Geotechnical Investigation and Recommendations Manual

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL ENGINEERING UNIT

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0.2 Introduction

Geotechnical investigations for roadway and structure projects for the North Carolina Department of Transportation shall be performed in accordance with current practices, policies and procedures of the Division of Technical Services, Geotechnical Engineering Unit.

This manual is intended for use by all persons, private or public, performing geotechnical investigations for the NCDOT.

0.3 Purpose of the Geotechnical Investigation and Recommendations Manual

The "Geotechnical Investigation and Recommendations Manual" has been prepared by the NCDOT Geotechnical Engineering Unit to provide investigators and designers with documentation for, and a reference to, the requirements for subsurface investigations and recommendations. All final reports, plans, inventories and recommendations should be concise, accurate and reflect the purpose and scope of the investigation.

The "Geotechnical Investigation and Recommendations Manual" is intended for continual updates to remain current as changes occur.

0.4 Geotechnical Engineering Unit Mission Statement

"Provide comprehensive, cost effective, quality Geotechnical solutions to our customers and ultimately to the travelling public"

0.5 Organization of the Geotechnical Engineering Unit

The Geotechnical Engineering Unit is headquartered in Raleigh and consists of three work groups. The Contract and Statewide Services Manager oversees the Contract Administration, Support Services, GeoEnvironmental and GeoPavement sections. Eastern and Western Regional offices are located in Raleigh and Harrisburg with satellite offices in Greenville and Asheville. Each Region consists of Geotechnical Investigations, Geotechnical Design and Operations groups.

1 Planning Geotechnical Investigations

1.1 Project Review

The first planning step should be to familiarize oneself with the proposed project. Review the plans, profiles, and cross-sections to identify the prominent geotechnical aspects. For roadway projects, note significant cuts and fills paying attention to the cross-sections as well as profiles. Also consider at grade sections due to potential for poor quality soils that commonly occur near the existing ground surface. For structure investigations note the wall or bent locations, the height of the structure, and any special features or requirements.

Identify any necessary permits or special entry requirements. These will include environmental permits i.e., NW-6 written notifications (for high quality waters, primary nursery areas, trout streams, wild and scenic rivers, barrier islands, wetlands, endangered species, historic properties), CAMA permits in coastal areas, stream buffer permits, environmental moratoriums (most commonly for spawning seasons in streams), and special entry permits (such as FERC permits commonly required near power production facilities).

Potential resources in addition to the project plans include: NCDOT Project Development and Environmental Analysis (PDEA) Unit documents and reports, (Bridge Survey and Hydraulic Design Reports (BSR) from the NCDOT Hydraulics Unit, NCDOT Bridge Documents (including routine inspection reports, underwater scour inspection reports, and as-built structure plans), and Preliminary General Drawings (PGD) from the Structures Management Unit.

1.2 Existing Subsurface Data Review

Existing subsurface data may be available from the NCDOT Geotechnical Engineering Unit. There is currently no public database access. Existing data may be supplied along with the project data files, or it may be requested from the unit (typically through the Project Geological Engineer). Useful information to supply when requesting subsurface data may include: previous NCDOT "TIP" or project numbers, map coordinates of the location, aerial photo with location marked, or a physical street address.

1.3 Review of Existing Data

Numerous sources of potentially useful data exist. These include topographic maps, aerial photos, satellite imagery, geologic mapping and reports (see below), soil surveys, water resource surveys, mining and aggregate source mapping, well logs, and personal communication with individuals possessing local knowledge. A review of all available data will provide a better understanding of the geology, geomorphology, and topography of the project area. This can be useful in identifying potential problem areas to improve the overall subsurface investigation plan.

Geologic mapping: There are numerous geologic units in North Carolina with a history of engineering problems. The Triassic Basins are known for in-situ slope stability issues and settlement problems when placed in embankments. Many of the mafic pluton bodies tend to weather to highly plastic clay soils. Large deposits of under-consolidated and organic, alluvial sediments often create global stability or settlement problems in areas of proposed embankments. Numerous igneous plutons throughout the state tend to be resistant to weathering and generate large quantities of rock blasting on roadway projects. An experienced geologist or geotechnical engineer can make useful inferences based on the parent rock type or formation.

The most commonly cited map reference in North Carolina is the "Geologic Map of North Carolina", North Carolina Geological Survey, 1985. There are also numerous maps published by the USGS and NCGS covering areas of North Carolina in greater detail than the statewide map

1.4 Reconnaissance

Following the data review process, the Project Engineer, Project Geologist, and/or field Geologist should visit the site and address the following:

- potential geotechnical problem areas/ unusual conditions
- location of the proposed borings,
- plan for access to the boring locations (clearing, grading, type of drill rig needed)
- utility conflicts
- traffic control requirements

1.5 Investigation Plan Development

After completion of the previous reviews, the project team should have a general understanding of the expected soil and rock properties; the effects of topography, vegetation, structures and utilities on the proposed site exploration plans; the probable depths of borings, the type of equipment needed for access, etc.

A boring plan should be developed for use by field personnel. The plan will typically utilize a plan view of the site with the proposed borings shown. The proposed depth of the borings will also be needed in some form, although in many instances the depths will need to be adjusted based on site conditions as work progresses. The boring plan should also include the following information: project identification numbers, existing contours, existing features (structures, roads, utilities, fences, utility poles, etc.), existing Right-Of-Way and property boundaries, and all proposed alignments and structures. This information is generally available on the roadway plans. Additionally, any environmentally sensitive areas should be clearly delineated.

1.6 Project Initiation

Prior to commencing the field investigation, conduct a project initiation meeting. Attendees should include, at a minimum, the NCDOT Project Geologist and NCDOT Geotechnical Design Engineer. For out-sourced projects, include the appropriate PEF personnel. Other individuals that may benefit from or add to the discussion include the driller, CADD technician, PEF Geologist and the PEF Geotechnical Engineer. This meeting can be held on-site or in the office. For small, uncomplicated projects, this meeting may be accomplished by phone and email. The purpose of this meeting is to insure that all involved personnel are fully aware of the investigation and design plan including all required activities and final products. For outsourced projects, the meeting can be used to review the NCDOT Request for Proposal and the firm's Proposal. It should also be used to identify the appropriate people to contact when questions arise during the course of field investigations. Document the meeting including specific topics discussed, any special instructions/considerations, and the contact information.

1.7 Final Product Determination

The most common GEU products are Roadway Subsurface Inventory, Geotechnical Roadway Recommendations, Structure Subsurface Inventory (for bridges, retaining walls, sound walls and culverts), Geotechnical Structure Recommendations, Design Build Inventory and various planning or environmental reports. The Unit also provides reports regarding construction and maintenance issues, pond siltation, water wells, rock blasting, stream scour, shoring, vibration monitoring, etc.

1.8 Entry for Surveys and Property Owner Contact

It is the responsibility of the project geologist or engineer to contact the property owner prior to entering the property. In-person contact is preferred especially when property owners reside on the property being impacted. When in-person contact of the property owner cannot be made, contact by telephone or by letter is required. Property owner contact should give detailed descriptions of the work being performed on the property. All contacts with property owners regarding work for NCDOT will be noted in detail in a Property Owner Contact Report which will be stored in the relevant project file.

Entry onto private property in performance of NCDOT duties is addressed in The North Carolina General Statute: GS 136-120 "Entry for Surveys."

http://www.ncleg.net/gascripts/statutes/statutelookup.pl?statute=136

GS 136-20 (as of July 15, 2015):

§ 136-120. Entry for surveys.

The Department of Transportation without having filed a complaint and a declaration of taking as provided in this Article is authorized to enter upon any lands and structures upon lands to make surveys, borings, soundings or examinations as may be necessary in carrying out and performing its duties under this Chapter, and such entry shall not be deemed a trespass, or taking within the meaning of this Article; provided, however, that the Department of Transportation shall make reimbursement for any damage resulting to such land as a result of such activities and the owner, if necessary, shall be entitled to proceed under the provisions of G.S. 136-111 of this Chapter to recover for such damage. (1959, c. 1025, s. 2; 1973, c. 507, s. 5; 1977, c. 464, s. 7.1.)

2 - Drilling and Data Collection

The North Carolina Department of Transportation, Geotechnical Engineering Unit generally adheres to the descriptions and methods in the National Highway Institute (NHI) manual, Publication No FHWA NHI-01-031, "Manual on Subsurface Investigations", 2002. The manual can be viewed at http://isddc.dot.gov/OLPFiles/FHWA/012546.pdf

For drilling and data collection, refer to Chapters 3 through 8. Other chapters in the Manual are useful for all aspects of Subsurface Inventories on NCDOT projects.
Items specific to NCDOT practice are listed in this section.

2.1 Soil Borings

All borings must be recorded on an approved NCDOT boring log form. The following required data must be included on the field log for each boring performed by or for NCDOT.

- NCDOT WBS number
- NCDOT TIP number
- Boring number
- Total depth
- Collar elevation
- Station
- Offset
- Alignment
- Northing and Easting coordinates
- Date started
- Date completed
- Personnel
- Equipment (with DOT Equip. No. or Serial No. for PEFs)
- Drill method
- Type of boring and tests performed
- 0 and 24 hour water depth
- Material descriptions
- Stratigraphic breaks or contacts and interpretation
- Estimated soil classifications (AASHTO)
- Final soil classifications (AASHTO) if tested
- Moisture estimation
- In-situ test results
- Termination notes
- Any other soil and strata descriptors that may be Geotechnically significant

Soil descriptions must include the origin, color, moisture content, density or stiffness and material type. Additional descriptors should also be included when they are Geotechnically significant and may include items such as mica content, organic content, mottling, saprolitic texture or other components.

The boring log created in the field at the time the boring is performed will remain the "log of record" for that boring and may only be modified by the "red-lining" process. "Red-lining" is the process by which corrections are made to the original field log by striking through the incorrect data and adding the correct data nearby. The "red-lining" must not obscure or destroy the original document or data contained within it. The geologist or engineer responsible for the "red-line" log must initial and date the log in the same color or style to identify ownership of the corrections.

Final boring logs will include all of the data noted on the field log and corrected during the "red-lining" process and will be recorded and stored in the gINT borelog program.

Test results other than classification will be presented as described in each project type in this manual.

2.1.1 SPT Borings, SPT Refusal and Boring Termination

The Standard Penetration Test is the most commonly used test on NCDOT projects for soil strength estimation, disturbed sample inspection and test samples for classification.

The NCDOT requires that all drill rigs receive SPT hammer calibration within one year prior to any work being performed in order to be accepted. All SPT hammers must be automatic and must have a means by which to verify drop distance.

Weathered Rock is defined as 100 blows within 1 foot of split spoon penetration.

SPT refusal is defined as 60 blows within 0.1 foot or less of split spoon penetration.

Soil drilling techniques may advance past SPT refusal so it must be noted on the log when this stratum is reached by inference and drill behavior refusal occurs between SPT drives.

Boring termination must be described for each boring and on each log as on, or in, a given stratum at the boring depth or bottom elevation. A few examples are:

- "Boring terminated at 56.6' ***in*** silty sand" (when boring terminates in soil)
- "Boring terminated at 23.5' ***in*** weathered rock" (derived from parent rock)
- "Boring terminated at 20.5' ***on*** rock" (when a boring is terminated by SPT refusal which does not penetrate rock)
- "Boring terminated at 20.3' ***in*** rock" (when a boring is terminated in strata that would yield SPT Refusal)

2.2 Core Borings

When rock core is identified as necessary, the NCDOT requires the use of either "N" or "H" sized core for all projects unless otherwise noted.

2.2.1 Logging of Rock Core

Any boring which is advanced with rock coring equipment must have a "core boring report" completed for that interval of the boring. The core boring report must note the beginning depth

and elevation for each core run, the amount of time elapsed for each foot advanced and the recovery and rock quality designation for each run. The field geologist or engineer must take note of changes in drilling speed, resistance, cuttings or other factors in order to identify the depths and locations of changes in stratigraphy. All rock core recovered must be placed in durable core boxes and the lids labelled with NCDOT project numbers, boring identification, run number and depth intervals, REC, RQD and box number (such as Box 1 of 2). Rock core boxes must also be labelled both on the lid end and the box end with NCDOT project number, boring identification and box number.

The "field classification and remarks" section should include descriptors such as color, fracture spacing, degree of weathering, hardness, mineral assemblages, rock type, formation name and any additional notes that describe the core.

2.2.1.1 Core Recovery (REC)

Core recovery (REC) is defined as total length of all material recovered in the core barrel divided by the total length of the core run, expressed as a percentage.

2.2.1.2 Rock Quality Designation (RQD)

Rock Quality Designation (RQD) is defined as a measure of rock quality described by total length of the rock segments equal to or greater than four inches in length divided by the total length of the core run expressed as a percentage.

When a piece of core is examined, a break or discontinuity is disregarded if it can be determined to have been caused by the drilling process or by handling. These breaks are considered mechanical breaks and should be disregarded when calculating RQD. A natural break as determined by sound geologic judgement represents an in-situ discontinuity that has no cohesion across the boundary. Breaks that are determined to be mechanical or those made intentionally by the geologist should be identified by lines crossing the breaks made with permanent marker.

2.2.2 Core Boring Report

The core boring report consists of a bore log representing the stratigraphy of the entire boring and a core log which represents only the portion of the boring which was cored.

Final Core Logs are recorded on the gINT borelog program. Required data include the items listed under "2.1 Soil Borings" and additionally include the following:

- Rock type, and description (per change and strata encountered at each depth)
- Core size
- Length and the depth intervals of each run
- Time (min: sec) per foot of coring
- Run Recovery (REC)
- Run Rock Quality Designation (RQD)
- Stratum Recovery (REC)
- Stratum Rock Quality Designation (RQD)

2.2.3 Rock Mass Rating

Rock Mass Rating (RMR) is used by NCDOT to evaluate and classify rock for drilled shaft foundation design. The method and criteria are described in "AASHTO LRFD Bridge Design Specifications", 2007, pg. 10-21.

RMR consists of tested data, almost exclusively from rock cores, and observational data about a rock mass best recorded in the field by project personnel. Rock cores are tested for Unconfined Compressive Strength (UC) and entered into a spreadsheet obtained from the Project Geologist, Engineer or through the GEU. The test depths for rock cores are determined in consultation with the Project or Design Engineer and are based on the characteristics of the proposed structure. Aside from testing, most applicable data can be recorded on the field core log at the time of drilling.

2.3 In Situ Testing

2.3.1 Cone Penetration Testing (CPT)

The Cone Penetrometer Test is a quasi-static penetration test in which a cylindrical rod with a conical point is advanced through the soil at a constant rate and the resistance to penetration is measured. A series of tests performed at varying depths at one location is commonly called a sounding. Several types of penetrometers are in use, including mechanical (mantle) cone, mechanical friction-cone, electric cone, electric friction-cone, piezocone, and hand cone penetrometers. Cone penetrometers measure the resistance to penetration at the tip of the penetrometer, or the end-bearing component of resistance. Friction-cone penetrometers are equipped with a friction sleeve, which provides the added capability of measuring the side friction component of resistance. Mechanical penetrometers have telescoping tips allowing measurements to be taken incrementally, generally at intervals of 8 inches or less. Electronic penetrometers use electronic force transducers to obtain continuous measurements with depth. Piezocone penetrometers are electronic penetrometers, which are also capable of measuring pore water pressures during penetration. Hand cone penetrometers are similar to mechanical cone penetrometers, except they are usually limited to determining cone tip resistance. Hand cone penetrometers are normally used to determine the strength of soils at shallow depth, and they are very useful for evaluating the strength of soils explored by hand auger methods. For all types of penetrometers, cone dimensions of a 60-degree tip angle and a 1.55 in^2 projected end area are standard. Friction sleeve outside diameter is the same as the base of the cone.

Penetration rates should be between 0.4 to 0.8 in/sec. Tests shall be performed in accordance with ASTM D 3441 (mechanical cones) and ASTM D 5778 (electronic friction cones and piezocones). The penetrometer data is plotted showing the end-bearing resistance, the friction resistance and the friction ratio (friction resistance divided by end bearing resistance) vs. depth. Pore pressures, if measured, can also be plotted with depth. The results should also be presented in tabular form indicating the interpreted results of the raw data. The friction ratio plot can be analyzed to determine soil type. Many correlations of the cone test results to other soil parameters have been made, and design methods are available for spread footings and piles. The penetrometer can be used in sands or clays, but not in rock or other extremely dense soils. Generally, soil samples are not obtained with soundings, so penetrometer exploration should always be augmented by SPT borings or other borings with soil samples taken.

The piezocone penetrometer can also be used to measure the dissipation rate of the excessive pore water pressure. This type of test is useful for subsoils such as fibrous peat or muck that are very sensitive to sampling techniques. The cone should be equipped with a pressure transducer that is capable of measuring the induced water pressure. To perform this test, the cone will be advanced into the subsoil at a standard rate of 0.8 inch/sec. Pore water pressures will be measured immediately and at several time intervals thereafter. Use the recorded data to plot a pore pressure versus log-time graph. Pore water pressure dissipation rates or rate of settlement of soil can be determined from these graphs.

2.3.2 Vane Shear Testing (VST)

This test consists of advancing a four-bladed vane into cohesive soil to the desired depth and applying a measured torque at a constant rate until the soil fails in shear along a cylindrical surface. The torque measured at failure provides the undrained shear strength of the soil. A second test performed immediately after remolding at the same depth provides the remolded strength of the soil and thus information on soil sensitivity. Tests shall be performed in accordance with ASTM D-2573.

This method is commonly used for measuring shear strength in soft clays and organic deposits. It should not be used in stiff and hard clays. Results can be affected by the presence of gravel, shells, roots, or sand layers. Shear strength may be overestimated in highly plastic clays and a correction factor should be applied.

The following table identifies Vane Shear Test Equivalents for interpretation of Vane Shear results.

	Psf
V. SOFT	<250
SOFT	250-500
MEDIUM	500-1000
STIFF	1000-2000
V. STIFF	2000-4000
HARD	>4000

2.3.3 Dilatometer Testing (DMT)

The dilatometer is a 3.75-inch wide and 0.55-inch thick stainless steel blade with a thin (2.4-inch) diameter expandable metal membrane on one side. While the membrane is flush with the blade surface, the blade is either pushed or driven into the soil using a penetrometer or drill rig. Rods carry pneumatic and electrical lines from the membrane to the surface. At depth intervals of 8 inches, the pressurized gas expands the membrane and both the pressure required to begin membrane movement and that required to expand the membrane into the soil 0.04 inches are measured. Additionally, upon venting the pressure corresponding to the return of the membrane to its original position may be recorded. Through developed correlations, information can be deduced concerning material type, pore water pressure, in-situ horizontal and vertical stresses, void ratio or relative density, modulus, shear strength parameters, and consolidation parameters. Compared to the pressure meter, the flat dilatometer has the advantage of reduced soil disturbance during penetration.

2.4 Measuring Groundwater Levels

The groundwater level is a critical measurement required for most Geotechnical Investigations. All groundwater measurements should be rounded to the nearest 0.1 foot.

Groundwater must be measured in auger borings immediately upon completion of the boring and the water level will be noted in the 0-hour field of the boring log. When borings are advanced with the use of water or drilling mud, the 0-hour field should be noted as "N/A."

The static groundwater level is considered to be measurable 24 hours after the boring is completed and left open, but covered. The boring must be covered during the 24-hour waiting period to prevent false measurements of groundwater from rainfall and run-off and to prevent injury to people or livestock which may step into an open hole. The 24-hour groundwater measurement is considered valid for any boring regardless of drilling technique or fluid used to advance the boring.

The presence of perched groundwater should be noted whenever possible. Generally, perched groundwater is most likely to be observed during the 0-hour measurement prior to the waiting period during which the boring may fill with water to the perched elevation. Perched groundwater presents cut slope stability problems because it often occurs in sedimentary strata that may be degradable and underdrain methods are ineffective for remediation.

When artesian water levels are present, the potentiometric surface must be measured. In order to measure the artesian head in borings where the collar elevation is below the potentiometric surface, pipe or casing must be stacked to an elevation above which the groundwater flow stops. Artesian conditions may also be observed within embankments, below the existing ground surface but above natural ground. The field professional must be aware when in Geologic regimes that have the potential for artesian groundwater conditions and recognize when artesian water levels are present within the embankment.

The potentiometric water surface elevation must be noted on the boring log with an indication or footnote that the elevation is "artesian."

2.5 Abandoning Boreholes

All borings must be properly abandoned at the completion of the field investigation, typically following the 24-hour water level measurement, for safety considerations and to prevent contamination of groundwater.

During the period that the bore hole will remain open prior to measurement of the 24-hour water level, the top of the boring must be covered to prevent injury to people, livestock or animals. Borings that do not encounter groundwater may be backfilled will drill cuttings and soil.

Borings that encounter groundwater must contain a minimum bentonite layer one-foot thick at a depth above seasonal high groundwater. The bentonite "plug" should be covered with a minimum of a half foot of soil at the top of the borehole to allow for revegetation. When low permeability soils are encountered above the water table, the bentonite plug should be placed within that layer whenever possible.

Borings that encounter artesian conditions must be backfilled with grout the full depth of the boring. Prior to backfilling, the artesian head must be measured by adding pipe above the ground surface until an elevation above the potentiometric surface is reached. Once this is reached and the measurements are taken, groundwater flow through the boring is arrested and the boring can be backfilled with grout without the grout being compromised.

Grout mixes for backfilling purposes should consist of a combination Portland cement and bentonite powder and should be pumped through the drill rods or a tremie pipe to ensure that the seal is present in the entirety of the hole.

Bore holes through pavement should be backfilled and compacted sufficiently to support an asphalt or quick-setting concrete patch. The asphalt or concrete patch should closely match the thickness of the existing pavement.

2.6 Other Geotechnical Drilling

There are many methods for obtaining subsurface information. These vary greatly across the physiographic regions of North Carolina and are dependent upon the project being investigated and designed. Special subsets for GeoPavement and GeoEnvironmental projects will have their own criteria. These will typically be outlined in a Request For Proposal before a project and may be modified after consultation with Project or Design Engineers and Project Geologists, either NCDOT or Consultant. Many standard techniques are discussed in the NHI Manual, referenced at the beginning of the Section.

3 Preliminary Geotechnical Reports for Project Development

The purpose of a preliminary geotechnical report is to identify geotechnical impacts to proposed projects. This input is useful in understanding the design feasibility of proposed roadways and bridges.

3.1 Preliminary Geotechnical Report Planning

Once a request for a preliminary geotechnical report is received, collect the information needed to produce a preliminary report.

- Review the proposed design; determine if project is widening, new alignment, bridge, etc.
- Gather preliminary design files, if available, aerial or satellite photos, and maps.
- Look for nearby existing projects with borings. Note the project numbers and make copies of the data that is referenced (i.e. profiles, cross sections, logs, maps).
- For structures, gather routine inspection reports from the Bridge Document Management System.
- For roadways, are there multiple or alternative routes to investigate?
- Determine if a site visit or borings are needed.

3.2 Geotechnical Field Investigations for Project Development

A thorough review of the project design, nearby projects, and a site visit are often sufficient to develop a Preliminary Geotechnical Report for Project Development. A field reconnaissance is necessary in most cases in order to identify potential Geotechnical liabilities associated with the project. Hand auger borings, rod soundings, probing rod tests and other low-cost techniques for investigation should be used when possible to reduce cost. Standard Penetration Test or core borings should be performed only when the need to gather more detailed information is necessary for Project Development.

3.2.1 Field Reconnaissance

While in the field, note any exposed rock in the creek bed or cut slopes, existing slope condition, alluvial or soft soils, soils impacted by earthwork, Triassic soils, access to proposed borings and future investigations, etc.

3.2.2 Preliminary Structure Investigation

Prior to any field investigation, locate utilities and coordinate traffic control.

Borings may be needed for preliminary design purposes to identify depth to rock or for soil classification to aid in providing a foundation type recommendation. Limit the number of SPT borings to one per bent at most. A boring should be performed at a proposed or a best estimate interior bent location to determine the foundation type (piles or drilled shafts). These borings may also be used in future inventory reporting. Follow GEU guidelines for proper bore hole logging, sampling, and determining boring depths. Note the presence of exposed or shallow rock, soil types within the zone of scour, location on NC Geologic Map, groundwater, existing foundation, condition of existing structure, possible foundation type, preference for detour location, etc.

3.2.3 Preliminary Roadway Investigation

Prior to any field investigation, locate utilities and coordinate traffic control.

Borings may be needed for preliminary design purposes to identify potential rock excavation or for soil classification. The goal is to provide the planners with enough information to know if a design is feasible or cost effective. Locate borings within the proposed earthwork boundaries to identify potential geotechnical impacts to the project. Boring locations should be limited to critical areas, and boring spacing is increased from that used during a typical roadway investigation. These borings may also be used in future inventory reporting. Follow GEU guidelines for proper bore hole logging, sampling, and determining boring depths. Note the presence of rock in cut slopes, highly plastic soils within cut sections or under embankments, soft/alluvial soils under proposed embankment, location on NC Geologic Map, wetland impact, will earthwork impact groundwater, soils suitable for embankment construction and stability, degradable rock or Triassic soils, recommended slope, condition of existing slopes, preference for detour location, etc.

3.3 Final Geotechnical Report for Project Development

The Preliminary Geotechnical Report will be on letterhead and include the following:

Techniques/Methodologies

- Review of maps and nearby projects
- Site reconnaissance
- Subsurface investigation

Findings

- Geologic province, geologic trends, rock types, exposures.
- Soils present
- Flooding history

Groundwater

- State the measured or estimated elevation and its impact construction.
- Drainage across the project site.

Anticipated Impacts

- For structures, state the likely foundation type, i.e. drilled shafts, footing, piles.
- For roadways, include the likelihood for undercut, rock blasting, wetland impacts, subgrade and embankment stability, and recommended slope.

Attachments/Other

- Drafted bore logs with Northing and Easting information when applicable.
- Graphical profiles and cross sections may be included when it is helpful to the designers.

4 Roadway Investigation and Recommendations

4.1 Roadway Investigation Overview

The roadway subsurface investigation provides other Units within NCDOT subsurface information needed to design or upgrade the transportation system. The results of the investigation are presented in two documents: the Roadway Subsurface Inventory and the Roadway Recommendations Report. The Roadway Subsurface Inventory report lists the areas investigated and presents all of the data collected and interpretations of the data in written and graphical formats. The Inventory Report includes a text portion detailing the presence of critical items and a graphics portion showing all the borings performed and results for all samples that were tested. The Inventory Report is available in the Let package for use by Contractors and is also used within NCDOT by designers to generate the Recommendations Report. The Roadway Recommendations report lists specific design and construction recommendations required to build the project. The Recommendations Report consists of a text report and is accompanied by a graphical report when specific recommendations must be drawn by the Geotechnical Design Engineer or Geological Engineer for inclusion in the final plans. The text portion details specific recommendations for addressing Geotechnical problems that may be encountered during construction. The Recommendations Report is used internally by NCDOT for development of the contract. Roadway Subsurface Inventory reports may be sealed by either a Licensed Geologist of a Professional Engineer licensed in the State of North Carolina. Roadway Recommendations Reports must be sealed by a Licensed Geologist and/or a Professional Engineer licensed in the State of North Carolina. Inventory and Recommendations Reports are required for all roadway projects.
When Special Provisions are required to show specific recommendations that are either unique to the project or are not represented in the current "Standard Provisions," a copy of the Project Special Provision must be included at the end of the Recommendations Report .

Comprehensive drilling is required for a roadway investigation in order to accomplish sufficient geotechnical coverage. The documents should provide a clear picture of the existing field conditions within the proposed Right-of-Way Limits.

4.2 Roadway Subsurface Field Investigation

The level of subsurface investigation for Roadway projects is dependent on the scope of earthwork associated with its construction. For small roadway projects such as bridge approaches with very little earthwork, minimal investigations may be sufficient. When the presence of a Geotechnical problem requires contract quantities to resolve, such as undercut, the investigator is required to provide an investigation sufficient to quantify the problem areas and to make recommendations for resolving them.

For all roadways the investigation shall include the following work:

a) All property owners shall be contacted according to the procedure outlines in Section 1.8 – Planning Geotechnical Investigations

b) Subsurface investigations should provide sufficient observations, field tests and laboratory samples to determine the soil and rock classification and the engineering properties pertinent to the proposed design.

c) The drilling equipment required for a roadway subsurface investigation depends upon the terrain and the type of project. The equipment must be suitable for the necessary exploration sampling operation, and in good working condition. Drill rigs are required to maintain SPT hammer calibration within one year of performing work for NCDOT.

d) The spacing of the test borings depends upon the geologic complexity, the soil and rock continuity of the project area and the roadway design. Therefore, boring placement must be made to optimize the geologist's ability to interpret subsurface stratigraphy. The spacing of borings or soundings is typically at intervals of 200 feet linearly, but may be less than or greater than 200 feet depending on site conditions or project design.

e) The exploration should be supplemented by mapping Geotechnically significant features such as springs, seeps, boulders, rock outcrops, surface boundaries of distinct soil and rock units, including data concerning bedding, foliation and joints which should be recorded using dip and dip direction. All visible rock outcrops within a project footprint will be denoted on Inventory plan sheets and the applicable cross sections regardless of whether a boring is performed at the outcrop location.

f) In proposed cut sections, borings shall be advanced to a depth at least 10 feet below the lowest proposed grade elevation or to rock. Borings in proposed cut sections shall be advanced to a depth necessary to obtain sufficient data for slope design.

g) When rock is encountered or present within 6ft of proposed grade, "Rock Sounding" borings shall be made along cross-sections sufficient to establish the rock surface and to generate an estimate of rock excavation. "Rock sounding" borings should be performed in a grid pattern generally with 50 to 100-foot bore spacing. In potential cut slopes with large quantities of rock, core borings may be required to describe the rock type, quality (RQD) and recovery (REC).

h) In proposed embankment sections, borings shall be advanced to a minimum depth sufficient to evaluate subsurface conditions affecting embankment stability. A standard depth of 1.5 times the height of the proposed embankment should be used for planning with a minimum boring depth of 10-feet by drill machine and 6-feet by hand methods unless weathered, crystalline or non-crystalline rock is encountered at less than 10 feet. When unsuitable foundation conditions are encountered, the thickness of the unsuitable material shall be determined and the suitability of underlying strata for embankment support shall be substantiated by samples and/or testing.

i) All boring locations and elevations shall be referenced to existing project surveys by station and offset on plan sheets and sections. Alignment, station, offset and coordinates must be reported on all borelogs.

j) All distances and boring locations shall be measured and reported to the nearest 1 foot horizontally. All elevations and depths shall be measured and reported within 0.1 feet accuracy vertically. Elevations for borings for roadways may be obtained from the roadway design files.

k) All test borings, core drilling, field and laboratory testing shall be performed according to applicable AASHTO or ASTM Standard Methods. Standard Methods T87, T88, T89 and T90 shall be used as modified by NCDOT. The classification of soils shall follow AASHTO designation M145-82.

l) Sampling guidelines for roadways - The following is a list of guidelines for determining test and sample location:

1. Sample soils sufficiently to classify all soils on the project. Increase sampling frequency for any soil that appears to have high clay content, especially for surficial soils or soils at proposed subgrade.
2. Moisture content samples should be taken in SPT borings or hand auger borings, with one taken in fine grained soils as the moisture content changes noticeably or when conditions dictate. Moisture samples are especially important in soils that are at-grade or within three feet of grade. Moisture samples must be associated with a corresponding quality test of the same layer within the same boring.
3. California Bearing Ratio (CBR) samples should be taken in cut or at-grade sections with at least one sample for every major cut section or one sample to represent every major soil type that will likely be used at subgrade.
4. In cuts or at-grade areas, surficial clays should be sampled frequently. Samples should be collected every 5 feet in depth to be tested for quality.
5. Shelby tubes for triaxial and consolidation testing (Coastal Plain, Piedmont): One Shelby Tube per 10 feet (2 drives) of cohesive material less than 15 BPF within 20 feet of the ground surface (typically for bridge approach embankments).
   Mountains: One Shelby Tube per 10 feet (2 drives) of any wet or saturated material less than 3 BPF within 20’ of the ground surface under proposed embankments.
6. Soil should be tested for organics whenever there appears to be more than 3% by weight in the soil. Organic content tests must be associated with a corresponding quality test of the same layer in the same boring.
7. Topsoil - Include the thickness of the topsoil/root mat/or organic soil when logging all borings. The recorded thickness in the field notes can be as little as 0.3 ft. The quality and quantity of this material will be addressed in the inventory and recommendations report as needed.

m) Upon completion of the test boring and after applicable ground water measurements have been made, bore holes must be abandoned properly (See Backfilling Drill Holes Section 2.5).

n) In areas where local, domestic or industrial water supplies may be in danger by constructing the proposed roadway, a water well or spring inventory survey shall be made. The well locations need to be listed in the Inventory report and shown on the plans. The maximum investigation distance used will vary project to project, but can extend to 1000 feet from the project corridor. The NCDOT Geotechnical project manager will determine the appropriate limits of investigation.

4.3 Roadway Subsurface Inventory
4.3.1 Roadway Subsurface Inventory Text

Project Description:

Briefly describe the proposed facility as it pertains to the level of the investigation. For example, "The proposed project consists of a four-lane widening with multiple retaining walls and embankments up to 20 feet and cut sections as deep as 50 feet." Give the project length and intersections with other routes.

List each survey line investigated including the begin construction and end construction stations for each alignment.

The following terms are referenced in this section and are defined as:

Region - Physiographic Province or Geomorphic Sub-Province
Project Area - Surrounding vicinity, neighborhood, county, etc.
Project Corridor - The width of the maximum potential ROW boundaries, taking into account any possible line shifts and grade changes for the length of the project.

Physiography and Geography

Describe the topographic setting, geomorphology, and geology of the region in general and the project corridor in particular. Some general geologic background may be warranted but the focus of the text should be the geotechnical aspects of each topic. The following is a partial list of items that may need to be addressed.

a. Physiographic Province - (geomorphic sub-province) Describe the project location as being in the Piedmont, Blue Ridge, Coastal Plain, etc.

b. Topographic Setting - Describe the terrain in the project area.

c. Miscellaneous Geomorphology - Describe any significant landforms along the project corridor which may have an engineering implication such as natural slope configurations with respect to slope stability, floodplains with respect to compressible soils, Carolina Bays, sinkholes, etc.

Soil Properties

Describe the major engineering soil types and soil profiles occurring along the project corridor. Discuss each soil with respect to the following:

a. Occurrence - Describe the mode of occurrence of each soil type or soils profile including horizontal and vertical distribution, predominance of any soil type, typical topographic settings of certain soils, and the relationship between a particular soil and the soils profile as a whole. Use the AASHTO classification system. Give a general overview of the project such as "The soils generally consist of silty sands (A-2-4) overlying silty clays (A-7-5)."

b. Origin - Classify soils and discuss the mechanism of their formation, including the parent material or the transporting and depositional mediums. This would particularly apply to the

coastal plain or large alluvial valleys in the other regions of the state. It would also include the nature of colluvial deposits on Mountain projects.

c. Mineralogy - Describe the mineralogy of the soil as it pertains to engineering properties and performance. This could include highly micaceous rock, rock with high MnO content, acid producing and pyritic units.

Rock Properties

Describe general rock types. For example: "The project crosses the Rolesville Granite which generally consists of highly competent, fine-grained granite which is often exposed at the surface and weathers to sandy soils".

Describe the mineralogy of the rock as it pertains to engineering properties and performance. This could include highly micaceous rock, rock with high MnO content, degradable siltstones, acid producing or pyritic units. In Piedmont and Mountain locations, excavated rock is often processed and used for rip rap, gravel, rock embankments, etc. Rock present in the unclassified excavation should be tested for its suitability for these purposes. Highly micaceous schists tend to not be suitable for processing into gravel but may be suitable for rock embankment construction.

Groundwater Properties

Describe the occurrence and general quality of the groundwater in the soil and rock units along the project corridor. The following items should be included:

a. General depth to the ground water

b. Unusual groundwater features such as perched or artesian ground water

c. Springs and Seeps

d. Locations of wells, lakes or ponds that may be affected by the project footprint, construction activities or engineering activities such as intentional drainage of areas in or adjacent to Right of Way limits.

Areas of Special Geotechnical Interest

List and briefly describe specific areas along the project that should be highlighted for geotechnical reasons. List the areas according to the type of special interest and potential problem that was encountered. Refer the reader to the appropriate descriptive analysis section for details.

This section is intended to serve as an index of special interest areas which are described in the inventory report and which possibly will be the subject of future recommendations. It should not be used to summarize the entire project or act as a table of contents. It should not be used to make recommendations.

The following examples are intended to present the format for the topics. The details and order will depend on the project and writer.

1. The following sections were found to contain potentially (or existing) unstable slope conditions:

Station	**Offset**
16+00 to 22+00	Rt. side of existing slope

2. The following sections were found to contain rock above or within 6 feet of grade:

Station	**Offset**
4+00 to 5+00	52ft to 93ft RT

Other items that may be addressed in the same format are soft or wet soils, highly plastic clays, organic soils, loose sands, artificial fills, high ground water (6 feet below grade or higher), poor drainage or any other item that may have a geotechnical impact on the project.

Appendix A
List all the undisturbed and bulk samples tested on the project. The sample number, station, offset, sample depth, and type of test performed should all be listed.

Earthwork Balance Sheet
For any projects in Divisions 11, 12, 13, or 14 where borrow or unclassified quantities exceed 100,000 cubic yards an estimate of soil and rock quantities must be calculated. The soil and rock quantities and the supportive calculations must be posted in the NONCADD folder when the roadway report is transmitted.

4.3.2 Roadway Subsurface Inventory Graphics
The following have been provided to aid in drafting. All items and the order listed below are required when submitting roadway investigation reports.

A. The Roadway Subsurface Inventory graphics (borings, test results, plan, profile, and cross-sections, etc.) shall be plotted on standard 11x17 inch paper. Small bridge approach roadways that do not require inventory graphics the inventory text shall be plotted on standard 8.5x11 inch paper. If borings were performed for these small projects a copy of the final boring logs and any sample results must be attached to the Roadway Subsurface Inventory text report.

B. The Roadway Subsurface Inventory graphical report must contain the items listed below and in the following order:

1. Title Page, including table of contents (Sheet 1)
2. Legend (Sheet 2)

2A. Roadway Title Sheet – current when project was investigated

3. Body of Inventory text as detailed in Section 4.3.1 (Sheets numbered 3, 3-A, 3-B, etc.)
4. Plan sheets (start with Sheet 4)

5. Profiles in the same order as supplied by Roadway or Design Firm (sheet numbering after Plan sheets)
6. Cross sections (sheet numbering after profile sheets)
7. Boring logs and coring logs (if needed) (sheet numbering after cross section sheets)
8. Soil Test Results if not shown with profiles or cross sections
9. Appendix of CPT data, if collected

The Inventory report graphics must contain all graphics sheets used in the Recommendations Report without the hatching or other references to any recommendations.

The following criteria apply to the graphical portion of the Subsurface Inventory Report:

1 Roadway Plan Sheets - Plot the boring locations using the appropriate boring cell sized approximately 0.25" diameter. Label boring locations with station and offset. The plan sheets will also be used to indicate rock outcrops, alluvial boundaries, trash and landfill boundaries, and other relevant geologic or topographic features. All relevant background information (buildings, waterways, existing roads, etc.) and design features (survey lines with stationing, proposed roadways, retaining walls, etc.) should be visible on the plan sheets. All of these limits and boundaries shown should match the limits shown on the profiles and cross sections.

2 Subsurface Profile - Profile sheets should include all borings performed at or near the profile location. Borings may be projected on to the profile from any distance determined to be necessary. Offset profiles may be used as necessary for projects where many of the borings were not performed at the centerline. Profiles are optional and are often useful in areas of low topographic relief with the absence of the need for drafted recommendations. Profiles are not typically included on Mountain region projects. Borings not shown on the profiles must be shown on either a cross section or as a boring log. In addition to the borings the following items must be included on the profile sheets.

a) 24 hr. Ground Water Measurements -Measurements must be clearly shown on all borings. If the borings are dry, indicate so by writing "DRY" under the bore hole. If another term is used (i.e. NGWE, NG, etc. . . .), the term must be listed in the Soil and Rock Classification Legend and Abbreviations page. The date (month/year) the 24 hour measurement was taken must also appear on the profile or section.

b) Descriptions of Strata - Soil descriptions should follow the soil test results and the consistency/denseness chart located on the Soil and Rock Classification Legend Sheet. Soil symbols may not be substituted for the symbols currently used without prior approval from the Support Services Section of the NCDOT Geotechnical Engineering Unit. Stratigraphy may be shown at the profile location or from boring to boring like done for a fence diagram. If the stratigraphy shown on the profile is from boring to boring and not for the profile location there must be a statement stating so on the profile sheet. The parent rock type should be listed for any weathered rock or rock strata.

c) AASHTO Soil Test Results - Soil test results (including Shelby tube, CBR, and RT tests) should be shown on the page that corresponds with the boring location. Sequential order of the samples is not required on the profile sheets. The preference is for the samples to be shown in order by station location. The sample numbers should be listed above each boring. If there is not enough room on a profile sheet to list the samples, a sheet may be inserted immediately following that lists the sample results.

d) Geological Features - Rock outcrops, alluvial boundaries, muck limits, and other significant geologic features that intersect the profile line should be shown on the profile. The symbol used to define the above listed items must be shown on the Soil and Rock Classification sheet.

e) Boring Termination Information - All borings shown on the profile should include a boring termination abbreviation below the boring.

f) Offset Information - All borings shown on the profile that are offset from the centerline of an alignment must have the offset from that alignment listed above the boring.

3 Cross Sections - Cross sections should be used to plot boring locations not shown on the profile or in areas where recommendations will be shown. The criteria for showing information on cross sections is the same as in section a) through e) listed under profiles. All borings shall be listed with Station and Offset. Borings should be shown on the section closest to its drilled location or in some cases the next closest section if site conditions are a better match. Any cross section sheets included in the report should show all borings that were performed on the cross sections shown even if the boring has already been shown on the profile. Mountain projects typically do not have profiles and show subsurface information on cross sections only.

All borings performed, including 0.5-inch “bridge rod” soundings and any logged soil excavations, must be plotted on the profile or cross section sheets. If two borings are performed at the same station (with different offsets) only one may be shown on the profile, but both must to be shown in cross section. If a boring cannot be shown on a profile or a cross section, a bore log sheet for that boring must be included in the report.

Laboratory test results must be included in the report on profile or cross section sheets or presented on separate sheets at the end of the report.

4.4 Roadway Recommendations

The Final Design and Construction Recommendations report includes a text report for all projects. A graphical report is generated when recommendations must be shown on cross sections. The Final Design and Construction Recommendations text and graphical reports are used to generate contract estimates for specific pay items, to provide input for earthwork balance and to provide guidance on specific recommendations that will be added to the construction plans.

4.4.1 Roadway Recommendations Text

A separate report shall be prepared to present geotechnical recommendations for the final design of the project, right of way plans, construction cost estimates and construction procedures.

The following contract pay items are included in Roadway Recommendation reports as contingency items for projects when no specific areas for their use are encountered during the Subsurface Investigation but there is some potential that the items will be required for small areas discovered during construction. Contingency items are also added as supplemental quantities on projects where the pay items are listed in the Recommendations report in specified areas. The contingency items in these cases are to account for smaller areas that may be encountered during construction that were not observed during the investigation. The quantities listed below are suggested minimums for small roadways such as bridge approaches and for larger roadway projects. These items are not required to be included in every report but should be used to provide line items in the contract whenever there is a reasonable likelihood the pay items will be utilized in small amounts during construction.

Pay Item	**Minimum Contingency for Small projects**	**Minimum Contingency for Large projects**
Undercut for Embankment Stability	200 cubic yards	1000 cubic yards
Geotextile for Soil Stabilization	200 cubic yards	1000 cubic yards
Undercut for Subgrade Stability	200 cubic yards	1000 cubic yards
Grade-point Undercut	50 cubic yards	250 cubic yards
Shallow Undercut for Aggregate Subgrade	100 cubic yards	500 cubic yards
Subsurface Drainage – Underdrains	200 linear feet	500 linear feet
Select Granular Material	200 cubic yards	1000 cubic yards
Class IV Subgrade Stabilization	100 tons	500 tons

Recommendations must be presented as noted below:

(I) Slope/Embankment Stability
  A. Slope Design

    1. Is the slope shown on the preliminary plans appropriate for soil and rock cuts, embankments, and embankments with retaining structures? Generally, recommend the steepest slope that will be stable. If the engineer anticipates potential slope stability problems, the problems and solutions must be addressed. Give a station to station overview as needed.

2. Typical items include slope design, undercut, slope drain, wick drains, surcharges, horizontal drains, grade revisions and geotextiles.

B. List the areas with soft soils that may affect embankment stability or settlement with recommendations for that particular area as appropriate. When topsoil has greater than 4% organic content and is more than 4 inches thick it must be shown as undercut in this section. When the proposed fill heights are less than 3 feet the recommendation may need to be included in the subgrade stability section. Potential solutions include:

1. Undercut - If this method is chosen, cross hatch the exact locations on the profile and cross section drawings and compute a quantity in cubic yards.
2. Wick drains
3. Surcharge
4. Geotextile soil stabilization

When undercut is recommended, criteria for backfill and geotextile for soil stabilization is recommended in subsequent sections of the Recommendations report.

C. List pay items and quantities associated with or necessary for the construction of items listed in Section I. B.

1. Geotextile for Soil Stabilization - Compute the amount of geotextile for soil stabilization required in square yards and include an item for backfill over the fabric in Section III.
2. Sand Drains (Wicks Drains) - Recommend as needed.
3. Surcharge - Recommend as needed.
4. Ponds within construction fill limits.
5. Rock Embankments in water.

(II) Subgrade Stability

A. Subsurface Drainage – Subsurface drainage is necessary when groundwater is present within 6 feet of proposed subgrade and is typically used instead of ditches where Right of Way is limited. There are two types of subsurface drainage which can be recommended for eliminating groundwater from subgrade, as follows:

1. Subdrain pipe used for subsurface drain (Roadway Standard Drawing 815.02) that is expected to function permanently throughout the project's life. This type of subsurface drainage should he recommended when it is likely that groundwater will remain near subgrade indefinitely without additional drainage.

2. Subdrain pipe used for underdrain (Roadway Standard Drawing 815.03) that is expected to function temporarily during the project construction phase. This type of subsurface drainage is recommended for areas with high groundwater prior to construction that may affect subgrade stability during construction, but is not expected to remain high after the excavation is completed.

When evaluating areas with groundwater near subgrade:

1. Determine where subsurface drainage is needed.
2. Determine if subsurface drainage is feasible. Subsurface drains must have a minimum slope in order to drain as determined by the Hydraulics Engineer, and must reach outfall.
3. Calculate the amount in linear feet of subsurface drainage required to drain the subject area and to reach outfall.
4. Determine whether the subsurface drainage will be required to function for the life of the project or whether drainage during the construction phase is sufficient.

B. Boulevard Ditches

Boulevard ditch depths are typically 6 feet below subgrade elevation with a minimum depth of 4 feet. Boulevard ditches are preferred over subsurface drains (Roadway Standard Drawing 815.02) where permanent lowering of the groundwater is required. Make ditch recommendations as soon as practical as the Roadway Design Unit will need to add the ditches to the plans and the Hydraulics Unit will need to determine the outfall.

C. Grade Point Undercut

Grade point undercut is undercut performed where the natural ground line crosses the grade line. Compute a quantity at these locations in cubic yards/cubic meters. Use the Grade Point Undercut diagram found in Appendix A-4.

D. Undercut for Subgrade Stability

List the quantity of undercut needed in cubic yards and the areas with unsuitable soils that will affect subgrade stability. A contingency quantity is typically included as well. For specific areas of undercut cross hatch the exact locations on the profile and cross section drawings and compute a quantity. Subgrade undercut is typically recommended when high plasticity soils, organic soils, or fine grained soils wetter than optimum are present. Undercut for subgrade stability is typically recommended to a depth of 3 feet below proposed subgrade elevation.

Many factors affect the suitability of subgrade soils and may have the potential to generate the need for undercutting for subgrade stability. In general, piedmont or mountain region soils with Plastic Index above 35 requires undercut. Soils with high percentage material passing a #200 sieve, high moisture content or high mica content may also require undercut.

In Coastal Plain regions where soils tend to be more moisture sensitive, soils with a plastic index above 20 or with greater than 50% of material passing a #200 sieve, undercut is often necessary.

To assist in the constructability of stable subgrade, the common practice is to lump marginal soils into larger areas of poor soils in order to make the recommendations for undercut more practical.

When undercut is recommended, criteria for backfill and geotextile for soil stabilization is recommended in subsequent sections of the Recommendations report.

E. Aggregate Subgrade
Shallow Undercut for Aggregate Subgrade is used in place of standard undercut in areas with utilities or traffic control concerns and can range from 0.5 to 2.0 feet thick. List the quantity of undercut needed in cubic yards and the areas with unsuitable soils that will affect subgrade stability. A contingency quantity is typically included as well. For specific areas of shallow undercut, delineate with a shaded pattern as indicated in the Legend the exact locations on the plan, profile and cross section drawings and compute a quantity. When appropriate, a typical section may be provided in lieu of showing shallow undercut on the cross sections.

Aggregate Subgrade requires backfill to consist of Class IV borrow material on top of geotextile for soils stabilization. Quantities for these pay items must be included in Section III of the Recommendations report.

F. Geotextile for Soil Stabilization
List a quantity of fabric needed in square yards and the areas where fabric should be used to improve subgrade stability, as part of shallow undercut. A contingency quantity can be included as needed.

(III) Borrow specifications

A. Disposal of Waste Materials - other uses (i.e. noise berms) of rock, soil, unsuitable materials.

B. Borrow Criteria – state if will be using the statewide criteria or the Coastal Plain criteria.

C. Shrinkage factor – include the appropriate shrinkage factor for the region and site conditions of the project. Shrinkage factors typically range from 15% in the mountains to 30% in the eastern Coastal Plain, see Appendix A-6.

D. Rock Swell Factor – Give a factor in percent of the amount of swell of earth work quantity anticipated on the particular project.

E. Select Granular Material – include the appropriate quantities of Class II and/or Class III select granular material needed to accommodate previous recommendations including over fabric, backfill in water, for shallow undercut, or just as a contingency. Be sure to reference the previous section of the report when the select granular material is to be used in conjunction with a previous recommendation.

(IV) Miscellaneous

A. Reduction of Unclassified Excavation - Clearing & Grubbing
Clearing and Grubbing refers to the intentional removal or accidental loss of topsoil, root mat, stumps, shrubs, trees, or other ground cover. Removal of this material causes a loss in the amount of unclassified excavation available for the project. Compute the

quantity in cubic yards, and recommend that the total unclassified excavation be reduced by that amount. Maximum thickness to use is 1ft with a typical range of 2 to 6 inches.

At locations where the combined thickness of organic topsoil is 1 foot or more, it should be shown as the surface layer on the soil profile. Where the combined thickness is less than 1 foot, it should be adequately described in the written inventory report and may or may not be shown on the soils profile depending on the overall impact to the project. In fill sections, any topsoil with greater than 4% organic content and more than 4 inches thick must be shown and may be used for the following:

a) Compute a quantity of loss of earth material due to clearing and grubbing, or estimate a shrinkage factor.

b) Compute quantity for undercut or special handling.

Root mat and organic topsoil should be considered a single unit and described as follows; "Root mat and organic topsoil are an accumulation of organic debris, forest litter, roots and typically dark organic soil material."

	To Be Considered Organic	To Be Considered Muck
Granular Soils A-1, A-2, A-3	Material tested must have an organic content of at least 3%.	Organic content must be greater than 10%.
Silty Clayey Soils A-4, A-5, A-6, A-7	Material tested must have an organic content of at least 5%.	Organic content must be greater than 20%.

B. Reduction of Unclassified Excavation - Unsuitable Unclassified Excavation - Soil that is removed from above subgrade on the project that is unsuitable as embankment material. For specific areas of unsuitable unclassified excavation single hatch the exact locations on the plan, profile and cross section drawings.

1. Unsuitable material - Material that does not meet regional borrow criteria, has a high moisture content, organic material, muck or peat.
2. If the material is unsuitable or marginal, make a recommendation as to its use, treatment or disposal.

C. Water Wells - List the station and offset of all wells within the proposed NCDOT right-of-way that need to be abandoned.

D. Springs and Seeps - List the station and offset of all springs or seeps within the construction limits that will require Spring Boxes or other drainage. List the quantity of Spring Boxes needed, the area of seep that will need to be treated, and any drain pipe needed to tie the flow into existing project drainage. You must contact the Hydraulics Unit to determine how and where to connect with existing project drainage. Depending

on the source of the flow and the outfall location there may be jurisdictional issues that will need to be addressed by the Hydraulics Unit.

E. Aesthetic or Environmental Concerns - Potential scenic sites, reclamation.

F. Construction Procedures - Stages, specified materials or techniques instrumentation, monitoring or inspection.

G. Potential Hazardous Conditions – Abandoned wells, petroleum odors in bore holes, Under Ground Storage Tanks, and landfills.

H. Ponds - List all ponds near cuts that may be affected by the lowering of the ground water table or a change in the ground water flow regime. List all ponds that need to be drained or filled with select material.

I. Rock - List all locations where rock may need to be ripped or blasted during excavation including ditches and known drainage or underdrain excavation. List areas requiring horizontal drains, rock bolt, rock fall protection, or containing acidic rock.

The report should be signed and sealed by both a geologist and an engineer if both were involved in generating the recommendations.

The Geotechnical Quantities Summary Chart and the project specific Project Special Provisions mentioned in the report are attached to the end of report as separate sheets. The geotechnical summary table is placed in the NONCADD folder as an excel spreadsheet with appropriate quantities entered.

4.4.2 Roadway Recommendations Graphics

The Roadway Recommendations Graphical report will be a subset of the information and areas displayed in the Subsurface Inventory Report with the exception that specific areas of recommendations will be shown on cross sections. Additionally, the Roadway Recommendations graphical report will include areas identified as Unsuitable Unclassified Excavation and areas of unclassified excavation containing rock in cross section views. A Roadway Recommendations graphical report is only required when specific areas of recommendations are delineated and require inclusion in the final plans.

A. The recommendation graphics (borings, test results, profile, and cross-sections, etc.) shall be plotted on standard 11x17 inch paper.

B. The Recommendation graphics must contain the items listed below in the following order:

1. Title Page (See Example), including table of contents (Sheet 1)
2. Legend (Sheet 2)
3. Roadway Title Sheet – current when project was investigated (Sheet 3)
4. Profiles are optional and should only be included if areas of recommendations are present at centerline. The profiles showing unsuitable material must be displayed in the

same order as supplied by Roadway or Design Firm (sheet numbering after the Roadway Title sheet).

5. Cross sections showing unsuitable material are required (sheet numbering after profile sheets). All recommendation graphics drawn on cross sections must be drawn in the ".xsc" file.

C. Undercut for Embankment Stability

Undercut for Embankment Stability is drawn on cross sections where soft foundation soils are encountered which must be removed prior to the placement of embankment. Undercut for embankment stability is drawn as a cross-hatch pattern which encompasses the entire cross-sectional area of the material to be excavated. The cross-hatch pattern consists of two sets of hatches at 45 and -45 degrees.

Begin stations for the area to be undercut must be placed below the first cross section showing undercut for that area within the cross section cell in the ".xsc" file. The end station for the area to be undercut must be placed above the last cross section showing undercut for that area within the cross section cell in the ".xsc" file.

D. Undercut for Subgrade Stability

Undercut for Subgrade Stability, generally considered "full-depth undercut," is drawn on cross sections where soft, wet, highly micaceous, highly plastic or soils with other problematic characteristics make it necessary that the material be removed prior to paving operations. Undercut for subgrade stability is recommended to a depth of three feet below subgrade and extends to one foot beyond the curb and gutter or pavement structure. The cross-hatch pattern consists of two sets of hatches at 45 and -45 degrees.

Begin stations for the area to be undercut must be placed below the first cross section showing undercut for that area within the cross section cell on the ".xsc" file. The end station for the area to be undercut must be placed above the last cross section showing undercut for that area within the cross section cell on the ".xsc" file.

E. Aggregate Subgrade

Shallow Undercut for Aggregate Subgrade is drawn on cross sections where soft, wet, highly micaceous, highly plastic or soils with other problematic characteristics make it necessary that the material be removed prior to paving operations and when other factors limit the depth of undercut. Shallow undercut may be used in lieu of "full-depth" undercut adjacent to areas where traffic will be maintained during construction, where utilities would be in conflict with "full-depth" undercut or other factors. Shallow undercut is represented in cross section by a shaded pattern which extends the depth of undercut, generally 12 inches, and laterally to one foot beyond curb and gutter or pavement structure.

Begin stations for the area of shallow undercut must be placed below the first cross section showing shallow undercut for that area within the cross section cell in the ".xsc" file. The end station of the area for shallow undercut must be placed above the last cross section showing shallow undercut for that area within the cross section cell in the ".xsc" file.

F. Unsuitable Unclassified Excavation – Material to be Wasted
Unclassified excavation may be unsuitable for embankment construction due to properties such as plasticity indices, rock that is degradable or other factors. Unclassified excavation unsuitable for embankment construction which is recommended to be wasted is represented in the cross sections by a single hatch pattern drawn at 45 degrees. The hatched area must include all unsuitable unclassified excavation encountered or present at the cross section.

Begin stations for the area of "Unsuitable Unclassified Excavation – Material to be Wasted" must be placed below the first cross section showing this material for that area within the cross section cell on the ".xsc" file. The end station of the area for "Unsuitable Unclassified Excavation – Material to be Wasted" must be placed above the last cross section showing this material for that area within the cross section cell on the ".xsc" file.

G. Unclassified Excavation – Acceptable but not in the top three feet of embankment or backfill
Unclassified Excavation which is marginally acceptable for embankment construction such as soils with plasticity indices identified in Standard Specification Section 1018-2(A) and (B) must be represented in the cross sections with the "asterisk" pattern. The pattern in cross section area must include all of this material encountered or present at the cross section.

Begin stations for the area of "Unclassified Excavation – Acceptable but not in the top three feet of embankment or backfill" must be placed below the first cross section showing this material for that area within the cross section cell in the ".xsc" file. The end station of the area for Unclassified Excavation – Acceptable but not in the top three feet of embankment or backfill" must be placed above the last cross section showing this material for that area within the cross section cell in the ".xsc" file.

H. Unclassified Excavation – Acceptable Degradable Rock
Unclassified excavation which contains degradable rock must be identified in the cross sections. When it is determined that the degradable rock may be used for embankment construction, its use is limited to areas outside of the top three feet of embankment. A special provision which establishes other criteria for its use must be included in the Recommendations report as well. The pattern for "Unclassified Excavation – Acceptable Degradable Rock" consists of a single hatch at -45 degrees.

Begin stations for the area of "Unclassified Excavation – Acceptable Degradable Rock" must be placed below the first cross section showing this material for that area within the cross section cell in the ".xsc" file. The end station of the area for "Unclassified Excavation – Acceptable Degradable Rock" must be placed above the last cross section showing this material for that area within the cross section cell in the ".xsc" file.

4.4.3 Geotechnical Quantity Summary Chart

The Geotechnical Quantities Summary Chart is included in the text portion of the Roadway Recommendations report and numbered as the last page of the report. The Geotechnical Quantity Summary Chart is included with each version of recommendations transmitted to the Roadway Design Unit. There should always be a statement at the top that tells whether the

quantities listed are in addition to previous quantities or in place of previous quantities on all but the first version of the chart. Be sure to coordinate with the GeoPavement Section to determine if some quantities have already been turned in with their pavement design report.

4.4.4 Geotechnical Summary of Quantities

The Geotechnical Summary of Quantities is provided to the Roadway Design Unit as a reference for certain Geotechnical Recommendations that must be included in the contract. The Roadway Design Unit copies the tables from the Geotechnical Summary Quantities for these items. The Geotechnical Summary of Quantities is not part of the Roadway Recommendations report but must be included in the "NONCADD" digital folder transmitted to "ProjectStore" upon completion of the Geotechnical reports.

4.4.5 Special Provisions

Special Provision recommended in the report should be listed at the end of the report and when needed should be attached after the Geotechnical Summary of Quantities chart. Project special provisions should include all necessary instructions for the contractor. Instructions to the contractor should not be included in the text of the recommendation report since the recommendations report is not provided to the contractor.

4.5 Design Considerations

The project design engineer shall be responsible for determining (but not limited to) the following items in connection with the geotechnical design of the roadway project. Provide construction detail sketches with special provisions along with the soil profile or cross section sheets as needed.

4.5.1 Soil Cut Design

Determine the stability of cut sections. Utilize recognized geotechnical engineering designs and construction methods to insure cut slope stability. The field investigation should provide adequate mapping, data and testing to prove stable soil slopes through soil classification, groundwater characteristics, actual or assumed cohesive and/or friction values, unit weights and other input necessary for proper modelling.

4.5.2 Rock Cut Design

Exposed outcrop should be shown on plans and cross sections and incorporated with drilling information to accurately depict rock elevations and quantities. Rock slope designs should be proven with data derived from outcrop line mapping and drilling that include but are not limited to: Rock type, mineralization and related hardness and durability; orientations of geologic discontinuities such as bedding, foliation, joints, faults and fractures; block size; groundwater characteristics; roughness and friction values for discontinuities; degree of weathering; recovery and RQD from drilled cores, etc., depending on the requirements of the analysis.

Weathered rock stability is a special case in which sampling and determination of strength parameters is often difficult. Consideration must be made for parent rock type, mineralization (including presence of Magnesium oxide, MnO, on discontinuity weathering planes), bulk strength characteristics (typically derived from SPT's) and direct shear strength testing (when feasible to obtain).

When designing rock slopes it is necessary to consider and include references to blasting. These may be done through the "Rock Blasting" Provision that may include pre-split blasting as a Geotechnical Special Provision or fall under the guidelines of Section 220 "Blasting" in the 2012 Standard Specifications. On slopes 1:1 or steeper where rock reaches 50% RQD, NCDOT expects pre-split blasting to be considered and a project Special Provision concerning this shall be included in the Recommendations. Slopes steeper than 1:1 should not be considered without pre-split or controlled blasting techniques.

When designing rock slopes with catchment areas or attenuation devices, NCDOT expects a 90% rockfall retention rate at the paved shoulder edge, once all considerations for a clean, scaled and stable cut have been achieved.

4.5.3 Degradable Rock Considerations

Degradable rocks include typically sedimentary and weak metamorphic rocks that occur in the mountains and Triassic basins of the Piedmont. Once exposed in cuts or used as excavated material in other construction activities they degrade or slake. Cut slope design should reflect differential weathering and long-term slope stability. Consider catchment area and how slope failure could affect properties above cuts. Degradable material used as fill should consider the properties once they have weathered. Slake tests may be desirable.

4.5.4 "Hot" Soil and Rock (Acid-Producing Materials)

These rocks produce acidic runoff when their sulfide minerals are exposed to air and water. This comes from freshly exposed rock faces and blasted and excavated rock and material from the rock units. There is particular concern in the Mountain region in Clay, Cherokee, Graham, Swain, Macon, Jackson and Haywood counties. Acidic units in the Coastal plain are Cretaceous in age and generally belong to the unoxidized portions of the Peedee, Black Creek, Middendorf and Cape Fear Formations. These typically need to be noted and accounted for at the Project Development stage. It may be necessary to have fresh hand or drilled samples tested early in Project Development or subsurface investigation stages to answer concerns from project permitting (tested for Net Neutralization Potential). Dealing with this issue is highly specialized and customized to individual projects. Consultants should utilize known experienced professionals in the topic or consult with the Western or Eastern Region Manager of the GEU if a proposed project is located in the listed locations. Testing and mapping are ongoing so up-to-date searches on the topic should occur in the pre-Field Investigation phase.

4.5.5 Embankment Slope Stability and Reinforced Slopes

1. Determine the stability of embankments and utilize recognized geotechnical engineering design and construction procedures to insure embankment stability.

    a. The feasibility of using geo-textiles to achieve stability, reduce excavation of soft soils, and reduce the effect of settlement on the roadway.

    b. The feasibility of using sand drains or wick drains to increase the rate of consolidation of compressible soils beneath embankments.

c. The need for settlement gages, slope inclinometers and other embankment monitoring devices and their placement and location.

2. Determine the likelihood of intolerable embankment settlements and their mitigation through use of surcharges, waiting periods, and excavation of compressible material.

3. Embankments of compacted soil in the Piedmont and mountains should not be constructed steeper than 2:1 without incorporating shot rock plating, shot rock construction, reinforced soil slope design or similar improvements. This applies to slopes steeper than 3:1 in the Coastal Plain.

5 Structure Investigation and Recommendations

The objective of a structure investigation is to obtain adequate subsurface information to allow a safe, environmentally acceptable, cost effective foundation design. The data obtained during the investigation are shown in the Structure Subsurface Inventory Report and are used to generate the Foundation Recommendations

5.1 Bridge Foundations

5.1.1 Bridge Foundation Field Investigation

Prior to the start of any fieldwork, utilities must be located and traffic control must be arranged.

5.1.1.1 Non-Coastal Plain Drilling Criteria

Non-Coastal Plain drilling criteria apply to projects located in the Piedmont and Mountain Physiological Provinces and to any projects in the Coastal Plain for which the subsurface investigation encounters underlying residual materials.

A minimum of two Standard Penetration Test (SPT) borings are required at every bent location on all non-Coastal Plain projects. Where bent lines measured along skew exceed 60 feet, one additional boring will be required per bent. Additional borings are also required when significant variation in subsurface conditions will impact the foundation design.

Standard Penetration Tests shall be conducted at intervals of 5 feet or less. The borings should extend a minimum of 10 feet below the anticipated ultimate design bearing capacity. The ultimate design bearing capacity for pile foundations for standard bridges is 180 tons. Pile foundations for non-standard bridges must be evaluated for ultimate bearing capacity by the Design Engineer. Additional soil or core borings may also be required when boulders are encountered or suspected.

Termination statements should be included on all boring logs and should be consistent between the field and final log. In soil or weathered rock, the termination statement should consist of the format “Boring Terminated at Elevation 325.1 feet in Silty Sand”. The boring termination statement for borings terminated in or on rock should consist of the format “Boring Terminated with SPT Refusal at Elevation 325.1 feet in Crystalline Rock”.

5.1.1.2 Coastal Plain Drilling Criteria

Coastal Plain Drilling criteria apply to any bridge investigation for which the entire depth of the investigation remains in Coastal Plain material. When the investigation encounters residual material below the Coastal Plain prior to termination, Non-Coastal Plain drilling criteria apply.

A minimum of one Standard Penetration Test (SPT) boring is required at every bent location on all Coastal Plain projects. Additional borings are necessary when variations in the subsurface may substantially impact the foundation design. Where bent lines measured along skew exceed 60 feet, one additional boring will be required per bent.

Standard Penetration Tests shall be conducted at intervals of not more than five feet. The borings should extend a minimum of 20 feet below the anticipated ultimate design bearing capacity. The ultimate design bearing capacity for pile foundations for standard bridges is 180 tons. Pile

foundations for non-standard bridges must be evaluated for ultimate bearing capacity by the Design Engineer.

Additional investigation is necessary when the foundation design or constructability of the design is impacted by the presence of Coastal Plain sedimentary rock. Because of the impacts to pile driving of relatively thin Coastal Plain sedimentary rock units within the Coastal Plain, increasing the frequency of SPT testing should be discussed with the design engineer. When Coastal Plain sedimentary rock is retrievable, it should be cored to provide data to the Foundation Design Engineer impacting pile drivability or drilled pier design.

Termination statements must be included on all boring logs and should be consistent between the field and final log. The Coastal Plain formational name or rock type should be included at the end of the termination statement when the formation is known. The termination statement for Coastal Plain borings terminated in formational soils should use the format "Boring Terminated at Elevation 89.2 feet in Silty Sand (Yorktown Formation)".

5.1.1.3 Investigation Criteria for all Bridges

Drilled pier foundation drilling criteria should be used in investigations with the following conditions.

- When there is less than 10 feet of functional pile length below the Design Scour Elevation.
- In water when rock is shallow such that insufficient material exists to provide lateral support for sheet pile cofferdams.
- For high structures such as those with column heights over 25 feet where the depth to rock is less than 16 feet.
- Railroad structures with high design load criteria and where other foundation designs may require the use of shoring.
- Nearby structures cause concern about vibration damage by pile driving.

Borings should be performed at the proposed drilled pier locations when possible.

For Drilled Piers in Rock

The depth of coring in rock will typically be determined in the field using the core RQD. The guideline below reflects embedment criteria for drilled piers from the top of the rock unit and allows for a nominal safety margin on lateral stability:

RQD	Core Depth (ft.)
75 - 100	10 - 15
50 - 75	15 - 20
25 - 50	20 - 25
0 - 25	25 - 30

Changing RQD conditions with depth tend to change the required coring depth. For drilled piers greater than 5 feet in diameter the design engineer should be consulted for boring depth. For details on collecting and logging rock core see Section 2.2 of this manual.

For Drilled Piers in Soil

The boring depth required for design of drilled piers in soil will be determined by the depth below the Design Scour Elevation or ground surface required to provide bearing and lateral stability with an adequate margin of safety.

When investigating for a drilled pier in soil, the standard method for obtaining soil data includes standard penetration tests, Cone Penetration Tests (CPT) and the collection of Shelby Tubes for lab analysis. Subsurface conditions affecting construction include the following.

- The stability of subsurface soils against caving or collapse
- The presence of ground water, flow rate, and potentiometric surface, whether artesian or not.
- The presence of cobbles or boulders.
- The presence of existing foundations or structures.
- The presence of landfills.
- Rock line elevation.
- Presence of a weak stratum below the drilled pier tip elevation.

Where spread footing foundations are anticipated, Standard Penetration Tests shall be performed at intervals of not more than 2.5 feet beginning at the highest possible bottom of footing elevation. The test boring shall extend to a depth equal to twice the anticipated footing width (2B) below bearing material up to 25 feet or until rock is encountered. If rock is present within 10 feet below the proposed bottom of cap elevations, the design engineer should be consulted. Cores may need to be taken ten 10 feet into rock for footings and 15 feet below proposed bottom of cap for piles to verify continuity of rock.

Standard Penetration Tests (SPT's) must be performed in accordance with AASHTO Standard Method T 206 or ASTM D1586 with the following exceptions to terminating SPT drives:

- Advance the sampler 1.5 feet
- Apply 100 blows to the sampler over any 2 consecutive 0.5 foot intervals.
- Apply a total of 60 blows with 0.1 ft. penetration or less (SPT refusal criteria)

A minimum of two undisturbed "Shelby tube" samples shall be taken at the end bent locations of any cohesive or organic soils with n-values less than 15. "Shelby tubes" must be sealed with wax at the top and the bottom of the tube in a manner to prevent loss of in situ moisture and the tube must be filled with material sufficient to prevent disturbance of the sample within the tube. Tubes must be transported in the upright position in a manner to prevent damage caused by movement. Shelby tubes must not be exposed to extreme heat or cold. The samples shall be tested for shear strength or consolidation and soils that are considered organic should be tested for organic contents (AASHTO T 267).

The offset must be given for every boring and when the offset is 0, the offset is recorded as centerline (CL).

Other in-situ soil testing such as vane shear, Cone Penetration Tests or Geophysical testing may be used to supplement the test boring information.

Soil samples shall be tested according to AASHTO Standard Methods T 87, T 88, T 89 and T 90 as modified by NCDOT. The classification of soils shall follow AASHTO Designation M 145.

All S and SS sample numbers should be listed consecutively as a group throughout the entire project. Shelby Tube (ST) samples should be listed consecutively throughout the entire project separate from S and SS samples.

Locations and elevations shall be referenced to existing project surveys and bench marks. The benchmark (BM) used to survey elevations will typically be located outside the construction limits. The benchmark noted on the legend sheet should be an NCDOT Location & Survey Unit control point typically listed on roadway profile sheets, structure preliminary general drawings or the Bridge Survey & Hydraulic Design Report. Survey-Grade GPS equipment may be used in lieu of physical benchmarks and traditional survey.

Upon completion of a test boring and after applicable groundwater readings have been made, the bore hole must be abandoned properly as indicated in Section 2.7 of this manual, "Abandoning Bore Holes".

Rock core testing is required for any foundation that will be designed in rock. The number of specimens tested depends upon the variability of the strata, column height, load and span length of the proposed bridge. The design engineer should be consulted to determine the likely bearing zones for shafts or footings so the actual bearing materials are submitted for testing. Weathered rock should be cored and tested when it can be retrieved.

Samples should be tested for unit weight (AASHTO T265), Compressive Strength of Intact Rock Core (ASTM D2938) and Standard Method for Elastic Moduli of Intact Rock Core (ASTM D3148). If there are not any pieces of the recovered core long enough to test for compressive strength a Split Tensile (ASTM D3967) test can be requested.

Highly variable stratigraphy or weathering warrants a higher frequency of rock core testing.

When artesian conditions are encountered, the field supervisor must direct the acquisition of the potentiometric surface and record that elevation on the boring log. Casing or pipe must be added above the collar elevation until the water level becomes static before the elevation can be measured. Artesian conditions which present within embankment must be measured after 24 hours and noted on the boring log as artesian.

5.1.1.4 Borings through Existing Bridge Decks

When borings performed from a bridge and it is necessary to cut access holes through the deck, contact the Division Bridge Maintenance Engineer. The Bridge Maintenance Department will cut the hole and repair the bridge deck or authorize the field crew to cut and repair the deck. The Bridge Maintenance Superintendents and Supervisors can be found on the Internet at https://apps.dot.state.nc.us/dot/directory/authenticated/ToC.aspx listed under the Division in which the project is located.

5.1.1.5 Survey Requirements for Bridges

All horizontal distances shall be measured to the nearest 1 foot. All vertical distances and elevations shall be measured to the nearest 0.1 feet.

5.1.2 Bridge Subsurface Inventory

All Units within the NCDOT use a uniform symbology which must be followed in all reports submitted for letting by the NCDOT. The following procedures have been provided to aid in drafting.

The Structure Subsurface Inventory Report must contain the items listed below in the following order:

- Structure Subsurface Investigation Title Sheet.
- NCDOT Geotechnical Engineering Unit Legend
- Site Plan
- Profile
- Cross sections (when needed)
- Final bore logs and core logs
- Scalable color photographs of rock core (no more than 4 to a page)
- Sample results (soil and rock test results)
- Site photographs

Projects with dual structures may be reported as multiple, individual projects with separate reports or they may be reported as a single report with the following format.

- Structure Subsurface Investigation Title Sheet.
- NCDOT Geotechnical Engineering Unit Legend
- Site Plan for LL/EBL/NBL/Main structure
- Profile for LL/EBL/NBL/Main structure
- Cross sections for LL/EBL/NBL/Main structure
- Final boring logs and core logs for LL/EBL/NBL/Main structure
- Scalable color photographs of rock core for LL/EBL/NBL/Main structure
- Sample results (soil and rock test results) for LL/EBL/NBL/Main structure

- Rock test results summary chart for LL/EBL/NBL/Main structure
- Site photographs for LL/EBL/NBL/Main structure
- Site Plan for RL/WBL/SBL/Detour structure
- Profile for RL/WBL/SBL/Detour structure
- Cross sections for RL/WBL/SBL/Detour structure
- Final boring logs and core logs for RL/WBL/SBL/Detour structure
- Scalable color photographs of rock core for RL/WBL/SBL/Detour structure
- Sample results (soil and rock test results) for RL/WBL/SBL/Detour structure
- Rock test results summary chart for RL/WBL/SBL/Detour structure
- Site photographs for RL/WBL/SBL/Detour structure

5.1.2.1 Title Sheet

All structure subsurface investigation reports must be sealed on the title sheet by a Geologist or Engineer licensed in the State of North Carolina. The standard title sheet approved by the Geotechnical Engineering Unit must be used for all structure subsurface investigation reports.

5.1.2.2 Legend

All structure subsurface investigation reports must include the Geotechnical Engineering Unit Subsurface Investigations Soil and Rock Legend. Notes may be added to the legend in the "Benchmark" and "Notes" sections and the description of equipment used on the project should be added to the "Equipment Used on the Subject Project" section. No other portion of the legend may be removed or edited for submittal.

Benchmark location and elevation data must be listed in the "Benchmark" section of the Legend.

5.1.2.3 Site Plan

A drafted site plan of the project must accompany the report. The site plan may be adapted from the Preliminary General Drawing or Bridge Survey and Hydraulic Design Report plan view and should be coordinately correct in the electronic version. The following items must be included on the plan view.

- Tip number
- Bridge number or bridge site number from Structure Management Unit
- North arrow
- Scale with units
- Line of reference -L-, -LREV-, -Y- etc.
- Stationing of line indicated at a minimum of 2 locations.
- Proposed bent lines at the station and skew listed on the Preliminary General Drawing or from the Bridge Survey and Hydraulic Design Report
- Flow direction of the creek, stream, tributary, or swamp
- Borings plotted with identifiers (EB1-A, EB2-B, etc.)
- Any significant geologic and geographic features such as outcrops, muck limits, alluvial boundaries, sandbars, dunes, existing roadways, structures, buildings, etc.)
- Other features such water wells, dumps, landfills etc.
- In the case of dual bridges refer to eastbound lane (EBL) and westbound lane (WBL) or left lane (LL) and right lane (RL), etc. The designation used should match the Preliminary General Drawing or Bridge Survey Report.

- Stream limits or water surface boundaries
  - The scale is dependent on the length of the bridge and must be one of the following standard scales: 1:10, 1:20, 1:30, 1:40, 1:50, and 1:60. Other scales may be considered for use with prior approval from the Geotechnical Engineering Unit.

Other proposed roadway and bridge design features may be shown on the plan view but should not obscure the boring locations or other significant geologic features that may affect design.

5.1.2.4 Profile

A profile represents the general subsurface conditions of a structure site along or parallel to a surveyed alignment. Drafted profiles must be included in all Bridge Subsurface Inventory reports. A ground-line must be shown and a reference to the ground-line source must be noted on the sheet, such as by field survey or ".tin" file. Stratigraphy on the profiles is recommended to be drawn at the profile offset, but may be drawn through the boring locations. A statement should be included on the profile describing how it was obtained and how the stratigraphy is drawn. Boring termination abbreviations must be included below the boring strips. The following items must be shown on the profile drawings.

- Tip number
- Bridge number or bridge site number from Structures Management Unit
- Scale with units
- Line of reference (-L-, -LREV-, -Y-, etc.)
- Stationing
- Ground surface line
- Water surface elevation
- Boring location and offset
- Elevation scale
- "24" hour water measurements with date or "DRY", "FIAD" or other notation
- SPT results (plotted 1 foot below top of the drive or at the bottom of a partial drive)
- Shelby tube locations
- Interpretations should be shown with dashed lines between embankment fill, alluvium, colluvium, residual, weathered rock, rock, and any other unit with a note near the top of the page describing if the interpretations are at the profile location or projected through the borings. (See example notes below)
- Provide a written description of the strata on the profile. Follow the Legend for soil and rock classification, abbreviations and consistencies.
  - The scale is dependent on the length of the bridge and must be one of the following standard scales: 1:10, 1:20, 1:30, 1:40, 1:50, and 1:60. Other scales may be considered for use with prior approval from the Geotechnical Engineering Unit.

5.1.2.5 Cross Sections

A cross section represents the subsurface conditions of a structure site along the centerline of or parallel to proposed bents or piers, regardless of skew. Drafted cross sections must be included on all bents with more than one boring. Cross Sections may be shown for bents with no borings or one boring when the ground surface along the proposed bent has a steep gradient, outcrop or other features that are useful for foundation design. Borings should be projected onto the cross section but the stratigraphy must be drawn on cross sections at the proposed bent line. Stratigraphy on the cross sections should match the profile stratigraphy at the intersection point. Boring termination abbreviations must be included below the borings. The following items must be included on the cross section.

- Tip number
- Bridge number or bridge site number from Structure Management Unit
- Scale with units
- Line of reference (-L-, -LREV-, -Y-, etc.)
- Bent number (EB1, EB2, B1, B2, etc.)
- Stationing
- Ground surface line at the profile location with a source note (i.e. field survey or .tin file)
- Water surface elevation
- "24" hour water measurements with date or "DRY", "FIAD" or other notation
- SPT results (plotted 1 foot below top of the drive or at the bottom of a partial drive)
- Shelby tube locations
- Tick mark with label showing CL of line of reference or work-point (dual structures)
- Interpretations should be shown with dashed lines between embankment fill, alluvium, colluvium, residual, soft weathered rock, crystalline rock, and any other stratigraphy distinguishable by origin.
- Provide a written description of the strata on the cross section. Follow the Legend for soil and rock classification, abbreviations and consistencies.
    - The scale is dependent on the length of the bent line and may be one of the following standard scales: 1:10, 1:20, 1:30, 1:40, 1:50, and 1:60. Other scales may be considered for use with prior approval from the Geotechnical Engineering Unit.

Borings on Skew for Cross Sections

When a bridge has a skew of 90 degrees, the perpendicular offset of the boring from the mainline is the offset along the bent line where the boring will be plotted on the cross section.

When a bridge has a skew other than 90 degrees, the boring is plotted on the bent line at the offset measured along the skewed bent line. When a boring does not fall on the bent line, the borings are projected to the cross section perpendicular to the bent line.

5.1.2.6 Bore Log Reports

Borelogs are required for each boring performed for a bridge foundation investigation. The following information will be required on borelog report:

- Project Number
- TIP Number
- County
- Site Description of the bridge including: Bridge #, road name or alignment name, Creek or Stream name, Railroad name or number etc.
- Field supervisor name
- Drilling equipment used and last hammer calibration date
- Method of drilling
- Date the boring started
- Date the boring was finished
- "24" hour water reading
- "0" Hour water reading
- Collar elevation (ground elevation at 0.0' depth of boring)
- Total depth of the boring
- Boring identification (EB1-A, B1-B, etc.)
- Offset of the boring
- Boring station
- Alignment
- Northing and Easting
- Hammer type
- Surface water depth (if any at boring location)
- Termination statement

Borings shall be identified by standard nomenclature where End Bent 1 is "EB1" and Bent 1 is "B1". Each boring name will contain a letter that corresponds to the boring location on the bent where A=left, B=right, C=center, D=fourth boring location, E=fifth boring location. When subsequent investigations are required at a bridge site, the designation REV should be added to the boring name as a suffix (B3-A REV). The borings performed during the first investigation will retain their original designations. If additional revisions are necessary, a number sequence is added to identify the revision for which the boring was performed, such as B3-A REV2. For dual structure investigations the abbreviations LL (Left Lane), RL (Right Lane), EBL (East Bound Lane), WBL (West Bound Lane) should be added at the end of the boring name to distinguish between the bridges (B1-A LL and B1-A RL).

Sample numbers, Shelby tube numbers, and moisture content shall be shown on all borelogs. In reference to the Geotechnical Engineering Unit Soil and Rock Legend, the following abbreviations will be used: S-Bulk sample, SS-Split barrel sample, ST-Shelby tube, SAT-Saturated, WET, M-Moist, DRY.

5.1.2.7 Core Log Reports

Core Log Reports are required for each core boring performed for a bridge foundation investigation. The following information will be required on core log reports submitted for each project:

- Project Number
- TIP Number
- County
- Site Description of the bridge including: Bridge #, road name or alignment name, Creek or Stream name, Railroad name or number etc.
- Field supervisor name
- Drilling equipment used and last hammer calibration date
- Method of drilling
- Core size
- Total run
- Date the boring started
- Date the boring was finished
- "24" hour water reading
- "0" Hour water reading
- Collar elevation (ground elevation at 0.0' depth of boring)
- Total depth of the boring
- Boring identification (EB1-A, B1-B, etc.)
- Offset of the boring
- Boring station
- Alignment
- Northing and Easting
- Hammer type
- Surface water depth (if any at boring location)
- Termination statement
- Individual run beginning and end depths
- Run length
- Drill Rate
- Core run Recovery
- Core run Rock Quality Designation
- Sample numbers
- Run Recovery and RQD
- Geologic Strength Index

Core runs are to be listed as RUN1, RUN2, RUN3 and the RQD (run and strata) and REC (run and strata) values must be shown on all core boring reports.

5.1.2.8 Sample Results

Soil and rock sample test results must be shown in a tabular form on a separate sheet in the report. This table should include a summary for all ST samples as well. The following items must be shown on the soil sample table:

- Boring number
- Sample number
- Passing #10 sieve
- Passing #40 sieve
- Passing #200 sieve
- % coarse sand
- % fine sand
- % silt
- % clay
- Liquid Limit (LL)
- Plastic Index (PI)
- AASHTO Classification (with Group Index)
- Depth the sample was taken
- Water content (if tested)
- Organic content (% ORG) (if tested)

The following items must be shown on the rock sample table:

- Boring number
- Sample number
- Sample depth
- Unit Weight
- Compressive strength

5.1.2.9 Core Photographs

Core photograph sheets must be included in the Subsurface Inventory report for any investigation where coring was performed. Core photographs must be scalable and have the beginning and end depth of each core run identified. Core photographs must be taken prior to the submittal of any rock core samples for testing and the samples must be identified in the photograph with sample number and depth range. Boring identifier, station and offset must be listed above each photograph and a scale must be shown below the photograph.

5.1.2.10 Site Photograph

A site photograph sheet is required for all Subsurface Inventory reports and must contain between one and four photographs which depict the existing structure or site at the time of investigation. Site photographs must include the direction of flow for stream crossings as well as labels and up-station direction for any alignments shown in the photograph.

5.1.2.11 Structure Foundation Cover Letter to the Regional Design Engineer

If there are specific conditions encountered during the investigation that need to be conveyed to the design engineer they should be included in a cover letter addressed to the Regional Design Engineer. These conditions should also be noted in the inventory report.

The list of items below is a partial list of topics that may need to be addressed in the cover letter. Individual projects may require the addition of other topics due to unique site characteristics.

- Dams
- Ponds
- Landfills or buried debris
- Rubble piles
- Cobbles and/or boulders
- Shallow groundwater
- Artesian groundwater
- Perched groundwater
- Highly weathered zones in rock
- Difficult drilling conditions
- Adverse rock structure

5.1.3 Design Scour Elevation

The FHWA Technical Advisory found at http://www.fhwa.dot.gov/engineering/hydraulics/scourtech/scour.cfm requires that the design of new bridges include a Scour Evaluation Study to establish the reasonable limits of scour for prescribed flood levels and upon which the bridge foundation will be designed. A Scour Evaluation Study includes contributions by the Hydraulics and Geotechnical Engineering Units as well as their Private Engineering Firms under contract.

5.1.3.1 Role of the Hydraulics Unit

The Hydraulics Unit begins a Scour Evaluation as part of the Hydraulic Design Study for stream crossings. Predictions of scour are made for:

- Long term channel profile changes (aggradation/degradation)
- Plan form change (lateral channel movement)
- Contraction scour
- Local scour
- Abutment

The long term channel profile and plan form change predictions are based on hydraulic factors and principals outlined in FHWA HEC No. 20 "Stream Stability at Highway Structures". This is the primary reference for this phase of the Hydraulic Design Study.

Three types of scour may be listed: contraction, local, and abutment. Contraction scour may be present at any structure over water. Local scour may occur when an interior bent is present within the stream during the specified flood event. Abutment scour may occur at the abutment face.

Contraction, local, and abutment scour estimates are determined through application of the process presented in FHWA publication HEC No. 18 "Evaluating Scour at Bridges". The formulas used in this process are based on sand bed model studies. Surface materials are considered in the mathematical analysis but subsurface conditions and their resistance to scour forces are not.

A summary of Theoretical Scour computations and a graphical representation of the Theoretical Scour envelope are reported on the "Bridge Survey and Hydraulic Design Report (BSR)".

5.1.3.2 Role of the Geotechnical Engineering Unit

The Geotechnical Engineering Unit will use the Theoretical Scour Elevation as reported in the BSR and data obtained during the Subsurface Investigation to determine a Design Scour Elevation (DSE). The scour evaluation by the Geotechnical Engineering Unit examines the scour resistance of the materials within the depth interval between the design flood elevation and the Theoretical Scour Elevation. The maximum theoretical scour depth is treated as an energy level that indicates the scour potential for the design flood at the site. The design flood is the 100-year or Overtopping event unless otherwise noted.

The structure foundation investigation is dependent on the scour depth. Therefore, scour depth must be estimated during the field investigation. The field supervisor considers the geomorphological setting, soil classification, density or hardness, standard penetration test values, core recovery and core RQD to evaluate resistance to scour. The field supervisor will determine the most likely type of structure foundation to be investigated. Spread footings, pile foundations, and drilled shaft foundations each require specific types of investigation.

Upon completion of the field investigation and laboratory testing, the project geologist/engineer assembles the red-lined boring logs and preliminary cross sections to evaluate the scour potential. Design Scour Elevation is reported at all bents where scour is shown for the design flood event. A Design Scour Elevation memorandum will be sent to the Project Engineer in Structures Management Unit (or Division Bridge Program Manager) and Hydraulics Unit (listing the 100-year DSE (or the Over-Topping event if it occurs before the 100 year).

5.1.3.3 Design Scour Elevation Procedure

A Design Scour Elevation (DSE) memorandum is required for all water crossings. Establish the locations for which a Design Scour Elevation will be required. Design Scour Elevations must be given for each interior bent. When subsurface conditions vary substantially across the bent, two or more DSE's may be required per bent. End bents with scour impacts predicted require a DSE, otherwise it is not necessary for end bent locations.

Identify the Theoretical Scour Elevation on the Bridge Survey & Hydraulic Design Report (BSR). The BSR contains calculations and a graphical representation of the theoretical scour at stream crossings. The Theoretical Scour Elevation is the elevation at which the theoretical scour envelope shown graphically crosses the Bent line in profile.

Summarize the subsurface data at each DSE location. Choose a starting elevation for calculations based on the Historical Scour Elevation (HSE). The Historical Scour Elevation is the elevation to which historical flood events have scoured residual or formational materials and is represented by

the contact between alluvial soils and residual or formational material. Determine the maximum theoretical scour (Zmt) by calculating the difference between the Historical Scour Elevation and the Theoretical Scour Elevation. Use the Theoretical Scour Elevation shown graphically in the BSR profile. Determine the thickness of each stratum from the Historical Scour Elevation to the Theoretical Scour Elevation. Apply the scour reduction factor from the Jim Keane Scour Reduction Chart to determine the reduction ratio (Zc) for each stratum.

Determine if each stratum will resist scour from progressing into the underlying layer. If an individual stratum does not resist the remaining scour entirely, then subtract the thickness of that stratum from the remaining Zmt. Once a stratum resists the available scour energy, determine what portion of that stratum remains and calculate the elevation scour will reach.

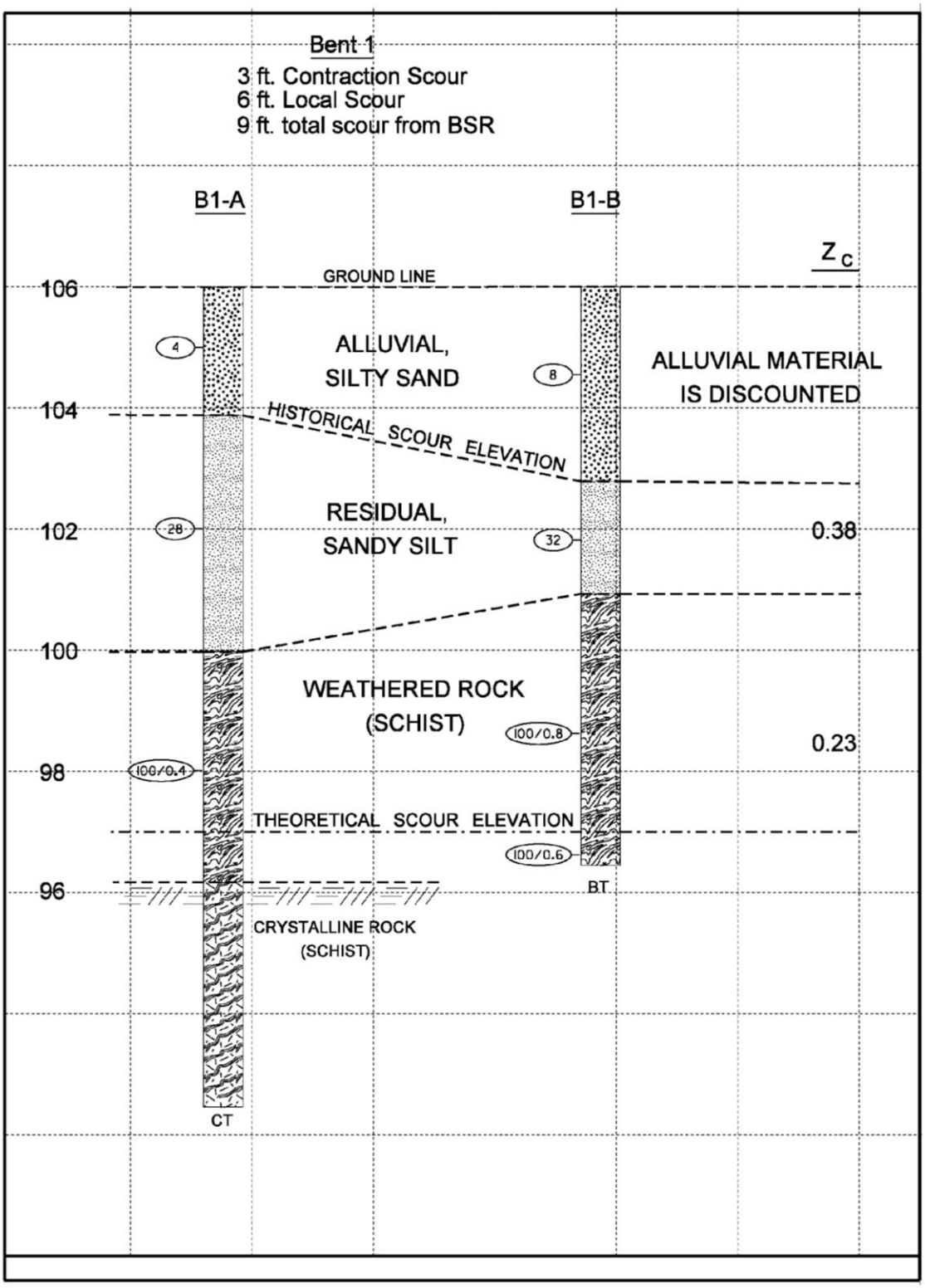
If the DSE impacts the end bents, notify the State Geotechnical Engineer before proceeding. The State Geotechnical Engineer and the State Hydraulics Engineer will reach a consensus for structures where the DSE impacts the end bents, and the DSE will be reported to Structures Management Unit (or Division Bridge Program Manager) and Hydraulics Unit with a memorandum from the Geotechnical Engineering Unit head. If the DSE does not impact the end bents, the Regional Geological Engineer will report the DSE to Structures Management Unit (or Division Bridge Program Manager) and Hydraulics Unit with a memorandum. The memorandum will include the Design Scour Elevations reported to the nearest foot and will indicate whether or not the DSE impacts the end bents. If the DSE is higher than the Theoretical Scour Elevation, state what the material is that will stop the scour. DSE memorandums for proposed single span structures with no scour impacts to the end bents should be written for consistency, but information can be conveyed with an email instead of a memorandum.

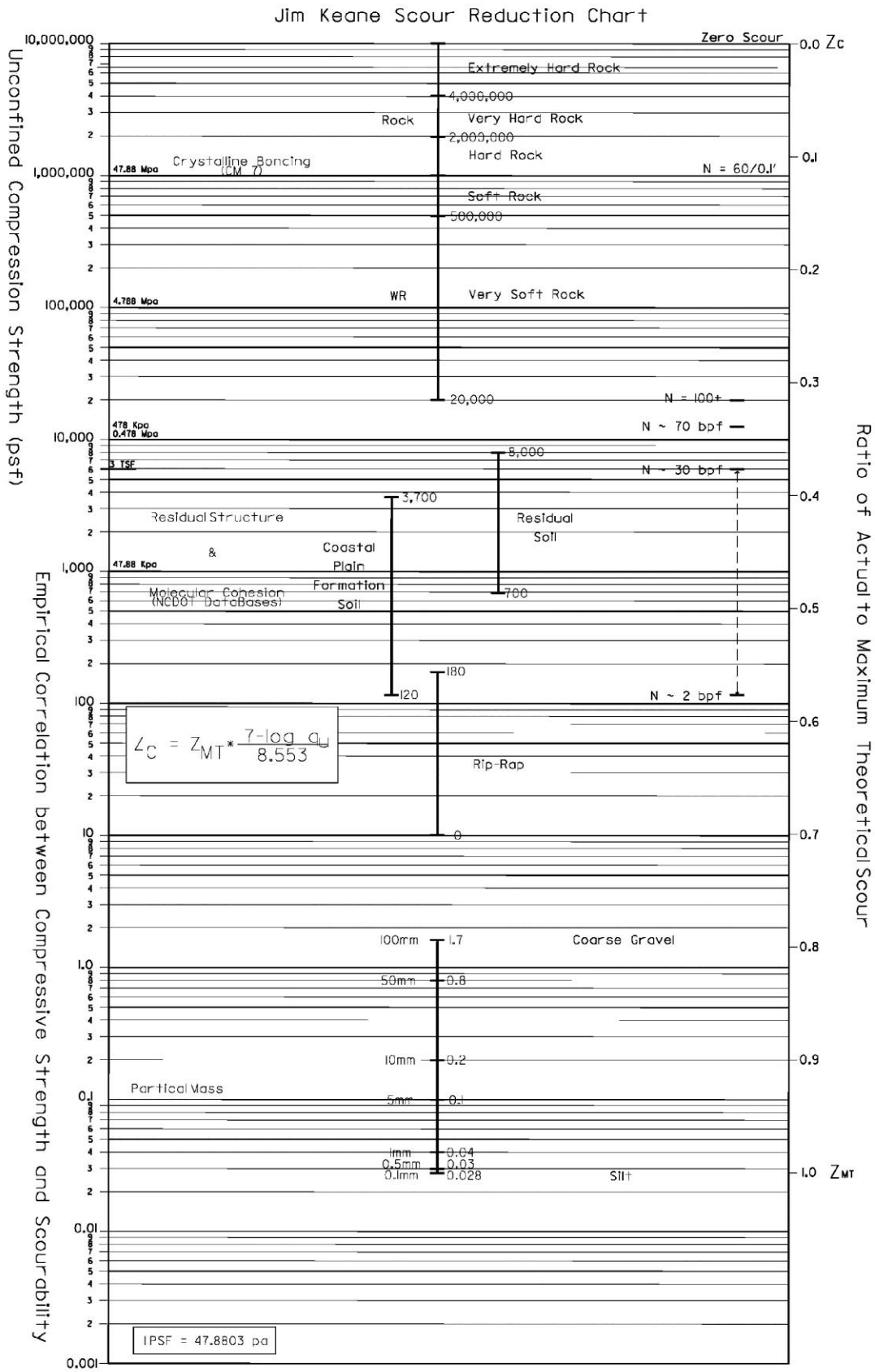
5.1.3.4 Design Scour Elevation Example Calculations

There is 3 feet of contraction scour and 6 feet of local scour for a total of 9 feet of scour at interior bent 1. The Theoretical Scour Elevation shown graphically in the BSR is measured at 97.0.

B1-A Historical Scour Elev. = 103.9
B1-A Theoretical Scour Elev. = 97.0
B1-A Zmt = 6.9'
B1-A Strat: 2.1' alluvial sand (discounted since it is above the HSE)
3.9' residual silt,
3.9' weathered rock (WR)
From Keane chart: residual Zc = 0.38
WR Zc = 0.23
Calculations: (Zmt) x (Zc of strata) =X. (Compare X to thickness of strata)
Strata 1: (6.9') (0.38) =2.6' < 3.9 (Therefore scour stops in strata 1)
DSE = HSE – adjusted scour depth
DSE = 103.9 – 2.6' (strata1)
DSE (B1-A**) =101.3', Round to nearest foot for memorandum.**

B1-B Historical Scour Elev. = 102.8
B1-B Theoretical Scour Elev. = 97.0
B1-B Zmt = 5.8
B1-B Strat: 3.2' alluvial sand (discounted since it is above the HSE)
1.8' residual silt,
4.6' weathered rock (WR)
From Keane chart: residual Zc = 0.38
WR Zc = 0.23
Calculations: (Zmt) x (Zc of strata) =X. (Compare X to thickness of strata)
Strata 1: (5.8') (0.38) =2.2' < 1.8 (Therefore scour impacts stratum 2)
Strata 2: (5.8'–1.8') (0.23) = 0.9 < 4.4 (Therefore scour stops in stratum 2)
DSE = HSE – adjusted scour depth
DSE = 102.8' - 1.8' (strata1) – 0.9' (scour depth in stratum 2)
DSE (B1-B**) = 100.1', Round to nearest foot for memorandum.**


Bent 1
3 ft. Contraction Scour
6 ft. Local Scour
9 ft. total scour from BSR
B1-A
B1-B
Z c
GROUND LINE
106
104
102
100
98
96
4
8
28
32
100/0.4
100/0.8
100/0.6
ALLUVIAL,
SILTY SAND
ALLUVIAL MATERIAL
IS DISCOUNTED
HISTORICAL SCOUR ELEVATION
RESIDUAL,
SANDY SILT
0.38
WEATHERED ROCK
(SCHIST)
0.23
THEORETICAL SCOUR ELEVATION
BT
CRYSTALLINE ROCK
(SCHIST)
CT



$$Z_C = Z_{MT} * \frac{7 - \log q_u}{8.553}$$

5.1.4 Bridge Foundation Recommendations
This section of the manual is forthcoming.

5.1.5 Detour Bridge Foundations
5.1.5.1 Detour Bridge Foundation Field Investigation
When on-site detour structures are required to maintain traffic during construction, the following guidelines should be used to provide subsurface data for their foundation design. Borings should be performed and the data is submitted within the Structure Subsurface Inventory report.

For Detour Structures less than 100 feet in length, a total of two borings should be performed, one boring at each end bent.

For Detour Bridges between 100 and 200 feet in length, a total of three borings should be performed, one boring at each end bent and one boring as close to the center of the bridge as is practical.

For Detour Structures greater than 200 feet in length, one boring should be taken at each end bent, and additional borings should be performed at one third intervals along the proposed bridge with a maximum spacing between borings of 200feet.

Boring depths should be determined by the same criteria as boring depths for the primary structure on the project.

5.1.5.2 Detour Bridge Foundation Subsurface Inventory
Detour Structure data is presented in the Structure Subsurface Inventory report for the primary structure on the project. A profile showing the detour structure borings should be incorporated in the main bridge report. If no detour profile is shown in the Subsurface Inventory for a particular detour structure then a note should be added to the main bridge report explaining the exception.

Bore logs performed for detour structures must be included in the Structure Subsurface Inventory report under the same guidelines as those under Section 5.1.2.6.

5.1.5.3 Detour Bridge Foundation Recommendations
No recommendations for on-site Detour Structures are required. The subsurface data obtained during the investigation will be used by the contractor to evaluate the structure and structure foundation design for the detour bridge.

5.2 Culvert Foundations
Culverts are used to carry small streams or creeks below roadways. There are numerous types of culverts including Reinforced Concrete Box Culverts (RCBC), Corrugated Metal Pipes (CMP), and Bottomless or 3 sided culverts.

Bottomless culverts are a special case and may be considered when in-place rock and weathered rock can be reliably verified to be within one foot of the stream bottom across the entire structure footprint by visible outcrop or by drilling. Consultation with the Hydraulics Project Engineer is required.

5.2.1 Culvert Field Investigation
Prior to any field investigation, locate utilities and coordinate traffic control.

Culverts are often included on roadway plans and borings should be performed during the roadway investigation. Boring depth will vary depending on the height of the fill over the culvert. Roadway boring drilling criteria can be used to determine depth. Borings may be terminated at rock or after penetrating 5 feet below the lowest possible footing elevation if the soils are sufficient for bearing. Hand augers and sounding rods may be used to gather additional information. One boring should be performed at each end of the culvert. The number of additional borings must be sufficient to characterize the site conditions.

Most culvert locations do not require separate Subsurface Inventory Reports and the data will be presented in the Roadway Subsurface Inventory report. A Culvert Subsurface Inventory report with Foundation Recommendations is only generated when specifically requested by the Hydraulics Unit, Structures Management Unit, Highway Division offices or other requesting agencies.

5.2.2 Culvert Subsurface Inventory
The Structure Subsurface Inventory report for culverts will consist of the following:

- Title Sheet
- Legend
- Structure Site Plan
- Profile along proposed culvert length with stratigraphy and borings
- Cross sections at the edges of the culvert when an existing culvert is extended

5.2.3 Culvert Foundation Recommendations
This section of the manual is forthcoming.

5.3 Shoring Foundations
Shoring is typically constructed of interlocking sheet piles, drilled-in soldier piles with timber lagging or temporary fabric walls and is used for the temporary support of an existing structure in order to maintain traffic during construction. Other uses for shoring include stabilizing deep excavations such as those for spread footings or footings on piles, to prevent water from flooding foundation excavations during construction near surface water, and to shore up ground during pipe or drainage structure installations.

5.3.1 Shoring Field Investigation
Locate utilities and coordinate traffic control prior to any field investigation. Shoring investigations are often in close proximity to moving traffic, underground and overhead utilities. Extra care with respect to safety should be taken when performing these investigations.

The boring plan for a shoring investigation will vary based on the length and height of the proposed shoring. When performing a boring near the top of proposed shoring, boring depth should be a minimum of 2 times the height of the exposed shoring or until 5 feet of 50 blows-per-foot material is encountered below the shoring face, whichever is less. Borings located at the

bottom of the shoring face should extend to a depth equal to the height of the exposed shoring. For culvert shoring, the borings should extend to 2 times the height of the culvert below the floor of the culvert or until 5 feet of 50 BPF material is encountered, whichever is less. The number of borings may vary depending on the length of the proposed shoring, but there should be enough borings performed to characterize the site conditions.

5.3.2 Shoring Subsurface Inventory

The following information shall be included in the inventory report:

- Title Sheet
- Legend
- Plan view showing existing structures, shoring location, and borings
- Bore log reports

5.3.3 Shoring Foundation Recommendations

This section of the manual is forthcoming.

5.4 Retaining Wall Foundations

5.4.1 Retaining Wall Field Investigation

In-situ and laboratory testing and borings must be sufficient to characterize the subsurface conditions above, behind and beneath retaining walls. Subsurface information is required to determine appropriate wall type and analyze internal and external stability. In general, borings should be located at the wall face. However, if subsurface conditions vary significantly within a horizontal distance of the wall face equal to H, offsetting some borings or drilling additional borings in front of or behind the wall face is recommended. Borings for retaining walls are generally required every 50 feet with a minimum of one boring at each end of the wall. Borings must be planned to evaluate the material acting on the wall in all cut-wall designs. Boring depths should be in accordance with the following table:

Type of Wall	Boring Depth
Fill Walls (e.g., gravity, MSE, Concrete, Etc.)	2H
Cantilever walls (e.g., sheet pile, pile panel, soldier pile, etc.)	2H
Non-cantilever (e.g. soil nail, anchored, etc.)	H

The design engineer should be consulted prior to beginning field activities to determine the preliminary wall type, whether coring will be needed when rock is encountered before the planned boring depth is reached, and if changes to the general guidelines listed above are needed.

5.4.2 Retaining Wall Subsurface Inventory

The following information shall be included in the inventory report:

- Title sheet
- Legend
- Plan view showing retaining wall borings
- Profile along face of the wall showing the wall borings. Prefer that the wall envelope from structure design be used or show the top and bottom of wall on the profile.
- Soil test results

If there are specific conditions encountered during the investigation that need to be conveyed to the design engineer they should be included in a cover letter addressed to the Regional Design Engineer. These conditions should also be noted in the inventory report. (See Section 100-7)

If a wall is investigated during the roadway investigation then the borings should be shown in the roadway inventory graphics and in a separate structure inventory report when the Structure Design Unit requests the wall design. If the wall is investigated during a bridge investigation then the wall borings and profile can be included in the inventory report for the bridge.

5.4.3 Retaining Wall Foundation Recommendations

This section of the manual is forthcoming.

5.5 Sound Barrier Wall Foundations

Sound walls are structures intended to abate the sound coming from roadway traffic to residential or other populated areas. The walls are constructed of a series of panels held in place by piles. Sound wall designs included in the roadway plans should be confirmed with the Structures Management Unit to confirm the wall locations.

5.5.1 Sound Barrier Wall Field Investigation

Borings for sound wall foundation design should be sufficient to characterize the subsurface conditions below the wall. In general, borings should be located at the wall face. However, if subsurface conditions vary significantly within a horizontal distance of the wall face equal to the wall height (H), offsetting some borings or drilling some borings in front of and behind the wall face is recommended. Borings for sound walls are generally required every 100 ft, with a minimum of one boring at each end of the wall. Boring depths should be advanced to a depth equal to the wall height. Borings are not needed in sections where the proposed embankment height is greater than wall height. For sound walls in an area of cut, borings should be advanced to a depth equal to the wall height from the bottom of the sound wall.

5.5.2 Sound Barrier Wall Subsurface Inventory

If a wall is investigated during the roadway investigation, then the borings should be shown in the roadway inventory graphics and in a separate structure inventory report when the Structure Design Unit requests the wall design. A standalone sound wall inventory should include the following:

- Structure Subsurface Inventory Title Sheet
- Legend
- Plan view showing sound wall borings
- Profile along face of the wall showing the wall borings. Prefer that the wall envelope from structure design be used or show the top and bottom of wall on the profile.
- Soil test results

5.5.3 Sound Barrier Wall Foundation Recommendations

This section of the manual is forthcoming.

5.6 Building Foundations

Proposed buildings of all types require subsurface investigations for foundation design. The level and type of investigation is dependent on the type of building proposed, site conditions and design loads. In-situ testing, laboratory analysis and boring data must be sufficient to characterize the subsurface conditions and allow for efficient foundation design. The level of investigation will be determined by the Architect or Engineer requesting the investigation.

5.6.1 Building Foundation Field Investigation

Buildings with high design loads or buildings with critical safety considerations generally require SPT borings performed at each corner of the proposed foundation and at spacing intervals of no greater than 50 feet. When subsurface conditions vary to a degree that differential settlement may be problematic, additional borings should be performed at intervals less than 50 feet. Borings for buildings must be a minimum of 18 feet deep with a surface drive and SPT tests at 2.5 feet intervals to a depth of 10 feet unless otherwise directed by the engineer. Continuous Standard Penetration Tests may be required if conditions warrant. One SPT boring shall be performed at the center of the building with additional borings along the centerline of the building when spacing between the borings otherwise exceeds 50 feet.

Within certain Geologic regimes and for certain building types, one SPT boring for seismic analysis may be required by the requesting Architect of Engineer. The center-of-building boring location should be used as the seismic boring when one is required. For more information on the requirements for seismic borings, see Section 1613.5.5 at the following link.

http://ecodes.biz/ecodes_support/free_resources/2012NorthCarolina/Building/PDFs/Chapter%2016%20-%20Structural%20Design.pdf

Buildings investigations for low design loads may be requested to be performed with Sowers Dynamic Cone Penetrometers (DCP's). Sowers DCP tests must be performed in accordance with ASTM STP 399 for foundation investigation and design (see example report). Testing are performed at 1 foot intervals. The DCP test consists of driving the penetrometer through three 1.75 inch intervals and averaging the blow counts for the second and third intervals. Sowers DCP data is presented in a table in the body of the Building Foundation Subsurface Inventory report.

5.6.2 Building Foundation Subsurface Inventory

The Building Foundation Subsurface Inventory report should include the following:

- Structure Subsurface Inventory Title Sheet
- Legend
- Text Report (with Foundation Design provided by Design Engineer, when requested)
- Plan view of borings and test locations
- Profile through selected borings (Optional)
- Borelogs
- Soil test results

5.6.3 Building Foundation Recommendations

This section of the manual is forthcoming.

6 Pavement and Subgrade Investigations

The GeoPavement section of the Geotechnical Engineering Unit collects and reports data on existing pavement and subgrade for roadway projects where widening, new location or pavement reconstruction is planned. The Pavement and Subgrade Report provides data to the Pavement Management Unit necessary for pavement design and includes geotechnical recommendations for subgrade.

6.1 Pavement and Subgrade Investigation Planning

6.1.1 Review of Existing Data

A preliminary search on the route should be conducted prior to the investigation for existing pavement data such as, overlays, widenings pavement type, pavement thickness and base materials. Some resources are: PMSS Database maintained by the Pavement Management Unit, existing PDI reports, Straight-line diagrams and As-Built plans, etc. may be used.

Review HICAMS for nearby projects to find trends in pay item quantities that may be expected.

Review existing satellite imagery for additional information on the project. Satellite imagery can assist in determining the number of turn-lanes, widenings and condition of the pavement.

Review any existing subsurface inventory plans, design and construction recommendation reports.

6.1.2 Review of Proposed Design

Review the proposed design to determine the areas which will need to be investigated and locations to collect bulk soil samples for laboratory testing.

Review of the proposed design should include but not limited to plan views, cross-sections, profiles, and typical sections.

6.1.3 Field Reconnaissance

Prior to the beginning of field work, a field reconnaissance trip will be made to identify traffic control requirements, utility conflicts, condition of the existing pavement, areas of special geotechnical interest and the need for additional investigation work.

During the field reconnaissance, proposed sample locations will be marked in the field as white circles painted for the exact locations to be tested. Geotechnical Engineering Unit personnel will determine core and sample locations. Core locations and approximate stations will be marked with white paint.

6.1.4 Developing an Investigation Plan

Plan to test a number of locations in the original mainline pavement areas sufficient to characterize the typical pavement structure, base and subgrade materials typical of the project. Boring and sample locations for mainline investigation are generally required between three and five locations per mile.

Mainline widenings are sections of pavement added to the original mainline to increase the overall width of the travel lanes or to accommodate additional lanes. Sampling frequency should be similar to that of original mainline pavement

Interstate and paved shoulder investigations should consist of a sampling frequency of 500 to 2500 feet between locations.

Widenings for turn lanes must include a minimum of one test location per widening for widenings less than 250 linear feet with additional locations added for every 1000 linear feet of widening.

The Investigating Supervisor, or Consultant, will provide the following prior to the initiation of fieldwork.

- A list of core locations by approximate station and offset
- Total estimated pavement thickness to be cored reported in feet.
- Total auger depth reported in feet.
- Total dynamic cone penetrometer (DCP) depth reported in feet.

6.2 Pavement and Subgrade Field Investigation

All relevant roadway, pavement and subgrade information must be recorded on the field log(s) provided by the GeoPavement Section. Record stationing for coring locations to an accuracy of 3 feet if location data is not provided by GEU personnel, and the exact offset of the core measured from the outside or inside white line used to mark the edge of pavement in tenths of a foot.

6.2.1 Traffic Control and Utility Location

Prior to the field investigation, locate utilities and coordinate traffic control with the Division Traffic Engineer.

An email shall be sent to the Division Traffic Engineer to communicate the intentions of the consultant. A directory for division personnel can be found at (http://www.ncdot.gov/doh/) click on the division in the Map of NC and click directory. The email will include the following:

1. Description of the project and project limits, route that will be impacted by the investigation and description of the fieldwork.
2. Dates of the fieldwork
3. Request Lane Closure and time restrictions requirements
4. Description of proposed traffic control operations.
5. Approximate duration of the investigation.
6. Requirements for TIMS or other traffic management systems.
7. Name of traffic control contractor.

8. Request information about conflicting traffic control or construction operations near the project during the time of the investigation.
9. Request contact information for any active traffic control within the proximity of the investigation.

The following people shall be copied on the email:

1. Division Construction Engineer
2. Division Maintenance Engineer
3. Division Bridge Maintenance Engineer
4. Resident if active construction is within the project limits
5. Geotechnical Engineering Unit Project Engineer

Traffic control must be provided and may include flaggers, impact attenuator and any other necessary devices to protect workers, equipment and the traveling public in accordance with the *Manual on Uniform Traffic Control Devices (MUTCD), NCDOT Construction and Maintenance Operations Supplement to the MUTCD* and the *North Carolina Survey Crew Safety Supplement*.

Utility location notification must be provided to utility owners a minimum of three full business days prior to the start of any boring or excavation.

6.2.2 Pavement Distress

Record pavement distress descriptions and severity observed at each test location in accordance with the guidelines provided in the *Distress Identification Manual for the Long-Term Pavement Performance Program*, FHWA publication FHWA-RD-03-031, June 2003. The Distress Identification Manual is available free of charge from the Federal Highway Administration (FHWA) website

Use a 4 foot to 6 foot level to measure all rutting depth when the depth of rutting exceeds 1/4 inch. Place the level perpendicular to the rut and measure the gap between the bottom surface of the level and the asphalt. Report the depth of rutting to the nearest 1/8 inch.

6.2.3 Pavement Coring

Use drill equipment capable of coring pavement and auger sampling of subgrade. A thin walled core bit shall be used to collect intact, four-inch, pavement cores from all pavement layers and depths. A coring guide is often required to start the pavement core in a precise location. The typical coring guide consists of a 2x6 or 2x8 board with a precut hole at one end which is slightly larger in size than the core barrel. The coring guide should be held in place by the drill leveling jack and be long enough to extend to the marked coring location.

Obtain cores with a portion of the painted circle on the core unless conflicts, such as the presence of utilities, require relocation of the core. Note when core or sample locations must be relocated. When relocating cores, the relocated core should represent the same pavement structure that was intended by the original location.

Clearly mark any mechanical breaks in the pavement core. At core locations where cracking is present within the painted circle, include the cracked portion of the pavement within the core. If

the core is extracted in multiple pieces try to retain as much of the core as possible either by taping large pieces together or bagging asphalt material.

Label the core with station and lane then store the samples in two-foot, non-waxed, sturdy cardboard boxes designed for asphalt pavement cores. When cores are broken, each piece should be labeled and placed in the box in their in-situ layer sequence. All cores within a core-box should be oriented in the same direction, with the top-of core direction identified. Use spacers between individual core samples to keep them separate. Store cores from a single location in the same box whenever possible. Store the cores in boxes in the order of stationing.

The top and one side of the box shall be labelled with the project number, TIP, list of cores contained within the box, station and lane, consultant name, and dates that the cores were obtained.

6.2.4 Dynamic Cone Penetrometer Testing

Refer to ASTM D 6951 Section Five (5) for Dynamic Cone Penetrometer (DCP) equipment specifications. The 17.6-pound hammer is used in this method and the DCP must be capable of reaching subgrade depths of three feet. A schematic of the standard Dynamic Cone Penetrometer is shown in Appendix section A-18 of this manual.

After extracting the core, remove any remnant water in the core-hole left from the coring process. Advance the Dynamic Cone Penetrometer through the base material and any subsequent layers to a minimum of 18 inches into the subgrade in accordance with ASTM D 6951 Section six (6).

DCP Refusal is identified as penetration of less than 4 inches over 50 blows and may be used to terminate a DCP test within a given subgrade structure (ABC, Chemical Stabilization or Subgrade). When DCP Refusal is achieved in either ABC or Chemical Stabilization, an auger must be used to advance the boring through to the next structural layer or subgrade. Use caution not to disturb the underlying layer. When DCP Refusal is not achieved in subgrade, the DCP test must not be terminated prior to utilization of the entire DCP apparatus.

Individual blow penetrations should be recorded on a wooden stake with a pencil mark representing the resting position after each blow. Date, station, lane, cut or fill and datum (ABC, SG, etc.) must be provided on the stake for each test location. Blow penetrations may be grouped in intervals of 2, 5, or 10 when blow penetration is less than 2 mm with the number of blows per group identified on the stake. Individual blow penetration depths must be recorded in centimeters on the logs provided by the GeoPavement Section and grouped blows must be reduced to the individual blow penetration depths.

6.2.5 Sampling

After DCP testing is completed, advance a 4-inch continuous flight, solid stem auger to a minimum depth of 18 inches into the subgrade. Extract the auger and clean any subgrade contamination from ABC or drainage sand by scraping the surface of the soils on the auger flights. Collect representative base material and subgrade soil samples from the auger stem and store in quart-sized, sealable, plastic bags. Describe the soil and moisture content on the field log. Include soil origin, color, moisture content, density or stiffness and AASHTO classification. Also include relative amounts of accessory materials such as mica and organic debris. Obtain natural moisture content samples for all subgrade soils and store in moisture tins with a 16oz capacity. Label samples with TIP, sample number, station and location (ie: RT LN) and depth.

Determine the predominant soil types on the project and when chemical stabilization will be utilized, collect bulk soil samples to represent the design soil types. Collect one bulk sample per mile with a minimum of two bulk samples per project. Do not collect more than 6 samples per project unless otherwise specified. Collect approximately 80lbs of soil material in several large containers and label samples with TIP, sample number, station, offset and depth or material represented, such as subgrade.

All samples should be protected from exposure to excessive moisture, heat or other environmental factors that might change the soil parameters.

6.2.6 Pavement, Base and Subgrade Measurements

All cores shall be measured to the nearest one quarter inch. Use intact cores to measure the thickness of the pavement sections. When the core sample is not intact, use a “scratch stick” to locate the bottom of the pavement section within the core hole and measure the pavement in-situ.

Record the thickness of aggregate base course (ABC), chemically stabilized soils, drainage sand and other subsequent structural layers on the field log to the nearest quarter inch for all locations. After the location has been augured use a “scratch stick” to locate the bottom surface of the ABC or subsequent layers by applying pressure and scratching the sidewall of the bore hole to identify the boundaries between the structural layers. Measure the layer thicknesses with a tape or fold-out ruler. A diagram of “scratch stick” is available upon request.

Measure all lanes and shoulders present within the vicinity of the core location to the nearest half a foot if it is safe to do so. Curb and gutter does not need to be measured but its presence should be noted in field log.

Crown Measurements shall be taken using a string line and string bubble level. Place the string on the high end of the crown and pull across the lane. Raise the end of the string until bubble is in the center of the level. Take the measurement to the nearest quarter inch.

Note the presence of any water that is not the result of coring operations. Record the depth of water in the core hole on the field log measured from the pavement surface. Ensure water from the coring operation does not impact the native water level in the core hole.

6.2.7 Backfilling and Patching Requirements

Backfill bore holes with cuttings, sand or soil and dynamically compact the material to a depth below the bottom of existing pavement. Backfill the remainders of the bore hole with asphalt, cold patch and dynamically compact with a heavy, round, metal tamp comparable in size to the core hole. Finish the final surface so that it is smooth and even with the existing pavement. Finally, clear the pavement surface within work area of all soil, gravel and debris. Field personnel will be required to fix core locations that are insufficiently back-filled and repaired.

6.3 Pavement and Subgrade Final Report and Submittals

6.3.1 Field Investigation Reporting and Submittals

The Field Investigation Report must be sealed by a North Carolina Registered Professional Engineer or Licensed Geologist and shall include the following:

- Typed pavement investigation data sheets including Northings and Eastings of each coring location on NCDOT template.
- Labeled color pavement core photos on NCDOT template.
- DCP logs with cumulative depth measurements per blow reported in centimeters on NCDOT Template.
- Submit all cores and samples to the GeoPavement Section at the following address:
- Submit all DCP wooden stakes.

Geotechnical Engineering Unit
GeoPavement Section
1020 Birch Ridge Dr.
Raleigh, NC 27610

6.3.2 Pavement and Subgrade Investigation Final Report

In preparation for the Pavement and Subgrade Final Report, submit bulk samples for Optimum Moisture Content, Maximum Dry Density, Specific Gravity, Chemical Stabilization by Lime and Cement for unconfined compressive strength, quality and moisture content. If cracking extends through the entire length of the core, record the depth of cracking as full depth.

For Design-Build projects, the depth of cracking within the pavement cores must be measured and reported.

The Pavement and Subgrade Investigation Report will include the following.

- The predominant soil types are listed with references to AASHTO classifications and pertinent characteristic to the soil that could impact design or construction.

- A table of results for Chemical samples tested for unconfined compressive strength.

- A table of results for environmental parameters of the design soil types which will include a table to report the results from lab testing.

- Report any areas of Special Geotechnical or Pavement Interest

Design and Construction Recommendations

Embankment Stability

Geotextile for Pavement Stabilization

Subgrade Stability

- Recommendations for Lime Stabilization and Cement Stabilization rates.
- Stabilizer Aggregate and Aggregate Stabilization
- Aggregate Subgrade

Miscellaneous Recommendations

- Proof Rolling
- Blotting Sand

7 GeoEnvironmental Guidelines

7.1 GeoEnvironmental Overview

The GeoEnvironmental Section (GES) of the North Carolina Department of Transportation (NCDOT), Geotechnical Engineering Unit, is primarily responsible for identifying and managing properties and potential hazardous waste sites located within the proposed and existing Right-of-Way. This Section investigates potentially contaminated properties at the earliest possible stage of project development. The Section coordinates their investigation with the Planning Development and Environmental Analysis, Highway Design, Right-of-Way, and Construction Branches, as well as with state and federal environmental agencies. The Section makes recommendations based on current environmental regulations.

7.2 Consultant Selection Process

The GES engages pre-qualified private environmental consulting firms for the purpose of conducting GeoEnvironmental site assessments and remedial actions on properties which are to be, or have been acquired for right-of-way on transportation projects throughout the state. The selected firms work on a state-wide basis and provide labor, equipment, and materials necessary to perform the required work at designated sites. All work is performed according to current Federal, State, County, and Municipal regulations.

The Firm must be staffed with an adequate number of employees judged by the Department to be capable of performing a majority of the work required. The Geologists or Engineers in responsible charge of the work must be a Licensed Geologist or Professional Engineers in the State of North Carolina and must have good ethical and professional standing.

The GeoEnvironmental Section contracts environmental work to these firms based on history with the project, availability, workload, and past performance along with other criteria.

7.3 GeoEnvironmental Reports

There are several types of reports that are prepared by both the GES and the environmental consultant firms. Any reports documenting field activities, data, and laboratory analysis, whether prepared in-house by the GES or by an environmental firm, must be signed and sealed by a Licensed Geologist or Professional Engineer. Reports required are based on the extent and types of contamination. The following is a list of reports that are prepared and/or reviewed by the GES for submittal to other NCDOT branches or to the NCDEQ for regulatory review.

7.3.1 Hazardous Materials Report for Planning

The Hazardous Materials Report for Planning is normally prepared by the GES based on the initial in-house field reconnaissance, regulatory files search, etc. This report is most often prepared by the GES for the Planning Development and Environmental Analysis Branch (PDEA). The PDEA Branch holds “scoping” meetings where representatives from all units are asked for their input on possible alternatives for a proposed transportation project. The HAZMAT report identifies sites of concern within the project study area without performing an intrusive investigation. A copy of this report should be sent to the appropriate Design Engineer, Planning Engineer, Right of Way Office, Division Office and Geotechnical Engineering Unit field office, and other involved NCDOT personnel. A DGN file is delivered with the report showing the sites of concern.

7.3.2 Preliminary Site Assessment

The Preliminary Site Assessment (PSA) report is most often prepared by the PEF but is occasionally prepared in-house. The PSA is required by the GES to obtain necessary information to develop right of way acquisition recommendations and design recommendations. The PSA is the first intrusive investigation performed on a property. It is normally performed only within the NCDOT proposed right of way and easements, but occasionally it is requested that an entire parcel be assessed, due to the possibility of acquiring the remnant. The PSA documents field activities and draws conclusions based on actual laboratory data and other information obtained during the investigation. The GES requires that the firm-prepared PSA provides the horizontal and vertical extents of soil and/or groundwater contamination and estimates the volume of contaminated soils existing in the proposed right of way and easements.

7.3.3 Regulatory Reports

Various reports may be requested or required by regulatory agencies, most commonly NCDEQ. Refer to the regulatory guidelines for the most up to date information regarding these reports. Refer to the current NCDEQ guidelines for sampling and reporting requirements.

7.3.4 Right of Way Recommendations

Right of Way Recommendations are prepared based on the results of PSAs or other available site information. Recommendations typically distinguish between fee simple or permanent easement right of way. The recommendations also recommend withholding money from the real estate transaction for contaminated soil disposal expenses. Contaminated remnants are recommended not to be acquired.

7.3.5 Design Recommendations

Design recommendations offer options to eliminate or reduce conflicts with sites of concern. They can also be used to recommend sealed drainage or the hardening of utilities or other subsurface materials.

7.4 Discovery of Potentially Hazardous Waste or Contaminated Sites

Refer to Standard Provision 107-25 for contamination discovered during subsurface investigation, construction or maintenance operations.

8 Geotechnical Support for Design Build Projects

8.1 Design-Build Overview

Design-Build is a project delivery method that combines construction and preconstruction services into one contract. Design-Build may also combine construction engineering, inspection requirements and testing requirements for a project into the same contract. All activities are performed in accordance with standard NCDOT criteria, specifications and contract administration practices. The purpose of the Design-Build process is to provide an alternate method of delivery for transportation projects through which contractors and designers collaborate in design and other preconstruction activities to expedite construction, enhance innovation and constructability and reduce costs.

The Geotechnical Engineering Unit provides Geotechnical data for the Design-Build teams to use while developing the Technical Proposals in the form of the Geotechnical Inventory for Design-Build. Additionally, the Geotechnical Engineering Unit creates the Geotechnical Scope of Work and the Geotechnical Cost Estimate to provide standards for the Geotechnical Engineering required in the contract and for estimating the overall cost of the project.

8.2 Planning for the Design-Build Subsurface Investigation

Several factors influence the level of Subsurface Investigation that will be required for Design-Build projects. They include the amount of time before Letting, the certainty of the project design and the project complexity.

Investigation and report preparation time for Design-Build projects is generally short due to the accelerated Letting schedule associated with most Design-Build projects. As a result, it is often necessary to limit the amount of data collected to allow adequate time to process and present the data prior to shortlisting.

Additionally, due to the competitive nature of the Design-Build process, interpretation of the data is minimized in the Subsurface Inventory Report such that the teams are not influenced by the Department's or the consultant's judgement. Interpretations such as stratigraphy are not included in the subsurface plans for Design-Build projects.

Public hearing maps and preliminary design files are generally available to assist in planning and executing the Design-Build investigation.

8.3 Design-Build Field Investigation

Although the amount of data collected and the interpretation of the data are minimized for Design-Build projects, the requirements for the data collection remain the same as for traditional Design-Bid-Build projects. The field subsurface investigation criteria are the same as those for traditional design-bid-build projects with the exception of the level of investigation with respect to the number and spacing of boring locations. Requirements for utility location, permit applications, property owner contacts, borehole logging, backfilling and measurements are consistent with those for traditionally Let projects as described in the respective sections of this Manual for Roadways and Structures.

8.4 Subsurface Inventory Reports for Design-Build

No Geotechnical recommendations are made by the Department for Design-Build projects since the Design and Construction will be the responsibility of the Design-Build team which is awarded the contract.

The Subsurface Inventory for Design-Build differs from standard reports in the language of title sheet caution notice, the absence of stratigraphy and origin boundaries, the omission of cross sections and roadway recommendations or foundation design for structures. Subsurface Inventories for Design-Build will include the raw laboratory data.

8.4.1 Contents of a Design-Build Roadway Report

A Design-Build roadway project should be investigated to obtain soil characterizations and presence of rock within the proposed footprint. Other geotechnical points of interest should be investigated including, but not limited to: likely cut areas, wall locations, culvert extensions and embankments. If these items are shown on the plans then they may be investigated to the detail prescribed under Roadway and Structure Investigations, Sections 4 and 5. The appropriate Design-Build engineer should be consulted prior to and during the investigation, whether Statewide Design-Build or Division Design-Build are managing the project. Design-Build Roadway Inventory reports are a special case that will follow the guidelines of Sections 4.3.1 and 4.3.2, with the exception that the graphics are limited to the following:

- Title Sheet with “Design-Build” caution notice included
- Geotechnical Engineering Unit Legend Sheet
- Title Sheet from Roadway Plans
- Plan sheets with boring type and location
- Profiles or cross sections with boring data only
- Bore logs and Core logs
- Core photographs
- Laboratory results with relevant raw data

No Recommendations Report is generated for Design-Build Projects.

8.4.2 Contents of a Design-Build Structure Report

- Title Sheet with “Design-Build” caution notice included
- Geotechnical Engineering Unit Legend Sheet
- Plan sheet with boring type and location
- Profile with boring data only
- Bore logs and Core logs
- Core photographs
- Laboratory results with relevant raw data
- Site Photo(s)

8.4.3 Electronic Deliverables to Design-Build Unit

Each portion of a Design-Build project will be a stand-alone report with the following electronic deliverables. Depending on project schedule, electronic deliverables may be transmitted to the Design-Build Unit in staged delivery.

- An intelligent, searchable pdf which has been sealed through the "DocuSign" process.
- Original gINT files
- Raw laboratory data for samples such as those from Shelby Tubes
- Raw Dynamic Cone Penetrometer (DCP) data for Geopavement reports

8.5 Geotechnical Scope of Work

The Geotechnical Engineering Unit provides a Geotechnical Scope of Work to be submitted with the Request for Proposal to the short-listed teams. The Scope of Work includes the criteria which will be required of the winning team with respect to the level of investigation required of the team above that performed prior to the team's shortlisting.

Requirements set forth by the Geotechnical Scope of Work may include the following.

- Use of English or Metric Units
- Qualifications of the Geotechnical Engineer of Record
- List of required submittals, such as structure foundation, roadway or wall recommendations
- Standards by which any Geotechnical investigation work is performed
- Spacing and number of borings required for retaining structures and bridges
- Borehole spacing for roadway alignments
- Foundation Design parameters
- Specific design criteria such as slope recommendations
- Construction testing methods
- Construction Requirements
- Testing requirements such as PDA's
- Drilled Pier inspection criteria
- Proof rolling
- Site or Building Surveys
- Vibration Monitoring

8.6 Geotechnical Quantity Estimate

A Geotechnical Quantities Estimate is used by the State Estimating Engineer to estimate and evaluate the Geotechnical costs associated with the investigation, design and construction of the project. The estimates are generally made in the absence of data sufficient for design. The estimates shall be generated by the Project Design Engineer or Project Geological Engineer. The quantity estimate shall be submitted to the State Estimating Engineer in the Contracts Standards and Development Unit by the date that the Design Build Unit issues the first Request for Proposal (RFP) for the project. The document lists the Geotechnical quantities found in standard Recommendation Reports and include monetary estimates for additional geotechnical work to fulfill the requirements in the Scope of Work.

9 Geotechnical Engineering Consultant Information

9.1 Working with NCDOT and the Geotechnical Engineering Unit

9.1.1 Prequalification

Prior to performing work for the Department all Private Consulting Firms, Prime Contractors and Subcontractors (generally referred to as Private Engineering Firms, or PEF's) must be prequalified for the services to be provided. The prequalification process requires that the firm provide examples of recent, representative work performed by key personnel to be approved by Contract Services. The Geotechnical Engineering Unit provides the evaluation of the prospective PEF's work to Contract Services to assist in prequalification of Geotechnical PEF's. There are some exceptions to this policy when bidding on Small Business Enterprise Contracts. In general, prequalification of a PEF is specific to key personnel and may be revoked if the PEF ceases to employ the key personnel upon which prequalification was based.

9.1.2 Limited Service Contract Process

The Limited Service Contract Process is the typical method of procuring work from PEF's. The Professional Services Management Unit (PSMU) advertises the contract with stipulations from the Geotechnical Engineering Unit. Firms may then submit a Letter of Interest and the GEU will provide a rating of the PEF based on the last three years of work performed for the Unit. If no work has been performed by the interested PEF, they may submit a list of assets and key personnel for evaluation.

9.2 Project Process

9.2.1 General Project Expectations

As a contractor for the State of North Carolina's Department of Transportation, and as a professional firm, it is expected that any work performed in such capacity be ethical, follow industry and/or NCDOT standards and best practices for the field of work contracted. At all times work should be performed safely and efficiently, with the mindset that as a contractor to the State you are a steward of this State's citizens' tax monies. Therefore all work and designs should be cost effective not only in the short term, but during the life expectancy of the project. Due dates are expected to be met, so careful considerations should be made as to work schedule prior to accepting and signing the Notice To Proceed.

The GEU will expect that all persons involved in projects assigned by this Unit be properly trained in their respective positions and able to perform the work assigned. Field procedures, reporting and design shall follow those outlined in this manual or those referenced by this manual. If there are questions that are not addressed in this manual it is expected that you will ask.

The GEU is a professional organization and you should expect to be treated in a courteous and professional manner and the same is expected from you. Should you have any complaints with any GEU personnel please address them to their immediate supervisor.

Finally, safety shall be the number one priority when working for the Department. Any required Personal Protection Equipment should be in place prior to entering the work zone. Proper signage, warning lights, traffic control, etc. shall be in place as required by MUTCD or NCDOT policy prior to starting work. At no time should the safety of the traveling public or project personnel be put at risk.

9.2.2 Proposal Procedure

Upon Firm acceptance of a project the GEU will prepare a Request for Proposal (RFP) and an in-house cost estimate. After internal review the executed RFP will be forwarded to the Firm along with the proposal form and weekly project status report form. The Firm shall prepare a statement of understanding and work plan on company letterhead, complete the Excel proposal workbook, and combine into a single PDF file using the file name from the Excel proposal form. The Firm shall use current approved blended labor rates and current approved overhead and, if applicable, cost of capital. The proposal PDF along with the Excel proposal workbook file shall be emailed to PSMU by the due date specified in the RFP. Do not copy any GEU personnel.

PSMU will review the proposal for correct labor and overhead/cost of capital rates and notify the firm of any errors. Once PSMU has approved the proposal it will be forwarded to the GEU Contract PM for review and negotiations. When negotiations are completed and the GEU Contract PM has approved the Firm's proposal the Firm shall forward the revised proposal to PSMU for review. If the GEU in-house estimate was revised the GEU Contract PM will forward the revised in-house proposal to PSMU for review. After review PSMU will forward the Firm's proposal to the GEU Contract PM to generate an Account Initiation Request (AIR) from which PSMU will create the Purchase Order and issue the Notice to Proceed. When the NTP is issued the GEU Contract PM will generate the Excel Invoice Workbook and forward to the Firm.

9.2.3 Product Review

Products shall be submitted for review by the requested draft due date to the GEU Project Geological Engineer and the Project Design Engineer, henceforth Project Engineer, listed in the RFP. Please refer to the appropriate section of the manual for specific product requirements. To further aid in the review, all supporting analyses and calculations, MicroStation files, gINT files, laboratory results, etc. shall be submit to the Project Engineer via email if file size allows (DOT limit is 25mb), NCDOT FTS or the Firm's FTS.

Reviews will be performed using Adobe Acrobat Pro and Drawing Markups under the Comment tools. Once the review has been completed the GEU Project Engineer will return the annotated PDF along with the required resubmittal date. Any questions regarding comments should be directed to the appropriate Project Engineer.

9.2.4 Invoicing Procedure

At the completion of a billing cycle a firm may submit an invoice for work completed on a project. The GEU has implemented a process that ensures compliance with NCDOT's Office of Inspector General and also allows the GEU to track specific cost associated with a project. Adherence to this procedure is paramount to ensure prompt review and payment of invoices. We strive to process and pay invoices within 30-days of receipt.

The first step in the invoicing process is issuance of the Notice to Proceed, NTP. When the Professional Services Management Unit (PSMU) issues the NTP, check the following items for accuracy:

- Contract Work Type matches RFP (either Cost Plus Fixed Fee or Lump Sum)
- Limited Services Contract Number
- Vendor Number
- Firm Name

- Purchase Order amount matches final proposal amount (in some instances a 10% contingency will be added to cover additional unforeseen work)

If there are issues with any of the above items contact PSMU immediately.

Shortly after receipt of the NTP the Contract Project Manager will email an Excel Workbook containing the Invoice Cover Sheet, Invoice Summary, DBE-IS Form and instructions. This workbook is generated from our Project Status Database and is prepopulated with contract, project and PO information. Maintain a clean copy of this file as it must be submitted with each invoice. The workbook file name format is as follows: TIP_GEO_Project Type_Invoice_Firm Name_Project ID.xlsx. Save a copy of the Excel workbook and append the invoice number to the end of the file name. (Use this file name as the file name for the PDF of the invoice) On the Invoice Cover Sheet, Invoice Summary and the DBE-IS tab populate the green fields with the requested information and save the file. Create a PDF of the Invoice Cover Sheet, Invoice Summary and the DBE-IS form and name the PDF file the same as the Excel Workbook. The remainder of the invoice documents will be appended to this file in the following order:

9.2.5 Cost Plus Fixed Fee Invoices

1. Invoice on Company Letterhead with project information, a unique invoice number, payment amount and the remit to address
2. Detail of professional charges outlining personnel utilized, actual labor rate, calculated amount of overhead and calculated amount of cost of capital if applicable. Since the fee amount is fixed based on the proposal the entire fee may be billed at any time.
3. Detail of non-professional services/field services
4. Personnel time sheets or Project Detail Billing Report
5. Mileage logs for any vehicles used on the project where mileage charges or rental fees are being invoiced
6. Per Diem charges by Employee
7. Subcontractor invoices
8. Daily Activity Logs and boring logs for period being invoiced (send as separate PDF and note supporting documents in file name)

9.2.6 Lump Sum Invoices

1. Invoice on Company Letterhead with project information, a unique invoice number, payment amount and the remit to address
2. No backup documentation is required

Submit the invoice PDF and the Excel Invoice Workbook via email to the contract section supervisor. Please include the TIP, project type and the word “Invoice” in the subject line of your email to ensure prompt processing.