Chapter 4

SUBSURFACE INVESTIGATION GUIDELINES

Final

SCDOT GEOTECHNICAL DESIGN MANUAL

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CHAPTER 4

SUBSURFACE INVESTIGATION GUIDELINES

4.1 INTRODUCTION

A subsurface investigation is typically required for new or replaced structures, and roadway alignments involving earthwork. Examples of this include bridge replacements, widening of existing bridges and roadway realignments including widenings, retaining walls, box culverts, overhead sign-structures, sound barrier walls, and other miscellaneous structures.

This Chapter presents guidelines to be used in the development of subsurface investigations, for both preliminary and final. The actual type of investigation, depth, location, and frequency of all testing locations shall be based on project specific information. Subsurface investigations shall also indicate the testing intervals to be used if different from the standard intervals contained in this Chapter. The specific requirements for conducting field and laboratory testing are contained in Chapter 5 – Field and Laboratory Testing Procedures. The requirements of this Chapter shall be applied to in-house projects, projects designed by consultants, and design-build projects.

For projects designed by the RPGs, the subsurface investigation shall be prepared by the GDS prior to submission to the OMR or the RPG Design Manager for use in the General Services On-Call contract. The subsurface investigation plan shall also include all backup documentation used to develop the plan. This backup documentation includes, but is not limited to, previous soil borings in the general vicinity of the project, USDA soils maps, USGS topographic maps, aerial photographs, and wetland inventory maps. OMR is responsible for determining site accessibility and potential impacts to sensitive environmental areas. Site accessibility difficulties and impacts to sensitive environmental areas shall be discussed with the GDS prior to the relocation of any testing location. In addition, OMR is responsible for coordination of all traffic control issues for projects conducted under the Geotechnical On-Call contract.

For consultant projects, the Geotechnical Engineering Consultant shall submit to the GDS, for review and acceptance, a detailed subsurface investigation plan prior to the commencement of any field operations. The plan shall describe the soil or rock stratification anticipated as the basis of the planned exploration. The plan shall outline proposed testing types (borings/soundings), depths, and locations of all testing. The consultant's subsurface investigation plan shall conform to the requirements of this Manual. Frequently explorations must be conducted in sensitive environmental areas or in high hazard traffic areas, the consultant's exploration plan shall describe any special access requirements or traffic control requirements necessary to protect the interests of the Department during the field investigation phase. The Consultant is responsible for all special access requirements and traffic control. All traffic control shall conform to the latest Department guidelines.

4.2 SUBSURFACE INVESTIGATION

Subsurface investigations are typically conducted in two phases; preliminary and final. The location and spacing of all testing locations shall be coordinated between the preliminary and final subsurface investigations. The preliminary subsurface investigation should be conducted early enough in the design process to assist in the selection of foundation types and in determining the bridge/structure location and length and to identify areas requiring additional exploration during the final exploration. The testing locations for the preliminary subsurface investigation should be easily accessible and within the current Department Right-of-Way (ROW). The final subsurface investigation should account for the testing locations from the preliminary subsurface investigation. The requirements for the preliminary and final subsurface investigations are presented in the following sub-sections. The frequency and spacing of testing locations are presented in the following sections.

4.2.1 Preliminary Subsurface Investigation

The purpose of the preliminary subsurface investigation is to collect enough basic information to assist in development of preliminary plans. The contents of the Preliminary Geotechnical Engineering Report (PGER) for both bridge and road are presented in Chapter 21 - Geotechnical Reports. The testing locations should be located in readily accessible locations within the SCDOT ROW and should be, as indicated previously, coordinated with the final subsurface investigation. The preliminary subsurface investigation should include the collection of shear wave velocity data to depths of at least 100 feet from the existing ground surface. Shear wave velocity measurements may be extended to the practical limit of the equipment used to measure the shear wave velocities. These shear wave velocities will be used to determine the Site Class as described in Chapter 12 – Earthquake Engineering and the latest version of SCDOT *Seismic Design Specifications for Highway Bridges* including any addenda and/or amendments. The preliminary subsurface investigation will include a laboratory-testing program that will consist primarily of index testing. The laboratory-testing program shall also include grain-size analysis, including hydrometer, for soils within the upper 10 feet of the bottom of the water crossing. This analysis is required in determining the amount of scour predicted for the bridge over a body of water. The grain-size analysis shall be provided to the Hydraulic Engineering Group. Further electro-chemical testing shall be performed to determine the potential impacts of the soils, groundwater, and surface water on the structural components. In addition, a composite bulk sample shall be obtained of the existing embankment material. The composite sample shall have the following laboratory tests performed:

- Moisture Density Relationship (Standard Proctor)
- Grain Size Distribution with wash No. 200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
- Natural Moisture Content
- Consolidation-Undrained Triaxial Shear Test with pore pressure measurements (sample remolded to 95 percent of Standard Proctor value)

The information (i.e. field and laboratory data) collected during the preliminary subsurface investigation will be used to refine the final subsurface investigation. The GDS, for in-house and Geotechnical Engineering Consultant for all other projects, is responsible for developing a soil

exploration program and preparing the PGER. The bridge PGER provides general geotechnical recommendations based on limited soil information obtained from existing soil information and the preliminary subsurface investigation. The road PGER provides design recommendations for roadway earthwork and roadway structures. The general geotechnical recommendations are used to evaluate the DFR plans. After the DFR has been conducted, a detailed subsurface soil exploration is conducted based on the required structures defined during the DFR.

4.2.2 Final Subsurface Investigation

The purpose of the final subsurface investigation is to collect detailed subsurface information for use in developing geo-structural plans. The contents of the Bridge Geotechnical Engineering Report (BGER) and the Roadway Geotechnical Engineering Report (RGER) are presented in Chapter 21 - Geotechnical Reports. The testing locations shall be located along the proposed alignment of the roadway and bridge structure whether within or outside of the SCDOT ROW. The testing locations should be coordinated with the preliminary exploration to avoid testing in the same location and to assure that the entire construction area is adequately explored. The final subsurface investigation shall include a dilatometer sounding at each end bent. The information collected during the final subsurface investigation shall be used to develop the final foundation and earthwork recommendations for the project. The final subsurface investigation shall include any additional laboratory analyses. These additional laboratory analyses should include additional index property testing as well as sophisticated shear and consolidation testing.

4.3 SUBSURFACE INVESTIGATION METHODS

This section discusses the number, location and anticipated depth of all testing locations. As indicated previously, the preliminary and final subsurface investigations shall be coordinated to assure that the complete structure (whether bridge and roadway embankment) is adequately explored. The frequency and spacing of test locations will depend on the anticipated variation in subsurface conditions and the type of facility to be designed. A licensed surveyor shall locate (station, offset, and GPS coordinates (latitude and longitude)) and establish ground elevation at all soil test borings. The testing location frequency/spacing and depth criteria indicated below are the minimum requirements. Soil test borings (SPT borings), electro-piezocone (CPT) soundings and/or dilatometer (DMT) soundings are to be conducted at test locations. No more than half of the testing locations can be CPT or DMT soundings. DMT soundings should typically be limited to end bent areas only.

Soil test borings shall include the Standard Penetration Test (SPT). SPTs shall be conducted every 2 feet in the upper 10 feet of the subsurface (five samples) and every 5 feet below that depth. Since SPT samples are highly disturbed, these samples can only be used for index and classification testing. If high quality consolidation and shear strength data are required then undisturbed samples will be required. The collection of undisturbed samples (location and depth) shall be determined by the engineer-in-charge of the project. For projects located in the Lowcountry and Pee Dee Region (see Chapter 1) and for Aiken, Allendale, Bamberg, Barnwell, Calhoun, Lexington, Orangeburg and Richland Counties located in the Midland Regions, wash rotary drilling methods (see Chapter 5) shall be used. Variations to this requirement shall be made in writing and shall be forwarded to the PCS/GDS for review prior to approval.

In areas of difficult access beneath fill embankments, hand augers (HA) with dynamic cone penetrometers (DCPs) may be utilized to evaluate undercutting requirements. The DCPs should be performed approximately every foot.

4.3.1 Bridge Foundations

All bridges shall have soil testing taken at each end bent and at interior bents to meet the minimum geotechnical site investigation indicated below:

Table 4-1, Bridge Foundation Minimum Requirements

Bridge Foundation Type	Minimum Geotechnical Site Investigation
Pile Foundation	Minimum one testing location per bent[1]
Single Foundation - Drilled Shaft	Minimum one testing location per foundation location
Multiple Foundation – Drilled Shaft[2]	Minimum two testing locations per bent location
Shallow Foundation – Founded on Soil	Minimum three testing locations per bent location
Shallow Foundation – Founded on Rock	Minimum two testing locations per bent location

[1]Spacing between testing locations may be increased, but shall be approved prior to field operations and shall include justification, spacing may not exceed 100 feet.

[2]Minimum one testing location per bent in Lowcountry and Pee Dee Regions and in Aiken, Allendale, Bamberg, Barnwell, Calhoun, Lexington, Orangeburg and Richland Counties in Midlands Region.

All boring/soundings taken for deep foundations shall extend below the anticipated pile or drilled shaft tip elevation a minimum of 20 feet or a minimum of four times the minimum pile group dimension, whichever is deeper. All boring/soundings taken for shallow foundations shall extend beneath the anticipated bearing elevation as indicated in the following table:

Table 4-2, Minimum Depth of Investigation

Spread Footing Case	Minimum Testing Depth[1]
$L \leq 2B$	2B
$L \geq 5B$	4B
$2B \leq L \leq 5B$	3B

[1]Beneath the anticipated bearing elevation

L = Length of spread footing; B = Width of spread footing (minimum side dimension of footing)

All bridge foundations (deep and shallow) bearing on rock shall have a minimum of 20 feet of rock coring or the minimum testing depth requirements listed above, whichever is greater.

4.3.2 Retaining Walls

All retaining walls shall have one testing location performed at least every 75 feet along the wall line, if the wall is within 150 feet of bridge abutments. Retaining walls more than 150 feet from the bridge abutment shall have one testing location performed at least every 200 feet along the wall line. Anchored walls shall have testing locations at both the wall line and within the anchored zone at the same intervals specified above. The testing locations within the anchored

zone shall be located approximately a distance equal to the height of the wall from the wall line. All testing locations shall be performed to a depth of at least twice the height of the wall beneath the anticipated bearing elevation or to auger refusal, whichever is shallower.

4.3.3 Embankments

All roadway embankments shall have one testing location performed at least every 500 feet along the roadway embankment. All testing locations shall be performed to a depth of at least twice the height of the embankment beneath the anticipated bearing elevation (i.e. to a depth sufficient to characterize settlement and stability issues) or to auger refusal, whichever is shallower.

4.3.4 Cut Excavations

All cut excavations shall have one test location performed at least every 300 feet along the cut area. All testing locations shall be performed to a depth of at least 25 feet below the anticipated bottom depth of the cut or to auger refusal, whichever is shallower. In addition, a composite bulk sample shall be collected from the area of the cut excavations. The composite sample shall have the following laboratory tests performed:

- Moisture Density Relationship (Standard Proctor)
- Grain Size Distribution with wash #200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
- Natural Moisture Content
- Consolidation-Undrained Triaxial Shear Test with pore pressure measurements (sample remolded to 95% of Standard Proctor value)

4.3.5 Culverts

All new crossline culverts (pipe, box, or floorless) shall have a minimum of one test location at each end of the culvert and at every 100 feet of the new crossline culvert. Crossline culvert extensions shall have a minimum of one test location at each extension. For crossline culvert extensions greater than 50 feet, testing locations shall be spaced every 50 feet. All testing locations shall extend to a depth beneath the anticipated bearing elevation of at least twice the height of the embankment or in accordance with the bridge spread footing criteria, whichever is deeper. Testing may be terminated above these depths if auger refusal is encountered.

4.3.6 Sound Barrier Walls

Sound barrier walls may be supported by either shallow foundations or deep foundations depending on the foundation system selected by the contractor. For sound barrier walls located on top of a berm, the testing locations shall extend a minimum of twice the berm height plus twice the height of the proposed sound barrier wall for shallow foundations. For sound barrier walls not located on top of a berm, the testing locations shall extend a minimum of twice the height of the proposed sound barrier wall for shallow foundations. If deep foundations are used to support the sound barrier walls, the testing shall extend a minimum of 20 feet beneath the anticipated deep foundation tip elevation. Testing locations for sound barrier walls shall be

placed at the beginning and ending of the wall, at the location of major changes in the wall alignment and at a minimum spacing of 200 feet between these locations.

4.3.7 Miscellaneous Structures

Miscellaneous structures such as overhead signs and light poles shall have a minimum of one test location performed per foundation location unless directed otherwise by the PCS/GDS. All test locations shall extend to the same depth criteria as specified for the bridge test locations for the same type of foundation.

4.3.8 Pavement Structures

Subsurface investigation requirements for pavement structure design vary with location, traffic level, and project size. Requirements for pavement structure design subsurface investigations are provided in SCDOT's *Pavement Design Guidelines* (latest edition), which is published by the OMR. Contact the OMR Geotechnical Materials Engineer for further information.