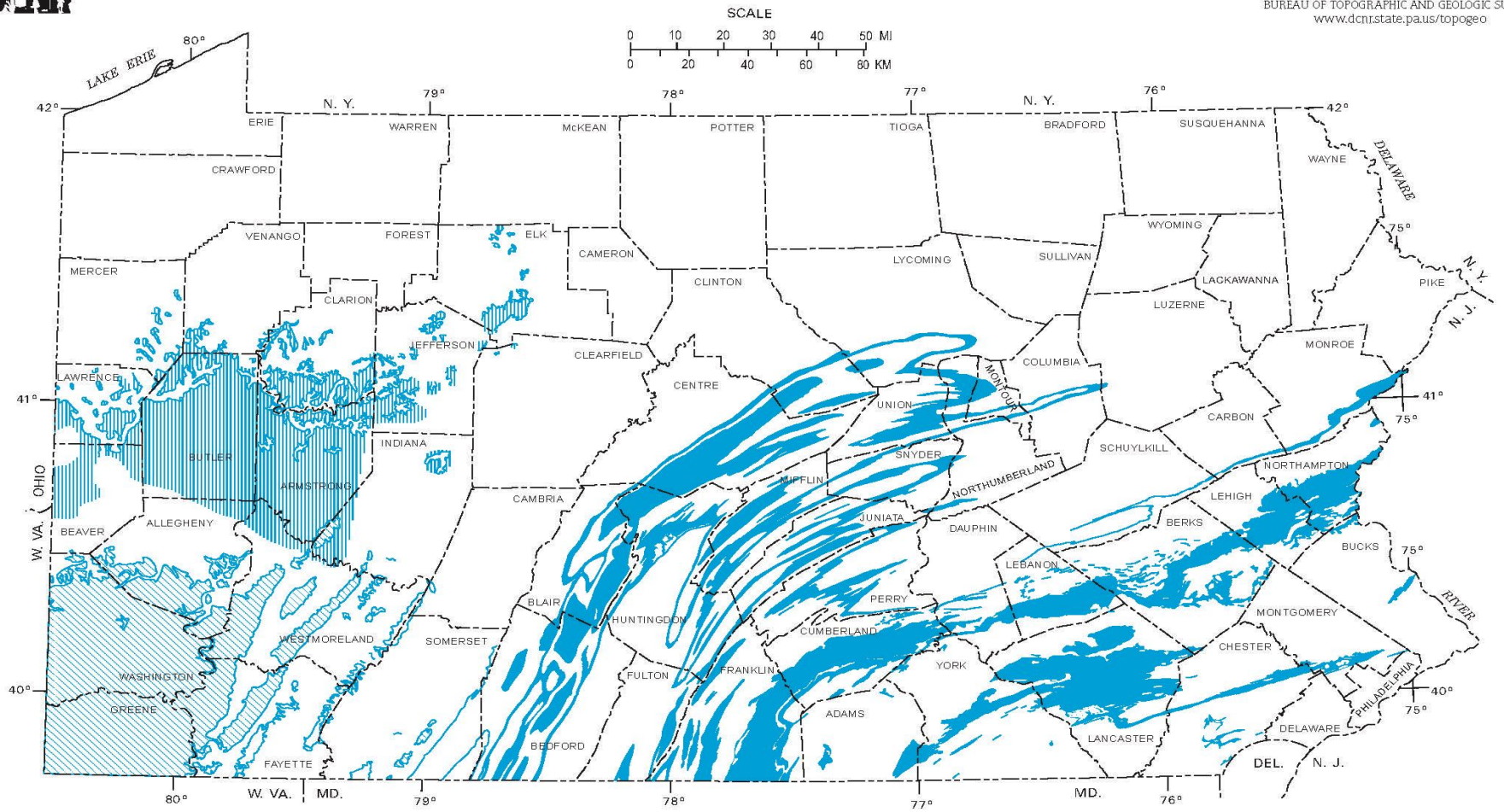
Prepared by Bureau of Topographic and Geologic Survey.
Third Edition, Revised, 2000; Third Printing, 2008.

2200-MP-DCNR0855
Printed on Recycled Paper

MAP 15

LIMESTONE AND DOLOMITE DISTRIBUTION IN PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

Area where limestone, dolomite, or both are at the surface. Layers are usually strongly folded and steeply dipping. Includes economically important high-calcium limestones of the Kinzers, Annville, Benner, and Keyser Formations and the Cockeysville Marble, as well as the high-magnesian dolomites of the Ledger Formation and the Cockeysville Marble. This area is most susceptible to sinkhole development.

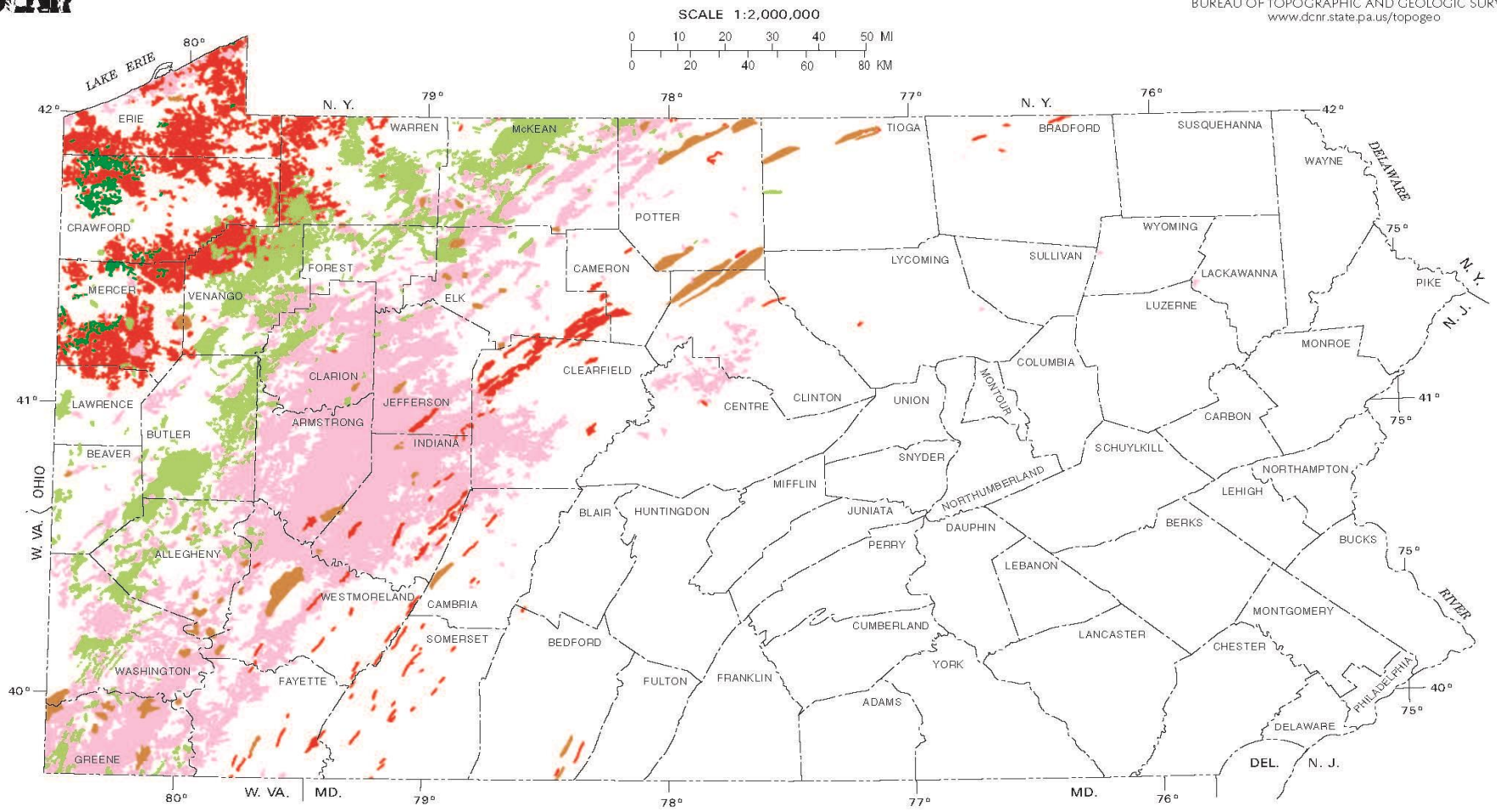
Area underlain by flat-lying, generally thin, but locally thick, limestone beds, which are discontinuous in places and are commonly interbedded with shale.

Area underlain by the generally flat lying Pennsylvanian Vanport Limestone, a high-calcium limestone. This limestone is generally overlain by less than 100 feet of sedimentary rocks, except in the southern part of the area.

MAP 10

OIL AND GAS FIELDS OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



EXPLANATION

Shallow oil field | Deep oil field | Shallow gas field | Deep gas field | Gas storage area

Compiled by K. L. McCoy and Zachary Schmitt.
Fourth Edition, 2007.

2200-MP-DCNR0854
Printed on Recycled Paper

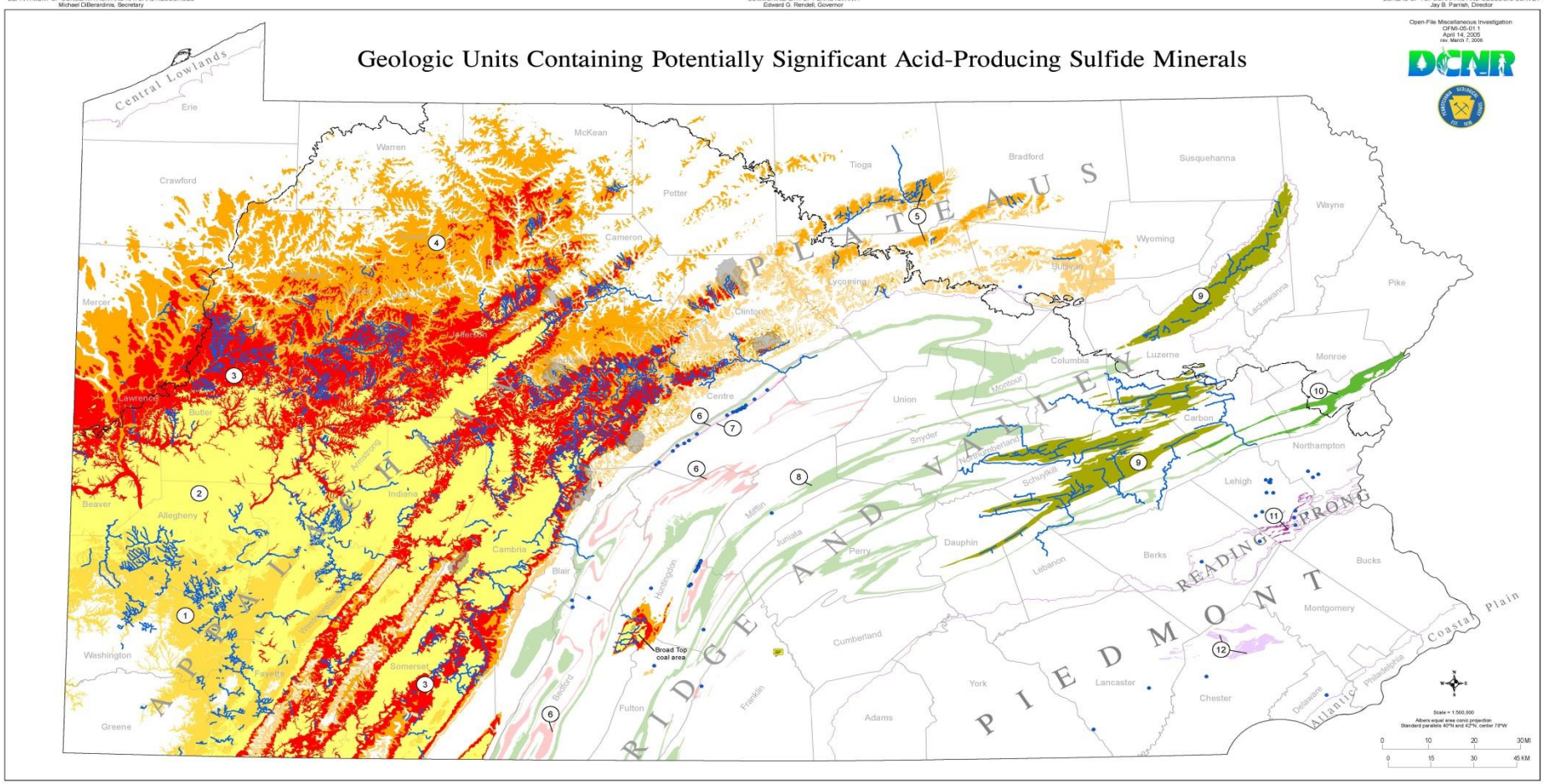
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Michael DiBerardinis, Secretary

COMMONWEALTH OF PENNSYLVANIA
Edward G. Rendell, Governor

BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
Jay B. Parrish, Director

Geologic Units Containing Potentially Significant Acid-Producing Sulfide Minerals

Open-File Miscellaneous Investigation
OFMI-05-01.1
April 14, 2005
rev. March 7, 2006



EXPLANATION

Map Compilation Notes

Original map scale is 1:500,000. The map is not intended to be used for detailed or site-specific analyses, nor is it intended to be used at any scale finer than 1:250,000 (for example, use at 1:24,000 or 1:100,00 scales is inappropriate).

Map rock formation color does not imply "risk" or potential of acid drainage, but only represents different geologic units.

Bedrock geology units are based on the digital compilation by Miles and Whitfield, 2001.

Map Layers

Point locations of potentially significant sulfide mineralization based on published and unpublished information, Pennsylvania Geological Survey (PaGS).

Late Wisconsinan glacial border (PaGS, 1995).

Preliminary landform subdivisions of Pennsylvania (PaGS, 1998).

Streams impaired by abandoned mine drainage from 1998 to 2004 with problems listed as including pH and/or metals, Pennsylvania Department of Environmental Protection, 2004.

Areas declared by Pennsylvania Department of Environmental Protection to be unsuitable for mining due to potential AD.

Appalachian Plateaus

(1) Monongahela Group and Waynesburg Formation. Includes known problematic coals such as the Pittsburgh and Waynesburg coals (and underclays), and the Sewickley coals, which can also have acidic drainage.

(2) Conemaugh Group. Includes the Casselman and Glenshaw Formations, and the Conemaugh Formation of the Broadtop coal region in northeastern Bedford and southern Huntingdon Counties. Although typically not as problematic as other coal-bearing units, the Conemaugh can produce acid drainage.

(3) Allegheny Formation. Includes problematic coals such as the Clarion, Lower Kittanning, and Middle Kittanning coals. Fewer problems occur with the Upper Kittanning and Freeport coals.

(4) Pottsville Formation, in western Pennsylvania, and Pottsville and Allegheny Formations, undivided, in north-central Pennsylvania. Especially east and southeast of the plateau along the Allegheny Front; includes the Mercer coals, which can be problematic. Calcareous minerals are rare in the Pottsville.

(5) Burgoon Formation, in north-central Pennsylvania and along the Allegheny Front.

Ridge and Valley

(6) The Tuscarora Formation in Huntingdon, Bedford, Blair, and Centre Counties, and in the Metal Township area, Franklin County.

(7) The Bald Eagle Formation along Bald Eagle ridge in Centre County.

(8) The top of Ridgeley Formation through base of Marcellus Formation (including the Onondaga Formation). Map units shown are the Ridgeley member of the Old Port Formation, Onondaga Formation, Onondaga and Old Port Formations, undivided, and the Hamilton Group, but only the top of the Ridgeley and the base of the Marcellus are targets.

(9) The anthracite coal fields in eastern Pennsylvania (includes the Pottsville and Llewellyn Formations).

(10) In the Carbon and Monroe Counties area, the top of Palmerton Sandstone through base of Marcellus Formation, Carbon County. Map units include Buttermilk Falls Limestone through Esopus Formation, undivided, and the Marcellus Formation, but only the top of Palmerton Sandstone and the base of Marcellus Formation are targets.

Piedmont and Reading Prong

(11) The base of Hardyston Formation in Lehigh County. All of the Hardyston Formation in Lehigh County is shown.

(12) The Pickering Gneiss. Map unit is the graphitic felsic gneiss.

Potential Acidic Rock Units in Pennsylvania

Typical geologic weathering of undisturbed rock is a slow process involving the natural stability of minerals on the Earth's surface. In most cases in Pennsylvania, acidic drainage involves iron sulfide minerals such as pyrite and its exposure to air to create iron oxides and acidic water. Naturally occurring acute acid drainage is uncommon in Pennsylvania. In every significant case, it is the exposure of iron sulfides to air by dropping the water table or excavating rock, the lack of any inherent buffering capability, and the flow of water through the rocks that create acidic drainage.

The chemistry of acid drainage (AD) is understood, and prediction of AD is possible through a combination of several methods. Experience and understanding of specific geologic formations and combinations of geologic units on a regional and local scale are used to assess the potential for acidic drainage. Quantitative onsite prediction of acidic drainage has become possible through the geochemical analysis of the rocks. Calculations of acid-base balance based on neutralization potential and potential acidity can be used to quantitatively predict whether disturbance of a site will cause AD. Such calculations in conjunction with site history and experience, along with judgments with regard to geology and site hydrology, allow accurate predictions to be made.

Although specific geologic units are known to possibly cause problems, numerous factors influence the outcome of mining or excavation of the rock unit. The presence of buffering substances (mainly calcareous minerals) is a chief factor in preventing the development of AD. The occurrence of calcareous minerals is related to the rock type and the depositional environment of rocks at the site. Calcareous minerals can prevent the occurrence of AD in rocks that contain acid-forming minerals. In addition, the kinetics of the reaction may not allow AD to be seen for years.

Coal-bearing rocks of Pennsylvania have been a particular source of AD. However, all coal units and associated formations are not equal sources. Some geologic units are typically AD free; others are commonly sources of AD. Some units will produce AD depending on the overburden composition at the site.

In the Appalachian plateaus of western Pennsylvania, the extent of knowledge is typically based on the mining of coal. Less is known about units that have not traditionally been mined. For specific information about coal mine prediction of these mainly coal containing units, see the report *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania* (Brady and others, 1998). The source of acidity (iron sulfides) is typically depositional, although structural features may have enhanced the occurrence of sulfides.

The abundance and distribution of sulfides in the Appalachian plateaus are often related to depositional environment, whereas the sulfides in the Ridge and Valley physiographic province have been more affected by Alleghanian structural features (faults, fractures, lineaments, etc.) and fluid movement. To the southeast in the Piedmont, structural complexities and metamorphism combine to defy simple explanation of the occurrence of sulfide mineralization. Where sulfides are not areally large or discontinuous, scattered point occurrences of sulfide mineralization are shown on the map.

This map indicates formations that may have acid-forming minerals, primarily pyrite. Although this map is useful for general planning and preliminary site studies, it does not substitute for site-specific subsurface investigations of the rock units that will be disturbed through excavation, mining, or drilling. The occurrence of AD depends on numerous factors, including rock type, mineralogy, geochemistry, geologic structure (e.g., fractures, joints, and faults), changing the water table, surface and sub-surface hydrology, extent of geologic weathering, and depositional environments.

In addition, the extent of Wisconsinan glaciation is indicated on the map. The Wisconsinan glaciation may have removed weathered (oxidized) rocks. Thus the "inert" oxidized zone that typically blankets most rocks in Pennsylvania may be thin or absent in glaciated areas. The effect of older glacial episodes on the oxidized bedrock is not well understood.

The map indicates geologic units and points that may have the potential to generate AD. It of course does not guarantee that AD will occur or conversely, that AD cannot occur in other areas and formations not shown on this map. The occurrence of AD, therefore, is not restricted to the areas delineated on the map.

Site-specific assessment of AD potential is the only reliable way to predict it. Pre-site investigation data is often available from previous studies, including college theses, consultant reports, geologic survey reports, aerial photographs, existing geophysical surveys, and the like. There is, however, no substitute for site specific information including interviews with local residents, geologic logs of borings, analysis of site geochemistry (water and rock), and other sources of information.

General guidelines on recognizing potential acid-producing rock in Pennsylvania

The presence of sulfide-bearing rock formations and isolated occurrences of sulfide deposits in Pennsylvania depends on a wide variety of factors including the rock's depositional and structural history, its mineralogy and geochemistry, and present surface and subsurface hydrologic and geochemical environment.

The common iron-sulfide minerals pyrite (FeS_2) and less common pyrrhotite (FeS) and marcasite (FeS_2) are the dominant sources of acidity. However, specific buffering minerals can offset their presence, and the groundwater and surface water setting can control the development of AD.

Appalachian Plateaus

(1) (2) (3) (4) (5)

In the Appalachian Plateaus physiographic province, the source of acidity (iron sulfides) is typically depositional, although structural features such as faults and lineaments may enhance the occurrence of sulfides or flow of groundwater. Sulfide minerals are associated with coal-bearing rocks, some underclays, and black shales.

Every coal-bearing unit in western Pennsylvania has some potential for AD. Potentially acid-producing rocks include underclays beneath coals, the coal beds themselves, or rocks of the coal overburden. Black shales may contain significant quantities of iron sulfides. The overburden of coals associated with marine or fresh water units are less likely to yield AD than marginal marine (brackish) units due to the association of limestones and other calcareous units with marine and freshwater environments.

Some geologic units may contain only moderate levels of pyrite, but lack buffering calcareous minerals. Sandstones in the Allegheny and Pottsville Formations and the Burgoon Sandstone fall into this category.

A history of AMD, presence of black shales, rocks with low amounts of calcareous minerals, or rocks with pyritic minerals are those that should be especially considered as having the potential to produce AD. However, an unmined area with no acidic drainage does not necessarily mean that there is not a possibility of AD when rocks are excavated or the water table drops and exposes acidic rocks.

Ridge and Valley

(6) (7) (8) (9) (10)

Dark shales, sulfide mineralized areas, fractured rocks, and rocks with little calcareous material are zones that should be considered as having the potential to produce AD in the Ridge and Valley physiographic province. This could include formations with thin dark shale layers that are not listed on the map (for example, the Mifflintown Formation in central Pennsylvania).

Dark shales commonly hold primary sulfide minerals derived from its specific depositional environment. The Tuscarora Formation, a sandstone, is the host of some secondary mineralization based on its proximity to a source of sulfide minerals, insignificant calcareous material, and its tendency to fracture. Mobile sulfide-bearing solutions amassed in secondary spaces of the rocks based on complex factors such as intersecting fractures and source fluid movement. Similar conditions may occur in carbonate rocks, but because of their dominant calcareous composition, they pose no known threat of AD.

Concentrated sulfide mineralization may be evident on the surface in the form of oxidized pyrite, leaving behind various iron oxide minerals as gossan. Newly excavated material beneath a gossan cap should be monitored for its ability to produce AD. The presence of sulfide minerals is typically apparent because of their production of iron oxide minerals. However, the potential of AD by rocks such as black shales that can have disseminated microscopic pyrite may be evident only through geochemical analysis.

Anthracite Region

(9)

The Anthracite Region is part of the Ridge and Valley physiographic province. Acid problems can occur when pyritic coal associated rocks are disturbed. The chemistry of the rock between the coals is poorly understood, but the presence of acid mine drainage from more than a century of mining indicates that the potential for acid drainage exists and caution should be exercised when excavating material.

Piedmont and Reading Prong

(11) (12)

Some sulfide mineralization is associated with the Pickering Gneiss and other formations. However, lithologic and structural complexity and regional metamorphism combine to make prediction of sulfide mineralization difficult. It is unlikely that all mineralization has been discovered. Scattered point occurrences of sulfide mineralization attest to the wide distribution of such mineralized areas.

As noted previously, site-specific assessment of AD potential is the only reliable way to predict it.

References

Brady, K., Smith, M. W., and Schueck, J. (editors), 1998, Coal mine drainage prediction and pollution prevention in Pennsylvania, Pennsylvania Department of Environmental Protection, 375 p., URL link: [http://www.dep.state.pa.us/dep/deputate/minres/districts/CMDP/main.htm].

Miles, C. E., and Whitfield, T. G., compilers, 2001, Bedrock geology of Pennsylvania: Pennsylvania Geological Survey, 4th ser., dataset, scale 1:250,000, URL link: [http://www.dcnr.state.pa.us/topogeo/map1/bedmap.aspx].

Pennsylvania Geological Survey, 1995, Late Wisconsinan glacial border 1:100,000, URL link: [http://www.pasda.psu.edu/summary.cgi/dcnr/pagq/pags_glacier1k.xml].

Pennsylvania Geological Survey, 1998, Preliminary landform subdivisions of Pennsylvania, URL link: [http://www.pasda.psu.edu/documents.cgi/dcnr/pagq/pags_landform98.xml].

Acknowledgements

Information compiled from published and unpublished information. Major contributions to this map are from:

S. Berkheiser, S. Reese, and R. Smith (retired) of the Pennsylvania Geological Survey; and D. Bisko, K. Brady, M. Gardner, M. Hill, K. Leebov, M. McCommons, M. Smith, and J. Terantino of the Pennsylvania Department of Environmental Protection.

Scale = 1:500,000
Albers equal area conic projection
Standard parallels 40°N and 42°N, center 78°W

0 10 20 30 MI
0 15 30 45 KM

APPENDIX G – ROCK IDENTIFICATION AND DIAGNOSTIC FLOW CHARTS

Refer to the Rock Type Identification Charts to aid in identifying:

Metamorphic Rocks

Igneous Rocks

Sedimentary Rocks (Two Pages)

Refer to the Pennsylvania Diagnostic Flow Charts to aid in identifying:

Metamorphic Rocks

Igneous Rocks

Sedimentary Rocks

Note: The charts are intended for use in identifying most metamorphic, igneous, and sedimentary rocks in Pennsylvania and therefore do not include all rock types.

Rock Type Identification Chart for Metamorphic Rocks [1]

Texture	Dominant Mineral Constituent		Description, Composition, and Diagnostic Features	Color (other variations possible)	Rock Type	Parent Rock	Example Map Unit/Locality [2]
Foliated [3] (a planar rock fabric with preferred orientation of mineral grains because of heat and pressure)	mica, quartz, feldspar, chlorite	Increasing grain size ↓	Microscopic to fine-grained (<0.04 to 1/32 in.)[4]; well foliated (slaty cleavage); dense	variable, gray, red, and green	Slate	Shale, claystone, siltstone	Peach Bottom Slate/York Co. Pen Argyl Member/Lehigh Co.
	mica, quartz, feldspar, chlorite		Fine-grained (0.04 to 1/32 in.); well foliated; lustrous; silky; may contain distinct crystals (porphyroblasts – commonly garnet if present)	most commonly silvery gray or greenish gray, red	Phyllite	Slate	Harpers Formation/Lancaster Co., present within Greenstone Schist/Adams Co. and within some limestone units (Elbrook Fm.)
	chlorite, mica, garnet, quartz, feldspar, amphibole		medium to coarse-grained (1/32 to 3/8 in.); schistose texture; platy minerals predominate; frequently contains distinct crystals (porphyroblasts common)	usually appears silvery-gray, to brown due to abundant mica content	Schist	Phyllite	Peters Creek and Marburg Schist/York Co.
	quartz, feldspar, hornblende, mica, garnet	Banded	alternating bands of light and dark minerals; medium to coarse-grained (1/32 to 3/8 in.); well foliated	gray, pink, darker layers foliated, lighter layers granular in texture	Gneiss	Schist, Granite	Baltimore Gneiss/Lancaster and Chester Co.
Non-Foliated (rock fabric is uniform or massive)	calcite, dolomite, phlogopite mica		reacts with 10% HCl; often distinctly crystalline or granular; sugary-textured; massive; can be scratched with a knife or nail	typically, white to light gray	Marble	Limestone, Dolomite	Cockeysville Marble/Lancaster and Chester Co.
	Quartz, muscovite, biotite		very hard – scratches glass and mild steel; massive; glassy appearance; vitreous; grains are fused when visible; grains more apparent on weathered surfaces	variable pale colors – white, reddish-pink, light gray, light brown	Quartzite	Sandstone	Setters Quartzite and Chickies Formation/ York, Lancaster and Chester Co.
	quartz, feldspars, epidote, pyrite, magnetite		microscopic to fine-grained (<0.04 to 1/32 in.); very hard – scratches glass and mild steel; massive; dense; randomly arranged minerals; will scratch glass and mild steel	dark colors – brown, dark gray, purplish black,	Hornfels[5]	most commonly Shale, Claystone, Siltstone [6]	small areal extent, located adjacent to igneous diabase intrusions/ York and Adams Co.
	serpentine, chlorite, amphibole, mica, magnetite		Fine-grained (0.04 to 1/32 in.); greasy or silky feel; waxy luster; commonly veined; generally soft but varies depending on silica content; can easily be scratched with knife or nail	greenish-gray, black, yellowish green	Serpentinite	Peridotite	small areal extent, mapped within granitic gneiss and gneiss/southern Lancaster and Chester Co.
Foliated or Non-foliated	hornblende, plagioclase, quartz, mica		medium to coarse-grained (1/32 to 3/8 in.); well foliated or schistose texture may be present but mineral grains can be randomly oriented; dense	brown, black, dark gray	Amphibolite	Basalt, Gabbro	small areal extent, occurs within the Wissahickon Formation/Chester and Delaware Co.

Notes: [1] Nearly all exposed Metamorphic Rocks of Pennsylvania are located in the Piedmont Province, or the South Mountain and Reading Prong Sections. See Glossary of Geologic and Geotechnical terms for further clarification of terms used in this chart.

[2] Example map unit/locality is a typical example for the rock type listed, the rock type can be found at other locations in Pennsylvania

[3] Foliation is not to be confused with bedding or fissility, which are characteristics of sedimentary rocks

[4] Rock grain-size descriptors and diameters: Source: USBR Engineering Geology Field Manual, (2001)

[5] Hornfels is a contact metamorphic rock that primarily occurs adjacent to igneous Diabase intrusions

[6] Associated with contact metamorphism; Some references indicate additional parent rock types

Rock Type Identification Chart for Igneous Rocks [1]

Mode of Occurrence	Dominant Mineral Constituent	Description, Composition, and Diagnostic Features [2]	Color [3]	Rock Type	Example Map Unit/Locality [4]
Intrusive (Igneous rock that formed from magma below surface of earth, cooling slowly allowing minerals to be visible with unaided eye)	quartz, potassium feldspar, plagioclase, biotite, minor hornblende	medium to coarse-grained (1/32 to 3/8 in.) [7]; with at least 2/3 light colored minerals by volume	grayish white, light pink, gray	Granite/Granodiorite [5]	Springfield Granodiorite and Ridley Park Granite/Philadelphia and Montgomery Co.
	quartz, potassium feldspar, mica, minor hornblende	very coarse-grained (>3/8 in.); highly variable grain size and mineral distribution	grayish white, light pink, gray	Pegmatite	small areal extent, most pegmatites occur as dikes/ Chester Co.
	calcium plagioclase, quartz, biotite, hornblende	medium to coarse-grained (1/32 to 3/8 in.); with at least 2/3 dark colored minerals by volume	gray to dark gray,	Anorthosite/Gabbro [6]	Anorthosite/Chester Co.
	plagioclase, pyroxene, magnetite,	medium to coarse-grained (1/32 to 3/8 in.); hard to very hard	black, dark gray, green	Diabase/Gabbro [6]	occurs as dikes and sheets in Adams and York Co
Extrusive (Igneous rock that formed from molten rock on or near the surface of the earth)	quartz, feldspar, hornblende	aphanitic to fine-grained (<0.04 to 1/32 in.); commonly contains phenocrysts (larger crystals in a finer matrix); hard; dense	Bluish gray, grayish red, reddish, purple	Rhyolite/ Metarhyolite [8]	Metarhyolite/Adams and Franklin Co.
	feldspar, amphibole, chlorite,	fine to medium grained (0.04 to 3/16 in.); porphyritic; commonly amygdaloidal; and vesicular	green, greenish gray, gray	Basalt/Metabasalt [8]	Metabasalt/Adams and Franklin Co.

Notes:
[1] Nearly all exposed Igneous Rocks of Pennsylvania are located in the Piedmont Province, or the South Mountain and Reading Prong Sections. See Glossary of Geologic and Geotechnical terms for further clarification of terms used in this chart.
[2] Igneous rocks do not exhibit foliation
[3] Other color variations are possible
[4] Example map unit/locality is a typical example for the rock type listed, the rock type can be found at other locations in Pennsylvania
[5] Granodiorite is typically darker in color, contains a higher percentage of plagioclase and lower percentage of potassium feldspar than Granite. Granite/Granodiorite located in Pennsylvania has undergone metamorphism and therefore exhibit varying degrees of foliation, a characteristic of metamorphic rocks.
[6] Diabase is a type of Gabbro that occurs as dikes and sheets within the Gettysburg-Newark Lowland Section, Anorthosite is also a type of Gabbro but does not occur as dikes and sheets and is located primarily in the Piedmont Upland Section.
[7] Rock grain-size descriptors and diameters: Source: USBR Engineering Geology Field Manual, (2001)
[8] Extrusive igneous rocks, (Rhyolite and Basalt) in Pennsylvania have undergone low grade metamorphism and therefore retain their igneous classification. These rocks are primarily located in the South Mountain Section and Piedmont Province.

Rock Type Identification Chart for Sedimentary Rocks [1]

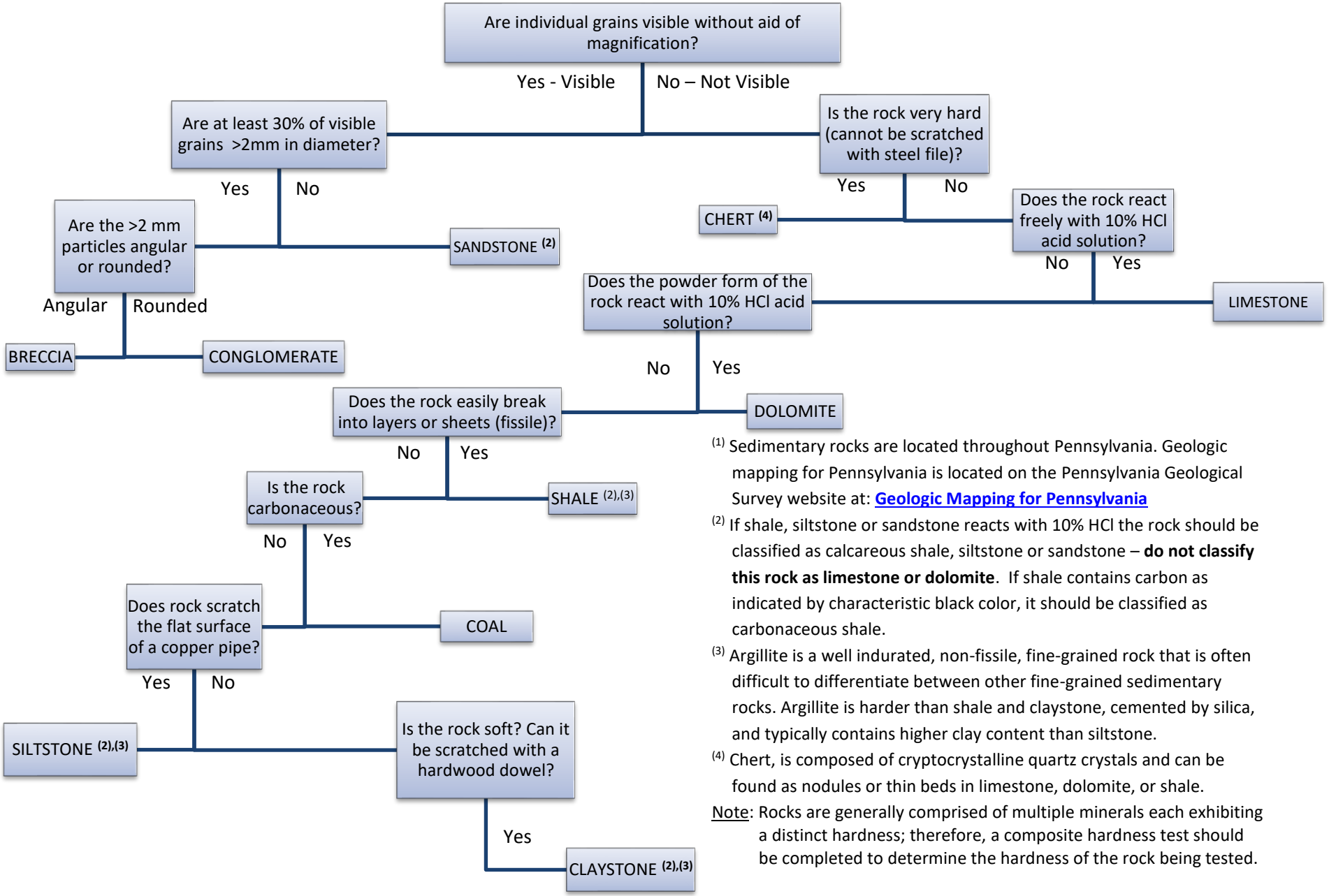
Origin	Textural Features and Particle Size [2]	Description, Composition, and Diagnostic Features	Color [3]	Rock Type	Example Map Unit/Locality [4]
Inorganic Detrital Materials (detrital materials result from erosion and transport of pre-existing rock)	rounded to subrounded particles greater than two millimeters in diameter	primary identifying feature: large grains (> 2mm) in matrix of finer cemented material; >30% of grains are >2mm in a cemented matrix of smaller particles; particles typically consist of chert, quartz, quartzite	variable, contrasting colors that include red, gray, brown, white	Conglomerate	comprises portion of Pottsville Group/Schuylkill Co. and Gettysburg Formation York Co.
	angular particles greater than two millimeters in diameter			Breccia	occurs as interbeds in Gettysburg Formation York Co.
	comprised of predominately (>50%) sand-size (1/16 to 2-millimeter diameter) granular particles	rough or gritty feel; grain sizes < 2mm; comprised mostly of quartz, feldspar, or chert and may be cemented with silica or iron oxides	variable, may include red, gray, brown, tan	Sandstone	Bald Eagle Formation and Burgoon Sandstone/Blair Co./numerous other formations
		rough or gritty feel; grain sizes < 2mm; comprised mostly of quartz, feldspar, or chert with a calcite matrix or cement; reacts with 10% HCL		Calcareous Sandstone	Decker Formation/Monroe Co./ numerous other formations
	Comprised of predominately of sand-size (1/16 to 2 millimeters diameter) granular particles	compositionally the rock is a sandstone but contains > 95% quartz grains with a silica cement; very hard	white to light gray, red	Quartz arenite (Sandstone)	Tuscarora Formation/Juniata and Perry Co.
	comprised of >66% silt size particles (1/16 to 0.0039-millimeter diameter)	> 66% of the particles are silt size; feels slightly gritty; will scratch flat surface of a copper pipe; non-fissile; contains more quartz than shale	variable	Siltstone	present in numerous formations throughout PA
		> 66% of the particles are silt size; it feels slightly gritty; non-fissile; reacts with 10% HCL		Calcareous Siltstone	
	comprised of 33% - 66% silt size particles (1/16 to 0.0039-millimeter diameter and 33% - 66% clay size particles (less than 0.0039-millimeter diameter)	usually well stratified or laminated, which imparts fissility (breaks into layers or sheets); can be scratched with a copper pipe	variable	Shale	present in numerous formations throughout PA
		usually well stratified or laminated, which imparts fissility (breaks into layers or sheets); reacts with 10% HCl; can be scratched with a copper pipe; calcium carbonate often interbedded with limestone	variable	Calcareous Shale	Onondaga and Wills Creek Formations/ numerous other formations
		contains carbon indicated by black to dark gray color; fissile (breaks into layers or sheets); can be scratched with a copper pipe; commonly associated with coal seams	dark gray, black	Carbonaceous Shale	Marcellus Shale/ Lycoming Co.
	comprised of >66% clay size particles (less than 0.0039-millimeter diameter)	>50% of the particles are clay size; typically, smooth appearance; non-fissile; can be scratched with a wood dowel; very soft; rock has soapy feel when wet	variable	Claystone	Pittsburgh red beds within the Conemaugh Group/Western PA
	comprised mainly of silt and clay size particles (1/16 to < 0.0039-millimeter diameter)	Non-fissile; compact; not easily scratched with knife; well indurated; massive; less clearly laminated than shale; will break into hard angular fragments	reddish brown, grayish red	Argillite	Lockatong Formation, Bucks Co.

Rock Type Identification Chart for Sedimentary Rocks (continued) [1]

Origin	Textural Features and Particle Size [2]	Description, Composition, and Diagnostic Features	Color [3]	Rock Type	Example Map Unit/Locality [4]
Inorganic Chemical Precipitates	grain size ranges from small, visible crystals, to grains too small to see individually	contains at least 50% (by weight) calcium carbonate; reacts freely with 10% HCl; can be scratched with a knife or nail; cannot scratch glass; may contain calcite veins; often interbedded with dolomite; may contain fossils	typically, light gray to black, tan when weathered	Limestone	Annville Formation/Lebanon Co. Rockdale Run Formation/Cumberland Co.
	grain size ranges from small, visible crystals, to grains too small to see individually	contains at least 50% (by weight) calcium magnesium carbonate; rock in powder form reacts with 10% HCl; can be scratched with knife or nail; often interbedded with limestone; may contain chert; slightly harder than limestone; may contain fossils	typically, gray, to white	Dolomite	Ledger and Vintage Formations/Lancaster Co.
Organic Detrital Materials	fine-grained, dense	composed of carbon formed by accumulation of plant matter; dull luster; frequently soft	black	Bituminous Coal	Pittsburgh Coal within the Monongahela Group, Freeport, Kittanning Coal within the Allegheny Group/ Western PA
	fine-grained, dense	composed of carbon formed by accumulation of plant matter; lustrous; harder than bituminous coal	black	Anthracite Coal [5]	Coal seams within the Llewellyn Formation/Schuylkill Co

Notes:
[1] Sedimentary Rocks occur throughout Pennsylvania. See Glossary of Geologic and Geotechnical terms for further clarification of terms used in this chart.
[2] Rock particle size diameters: Source: USBR Engineering Geology Field Manual, (2001)
[3] Other color variations are possible
[4] Example map unit/locality is a typical example for the rock type listed, the rock type can be found at other locations in Pennsylvania
[5] Anthracite coal is classified as sedimentary by some references and as a low grade metamorphic by other references. For the purpose of rock identification, it has been included in the sedimentary rock table because in PA it is primarily found in sedimentary rock formations. Anthracite coal is located only in the anthracite fields of eastern and northeastern Pennsylvania

Diagnostic Flow Chart for Sedimentary Rocks found in Pennsylvania [1]



[1] Sedimentary rocks are located throughout Pennsylvania. Geologic mapping for Pennsylvania is located on the Pennsylvania Geological Survey website at: **Geologic Mapping for Pennsylvania**

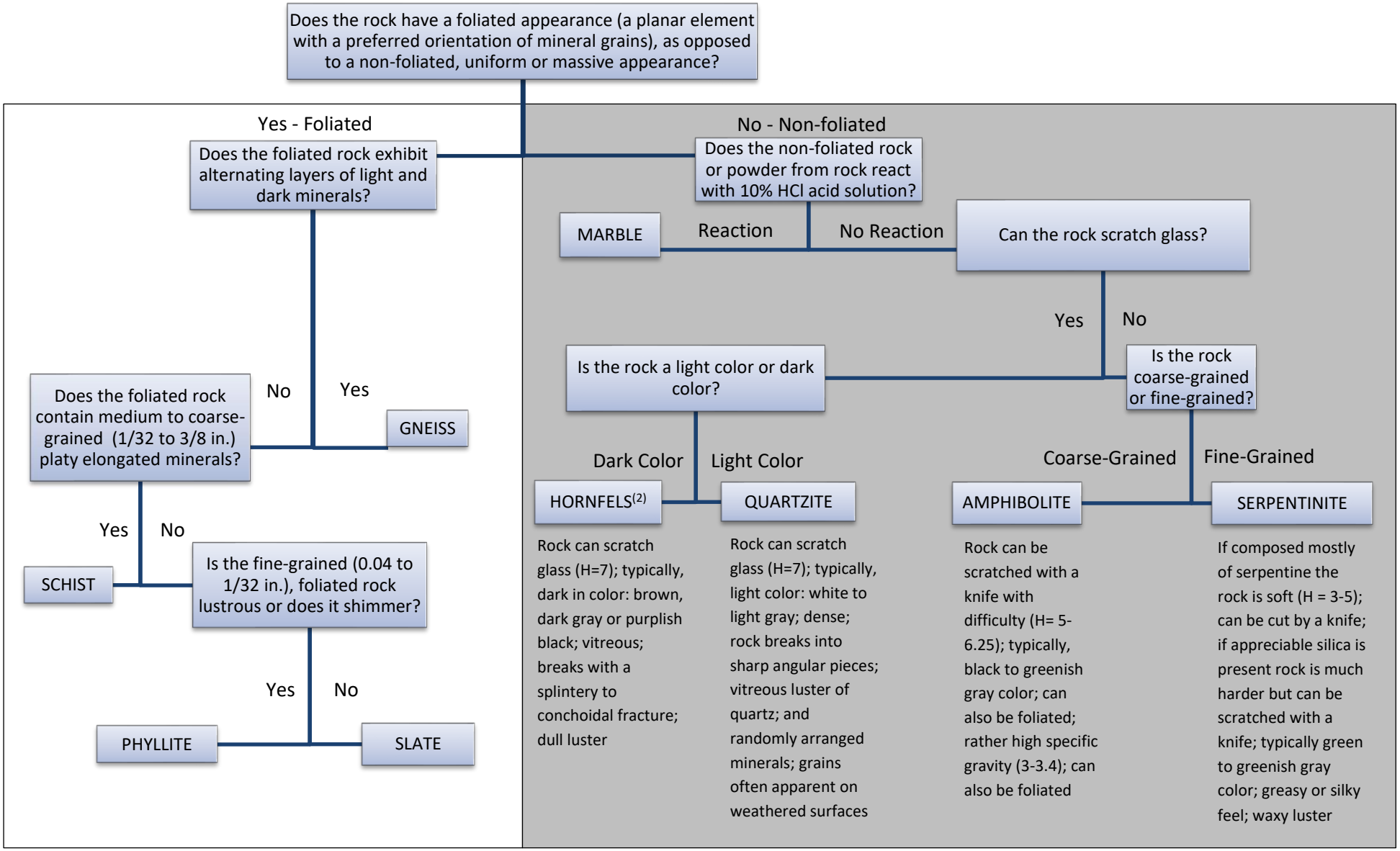
[2] If shale, siltstone or sandstone reacts with 10% HCl the rock should be classified as calcareous shale, siltstone or sandstone – **do not classify this rock as limestone or dolomite**. If shale contains carbon as indicated by characteristic black color, it should be classified as carbonaceous shale.

[3] Argillite is a well indurated, non-fissile, fine-grained rock that is often difficult to differentiate between other fine-grained sedimentary rocks. Argillite is harder than shale and claystone, cemented by silica, and typically contains higher clay content than siltstone.

[4] Chert, is composed of cryptocrystalline quartz crystals and can be found as nodules or thin beds in limestone, dolomite, or shale.

Note: Rocks are generally comprised of multiple minerals each exhibiting a distinct hardness; therefore, a composite hardness test should be completed to determine the hardness of the rock being tested.

Diagnostic Flow Chart for Metamorphic Rocks found in Pennsylvania [1]

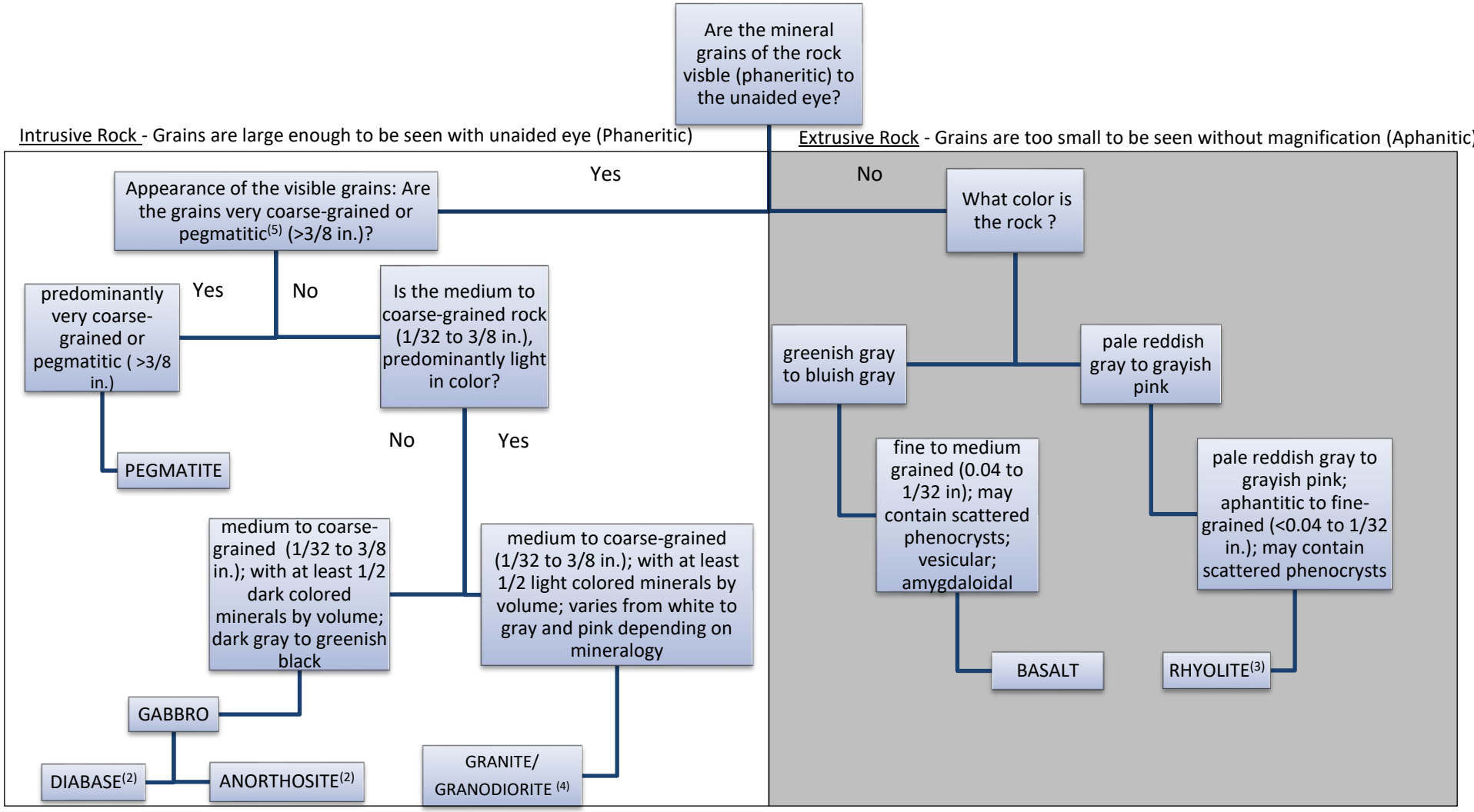


[1] The flow chart is intended for use in identifying most metamorphic rocks in Pennsylvania and therefore does not include all metamorphic rock types. Nearly all metamorphic rocks in Pennsylvania are located in the Piedmont Province, or the South Mountain and Reading Prong Sections. Geologic mapping for Pennsylvania is located on the Pennsylvania Geological Survey website at: **Geologic Mapping for Pennsylvania**

[2] Hornfels is a contact metamorphic rock that primarily occurs adjacent to igneous Diabase intrusions.

Note: Rocks are generally comprised of multiple minerals each exhibiting a distinct hardness; therefore, a composite hardness test should be completed to determine the hardness of the rock being tested.

Diagnostic Flow Chart for Igneous Rocks found in Pennsylvania [1]



[1] The flow chart is intended for use in identifying most igneous rocks in Pennsylvania and therefore does not include all igneous rock types. Nearly all igneous rocks in Pennsylvania are located in the Piedmont Province, or the South Mountain and Reading Prong Sections. The most commonly encountered igneous rocks in PA are Diabase and Granite. Geologic mapping for Pennsylvania is located on the Pennsylvania Geological Survey website at: Geologic Mapping for Pennsylvania

[2] Diabase and Anorthosite are types of Gabbro identified on geologic mapping published by the Pennsylvania Geological Survey. Diabase occurs as dikes and sheets, within the Gettysburg-Newark Lowland Section, is medium to fine-grained and occurs in Adams, York and Lancaster Co and other locations. Anorthosite does not occur as dikes and sheets, is located in the Piedmont Upland Section, is coarse to medium grained, is less common than Diabase and occurs primarily in Chester Co.

[3] Basalt and Rhyolite in Pennsylvania have undergone low-grade metamorphism and are typically described as Metabasalt and Metarhyolite and occur in the South Mountain Section.

[4] Granite units identified on geologic mapping published by the Pennsylvania Geological Survey have undergone some degree of metamorphism and therefore exhibit varying degrees of foliation, a characteristic of metamorphic rocks.

[5] Pegmatitic describes a rock texture containing grain sizes from 3/8 to several inches in size; common minerals are quartz, orthoclase, and mica.

Note: Rocks are generally comprised of multiple minerals each exhibiting a distinct hardness; therefore, a composite hardness test should be completed to determine the hardness of the rock being

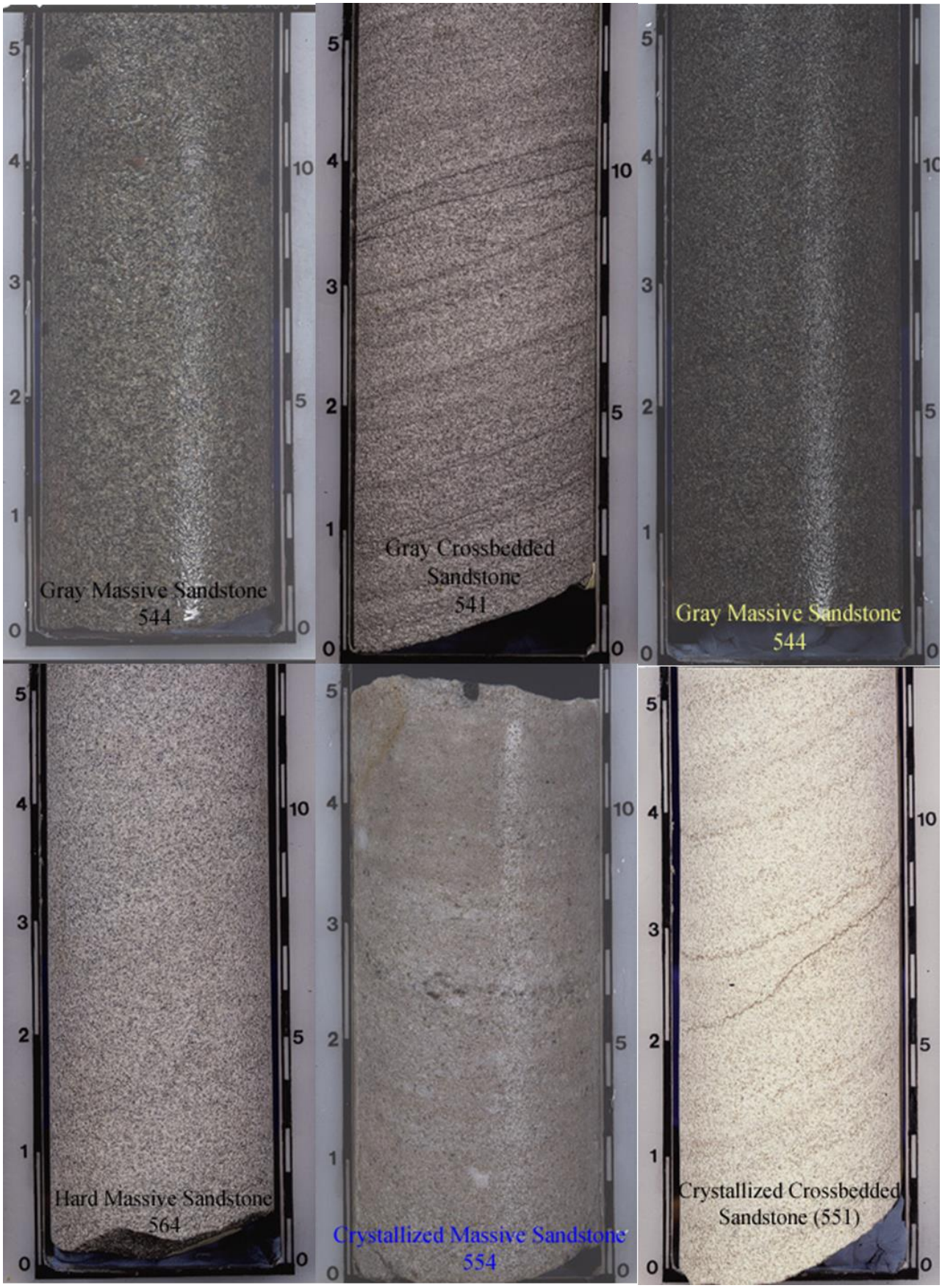
---

APPENDIX H – PHOTOS OF COMMONLY ENCOUNTERED ROCK TYPES IN PENNSYLVANIA

SEDIMENTARY ROCKS

Sandstone

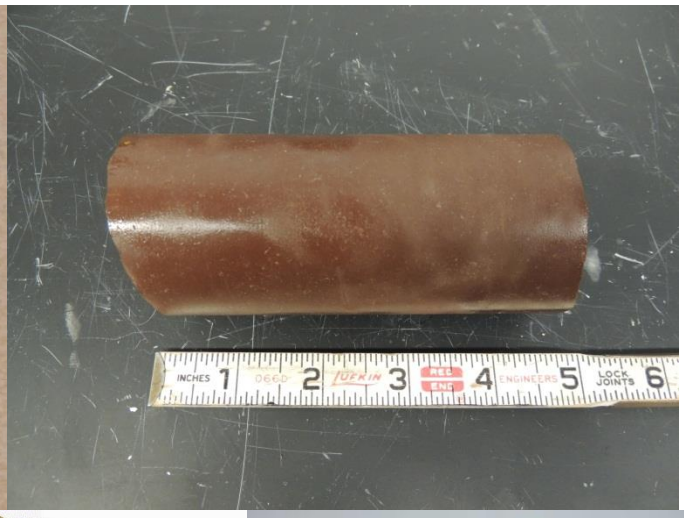
Sandstone


Gray Massive Sandstone
544
Gray Crossbedded
Sandstone
541
Gray Massive Sandstone
544
Hard Massive Sandstone
564
Crystallized Massive Sandstone
554
Crystallized Crossbedded
Sandstone (551)

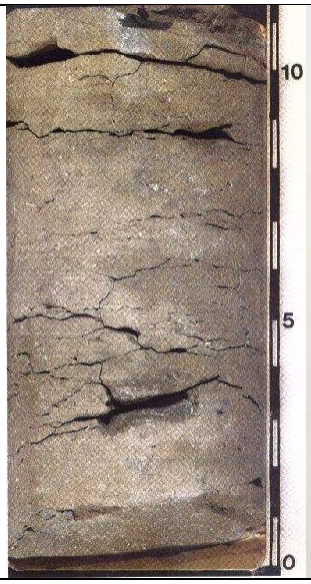
Sandstone (cont.)

Conglomerate

Siltstone



Claystone

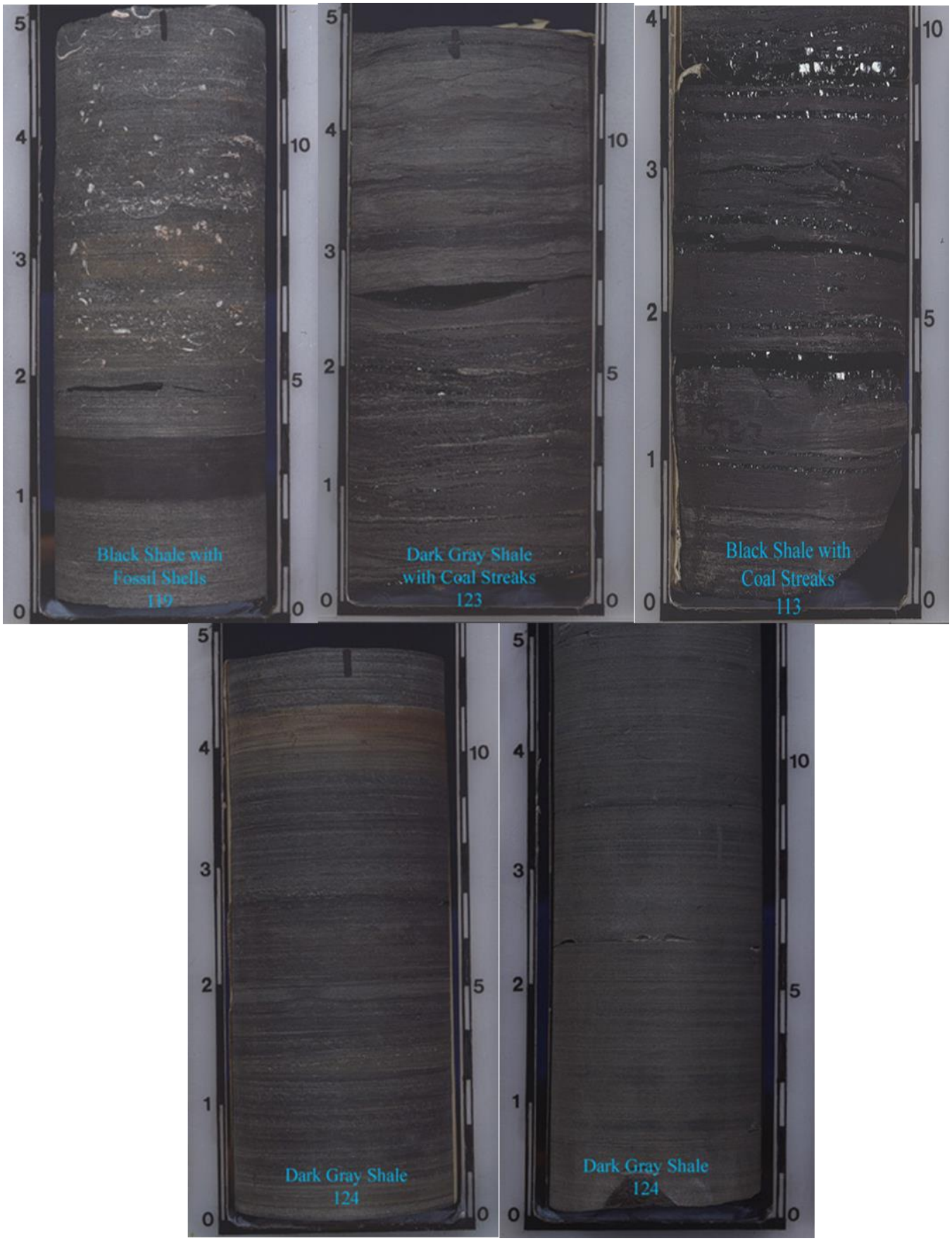


Shale


© geology.com


Dark Gray Shale with
Sandstone Streaks
(323)
Black Shale with
Sandstone Streaks
(313)

Shale (cont.)


Black Shale with
Fossil Shells
119
Dark Gray Shale
with Coal Streaks
123
Black Shale with
Coal Streaks
113
Dark Gray Shale
124
Dark Gray Shale
124

Limestone


Massive Fine Grained
Shaley Limetone with
Fossil Shells
894
Massive Fine Grained
Limestone with
Fossil Shells
994
Massive Fine Grained
Shaley Limestone
804

Dolomite

Argillite







Coal

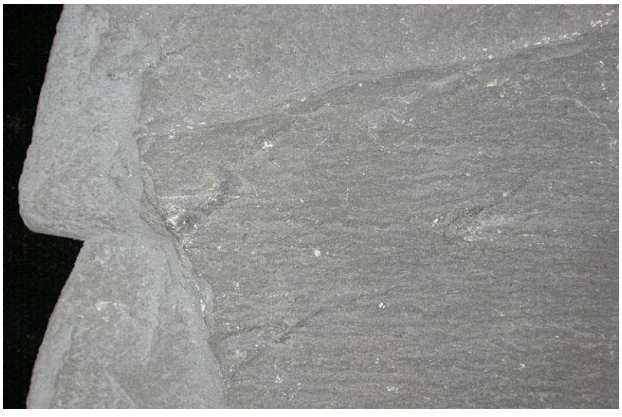
Bituminous Coal	Anthracite Coal
	
	
	

IGNEOUS ROCKS

Diabase

Metabasalt

METAMORPHIC ROCKS

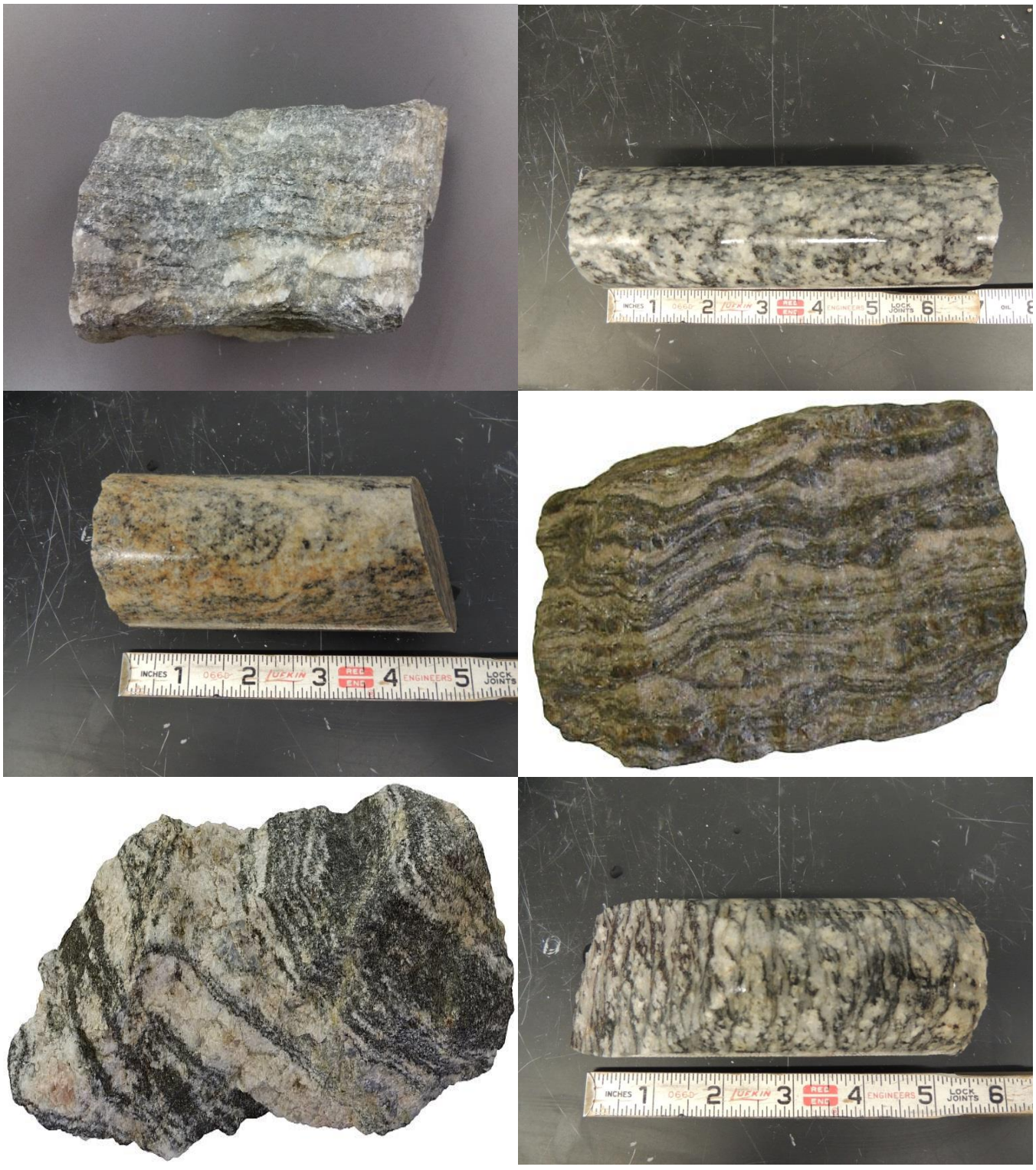
Slate	Phyllite
   	   

Quartzite

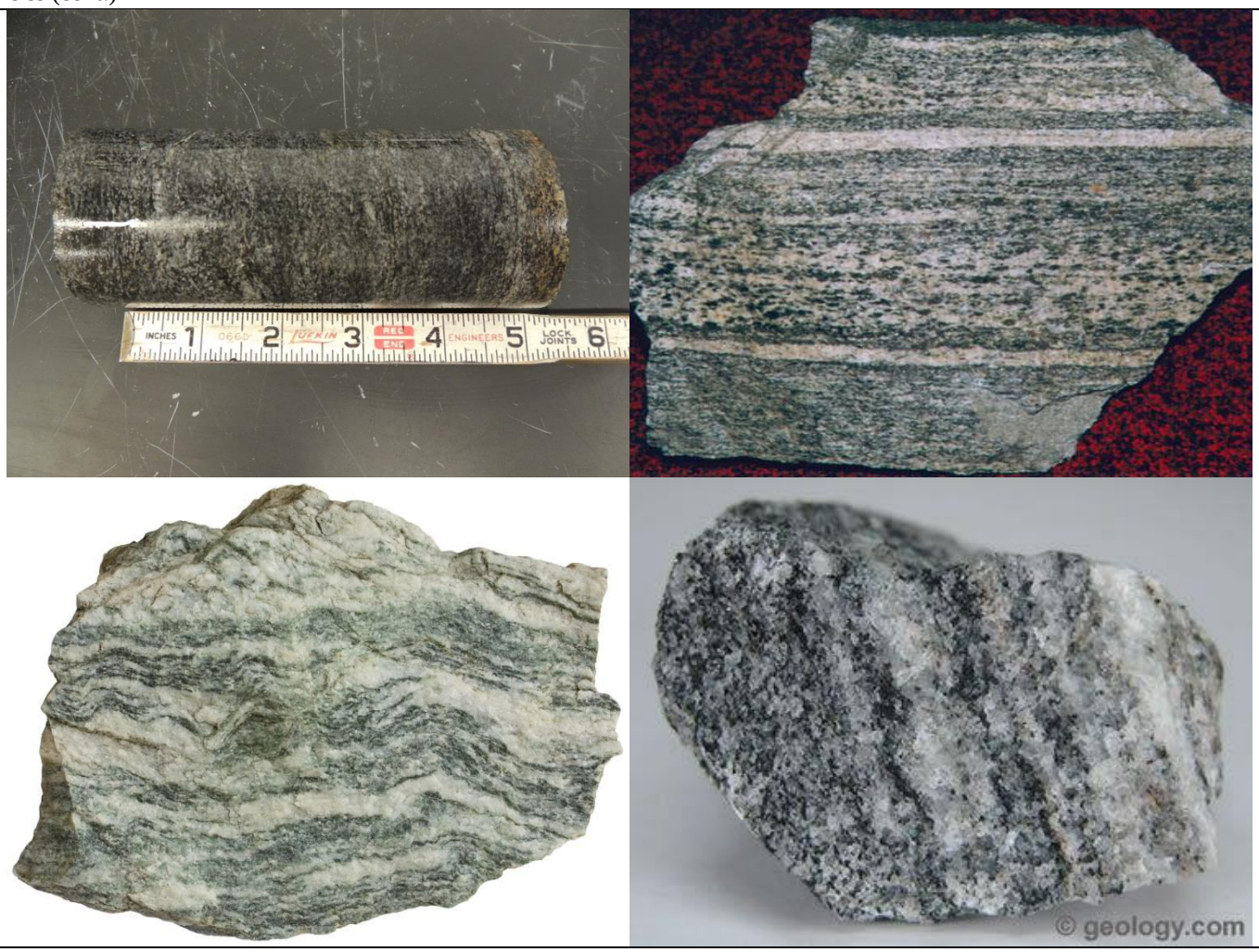
Schist

Mica Schist

Gneiss



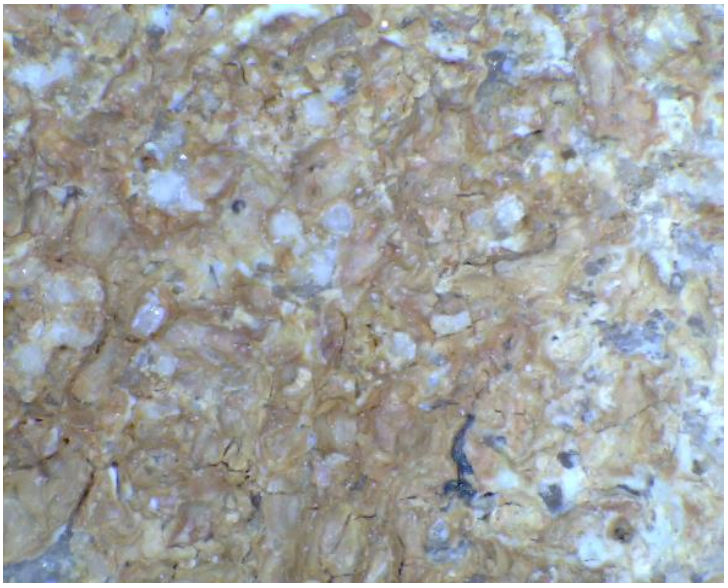
Gneiss (cont.)



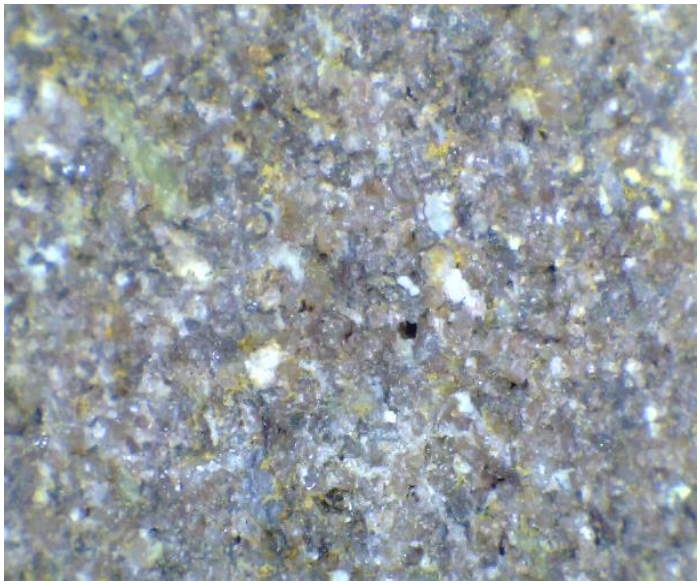
Marble

Quartzite versus Sandstone – Images of Quartzite and Sandstone Structure at 30x Magnification

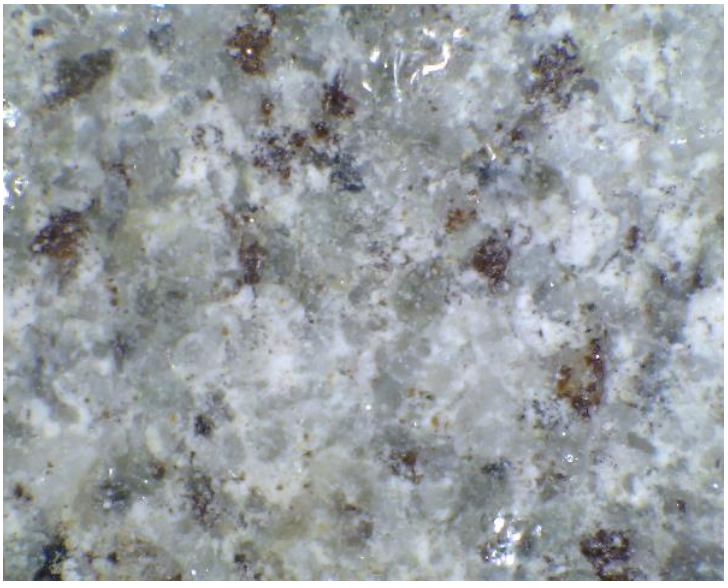
Quartzite at 30x Magnification – Note fusing of grains, low appearance of grain structure, more massive appearance and glassy texture; Other quartzite sample may exhibit a more coarse grained structure, but grains would be fused, with glassy texture and samples would fracture predominantly through grains as opposed to along grain faces.



Quartzite at 30x Magnification along Weathered Face – Note more distinct appearance of grains as opposed to an unweathered face.

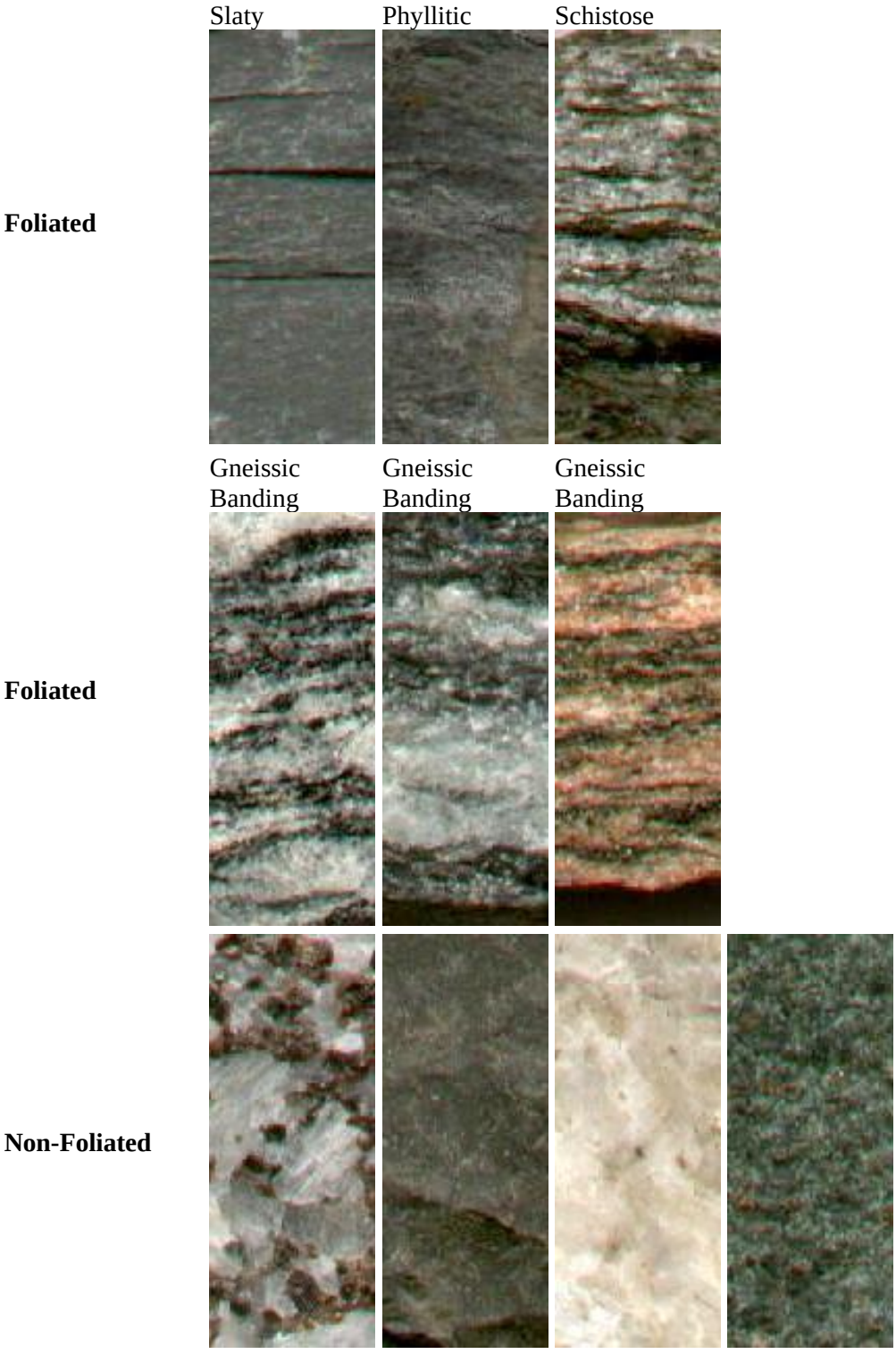


Sandstone at 30x Magnification – Note cementing of grains and fracture along grain faces



Sandstone at 30x Magnification – Note cementing of grains and fracture along grain faces

Examples of Foliated and Non-Foliated Metamorphic Rock Textures



APPENDIX I – N60 VALUES FOR VARIOUS HAMMER TYPES AT INDICATED ASSUMED EFFICIENCIES

Hammer Type	Donut	Safety	Automatic		Hammer Type	Donut	Safety	Automatic
Assumed Hammer Efficiency	**0.45**	**0.60**	**0.80**		**Assumed Hammer Efficiency**	**0.45**	**0.60**	**0.80**
SPT - N_{unc} (blows per ft.)	**SPT - N_{60}** (blows per ft.)				**SPT - N_{unc}** (blows per ft.)	**SPT - N_{60}** (blows per ft.)		
1	1	1	1		26	20	26	35
2	2	2	3		27	20	27	36
3	2	3	4		28	21	28	37
4	3	4	5		29	22	29	39
5	4	5	7		30	23	30	40
6	5	6	8		31	23	31	41
7	5	7	9		32	24	32	43
8	6	8	11		33	25	33	44
9	7	9	12		34	26	34	45
10	8	10	13		35	26	35	47
11	8	11	15		36	27	36	48
12	9	12	16		37	28	37	49
13	10	13	17		38	29	38	51
14	11	14	19		39	29	39	52
15	11	15	20		40	30	40	53
16	12	16	21		41	31	41	55
17	13	17	23		42	32	42	56
18	14	18	24		43	32	43	57
19	14	19	25		44	33	44	59
20	15	20	27		45	34	45	60
21	16	21	28		46	35	46	61
22	17	22	29		47	35	47	63
23	17	23	31		48	36	48	64
24	18	24	32		49	37	49	65
25	19	25	33		50	38	50	67

Note: If hammer efficiency is measured, use equation in Chapter 3.6.2 to determine N_{60}

APPENDIX J – DELINEATION MAPS FOR ACCEPTABLE NON-DEPARTMENT BORING INSPECTION

See the following Delineation Maps that define the borders within or along surrounding states where borings may be determined to be acceptable for Non-Department boring inspection requirements.

Composite State Border and Roadway Map

Composite Physiographic Province Map

Composite Geology Map

Abbreviations:

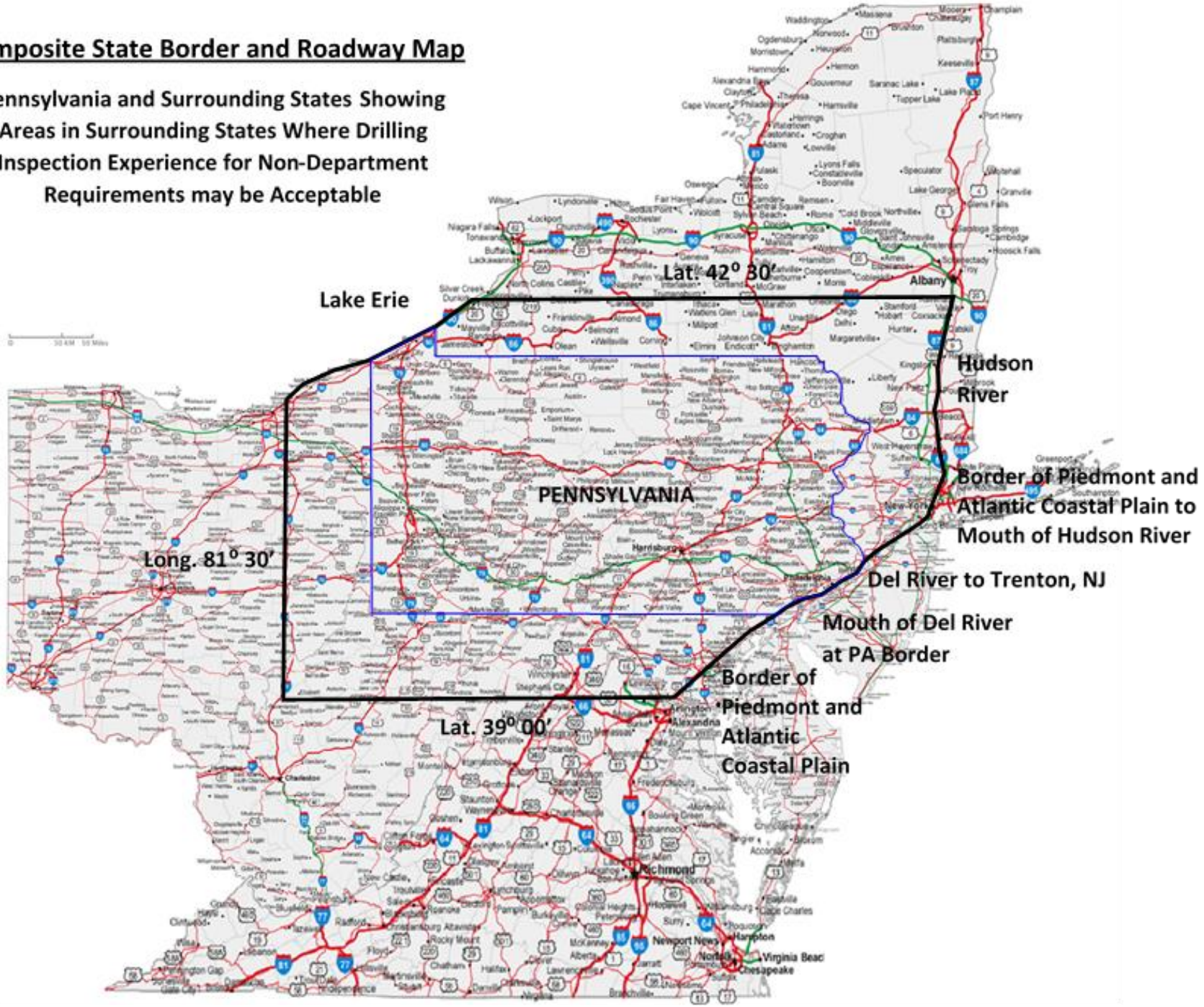
Piedmont	= Piedmont Physiographic Province
ACP	= Atlantic Coastal Plain Physiographic Province
Long.	= Longitude
Lat.	= Latitude

Borders are as follows, starting from Lake Erie near Cleveland Ohio:

1) Head south in Ohio east of Long. 81º 30’
2) Continue heading south staying east of Long. 81º 30’ to Lat. 39º 00’
3) Head east staying north of Lat. 39º 00’ to the border of the Piedmont and ACP
4) Head northeast staying north of the Piedmont/ACP border up to the mouth of the Delaware River at the PA state border.
5) Continue north along the Delaware River (staying in PA) to Trenton, NJ
6) From Trenton, NJ head northeast staying north of the Piedmont/ACP border to the mouth of the Hudson River at Staten Island, NY
7) Head north staying west of the Hudson River to Lat. 42º 30’
8) Head west from Hudson River staying south of Lat. 42º 30’ to Lake Erie.

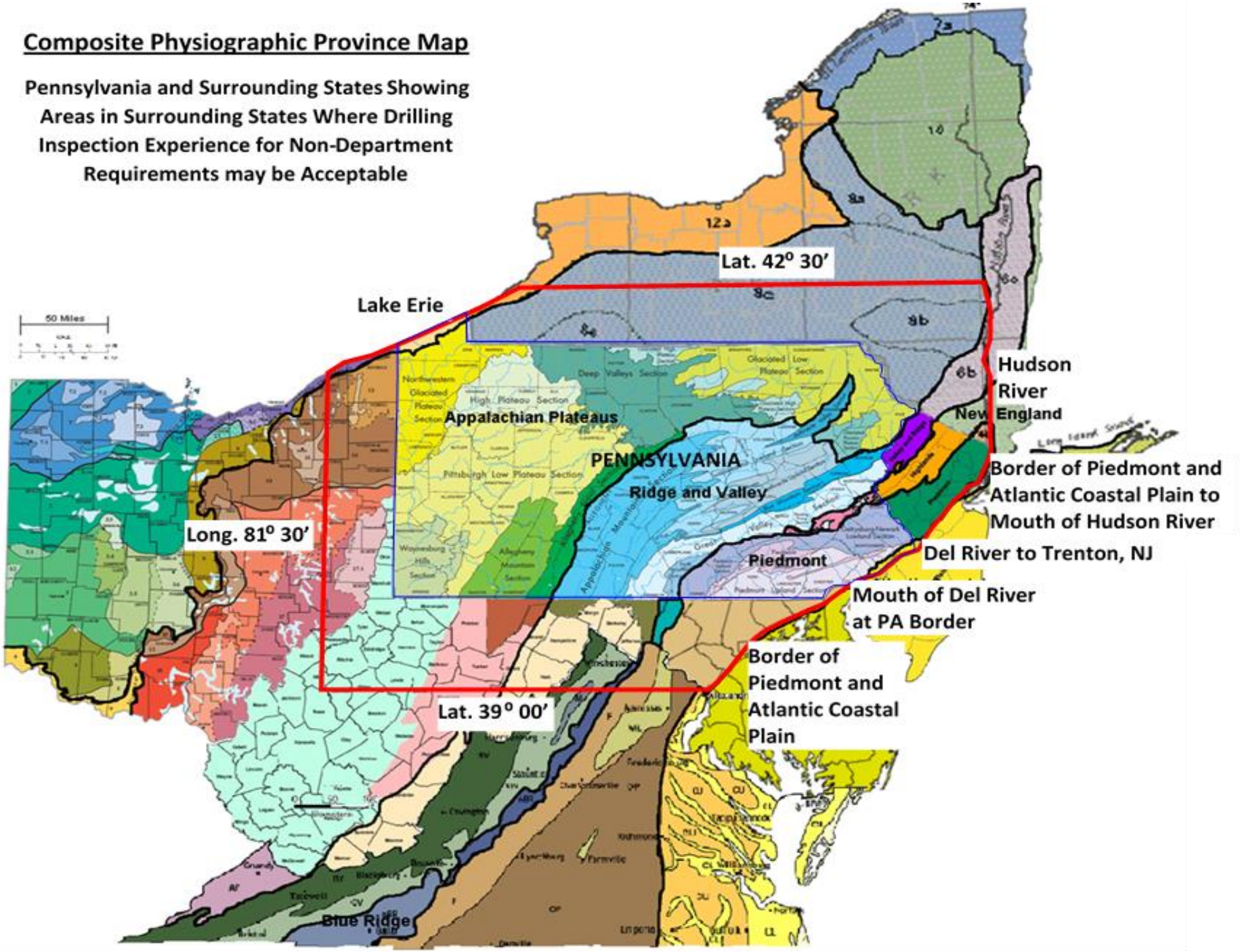
Composite State Border and Roadway Map

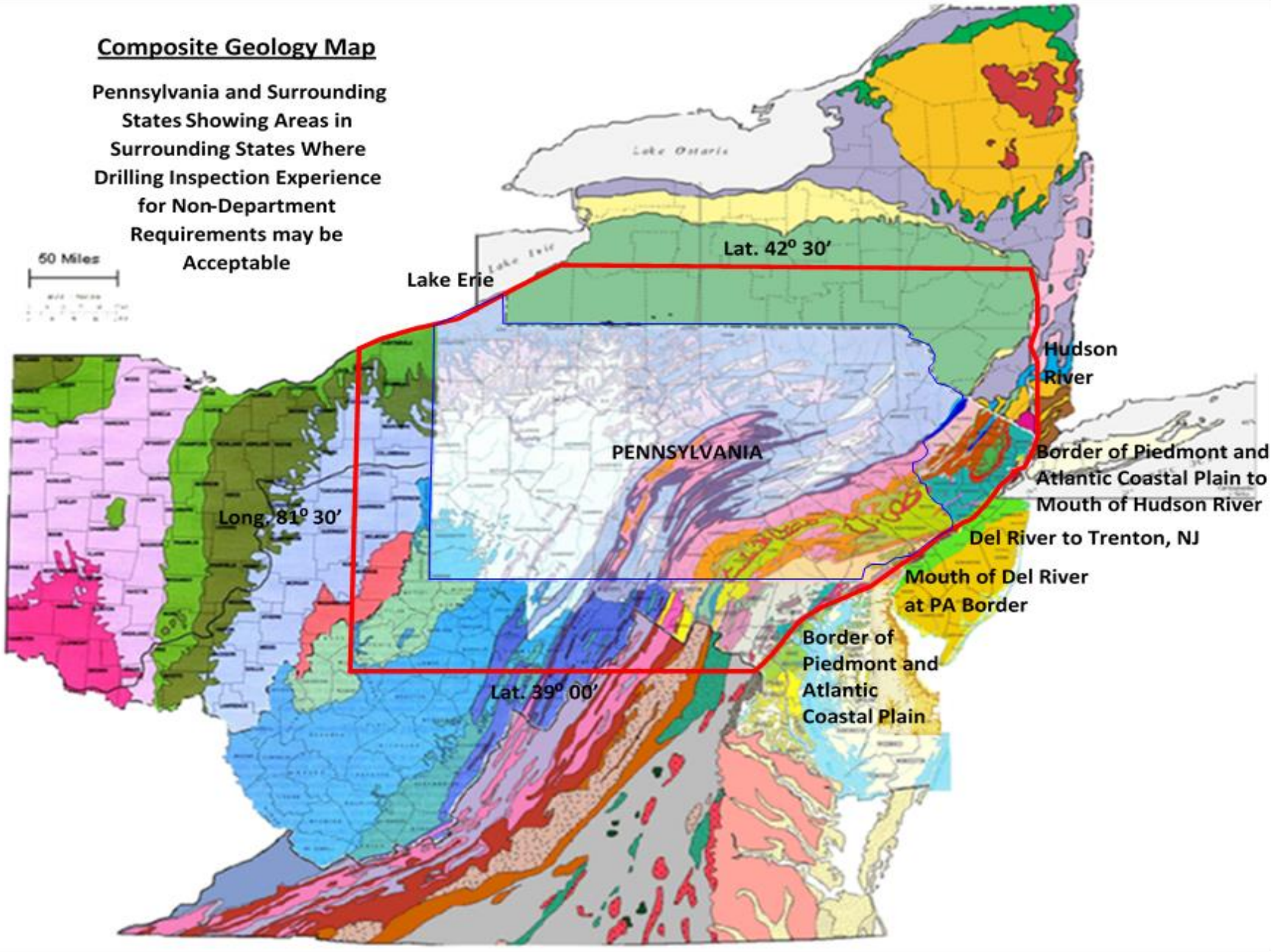
Pennsylvania and Surrounding States Showing Areas in Surrounding States Where Drilling Inspection Experience for Non-Department Requirements may be Acceptable



Composite Physiographic Province Map

Pennsylvania and Surrounding States Showing Areas in Surrounding States Where Drilling Inspection Experience for Non-Department Requirements may be Acceptable




Composite Geology Map
Pennsylvania and Surrounding States Showing Areas in Surrounding States Where Drilling Inspection Experience for Non-Department Requirements may be Acceptable
50 Miles
Lake Ontario
Lake Erie
Lat. 42° 30'
Lake Erie
Hudson River
PENNSYLVANIA
Border of Piedmont and Atlantic Coastal Plain to Mouth of Hudson River
Long. 81° 30'
Del River to Trenton, NJ
Mouth of Del River at PA Border
Border of Piedmont and Atlantic Coastal Plain
Lat. 39° 00'

APPENDIX K – FIELD SHEET SUMMARIES OF SOIL AND ROCK DESCRIPTORS

The next four pages of this appendix are intended to be an aid to Drilling Inspectors. Making two double-sided laminated copies of each of these references will make convenient and durable reference sheets for use during logging of borings.

Soil Description Reference Sheet

Rock Description Reference Sheet

Soil Description Sequence	
1	Soil Constituents, Fractions, and Modifiers
2	Soil State: Consistency/Relative Density
3	Soil Moisture Range
4	Soil Structure
5	Soil Gradation
6	Soil Particle Shape/Plasticity
7	Soil Color Range
8	Depositional Environment
9	AASHTO/USCS
10	General Remarks/Additional Information

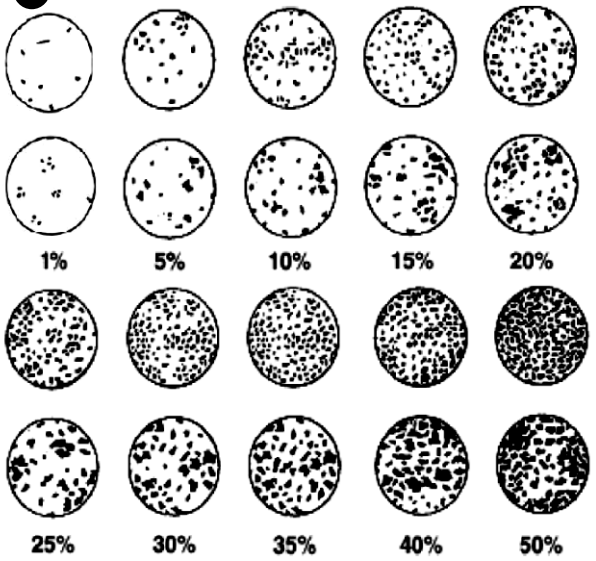
1a Descriptors for Grain Material based on Grain Size

Constituent	Primary Descriptor	Grain Sizes	
		inches	sieve
Coarse-Grained	Boulders	≥ 12	-
	Cobbles	≤ 12 to > 3	-
	Coarse Gravel	≤ 3 to > 1	≤ 3" to > 1"
	Medium Gravel	≤ 1 to > $^3/_8$	≤ 1" to > $^3/_8$"
	Fine Gravel	≤ $^3/_8$ to > $^5/_{64}$	≤ $^3/_8$" to > #10
	Coarse Sand	-	≤ #10 to > #40
	Fine Sand	-	≤ #40 to > #200
Fine-Grained	Silt/Clay	-	≤ #200

1b Soil Fraction Descriptors

Descriptor (Abbrev.)	Relative Amount (based on total sample volume)
Trace (Tr)	Content < 10%
Little (Lt)	Content ≥ 10 to < 20%
Some (Sm)	Content ≥ 20 to < 35%
And (An)	Content ≥ 35%

1c Visual Estimation of Coarse Fragments



1d Composition Modifers

Descriptor	Abbreviation
Contains ash and cinders	Ash
Contains organics	Org
Contains rock fragments	Rfg
Contains slag	Slg
Micaceous	Mic
Contains bituminous concrete fragments	Bcf
Contains cement concrete fragments	Ccf
Contains brick fragments	Cbf

2a Consistency of Cohesive Fine-grained Soil

Descriptor	Abbreviation	Typical Consistency	Est. Unconfined Compressive Strength Tons/Sq. Ft. (MPa)	SPT-N_{60} (blows per ft.)
Very Soft	Vsf	Extruded between your fingers when squeezed	≤ 0.25 (≤ 0.025)	≤2
Soft	Sf	Molded by light finger pressure	≥ 0.25 - 0.5 (0.025 - 0.05)	3-4
Medium	Md	Molded by strong finger pressure	> 0.5 – 1.0 (0.05 – 0.1)	5-8
Stiff	St	Readily indented by thumbs but penetrated with great effort	> 1.0 - 2.0 (0.1 – 0.2)	9-15
Very Stiff	Vst	Readily indented by thumbnail	> 2.0 – 4.0 (0.2 – 0.4)	16-30
Hard	Hd	Indented with difficulty by thumbnail	> 4.0 (> 0.4)	≥31

2b Relative Density of Granular Coarse-grained Soils

Descriptor	Abbreviation	SPT-N_{60} (blows per ft.)
Very Loose	Vls	≤4
Loose	Ls	5-10
Medium Dense	Md	11-30
Dense	Dn	31-50
Very Dense	Vdn	≥50

3 Standard Moisture Descriptors

Descriptor	Abbreviation	Appearance
Dry	Dr	Absence of moisture, dusty, completely dry to the touch
Damp	Dp	Slight moisture perceptible by touch, fine-grained soils are usually firm, granular soils usually have very little apparent cohesive binding
Moist	Ms	Sample visibly wet but no visible free water, sample cool to the touch, at or above optimum moisture, granular soil may exhibit slight apparent cohesive binding
Wet	Wt	Visible free water throughout sample, usually soil is below water table, contains significantly more moisture than moist soil, fine-grained soils usually soft or very soft, granular soils exhibit no apparent cohesive binding

4 Soil Structure Descriptors

Descriptor	Abbreviation	Description
Blocky	Bl	Cohesive soil that can be broken down into small angular blocks which resist further breakdown
Fissured	Fi	Soil tends to break along definite planes of fracture with little resistance to fracturing
Homogeneous	Ho	Similar color and texture throughout
Heterogeneous	He	Composed of dissimilar parts throughout
Laminated	La	Alternating very thin layers of varying material or colors with the layers less than ¼" thick
Lensed	Le	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Saprolitic	Sa	Soil composed of completely weathered rock that retains the fabric and appearance of the original rock but with only a trace of the original bond strength
Slickensided	Sl	Contains shear planes that appear striated, polished and/or glossy
Stratified	St	Alternating thin layers of varying material or color with layers at least or greater than ¼" thick
Varved	Va	Layered soil having a repetitive structure of contrasting color (often alternating between fine sand and silt or clay), resulting from variations in annual seasonal deposition

5 Soil Gradation Descriptors

Descriptor	Abbreviation	Description
Well Graded	Wg	Having a good distribution of particles sizes
Poorly Graded	Pg	Lacking good representation of particle sizes within the maximum to minimum particle size range of the material. Use this term when the gradation is not well distributed, but sufficiently different from a uniform or gap graded material.
Uniformly Graded	Ug	Particles are nearly all the same size (or fall within a tight range of sizes)
Gap Graded	Gg	Gradation is missing a band or range of particle sizes

6a Soil Shape Descriptors

Descriptor	Abbreviation	Description
Angular	An	Particles have irregular shape with crisp angular edges
Sub Angular	Sa	Particles have irregular shape with weathered or rounded angular edges
Sub Rounded	Sr	Particles have an irregular shape with well rounded edges
Rounded	Ro	Particle has a generally smooth rounded shape
Elongated	El	Particle length is more than three times particle width
Flat	Fl	Particle thickness is more than three times particle thickness
Flat and Elongated	Fe	Criteria for both flat and elongated are met

6b Descriptors for Fine-Grained Materials Based on Behavior

Fine-Grained Constituent	Plasticity Description/ Abbreviation	Estimated Plasticity Index (PI)	Smallest Thread Diameter	Physical Behavior							
				Thread Characteristics	Workability to reach Plastic Limit	Moldability	Dilatancy	Adhesion	Appearance and or Texture	Drying Time	Dry Residue
Predominately Silt (Silt ↑ More Silt ↑)	Non-plastic (Np)	0% - 2%	Ball cracks	Dries rapidly when rolling; a 1/8-inch thread cannot be rolled at any water content	Not applicable, thread cannot be rolled	Does not mold well	Moist soil ball sheds water when shaken giving a glossy appearance	Non-sticky	Rough or gritty texture, dull smear btw. thumb and forefinger	Rapid	Very powdery residue when dry
	Low Plastic Fines (Lp)	3% - 10%	1/4 to 1/8 -inch	Feels powdery when drying out during rolling; The thread can barely be rolled; the thread is weak and soft	Thread can barely be rolled	Moldable under small range of water content	Moist soil ball retains water or sheds water slowly when shaken	Slightly sticky	Rough to smooth texture, dull smear btw. thumb and forefinger	Moderate	Powdery residue when dry
Predominately Clay (More Clay ↓ Clay)	Medium Plastic Fines (Mp)	>10% - 20%	1/16 -inch	The thread cannot be rerolled after reaching plastic limit; the thread has medium stiffness	Short working time to reach plastic limit	Very moldable		Moderately sticky	Smooth texture, dull to shiny smear btw. thumb and forefinger	Slow	Generally little powdery residue when dry
	High Plastic Fines (Hp)	>20%	1/32 -inch	The thread can be rerolled after reaching the plastic limit; the thread has very high stiffness	Very long working time to reach plastic limit	Very moldable over a wide range of water content	Moist soil ball retains water when shaken	Very sticky	Slick texture, very shiny or waxy appearance	Very slow	Very little powdery residue when dry

Procedure for Determining Dry Strength –
The dry strength test is performed on material passing the No. 40 sieve. The test is made on a soil sample about 0.5-inch-thick and about 1.5 inches in diameter. Mold the sample until it has the consistency of putty, adding water if necessary. Allow the test specimen to dry in air, or sun or by artificial means. Upon drying, test the strength of the test specimen by crushing between fingers. Note the strength as none, low, medium, high, or very high as specified in the table below.

Criteria for Describing Dry Strength	
Description	Criteria/Test Result
None	The dry sample crumbles into a powder with mere pressure of handling.
Low	The dry sample crumbles with some finger pressure.
Medium	The dry sample breaks into fragments or crumbles with considerable finger pressure.
High	The dry sample cannot be broken with finger pressure. Sample with break into fragments between thumb and hard surface.
Very High	The dry sample cannot be broken between thumb and a hard surface.

Procedure for Determining Dilatancy –
The dilatancy test is performed on material passing the No. 40 sieve. The test is made on a soil sample about ¾ inch in diameter. Mold the material, adding water if necessary until it has a soft but not sticky consistency. Smooth the ball of soil in the palm of the hand and shake horizontally, while striking the side of the hand 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 as specified in the table below.

Criteria for Describing Dilatancy	
Description	Criteria/Test Result
None	No visible change in the sample.
Slow	Water slowly appears on the surface of the sample during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water quickly appears on the surface of the sample during shaking and disappears upon squeezing.

Procedure for Determining Toughness –
The toughness test is performed on material passing the No. 40 sieve. The test is made on a soil sample about ¾ inch in diameter. The sample is rolled by hand on a smooth surface or between the palms into a thread about 1/8 inch in diameter. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of 1.8 inch when the soil is near the plastic limit. 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 as low, medium, or high as specified in the table below.

Criteria for Describing Toughness	
Description	Criteria/Test Result
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and 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 lump have very high stiffness.

7a Standard Soil and Rock Color Modifiers and Abbreviations

Light	Lt	Lighter side of color range
Dark	Dk	Darker side of color range
Mottled	Mt	Irregularly marked with spots of different colors
Banded	Bd	Distinct alternating light and dark shades, or alternating colors

7b Standard Soil and Rock Colors and Abbreviations

Black	Bk	Blue	Bu
Green	Gn	Olive	Ol
Purple	Pr	Red	Rd
White	Wh	Yellow	Yl
Brown	Bn	Gray	Ga
Orange	Or	Pink	Pk
Silver	Sv	Tan	Tn

7c Standard Soil and Rock Hues and Abbreviations

Blue	Bu	Brown	Bn
Olive	Ol	Orange	Or
Red	Rd	Yellow	Yl
Gray	Ga	Green	Gn
Pink	Pk	Purple	Pr

8 Types of Soil Deposit

Descriptor	Abbreviation	Description
Aeolian	Ae	Soil deposited by wind
Alluvium	Al	Soil deposited by flowing water
Colluvium	Co	Soil deposited by gravity
Glacial Outwash	Go	Soil deposited from glacial meltwater
Glacial Till	Gt	Soil deposited from unsorted glacial settlement
Residuum	Re	Insoluble material remaining from weathered rock
Fill	Fl	Human-made deposit

Examples of Field Soil Descriptions:

1. fine SAND, some Silt, trace Gravel, medium dense, moist, poorly graded, rounded, brown, fill, a-2-4/sm
2. CLAY and SILT, some Gravel, trace Sand, soft to medium, moist to wet, well graded, sub angular, high plastic fines, mottled yellow and light gray, glacial outwash, a-6/cl, (trace roots), (with sandstone fragments)
3. fine SAND, some Clay, medium dense, moist, poorly graded, dark gray, fill, a-2-6/sc, (trace shell fragments)
4. coarse GRAVEL, some Silt, loose, dry, uniformly graded, elongated, red-brown, glacial till, a-2-5/gm,
5. fine SAND, some Gravel, little Silt, dense, moist, homogeneous, well graded, rounded, light brown, residuum, a-2-4/sm, (slight petroleum odor)
6. fine GRAVEL and SAND, little Silt, trace Clay, micaceous, medium dense, damp, homogeneous, well graded, angular to sub-rounded, non-plastic, light brown to red-brown, fill, a-1-b/sw, (occasional fragments of brick and concrete)

Rock Description Sequence	
1	Rock Composition Modifier
2	Rock Type and Interbedded Rock
3	Rock Color
4	Rock Structure
5	Rock Texture and Modifier
6	Rock Hardness
7	Rock Weathering
8	Bedding Thickness and Dip
9	Geologic Formation
10	Discontinuities
11	General Remarks

1 Rock Composition Modifier

Descriptor	Abbreviation	Description
Argillaceous	Arg	Pertaining to a sedimentary rock which contains an appreciable amount of clay
Calcareous	Cal	Containing calcite; in particular rock in which grains are cemented with calcite
Carbonaceous	Car	Rich in carbon or organic matter
Dolomitic	Dol	Containing an appreciable amount of magnesium carbonate
Ferruginous	Fer	Containing iron oxides
Fossiliferous	Fos	Containing fossils; usually applied to rocks in which the fossils are abundant
Micaceous	Mic	Group of silicate minerals exhibiting perfect basal cleavage, which commonly forms flakes, scales, or sheets.
Pyritic	Pyr	Containing the mineral pyrite (iron disulfide – "fool's gold"); may only be visible with a hand lens.

3a Standard Soil and Rock Color Modifiers and Abbreviations

Light	Lt	Lighter side of color range
Dark	Dk	Darker side of color range
Mottled	Mt	Irregularly marked with spots of different colors
Banded	Bd	Distinct alternating light and dark shades, or alternating colors

3b Standard Soil and Rock Colors and Abbreviations

Black	Bk	Blue	Bu
Green	Gn	Olive	Ol
Purple	Pr	Red	Rd
White	Wh	Yellow	Yl
Brown	Bn	Gray	Ga
Orange	Or	Pink	Pk
Silver	Sv	Tan	Tn

3c Standard Soil and Rock Hues and Abbreviations

Blue	Bu	Brown	Bn
Olive	Ol	Orange	Or
Red	Rd	Yellow	Yl
Gray	Ga	Green	Gn
Pink	Pk	Purple	Pr

2 General Rock Types in Pennsylvania

Rock Type	Abbreviation	Rock Origin	Graphic Symbol
Amphibolite	Am	Metamorphic	Metamorphic
Anorthosite (Gabbro)	An	Igneous	Igneous
Anthracite Coal	Co-A	Sedimentary	Coal
Argillite	Ar	Sedimentary	Argillite
Bituminous Concrete	BC	Human-Made	Asphalt Concrete
Basalt/Metabasalt	Ba	Igneous	Igneous
Bituminous Coal	Co-B	Sedimentary	Coal
Breccia	Br	Sedimentary	Conglomerate
Cement Concrete	CC	Human-Made	Cement Concrete
Chert	Ch	Sedimentary	Sedimentary - Other
Claystone	Cl	Sedimentary	Claystone
Coal	Co	Sedimentary	Coal
Conglomerate	Cn	Sedimentary	Conglomerate
Diabase (Gabbro)	Di	Igneous	Igneous
Dolomite	Do	Sedimentary	Limestone
Flint Clay	FlC	Sedimentary	Sedimentary - Other
Gabbro	Ga	Igneous	Igneous
Gneiss	Gn	Metamorphic	Metamorphic
Granite/Granodiorite	Gr	Igneous	Igneous
Hornfels	Hr	Metamorphic	Metamorphic
Igneous rock type not identified in this listing		Igneous	Igneous
Limestone	Lm	Sedimentary	Limestone
Marble	Mr	Metamorphic	Metamorphic
Masonry	MA	Human-Made	Cement Concrete
Metamorphic rock type not identified in this listing		Metamorphic	Metamorphic
No Recovery	NREC	N/A	No Recovery
Orthoquartzite (Sandstone)	Or	Sedimentary	Sandstone
Pegmatite	Pg	Igneous	Igneous
Phyllite	Ph	Metamorphic	Metamorphic
Quartzite	Qr	Metamorphic	Metamorphic
Rhyolite/Metarhyolite	Rh	Igneous	Igneous
Sandstone	Sa	Sedimentary	Sandstone
Schist	Sch	Metamorphic	Metamorphic
Sedimentary rock type not identified in this listing		Sedimentary	Sedimentary - Other
Serpentinite	Sr	Metamorphic	Metamorphic
Shale	Sh	Sedimentary	Shale
Siltstone	Si	Sedimentary	Siltstone
Slate	Sl	Metamorphic	Metamorphic
Unsampled	Uns	N/A	Unsampled
Void	Vd	N/A	Void

4 Rock Structure Descriptors

Descriptor	Abbreviation	Rock Origin	Description
Amygdaloidal	Amg	Igneous	Vesicle which has been filled with secondary minerals
Concretions	Ccr	Sedimentary	Hard, compact masses formed by the precipitation of minerals
Cross Bedded	Crb	Sedimentary	Original depositional layering is inclined
Fissile	Fsl	Sedimentary	Splits easily along planes of weakness into thin sheets
Flow-Banding	Flb	Igneous	Bands or layers formed during original molten rock flow
Foliated	Fol	Metamorphic	Thin layering from alignment of constituent mineral grains
Gneissic Foliation	Gnf	Metamorphic	Planar zones of dark and light colored minerals
Graded Bedding	Grb	Sedimentary	Change in grain size from the base of the bed to the top; typically coarser sediments at base
Nodules	Nd	Sedimentary	Solid mineral replacement body generally rounded in shape
Non-Foliated	Nfo	Metamorphic	Absence of foliation
Oolitic	Olt	Sedimentary	Containing small round calcareous grains
Schistose	Sct	Metamorphic	Containing parallel arrangement of platy or prismatic minerals
Shaley	Sha	Sedimentary	Exhibiting shaley structure, fissility, or thin partings
Slaty Cleavage	Scl	Metamorphic	Cleavage into thin layers or plates, like those of slate
Slickensided	Slk	All Rock Origins	Exhibiting polished, striated surface along which movement of rock has occurred
Vesicular	Vsc	Igneous	Containing small cavities called vesicles which formed when gases escaped from lava
Weakly Foliated	Wfo	Metamorphic	Exhibiting weak or less distinct foliation

5a Rock Texture Descriptors

Descriptor	Abbreviation	Rock Origin	Description
Aphanitic	Aph	Igneous	Contains crystals so fine that individual minerals cannot be distinguished with naked eye
Coarse-Grained	Cgr	Sedimentary	Consists of predominately coarse-grained particles
Crystalline	Crs	All Rock Origins	Consisting of or containing crystals
Fine-Grained	Fgr	Sedimentary	Consists of predominately fine-grained particles
Glassy	Gls	Igneous	Resembling glass in smoothness and shininess
Pegmatic	Peg	Igneous	Containing very coarse grains greater than 3 cm in length
Phaneritic	Pha	Igneous	Contains crystals roughly equal in size and individual minerals can be distinguished with naked eye
Phenocrystic	Phe	Igneous	Contains large conspicuous crystals
Pitted	Ptd	All Rock Origins	Contains numerous very small voids
Porphyroblastic	Pbl	Metamorphic	Contains large crystals embedded in a finer-grained matrix
Porphyritic	Prt	Igneous	Contains relatively large isolated crystals in fine texture matrix
Vitreous	Vit	All Rock Origins	Resembling glass, but with a vitreous (pearly) luster
Vuggy	Vug	All Rock Origins	Containing voids usually with a mineral lining of different composition

5b Rock Descriptor Modifiers

Descriptor	Abbreviation	Rock Origin	Description
Dull Luster	Dls	All Rock Origins	Dull earthy appearance
Evaporites	Evp	Sedimentary	Formed from evaporation of lake or sea water
Friable	Frb	All Rock Origins	Easily broken or crumbled
Glassy Luster	Gls	All Rock Origins	Having a glassy appearance
Metallic Luster	Mls	All Rock Origins	Having a surface appearance similar to or resembling metal
Mineral Veins	Mnv	Sedimentary	Having fractures that have been filled with mineral material (quartz)
Pearly Luster	Pls	All Rock Origins	Having a surface appearance similar to or resembling a pearl
Waxy Luster	Wls	All Rock Origins	Having a surface appearance similar to or resembling wax

6 Rock Hardness Descriptors

Descriptor (Abbrev.)	Test Criteria for Hand Specimen	Typical PA Rock Type	Approx. Mohs Hardness Scale	Materials in Hardness Range
Very Soft (**Vs**)	Scratched by a wood dowel or fingernail	Gypsum, evaporites, some shale	1 – 2	PVC, fingernail
Soft (**Sf**)	Scratched by rubbing against the surface of a copper pipe or fitting, but not scratched by a wood dowel or fingernail	Schist, shale, most limestone	3 – 3.5	copper pipe
Medium Hard (**Mh**)	Scratched by rubbing against the surface of a common steel nail, but not scratched by rubbing against the surface of a copper pipe or fitting	Siltstone, sandstone, some limestone	5 – 5.5	common nail, glass
Hard (**Hd**)	Scratched by rubbing against a hardened steel file, but not scratched by rubbing against the surface of a common steel nail	Some sandstone, chert, granite, gneiss	7.5 - 8	hardened steel, porcelain
Very Hard (**Vh**)	Not scratched by rubbing against a hardened steel file	Some hornfels	> 8	corundum

7 Rock Weathering Descriptors

Descriptor (Abbrev.)	Criteria
Fresh (**Fw**)	No visible decomposition, discoloration, or oxidation.
Slightly Weathered (**Sw**)	Slight decomposition, discoloration, or oxidation **impacting < 20 % of the rock mass.**
Weathered (**Ww**)	Significant decomposition, discoloration, or oxidation **impacting 20 to 40 % of the rock mass.** Weaker minerals decomposed. Apparent strength less than fresh parent rock.
Moderately Weathered (**Mw**)	Moderate decomposition, discoloration, or oxidation **impacting 40 to 60 % of the rock mass.** Noticeable loss of strength relative to fresh parent rock.
Highly Weathered (**Hw**)	Major decomposition, discoloration, or oxidation **impacting > 60 % of the rock mass.** Rock is significantly weakened relative to its un-weathered state. Less weathered components may be present in rock mass.

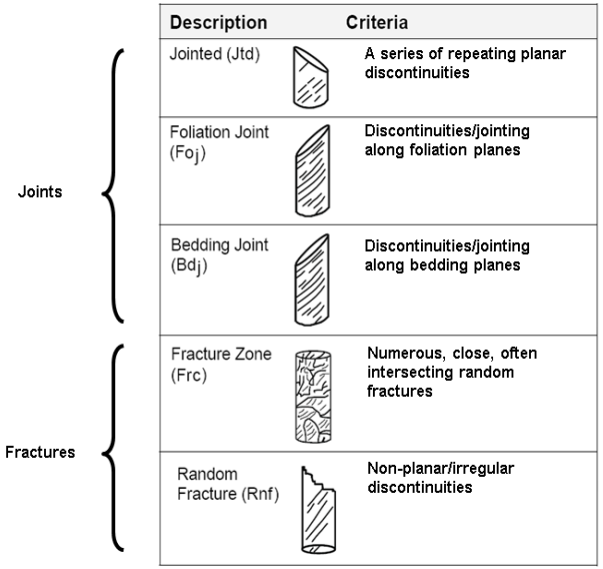
8a Rock Bedding

Bedding Thickness (Abbrev.)	Description
Indistinct Bedding (**Inb**)	Bedding structure not clearly defined
Laminated Bedding (**Lmb**)	Bedding thickness < 1/4 inch
Thin Bedding (**Tnb**)	Bedding thickness 1/4 to 1 inch
Narrow Bedding (**Nrb**)	Bedding thickness 1 to 3 inches
Moderate Bedding (**Mob**)	Bedding thickness 3 to 9 inches
Medium Bedding (**Meb**)	Bedding thickness 9 to 24 inches
Thick Bedding (**Tkb**)	Bedding thickness 2 to 6 feet
Massive Bedding (**Mab**)	Bedding thickness > 6 feet

8b Bedding/Discontinuity Dip Descriptors

Bedding/ Discontinuity Dip (Abbrev.)	Description
Flat Dip (**Fld**)	Beds/Discontinuities dipping < 5 degrees
Shallow Dip (**Sld**)	Beds/Discontinuities dipping from 5 to 15 degrees
Moderate Dip (**Mdd**)	Beds/Discontinuities dipping from 15 to 30 degrees
Steep Dip (**Std**)	Beds/Discontinuities dipping from 30 to 45 degrees
Very Steep Dip (**Vsd**)	Beds/Discontinuities dipping from 45 to 60 degrees
Sheer Dip (**Srd**)	Beds/Discontinuities dipping > 60 degrees

10a Standard Core Log Descriptors for Discontinuity Types



10b Discontinuity Spacing Descriptors

Descriptor	Abbreviation	Description
Laminated	Lmd	Discontinuity spacing < ¼ inch
Narrow	Nrd	Discontinuity spacing from > ¼ inch up to 1 inch
Close	Cld	Discontinuity spacing > 1 inch up to 3 inches
Moderate	Mod	Discontinuity spacing > 3 inches up to 9 inches
Medium	Med	Discontinuity spacing > 9 inches up to 2 feet
Wide	Wdd	Discontinuity spacing > 2 feet up to 6 feet
Massive	Mad	Discontinuity spacing > 6 feet

10c Discontinuity Opening Descriptors

Descriptor	Abbreviation	Description
Tight Joints	Tjo	No open space at discontinuities - fits together tight, but not a fresh break
Narrow Joint Opening	Njo	Open spacing up to 1/8 inch - aligned well but may have some evidence of weathering along discontinuity planes
Open Joints	Ojo	Open space > 1/8 inch up to 3/8 inch – usually weathering along discontinuity planes
Large Joint Opening	Ljo	Open space > 3/8 inch up to 1 inch – often significant weathering along discontinuity planes
Wide Joint Opening	Wjo	Open space > 1 inch – may have significant weathering or may have infilling

Examples of Field Rock Descriptions:

1. fossiliferous BRECCIA, dark red-brown, very soft, fresh, medium bedding, steep dip, fracture zone, narrowly spaced discontinuity, sheer dip, narrow joint opening, (1/8-in thick, filled with calcite, very soft)
2. micaceous SCHIST, brown with mottled yellow-brown, foliated, soft, highly weathered, jointed, medium spaced discontinuity, sheer dip, wide joint opening
3. CLAYSTONE, gray and red-brown, metallic luster, soft, slightly weathered, moderate bedding, moderate dip, fracture zone, medium spaced discontinuity, sheer dip, (no infill)
4. SILTSTONE, red-brown, medium hard, slightly weathered, medium bedding, flat dip, random fractures, widely spaced discontinuity, sheer dip, tight joints
5. dolomitic LIMESTONE, gray to blue-gray, vuggy, mineral veins, medium hard, slightly weathered to moderately weathered, moderate bedding, steep dip, bedding joint, moderately spaced discontinuity, moderate dip, narrow joint opening (slickensided)

Publication 222

pennsylvania
DEPARTMENT OF TRANSPORTATION