Consultant Specifications for Subsurface Investigation & Geotechnical Analysis and Design Recommendations

Mn/DOT Geotechnical Section - Office of Materials & Road Research

http://www.mrr.dot.state.mn.us/geotechnical/foundations/tcontract.asp

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1.0 General Requirements for Subsurface Investigation

The subsurface investigation will consist of

1) a study of preliminary plans and temporary staging plans
2) an on-the-site inspection
3) planning the test boring and sampling program
4) performing foundation soils borings
5) performing Standard Penetration Tests
6) obtaining undisturbed soil samples
7) obtaining rock core when appropriate
8) measuring ground water levels
9) preparing a field boring log
10) perform laboratory tests on soil samples
11) produce a final boring log summarizing all drilling and testing information
12) performing Cone Penetration Test (CPT) Soundings (where needed)

The Consultant will review preliminary plans and temporary staging plans to ascertain alignment, topography of site, location of bridge abutments and piers, profile of proposed bridge footing and approach embankments, location of utilities in the vicinity of the proposed soils borings, and general location of structure with regard to existing roads and waterways.

The on-the-site inspection will consist of a general engineering reconnaissance of soil and geologic conditions existing at the site. The contemplated effect of the proposed construction indicated by the preliminary plans will also be reviewed. Observations will be made and appropriate notes recorded on performance of existing embankments in the immediate vicinity, differential settlement, foundation failures, active landslides, bedrock exposure, limits of questionable foundation areas, stability of adjacent earth or man made masses and possible damage to existing structures and facilities. The possible location of borings will also be established during the field reconnaissance study.

1.1 Foundation Boring Locations

Foundation Borings will be selectively located by the Consultant on the basis of field observations, design considerations and the minimum number of borings specified on the following table. Location and spacing of borings will be as topography, site conditions, soil conditions and design factors dictate. However, the borings will be no further than 30 ft. from the proposed structure location.

Before the subsurface investigation begins, the Consultant will provide the State with a proposed boring plan for review and approval. The boring plan will show the location of all proposed borings (with labels) in relation to in-place topography and proposed structures and alignments. As the boring program progresses, the location of borings will be reviewed with consideration given to changing borings to more strategic locations or changing the number of borings.

The following table outlines the minimum number of foundation borings and/or maximum boring spacing for different structures.

Table 1: Minimum number of borings and minimum depth

Application	Minimum number of Exploration Points	Minimum Depth of Exploration
Shallow Foundations	(1) For bridge substructure widths less than or equal to 100 ft., a minimum of one SPT boring per substructure (2) For bridge substructure widths greater than 100 ft., a minimum of two SPT borings per substructure (3) For Large Box Culverts (80 sq. ft. of opening or greater), a minimum of two SPT borings per structure for culverts less than or equal to 300 ft. in length and a minimum of three SPT borings for culverts greater than 300 ft. in length (4) For Buildings, a minimum of one SPT boring at each building corner and one SPT boring near the center of the building (5) For vertical structures (light towers, radio towers, etc.) a minimum of one SPT boring per substructure	Depth of exploration will be: (1) great enough to fully penetrate unsuitable foundation soils (e.g., peat, organic silt, soft fine grained soils) into competent material of suitable bearing capacity (e.g. stiff to hard cohesive soil, compact to dense granular soil or bedrock); and (2) at least to a depth where stress increase due to estimated footing load is less than 15% of the applied stress at the base of the footing; and (3) in terms of the width of the footing: at least two times for axis-symmetric case and four times for strip footing (interpolate for intermediate cases); and (4) if bedrock is encountered before the depth required by item (2) above is achieved, exploration depth should be great enough to penetrate a minimum of 10 ft. into the bedrock, but rock exploration will be sufficient to characterize compressibility of infill material or near horizontal to horizontal discontinuities
Deep Foundations – Driven Piles	1) For bridge substructure widths less than or equal to 100 ft., a minimum of one SPT boring per substructure (2) For bridge substructure widths greater than 100 ft., a minimum of two SPT borings per substructure (3) For Large Box Culverts (80 sq. ft. of opening or greater), a minimum of two SPT borings per structure for culverts less than or equal to 300 ft. in length and a minimum of three SPT borings for culverts greater than 300 ft. in length (4) For Buildings, a minimum of one SPT boring (5) For vertical structures (light towers, radio towers, etc.) a minimum of one SPT boring per substructure	Depth of exploration will be: (1) In soil, depth of exploration will extend below the anticipated pile tip elevation a minimum of 10 ft. (2) Suggested criteria for meeting (1) above is to advance boring to a depth criteria that meets Mn/DOT's *2,500 Aggregate N values. (3) All borings will extend through unsuitable strata such as unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse grained soils to reach hard or dense materials. (4) For pile bearing on rock, a minimum of 10 ft. of rock core will be obtained at each SPT boring to verify that the boring has not terminated on a boulder.

Deep Foundations – Drilled Shafts	(1) For bridge substructure widths less than or equal to 100 ft., a minimum of one SPT boring per substructure (2) For bridge substructure widths greater than 100 ft., a minimum of two SPT borings per substructure (3) For Large Box Culverts (80 sq. ft. of opening or greater), a minimum of two SPT borings per structure for culverts less than or equal to 300 ft. in length and a minimum of three SPT borings for culverts greater than 300 ft. in length (4) For Buildings, a minimum of one SPT boring (5) For vertical structures (light towers, radio towers, etc.) a minimum of one SPT boring per substructure	(1) In soil, depth of exploration will extend below the anticipated pile tip elevation a minimum of 10 ft. All borings will extend through unsuitable strata such as unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse grained soils to reach hard or dense materials. (2) If bedrock is encountered before the depth required by item 1 above is achieved, exploration depth should be great enough to penetrate a minimum of 10 ft. below the anticipated shaft tip elevation.
Retaining Walls	(1) A minimum of one SPT boring per retaining wall (2) For retaining walls more than 100 ft. in length: (a) one SPT boring spaced every 400 ft. and one CPT sounding every 100 ft.; or (b) one SPT boring spaced every 150 ft. (3) For anchored walls, additional SPT borings or CPT soundings in the anchorage zone spaced at 200 ft. (4) For MSE and Soil Nail Walls additional SPT borings or CPT soundings at a distance of 1.0 to 1.5 times the height of the wall behind the wall face spaced at 200 ft.	(1) Investigate to a depth below bottom of wall three times the wall height or a minimum of 10 ft. into bedrock (2) Exploration depths should be great enough to fully penetrate soft highly compressible soils (e.g. peat, organic silt, soft fine grained soils) into competent material of suitable bearing capacity (e.g. stiff to hard cohesive soil, compact dense granular soil, or bedrock).
Embankment Foundations over highly compressible materials (e.g. peat, organic silt, soft fine grained soils)	(1) A minimum of one SPT boring every 200 ft. (erratic conditions) to 400 ft. (uniform conditions) of embankment length along centerline of embankment (2) At critical locations, (e.g. maximum embankment heights, maximum depths of soft strata) a minimum of three SPT borings in the transverse direction to define the existing subsurface conditions for stability analyses (3) For bridge approach embankments, at least one SPT boring at abutment locations	(1) Embankment depth will be, at a minimum, equal to twice the embankment height unless a hard stratum is encountered above this depth. (2) If soft strata are encountered extending to a depth greater than twice the embankment height, the exploration depth should be great enough to fully penetrate the soft strata into competent material (e.g. stiff to hard cohesive soil, compact to dense granular soil, or bedrock)
Cut Slopes	(1) A minimum of one SPT boring every 200 ft. (erratic conditions) to 400 ft. (uniform conditions) of slope length	(1) Exploration depth will be, at a minimum, 15 ft below the minimum elevation of the cut unless a hard stratum is encountered below the minimum elevation

	(2) At critical locations (e.g. maximum cut depths, maximum depths of soft strata) a minimum of three SPT borings in the transverse direction to define the subsurface conditions for stability analyses (3) For cut slopes in rock, perform geologic mapping along the length of the cut slope	of the cut. (2) Exploration depth will be great enough to fully penetrate through soft strata into competent material (e.g. stiff to hard cohesive soil, compact to dense granular soil or bedrock (3) In locations where the base of the cut is below ground-water level, increase depth of exploration as needed to determine the depth of underlying pervious strata.
Cable Median Barrier Anchor	(1) A minimum of one SPT boring for each anchor location (2) Boring must be within 25 ft. of anchor location	(1) Exploration depth will be a minimum of 25 ft. below the existing ground surface

*2500 Aggregate SPT N60 blows:

Bridge foundation undisturberd borings will be taken to a depth below footing elevation that will produce a total blow count of 2,500, based on N values corrected for a standard hammer energy of 60% (N_{60}).

Total blow count will be determined by averaging the N_{60} values throughout a uniform layer (with similar blow counts) and multiplying by the thickness of the layer in feet.

The region above the footing elevation and areas where blow counts are less than 15 blows per foot will be disregarded (disregard blows and layer thickness). For the purpose of determining depth of borings and for those structures for which no footing elevations are given herein, the footing elevation will be assumed to be 5 feet below the in place ground elevation.

Borings will be made to the depth specified regardless of the type of material and water condition encountered, including boulders, fill, other types of obstructions and artesian conditions.

High blow counts that are not representative of the strata from which they were taken are to be recorded but disregarded (for example, driving against a boulder).

Penetration resistances in hard, uniform material where penetration is less than 1.0 feet per 50 blows, will be calculated as though the sample had been driven the entire foot. For example, if penetration is 0.5 feet in 50 blows, the blow count in this case would be 100. (This is for calculating criteria only, the actual penetration resistance of 50/.5 foot will be noted on the field log.)

If the required blow count of 2,500 is reached and the blow count on the final sample is less than ½ that of the sample preceding it, sampling will continue to the next zone of harder material. A minimum of two samples will be obtained in the harder material.

If refusal on possible bedrock or boulders or detached bedrock is encountered before the required blow count of 2,500 is reached, the rock will be plug drilled or cored a minimum of 10 ft. to discern between bedrock and a boulder field. For plug drilling, wash samples (cuttings) will be taken and retained for rock classification and formation and member information. For rock coring, see section 1.7.

All bridge borings in soil will be carried to a depth of not less than fifty feet below proposed bridge footing elevation unless bedrock is encountered.

1.2 Drilling Methods

Either the Rotary Drill Method or Hollow Stem Auger Method will be considered satisfactory for advancing the boring and recovery of undisturbed samples. The Rotary Drill Method will be conducted as described in section 7.5.1.4 in the AASHTO Manual on Subsurface Investigations (1988). The use of casing will be at the discretion of the Consultant, except that the casing shoe or bit will never extend below the top of any interval to be sampled. All casing will be removed upon completion of the boring. The Hollow Stem Auger Method will be conducted as described in section 7.5.1.5 in the AASHTO Manual on Subsurface Investigations (1988).

1.3 Cone Penetration Test

Cone Penetration Test (CPT) Soundings will be taken at designated locations to supplement the conventional foundation boring program. CPT soundings should be performed in accordance with ASTM D5778. Data to be collected includes corrected tip resistance, side friction and pore water pressure. This data will be presented in graphical and tabulated format and will include an interpretation of the soil behavior type. An electronic copy of the final CPT logs will be submitted to the State's Geotechnical Section (Maplewood Lab). This electronic file should be compatible with the gINT© for Windows computer program and should match the format used by the Mn/DOT Geotechnical Section. Electronic templates for the boring log program are available at http://www.mrr.dot.state.mn.us/geotechnical/foundations/tcontract.asp or by contacting Rich Lamb at 651-366-5595.

1.4 Modified Standard Penetration Test

Standard Penetration Test (SPT) and Split-Barrel Sampling of soils will proceed in accordance with ASTM Designation: D 1586-84 (Reapproved 1992) with the following exceptions:

> The Consultant will calibrate the hammers annually such that each hammer delivers between 60-70% of the potential energy of the system (2520-2940 in. lbs.) The calibrated hammer blow counts should be denoted as N_{60} on the final boring logs. In addition, the calibrated hammer efficiency and last calibration date will be noted on the first page of each boring log (in the remarks column). As an example, the text will read “SPT hammer calibrated to 65% efficiency on 3/11/2000”. Energy tests should be performed at depths greater than 25 ft. and in soils with blow counts ranging from 10-50 bpf.

1.5 Soil Sampling

Thin-Walled Tube Sampling of Soils will proceed in accordance with ASTM Designation D 1587-74, with the following exceptions.

A) Thin wall samplers will be three inches in outside diameter.
B) The length of push will not exceed 24 inches.

Type of sampling will be as indicated in the following table:

Table 2

Soil Type	**Type of Sampling**
Granular Soils	Split-tube
Plastic (cohesive) Soils (N<30)	Alternate split-tube and thin-wall
Plastic (cohesive) Soils (N>30)	Split-tube
Organic Soils	Thin-wall

Sampling will start at the in place ground elevation or at the bottom of water when the ground is submerged. The frequency of soil sampling will be as follows:

Table 3

Depth	**Sample Rate**
0-50 ft.	2 samples per 5 ft. interval
50-100 ft.	1 sample per 5 ft. interval
100 ft.	1 sample per 10 ft. interval

1.6 Boring Depths
See Table 1

1.7 Diamond core drilling
Diamond core drilling for site investigation will proceed in accordance with ASTM Designation D 2113-70 (or the most current specification) with the following exceptions:

- Either NQ or NMX Barrel sizes may be used
- The method of plug drilling will be at the discretion of the Consultant.
- Wash samples will be taken during the period of plug drilling.

1.8 Field Logs
A field log setting forth pertinent information will be prepared by the Consultant for each boring. Field boring logs will be prepared in ink and a copy will be included with the final project report. The field boring log will include the following:

1) The project identification and bridge number.
2) Location of boring referenced to centerline survey stationing measured to nearest foot.
3) Method of drilling and sampling employed.
4) Diameter of boring.
5) Date of start and completion of boring.
6) Name of driller and crew.
7) Preliminary ground surface elevation of boring to nearest 0.5 feet (if vertical reference is available). Final surveyed elevation should be reported on the final boring log.
8) Sheet number and total number of log sheets for each boring.
9) Definition of all symbols that are not otherwise self-explanatory.
10) Description of each layer encountered and sample obtained; including information pertaining to color, strength, moisture content, composition, and degree of compactness.
11) Field number of each sample, type of sample and depth at which taken.
12) Depth at which obstacles were encountered in advancing the boring. Depth to which casing was driven.
13) Number of blows in six inch increments required to drive sampler during Standard Penetration Test.
14) Length of each run for rock core and footage of core recovered.
15) Record of type of cuttings flushed to surface while plug drilling.
16) Depth where drilling mud return circulation was lost.
17) Changes occurring in rate of advance of bit.
18) Reason for abandoning boring in the event specified depth was not reached.
19) Water measurement data.
20) Description of drill rig and type of SPT hammer used.
21) Any other unusual conditions encountered during drilling and sampling

1.9 Borehole Sealing

All foundation borings and CPT soundings will be back filled or sealed in accordance with the Minnesota Rules, Chapter 4725, Rules Relating to Wells and Borings, effective May 10, 1993, including the revisions of November 15, 1993 and any current revisions. Please note that the required owner’s copy of the sealing records should be sent to Gary Person at the following address:

Gary Person, Foundations Engineer
Geotechnical Engineering Section
Minnesota Department of Transportation
1400 Gervais Avenue
Maplewood, MN 55109

Also, all holes will be back filled in such a manner as to ensure against subsequent damage to farm tilling and harvesting equipment and subsequent settlement of the backfilling resulting in a hole hazardous to persons, animals, or equipment. If flowing artesian conditions are encountered it will be the Consultant's responsibility to see that the flow is stopped, that the source is properly sealed against future leakage, and to prevent water from infiltrating other strata.

1.10 Borehole Site Cleanup

Upon completion of the field investigation work, all surplus material, temporary structures and debris on land and water resulting from the work will be removed and the premises left in a neat, orderly condition. Any improvements disturbed during boring operations will be restored in kind and character existing before the work was started.

1.11 Property Access

The Consultant will obtain permission from property owners to take all borings which are located on property not currently owned by Mn./DOT. All railroad charges such as for flagging will be the responsibility of the Consultants.

1.12 Utility Clearance

The Consultant will contact utility companies prior to taking borings and will assure that in place utility structures will not be encountered. The Consultant will be responsible for any claims resulting from damage to any structures both above and below ground.

1.13 Roadway Safety

Prior to starting work on Mn/DOT projects, notification will be given to the District/Metro Division Soils Engineer. In addition, the Consultant will be responsible for providing proper temporary traffic control when working on Mn/DOT Right-of-Way. Consultant should obtain and follow the guidelines in the most recent version of the Mn/DOT Field Manual entitled "Temporary Traffic Control Zone Layouts".

1.14 Borehole Survey Information

Preliminary and final survey information will be included for each borehole. This information will include the following:

- a horizontal and vertical tie in to permanent structures (can be in the form of a sketch)
- NAD 83 Minnesota County Coordinates or Universal Transverse Mercator Coordinates (UTMs) (Zone 15E)
- MSL (mean sea level) reference elevations (NAVD 88) taken from know benchmarks accurate to ±0.1 ft.
- station offset information for current alignment designators (if required)

2.0 Laboratory Soil Testing and Final Boring Log

The Consultant will perform laboratory soils tests of sufficient number and type to ascertain the nature, strength, conditions, stability and consolidation characteristics of soil conditions existing at the site which influence the proposed design and construction activities.

The following table shows the minimum number and lab tests to be performed for each sample type. Additional lab tests may be required to determine additional soil properties such as strength, compressibility, and permeability.

Table 4

Sample Type	**Minimum Required Lab Tests**
Thin Wall	One (1) unconfined compression test One (1) moisture test One (1) unit weight determination
Split-Tube	One (1) moisture test

2.1 Soil and Rock Classification

Every sample taken by the test boring and sampling program will be inspected visually, manipulated by the hands and given a description with consideration being given to the driller's description of the material and particularly to soil layer changes. All mineral soils will be classified according to the soils triangle in Figure 3-2.15 of the State's *Geotechnical Manual*. Each layer and/or sample will have a description pertaining to color, moisture content, relative density, and relative consistency. Method of description will be at the discretion of the Consultant except that all symbols and all descriptions be defined on the finished boring log. Organic soils will be described as indicated below.

Table 5

Percentage of Organic Matter (by weight)	**Description**
2-5	Slightly Organic
6-10	Organic
11-25	Highly Organic
>25	Peat

Soils described as peat will also be identified in section 2-1.0 (16) of the State's Geotechnical and Pavement Manual.

All rock samples taken will be examined and depending on the type of sample retrieved, the appropriate engineering and geological characteristics described. Details, definitions and accepted abbreviations of materials characterization terminology can be found in Mn/DOT’s *Geotechnical Manual*.

- Augured washed samples: Lithology and/or rock type (with modifying mineral descriptions when possible), grain size and/or texture, color, name of formation and member (when possible).

- Split-tube samples: Lithology and/or rock type (with modifying mineral descriptions when possible), weathering, grain size and/or texture, relative hardness, color, name of formation and member (when possible).

- Core: Lithology and/or rock type (with modifying mineral descriptions when possible), weathering, grain size and/or texture, minor constituents, relative hardness, geological discontinuities (including voids, and joint or bedding spacing and angle), color, name of formation and member (when possible).

In addition each rock core interval will be measured and the following properties determined: 1) Percent Recovery (%REC), 2) Rock Quality Designation (RQD) be determined and reported as a percentage (%RQD), 3) Average Core Length (ACL). Discontinuities in the form of core breaks will also be identified and recorded as the number of Fractures per Two-foot Interval.

2.2 Moisture Content Tests

Laboratory determination of moisture content of soil will proceed in accordance with AASHTO T265-93. The moisture content will be determined for every sample procured by the test boring program, except wash samples and tailings.

2.3 Unconfined Compression Tests

Unconfined Compressive Strength of Cohesive Soil will proceed in accordance with AASHTO T208-92, with the following exceptions:

A) Specimens will have a minimum diameter of 2.8 inches.
B) Humidity Room and Vertical Lathe will not be required.
C) Specimens will be free of tailings, seams, cracks and other characteristics which will affect the strength value obtained. No specimens will be obtained from the upper 6 inches of thin-walled sample or from areas of noticeable disturbance caused by the sampling operation.
D) Testing remolded specimens will not be required.
E) Testing by the Controlled Stress Method will not be required.
F) Preparing a load-strain graph will not be required.
G) Unconfined compressive strength will be determined from the maximum load value obtained or the load at 15 percent strain, whichever is secured first.

A minimum of one unconfined compression test will be conducted on each thin-walled sample of cohesive soil insofar that sufficient undisturbed specimens are obtained. An undisturbed residual portion of each sample not used in performance of the unconfined compression test will be retained and stored by the Consultant for future consolidation or triaxial tests or for rechecking purposes. Residual samples will be sealed, packaged and stored to preserve their original condition.

2.4 One Dimensional Consolidation Tests

One-dimensional consolidation properties of soils will proceed in accordance with AASHTO T216-94. The choosing of samples for consolidation testing will be at the discretion of the Consultant except that the samples will be selectively chosen to represent major compressible soil strata on the overall project. Consolidation testing will not be performed 1) when the natural moisture content of the soils are near the plastic limit, 2) on soft soils near the ground surface (depth less than 10 feet) which will be excavated, and 3) when the proposed additional loading is 0.25 tons or less.

2.5 Triaxial Compression Tests
Strength Parameters of Soils by Triaxial Compression will proceed in accordance with AASHTO T297-94, consolidated undrained method with pore water pressure measurement. The choosing of samples for triaxial testing will be at the discretion of the Consultant. Three different consolidation pressures will be used to define a failure envelope. When Mohr's circles have been plotted and a line cannot be constructed tangent to three circles, an additional test will be performed at increased consolidation pressure. Triaxial testing will not be performed on soft soils near the ground surface (depth less that 10 feet) which will be excavated.

2.6 Unit Weight Tests
The moist unit weight will be determined in conjunction with unconfined compression and triaxial compression tests.

2.7 Specific Gravity
Specific Gravity of Soils will proceed in accordance with AASHTO T100-95. The specific gravity of soils will be determined in conjunction with consolidation tests.

2.8 Atterberg Limit Tests
Liquid Limit of soils will proceed in accordance with AASHTO T89-96. The Liquid Limit will be determined for cohesive soils with N_{60} values of less than 15 and not to exceed two Liquid Limit tests per bore hole. The choosing of samples for Liquid Limit tests will be at the discretion of the Consultant, except that the samples will represent major soil strata on the overall project. Plastic Limit and Plasticity Index of Soils will proceed in accordance with AASHTO T90-96. The Plastic Limit and Plastic Index will, be determined for all samples that are tested for Liquid Limit.

2.9 Grain Size Analysis
Particle-size analysis of soils will proceed in accordance with AASHTO T88-93. The particle-size analysis will be determined for all samples that are tested for Liquid Limit.

2.10 Organic Content Tests
Organic Matter Content of Soils will proceed in accordance with AASHTO T267-86. The choosing of samples for organic matter content will be at the discretion of the Consultant. Samples for organic matter testing will be selectively chosen to represent major soil strata on the overall project that are black in color or described as organic.

2.11 Final Boring Log
A finished boring log based on the driller's field boring log and containing all laboratory test results will be prepared for each test boring. The boring log format will match that used by Mn/DOT. The finished boring log <u>title page</u> will contain

1) boring number
2) project number
3) bridge number, if applicable
4) centerline station and offset distance
5) surface elevation
6) NAD83 county coordinates
7) latitude and longitude
8) type of drilling equipment
9) SPT hammer type (auto or manual)
10) SPT hammer calibration information (in notes column)
11) Drillers notes describing whether drilling mud was used
12) definition of all symbols and terms that are otherwise not self-explanatory;
13) sheet number and total number of log sheets for each boring
14) date of drilling.

The finished boring log <u>body</u> will contain:

1) depth scale
2) horizontal line at stratum change
3) elevation of bottom of boring
4) all drillers' notes tabulated in relation to the zone where the conditions were encountered
5) all laboratory test results tabulated in relation to the exact depth from which the sample was retrieved
6) a description of material of each stratum
7) water level observation and a description of how water level was determined
8) and all corrected Standard Penetration Test values (N60) tabulated in relation to the exact depth that the test was conducted.

An electronic copy of the final boring logs will be submitted to the State's Geotechnical Section (Maplewood Lab). This electronic file should be compatible with the gINT© for Windows (version 5 or higher) computer program and should match the format used by the Mn/DOT Geotechnical Section. Electronic templates for the boring log program are available by contacting Rich Lamb at 651-366-5595.

3.0 Geotechnical Analysis and Design

When required, the Consultant will provide a geotechnical analysis and design for proposed structures.

3.1 Geotechnical Design Criteria

Geotechnical design will be done in accordance with the criteria in this section. All Geotechnical Analyses will be performed using the Allowable Stress Design Method.

The following minimum factors of safety will be used for geotechnical analysis and design.

Table 6

Foundation Design	**Minimum Factor of Safety**

Spread Footings	As outlined in AASHTO Standard Specifications for Highway Bridges, 16th Edition, 1996, with current interim addenda
Drilled Shafts	As outlined in "Drilled Shafts: Construction Procedures and Design Methods", IF-99-025, FHWA, 1999
Driven Piles (axial bearing capacity)	Construction Control Method — Factor of Safety Static load test with wave equation analysis — 2.00 Dynamic testing with wave equation analysis — 2.25 Indicator piles with wave equation analysis — 2.50 Wave Equation Analysis — 2.75 Dynamic Formula — 3.50
Slope Stability Analysis (Embankments, Excavation Slopes)	1.4

3.2 Geotechnical Reports

The Consultant will use the subsurface investigation information along with any supplemental information to produce a Geotechnical Engineering Report for each structure or geotechnical feature on the project. The recommendations will include engineering analyses and design recommendations and should be brief, concise, definite and easily interpreted. The reports will meet prudent and applicable industry standards unless otherwise noted hereinafter

Designs, calculations, and recommendations will be reviewed, checked, dated, and initialed by a registered professional engineer. All analysis work and calculations performed by the Consultant will be in accordance with methods recognized as conforming-to good engineering practice. Methods and procedures for analyzing stability, settlement, bearing capacity and pile requirements will be at the discretion of the Consultant, except that all assumptions, soil parameters, water levels and design criteria will be indicated. The method of analysis and procedures will be referenced to engineering texts, handbooks, and journals including page numbers. The Consultant will at his discretion use computer programs for performing computations and for analysis purposes insofar that such programs are available. If a computer program is used, the output forms with the specific title of the computer program may be submitted in lieu of design computations. A check calculation initialed by a Registered Engineer will be performed on the most critical slip circle when slope stability computer analysis is used.

3.2.1 Presentation of subsurface investigation

The Consultant will present the results of the subsurface investigation with each Geotechnical Report in the form of plotted borings on proposed plans and profiles and cross sections where applicable. The plotted borings may be abbreviated but must include soil and rock classifications, Standard Penetration Test values, unconfined compression test results and a water table symbol all plotted with depth. All plots will be made on tabloid (11 in. by 17 in.) size paper and plotted to an engineering scale.

3.2.2 Project Information

The Geotechnical Report will contain a separate section labeled “Project Information”. This section will include information about the type of structure analyzed, the location of the structure and any other pertinent information which aids in the general description of the design.

3.2.3 Subsurface Investigation Summary

The Geotechnical Report will contain a separate section labeled “Subsurface Investigation Summary”. This section will include information about the borings taken for the site, a brief description of the foundation soil and rock conditions at the site and a summary of the water table measurements taken and an interpretation of the static water level.

3.2.4 Foundation Analysis

The Geotechnical Report will contain a separate section labeled “Foundation Analysis”. For this section, the Consultant will summarize the results of a detailed geotechnical engineering analysis to identify critical design elements and provide a basis for geotechnical recommendations. At a minimum, the Consultant will address the following:

a) A summary of the design assumptions including but not limited to information about embankment fill heights, unit weights of fill, side slope and end slope angles, bridge loading information (both axial and horizontal), retaining wall loading information, design methodologies, and other pertinent information will be provided.
b) For structures, suitable foundation types will be assessed and alternate foundation types reviewed.
c) For embankments, the overall stability will be assessed including a bearing capacity analysis, settlement analysis and global stability analysis. If necessary, the Consultant will provide a settlement analysis for the use of wick drains, surcharge embankments, and lightweight fill material. In addition, an estimate of the time rate of settlement will be included to account for the primary and secondary settlement that may be expected over the life of the project
d) For spread footing foundations, a bearing capacity and settlement analysis will be provided. The analysis will include a summary of the allowable and ultimate bearing capacities and the assumed safety factors. The analysis will include an estimate of the total and differential settlements anticipated for each structure analyzed. Differential settlements for retaining walls will be calculated based on a 30 ft. spacing. In addition, an estimate of the time rate of settlement will be included to account for the primary and secondary settlement that may be expected over the life of the project. All spread footings will be designed for a minimum embedment depth of 4.5 feet to protect against frost heave effects.
e) For piles and drilled shafts, ultimate capacity figures will be developed that show the capacity in relation to tip elevation for both compression and tension. In addition, downdrag and lateral squeeze will be

reviewed. Lateral earth pressure calculations including parameters for P-y curve development for structures subject to horizontal loads will be developed. Minimum tip elevations, casing requirements and estimates of overdrive will be provided.

f) All foundation elements will be designed to account for losses in lateral and axial capacities resulting from calculated design scour depths.
g) Analyses for structures supported on rock or tied to rock formations will be addressed. This includes analyses for areas such as rock bolts and rock cuts.
h) Construction considerations such as design of temporary slopes and shoring limits will be addressed. Special Provisions will be prepared for elements that may encounter difficult ground conditions or that may require non typical construction methods. Over excavation (subcuts) recommendations and backfill requirements will be discussed and details prepared for the project. Construction staging requirements, where applicable, will be addressed. Wet weather construction and temporary construction water control will be evaluated.

3.2.5 Foundation Recommendations

The Geotechnical Report will include a section labeled "Foundation Recommendations". This section will include definitive recommendations such as

a) ultimate and allowable bearing capacities and associated safety factors
b) recommended footing sizes and embedment depths
c) recommended pile size, length and tip elevation
d) recommended drilled shaft dimensions and construction methods
e) recommended slope angles
f) waiting periods for embankments
g) surcharge systems recommendations
h) recommended foundation types, sizes, and embedment depths
i) recommended rock cut slopes, including slope and subsurface drainage recommendations
j) top soil excavations and muck and poor soil excavations
k) trench excavation slopes
l) temporary slopes and shoring limits
m) rock excavation and any other recommendations as they apply to the design.