CHAPTER III - GEOTECHNICAL ENGINEERING

Chapter III - GEOTECHNICAL ENGINEERING

SECTION 301 INTRODUCTION

This Manual of Instructions (MOI) presents minimum requirements for conducting geotechnical engineering studies for VDOT projects throughout the Commonwealth of Virginia. This document is the work product of the Materials Division and is prepared in conjunction with VDOT's Structure and Bridge Division, which relies on geotechnical data and interpretation for the design of structure foundations.

Geotechnical engineering explorations and analyses within the Commonwealth of Virginia occur in widely varying geologic terrain throughout the five physiographic provinces (i.e., Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge and Appalachian Plateau). Work on VDOT projects is primarily coordinated through nine district offices. This document is intended to establish typical requirements pertaining to state-wide geotechnical exploration and analyses. However, VDOT acknowledges that in instances where unique field conditions or local practices warrant exceptions to this manual, such exceptions shall be approved in advance by the District Materials Engineer.

VDOT projects include the efforts of Central Office, district offices, on-call consultants, design-builders, PPTA concessionaires, localities, and developers. To develop conformity in those work products, this MOI establishes minimum standards and design criteria for our projects.

Depending on the nature of the project, geotechnical engineering studies for VDOT projects may include the following:

1. The various soil and/or rock types within the limits of the project.
2. The effect of ground water on the proposed project.
3. Soils in proposed cut areas (i.e., soil classification, moisture content and moisture-density relations) for proposed reuse as compacted fill.
4. Representative samples of each soil or rock type or stratum for testing and classification in the laboratory.
    a. Soil samples for testing to determine particle size distribution, moisture content, liquid and plastic limits, CBR (California Bearing Ratio), M_r (resilient modulus), etc.
    b. Undisturbed (e.g., Shelby tube) samples for testing to determine consolidation and shear strength parameters under various loading conditions.
    c. Rock core samples for direct visual evaluation, RQD (rock quality designation), RMR (rock mass rating), GSI (Geological Strength Index), or strength testing.
5. Soil and surface water sampling and test data to assess the potential for pipe corrosion (pH and resistivity).
6. Samples of stream bed materials for testing to provide information for scour analysis when the proposed construction will bridge streams or rivers as part of the foundation evaluation.
7. Physical/behavioral properties of soils using in-situ testing techniques and laboratory testing methods.
8. Seismic site classification as defined by AASHTO LRFD.
9. The capacity for the bearing material to support loads at various depths beneath sites where embankments, structures, and/or structural components (foundations) will be located.
10. Stability of soil and rock slopes for cut and fill conditions, including the strength and settlement characteristics of the soil that is beneath proposed embankments.
11. The anticipated magnitude and time rate of settlement owing to the applied loads of the proposed earthwork and/or structure(s). If settlement determinations exceed VDOT's requirements, the geotechnical study shall provide site improvement design to limit settlement.
12. Geologic constraints or conditions that may have an adverse effect on the project.

Prior to conducting any subsurface exploration program, the scope of work for the project is typically defined by the project scoping report prepared by the Central Office L&D (Location and Design) Division or the district's L&D Section. Such definition shall include a copy of any proposed structure layouts indicating the proposed locations of bridge substructure elements and any retaining walls. The definition of the scope of work will typically include the major project elements including proposed embankments, cut slopes, new pavements, pavement rehabilitation areas, retaining walls, sound walls, minor structures, stormwater management facilities, foundation elements and the need to address scour.

It is the obligation of VDOT to coordinate with the on-call consultant to convey the design elements of the project to facilitate their execution of an appropriate geotechnical engineering program.

It is the obligation of design-build contractors and PPTA concessionaires to fulfill the minimum requirements of this MOI upon contract award. Background data provided in the RFP can be incorporated into such efforts, as deemed appropriate by the professional engineer in responsible charge of the effort.

Local Assistance Projects and private land development projects intended to be brought into the VDOT network of roads shall also include geotechnical engineering studies that conform to the requirements of this MOI.

SECTION 302 ADMINISTRATIVE REQUIREMENTS

Administrative requirements relate to all field explorations performed by or for VDOT.

302.01 Safety

All field exploration and other project-related activities shall conform to all applicable safety requirements of OSHA (U. S. Department of Labor, Occupational Safety & Health Administration), VOSH (Virginia State Occupational Safety and Health) and VDOT. On-call consultants are responsible for ensuring that all field personnel (including subconsultants), have the requisite training and/or certifications to perform their assigned tasks safely.

302.02 Existing Utility Protection

"Miss Utility" shall be notified at least 72 hours in advance of any subsurface exploration. Miss Utility's marking service includes public utilities. Many of VDOT's utilities (i.e., culverts, wiring, etc.) and utilities on private land are considered "private" as they are not owned by designated public utility companies. To protect the private utilities of VDOT or neighboring landowners, work on such land may require the services of private utility locating companies.

302.03 Landowner Notification

No investigation shall be undertaken on any property that is not within VDOT's right-of-way without first notifying the landowner in accordance with **§**33.1-94 **of the Code of Virginia**. This restriction includes crossing of property by personnel and equipment to gain access to another property where an investigation will be conducted. Property belonging to other government bodies, agencies or institutions, and highway property that is not part of the public road system, is also included in this restriction.

The District Geologist, Geotechnical Engineer, on-call consultant, or other person in charge of the investigation, shall ensure that each property owner has been notified in writing prior to the commencement of any work on that property, in accordance with the aforementioned code. The property owner should be advised of the nature and extent of the investigation. They should also be provided with the name and telephone number of the person to be notified, usually the District Materials Engineer, in case problems or additional questions arise. Any legitimate questions that cannot be answered by the geologist/geotechnical engineer or other person in charge should be referred to the District Materials Engineer. The property owner should receive a prompt response. This need not interfere with the commencement of the investigation.

In instances where property damage occurs during the field exploration, the District Materials Section shall notify the Right-of-Way and Utilities Section for assistance.

Property owners should be advised that a follow-up inspection by the District Materials Section or on-call consultant will occur within approximately thirty days after completion of the field exploration. The purpose of the inspection is to check for and correct subsidence of the backfill in the boreholes, if noted. Photographs shall be taken of all damaged areas and all completed repairs. To protect the interests of VDOT, photographs of properties outside of the right-of-way shall be taken prior to commencing fieldwork.

In any case where the property owner indicates reluctance regarding the necessary exploration, the field personnel shall avoid an argument. If the District Materials Section or on-call consultant is unsuccessful in resolving the landowner's concern, the Right of Way and Utilities Section shall be engaged for assistance. If necessary, the situation shall be elevated and ultimately, the support of the State Police may be required to ensure access as well as the safety of the field personnel.

302.04 Work on Railroad Property

A working arrangement has been established with the railroad companies in Virginia through the DRPT (Department of Rail and Public Transportation Division) whenever a project requires entry on or accessing through railroad property. To perform work on or accessing through railroad property, District Materials' staff are to write to the DRPT and request that arrangements be made for permission to enter. A copy of the letter should be sent to the office of the Assistant Administrative Services Officer (who will arrange for the required insurance). Two copies of the proposed subsurface exploration plan (showing proposed boring or in-situ test locations) are to be forwarded with the letter of request. The letter of request shall include the following information:

1. Name of the railroad;
2. Lateral limits of the project (with respect to the nearest railroad milepost) and the locations of abutments and/or piers relative to the tracks;
3. Project number;
4. Special requirements such as, flagperson (who will be provided by railroad), train schedule, etc.;
5. Estimated start date of field work; and
6. Estimated end date of field work.

The DRPT and the Assistant Administrative Services Officer must be notified if a time extension is required. For investigations performed by consultants, VDOT will secure the right of entry and a list of any restrictions. VDOT will either secure or reimburse the consultants for obtaining Railroad Protective Liability Insurance coverage when field exploration is required on railroad property.

302.05 Traffic Control

All field exploration activities shall include traffic control as required by the "Virginia Work Area Protection Manual" and the Manual on Uniform Traffic Control Devices, which are available at the following URLs:

www.VirginiaDOT.org
http://mutcd.fhwa.dot.gov/

For any work involving partial or full lane closures for any amount of time, an appropriate traffic control plan must be submitted to the VDOT district office for approval. The district office must be notified of all lane closures at least one week prior to commencing field operations. This notification shall indicate the route number, travel direction, number of lanes affected, hours of closure, number and types of equipment to be used, number of field personnel, supervisor contact name and telephone number, and the nature and purpose of the work. On-call consultants must obtain all written authorization and/or approvals from VDOT prior to commencing any lane closures. A copy of all authorizations and/or approval forms shall be with the field crew(s) at all times. All time-of-work or other restrictions required by the district office shall be strictly obeyed. The field supervisor must call the district office upon commencement of the lane closure and immediately upon removal of the lane closure.

302.06 Work in Environmentally Protected Lands

Prior to initiating any field study, the District Materials Section shall submit to the District Environmental Section a request for a "permit determination." Such permit determination shall include a test boring location plan showing the proposed boring locations and proposed locations with routes of travel to each boring. Such requests may be submitted via email or through the CEDAR EQ-429 format. Typically, the Environmental Section requires 30 days to process a permit determination. If a permit is required, permit documents provided by the Environmental Section shall be on-hand with the field crew(s) at all times while performing the work. The field crew(s) must comply with all conditions of the permit documents.

Prior to the field exploration program, the District Materials Section shall check with the District Environmental Section to ascertain whether the site has any known environmental contamination. Health and safety requirements for geotechnical field exploration in sites with known contamination shall be coordinated with the District Environmental Section.

If unanticipated contamination is found during the course of any subsurface exploration, the work shall cease, the drilling equipment left in place, and the District Environmental Section shall be notified immediately. No further work shall be performed until cleared by the District Environmental Section.

SECTION 303 MINIMUM GEOTECHNICAL INVESTIGATION REQUIREMENTS

Geotechnical investigations include the field exploration and laboratory testing programs. These two programs must be tailored to the nature of the proposed construction, anticipated structural/earthwork loads, and the geologic conditions of the project. The proposed geotechnical investigation program shall be submitted to the District Materials Engineer for approval prior to starting the work. Modifications or clarifications to the minimum required exploration or laboratory testing programs shall be subject to the approval of the District Materials Engineer.

303.01 Subsurface Exploration Program

Planning for the subsurface exploration program should assure adequate coverage, location, and depths of borings, and sufficient laboratory tests to produce data required for thorough analyses. The exploration program should result in recommendations for technically sound and cost-effective construction. Each project must be evaluated according to its specific site characteristics, types of proposed construction, and the amount of funds available. The subsurface exploration program shall include sufficient number and depth of exploration points to adequately characterize the subsurface conditions for the proposed construction. Refer to Table 3-1 and Figures 3-1 through 3-4 for minimum requirements. Consult with the District Materials Engineer for those projects not addressed by the table or figures.

Unless other arrangements are made by the District Materials Engineer, subsurface exploration programs for VDOT projects shall include full-time observation and documentation by a field engineer or geologist familiar with the local geology and the minimum requirements of this MOI. Field engineers and geologists shall work under the direct supervision of a licensed professional engineer registered in the Commonwealth of Virginia or a professional geologist certified in the Commonwealth of Virginia.

During the performance of conventional soil or rock borings, the field engineer or geologist shall develop field logs as the exploration progresses, and document the following: Changes in lithology, drilling rate, driller's comments, observations from auger cuttings, changes in drill mud character, and other relevant information (i.e., loss of return water, loss of tools, etc.). The field engineer or geologist should also perform pocket penetrometer strength tests on all cohesive samples recovered during the field program. Comments and any results from pocket penetrometer strength tests shall be recorded on the field boring logs.

The table and figures below refer to exploration points with specific spacing and depth requirements. In many instances these exploration points will consist of conventional soil or rock borings. However, when appropriate, select exploration points may be substituted with in-situ test exploration, such as CPTu (cone penetration test with pore pressure measurements), DMT (flat plate dilatometer test) or FVST (field vane shear test). Where in-situ testing methods are employed, at least 50 percent of the exploration points shall consist of conventional soil borings (i.e., no greater than alternating frequency). At least 10 percent of the in-situ testing locations shall be immediately adjacent to conventional boring locations. The appropriate use of in-situ testing methods shall be approved by the District Materials Engineer prior to implementing the subsurface exploration program.

VDOT routinely performs subsurface exploration programs for the benefit of advertising RFPs (requests for proposals) for design-build services. The subsurface exploration and laboratory test programs are used to prepare a GDR (geotechnical data report). Typically the subsurface exploration program for a GDR consists of between 30 and 70 percent of the subsurface exploration program shown in the table and figures below.

303.02 Subsurface Exploration Methods

Conventional soil borings shall be advanced using hollow-stem augers (ASTM D6151), mud-rotary, or other approved methods. A plug shall be used to prevent cuttings from migrating upward through the hollow-stem auger. In no case shall hollow-stem augers be used to advance a boring if the driller cannot control running sand, and heave is observed to obstruct the hollow stem auger. Where heave is observed in the hollow-stem auger, water can be added in an attempt to control heave. If heave cannot be controlled by adding water then the drilling method shall be converted to mud-rotary or cased-boring methods.

As an alternate to the use of hollow-stem augers, VDOT allows the mud-rotary method. The mud-rotary method uses drilling fluid to convey cuttings to the ground surface. The proper mixture of drilling fluid provides sidewall stability without the corresponding need to advance casing. If mud-rotary methods are required in a boring that was begun using hollow-stem augers, the log shall indicate the depth where the drilling method was changed.

In some geologic terrain, the subsurface materials may be too coarse-grained (i.e., containing gravel or cobbles) for hollow-stem auger or mud-rotary methods. In these instances, cased borings are required.

Cased borings require the advancement of casing to the sample depth and rotary drilling methods to flush out the casing. Casing shall be driven vertically. The casing shall have a nominal inside diameter of 2½ or 4 inches. When casing is driven, use clean water as the drilling fluid. Simultaneous washing and driving of the casing will not be permitted unless approved in advance by the District Materials Engineer.

N-sized rock core shall be taken in accordance with ASTM D2113 unless otherwise approved by the District Materials Engineer. Wireline recovery methods are preferred when coring lengths exceed 10 ft. Run lengths shall be limited by the length of the core barrel, but in no instance shall drilling runs continue when water flow is blocked. (Blocked water flow results in elevated water pressure and typically indicates rotation of the inner core barrel, which results in core loss.) Those intervals with high water pressure shall be noted on the boring logs. Boring logs shall also depict the run depths, recovery, RQD (ASTM D6032) and duration (i.e., coring rate) of each run.

Water loss, subsequent water recovery, voids, and other relevant coring information shall also be noted on the boring logs.

Ground water and cave-in depth measurements shall be obtained in hollow-stem auger borings immediately upon extraction of the augers and prior to rock coring (if applicable). Also the approximate depth of ground water encountered during drilling should be noted on the boring log. Ground water and cave-in depth measurements shall be obtained in all types of borings at least 24 hours after completion of the borings, unless safety, traffic, or other factors require that the boreholes be backfilled upon completion. Field engineers and geologists shall record ground water and cave-in depths to the nearest 0.1 ft.

NCHRP Synthesis 368 (2007) provides information on the use of CPT. The following URL provides a link to this Synthesis:

(http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_368.pdf).

FHWA Publication FHWA-SA-91-044 (1992) provides information on the use of the DMT, ASTM test methods D1586, D5778 and D6635 also present information on the use of CPTu (cone penetration test with pore pressures), FVST, and DMT, respectively.

Drilling, sampling and in-situ testing methods not referenced herein shall be in accordance with applicable ASTM or AASHTO tests methods and shall be approved in advance by the District Materials Engineer or the Central Office Geotechnical Engineering Program Manager.

TABLE 3-1 – GUIDELINES FOR MINIMUM NUMBER OF INVESTIGATION POINTS AND DEPTHS OF INVESTIGATION		
Application	**Min. Number and Location of Exploration Points**	**Minimum Depth of Investigation**
Pavement Subgrade (Cuts and Fills less than 25 feet)	For two lane roads or single lane ramps place one exploration every 200 feet, alternating along the centerline of each lane (See Figure 3-1). For divided highways, one exploration shall be performed every 100 ft, alternating between the centerline of each lane sets (See Figure 3-3).	Each exploration shall be advanced to at least 5 feet below the proposed subgrade elevation (in cut areas). In fill areas, the explorations shall be advanced to a depth equal to the height of fill but not less than 5 feet below the existing grade. The exploration depths shall be extended in areas where culverts or storm drains are to be installed in the vicinity of the proposed pavement area. In this case, the explorations shall be advanced to at least one pipe diameter below the lowest invert elevation of the proposed buried structure. The explorations shall be extended to fully penetrate any unsuitable natural soils (i.e., soft, compressible or organic soils) or existing fill and penetrate at least 5 feet into the underlying suitable natural soils unless rock is encountered at shallower depths.
Cut Slopes greater than 25 feet or cuts where bedrock is expected to be encountered above planned depth of excavation.	Place one exploration at every 200 ft interval along the anticipated limits of cut (top of slope) along with the exploration pattern for pavement subgrade as illustrated in Figures 3-2 and 3-4. In non-pavement areas, explorations shall be placed at the anticipated top and bottom of the slope at every 200 ft interval of slope length. These explorations shall be included in order to define the soil profile for use in stability analysis and/or to estimate rock quantities.	Each exploration shall be advanced at least 10 feet below the minimum elevation of the cut unless rock is encountered at shallower depths. If rock is present above the minimum elevation of the cut, the rock shall be cored to the full depth of the planned cut. The explorations shall fully penetrate any unsuitable natural soil or existing fill encountered at the minimum elevation of cut at least 10 feet into the underlying suitable natural soils. A ground water observation well may also be installed in at least one boring in order to obtain stabilized water level readings.
Embankments greater than 25 feet high	Place one exploration at every 200 ft interval along the anticipated limits of fill (toe of slope) along with the exploration pattern for pavement subgrade as illustrated in Figures 3-2 and 3-4. In non-pavement areas, place one exploration every 200 feet along the centerline of the embankment and along each toe in order to define the soil profile beneath the entire width of the embankment for use in stability and settlement analysis.	Each exploration shall be advanced to a depth of at least twice the embankment height unless rock is encountered at shallower depths. Each exploration shall be extended to fully penetrate any unsuitable natural soils or existing fill and penetrate at least 10 feet into the underlying suitable natural soils.

TABLE 3-1 – GUIDELINES FOR MINIMUM NUMBER OF INVESTIGATION POINTS AND DEPTHS OF INVESTIGATION (CONTINUED)		
Application	**Min. Number and Location of Exploration Points**	**Minimum Depth of Investigation**
Retaining Walls and Sound Walls	Explorations shall be spaced no greater than 100 feet along the alignment of retaining walls and 200 feet for sound walls. At least one exploration shall be drilled for walls less than 100 feet in length. For anchored or tieback walls, additional explorations shall be sited in the anchored or tieback zone. For soil nail walls, additional explorations shall be performed behind the wall at a distance corresponding to 1.0 to 1.5 times the height of the wall at 100 feet maximum spacing.	Each exploration shall extend below the bottom of the wall to a depth of between 1.0 to 2.0 times the wall height or to the depths indicated herein for shallow or deep foundations. The exploration shall be extended to fully penetrate any unsuitable soils or existing fill. Each exploration shall extend at least 10 feet into competent material of suitable bearing capacity. If rock is encountered at grades above the proposed foundation elevation, it shall be cored to a depth of at least 10 feet to determine the integrity and load capacity of the rock, and to verify that the exploration was not terminated on a boulder.
Bridge Piers and Abutments on Shallow Foundations	A minimum of two explorations shall be performed per substructure unit. More explorations may be necessary if variable subsurface conditions are anticipated or encountered.	The explorations shall be drilled to a depth where the stress increase due to estimated footing load is less than 10 percent of the existing effective overburden stress. Typically, this depth represents approximately 2 times the estimated width of the pier footing ($L \leq 2B$), or 4 times the estimated width of the strip footing ($L > 5B$). For intermediate footing lengths, the minimum depth of exploration may be estimated by linearly interpolation as a function of L between the depths of 2B and 4B below the bearing level. If rock is encountered, it shall be cored to a depth of at least 10 feet to determine the integrity and load capacity of the rock, and to verify that the exploration was not terminated on a boulder.
Bridge Piers and Abutments on Deep Foundations	For bridges less than or equal to 100 feet wide, a minimum of one boring shall be performed per substructure. For bridges greater than 100 feet wide, a minimum of two borings shall be performed per substructure.	In soils, the depth of investigation shall extend at least 20 feet below the anticipated pile or shaft tip elevation or a minimum of 2 times the maximum pile group dimension, whichever is greater. For piles bearing on rock, a minimum of 10 feet of rock core shall be obtained at each investigation point in order to determine the integrity and load capacity of the rock, and to verify that the exploration was not terminated on a boulder. For drilled shafts that are supported on, or socketed into the rock, obtain a minimum of 10 feet of rock core, or a length of rock core equal to at least 3 times the estimated shaft diameter (for isolated shafts) or 2 times the minimum shaft group dimensions, whichever is greater. These coring requirements represent depths below the anticipated shaft tip elevation to determine the physical and strength characteristics of the rock within the zone of foundation influence.

TABLE 3-1 – GUIDELINES FOR MINIMUM NUMBER OF INVESTIGATION POINTS AND DEPTHS OF INVESTIGATION (CONTINUED)		
Application	**Min. Number and Location of Exploration Points**	**Minimum Depth of Investigation**
Stormwater Management Basin (impoundment area)	A minimum of two explorations shall be advanced per basin two acres or less in size. One additional exploration shall be drilled for each additional acre of pond area greater than two acres. The explorations shall be spaced to provide adequate coverage/profiling of the impoundment area.	Explorations performed within the impoundment area shall extend a minimum of 5 ft below the lowest bottom elevation of the proposed basin unless rock is encountered at shallower depths. The borings shall fully penetrate all unsuitable natural soils or existing fill and shall extend at least 5 ft into the underlying natural soils. For excavated basins, bulk soil samples shall be obtained for laboratory moisture-density relations (i.e., VTM-1). A ground water observation well may also be installed in at least one exploration in order to monitor the long-term ground water levels.
Stormwater Management Basin (embankment and outfall pipe)	At least one exploration shall be performed near each end and at the maximum height of the embankment. For embankments greater than 20-ft high, explorations shall be performed at maximum 200-ft intervals along the embankment centerline (longitudinal axis) and at the corresponding upstream and downstream toe locations. One exploration shall be performed at each end of the outfall pipe and at maximum 100-ft intervals along the length of the pipe. Additional explorations shall be provided at other critical locations. Existing embankments that are to be converted or incorporated into a proposed stormwater management basin embankment shall be investigated using the above guidelines so the existing embankment can be adequately evaluated.	The depth of exploration shall be at least equal to the maximum height of the proposed embankment dam. Explorations may be terminated after penetrating a minimum of 10 ft into hard and impervious stratum if continuity of this stratum is known from reconnaissance. If rock is present within 10 ft or less of the bottom of the embankment, a minimum 10 ft of rock core shall be obtained at each exploration point in order to assess the integrity and seepage characteristics of the rock. The borings for the outfall works shall be drilled to the depths recommended herein for culverts and foundations. A minimum of two Shelby tube samples of the foundation material within the embankment site shall be obtained for permeability, shear strength, and/or consolidation testing, in case such testing is deemed necessary to evaluate stability and/or settlement of the embankment.
Pipes and Culverts (greater than or equal to 36 inches in diameter)	One exploration shall be performed at each end wall and at 200-ft intervals along the length of the pipe or culvert. Foundation investigation is generally not required for pipes and culverts less than 36-in diameter unless the preliminary engineering program indentifies soft, compressible, organic-rich soils or rock in advance of construction.	The borings shall be drilled to at least one pipe diameter below the invert elevation of the pipe or culvert unless rock is encountered at shallower depths. The borings shall be extended to fully penetrate any unsuitable natural soils or existing fill and extend at least 5 ft into the underlying natural soils. A ground water observation well may also be installed in at least one boring to monitor long-term groundwater level in areas where it is expected to be encountered at or above the design invert grade of the pipe or culvert.

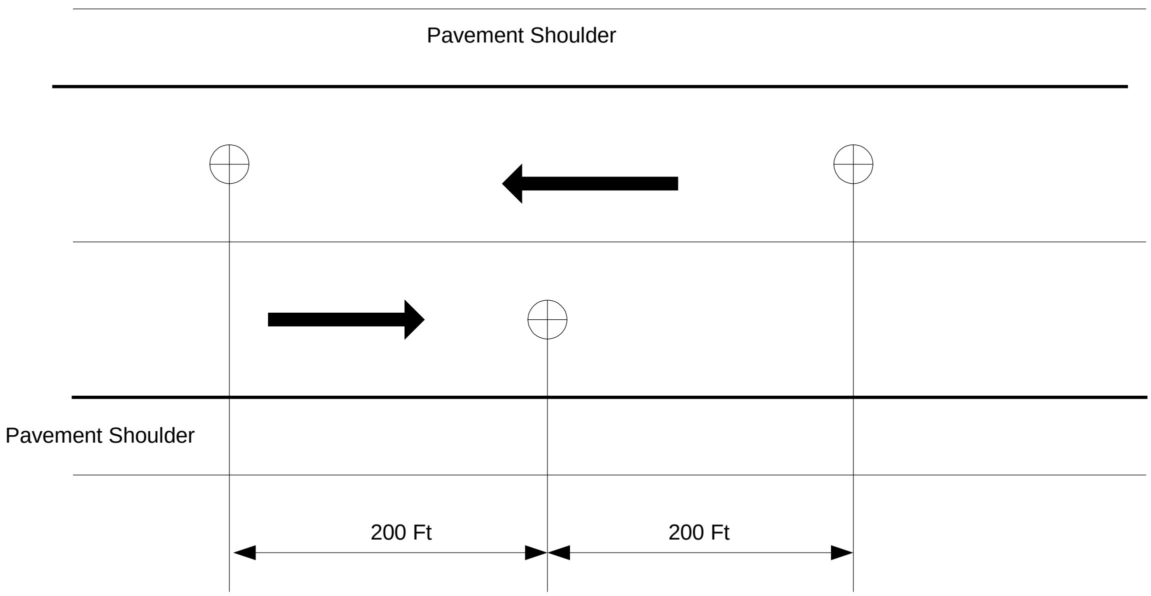

FIGURE 3-1 EXPLORATION LAYOUT FOR A TWO LANE ROAD OR SINGLE LANE RAMP

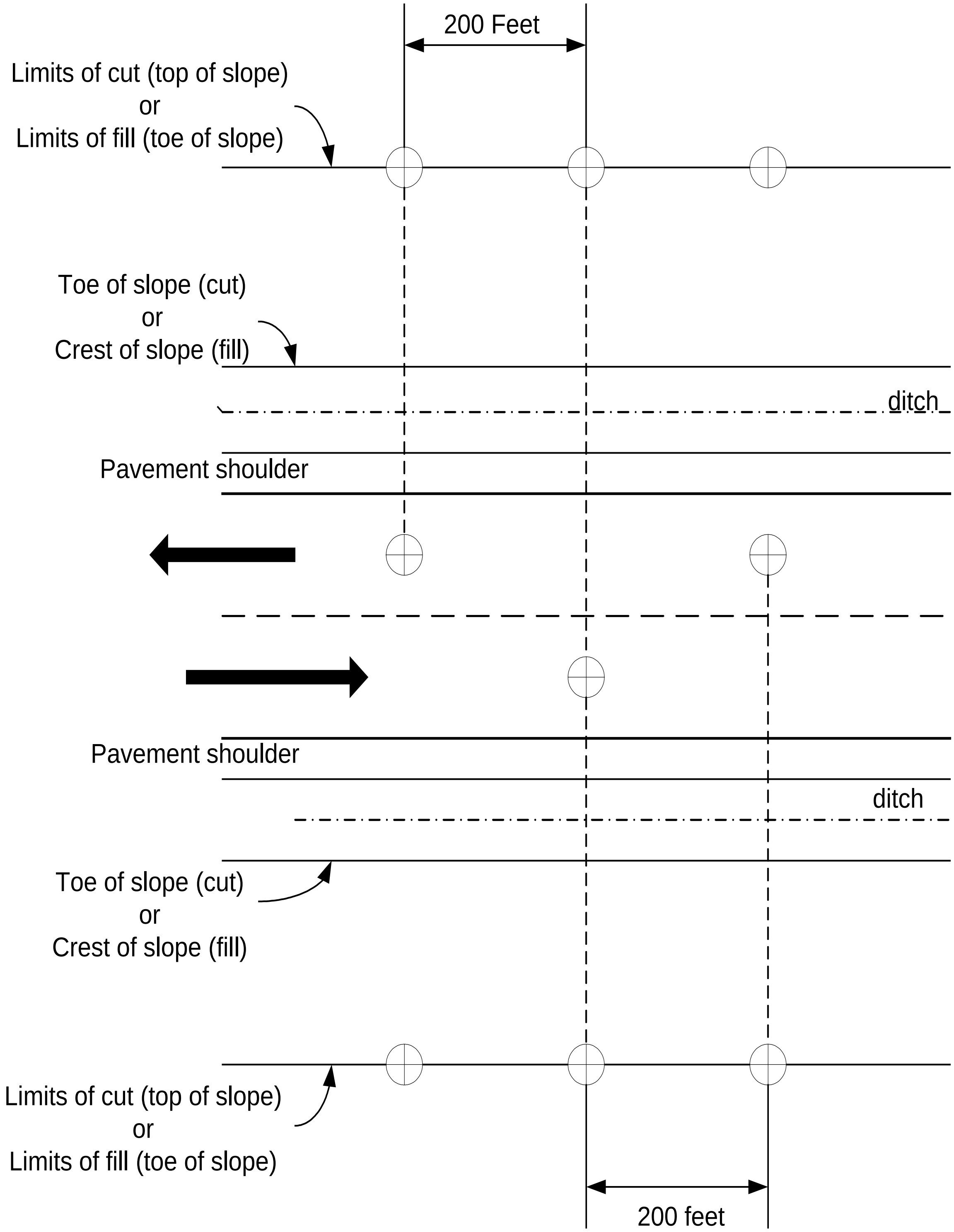

FIGURE 3-2 EXPLORATION LAYOUT FOR A TWO LANE ROAD WITH CUT OR FILL SLOPES EQUAL TO OR GREATER THAN 25 FT HIGH OR AREA WHERE ROCK IS EXPECTED TO BE ENCOUNTERED ABOVE THE PLANNED DEPTHS OF EXCAVATION

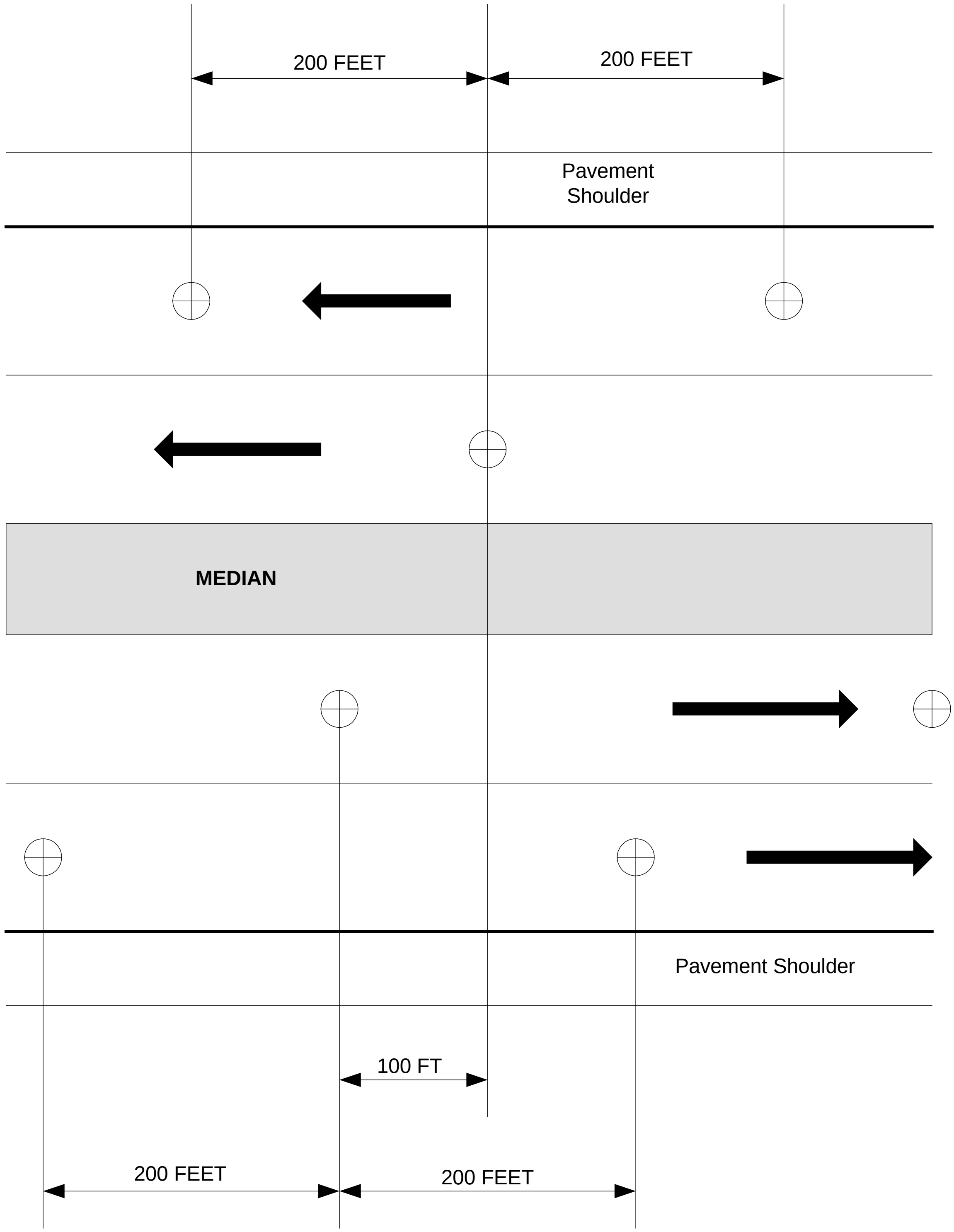

FIGURE 3-3 EXPLORATION LAYOUT FOR A FOUR (4) LANE DIVIDED ROAD

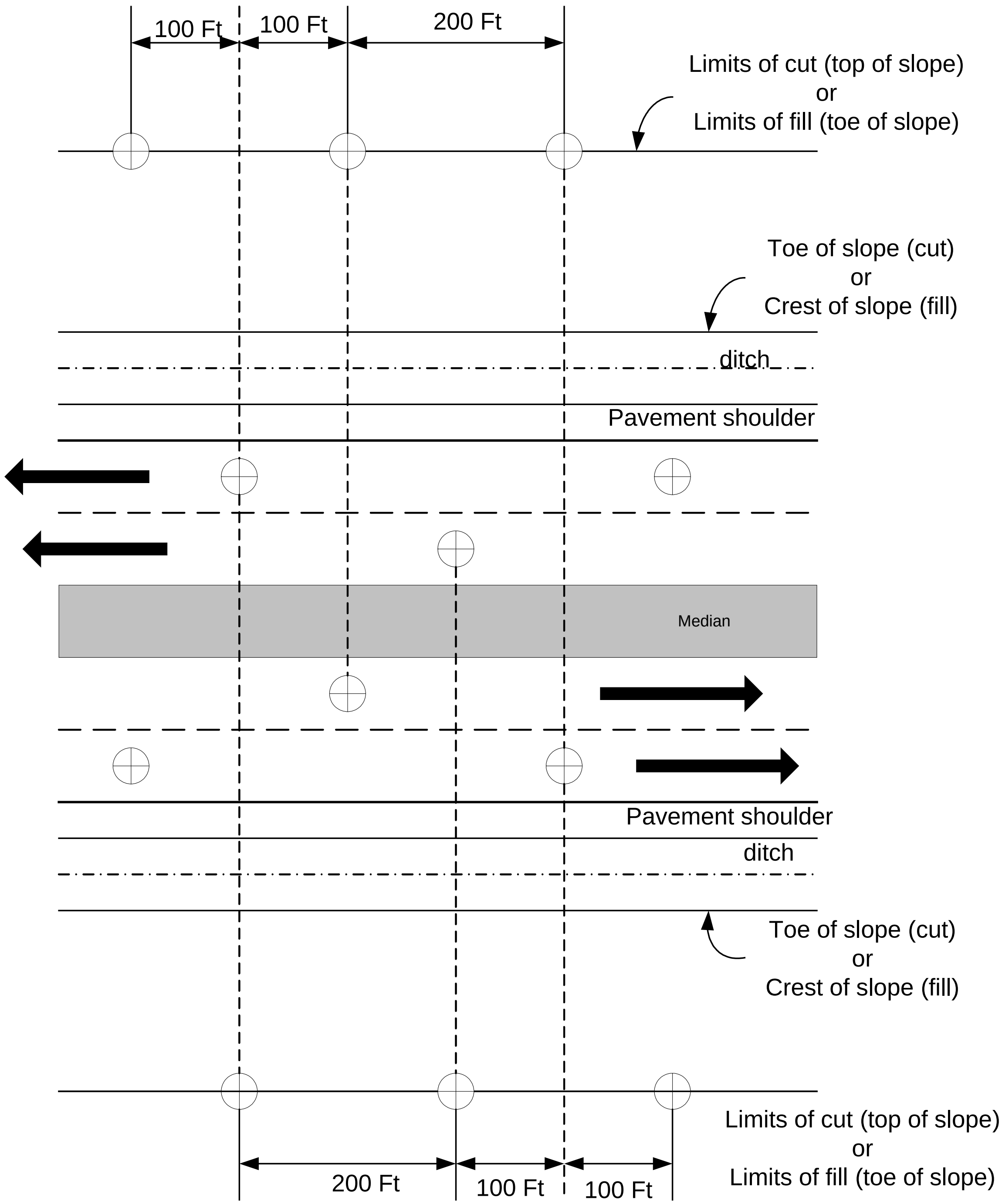

FIGURE 3-4 EXPLORATION LAYOUT FOR A FOUR (4) LANE DIVIDED ROAD WITH CUT OR FILL SLOPES EQUAL TO OR GREATER THAN 25 FT HIGH OR AREAS WHERE ROCK EXCAVATION IS EXPECTED TO BE ENCOUNTERED ABOVE THE PLANNED DEPTHS OF EXCAVATION

Geophysical exploration is an appropriate adjunct to a subsurface exploration program. Table 4.2 of EM-1110-1-1804 (http://140.194.76.129/publications/eng-manuals/em1110-1-1804/entire.pdf) presents the applicability of various geophysical methods. Field exploration programs that include those methods showing score values of "3" or "4" (as shown in Table 4.2 of EM-1110-1-1804) are appropriate for use on VDOT projects, providing the data objectives are related to the project requirements and the field program and data interpretation considers existing boring data and is performed under the direct supervision of a licensed professional engineer registered in the Commonwealth of Virginia. The appropriate use of geophysical methods shall be approved by the District Materials Engineer prior to implementing the field program.

303.03 Ground Water Observation Wells

Ground water observation wells are a means to measure the position of the water table, phreatic surface, or pore-water pressure that exists within a saturated geologic formation. Properly installed ground water observation wells can also facilitate the in-situ measurement of hydraulic conductivity (i.e., permeability). Ground water observation wells can also be a useful tool to quantify whether near-surface ground water is perched atop unsaturated soil or whether a vertical gradient exists.

The critical component of observation well construction is to isolate the screened interval (i.e., the portion of the well that is in contact with the ground water) in a portion of the formation that is defined. As such, some level of geologic exploration is needed prior to installing a ground water observation well.

A properly constructed ground water observation well includes the following:

1. Geologic log showing stratum breaks and approximation of the water table elevation;
2. Sufficient annular space to facilitate the installation of well construction materials;
3. Slotted well screen;
4. "Gravel pack" medium;
5. 12-in thick bentonite "plug;"
6. Water-tight stand pipe;
7. Backfill materials above the bentonite plug;
8. Surface seal (typically bentonite plug or concrete);
9. Surface completion (typically a pipe cap, flush-mount metal cover or locking guard box); and
10. Documented well-construction details in a graphic format (i.e., provide a drawing).

The best method of construction positions the bentonite plug below the ground water table. This construction approach allows for straight-forward completion of in-situ hydraulic conductivity testing, when required.

Borings advanced using HSAs (hollow-stem augers) are preferred when constructing ground water observation wells. When mud-rotary drilling is used, the presence of mud and the smaller hole diameter can complicate the placement of well-construction materials (i.e., gravel pack and bentonite plug). Also the mud used in rotary drilling can affect subsequent hydraulic conductivity testing.

Long well screens should not be used. Typical well-screens should be limited to a length of 5 ft. The use of longer well screens (i.e., 10 or 20 ft) tends to average the pore pressure (i.e., the position of the water elevation) to the average value for the entire screen interval. When a vertical gradient is present (or when the long well screen intersects multiple soil layers with differing hydraulic gradients) the long well screen will not provide meaningful data. Additionally, the use of a long well screen (i.e., greater than 5 ft) fails to isolate a discrete interval when performing in-situ hydraulic conductivity testing.

The position of the bentonite plug shall be 12 inches above the uppermost screen elevation. The purpose of the bentonite plug is to isolate the water elevation reading to a discrete interval. Considering that the gravel pack is present all the way up to the underside of the bentonite plug, it is actually the gravel pack interval that serves as the recording interval – not the slotted length.

The screen interval shall be set at the bottom of the boring. This may require a separate unsampled auger-probe boring be drilled in proximity to the original test boring. Consider the following: If the original test boring is advanced to a depth of 50 ft and groundwater is observed during drilling in a 10-ft thick sand layer below a depth of 15 ft, a well with a 5-ft long well screen in the bottom of the boring may not fully capture the position of the water table in the sand layer. An offset boring (i.e., within 10 ft of the original test boring) drilled to a depth of 25 ft with a 5-ft long well screen (and bentonite plug at 19 ft) would better characterize the water table elevation (and better facilitate in-situ hydraulic conductivity testing).

Polyvinyl chloride (PVC) well screens are provided in multiple lengths, diameters and slot dimensions. As discussed, the 5-ft long well screen should be considered the typical VDOT standard. To facilitate using a water level indicator, a minimum 1-in diameter casing should be used for well construction. Slot opening size (typically ranging from 0.006 - 0.500 in) should be selected, based on the anticipated geology (i.e., a smaller slot for clays or silts and a larger slot for sands or gravels). Any slot size will be effective in measuring the position of the water table, but using small slots in a coarse-grained soil can affect the results of in-situ hydraulic conductivity testing. The slot size of the well screen should retain 70 to 90 percent of the gravel-pack particle size.

The gradation of the gravel pack should be compatible with the gradation of the formation soils adjacent to the gravel pack. For typical installation, VDOT type “A” fine aggregate (i.e., concrete sand) should be used. When type “A” fine aggregate is used for the gravel pack, a 30-slot well screen is appropriate (i.e., 0.030 in slot opening size).

Ground water observation wells should be abandoned in accordance with all applicable federal, state, and local regulations.

303.04 Sampling Requirements

All soil samples recovered during the subsurface exploration shall be labeled, preserved and transported in accordance with ASTM D4220.

Soil samples from soil borings shall be obtained using the SPT (Standard Penetration Test – ASTM D1586). VDOT requires continuous sampling in the upper 10 ft and sampling at 5-ft intervals thereafter. The District Materials Engineer may modify this sampling requirement for a specific project need. The driller is responsible for sample recovery. When no recovery is obtained from a sample interval the driller shall advance the drill hole to the bottom depth of the failed sample interval and re-attempt sampling. Lack of sample recovery and follow-up sample attempt shall not affect the intended sample intervals for the remainder of the boring.

SPT samples shall be retained in glass jars with screw caps and placed into cardboard boxes with jar dividers. Each sample shall be marked with the boring number, sample depth, project number (i.e., UPC) and SPT hammer blow values for each 0.5-ft increment of penetration. The outside of the cardboard box shall include boring number(s), depth range(s), project name, project number, date and geologist’s/field engineer’s initials.

All test boring logs shall reference the type of hammer used to advance the SPT sample. The type of hammer has direct implication on engineering correlations as referenced by LRFD (AASHTO Load and Resistance Factor Design).

To address consolidation settlement and strength of cohesive strata, at least one Shelby tube sample (i.e., ASTM D1587) should be obtained for each cohesive soil stratum having strength and compressibility characteristics that cannot be adequately estimated for the intended construction, or cohesive soil strata having SPT N-values less than 5 or pocket penetrometer unconfined compressive strength values less than 1.0 tsf. The field geologist or field engineer shall record the recovery for each Shelby tube sample interval and present these data on the field boring log. Prior to sealing the Shelby tube sample, the geologist or field engineer shall classify the soil within the tube. Additionally, the field engineer or geologist should document the pocket penetrometer strength value of the Shelby tube sample for inclusion onto the boring log. Undisturbed samples may not be needed in each boring if the soil deposits throughout the project site are relatively uniform.

For projects requiring moisture-density relations (i.e., VTM-1, Standard Proctor test) and/or CBR (California Bearing Ratio) tests (i.e., VTM-8), a minimum of 75 pounds of soil shall be obtained from the desired stratum. If the project is part of the primary, arterial or interstate system, a 100 lb bulk sample is required for both CBR and M_r (resilient modulus – AASHTO T-307) testing. All bulk samples shall include a separate representative sample placed into a sealed container for moisture content testing. Bulk samples shall be marked to show the designation for sample location (e.g., boring, hand auger, test pit number), sample depth, project name, project number, date and geologist's/field engineer's initials.

Where finished subgrade for pavement is in cut, samples for CBR or M_r testing shall include each soil type in proximity to the intended subgrade elevation and a minimum of three samples per mile. These samples shall be obtained within 5 ft of the proposed finished subgrade elevation. Where finished subgrade will be placed as fill, samples for CBR or M_r testing shall be obtained at a frequency of one sample per 2,000 cy. The sample of proposed fill material shall represent the intended materials to be placed within 2 ft of the finished embankment subgrade. In all cases, the geotechnical engineer or geologist shall assure that a sufficient number of CBR or M_r test samples are obtained to adequately represent the various soils encountered on the project. Soil sample and CBR test frequency for design of subdivision and secondary roads shall be performed in accordance with the VDOT 2009 publication, "Pavement Design Guide for Subdivision and Secondary Roads in Virginia."

For projects requiring scour analyses, representative bulk samples shall be obtained from the bedload (i.e., the sediment within ±12-in of the stream bed) and also those sediments 20 ft below the bedload. If rock (RQD >50) is present within 20 ft of the stream bed scour in that interval is no longer a design concern. Representative samples for scour analyses shall be described according to ASTM D2487. The undrained shear strength of cohesive samples can be approximated using the pocket penetrometer. Samples for scour analyses shall also be submitted for grain-size distribution, in accordance with the methodologies presented in HEC-18, "Evaluating Scour at Bridges," Fourth Edition (FHWA Publication NHI-01-001, http://isddc.dot.gov/OLPFiles/FHWA/010590.pdf). The following table presents the appropriate sample size depending on the maximum grain-size diameter. Bulk samples for scour analysis shall be labeled as shown above (i.e., as bulk samples for moisture-density, CBR or M_r testing).

TABLE 3-2 - SAMPLE REQUIREMENTS FOR SCOUR ANALYSIS	
Nominal Size of Largest Particles (in.)	**Minimum Weight of Sample (lb.)**
3/8	1
1	5
2	9
3	11

When drilling below the bedload, conventional sampling equipment can often result in a grain-size bias. Such bias can have a significant effect on the resulting scour analysis. As such, field methods shall carefully document whether coarse-grained gravel, cobbles or boulders are present with depth. Field engineers and geologists shall consider the soils that are conveyed to the ground by the augers and note drilling activity when evaluating stream sediments for scour potential.

All soil, rock and other samples for VDOT projects shall be retained for 5 years following delivery of the project to the public. Such storage shall be provided by VDOT. Our on-call consultants shall deliver samples from completed projects to the District Materials Section and provide a transmittal letter to document chain of custody.

303.05 Soil, Intermediate Geomaterial, and Rock Descriptions

All boring logs shall begin by describing the type and depth of ground cover. If the ground is bare, indicate "no ground cover." Ground cover often consists of topsoil, root mat, forest litter, etc. In a cultivated field it is important to note cultivation depths, e.g., "Cultivated to a depth of approximately __ feet". Determine the thickness of the organic ground cover by using a shovel. Measuring the thickness of the layer in the SPT sampler generally results in inaccurate readings since the sampler tends to compress the material. It is not necessary to record the soil components of the topsoil layer on the boring log. It is sufficient to identify this layer as TOPSOIL (TOPS) along with the thickness in inches. For example an 8-in thick layer of topsoil would be recorded on the log as, "8-in TOPSOIL (TOPS)". Please note that the presence of organic-rich ground cover is often interpreted by the contractor as the stripping depth.

In many instances, the ground cover will consist of existing pavement materials. Note the thicknesses of asphalt concrete, Portland-cement concrete and subbase aggregate when pavement is present on the ground surface. If required by the project, determine the layer thicknesses of surface- and base-mix asphalt. The thickness of existing pavement materials shall be documented to the nearest 0.1 in. In addition, a digital photograph shall be recorded for each pavement core with a scale for comparison. A description of the condition of the core (e.g., badly stripped, good, etc.) as well as a description of the various layers (e.g., surface, intermediate, base, etc.) shall be included on the boring log.

Phenolphthalein solution ("indicator solution") shall be used to verify cement-treated aggregate or cement-stabilized subgrade. Phenolphthalein turns bright pink in the presence of Portland cement.

(a) Soil Descriptions

Soil samples in the field shall be described using ASTM D2488 and the following order of descriptive terms:

> [*Geologic origin*], [Color], [gradation], [ASTM GROUP NAME], [trace component], [percentage descriptor], [contains component], [consistency/relative density], [moisture], [(ASTM GROUP SYMBOL)]

Please note the following: ASTM does not recognize medium gravel; the ASTM Group Name (entire item to be capitalized) includes more than one word; ASTM D2488 does not include soil classifying as silty clay; trace (or other such terms) cannot be used to depict a percentage of clay or silt; and ASTM D2488 does not include soil classifying as organic silt or organic clay. The ASTM method allows the use of trace as a method to cite the presence of nonplastic, and low-, medium-, or high-plasticity fines. Silty clay, organic silt, and organic clay group names are the results of laboratory testing and described under ASTM D2487.

ASTM D2488 includes “percentage” terms such as “trace,” “few,” “little,” “some,” and “mostly.” These terms shall not be used in opposition to the group name. For example it is not acceptable to describe a soil, “yellow-brown, fine to coarse, SILTY SAND, little gravel, loose, wet (SM)” as ASTM D2488 would require a group name of “SILTY SAND WITH GRAVEL.”

Refer to the following examples of soil descriptions:

> *Residual*, Yellow-brown, fine, SANDY ELASTIC SILT, trace gravel, contains mica, medium stiff, moist (MH)
>
> *Palustrine*, Gray, fine to medium, SANDY ORGANIC SOIL, trace gravel, mostly fibrous organic matter, medium, wet (OL/OH)
>
> *Alluvial*, Red-brown, fine to coarse, POORLY-GRADED SAND, trace low-plasticity fines, mostly medium sand, contains lenses of silt, very dense, wet (SP)
>
> *Fill*, Brown and gray, fine to coarse, SILTY SAND FILL, trace gravel, contains glass, brick and rock fragments, contains pockets of fat clay, loose, moist (SM)

In some cases, subsurface conditions may consist primarily of construction debris or rubble, and not soil. For these conditions, describe the nature of the fill and use “FL” as the group symbol.

Refer to the following examples:

> *RUBBLE FILL*, contains bricks, wood, and other construction debris (FL)
> *TRASH FILL*, contains whole tires, tree stumps, and domestic debris (FL)

GEOLOGIC ORIGIN

Terms for geologic origin shall be shown in italics.

Proper soil classification should be performed within the context of the geologic setting. Throughout Virginia, there are settings where fluvial soils are present atop residual soils. As such, a given geologic setting could have a fine silty sand layer (fluvial) atop a fine silty sand layer (residual). It is important to note these geologic origins.

In advance of a subsurface exploration program, the geologist or field engineer should refer to published geologic references to understand the formation names and characteristics that may be present at the project site.

It is essential that man-made fill materials be properly distinguished from soil that formed naturally. Fill materials typically contain debris or an unusual stratification. Fill soils are classified using the same terminology as natural soils except the term FILL is added to the group name. If there is doubt pertaining to the origin of the soil, the term “POSSIBLE FILL” can be used.

COLOR

Color describes the soil in a moist state. Soil descriptions may reference a single color (red, brown, green, gray, light gray, dark gray, etc.), a combination of colors (red-brown, green-gray, etc.) or multiple colors (such as red-brown, white and light gray). VDOT convention does not include the use of “ish” (i.e., reddish brown would be incorrect – use instead, “red-brown”). The use of more than three color descriptors is generally considered unnecessary. The color may also be followed by the term “mottled” if colored areas are blotchy and/or irregularly shaped. When color variation is shown as bedding, this character should be described.

RELATIVE DENSITY/CONSISTENCY OF SOIL

VDOT uses relative density and consistency terms consistent with the terms used by FHWA. These terms are summarized in Table 3-3.

TABLE 3-3 - SOIL RELATIVE DENSITY AND CONSISTENCY

Sands		**Silts and Clays**			
N_{60}	Relative Density	N_{60}	Field Test*	Unconfined Compressive Strength (tsf – e.g., from Pocket Penetrometer)*	Consistency
0 – 3	Very Loose	0 - 1	Extruded between fingers when squeezed	<0.25	Very Soft
4 – 9	Loose	2 - 4	Molded by light finger pressure	0.25 - 0.5	Soft
10 – 29	Medium Dense	5 - 8	Molded by strong finger pressure	0.5 - 1.0	Firm
30 – 50	Dense	9 - 15	Readily indented by thumb but penetrated with great effort	1.0 - 2.0	Stiff
Over 50	Very Dense	16 - 30	Readily indented by thumbnail	2.0 - 4.0	Very Stiff
		31 - 60	Indented with difficulty by thumbnail	Over 4.0	Hard
		Over 60	-	-	Very Hard

*Taken after Table 4 – NAVFAC DM 7.1

CONTAINS

“Contains” is used to describe an attribute of the soil sample that is not captured by the ASTM soil description alone. This may include the presence of a unique mineral (i.e., mica) or man-made debris (wood chips, rock fragments, glass, brick, etc.). In some instances, “contains” is describing an attribute of the soil that contributes to the overall soil description. For example, “Gray, fine to coarse, SILTY SAND

WITH GRAVEL FILL, contains rock fragments, dense, moist (SM). In this instance, the "contains" component is describing that that the gravel-sized material within the soil classification includes rock fragments.

"Contains" can also be used to document the presence of lenses or pockets within the principal soil mass, e.g., "Brown, fine, SILTY SAND, contains lenses of sandy fat clay, loose, moist (SM)."

"Contains" can also be used to reference the presence of organic matter or debris within a fill layer. Except for the case of organic soils (i.e., PT, OL/OH), the ASTM flow chart does not address the presence of organic matter disseminated throughout the soil mass. When "contains" is used to reference the presence of debris or organic matter, the field geologist or field engineer shall estimate the overall percentage of such material.

DESCRIPTIONS FOR LAYERED SOILS

The following table can be used to describe the occurrence of multiple soil types within one sample.

Refer to the following example of a layered soil description:

> *Alluvial*, yellow brown, fine SILTY SAND, contains frequent seams of elastic silt, loose, moist (SM)

TABLE 3-4 – DESCRIPTIVE TERMS FOR LAYERING

Type of Layer	Thickness	Occurrence
Parting	< 1/16 in	
Seam	1/16 to ½ in	
Layer	½ to 12 in	
Stratum	>12 in	
Pocket		Small erratic deposit
Lens		Lenticular deposit
Varved (also layered)		Alternating seams or layers of silt and/or clay and sometimes fine sand
Occasional		One or less per 12 in of thickness
Frequent		More than one per 12 in of thickness

MOISTURE

Moisture is described at the time of sampling. Use, "dry," "moist," or "wet." Do not use very dry, very moist, or very wet.

Dry – Absent of moisture, dusty, dry to the touch
Moist – Damp, but no visible water
Wet – Visible free water

The moisture content may not be the same throughout the entire sample or throughout a similar stratum. This is especially true if the position of the water table is within the sample interval or a stratum. In these cases, the depth of the change in moisture should be indicated.

Refer to the following example of a soil description showing change in moisture:

> *Alluvial*, Red-brown, fine to coarse, POORLY-GRADED SAND, trace low-plasticity fines, mostly medium sand, contains lenses of silt, very dense, moist to wet below 8 ft (SP)

<u>GROUP SYMBOL</u>

ASTM D2488 provides group symbols for all published group names. ASTM D2488 also acknowledges the use of borderline symbols for those cases where a soil has been identified as having properties that do not distinctly place the soil into a specific group. Examples of borderline symbols include CL/CH, SM/SC, etc.

There are no dual symbols in ASTM D2488. Dual symbols are unique to ASTM D2487, which is the laboratory soil classification method. As such, in the absence of laboratory data group symbols such as CL-ML are not appropriate.

Refer to ASTM D2488, including its Appendix X3 for more information.

<u>(b) Intermediate Geomaterials</u>

Intermediate Geomaterial (IGM) is a term used to describe residual material as it transitions between soil and rock, and vice-versa. Residual material (i.e., displaying parent rock structure) with SPT N-values greater than 50 blows per 6 inches of penetration shall be described as IGM and assigned an ASTM D2488 (or D2487) soil description (per section 303.05(a)) when friable, or a weathered rock description (per section 303.05(c)) when not friable. Additionally, "*IGM*" will be shown in the description for geologic origin. Such strata shall be correlated based on their SPT resistance, their classification, and their position in the geologic sequence.

Refer to the following examples of friable and non-friable IGM descriptions:

Friable:

> *IGM*, Red-brown, fine, SANDY FAT CLAY, contains rock fragments, very hard, moist (CH)

Non-Friable:

> *IGM*, Highly weathered, moderately hard, medium bedded, gray-brown, SILTSTONE.

The shear strength of IGM is greater than that of soil, but less than that of unweathered rock. Numerous factors (relic rock texture, mineralogy, presence of salts in the pore water, type of weathering, presence of cavities, etc.) can play a role in the shear strength of IGMs. Thus, the shear strength and the behavior in general of IGMs can vary significantly and can be difficult to predict.

Definitions for IGMs are based on the material's unconfined compressive strength (UCS) or the SPT N-value. A few definitions (and the author who proposed them) are presented in the table below. Note the wide range of values indicated in the table.

Table 3-5 Various Definitions of IGM		
Author (Year)	**IGM Type**	**Definition**
International Society of Rock Mechanics (1993)	All	UCS 50 to 250 tsf
Mayne and Harris (1993)	Cohesionless	SPT N-values > 50 bpf
O'Neill et al (1996)	All	UCS 5 tsf to 50 tsf
Johnston (1989)	All	UCS > 5 tsf
Akai (1993)	All	UCS 10 tsf to 100 tsf
Clarke and Smith (1993)	All	UCS < 50 tsf

IGMs are quite heterogeneous, particularly over small horizontal and vertical distances. This variation means that several geological and geotechnical considerations must be evaluated during design, including the method of formation, jointing, fissuring, type of bonding, and the frictional aspects.

SPT or rock coring techniques are the most common methods for sampling IGMs. These methods may be acceptable for obtaining a sample for identification; however, these methods may not provide samples that are well-suited for strength or compressibility testing in the laboratory. Block sampling has been used, but is likely not practical or economical for most projects. If a high quality, intact sample can be extracted from the ground, unconfined compression testing is generally the most common laboratory test performed.

Where IGMs are expected to be encountered, supplemental investigation techniques should be considered. These include the use of in-situ testing (e.g., pressuremeter test, borehole shear test, etc.) to evaluate strength and compressibility parameters; geophysical techniques, auger probes, and/or air track probes to better define variability within the subsurface profile; and geophysical techniques to evaluate other material properties (e.g., shear modulus, seismic velocity, etc).

In-situ test methods such as the PMT (pressuremeter test) and the BST (borehole shear test) are considered superior to laboratory testing in determining the stiffness (modulus) of IGM. Such test results can be useful in estimating settlements of shallow foundations that affect stresses within IGMs. The PMT, however, can be difficult to perform in material that contains rock fragments.

Geophysical testing should be considered to help characterize subsurface conditions in areas with IGM. The following geophysical surveys may be appropriate to characterize subsurface conditions in areas of IGM.

- electrical resistivity;
- electro-magnetic;
- seismic refraction;
- seismic reflection;
- ground penetrating radar;
- microgravity;
- spectral analysis of surface waves.

The most important factors related to a useful geophysical testing program are selection of the most appropriate technique(s) for a particular site and purpose, understanding the strengths and limitations of the various techniques, and accurate interpretation of the data. Therefore, a qualified geophysical testing consultant should be contracted to plan and execute a geophysical testing program. When possible, the geophysical investigation should be performed prior to the final drilling program so that the geophysical results can be used to optimize the final boring locations.

(c) Rock Descriptions

Rock descriptions differ from soil descriptions as laboratory methods are typically not used to corroborate the rock type (notwithstanding the use of hydrochloric acid to differentiate limestone from dolostone). For engineering evaluations it is often the secondary characteristics of the rock mass that govern the strength and behavior of rock.

Igneous, metamorphic and sedimentary rocks are present within the Commonwealth of Virginia. The "Geologic Map of Virginia," (DMME, 1993) and other DMME publications show the distribution of rock types throughout Virginia and within specific regions of Virginia.

In assigning a rock type to a rock outcrop or a core sample taken from a drill hole, background geologic reference is often the best approach. That said, many Virginia formations include a geologic sequence that includes multiple rock types. As an example, the Martinsburg formation includes shale, limestone and sandstone, depending on stratigraphic position within the formation. To this end, the rock description shown on the boring log should provide the specific finding from the drill core. (Please note it is not necessary to capitalize the word "formation" when referencing the name of the specific geologic formation.)

Table 3-6 illustrates the classification of typical rock types.

TABLE 3-6 CLASSIFICATION OF ROCKS

Igneous		
Intrusive (Coarse Grained)	Extrusive (Fine Grained)	Pyroclastic
Granite Syanite Diorite Diabase Gabbro Peridotite Pegmatite	Rhyolite Trachyte Andesite Basalt	Obsidian Pumice Tuff
Sedimentary		
Clastic (sediment)	Chemically Formed	Organic Remains
Shale Mudstone Claystone Siltstone Sandstone Conglomerate Limestone, oolitic Breccia	Limestone Dolostone Gypsum Halite	Chalk Coquina Coal

Metamorphic	
Foliated	Non-Foliated
Slate Phyllite Schist Gneiss	Quartzite Amphibolite Marble Hornfels

NOTE: OBSIDIAN DOES NOT EXIST WITHIN THE COMMONWEALTH OF VIRGINIA. WHERE PYROCLASTIC ROCKS WERE ONCE DEPOSITED, THESE ORIGINAL ROCKS HAVE SINCE BEEN ALTERED OR REMINERALIZED OVER GEOLOGIC TIME.

Rock core descriptions shall be provided for each run. If the following run is substantially similar to the previous run, the construction of the following example may be used:

SAME: Thin Coal stringers from 29.3' to 30.2'

Formatting – Lower case letters shall be used except for naming the major rock type of each run, which should be capitalized. Use commas between descriptive terms, and a semicolon to separate the main rock type from the secondary descriptions or other notes.

Descriptive Sequence – Rock core descriptions shall be expressed in the following sequence, to read as one or more articulate sentences:

1. Weathering
2. Hardness
3. Bedding (if present – sedimentary rocks only)
4. Color
5. ROCK TYPE
6. Fracturing /Joint Condition, including spacing, surface condition, separation of joint planes, wall rock condition, continuity of joints, and orientation of each joint set.
7. Inclusions, minor rock types, and minerals observed (i.e. Pyrite, Anhydrite, etc).
8. Other features that might need to be brought to the attention of the engineer.

The following subsections explain items in the descriptive sequence.

Degree of Weathering
1. Unweathered: No evidence of any chemical or mechanical alteration.
2. Slightly weathered: Slight discoloration on surface, slight alteration along discontinuities, less than 10 percent of the rock volume altered.
3. Moderately weathered: Discoloring evident, surface pitted and altered with alteration penetrating well below rock surfaces, weathering "halos" evident. 10 to 50 percent of the rock altered.
4. Highly weathered: Entire mass discolored, alteration pervading nearly all of the rock, with some pockets of slightly weathered rock noticeable, some minerals leached away.
5. Decomposed: Rock reduced to a soil with relict rock structure remaining (i.e. saprolite). Generally molded and crumbled by hand (friable).

Hardness
1. Very soft: Can be deformed by hand.
2. Soft: Can be scratched with a fingernail.
3. Moderately hard: Can be scratched easily with a knife
4. Hard: Can be scratched with difficulty with a knife
5. Very Hard: Cannot be scratched with a knife.

Bedding
1. Thin bedded: 0.3 ft thick, or less.
2. Medium bedded: Beds 0.3 ft to 1ft thick.
3. Thick bedded: Beds 1ft to 3 ft thick.
4. Massive: Beds more than 3 ft thick.

Color
The color is to be described immediately after the core is extracted from the core barrel (i.e., in the wet state). The color in the dry state shall also be described. Colors may be determined using a Munsell

Color Chart or by using commonly-understood simplified color terms. Place commas between colors, and use "and" before the last color. Use hyphens for compound colors. The terms "variegated" and "mottled" may be added to a compound color description, where relevant.

Rock Type

The rock type shall consist of one of the terms referenced above or as referenced in a publication by DMME. Where varying rock types are present, every effort shall be made to break out the top and bottom depths of each rock type unless the interbedding or interlayering makes this impractical, in which case the term "interbedded" (in the case of sedimentary rocks) or "interlayered" (in the case of igneous and metamorphic rocks) shall be used.

When describing schist provide reference to the prominent minerals (e.g., BIOTITE GARNET SCHIST).

The use of other descriptive terms, such as argillaceous, vuggy, friable, indurated, cross-bedded, well-graded, etc. can be used in front of the major rock type.

Fracturing and Joint Condition

Terminology for fracturing and jointing should be in accordance with the most recent edition of the AASHTO LRFD Bridge Design Specifications.

"Fracturing" terminology shall be used when the breaks in a core run are nonparallel, nonsystematic, or cut across bedding or other foliations. "Joint" terminology shall be used when the breaks in a core run are parallel or systematic. Breaks believed to be mechanical (i.e., caused by the drilling process) are not considered in the description.

The following summarize the fracturing and joint condition criteria of LRFD:

SPACING

The actual spacing of fractures, and joints within each joint set, measured perpendicular to the joint surface, shall be measured when possible. If no measurement is possible, the following estimating terms shall be applied:

1. Very widely fractured/jointed: At spacing greater than 10 feet.
2. Slightly fractured/jointed: At spacing of 3 to 10 feet.
3. Moderately fractured/jointed: At spacing of 1 to 3 feet.
4. Highly fractured/jointed: At spacing of 2 inches to 1 foot.
5. Intensely fractured/jointed: At spacing of less than 2 inches.

When fractures or joints are filled, the mineralogy of the material filling the fractures shall be noted.

SURFACE CONDITION

The following qualitative terms shall be used to describe surface condition of joints and fractures: Very rough, slightly rough, slickensided, or gouge. Multiple terms can be used.

SEPARATION OF JOINT PLANES

The following terms shall be used to describe separation of joint or fracture planes: No separation; separation <0.05 in; gouge <0.2 in thick; gouge >0.2 in thick; joints open 0.05 to 0.2 in, or joints open >0.2 inches. Multiple terms can be used.

WALL ROCK CONDITION

The qualitative terms “hard wall rock” or “soft wall rock” shall be used to describe the condition of the parent rock on either side of the joint or fracture.

JOINT OR FRACTURE CONTINUITY

It shall be noted whether the joints or fractures are continuous or discontinuous. If continuity of joints is not discernable at the scale of the rock core, continuous joints or fractures shall be assumed.

JOINT OR FRACTURE ORIENTATION

The range or average orientation of each joint set or fracture trend shall be measured in degrees from a horizontal plane where possible. If no measurement is possible, the qualitative terms High, Moderate, or Low-angle shall be used. Record whether the joints are present in conjugate sets (i.e. having an opposite sense of dip).

Other Features

Any type of structure or feature that may need to be brought to the attention of the engineer, such as voids, rate of drilling, loss of circulation, etc.

Refer to the following examples of rock descriptions.

> Moderately weathered, hard, thick bedded, yellow-brown, coarse SANDSTONE; gray, soft shale from 23.2’ to 25.1’.
>
> Unweathered, hard, thin foliation, slightly jointed, gray and green QUARTZ MUSCOVITE SCHIST; foliation present with dip of 23 degrees, primary joint set at 72 degrees, joints typically infilled with quartz and slightly rough.
>
> Slightly weathered, moderately hard, moderately jointed, light-gray, vuggy DOLOSTONE; occasional pyrite crystals on very rough joints with typical joint separation of 1/32 in and dip of 14 degrees.

RQD – The Rock Quality Designation of each run shall be calculated and recorded according ASTM Standard D6032 (Standard Test Method for Determining Rock Quality Designation of Rock Core).

N-size rock core is optimal for measuring RQD. Breaks caused by drilling action or mishandling the core should be disregarded. Unsound (i.e. “highly weathered”) pieces of rock should not be counted. The determination should be performed at the time that the core is retrieved to avoid possible post removal slaking and separation along bedding planes, as in some shales.

Core Boxes - Core boxes shall be marked on the outside end and cover with the names and affiliations of the driller and logger, VDOT project and UPC numbers, borehole number, box number (i.e., X of Y), and beginning and ending depths. Inside, the core should be laid out in book-fashion, with the core closest to the surface placed at the top left and the bottom of the core placed at the bottom left. Clearly legible depths should be marked on spacers at the beginning and end of each core run, and indicating the position and depths of core loss, cavities, or core removed for testing. Core breaks made to fit the core box should be marked.

Digital photographs of core boxes should be taken from a position overlooking the entire core box, with uniform lighting conditions. The frame should include a strip of white card clearly showing project number, borehole number, and the drilling date, along with a suitable scale. A photograph of core in the wet condition is required, but a supplementary photograph of dry core may also be presented. Close-up photographs of important features may also be presented.

303.06 Boring Logs

All boring logs for VDOT projects shall be prepared on the VDOT template using the most current gINT library file and incorporate the soil descriptions from ASTM D2488 or D2487 using the order of descriptive terms cited herein. Boring logs shall be prepared under the direct supervision of a professional engineer licensed in the Commonwealth of Virginia or a professional geologist certified in the Commonwealth of Virginia. All project information as required by the VDOT template shall be complete and accurate. Longitude and latitude information shall be provided with six digits past the decimal point (decimal-degree units) and a negative value for longitude. Ground surface elevation (NAVD88) is required for all boring locations accurate to 0.1 feet. Upon completion and internal QC (quality control), all electronic gINT boring log files will be provided to VDOT Central Office Materials Division for inclusion in the statewide GDBMS (Geotechnical Database Management System).

All boring logs shall graphically depict the position of the water table and also show specific dates when the ground water measurements were obtained.

Final boring logs shall also present pocket penetrometer (i.e., where recorded) and rock core data (i.e., run interval, recovery, RQD, discontinuities, depth of any return water loss, etc). When pocket penetrometer data is entered into gINT, the software will automatically generate a data column on the boring log. This data column will not show the standard “tsf” units as conventional for pocket penetrometer testing. As cited above, the boring log shall also state whether the SPT samples were obtained using a donut, safety or automatic hammer as LRFD assigns different hammer efficiencies to each of these hammer types.

SECTION 304 LABORATORY TESTING

Geotechnical engineering studies for VDOT projects shall include a laboratory testing program. The purpose of the laboratory testing program is to validate visual soil classifications and assess the engineering properties of the soil and bedrock identified by the field exploration.

Laboratory test results shall be provided using U. S. Customary Units. VDOT requires all laboratory testing conform to the requirements of the cited ASTM, AASHTO, or VTM standards. Users of this manual shall familiarize themselves with the requirements of these standards and issue laboratory reports that follow such protocols and include the required reporting information. All laboratory work shall be performed in an AMRL-certified laboratory with specific certification for the tests being performed.

304.01 Soil Laboratory Testing

Natural moisture content shall be determined for each SPT sample unless other arrangements are made with the District Materials Engineer. Natural moisture content, laboratory soil classification (i.e., ASTM D2487), and unit weight shall also be provided for all undisturbed samples. Natural moisture content and laboratory soil classification shall be determined for bulk samples tested in the laboratory for Standard Proctor moisture-density relations, CBR and/or M_r. Samples obtained for scour analyses shall be tested for grain-size distribution (ASTM D422), including hydrometer analyses when the sample includes more than 20 percent material finer than the #200 sieve.

Except for very small projects, a minimum of three discrete samples from each prominent stratum shall be classified in the laboratory using ASTM D2487. These samples shall be selected to characterize variation in the character of the stratum. Engineering judgment shall be used to distinguish the character of the stratum using SPT N-values, pocket penetrometer data, moisture content, plasticity or findings from in-situ testing, if used. Additional classification tests may be warranted, depending on the geologic nature of the site. Soil classifications determined in the laboratory shall be inserted into the final boring logs (i.e., ASTM D2488 classifications shall be replaced by ASTM D2487 classifications when available).

Geotechnical exploration for pipes and culverts greater than 36-in diameter shall include pH (AASHTO Method T 289), resistivity (AASHTO Method T 288) and classification testing (ASTM D2487) at a frequency of one test for each pipe alignment. Such testing shall consider the most prevalent soil type in proximity to the bedding elevation. If the overall length of the pipe alignment exceeds 500 ft or if multiple soil types are in proximity to the bedding elevation additional testing may be required.

Soil classification (i.e., ASTM D-2487) shall be provided at the design outfall of all pipes 36-in diameter or greater. This soil sample can be obtained using a hand auger or shovel and should typify the soil conditions in proximity to the ground surface (i.e., within 2 to 3 ft). The results from this soil classification testing will be used to assess potential erodibility from the pipe discharge.

Surface water sources in proximity to pipe alignments shall be sampled for pH testing. Such samples shall be collected in sterilized containers and transported to the laboratory for testing within 24 hours.

CBR testing shall be in accordance with VTM-8, which directly references AASHTO T 193. Corrections shall be made to the stress versus strain curve, when applicable, as shown by Method T 193. Additionally, when the CBR value calculated for 0.2 in penetration is greater than the CBR value calculated for 0.1 in penetration, the test shall be rerun, as required by Method T 193.

M_r testing shall be performed in accordance with AASHTO T 307.

Strength testing of in-situ and compacted soil samples is project specific and dependent on the anticipated change in load within the soil mass. Selection of appropriate strength testing shall be coordinated with the District Materials Engineer on a case-by-case basis. The information below establishes guidance on strength testing.

UUTXC (unconsolidated undrained triaxial compression – ASTM D2850) testing for any given undisturbed soil sample shall include three confining stresses: Existing effective overburden stress, existing total overburden stress, proposed total stress (in fill areas) or proposed effective stress (in cut areas). To obtain three soil samples from one Shelby tube and to preserve the ASTM-required sample aspect ratio, the laboratory may be required to trim the diameter of the Shelby-tube sample.

CU-bar (consolidated undrained triaxial compression strength with pore pressure readings – ASTM D4767) testing provides the total and effective friction angle and cohesion intercept of soils. Consolidation cell pressures shall consider the effective overburden stresses, the proposed effective stress and a third effective stress condition such that the stress range in the laboratory replicates the anticipated stress conditions in the field. Soils for strength testing shall be classified in the laboratory. When preparing remolded samples for CU-bar testing, the sample shall be remolded at the minimum acceptable dry density and a moisture content that is wet of optimum.

Depending on the nature of the project, DDS (drained direct shear – ASTM D3080) testing may be required to evaluate the long-term strength of highly plastic silts or clays (i.e., MH or CH) and provide the data needed for slope stability analyses. DDS testing can be performed to determine either the fully-softened shear strength or the residual shear strength. To determine the fully-softened shear strength, the test shall be performed on normally-consolidated reconstituted samples. Such reconstituted samples shall be processed through the No. 40 sieve (i.e., pushed through without air drying), hydrated to their Liquid Limit (48 hour hold time) and consolidated incrementally in the DDS device to the target vertical confining pressure. Incremental consolidation is needed to minimize squeezing of the sample. Four stress points are required, one of which is at or below a confining stress of 500 psf. Peak strength from the normally-consolidated reconstituted DDS test shall be used as the fully-softened shear strength and used for the long-term performance of engineered slopes in highly-plastic silts and clays (whether in cut or fill). As an alternate to DDS testing for fully-softened shear strength, VDOT also accepts ASTM Method D7608, which uses the torsional ring shear device. Reconstituted samples shall also be prepared as described above for torsional ring-shear testing of highly plastic silts and clays.

To determine the residual shear strength, the DDS test shall be performed in accordance with U.S. Army Corps of Engineers test method EM-1110-2-1906 using multiple shear reversals of a conventional sample (undisturbed or remolded). This is appropriate for cases where large shear displacements have occurred or may be expected to occur (i.e. slickensided and/or highly plastic silt or clay).

One-dimensional consolidation testing (ASTM D2435) is required for compressible strata (i.e., likely subject to virgin consolidation under proposed loading conditions). Typical load increments shall include the following: ¼, ½, 1, 2, 4, 8, 2, 4, 8, 16 and ¼ tsf. In some instances, the maximum applied load may need to extend to 32 tsf in order to obtain the required minimum load of four times the maximum past pressure (i.e., P_p). Load increments of 1, 2, 4, 8 (first application) and 16 tsf (32 tsf if required) shall remain on the sample a minimum of 4 hours after the end of primary consolidation. Time readings are required for these load increments at the frequency shown in the ASTM Method. The requirement for time readings allows for the interpretation of C_α (coefficient of secondary compression). Consolidation strain shall be recorded with respect to elapsed time (i.e., as opposed to change in void ratio). The data from each load increment shall be shown on a strain versus log stress graph. Straight lines shall not be drawn between the data points. As stated in the ASTM procedure, interpretation of the data points shall be performed to develop a reported value of P_p. The laboratory shall present the interpolation of data points with annotations to show the development of P_p (maximum past pressure). Initial void ratio and value for specific gravity of soil grains (estimated or laboratory determined) shall be provided for all consolidation tests.

304.02 Rock Testing

Determination of rock mass engineering properties is influenced by both the intact rock properties and the nature of discontinuities within the rock mass. A thorough rock description includes a detailed description of the discontinuity characteristics, which is essential to evaluating the overall rock-mass properties.

Appropriate tests for intact rock properties include unconfined compressive strength (ASTM D7012) and point load index (ASTM D5731). The District Materials Engineer will determine whether Method C or Method D is appropriate for a given project, when conducting unconfined compressive strength testing.

SECTION 305 GEOTECHNICAL ANALYSES

Geotechnical analyses for VDOT projects shall be performed under the direct supervision of a licensed professional engineer registered in the Commonwealth of Virginia. For specific design references for substructures, retaining walls, etc., refer to “Geotechnical References” below.

Engineering analyses that include correlations to SPT N-values, shall include summary tables showing N_{60} and N_{1-60} values, as required by the engineering correlation. These tables shall show the assumptions used in computing the effective overburden stress (i.e., unit weight, layer thicknesses and position of the water table).

Geotechnical engineering analyses for VDOT design-build projects shall incorporate reliability assessments in conjunction with standard analysis methods. An acceptable method for evaluation of reliability is given by Duncan, J. M. (April 2000) "Factors of Safety and Reliability in Geotechnical Engineering," Journal of Geotechnical and Geo-environmental Engineering, ASCE. Suitable design will provide a probability of success equal to or greater than 99 percent unless otherwise specified within the design-build contract. Reliability assessments shall address the selection of soil parameters used in retaining wall design, the factors of safety for slope stability and the requirements of LRFD. Reliability assessments shall also address settlement calculations. Reliability assessments are not required on Design-Bid-Build projects.

305.01 Geotechnical Design for Substructures

Geotechnical engineering recommendations for structural design shall conform to LRFD methodologies, where applicable. Refer to AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, current addition and interim revisions for information on LRFD. It is incumbent on the geotechnical engineer to obtain anticipated structural loads and use appropriate load and resistance factors when providing design parameters.

305.02 Soils for Embankments and Subgrades

Unsuitable materials shall not be used in embankments, present within 3 ft of pavement subgrades or present within 2 ft of pipe bedding without advance approval by the District Materials Engineer. Unsuitable materials shall be as defined in Section 101 and 303 of the most current VDOT Road and Bridge Specifications and in the case of Design-Build or PPTA projects as defined by contract.

Topsoil and organic soils are suited for use in the upper 12 inches of embankment slope faces to support vegetative cover.

Geotechnical design for earthworks and pavement subgrades shall consider the site-specific CBR or M_r value, moisture-density relations, natural moisture contents and strength values as appropriate for the specific project.

305.03 Geotechnical Design for Embankments and Cut Slopes (soil)

Embankments and certain aspects of retaining wall design are not addressed by LRFD. As such when addressing slope angles for finished grades, settlement of natural soils, lateral earth pressures and global stability, the geotechnical engineering study shall provide design values for friction angle (peak, fully-softened or residual as appropriate), undrained shear strength, soil modulus, one-dimensional consolidation parameters (including the coefficient of secondary compression), lateral earth pressure coefficients, unit densities, the position of the ground water table and stratigraphy as simplified for the geotechnical design. It is not sufficient to state, "Total settlements are expected to be less than 1 inch" if the data are not provided to corroborate such a statement.

Engineering design of stable soil slopes (cut slopes and embankment slopes) shall include an evaluation of stability for interim construction stages, for the end of construction condition, and for design-life conditions. Cut and fill slopes shall be no steeper than 2H:1V unless supported by engineering analyses based on site specific field investigation and site specific laboratory strength testing. Slopes steeper than 2H:1V must be approved by the Department. Cut slopes in Potomac formation clays and silts shall be designed using residual strength values as determined by laboratory testing, neglecting any cohesion. The long-term design of highly plastic embankment slopes shall be based on fully-softened shear strength.

The factors of safety tabulated below shall be used with limit equilibrium methods of analysis for representative sections of slope greater than 10 feet in height, for critical slopes, or for slopes in "problem soils" as defined below. The factors of safety are valid for subsurface investigations performed in accordance with this MOI or for site-specific investigation plans approved by the District Materials Engineer. Approval of site specific investigation plans with reduced boring frequency may require higher factors of safety.

Circular failure surfaces shall be analyzed by methods such as the Modified Bishop, Simplified Janbu, or Spencer methods. In addition, block (i.e., wedge failure) analyses may be required to verify the minimum factor of safety. All slope stability analyses shall consider the effects of groundwater, external loads, tension cracks, and other pertinent factors as applicable.

TABLE 3-7 – MINIMUM FACTORS OF SAFETY FOR SOIL SLOPES

Basis for Soil Parameters	Factor of Safety	
	Critical Slope[1]	Non-Critical Slope
Site specific in-situ or laboratory strength tests of soils[2]	1.5	1.3
No site specific in-situ or laboratory strength tests of soils	N/A[3]	1.5

NOTES:
1. A critical slope is defined as any slope that is greater than 25 feet in height, affects or supports a structure (i.e., irrespective of height), impounds water or whose failure would result in significant cost for repair, or damage to private property.
2. Site specific in-situ testing for critical slopes shall include the use of CPT, and/or DMT tests. Correlation to SPT N-values can be used as in-situ testing for non-critical slopes. Where design is governed by peak strength, appropriate laboratory tests shall include CU-bar or DDS testing of undisturbed or remolded samples. Where design is governed by fully-softened strength (i.e., highly plastic silts and clays), appropriate laboratory tests shall include DDS or torsional ring shear testing of normally-consolidated, reconstituted samples. Where design is governed by residual strength (i.e., slickensided, stiff-fissured clays and silts), appropriate laboratory tests shall include residual-strength DDS testing of undisturbed or remolded samples in accordance with U.S. Army Corps of Engineers test method EM-1110-2-1906.
3. When approved by the District Materials Engineer (and recognizing the requirement for reliability assessment) the strength of cut slopes in coarse-grained soil or coarse-grained subgrades supporting embankments can be based on published correlations to SPT N-value. Coarse-grained soil is defined by ASTM D2488 and D2487.

Back calculation may be appropriate to evaluate the residual friction angle of failed slopes. Back calculation shall be performed using a cohesion intercept of zero and geometry as mapped in the field for the failed slope condition. The use of back-calculated friction angles for design shall be approved by the District Materials Engineer on a case-by-case basis.

Problem soils for slope stability include soft and very soft soils (i.e., low strength and high compressibility), organic soils, micaceous soils, very loose soils (i.e., low strength, liquefiable, low modulus), highly plastic soils (that can realize significant strength reduction over time), and fissured or heavily over-consolidated soils that may contain latent defects (i.e., prior failure surfaces). Fissured or heavily over-consolidated soils include the Potomac and Calvert formation silt and clay soils. Problem soils shall be analyzed for short- and long-term stability using appropriate undrained strength and peak, fully-softened, or residual drained-strength parameters determined from laboratory shear testing.

When soil slope stability analyses are conducted, the following geotechnical and geological conditions must also be addressed:

- Slip planes occurring between heterogeneous soil strata;
- In karst geology, the short- and long-term effects of voids and sinkholes encountered;
- Moisture effects on strength and compressibility of micaceous soils;
- Settlement of embankments;
- The position of and anticipated seasonal change of the groundwater table; and
- Tension cracks at head of slope.

Construction documents shall specify the strength of embankment fill material to be consistent with the fill material modeled in the slope stability assessment.

Locations where ground water seepage in the finished cut slope is anticipated shall be determined and slope surface treatments to stabilize the conditions shall be provided. This is in addition to treatments needed to prevent scour and undermining of both cut and fill slopes within the drainage areas of the site.

All data, assumptions, and calculations (hand calculations and electronic files if warranted, including software input and output files) shall be included in slope stability reports submitted for review.

305.04 Geotechnical Design for Rock Slopes and Rock Cuts

This section provides general guidance for analysis and mitigation of rock slope hazards using generally accepted techniques and widely-available tools and references. It is not a fundamental and comprehensive design guide. Please refer to the references below for specific design guidance.

(a) Definitions and Tools

For the purposes of this chapter, the general definitions of terms and expressions are presented in Tables 3-8 and 3-9.

TABLE 3-8 – GENERAL DEFINITIONS OF TERMS AND EXPRESSIONS

Item	Definition
Clast	Loose rock of any size, either resting on the slope or having detached and fallen from the slope.
Critical Rock Slope	Any cut or naturally-occurring section consisting of rock, greater than 25 ft high, or any cut section greater than 25 ft high with rock beds or veins greater than 1 ft wide that affects or supports a structure, or whose failure would result in significant cost for repair or damage to private property; or any cut or naturally-occurring section consisting or rock, of any height, adjacent to an interstate or primary route.
Dip	The angle of any feature with respect to a horizontal plane.
Event	Any discrete global or sub-global failure.
Discontinuity	A planar or non-planar surface between two rock masses, including but not limited to bedding planes, metamorphic fabric, faults, or formation contacts, which separates rock masses of differing geological or engineering characteristics.
Event Energy	The peak kinetic energy of a global or sub-global event. In global events, the mass of the entire moving body controls the event energy; in sub-global events, the mass of the largest individual clast controls the event energy. Event energy is qualitative and expressed in terms of high, moderate or low energy
Event Volume	The cumulative volume of all clastic material shed from a rock slope during an event. Event volume is qualitative and expressed in terms of high, moderate or low volume.

TABLE 3-8 – GENERAL DEFINITIONS OF TERMS AND EXPRESSIONS (CONT'D)	
Item	**Definition**
Debris-Flow Nets or High-Energy Absorbing Devices	Large-scale, mass-movement, interception systems designed to absorb the energy and volume of large-volume and/or large-energy events. Such devices are designed to incorporate energy-absorbing systems such as, but not limited to, friction brakes or expandable high-tensile wire mesh.
Formation	A formally-named fundamental rock unit, recognized on published maps or documents, and used in accordance with the most recent North American Stratigraphic Code; formations may be subdivided into members or beds
Global Stability	Stability controlled by structural features that penetrate the rock mass such as bedding planes, joints, veins, metamorphic fabric, faults, etc. Global stability failures involve mass movement.
Hazard	The probability of occurrence, calculated or estimated, of a specific concern, condition, activity, or occurrence that poses the possibility of damage, loss, or other impact to infrastructure, human life or activity, or the natural environment.
Heavy-Tail Events	Events greatly beyond the scope of any previously observed events, and that cannot be predicted due to the lack of modeling data.
Kinematics	Refers to motion of bodies without regard to driving forces or probability of motion. Tendency for kinematic motion is generally modeled using stereonets
Launching Feature	A change in the profile of a rock slope that changes the vector of rolling or sliding clasts towards the horizontal plane, or a change that allows a rolling or sliding block to free-fall.
Non-critical Rock Slope	Any cut or naturally-occurring slope consisting of rock less than 25 ft high, or any cut slope less than 25 ft high with rock beds or veins greater than 1 foot in width that does not affect or support a structure, or whose failure would not result in significant cost for repair or damage to private property.
Remediation	Actions taken, or engineering or construction methods used, to reduce hazard or manage risk.
Risk	The potential effect, cost, or severity, calculated or estimated, of a specific hazard.
Rock Bolting	Installation of grouted bolts or dowels into a rock mass in order to improve global stability and sub-global stability of isolated rock blocks, slabs, or wedges.
Rock Slope Drape	A mesh on a rock surface that allows clasts to detach and migrate down the rock surface safely.
Rockfall	Failure involving detachment of individual or few clasts from a rock slope face, regardless of clast size. This is synonymous with "Sub-Global Stability."
Rockfall Barrier	A rigid or flexible barrier installed on a rock slope or at the toe of the slope intended to intercept falling clasts.
Rock Mesh or Shallow Stabilization	A method to stabilize the mass of a shallow failure zone parallel or subparallel to the rock slope surface, including but not limited to installation of high-tensile mesh, high-pressure injection of grout or polyurethane resins, or application of shotcrete.
Rock Slope	A critical or non-critical rock slope consisting of one or more slope sections.
Scaling	Physical removal of clasts on the slope surface by hand or mechanical means.
Slope Activity	Volume of clasts shed from a rock slope per surface area per time.
Slab	A planar or sub-planar, tabular volume of rock formed by parallel or sub-parallel bedding planes, faults, lithological or metamorphic fabric change, or other physical discontinuities.
Slope Angle	The generalized angle between the surface of a rock slope and a horizontal plane; this is synonymous with the "slope dip".
Slope Aspect	The azimuth of the strike of the rock slope face.
Slope Face	The outer surface of a rock slope.
Slope Intersection Angle	The angle between the slope aspect and the azimuth of the road alignment.
Slope Profile	The trace of the intersection of the surface of a slope and a vertical plane at a right angle to the slope aspect.

TABLE 3-8 – GENERAL DEFINITIONS OF TERMS AND EXPRESSIONS (CONT'D)	
Item	**Definition**
Slope Section	A subdivision of a physically contiguous slope exhibiting characteristics sufficiently different from adjacent areas as to require separate analysis
Strike	The azimuth of a horizontal line on any inclined surface.
Structure	The physical characteristics of the rock mass, including but not limited to features such as bedding, folds, faults, etc.
Sub-Global Stability	Stability controlled by the detachment of an individual or a few clasts from a rock slope face, regardless of clast size. This is synonymous with "Rockfall".
Talus	Clastic material shed from a slope, accumulating at the toe of a slope.
Terrain	An intact geological unit uncrossed by faults or formation boundaries.
Wedge	A body of rock formed by two discontinuities at an angle to each other.

TABLE 3-9 – SLOPE CLASSIFICATIONS AND DEFINITIONS	
Slope Class	**Definition**
Class A Slopes	High-risk slopes characterized by the following: Few, large wedges or slabs formed by widely-spaced, persistent discontinuities or thick, massive slabs; Slopes with overhangs caused by differential weathering or poor cut design; Long slopes due to planar bedding or discontinuity persistence; Slopes formed from massive, hard, unweathered rock or tight or metamorphic fabric; and, Very high, vertical or near-vertical slopes.
Class B Slopes	Moderate-risk slopes characterized by numerous small wedges or thin slabs; weak lithology, or many launching features.
Class C Slopes	Low-risk slopes characterized by very frequent, persistent discontinuities; thinly bedded rock masses; heavily weathered lithology; high degree of tectonic deformation; very small-weathering clasts; or very low slope angles.
Class D Slopes	Slopes characterized by less-weathered blocks suspended in a matrix of weak material such as soil (synonymous with "block-in-matrix" and "Terra Rossa").
Hybrid Slopes	Slopes exhibiting characteristics of 2 or more of the above classes and which cannot be subdivided into slope sections that can be characterized as any other Slope Class

The texts and computer programs suggested as tools for performing the analytical requirements of this section are presented in Table 3-10.

TABLE 3-10 – TOOLS AND REFERENCES		
Type	**Reference**	**Purpose**
Text	AASHTO LRFD Bridge Design Specifications, Fifth Edition, 2010	Rock Mass rating (RMR)
Text	ASTM D5731 - 08 Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications	Point Load Index and correlation to unconfined compressive strength
Program	CRSP (Colorado Rockfall Simulation Program) Jones, C.L., Higgins, J.D., and Andrew, R.D., 2000	Rockfall simulation
Text	Bruckno, B., 2011, (Sub)Global Rock Slope Stability, *in* Proceedings, Georisk 2011; Geotechnical Risk Assessment & Management: American Society of Civil Engineers, Atlanta, GA, June 2011, p. 787-794	General explanation of triggered and untriggered rockfall events
Text	Hoek, 2007, Practical Rock Engineering, http://www.rocscience.com/education/hoeks_corner	Field estimates of unconfined compressive strength

TABLE 3-10 – TOOLS AND REFERENCES (CONT'D)		
Type	**Reference**	**Purpose**
Text	Munfakh, G., Wyllie, D., and Mah, C.W., 1998, Rock Slopes Reference Manual, Publication FHWA-HI-99-007, NHI Course No 13235 Module 5	Data collection/304.4 Analysis methods of wedge, slab, and toppling failures
Text	Pierson, L.A., Gullixson, C.F., and Chassie, R.G., 2001, Rockfall Catchment Area Design Guide Final Report SPR-3(032)	Sizing of ditches and catchment
Program	RockPack III Watts, C.F., Gilliam, D.R., Hrovatic, M.D., and Hong, H., 2003	Kinematic analysis tool for wedge, slab, and toppling failures and factors of safety
Program	RUVOLUM 7.0 Geobrugg AG, 2008	Design of debris-flow nets, rock mesh, and rock drape
Text	Twiss, R.J., and Moores, E.M., 2007, Structural Geology: New York, W,H, Freeman and Company, 736 p	Structural data

(b) General

Rock slope stability analyses shall consist of two phases, the first being for global slope stability hazard, and the second being for rockfall (sub-global) hazard. In some cases, the remediation method required for global slope stability will also manage rockfall hazard; in other cases rockfall hazard must be managed even though there is no global slope stability hazard.

(c) Personnel

Data shall be gathered and analyzed by a licensed professional engineer registered in the Commonwealth of Virginia or a professional geologist certified in the Commonwealth of Virginia who, by a combination of education, experience, and training, has the requisite ability to address rock slope stability issues. The qualifications of the engineer or geologist performing the work shall be approved in advance by the District Materials Engineer.

(d) Data Collection

The following procedure shall be followed in collecting rock slope data:

A. Slope Section Mapping: The rock slope shall be subdivided into smaller units as necessary when any of the following conditions are met. Each smaller unit shall be given a unique identifier to allow reference to analyses.

   1. Change in slope aspect of greater than 20 degrees, or change in strike or dip of geologic structure, or slope face, of more than 20 degrees;
   2. Change in the slope interception angle of more than 20 degrees;
   3. Change in lithology;
   4. Change in structural style, including bedding thickness, metamorphic grade, or change in number, persistence, orientation, surface roughness, or infill of discontinuities;
   5. Change in launching features;
   6. Across faults or fault zones, including brecciated zones, or across fold hinges or axial planes; or
   7. Across formations, members, or beds within a formation.

B. Data: The following data shall be collected for each slope section.

1. Structural data, including spacing and strike and dip of bedding, joints, faults, foliation, joint surfaces, veins, or other discontinuities;
2. Engineering geology data, including joint surface roughness, discontinuity infill characteristics, wall rock hardness, field estimates of unconfined compressive strength or point load index, bedding thickness, lithology, and water characteristics; and
3. Field survey data, including slope profile and geographic slope location.

(e) Sufficiency of Data

The data requirements increase with the size of the rock slope and the number of rock slope sections. Care should be taken that each rock slope section is fully characterized. Where rock slope sections are not safely accessible, survey methods may be used.

In construction projects, where no existing slope exists, the data may be interpolated from rock core or from nearby outcrops within the same terrain. Where no outcrops exist, data may be interpolated from literature, such as Open-File Reports of the Virginia Department of Mines, Minerals and Energy. The use of published data necessarily reduces the reliability of recommendations.

(f) Remediation Options

Engineering practices, methods and costs to address rock-slope stability frequently change. As such, the engineer or geologist performing the work shall be familiar with current practices. The following is not intended to be an all-inclusive list of remediation options. Remediation options are generally correlated to the energy or volume of the global or sub-global event and can be simplified as follows:

A. Reconstruction and Excavation
1. Intended to minimize probability of an event;
2. Highest cost per unit of remediated slope area;
3. Appropriate for the most high-energy events; and
4. Requires limited inspection and maintenance.

B. Debris-Flow Nets or High-Energy Absorbing Devices
1. Intended to intercept and hold a large mass of failed material;
2. High cost per unit of remediated slope area;
3. Appropriate for both high-energy and high-volume events; and
4. Requires periodic inspection and inspection after each event.

C. Rock Bolting or Drainage
1. Intended to increase factor of safety or stabilize large wedges, slabs, or toppling masses;
2. High cost per unit of remediated slope area;
3. Appropriate for moderate- to high-energy and -volume events; and
4. Requires limited inspection and maintenance.

D. Rock Mesh or Shallow Stabilization
1. Intended to stabilize large areas of slope face displaying shallow failure zones parallel to slope surface;
2. Moderate cost per unit of remediated slope area;
3. Appropriate for moderate-energy and moderate-volume events; and
4. Requires periodic inspection.

E. Scaling
   1. Intended to remove moderate to small rock masses by hand or mechanical means;
   2. Moderate to low cost per unit of remediated slope area;
   3. Appropriate for small- to moderate-energy and moderate-volume events; and
   4. Requires limited inspection and maintenance.

F. Barrier (Flexible or Rigid)
   1. Intended to intercept events;
   2. Moderate cost (flexible barrier) to low cost (rigid barrier) per unit of remediated slope area;
   3. Appropriate for low-energy and low-volume events; and
   4. Requires periodic inspection and maintenance (flexible barrier) or repair/replacement after any event (rigid barrier).

G. Rock Slope Drape
   1. Intended to allow clasts to roll or slide down to talus for maintenance;
   2. Low cost per unit of remediated slope area;
   3. Appropriate for lowest-energy events; and
   4. Requires limited inspection and maintenance.

H. Talus Maintenance
   1. Intended at sites where clasts fall safely to talus;
   2. Low cost per unit of remediated slope area;
   3. Appropriate for lowest-energy events; and
   4. Requires normal ditchline inspection and maintenance.

(g) Data Analysis and Remediation for Global Rock-Slope Stability

Each slope section shall be analyzed according to the following procedure, applying the factors of safety presented in Table 3-11.

TABLE 3-11 – APPLICABLE FACTORS OF SAFETY FOR ROCK SLOPES

Sufficiency of Data	Critical Rock Slope	Non-critical Rock Slope
Testing and Site-Specific Measurements	1.5	1.3
No Testing or Site-Specific Measurements	N/A	1.5

A. Analyze for Wedge Failures

   1. If a wedge failure is not kinematically possible, proceed to B.
   2. If a wedge failure is kinematically possible, calculate the factor of safety using RockPack III or similar program. If the factor of safety is greater than that shown in the table above, proceed to B.
   3. If the factor of safety is less than that shown in the table above, consider the following risk mitigation measures and re-evaluate until the factor of safety meets or exceeds the values shown in the table above.

Class A Slopes:	Reconstruction or Excavation Rock Bolting Debris-Flow Nets or High-Energy Absorbing Devices
Class B Slopes:	Scaling Rock Mesh or Shallow Stabilization Rockfall Barrier
Class C Slopes:	Rockfall Barrier Rock Slope Drape Talus Maintenance
Class D Slopes:	Class D Slopes do Not Fail as Wedges
Hybrid Slopes:	Consider the Risk Mitigation Measures for the Next-Highest Slope Class

B. Analyze for Slab Failures

1. If slab failure is not kinematically possible, proceed to C.
2. If a slab failure is kinematically possible, calculate the factor of safety using RockPack III or similar program. If the factor of safety is greater than required, proceed to C.
3. If the factor of safety is less than the required value, consider the following risk mitigation measures and re-evaluate until the factor of safety meets or exceeds the required value.

Class A Slopes:	Excavation or Reconstruction Rock Bolting or Drainage Debris-Flow Nets or High-Energy Absorbing Devices
Class B Slopes:	Scaling Rock Mesh or Shallow Stabilization Rockfall Barrier
Class C Slopes:	Rockfall Barrier Rock Slope Drape
Class D Slopes:	Class D Slopes do Not Fail as Slabs
Hybrid Slopes:	Consider the Risk Mitigation Measures for the Next-Highest Slope Class

C. Analyze for Toppling Failures

1. If toppling failure is not kinematically possible, proceed to Section 305.04(h).
2. If a toppling failure is kinematically possible, consider the following risk mitigation measures (factor of safety for toppling failures cannot reliably be calculated).

Class A Slopes:	Excavation or Reconstruction Rock Bolting Debris-Flow Nets or High-Energy Absorbing Devices
Class B Slopes:	Scaling Rock Mesh Rockfall Barrier
Class C or D Slopes:	Rock Mesh or Shallow Stabilization Rockfall Barrier Rock Slope Drape
Hybrid Slopes:	Consider the Risk Mitigation Measures for the Next-Highest Slope Class

(h) Data Analyses and Remediation of Rockfall Hazard

Rock slopes that have been determined to be globally stable according to the process outlined above will not necessarily be safe with regard to rockfall. While some component of rockfall has been shown to react to triggering events, such as rainfall or seismic events, another component of rockfall occurs in the absence of any obvious triggering mechanisms. All rock slopes will exhibit rockfall at some nonzero level of risk. Therefore, factors of safety for rockfall hazard cannot be reliably calculated.

The CRSP (Colorado Rockfall Simulation Program) computer program or the Catchment Area Design Guide, allow the user to evaluate the rockfall behavior of a slope with user-defined slope geometry and clast characteristics. Such models allow the evaluation of a hypothetical rockfall but do not allow any evaluation of the probability of such an event happening.

The probability of rockfall events is controlled by the structure and lithology of the rock slope. The strength and characteristics of the rock mass are required to assess rockfall risk. High-strength rock masses tend to have less-frequent, high- and heavy-tail-energy events. Weak-strength rock masses tend to have more frequent low-energy events. Intermediate-strength rock masses fall along a continuum. Therefore, both the modeling of hypothetical rockfall events and evaluations of rock mass strength indices should be used in order to model the risk and probability of a hypothetical rockfall event.

Each slope section shall be analyzed according to the following, applying the allowable percentage of clasts entering the travel lane as presented in Table 3-12.

TABLE 3-12 - ALLOWABLE PERCENTAGE OF CLASTS ENTERING THE TRAVEL LANE

Alignment Type	Critical Rock Slope	Non-critical Rock Slope
Interstate	0%	N/A
Primary	0%	N/A
High-Volume Secondary	<1%	5%
Low-Volume Secondary	1%	5%

Apply CRSP, Catchment Area Design Guide, or similar to each slope section. If, after 10 or more simulations of 100- to 1000-clast events, less than the allowable percentage of the clasts is shown to enter the travel lane, proceed to B. If more than the allowable percentages of the clasts are shown to enter the travel lane, calculate the Rock Mass Rating (RMR) according to LRFD Table 10.4.6.4-1.

Consider the following remediation options according to RMR:

a.	RMR 61-100: (High-energy events, low activity)	Debris-Flow Nets High-Energy Absorbing Devices Rockfall Barrier
b.	RMR 41-80: (Intermediate-energy events, moderate-activity)	Rockfall Barrier Rock Mesh or Shallow Stabilization
c.	RMR 21-60: (Intermediate- to low-energy events, High activity)	Rockfall Barrier Rock Mesh Rock Drape Increase Catchment
d.	RMR <20: (Very low-energy events, very high activity)	Talus Maintenance

A. In the cases of a, b, and c above, re-apply CRSP, Catchment Area Design Guide, or similar method to ensure that if, after 10 or more simulations of 100- to 1000-clast events, fewer than the allowable percentage of the clasts are shown to enter the travel lane as per Table 3-11 or a risk mitigation method is selected.
B. For RMR 61-100, model the risk of a heavy-tail energy event by modeling a single-clast rockfall of 5 to 10 times the diameter of the 90th percentile diameter size in observed talus clasts, or a clast bounded by 5 to 10 times the greatest joint and bedding scale. If the risk of such an event is considered unacceptable, or in the case of critical rock slopes, consider remediation options as above. If the cost of remediation is considered excessive, consider drafting an Emergency Action Plan to react to the event. If the risk is acceptable, proceed to C.
C. For all remaining conditions, consider talus maintenance.

305.05 Drainage Pipes and Culverts

Drainage pipes and culverts for VDOT projects may be installed in native ground, existing embankments or embankments to be constructed. When developing geotechnical engineering recommendations for drainage pipes and culverts, the geotechnical engineer is responsible to address the following:

- Suitability of excavated soil for re-use as backfill.
- Anticipated soil settlement resulting from newly-placed embankment fill.
- The extent to which engineering measures are required to mitigate settlement concerns (i.e., use of pile support, use of pre-loads, prefabricated vertical drains, staged construction, etc.)
- The likely presence of ground water and its affect on bedding conditions (i.e., the extent to which construction dewatering may be required)
- pH, resistivity and classification of soil and pH of surface water in proximity to the drainage pipe or culvert.
- Soil classification (D2487) of soil within 2 to 3 ft (depth) of pipe outfalls.

305.06 Stormwater Management Basins

The VDOT Drainage Manual and the L&D (Location & Design) Memorandum IIM-LD-195.7 present VDOT's criteria for the planning and design of stormwater management basins. Prior to developing the field program for SWM (stormwater management) basins, the District L&D Section shall provide the District Materials Section detailed plans outlining the proposed location and elevation(s) of the stormwater management basin(s). These detailed plans shall also convey the proposed size, location and type of outfall works; whether the basin is to be designed as a "wet" or "dry" pond; and, whether the dam structure is expected to fall under the Commonwealth of Virginia, Department of Conservation and Recreation Dam Safety Regulations.

Subsurface exploration for stormwater management basins shall determine if the native material will support the proposed dam and outfall works and not allow excessive seepage or seepage forces within and/or beneath the embankment. Such seepage analysis is especially critical when the basin is designed with a permanent pool. In addition, the subsurface exploration program shall evaluate whether on-site soils are suitable for use in embankment dam construction or for use as compacted structural fill in other areas of the project. Subsurface exploration shall also identify whether bedrock is present in anticipated excavation areas and the position of the ground water table.

Stormwater management dams shall be designed by a licensed professional engineer registered in the Commonwealth of Virginia. The design of the dam embankment and outfall works shall be in accordance with the minimum design criteria set forth in the references cited above and the DCR (Virginia Department of Conservation and Recreation) "**Virginia Stormwater Management Handbook," Volumes 1 and 2, First Edition, 1999 (with 2011 updates)**. Electronic access to the Handbook is available at the following URL:

http://www.dcr.virginia.gov/stormwater_management/stormwat.shtml#vswmhnbk .

The U.S. Department of the Interior's Bureau of Reclamation publication entitled "Design of Small Dams" provides guidelines that may also be used to evaluate and design earthen dam structures. This publication is available at the following URL:

http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/SmallDams.pdf

According to the L&D memorandum, the dam should have a minimum crest width of 10 feet and upstream and downstream slopes no steeper than 3H:1V to facilitate both construction and maintenance. If a discrepancy exists between VDOT criteria and non-VDOT criteria then the VDOT criteria shall take precedence. Incorporation of an existing roadway embankment as a dam for either a detention or retention pond must be first approved on a case-by-case basis by VDOT.

Construction of stormwater management facilities within a sinkhole is regulated by the U. S. Environmental Protection Agency. Accordingly, special investigation and planning during the preliminary phase of the project may be required in areas of karst terrain or areas where mining was previously performed. If SWM facilities are required along the periphery of a sinkhole, the design of such facilities shall comply with the guidelines in L&D Memorandum IIM-LD-228 and DCR Technical Bulletin #2 (Hydrologic Modeling and Design in Karst) and applicable sections of the DCR SWM Handbook.

SECTION 306 GEOTECHNICAL WORK PRODUCTS

Geotechnical work products include GDRs (Geotechnical Data Reports) and GERs (Geotechnical Engineering Reports). The former is for the benefit of our design-build and PPTA projects and the latter for the benefit of our design-bid-build projects. Both work products are required to include properly formatted boring logs and laboratory data as specified by the referenced test methods.

In some instances, VDOT may require the preparation of a "Preliminary Soil Survey," which relies on available information and limited subsurface exploration data.

306.01 Preliminary Soil Survey

The main purpose of the preliminary soil survey is to identify general site characteristics and subsurface conditions that should be considered during the planning and preliminary design phases of the project. The need and magnitude of this preliminary study will depend upon the size and complexity of the project. For most projects, the survey can be accomplished by performing a literature review and site reconnaissance.

The following items represent typical data sources to consider when performing a literature review:

Topographic Maps	Facilitate an assessment of landforms such as slopes, sinkholes, potential outcrop areas and stream crossings. These features can assist in the interpretation of subsurface conditions and materials.
Geological Maps	Present published reference on the underlying geologic formations that may exist at the site. In addition to the, "Geologic Map of Virginia" the most common reference maps are the U.S. Geological Survey (USGS) quadrangle maps. These maps, and other geologic publications, can be obtained from the Virginia Department of Mines, Minerals and Energy (Division of Mineral Resources).
Agricultural Soil Surveys	Provide a general guide on the anticipated soils within 5 ft of the ground surface. Published for counties within Virginia by the U. S. Department of Agriculture.
Aerial Photographs	Comparison of old and new aerial photographs may show changes in landforms that are the result of man-made (or catastrophic natural) activities. Along many existing VDOT right-of-ways, the Location and Design Division maintains historical aerial photographs.
Previous Subsurface Data	Previous subsurface exploration data can be used to anticipate stratigraphy and soil characteristics in proximity to a proposed project. These data, when available should be used in the initial planning of the project-specific field investigation.

There are other resources that may be useful in evaluating the site and soil characteristics. These include well drilling logs, historical reports/maps, journals, research studies, etc. The extent of the office research should consider the scope of the project and the ease of acquiring the historical information.

A preliminary soil survey may include a few borings. The purpose of the borings is to confirm the information obtained during the office reconnaissance, to investigate a specific area of the site (that could adversely affect the planning and design and/or construction of a project), and/or to provide physical data that can be used in preliminary design of foundations, pavements, stormwater management ponds, etc. The borings, if performed, should be drilled in locations that will allow their integration into the final subsurface investigation (i.e., as required to complete the final GER for the project).

The preliminary soil survey report should include a brief project description and a summary of the general site characteristics and subsurface conditions. It should also include preliminary engineering recommendations that should be considered during the planning and preliminary design of the project.

306.02 Geotechnical Data Reports

The GDR is a presentation of geotechnical data without reference to design solutions, recommendations or conclusions to govern the project design.

The GDR presents an overview of the project, background information about the project setting (e.g., published geologic reference, original plans, as-built drawings, etc.) and the results of site-specific subsurface exploration and laboratory testing programs. One purpose of a GDR is to provide design-build and PPTA offerors meaningful data to assist in their proposal preparations. To facilitate the preparation of such proposals, GDRs for new roadways typically provide minimum pavement sections, based on site-specific CBR or M_r data and VDOT-generated traffic projections.

VDOT has specific requirements for the preparation of GDRs for design-build and PPTA projects. These specific requirements include standard language pertaining to the limitations and obligations of the selected design-builder or PPTA concessionaire to obtain required subsurface information and perform the required geotechnical engineering analyses and design after contract award. Contracted design-builders shall prepare the requisite geotechnical engineering studies that meet the minimum standards for subsurface exploration and laboratory testing as presented in this MOI.

Sound walls for VDOT projects are always procured using design-build. This is true even when the overall project is procured using design-bid-build. As such, reference to subsurface conditions and laboratory testing for sound walls shall only include data when such reference is within a GER.

In some instances, VDOT prepares MSDRs (Major Structure Data Reports). These reports specifically address the geologic setting and subsurface conditions for a proposed major structure, but do not include specific geotechnical parameters to govern the structural design (e.g., unit skin friction or tip resistance for piling, lateral earth pressure coefficients, bearing capacity and settlement of spread footings, etc.). MSDRs are typically produced by the District Materials Section and serve as an attachment to the MSR (Major Structure Report). Essentially, a MSDR is a GDR for a major structure and a MSR is a GER for a major structure.

GDRs for design-build and PPTA projects shall be prepared by the District Materials Section. Review of these GDRs is the responsibility of the District Materials Engineer and the Central Office Materials Division Point of Contact for design-build and PPTA projects.

VDOT has recently implemented a “two tier” approach to project implementation. Tier 1 projects are those projects with total budgets less than $5M and Tier 2 projects are those projects with total budgets greater than $5M. Our approach is to execute Tier 1 projects solely with the involvement of District personnel or on-call consultants. Tier 2 projects may require collaboration between District (or their on-call consultants) and Central Office personnel.

For Tier 1 and Tier 2 projects, the Major Structure or Sound Wall Data Reports will be developed by the District Materials Section or through the Materials Division's on-call consultant. Review for Tier 1 and Tier 2 projects will be the responsibility of the District Materials Engineer. A courtesy review is available through the Central Office Materials Division Geotechnical Section.

306.03 Geotechnical Engineering Reports

Every VDOT project has defined objectives, which may include requirements for any or all of the following:

- Minor Structures
- Major Structures
- Stormwater Management Facilities
- Road beds and engineered slopes (i.e., soil surveys)
- Sound Walls
- Pavement Design

It is the responsibility of the District Materials Engineer, Central Office Structure and Bridge Geotechnical Section, on-call consultants, design-builders, PPTA concessionaires, or Local Assistance consultant/staff to prepare GERs to address these elements of work.

Geotechnical engineering analyses for VDOT projects shall confirm the following:

- Total vertical settlement of embankment fill and underlying native soil shall be less than two inches over the initial 20-years, and less than one inch over the initial 20-years within 100 ft of bridge abutments;
- Projected settlement of embankment fill and underlying native soils will not impede positive drainage of the pavement surface especially within the travel lanes;
- Settlement will not result in damage to adjacent or underlying structures, including utilities;
- Compliance to soil and rock slope safety factors as shown above;
- Angular distortion between adjacent foundations shall be compliant with the most current LRFD requirements.
- Soil strength parameters, reliability assessments (design-build/PPTA projects only), and calculations showing safety factors as required for engineered slopes.
- Pavement design that meets the requirements of Chapter VI of the Manual of Instructions in consideration of the on-site soil properties.

Major structures for VDOT projects include bridges, retaining walls greater than 10-ft high and any structures to be supported on deep foundations including pile-supported embankments, culverts, and utilities.

Minor structures for VDOT projects primarily include drainage pipes, culverts, and retaining walls less than 10-ft high. In many instances limited geotechnical engineering analyses are required for drainage pipes and culverts; however, when drainage pipes or culverts are greater than 36-in diameter, VDOT requires a specific subsurface exploration and geotechnical study. Any drainage pipe or culvert installed in soft ground prone to settlement shall include the data and analyses necessary to support long-term performance, irrespective of the pipe or culvert dimension.

For single-objective GERs, VDOT prepares the following work products:

- Minor Structure Report.
- Major Structure Report.
- Stormwater Facility Report.
- Soil Survey (addresses the geotechnical engineering requirements for a roadway including cut and embankment slopes and pavement design).

For multi-objective reports (e.g., a new road with retaining walls, bridges, utilities and sound walls), the GER is prepared to address the geotechnical aspects for each of these objectives. It is not a requirement of VDOT to develop multiple reports for each objective of a single project.

Whether preparing a single- or multi-objective report, GERs shall include the following:

- Project description;
- Background information (i.e., former studies, published geologic reference, NRCS soil maps, etc.);
- Subsurface exploration data;
- Laboratory testing data;
- Design parameters and analyses;
- Geotechnical recommendations;
- Construction considerations;
- Appendix with independently checked calculations and software output; and
- Recommended geotechnical Special Provisions.

In developing the geotechnical engineering study for a major structure, consideration must be given to the type and size of structure, anticipated design loads, settlement (total, differential and time rate), lateral deflection criteria, site and subsurface characteristics, and proposed project constraints. Major structures shall be designed according to LRFD.

When GERs are prepared by design-build teams or PPTA concessionaires, review of such documents is the responsibility of the District Materials Engineer and the Central Office Materials Division Point of Contact.

Owing to the nature of VDOT’s newly-implemented Tier 1 and Tier 2 process, there are differing responsibilities within VDOT during the development of Major Structure Geotechnical Engineering Studies.

For Tier 1 projects, the MSR will be developed by the District Materials Section or the Materials Division’s on-call consultant. Review for Tier 1 projects will be the responsibility of the District Materials Engineer and the District Structure and Bridge Engineer. For MSRs developed by the District Materials Section or the Materials Division’s on-call consultant, a courtesy review is available through the Central Office Structure and Bridge Division Geotechnical Section.

For Tier 2 projects, the MSR will be developed by the design consultant selected by the Central Office, the Materials Division’s on-call consultant, or the District Materials Section, provided they have properly qualified (i.e., by virtue of education and experience) geotechnical engineering personnel. Review for Tier 2 projects will be the responsibility of the Central Office Structure and Bridge Division Geotechnical

Section and the District Structure and Bridge Engineer. QA will be provided by the Central Office Structure and Bridge Division Geotechnical Program Manager.

306.04 Geotechnical Design References

As a compliment to the requirements of LRFD, the following references provide specific information to support VDOT's design efforts:

Shallow Foundations – FHWA-SA-02-054 available at the following URL:
http://isddc.dot.gov/OLPFiles/FHWA/010943.pdf

Driven Piles – FHWA HI 97-013 and FHWA HI 97-014 available at the following URLs:
http://isddc.dot.gov/OLPFiles/FHWA/009746.pdf
http://isddc.dot.gov/OLPFiles/FHWA/009747.pdf
http://www.extranet.vdot.state.va.us/locdes/electronic%20pubs/Bridge%20Manuals/VolumeV-Part_11/Chapter%209.pdf

MicroPiles – FHWA-SA-97-070 available at the following URL:
http://www.vulcanhammer.net/geotechnical/FHWA-SA-97-070.pdf

Continuous Flight Auger Piles – FHWA-HIF-07-039 available at the following URL
http://www.fhwa.dot.gov/engineering/geotech/pubs/gec8/gec8.pdf

Drilled Shafts – FHWA-NHI-10-016 available at the following URL:
http://www.fhwa.dot.gov/engineering/geotech/foundations/nhi10016/nhi10016.pdf

MSE Walls – FHWA-NHI-10-024/FHWA GEC 011 – Volume I, FHWA-NHI-10-025/FHWA GEC 011 – Volume II, FHWA-NHI-09-087

Retaining Walls – Refer to guidance from VDOT Structure and Bridge Division

Soil Nail Walls – FHWA-SA-96-069R and FHWA0-IF-03-017 available at the following URLs:
http://isddc.dot.gov/OLPFiles/FHWA/010571.pdf
http://isddc.dot.gov/OLPFiles/FHWA/016917.pdf

Tieback Walls – FHWA-IF-99-015 available at the following URL:
http://www.fhwa.dot.gov/engineering/geotech/pubs/if99015.pdf

Box Culverts – Refer to VDOT Road and Bridge Specifications

Pipes – Refer to VDOT Road and Bridge Specifications

Stormwater Management Basins – Refer to the Virginia Department of Conservation and Recreation Stormwater Management Handbook.

http://www.dcr.virginia.gov/stormwater_management/stormwat.shtml#vswmhnbk

Sheetpiles – Refer to USACE (U.S. Army Corps of Engineers) EM 1110-2-2504 available at the following URL:
http://140.194.76.129/publications/eng-manuals/em1110-2-2504/entire.pdf

SECTION 307 MONITORING PERFORMANCE DURING CONSTRUCTION

The nature of the geotechnical engineering design, the subsurface and field conditions at the site, and the proposed construction may require performance monitoring during and/or after construction. Such performance monitoring may relate to settlement of embankments and structures, movement of cut and fill slopes, construction induced vibrations, groundwater levels, pore-pressure dissipation, deep foundation installation and testing, and/or lateral displacement. GERs for VDOT projects should address performance monitoring requirements when such details are known or anticipated at the time of report preparation.

VDOT projects that require pile driving or rock blasting may necessitate provisions for vibration monitoring. Vibration monitoring shall be in accordance with the Special Provision for Blasting. The District Materials Engineer shall review all plans for vibration monitoring and review all recorded data.

Driven pile foundations may require PDA (pile diving analyzer) testing during installation to evaluate the integrity and capacity of the as-built foundation. Dynamic and/or static load tests shall be performed in accordance with the latest VDOT Road and Bridge Specifications. All test data shall be provided to the District Structure and Bridge Engineer, the District Materials Engineer, and the Central Office Structure and Bridge Geotechnical Program Manager. The District Structure and Bridge Engineer is responsible for determining the acceptability of the test data.

Load testing of drilled shafts may require the use of the static load test, the Osterberg cell, or other similarly-approved load test methods (e.g., the Statnamic Method). Load tests shall be performed in accordance with the Special Provision for Drilled Shafts. All test data shall be provided to the District Structure and Bridge Engineer, the District Materials Engineer, and the Central Office Structure and Bridge Geotechnical Program Manager. The District Structure and Bridge Engineer is responsible determining the acceptability of the test data.

Load testing of micropiles may require the use of the static load test. Dynamic load testing using the PDA may be used as a substitute for a portion of the static load tests. VDOT typically requires at least two static load tests be performed per structure. Use of dynamic load tests for micropiles is subject to the approval of the District Structure and Bridge Engineer, the District Materials Engineer, and the Central Office Structure and Bridge Geotechnical Program Manager. Load tests shall be performed in accordance with the Special Provision for Micropiles. All test data shall be provided to the District Structure and Bridge Engineer, the District Materials Engineer, and the Central Office Structure and Bridge Geotechnical Program Manager. The District Structure and Bridge Engineer is responsible determining the acceptability of the test data.

When specified, settlement plates shall be employed to monitor the settlement below embankments on soft ground as well as to monitor settlement of thick fills. Settlement plates are also used to monitor the performance of wick drains, the performance of dewatering operations, potential settlement caused by construction, etc. Settlement plates shall conform to the requirements of the latest VDOT Road and Bridge Specifications. Settlement plate data shall be approved by the geotechnical engineer of record and provided to the District Materials Engineer for review.

When specified, slope inclinometers shall be used to measure the location, rate and magnitude of lateral or vertical movement within a soil or rock mass, particularly for cut and fill slopes. The following are some of the requirements for slope inclinometers:

- Slope inclinometers shall be installed in accordance with the manufacturer's specifications, which are to be submitted to the District Materials Engineer for approval at least 14 calendar days prior to installation.
- The casing shall be installed in a borehole of sufficient diameter to allow for grouting of the annular space between the borehole and the casing. Cement-bentonite grout shall be used.
- Casing shall be PVC and flush-mounted with o-ring joints or telescoping casing that is sealed to prevent the intrusion of grout into the casing. The diameter of the casing shall be 2.75 or 3.34 in.
- The casing shall be oriented with the "A" axis grooves perpendicular to the slope face and shall be installed within 5 degrees of vertical.
- The casing shall be installed to a minimum depth of 10 ft into stable material (e.g., N-values of 50) or to a depth as determined by the District Materials Engineer.
- Upon completion of installation, the casing shall be filled with water to keep the slope inclinometer from floating out of the ground.
- The probe shall be properly calibrated prior to use. The probe shall be stainless steel with a system accuracy 0.4 in. per 80 ft.
- The digital readout device shall be capable of storing 40 data sets and recording readings at depth intervals of 20 in.
- Dual (reverse) readings will be obtained for both the "A" and "B" axes for each set of readings obtained.
- All data shall be provided to the District Materials Engineer for review and acceptance. Reading intervals will be determined or approved by the District Materials Engineer based on the site specific conditions.

SECTION 308 QUALITY ASSURANCE OF CENTRAL MIX SELECT MATERIAL AND DENSE-GRADED AGGREGATE FOR SUBBASE AND BASE

This section covers the VDOT Materials Division quality assurance program for central mix (pugmill) production of select material and dense-graded aggregate subbase and base material, all collectively referred to as Central Mix Aggregate (CMA) (reference Secs. 207 and 208 of the VDOT Road and Bridge Specifications, respectively).

The production of high-quality CMA requires that the product meets definite specifications. These specifications are not arbitrary figures, but are the end result of years of experience, data analysis and research. It shall be the duty of the Producer's Certified Central Mix Aggregate Technician to see that all component materials have been approved for use and that they are combined into a mixture that meets all specification requirements.

The advantage of a CMA mixture that meets the specifications is in low cost maintenance. The initial responsibility of obtaining a mixture meeting the specification requirements, thus ensuring the best possible construction at a minimum total cost, rests with the Producer's Certified Central Mix Aggregate Technician. VDOT has had a comprehensive quality assurance program for the production and placement of these materials in place since at least the 1980s, and since the mid-1990s has maintained the program to meet requirements of the United States Code of Federal Regulations (CFR) Title 23 Part 637 as well, which is administered by the Federal Highway Administration (FHWA). This program is a system of Quality Control (QC) sampling and testing, Independent Assurance (IA) sampling and testing, and Verification (VST) sampling and testing. The QC component is performed by the Producer; both the IA and VST components are performed by VDOT. QC, IA, and VST testing also include visual checks, statistical analyses, inspections, and certifications. See Sec. 206 for more on IA and VST, including definitions.

Section 308.01 General

Aggregate base, subbase, and select material when specified, will be mixed in a central mixing plant of the pugmill or other approved type. Material shall be blended prior to or during mechanical mixing, in such a manner that will ensure conformance with specified requirements.

The rest of this section covers the quality assurance program for dense-graded aggregate base, subbase, and select materials for gradation, Atterberg Limits, CBR, and other physical tests, except depth and density, which are covered in Section 309. Samples of dense-graded aggregates for soundness tests (AASHTO T104) shall be handled as outlined in Sec. 204.02. See also Sec. 206 for Independent Assurance sampling requirements.

Section 308.02 CMA Plant

(a) Materials

The Central Mix Aggregate Producer is responsible for the quality control and condition of all materials used in central mix aggregate, as well as the handling, blending, and mixing operations, in accordance with Secs. 207 and 208 of the VDOT Road and Bridge Specifications. The Producer is responsible for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified mix. If sample failure occurs at any time during the plant operation after initial setup, immediate adjustments shall be made. If these adjustments do not correct the cause of failure, the plant shall be stopped and recalibrated.

(b) Performance of Sampling, Testing, and Recording of Results for CMA

The production control samples and tests shall be taken and performed by the Producer's Certified Central Mix Aggregate Technician, as outlined in Section 308.05(a). Aggregate or select material paid for on a volume basis shall be sampled as directed by the District Materials Engineer.

The Producer shall be responsible for recording test results and maintaining quality control charts. The Producer shall furnish to the VDOT Materials Representative copies of the test results on forms furnished by VDOT and maintain current control charts at the plant for review by VDOT. The Producer shall likewise maintain all records and test results associated with materials production; e.g., hydraulic cement, etc.

(c) Notification of Production

The Producer shall notify the District Materials Engineer when production will start or resume after a delay.

(d) Assisting Materials Representative

The Producer shall obtain a sample at the request and under the direction and control of the Materials Representative and analyze one-half of the sample. VDOT shall be responsible for analyzing the other one-half. The Producer's portion of the split sample shall be used as the next production control sample. See Section 308.05(b) for additional details of performing this sampling.

(e) Plant Laboratory Equipment

Central mix aggregate laboratories and calibrated testing equipment shall be furnished by the Producer. Plant production laboratories will be equipped, as outlined in Sec. 106.07 of the Road and Bridge Specifications. (Reference - AASHTO T87, T88, T89, T90, and VTM-1, VTM-7, VTM-8, VTM-12, VTM-25, VTM-40.) The full list of Virginia Test Methods (VTMs) can be found online at:

http://www.virginiadot.org/business/resources/Materials/bu-mat-VTMs.pdf

(f) Regional CMA, or Multiple Use Laboratories

VDOT reserves the right to require a laboratory conforming to the requirements of Sec. 106.07 at each plant which is processing material for Department use; however, use of a single regional laboratory to serve several plants in a given area may be permitted, provided such use does not adversely affect the sufficiency and timeliness of the sampling and testing program at each plant. In the event a dispute arises over the practicality of multiple plant use of a single laboratory, such disputes shall be referred to the District Materials Engineer for resolution.

(g) Personnel

All sources supplying central mix aggregate to VDOT shall be required to have present during the initial setup, for all subsequent adjustments of the plant, and at all times during production for each job-mix, a Certified Central Mix Aggregate Technician, as outlined in Secs. 207.04 and 208.05 of the VDOT Road and Bridge Specifications. Such Technician shall be capable of designing, sampling, testing, and adjusting the mixture.

(h) Personnel Certification (see also Sec. 115)

VDOT shall provide (for a fee to non-VDOT personnel) classroom technical instruction and classroom and online examination and certification. The State Materials Engineer in conjunction with the VDOT Learning Center shall direct the administering of examinations and certifications to Technicians and Inspectors.

Written examinations for certification shall be administered by the VDOT Learning Center. The written examination shall be monitored by the VDOT Learning Center staff or designated assistants and an accurate accounting of all examination papers shall be maintained.

All written examinations shall be prepared, graded, and recorded under the direction of the State Materials Engineer in conjunction with the VDOT Learning Center.

Reexamination and recertification shall be required 5 years from the date the certificates are issued. The status of the certification for Inspector and Technician shall be valid only for the specific responsibilities and privileges granted to the bearer and name appearing on the certificate issued. If at any time an Inspector or Technician is found incapable of performing his or her duties as prescribed herein, he or she shall not be allowed to take part in the production of central mix aggregate being manufactured for VDOT use. The certification may be suspended following the procedure of Sec. 115.07.

More on the VDOT Certification program can be found online at:

http://www.virginiadot.org/business/matschools.asp.

(i) Inspection of Plant, Equipment and Personnel

(1) Initial Plant Inspection

The plant shall be inspected before production for compliance with specification requirements governing plants and testing equipment. A program of regular but unannounced inspection shall be scheduled and supervised by the District Materials Engineer at all central mix aggregate plants supplying dense-graded aggregate or select material for VDOT work. This inspection shall be conducted at any plant initially setting up and starting production, and at least once per year thereafter or as required. The purpose of this inspection is to determine that the plant, equipment and personnel meet specification requirements. A record shall be prepared on a checklist type form of all items covered during the plant inspections by the District Materials Section. (See the standardized "CMA Pugmill Plant Inspection Report" at the end of this chapter.)

(2) Regular or Routine Plant Inspection

The plant shall be inspected periodically during production, including items such as stockpiles, equipment, control charts, sampling, testing and records kept by the Producer's Certified Central Mix Aggregate Technician. These inspections shall be in addition to the initial or annual inspections noted in Paragraph (i)(1) above; shall likewise be completely unannounced and shall be conducted by the Materials Representative. The inspections shall be conducted for the purpose of determining whether or not specifications and instructions are being followed by the Producer in the production, sampling, testing and inspection of central mix aggregate.

The frequency of these latter plant inspections shall be related to the overall quality of the plant equipment and competence of the plant personnel. Plants that have a record of continually producing good materials, being in excellent condition and manned by well-trained personnel may be inspected as seldom as once a year. Plants with poor records shall be inspected more often as resources permit. Periodic inspection of all plants at the same frequency regardless of record is not recommended.

A plant inspection report shall be issued on the "CMA Pugmill Plant Inspection Report" immediately upon completion of this inspection. The forms shall be completely and accurately filled out by the Materials Representative conducting the inspection, noting any and all discrepancies and any corrective action taken by the inspection personnel. Thereafter, this report shall be reviewed by the District Materials Engineer or his representative and copies of the report retained for District use. Unfamiliar Department and Industry personnel shall be requested to show evidence of their certification to visiting representatives of the Materials Division.

(j) Maintaining Records

Materials personnel shall keep a diary of plant visits, observations, and comments made to the Producer. The Materials Representative shall also furnish the Producer with the optimum water content of the aggregate being produced.

Section 308.03 Approval of Job Mix

The Materials Representative shall determine that the CMA mix design (job-mix formula) and all material proposed for use have been approved by the Materials Division prior to the start of mixing operations, as outlined in Section 106.01(c) and Chapter VIII, Sec. 803.63 Form TL-127A, Job-Mix Input Form – Central Mix Aggregate.

Section 308.04 Documentation of Tonnage Material

For details of documentation of tonnage material and the bonded weigh program, see Secs. 107, 108, Chapter VIII – Reports and Forms, and the Bonded Weigh Program Weighperson Training Manual which can be found online at:

http://www.virginiadot.org/business/resources/Materials/bu-mat-Bonded_weigh_program.pdf.

Section 308.05 Sampling, Testing, and Acceptance of CMA

Sampling, testing, and acceptance of CMA shall be in accordance with the procedures designated herein, and shall consist of Producer Quality Control (QC) sampling and testing, VDOT Independent Assurance (IA) sampling and testing, and VDOT Verification (VST) sampling and testing. All of these components together comprise the quality assurance program.

(a) Quality Control (Producer) Samples and Tests

Quality Control samples are those obtained by the Producer's Certified Central Mix Aggregate Technician at the plant and tested in the plant laboratory for gradation, Atterberg Limits, water content, and cement content (if applicable).

In the production of these materials, the optimum water content, plus or minus two (2) percentage points, shall be required.

A statistically acceptable method of randomization shall be used to determine the time and location for taking stratified random samples of the aggregate or select material. See the Central Mix Aggregate Certification Study Guide for an approved randomization method. Testing shall be in accordance with the VDOT Road and Bridge Specifications Sections 207 and 208. The frequency of sampling shall be at a rate of 4 samples per lot (either 2000 or 4000 tons). Lot size shall be chosen, upon request by the Producer or District Materials Engineer and at the discretion of the District Materials Engineer, from either 2000 or 4000 ton lots. Lots shall be chosen in order to match Producer shipping rates, to reduce unnecessary testing, when past performance indicates stability, and when lot sizes/shipping rates are appropriate to ensure statistical significance will be obtained. Samples shall be taken after the material has been mixed according to Sections 207.04 and 208.05 of the VDOT Road and Bridge Specifications to satisfy the blending and water content requirements (optimum water content plus or minus two (2) percentage points). The size of the sample shall be 30 to 40 lbs.

The representative sample, secured from the randomly selected material that is being shipped to the project site and weighing 30 to 40 pounds, shall be obtained by one of the following methods: (1) The sample shall be obtained from the approximate center of the loaded truck; (2) A loaded truck shall dump at a convenient location within the plant facility to create a representative mini-stockpile. The top of the dumped load shall be struck with the bucket of a front-end loader to create a flat spot on top of the pile from which the representative sample shall be obtained; (3) A mini-stockpile shall be created by material extracted from the post-pugmill shipping stockpile. When the truck containing the load that will be sampled is in the process of being loaded, a randomly selected front-end loader bucket of aggregate being taken from the post-pugmill shipping stockpile shall be dumped at a convenient location within the plant facility to create the mini-stockpile. The top of the mini-stockpile shall be struck with the bucket of the front-end loader to create a flat spot from which the representative sample shall be obtained. Separate the sample into two (2) approximately equal portions by processing the sample through a sample splitter or split by the quartering method. If no IA sample is being taken, as detailed in Paragraph (b) below, the

Producer's Technician shall still split the sample as noted above before running the tests on one of the split portions.

(b) Independent Assurance Samples and Tests

Independent Assurance (IA) samples are those obtained at the central mix aggregate plant by the Producer's Certified Central Mix Aggregate Technician in the presence and under the observation of the VDOT Materials Representative, and tested in the VDOT Laboratory or by AMRL-accredited consultant laboratories. These samples are tested for gradation, Atterberg Limits, water content, and cement content (if applicable).

IA samples shall be obtained at a rate that both provides a statistically significant number of samples for each mix produced and allows verification of unstable mixes. At least one (1) IA sample shall be obtained and tested from each lot and as necessary to ensure statistical significance and to monitor unstable or nonconforming mixes. Unstable mixes are those that exceed variability tolerances provided in VTM-59. Lot size shall be chosen, upon request by the Producer or District Materials Engineer and at the discretion of the District Materials Engineer, from either 2000 or 4000 ton lots. Lots shall be chosen in order to match Producer shipping rates, to reduce unnecessary testing, when past performance indicates stability, and when lot sizes/shipping rates are appropriate to ensure statistical significance will be obtained.

This rate of IA sampling is mandatory, and is the responsibility of the District Materials Engineer to see that it is accomplished. Should the QA effort fall behind the required frequency of sampling and/or testing, the District Administrator shall be advised immediately. Sufficient personnel shall be provided for the QA effort. The Materials Representative will observe the manner in which sampling is performed by the Producer. Not only is the "when", "where", and "how" of obtaining the sample important, but also the care taken to properly reduce the sample to testing size. The Materials Representative directs when the sample shall be obtained. He/she shall observe the Producer’s Certified Central Mix Aggregate Technician obtaining and splitting (or quartering) the sample into two (2) approximately equal portions. The Materials Representative takes one-half of the sample to serve as the Independent Assurance sample. The Producer's Certified Central Mix Aggregate Technician shall perform the test on the other half, which shall be considered the next quality control sample for the Producer. (See Paragraph (a) above.)

The Producer’s test results and the District Materials’ copy of the daily summary sheets (Form TL-102A) shall be provided to the Department within 24 hours of completion. The forms are reviewed for correctness and legibility. The contract number(s) and tonnage(s) are obtained from the weigh sheets and recorded on the input form, Form TL-52A, which is input into VDOT’s CMA database. The original and one copy of the CMA Point Adjustment Analysis Report (E12-1710-01) test report will be produced by the VDOT Materials Representative. The report shall be reviewed for correctness. The original shall be put in the District Materials Engineer's project folder. The other copy shall be forwarded to the Contractor/Producer that is producing the material. If there is more than one contract on the lot, only one lot copy shall be sent. One copy of the lot report shall also be put in a plant file. This is the only distribution that is needed. The materials notebook requires a one line entry identifying the daily tonnage, gradation or type mix, and source. In case of nonconformance to the specifications, a copy of the test report shall be furnished to the Prime Contractor by VDOT.

The success of the quality assurance program will be determined to a large extent by the effectiveness of the IA sampling and testing effort. Deficiencies revealed through this effort shall be addressed promptly and decisively. The results of the IA tests are recorded in the VDOT CMA Database. The CMA Database is capable of performing all of the statistical analyses required by VTM-59, except for the D2S comparison. Thus, this statistical test shall be made by the VDOT IA Technician immediately when the data is available, that is, after gradation results for a single lot's split sample are available from both the Producer and VDOT.

(1) D2S Test

The D2S test is an individual test comparison between the Producer's results and VDOT's results on their respective splits of the IA sample. The D2S comparison is the individual test percent difference between two (2) results obtained on test portions of the same material. The figures for acceptable range of two (2) results, in percent, applicable for all sieve sizes, are those found in Table 2 – Estimates of Precision of the AASHTO Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates, T 27-06, for multilaboratory precision for coarse aggregate, and are listed below:

Total Percentage of Material Passing		Acceptable Range of Two Results (D2S), Percent
100	≥95	1.0
<95	≥85	3.9
<85	≥80	5.4
<80	≥60	8.0
<60	≥20	5.6
<20	≥15	4.5
<15	≥10	4.2
<10	≥5	3.4
<5	≥2	3.0
<2	0	1.3

In the event that for a given sieve, the total percentages of material passing obtained by the Producer and VDOT fall into different brackets, the acceptable range to use for the D2S test shall be that corresponding to the bracket designated by the job-mix formula for the given sieve.

The benefit of performing the D2S test immediately upon the results of the IA sampling of a lot of material is that if discrepancies are found between the Producer's results and VDOT's results the reason for the discrepancies can be immediately investigated and remedied and material quality problems minimized. If the results are not in agreement, an investigation shall be made to determine the reasons for differences as given in Paragraph (d) below.

(**2) Matched Comparison Test**

The IA tests performed by the CMA Database are made in a matched comparison report that compares the results of gradation, Atterberg Limits, and cement content tests of the Producer against those of VDOT on the split (matched) samples on a given job mix for a given plant using the VTM-59 methodology. The frequency of these reports shall be adjusted by the District Materials Engineer according to production schedule. The report shall use dates that include at least seven (7) IA results, if possible. Also, if there is a change in the production mix, the report shall begin with the date of the change. The report shall flag those values that are outside the statistically accepted range for samples collected from the same production operation. The report shall be reviewed by VDOT for correctness and one copy sent to the Contractor/Producer by way of a Materials Representative. If the results are not in agreement, an investigation shall be made to determine the reasons for differences as given in Paragraph (d) below.

(c) Verification Samples and Tests

Separate verification samples are not collected. The VST tests performed by the CMA Database are made in a non-matched comparison report that compares the results of gradation, Atterberg Limits, and cement content tests of the Producer against those of VDOT using the VDOT portion of the split sample and the non-split (non-matched) QC samples of the Producer on a given job mix for a given plant using the VTM-59 methodology. The frequency of these reports shall be adjusted by the District Materials Engineer according to production schedule. The report shall use dates that include at least seven (7) IA results, if possible. Also, if there is a change in the production mix, the report shall begin with the date of the change. The report shall flag those values that are outside the statistically accepted range for samples collected from the same production operation. The report shall be reviewed by VDOT for correctness and one copy sent to the Contractor/Producer by way of a Materials Representative. When flags occur in which the data generated from VDOT's non-matched IA samples indicate that the material may not be within specification limits but the data generated from the Producer's non-matched QC samples indicate that the material is within specification limits, a thorough investigation shall be conducted. If the results are not in agreement, an investigation shall be made to determine the reasons for differences as given in Paragraph (d) below.

(d) Material Acceptance

Material is accepted in accordance with specifications, based upon the Producer's test results, provided such results are statistically comparable (per VTM-59 and as described below) to VDOT's IA and VST test results and provided the material passes a visual examination for contamination and segregation at the project site.

In the event a statistical comparative analysis of the Producer's quality control test results and VDOT's IA or VST test results indicate a statistically significant difference in the results, or either of the results indicate that the material does not conform to the gradation and Atterberg Limits requirements of the specifications, an investigation shall made to determine the reason for the differences.

Suggested checks are:
(1) Check to see if the IA test results meet the specifications for Average and Standard Deviation.
(2) Compare results of VDOT/Producer split samples.
(3) Check to see if one of the systems is indicating a trend (consistently fine, coarse, erratic, etc.)
(4) Check sampling and testing procedure.
(5) Check testing equipment.

The results of the investigation shall be sent to the State Materials Engineer for use in preparing the annual report to FHWA, and to the Producer for their records. The sampling and testing procedures and laboratory test equipment (both the Producer's and the Materials Representative's) shall be checked as necessary. If the differences can be determined, the material shall be accepted, adjusted, or rejected in accordance with the specification. If differences still cannot be explained, then either the Producer or VDOT may call for the referee system to determine final disposition of the material. If it becomes necessary to implement the referee system, refer to Secs. 207.06 and 208.07 of the VDOT Road and Bridge Specifications to determine the sampling and testing details. If it is determined that the Producer's test results are not representative of the product, VDOT shall take such action as it deems appropriate to protect its interests.

(e) Treating with Cement

When these materials are treated with cement at the pugmill, sampling of materials shall be the same as outlined in Paragraphs (a) and (b) above, except the sampling for gradation, Atterberg Limits, and water content shall be done before the cement is added. The cement content shall be determined in accordance with VTM-40 and Sec. 307.05(b) of the VDOT Road and Bridge Specifications.

(f) Computations for Aggregate and Water in CMA

Outlined herein are guidelines for computing the various amounts of aggregate and water needed (with or without cement) to determine pay items, etc., when aggregate base, subbase, and select materials are pugmill mixed. This method shall be used along with the tests for water content determination, such as with the "Speedy" Moisture Tester. Accordingly, corrections for excess water content shall be made as indicated herein.

(1) Determine allowable water content for the mix. For example, assume that the average optimum water content of the material is 6 percent. The allowable water content would be:

6% +/- 2% = 4% to 8% (Sections 308.03 & 309.05 of the VDOT Road and Bridge Specifications.)

(2) Determine Water Content Correction. For example, assume 1000 tons of material shipped containing 10 percent total water content. (The test for total water content shall be made on a sample of material obtained by the Producer's Certified Central Mix Aggregate Technician, after all water has been added to the mix in the pugmill, and after the material is ready for job shipment.):

$\frac{1000}{1.10}$ tons = 909.1 tons of dry aggregate.

(3) Determine Pay Quantity:

909.1 tons x 1.08 = 981.8 tons of aggregate.

This is the total combined tonnage (dry aggregate and water) that shall be computed as the amount eligible for payment. Notes shall also be made on the computerized CMA Point Adjustment Analysis Report (E12-1710-01) test report and on the Weighperson's Daily Summary Report, Form TL-102A, showing the average optimum water content and the total water in order that proper corrections for payment can be made later in the net weight recorded on the weigh ticket and in materials notebooks.

(g) Stockpiling After Mixing

If due to heavy demand material is stockpiled after production, it shall be necessary to make tests for total water and record the results on the forms listed above at the time of shipment of material to the project. If water content of the aggregate in the stockpile is below the minimum required (optimum minus two (2) percentage points), either the stockpiles shall be sprinkled to bring the water content within tolerance or the District Materials Engineer may require that the aggregate shall be run through the pugmill again to bring the water content within tolerance. Computations for the pay quantity shall be carried out to the same decimal point as the pay item.

When these materials are stockpiled at the plant after mixing and before shipment to the project, neither independent assurance sampling, nor quality control sampling for the purpose of lot acceptance, shall be performed while the Producer is stockpiling material. Instead, quality control samples for lot acceptance and independent assurance samples shall be taken, as outlined in Paragraphs (a) and (b) above, when the material is shipped to the project from the stockpile. If the material was not pugmill mixed prior to stockpiling, then it shall be necessary to run the material through the pugmill prior to both production quality control sampling and testing and independent assurance sampling and testing.

SECTION 309 PROJECT SAMPLING, TESTING AND INSPECTION

Sampling aggregate base, subbase, and select material from the project for gradation and Atterberg Limits tests normally shall not be required, unless the material has not received acceptance testing at the source prior to shipment, as outlined in Sections 308.05(a), (b), and (c) above, or unless the material being placed on the project is visually observed to be contaminated or segregated, regardless of prior acceptance testing.

If roadway sampling becomes necessary, it shall be done immediately after placement has been completed and prior to compaction. The Project Inspector, when properly trained and experienced, may obtain samples. Samples of the material shall be obtained from three (3) points within the roadway. These shall be at the center and approximately four (4) ft. transversely from the outer edges of the course being laid. The material from the three (3) points shall be taken from the full depth of the course being laid. The sides of the hole shall be kept as nearly vertical as possible. The material shall be placed on a canvas or other surface of sufficient size, thoroughly mixed, and quartered or split to obtain the proper size sample.

Project samples shall be tested in the VDOT or an AMRL-accredited consultant laboratory at the discretion of the District Materials Engineer and at the rate of sampling previously specified. Samples of select material for CBR tests shall be obtained at the minimum rate of one (1) per project, or more often as needed for control, if these tests have not been performed prior to the receipt of the material at the job site, whether the material is processed or local. However, if the stockpile or borrow location of material is serving multiple projects and has already been tested for CBR for other projects, those previous test results may be used as long as the material has not been altered or contaminated. The same rate of sampling outlined above applies to aggregate used as shoulder material.

Arrangements shall be made for a daily pickup of samples taken by the Inspector, if it becomes necessary to sample material from the project.

Each sample submitted to the Materials Division shall be accompanied by two (2) Form TL-11 cards. One card shall be placed in an envelope and attached to the outside of the bag, and the duplicate card shall be submitted by mail. Form TL-11 shall be completely filled out including the amount of material represented by the sample. This can be volume, lineal feet (Sta. to Sta.), tonnage, or percentage, as the case may be. Further instruction for Form TL-11 is found in Chapter VIII, Sec. 803.04 Form TL-11, Notice of Shipment of Sample for Test (Soil and Local Materials).

Size of sample to be submitted shall be 75 to 100 lbs (two (2) bags) in all cases for the following samples:

(1) Local pit or select material.

(2) Material to be used in embankments.

(3) Material for CBR Test (from soil survey or source). Two (2) bags if all material will pass 3/4 in. sieve; three (3) bags if considerable amount of plus (+) 3/4 in. material is present.

(4) Pugmill material (regardless of where tested).

(5) Subbase or base material from project.

(6) Material for soil-cement stabilization.

(7) Material for soil-lime stabilization.

Where soil-cement or soil-lime stabilization will be used on a new location, on an existing road, or on a change in grade, representative samples of the material in the road or of the soil to be stabilized shall be submitted to the VDOT or an AMRL-accredited consultant laboratory for tests. Samples shall be taken from each different soil type encountered. If the materials in the existing roadway or on the new location are reasonably uniform, one sample may be sufficient.

In some cases, aggregate base, subbase, or select materials to be treated may be open graded, requiring excessive amounts of stabilizing agent acting as an expensive filler, or resulting in a product with an excessive amount of voids if the cement content is held to acceptable limits. The recommended gradation on critical sieves for these materials is given below and should be adhered to as closely as possible when the materials will be treated with cement or lime:

Sieve Number	Minimum Percent Passing
4	55
10	37
-10/+200	25 (Minimum % retained between these sieves.)

Select material may require additional care to maintain the material close to these limits without requiring tighter gradation controls when it will be treated with cement or lime.

The following sections 309.01 and 309.02 contain instructions for density control and depth control of compacted materials, respectively. This includes the following: embankment material; finished subgrade (prior to paving); cement or lime stabilized subgrade (consisting of material in-place or imported material other than aggregate base, subbase or select material); stabilized or untreated aggregate base, subbase or select material; and stabilized or untreated aggregate shoulder material.

Section 309.01 Density Control

(a) General

(Reference Secs. 303.04, 304, 305.03, 306.03, 307.05, 308.03, and 309.05, VDOT Road and Bridge Specifications.) See Sec. 207 herein for possible waiver of density tests on special projects.

The density of soil is defined as the weight of the soil (and water) per unit volume (lbs per ft^3). The dry density of a soil is defined as the weight of just the soil per unit volume (lbs per ft^3). The water content of a soil is the ratio of the weight of water in a soil mass versus the weight of the dry soil in that same volume, expressed as a percentage. The optimum water content is the water content at which maximum density can be achieved by a standard compactive effort. The maximum theoretical density is that density where the most soil is compacted into a unit volume by a standard compactive effort. The maximum theoretical density of a soil shall be determined using VTM-1 or the One-Point Proctor Method VTM-12. The percent compaction is the ratio of the in-place density versus the maximum theoretical density expressed as a percentage.

Before field control of compaction can be exercised, it is necessary that the theoretical maximum density and optimum water content for each type of soil or aggregate (pavement base or subbase materials) be determined in advance of the compaction operation.

In addition to information available on soil survey reports, it may be necessary to submit representative samples of the soil for testing per VTM-1 to a VDOT laboratory or an AMRL-accredited consultant laboratory, unless the One-Point Proctor Method (VTM-12) is used for this determination in the field. Samples submitted to a laboratory for this purpose shall be from 75 to 100 lbs or two (2) full bags (four (4) full sample bags if resilient modulus testing is required). The following information shall supplement that normally given on Form TL-11 which accompanies the sample:

(1) Horizontal limits (by station number) represented by the sample.
(2) Vertical limits (in feet) represented by the sample.
(3) Visual description of material (Example: Silty Sand, containing some mica).

(b) Compaction and Determination of Field Density

(1) Use of Maximum Laboratory and One-Point Proctor Densities (theoretical maximum densities) - As noted above, in computing the percent of compaction in the field, the density determined in the field shall be compared to a standard density, as determined by VTM-1, or the One-Point Proctor density (VTM-12), unless otherwise noted herein.

(2) Equipment Needed for Field Density Test - The equipment necessary for performing field density tests is available to VDOT staff through the District Materials Engineer. The equipment is however only required to be provided to non-VDOT personnel or firms when contracts with VDOT require it (e.g., District or Statewide or Regional Construction Engineering and Inspection (CEI) contracts or Statewide or Regional Laboratory Testing and Technician Services contracts). The District Materials Section is available to provide instruction and assistance to the Project Inspectors who operate nuclear gauges for measurement of density and moisture of soils, aggregates, and other paving materials. See Secs. 105.02, 105.03, and 105.04 herein for details and safety precautions for the use of nuclear equipment.

(3) Control of Water - Control of water is most important in obtaining proper compaction of soils and granular materials. Too little water will require more compactive effort to obtain the desired density. If there is too much water, the maximum density cannot be reached regardless of how much the soil is rolled. The Inspector should perform frequent water content tests, in order to be sure that the soil has correct water content.

Materials having a water content above optimum by more than 30 percent of optimum shall not be placed on a previously placed layer for drying, unless it is shown that the previously placed layers will not become saturated by downward migration of water into the material. If water content is not within the specified tolerances, then the lift will have to be aerated or water added, as the case may be. All water content tests taken are to be recorded and become a permanent part of the record of the project.

It is suggested that the "Speedy" Moisture Tester be used for expediency in conducting these tests, except when the soils are heavy clays, in which case the field stove method shall be used.

The above instructions apply primarily when conducting field density tests by one of the methods other than the nuclear moisture-density method. When using the nuclear moisture-density method, water content shall be determined as outlined in Paragraph (c)(1) below.

(c) Methods of Field Density Determination

(1) Nuclear Moisture-Density Method

The nuclear moisture-density method of field density determination, when specified, shall be conducted in accordance with VTM-10 and Secs. 303 and 304 of the VDOT Road and Bridge Specifications. The entire scope of nuclear testing is also outlined in detail in AASHTO T-310.

Nuclear moisture-density tests of embankments, subgrade, cement or lime stabilized subgrade, and backfill for pipes and culverts and other structures as delineated in (d)(5) through (d)(9) below shall be conducted using the Direct Transmission Method of testing. The density obtained shall be compared with the theoretical maximum density, obtained either by the Laboratory method (VTM-1) or the One-Point Proctor method (VTM-12) to determine the percentage compaction.

Nuclear moisture-density tests of aggregate base, subbase, and select materials, both untreated and treated with cement or lime, for pavement as well as shoulder material, shall be conducted using the Backscatter, Control Strip Method of testing. The nuclear density obtained in the test sections shall be compared with that of the corresponding control strip. Alternatively, the District Materials Engineer may waive the Control Strip Method in favor of the Direct Transmission Method of testing, and compare the density obtained with the theoretical maximum density from either the Laboratory method (VTM-1) or One-Point Proctor method (VTM-12).

Water content tests of soils shall be made directly using the nuclear device, rather than as outlined in Paragraph (b)(3) above.

If there is a breakdown in the nuclear testing equipment, then the Inspector shall continue checking density using other conventional methods.

Nuclear equipment necessary for performing nuclear moisture-density tests, when specified, is available through the VDOT Central Office Soils Laboratory. This equipment is however only required to be provided to non-VDOT personnel or firms when contracts with VDOT require it (e.g., District or Statewide or Regional Construction Engineering and Inspection (CEI) contracts or Statewide or Regional Laboratory Testing and Technician Services contracts). The District Materials Section is available to provide instruction and assistance to the Project Inspectors who operate nuclear gauges for measurement of density and moisture of soils, aggregates, and other paving materials. Instructions for the operation, administration, and safety in the use of this equipment are detailed in Secs. 105.02, 105.03, and 105.04.

(2) Sand-Cone Method

When specified, field density tests by the Sand-Cone Method shall be conducted in accordance with AASHTO T191. Next to the nuclear method, this is probably the most widely used method of determining field density. Briefly, it involves finding the weight of a sample and measuring the volume occupied by the sample prior to removal. This volume shall be measured by filling the space with a material of predetermined weight per unit volume, in this case sand. The percentage compaction shall be determined by comparing the field density obtained with the maximum theoretical density from either the Laboratory method (VTM-1) or the One-Point Proctor method (VTM-12).

(3) Other Methods

Other approved methods may be adopted for use in determining field density at the discretion of the District Materials Engineer. These other methods may for example include use of Intelligent Compaction, non-nuclear gauges, Light Weight Deflectometers (LWD), or Dynamic Cone Penetrometers (DCP).

(d) Frequency of Field Density Tests

The frequency of field density tests shall be as outlined herein. Again, it should be emphasized that the rates given for testing are the minimums considered desirable to provide effective control of material under ideal conditions, and more testing than that specified shall be done if deemed necessary by the Engineer.

(1) Embankments and Finished Subgrades

The minimum number of field density tests required shall be one for each 2500 yd^3 or less of fill material placed, with the following additional requirements:

(a) For fill areas less than 500 ft. in length, a minimum of one (1) field density test for every other 6-in. compacted layer from the bottom to the top of fill starting with the second lift.
(b) For fills 500 to 2000 ft. in length, a minimum of two (2) field density tests for each 6-in. compacted layer within the top five (5) ft. of fill.
(c) For fills greater than 2000 ft. in length, break into equal sections not to exceed 2000 ft. and test each section in accordance with (b) above.

The terms "embankment" and "fill" as used here are intended to encompass the entire roadway in width, under construction between right-of-way lines, regardless of whether the roadway is single or dual lane. For example, a dual lane fill shall be considered as a single fill. However, each separate linear embankment or fill shall be considered as a separate item and tested at the above specified rate, separately and independently of adjoining fills. Locations of tests shall be staggered, so that the entire length, width, and depth of the fill are covered by tests, inclusive of slopes. When testing is not being conducted, the Inspector shall visually observe lifts being placed to ensure that proper placement and compaction procedures are being followed.

The amount of rock present in the embankment that will preclude conducting the density test shall remain flexible, and shall be at the discretion of the Project Inspector. However, it should be understood that if it is possible to conduct a test, then the test should be performed. If a test cannot be performed, location documentation of the rock layer shall be submitted in lieu of the test data on the appropriate density report.

In the finished subgrade in both cut and fill sections, a minimum of one (1) test shall be performed for each 2000 linear ft. of subgrade for each roadway (full width).

(2) Cement or Lime Stabilized Subgrade

When the subgrade, consisting of material-in-place or imported material other than aggregate base, subbase, or select material, is stabilized with cement or lime, one density test shall be conducted for each one-half (1/2) mile of stabilization per paver (mixer) application width. In other words, each separately applied width of stabilization, regardless of roadway width, shall require a separate series of tests.

The tests shall be started from 25 to 100 ft. from the beginning or end of the project, with the remaining tests being spaced at variable intervals not exceeding the linear spacing noted above. The tests shall be located in the approximate center of the applied width, but occasionally shall be staggered across the applied width at random locations to check density, particularly near the edges of the stabilization. Care shall be taken not to perform a uniform pattern of tests.

(3) Aggregate Base, Subbase, and Select Material

Density tests of aggregate base, subbase, and select material, whether treated with cement or lime or untreated, shall be performed the same as outlined in Paragraph (d)(2), except that the tests shall be performed on each compacted layer of the pavement course, if the course is applied in more than one (1) layer. Also, when using the nuclear method, each recorded test specified above shall consist of the average of five (5) readings, the location of which shall be at randomly selected sites.

When using the nuclear method, a roller pattern and control strip (or maximum theoretical density, see Paragraph (c)(1) above) shall be performed for each layer or lift placed, in order to establish the maximum density required before testing of the test section.

(4) Aggregate Shoulder Material

Density tests of aggregate shoulder material shall be performed as outlined in Paragraph (d)(3) above, except that the tests shall be performed on alternating sides of the road each one-half (1/2) mile.

(5) Backfill for Pipes and Box Culverts

A minimum of one (1) test shall be performed per lift on alternating sides of the structure for each 300 linear ft. or portion thereof in structure length. This test pattern shall begin after the first 4-in. compacted layer above the structure's bedding and shall continue to one (1) foot above the top of the structure.

(6) Backfill for Abutments, Gravity and Cantilever Retaining Walls

A minimum of two (2) tests every other lift up to 100 linear ft. shall be performed. Testing shall be performed behind these structures at a distance from the heel no farther than a length equal to the height of the structure plus 10 ft.

(7) Mechanically Stabilized Earth (MSE) Walls

Less than 100 linear ft. a minimum of one (1) test every other lift shall be performed. The testing shall be performed a minimum distance of 8 ft. away from the face of the wall, to within three feet of the back edge of the zone of the reinforced fill area. Test sites shall be staggered throughout the length of the wall to obtain uniform coverage. Testing shall begin after the first two (2) lifts of reinforced fill have been placed and compacted.

Walls more than 100 linear ft., a minimum of two (2) tests every other lift not to exceed 200 linear ft. shall be performed.

(8) Backfill for Drop Inlets

A minimum of one (1) test every other lift around the perimeter of the structure shall be performed. The test pattern shall begin after the first 4-in. compacted layer above the bedding and shall continue to the top of the structure. Tests shall be staggered to assure consistent compactive effort has been achieved throughout.

(9) Backfill for Manholes

Manholes shall have a minimum of one (1) test performed around the perimeter of the structure every fourth compacted layer until the top five (5) feet of the structure; in the top five (5) feet one (1) test every other lift around the perimeter of the structure shall be performed. The test pattern shall begin after the first 4-in. compacted layer above the bedding and shall continue to the top of the structure.

(e) District Materials Oversight

For Items (1) through (9) above, the District Materials Section shall conduct a continuous program of instruction for project personnel in performing density tests and shall inspect all density testing equipment used by Project Inspectors, to ascertain that it is kept clean and properly calibrated.

A Materials Representative shall also inspect density test reports prepared by the Inspectors to determine if sufficient tests and proper coverage have been made, that reports are properly prepared and completed and that all pertinent information has been included on the test reports.

(f) Corrections for Areas Outside of Tolerance

If any areas are found to be outside of specification tolerances for density, the corrections shall be made in accordance with the particular VDOT Road and Bridge Specification relating to the material in question. (Sections 303.04, 304, 305.03, 306.03, 307.05, 308.03, and 309.05, VDOT Road and Bridge Specifications.)

(g) Reports

Results of acceptance density tests in the field shall be reported on Forms TL-53, TL-54, TL-55, and TL-124 (for the nuclear methods), Form TL-125 (for the sand-cone method), and Form TL-125A (for the One-Point Proctor Method of determining theoretical maximum density). All test reports shall be completely filled out, giving all required information. All tests, both passing and failing, shall be reported. The failing test report shall indicate what corrective action was taken. When tests are not run due to gravel, muck, rock, or any other reason, a report shall be submitted giving reasons for the tests not being conducted, and such information as the length (station to station) of roadway not tested, as well as depth or elevation in the fill not tested. Independent Assurance density tests shall be so marked on the form in bold letters (INDEPENDENT ASSURANCE DENSITY TEST), and the results of IA density tests shall also be tabulated on Form TL-136, in addition to the forms noted above.

See Chapter VIII for details of completing and distributing these forms.

Section 309.02 Depth Control

(a) General

(Reference Secs. 305.03(a), 306.03(g), 307.05(e) 308.04, and 309.05, VDOT Road and Bridge Specifications.) Job acceptance depth tests shall be made by the Inspector or other project personnel.

Measurements shall be taken at random for each course after completion of the course depth as the work progresses. This shall not be construed as requiring that the entire project be completed before conducting depth tests. Depth tests shall be made as sections of the project are completed. The volume of material measured on the basis of cubic yards compacted in place shall be computed from the length and width shown on the plans and the average depth of the material on the entire project, determined from measurements taken at the below noted intervals, measured longitudinally along the surface.

(b) Frequency of Depth Tests

For the purpose of determining depth, and to define areas of deficient or excessive depth, job acceptance depth tests shall be made, as outlined in VTM-38. Materials to be tested by VTM-38A include cement or lime stabilized subgrade, consisting of material-in-place or imported material other than aggregate base, subbase, or select material. Materials to be tested by VTM-38B include (1) treated or untreated aggregate base, subbase, and select material, and (2) aggregate shoulder material.

For Method VTM-38A, one (1) depth test shall be conducted for each one-half (1/2) mile of stabilization per paver (mixer) application width. In other words, each separately applied width of stabilization, regardless of roadway width, shall require a series of tests.

The tests shall be started from 25 to 100 ft. from the beginning or end of the project, with the remaining tests being spaced at variable intervals not exceeding the linear spacing noted above. The tests shall be located in the approximate center of the applied width, but occasionally shall be staggered across the applied width at random locations to check depth, particularly near the edges of the stabilization. Care shall be taken not to set up a uniform pattern of tests.

The depth recorded at each location shall be considered the depth for the applied width of material and extending one-fourth (1/4) mile longitudinally in each direction from the test location. If the tests are made at closer intervals than specified, the test data shall apply to a point extending half-way between the test point and the next test point on either side.

In cases in which the depth determined is deficient or excessive beyond the allowable specification tolerances, additional depth tests, as outlined in VTM-38A, shall be performed to bracket this area.

For method VTM-38B, the project shall be divided into lots, with each lot stratified, and the location of each test within the stratified section determined randomly. A lot of material is defined as the quantity being tested for acceptance, except the maximum lot size shall be two (2) miles for each paver application width. The randomization procedure used shall be at the direction of the Engineer. (See VTM-38 for example.) Samples shall be taken from the lot at the following rate:

Lot Size	No. of Samples Required
0 - 1 Mile	2
1 - 1 1/2 Miles	3
1 1/2 - 2 Miles	4

In the case of aggregate shoulder material, use the same linear frequency of testing as used on the mainline, except alternate the tests from one side of the road to the other.

Tests shall be performed in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc. at the discretion of the Engineer. These samples shall not be taken at random; however, care shall be taken not to set up a uniform pattern. The tolerance for an individual test result shall apply.

It is not the intent of this procedure to prohibit the sampling and testing of the material at any location which is visually determined to be out of specification tolerance for an individual test.

In some cases, select material or similar material may be used in certain undercut sections, etc., in depths exceeding that shown on the plans as the uniform design depth of the pavement structure for the entire project. In these cases, the Inspector shall be responsible for checking only that uniform depth shown for the entire project (usually 12 in. or less). It shall be the responsibility of the Inspector to ensure that the depths of materials used for backfill, etc. in certain isolated sections are maintained.

(c) Corrections for Areas Outside of Tolerance

If any areas are found to be outside of specification tolerances for depth, the corrections shall be made in accordance with the particular section of the VDOT Road and Bridge Specifications relating to the material in question (Sections 305.03(a), 306.03(g), 307.05(e), 308.04, and 309.05, VDOT Road and Bridge Specifications).

(d) Reports

Results of job acceptance depth tests of the above noted materials shall be retained as part of the permanent project records. The data may be kept in the form of a worksheet. Those depth tests that fail to meet specification requirements and subsequent delineation and/or correction determinations shall be recorded on Form TL-105. Results of Independent Assurance depth tests shall be tabulated on Form TL-136. See Chapter VIII for details of completing and distributing these forms.

Section 309.03 Sampling, Testing, and Analysis of Resilient Modulus for Subgrade, Subbase, and Base

VDOT is in the process of revising its pavement design procedures to incorporate a Mechanistic-Empirical (ME) rationale. VDOT's goal is to have an ME procedure in place by the end of year 2013. Part of this revision will be to incorporate the use of resilient modulus testing for subgrade and aggregate strength properties.

VDOT is currently working toward this goal by collecting subgrade samples from around the state and performing resilient modulus tests on them and attempting to correlate the results with other more conventional test results such as those from unconfined compression tests. VDOT has completed some resilient modulus testing on aggregate. The catalog of resilient modulus test results for Virginia soils will be developed for soils from all districts. As of the summer of 2011, VDOT had completed approximately 400 resilient modulus tests (for 190 soils), and is attempting to complete another 200 by the end of 2012. VDOT also plans to analyze moisture effects on resilient modulus. VDOT is also working with FHWA and other states on resilient modulus test reliability analyses.

Section 309.04 Subgrade Chemical Stabilization

In order to improve the subgrade upon which a pavement structure will be built, chemical stabilization may be utilized. The two most common chemicals used for subgrade stabilization are lime and cement. This section provides guidance and requirements for chemical stabilization of subgrade.

Subgrade is defined at VDOT as "the top surface of an embankment or cut section, shaped to conform to the typical section upon which the pavement structure and shoulders will be constructed" (from Chapter 3 of the VDOT Soils and Aggregate Compaction Certification Study Guide). It is typically considered to be the top 6 inches of finished, compacted soil; however, chemical stabilization is typically performed on the upper 12 inches of soil.

Fine-grained soils consisting primarily of silt and clay size particles often have relatively low resilient modulus values (2,000 psi to 10,000 psi, traditionally corresponding to CBR values of approximately 1 to 7). In such cases chemical stabilization of the subgrade may be considered as an economical way to reduce the required thickness of the overlying pavement structure.

Typically cement is more effective and economical for stabilizing soil with a Plasticity Index (PI) of 16 or less. Lime is more effective and economical for stabilizing soil with a PI of 20 or greater. For soil with a PI between these ranges either cement or lime can be used.

Silt and clay soils also often have relatively high natural water contents. Lime (or lime kiln dust) in particular is often used to dry such soils. Lime treatment of soil can be classified into three tiers of treatment. Drying is the addition of the least amount of lime (typically up to 3% by dry weight of soil). Drying is used to reduce the water content of the soil in order to provide a stable working platform. Lime kiln dust as well as lime may be used for drying, but lime kiln dust should not be used for modification or stabilization. Modification is the addition of a greater amount of lime (typically 3% to 5% by dry weight of soil) in order to both provide a working platform and give the soil greater strength, at least temporarily, to provide for trafficking of construction equipment. Finally, stabilization is the term used when the greatest amount of lime is used (typically 5% to 8% by dry weight of soil), which not only provides the former benefits, but also provides a long-term strength and durability gain that can be utilized in the design of the pavement structure. When cement is used for stabilization of soil, it is typically added in the range of 5% to 9% by dry weight of soil. The stabilized subgrade can be counted as a layer of the pavement structure and given a layer coefficient (for flexible pavement design). See Sec. 604.02 for layer coefficient values.

Laboratory testing, by VTM-11 for lime stabilization or VTM-72 for cement stabilization shall be performed to determine if subgrade soil is suitable for chemical stabilization. (Except that in using VTM-72 two (2) specimens shall be made and cured for each quantity of cement tested, and the cure time shall be only seven (7) days and the specimens will only be tested for compressive strength.) The quantity of lime required for stabilization shall be that quantity that yields a minimum unconfined compressive strength (UC) strength of 100 psi as the average of two (2) specimens made with the same lime content. In no case shall the quantity of lime used be less than 5% by dry weight of soil, and lime stabilization shall not be used if a UC strength of 100 psi cannot be obtained with 8% or less lime by dry weight of soil. The quantity of cement required for stabilization shall be that quantity that yields a minimum UC strength of 250 psi as the average of two (2) specimens made with the same cement content, found by testing specimens at varying cement contents, typically 5%, 7%, and 9% by dry weight of soil. In no case shall the quantity of cement used be less than 5% by dry weight of soil, and cement stabilization shall not be used if a UC strength of 250 psi cannot be obtained with 9% or less cement by dry weight of soil. The reason for the difference in required strength between lime and cement (100 psi vs. 250 psi) is based primarily on the differences in time to cure and rates of strength increase and durability requirements.

Chemical stabilization may be designed into a project from conception, or it may be considered later as more soil exploration data becomes available or other project considerations change. This section is intended for basic guidance; however, the Materials Section and project staff of the district in which the project is located shall be consulted when chemical stabilization of subgrade is considered.

SECTION 310 PROJECT SAMPLING OF STABILIZED OPEN-GRADED BASE MATERIAL FOR ACCEPTANCE

Section 310.01 General

Job acceptance permeability tests of stabilized open-graded base material shall be performed in accordance with VTM-84. Sampling shall occur after asphalt stabilized material has been in place overnight and after cement stabilized material has cured sufficiently to permit coring.

Section 310.02 Frequency of Test Samples

Initial sampling for permeability tests shall be at the rate of three (3) 6-in. diameter cores taken at approximately even intervals over the first one (1) mile of stabilized open-graded base material placed in one (1) pass of the paver. Samples shall not be taken within two (2) ft. of the edge of the layer or directly over any underdrain or trench in the subbase or subgrade.

Additional permeability sampling and testing may be waived by the District Materials Engineer if initial tests are passing and no changes occur in the mix design, compactive effort, or visual appearance of the material. Further testing may be necessary if changes occur in the gradation of the material or asphalt or cement content.

If a change occurs, sampling shall be at the same rate as initial sampling.

If localized areas of the stabilized open-graded base material are suspect, a minimum of two (2) 6-in. diameter cores shall be taken from the area for permeability testing and the average coefficient of permeability shall be used for acceptance or rejection.

For investigative purposes, a minimum of one (1) sample shall be required.

Filling of holes shall be with a stabilized or unstabilized open-graded material placed in a single layer and tamped until no further consolidation occurs within the hole. The finished material shall be leveled to the grade of the surrounding material and all remaining loose material shall be removed. Unstabilized material used to fill the holes shall be Aggregate No. 57, 68, 78, or 8. Stabilized material, if used, shall be of any cement or asphalt cement concrete material approved for VDOT use.

Section 310.03 Reports

Results of job acceptance permeability tests shall be reported on Form TL-51.

All test reports shall be completely filled out, including all required information. All tests, both passing and failing, shall be reported.

See Chapter VIII for details of completing and distributing these forms.

SECTION 311 SUMMARY OF MINIMUM ACCEPTANCE AND INDEPENDENT ASSURANCE SAMPLING AND TESTING REQUIREMENTS

Following is a condensed tabulation showing the minimum requirements for acceptance testing of soils and central mix aggregate. See also Secs. 205 and 206 for additional details governing minimum acceptance sampling and Independent Assurance sampling.

On projects in which the owner (VDOT or local agency) is not the entity performing the acceptance tests for field density and depth, both third party and owner IA and VST tests are required. Types of projects on which this occurs are for example Design-Build (DB) projects or Public-Private Transportation Act (PPTA) projects. For frequency of third party and owner IA and VST tests, Table 105.4 of the manual "VDOT's Minimum Requirements for Quality Assurance & Quality Control on Design Build & Public-Private Transportation Act Projects" shall be followed. For comparison tolerances between acceptance and IA tests, Table 105-2 of the same manual shall be followed. This document can be found online at:

http://www.virginiadot.org/business/resources/PPTA/ApprovedQA-QCGuide4DBP-rev1.pdf

(Table 105.4 is "Department's Minimum Requirements for Design-Builder's QA/QC Plans on Design-Build Projects - Minimum Requirements for Quality Assurance and Quality Control on Design-Build Projects". Table 105-2 details comparison tolerances for testing which will trigger the referee and disputes processes.)

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
1. Embankments				
(a) Density, Any Method	303.04(h)	One (1) test per 2500 yd^3 or less plus: (a) for fills less than 500 ft. length one (1) test on every other 6-in. layer bottom to top of fill starting with the second lift; (b) for fills from 500-2000 ft. length, two (2) tests per 6-in. layer within top five (5) ft. of fill; (c) for fills greater than 2000 ft length, break into equal segments not to exceed 2000 ft. and use same frequency for each section as for fills 500 to 2000 ft. in length.	Roadway	When tests are not run due to gravel, muck, rock, etc. give sta. and depth on report in lieu of test, with reason. For nuclear test, use Direct Transmission Method, VTM-10. See Notes 1 and 2.
2. Finished Sub-grade (Both Cut and Fill Sections)				
(a) Density, Any Method	305.03	One (1) test per 2000 linear. ft.	Roadway (24 ft.)	For nuclear test, use Direct Transmission Method, VTM-10. See Notes 1 and 2.

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
3. Stabilized Subgrade (Mat'l.-in-Place or Imported Mat'l., Other Than Agg. Base, Subbase, or Select Mat'l.)				
(a) Density, Any Method	306.03(f) & 307.05(e)	One (1) test per 1/2 mile per paver (mixer) application width.	Roadway	For nuclear test, use Direct Transmission Method, VTM-10. Tests to be located in approximate center of applied width. Care shall be taken not to set up uniform pattern of tests. See Notes 1 and 2.
(b) Depth	306.03(g) & 307.05(e)	One (1) test per 1/2 mile per paver (mixer) application width.	Roadway	Tests to be conducted by VTM-38A. Tests to be located in approximate center of the applied width. Care shall be taken not to set up uniform pattern of tests. Deficient or excessive areas of depth shall be as defined in VTM-38A. See Notes 1 and 3 for reports. Tests in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at discretion of Engineer.

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
4(a). Central Mix Aggregate (Treated or Un-treated) Base, Subbase, and Select Material				
(1) CBR (On Select Material Only)	207.02(c)	One (1) 75 to 100 lb sample per project, or more often as needed for control, on processed or local material, to VDOT or AMRL-accredited consultant laboratory.	From processing or mixing plant or roadway	If material is treated with additive, sample shall be taken without additive included. See Note 4 for reports.
(2) Gradation and Atterberg Limits	207 & 208	Producer: Four (4) 30 to 40 lb samples per lot (either 2000 ton lot or 4000 ton lot). Samples taken in stratified random manner.	From processing or mixing plant.	Same as Item 4(a)(1). Samples to be taken and tested by Producer's Certified Central Mix Aggregate Technician who shall keep records of tests on Form TL-52A and maintain quality control charts. Test results shall be reported by VDOT on the CMA Point Adjustment Analysis Report (E12-1710-01).

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
4(a)2 Cont'd		IA sampling duplicates at least one (1) of the four (4) samples from 4(a)(2) above.	From processing or mixing plant at time of shipment. Sampling from roadway normally shall not be required, unless material has not received acceptance testing at source, or unless material being placed on road indicates contamination or segregation, regardless of prior acceptance testing.	Same as Item 4(a)(1). Sample taken by Producer's Certified Central Mix Aggregate Technician in presence of Materials Representative, and tested in VDOT or AMRL-accredited consultant laboratory, and reported on Forms TL-32 and TL-52C. District Materials Representative will make weekly comparisons of production control test results vs. IA test results. See Secs. 308.05(b) and (c) for additional details. Select material not centrally mixed and aggregates paid for on a volume basis shall be sampled as directed by the District Materials Engineer.

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
(3) Density, Any Method	305.03, 308.03, & 309.05,	One (1) test per 1/2 mile per paver (mixer) application width per layer. If testing by nuclear method, each test shall consist of average of five (5) readings.	Roadway. Location of five (5) nuclear readings at randomly selected sites.	For nuclear tests, use Backscatter, Control Strip Method, VTM-10. With nuclear method, set up roller pattern and control strip for each layer or lift placed. See Notes 1 and 2.
(4) Depth	308.04 & 309.05	Two (2) tests each paver (mixer) application width from 0 to 1 mile , three (3) tests each width from 1 to 1 1/2 miles, and four (4) tests each width from 1 1/2 to 2 miles. Maximum lot size is 2 miles for each paver application width. Project divided into lots, each lot stratified, and location of each test within stratified section determined randomly.	Roadway.	Tests shall be conducted by VTM-38B. Tests in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at the discretion of the Engineer, and shall not be taken at random. However, care shall be taken not to set up uniform patterns of tests. For these miscellaneous items, the tolerance for an individual test result shall apply. See Note 3 for reports
(b) Shoulder Material- (1) CBR (On Select Material Only)	207.02.	Item 4(a)(1) governs.	Same as Item 4(a)(1).	Same as Item 4(a)(1).

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	**RATE OF SAMPLING**	LOCATION OF SAMPLING	REMARKS
(2) Gradation and Atterberg Limits	207 & 208	Item 4(a)(2) governs.	Same as Item 4(a)(2).	Same as Item 4 (a)(2).
(3) Density, Any Method	305.03(a)	Same as Item 4(a)(3), alternating sides.	Same as Item 4(a)(3).	Same as Item 4(a)(3).
(4) Depth	305.03(a)	Same as Item 4(a)(4), alternating sides.	Same as Item 4(a)(4).	Same as Item 4(a)(4).
5. Backfill for Pipes and Box Culverts	302.03, 303.04(g), 401.03(i)	Minimum one (1) test per lift on alternating sides of structure for each 300 linear ft. or portion thereof in structure length, starting after first 4-in. layer above bedding and continue to one (1) ft. above the top of the structure.	Alternating sides of structure	For nuclear test, use Direct Transmission Methods, VTM-10. See Notes 1 and 2 for reports.
6. Backfill for Abutments, Gravity and Cantilever Retaining Walls	303.04(g), 401.03(i)	Minimum of two (2) tests every other lift up to 100 linear ft.	Behind heel a distance of H + 10 ft.	For nuclear test, use Direct Transmission Methods, VTM-10. See Notes 1 and 2 for reports.
7. Mechanically Stabilized Earth Walls (MSE)	303.04(g), 401.03(i)	Walls less than 100 linear ft. shall have a minimum of one (1) test every other lift. Walls more than 100 linear ft. shall have a minimum of two (2) tests every other lift not to exceed 200 linear ft.	Zone of reinforced fill for MSE wall	For nuclear test, use Direct Transmission Methods, VTM-10. See Notes 1 and 2 for reports.
8. Backfill for Drop Inlets	302.03, 303.04(g)	Minimum one (1) test every other lift around the perimeter of each structure, after first 4-in. layer above bedding and continue to top of structure.	Perimeter of structure	To include drop inlets, junction boxes, etc. For nuclear test, use Direct Transmission Methods, VTM-10. See Notes 1 and 2 for reports.

9. Backfill for Manholes	302.03, 303.04(g)	Minimum one (1) test (around the perimeter of the structure) every fourth compacted layer until the top five (5) feet of the structure, after 4-in. layer above bedding and continue to the top five (5) feet. Top five (5) feet shall have one (1) test every other lift around the structure to the top of structure.	Perimeter of structure	For nuclear test, use Direct Transmission Methods, VTM-10. See Notes 1 and 2 for reports.

Note 1. Density tests are reported on Forms TL-53, TL-54, TL-55, TL-124, Form TL-125 (Sand-Cone Method), and Form TL-125A (One- Point Proctor Method).

Note 2. If there is a breakdown in the nuclear testing equipment, then the Inspector shall continue checking density using other approved methods.

Note 3. Depth tests are reported on Form TL-105.

Note 4. CBR tests are reported on Form TL-32; gradation and Atterberg Limits tests on Form TL-52 for CMA. Other routine soils test, including gradation and Atterberg Limits tests performed as part of soil investigation in a VDOT Laboratory, are reported on Form TL-32, Form TL-34 (Unconfined Compression Test), Form TL-35 (Soil-Cement Mixture), Form TL-36 (Soil Consolidation Test), and Form TL-37 (Soil Triaxial Test).

Central Mix Aggregate (CMA) Pugmill Plant Inspection Report

Date: ______________________________ Producer ______________________________

Location ______________________________ District ______________________________

Plant Number ______________________________

<u>Part I</u>. Condition of Equipment

1. Sample Splitter______________________________
2. Motorized Screen Shaker with a set of large screens: 3”, 2 1/2”, 2”, 1 1/2”, 1”, 3/4”, 3/8”, #4, #10 ________
____
3. Soil Grinder, pot and rubber maul (if applicable) ______________________________
____
4. Sink with running water______________________________
____
5. Liquid Limit Device and grooving tool ______________________________
____
6. Balance for fine aggregate analysis ______________________________
______________________________Date of Calibration ______________________________
7. General Purpose balance for coarse aggregate analysis______________________________
______________________________Date of Calibration ______________________________
8. Motorized sieve shaker or attachment for motorized shaker ______________________________
____
9. All 8” round sieves: No. 20, No. 40, No. 60, No. 80, No. 100, No. 200______________________________
____
10. Specify the type of drying apparatus that is being used______________________________
____
11. All other equipment, such as: moisture cans, square end shovel, counter brush, bread pan, etc. ______________________________
____
____
____

Part II. Sample Preparation and Procedures:

1. Is the sample preparation in accordance with VTM-25? ______

2. Are all materials tested in accordance with the current AASHTO and/or VTM methods? ______
3. Is the size O.K.? ______
4. Is the portion of the sample finer than the No. 10 sieve being washed? ______

5. If the Liquid Limits and Plastic Limits are being run, is the sample being prepared and tested per VTM-7? ______

6. Does the Technician have a record of test results? ______

7. Are numbers drawn statistically just prior to beginning of production of a lot? ______

8. How are the numbers generated to represent the ton to be sampled? ______

9. Is the sample being taken according to instructions? ______
10. Is a permanent record of water contents being kept? ______
11. Does the Plant Technician have current written instructions for sampling and testing material at Pugmills? ______

12. Are control charts accurate and current? ______

Technician Signature ______

Certification Number ______

Part III Inspection of Pugmill:

1. Type of Plants ______
2. Type of Feeder, if cement is being added ______

3. On cement treated aggregate, is the titration test being conducted properly? ______

4. Stratified random samples are taken from ______

<u>Part IV</u> Materials Representative Responsibility **Yes** **No**

1. Is plant inspected before production begins? ____ ____
2. Is optimum water content furnished ____ ____
3. Are there unannounced periodic inspections and a record of same? ____ ____
4. Is a diary kept of plant visits? ____ ____
5. Is manner of sampling observed? ____ ____
6. Is manner of splitting observed? ____ ____
7. Has Producer Technician been furnished copy of comparison production and IA test results? ____ ____
8. Are corrective measures taken when there are differences? ____ ____
9. What action was taken to resolve differences? ______________________________

____

____

____

CMA Technician______________________________

This report has been reviewed and I concur with the findings of this inspection. Follow-up action to correct deficiencies (if any) will be taken.

____

District Materials Engineer

Cy: State Materials Engineer