PDHonline Course C407 (2 PDH)

Geotechnical Review Checklists - P & S

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CHAPTER 11.0

GEOTECHNICAL REPORTS

11.1 TYPES OF REPORTS

Upon completion of the field investigation and laboratory testing program, the geotechnical engineer will compile, evaluate, and interpret the data and perform engineering analyses for the design of foundations, cuts, embankments, and other required facilities. Additionally, the geotechnical engineer will be responsible for producing a report that presents the subsurface information obtained from the site investigations and provides specific technical recommendations. The evaluation and interpretation of the exploratory data were discussed in Chapters 7 and 8 of this module. The geotechnical analyses and design procedures to be implemented for the various types of highway facilities are addressed in various other FHWA pulications. This chapter provides guidelines and recommendations for developing a geotechnical report.

Generally, one or more of three types of reports will be prepared: A geotechnical investigation (or data) report; a geotechnical design report; or a geoenvironmental report. The choice depends on the requirements of the highway agency (owner) and the agreement between the geotechnical engineer and the facility designer. The need for multiple types of reports on a single project depends on the project size, phasing and complexity.

11.1.1 Geotechnical Investigation Reports

Geotechnical investigation reports present site-specific data and have three major components:

1. *Background Information:* The initial sections of the report summarize the geotechnical engineer's understanding of the facility for which the report is being prepared and the purposes of the geotechnical investigation. This section would include information on loads, deformations and additional performance requirements. This section also presents a general description of site conditions, geology and geologic features, drainage, ground cover and accessibility, and any peculiarities of the site that may affect the design.
2. *Work Scope:* The second part of the investigation report documents the scope of the investigation program and the specific procedures used to perform this work. These sections will identify the types of investigation methods used; the number, location and depths of borings, exploration pits and in situ tests; the types and frequency of samples obtained; the dates when the field investigation was performed; the subcontractors used to perform the work; the types and number of laboratory tests performed; the testing standards used; and any variations from conventional procedures.
3. *Data Presentation:* This portion of the report, generally contained in appendices, presents the data obtained from the field investigation and laboratory testing program, and typically includes final logs of all borings, exploration pits, and piezometer or well installations, water level readings, data plots from each in-situ test hole, summary tables and individual data sheets for all laboratory tests performed, rock core photographs, geologic mapping data sheets and summary plots, subsurface profiles developed from the field and laboratory test data, as well as statistical summaries. Often, the investigation report will also include copies of existing information such as boring logs or laboratory test data from previous investigations at the project site.

The intent of a geotechnical investigation report should be to document the investigation performed and present the data obtained. The report should include a summary of the subsurface and lab data.

Interpretation and recommendations on the index and design properties of soil and rock should also be included. This type of report typically does not include interpretations of the subsurface conditions and design recommendations. The geotechnical investigation report is sometimes used when the field investigations are subcontracted to a geotechnical consultant, but the data interpretation and design tasks are to be performed by the owner's or the prime consultant's in-house geotechnical staff. An example *Table of Contents* for a geotechnical investigation report is presented in Figure 11-1.

11.1.2 Geotechnical Design Reports

A geotechnical design report typically provides an assessment of existing subsurface conditions at a project site, presents, describes and summarizes the procedures and findings of any geotechnical analyses performed, and provides appropriate recommendations for design and construction of foundations, earth retaining structures, embankments, cuts, and other required facilities. Unless a separate investigation (data) report has previously been developed, the geotechnical design report will also include documentation of any subsurface investigations performed and a presentation of the investigation data as described in Section 11.1.1. An example *Table of Contents* for a geotechnical design report is presented in Figure 11-2.

Since the scope, site conditions, and design/construction requirements of each project are unique, the specific contents of a geotechnical design report must be tailored for each project. In order to develop this report, the author must possess detailed knowledge of the facility. In general, however, the geotechnical design report must address all the geotechnical issues that may be anticipated on a project. The report must identify each soil and rock unit of engineering significance, and must provide recommended design parameters for each of these units. This requires a summarization and analysis of all factual data to justify the recommended index and design properties. Groundwater conditions are particularly important for both design and construction and, accordingly, they need to be carefully assessed and described. For every project, the subsurface conditions encountered in the site investigation need to be compared with the geologic setting to better understand the nature of the deposits and to predict the degree of variability between borings.

Each geotechnical design issue must be addressed in accordance with the methodology described in subsequent modules of this training course, and the results of these studies need to be concisely and clearly discussed in the report. Of particular importance is an assessment of the impact of existing subsurface conditions on construction operations, phasing and timing. Properly addressing these items in the report can preclude change-of-conditions claims. Examples include but are not limited to:

- Vertical and lateral limits for recommended excavation and replacement of any unsuitable shallow surface deposits (peat, muck, top soil etc.);
- Excavation and cut requirements (i.e., safe slopes for open excavations or the need for sheeting or shoring);
- Anticipated fluctuation of groundwater table along with the consequences of high groundwater table on excavations;
- Effect of boulders on pile driveability or deep foundation drilling, and
- rock hardness on rippability.

Recommendations should be provided for solution of anticipated problems.

Figure 11-1. Example *Table of Contents* for a Geotechnical Investigation (Data) Report.

1.0 INTRODUCTION
- 1.1 Project Description
  (Includes facility description, loads and performance requirements)
- 1.2 Scope of Work

2.0 GEOLOGY
- 2.1 Regional Geology
- 2.2 Site Geology

3.0 EXISTING GEOTECHNICAL INFORMATION

4.0 SUBSURFACE EXPLORATION PROGRAM
- 4.1 Subsurface Exploration Procedures
- 4.2 Laboratory Testing

5.0 SUBSURFACE CONDITIONS
- 5.1 Topography
- 5.2 Stratigraphy
- 5.3 Soil Properties
- 5.4 Groundwater Conditions

6.0 RECOMMENDATIONS FOR BRIDGE FOUNDATIONS
- 6.1 Design Alternatives
- 6.2 Group Effects
- 6.3 Foundation Settlement
- 6.4 Downdrag
- 6.5 Lateral Loading
- 6.6 Construction Considerations
- 6.7 Pile Testing

7.0 RECOMMENDATIONS FOR EARTH RETAINING STRUCTURES
- 7.1 Suitable Types
- 7.2 Design and Construction Considerations

8.0 ROADWAY RECOMMENDATIONS
- 8.1 Embankments and Embankment Foundations
- 8.2 Cuts
- 8.3 Pavement

9.0 SEISMIC CONSIDERATIONS
- 9.1 Seismicity
- 9.2 Seismic Hazard Criteria
- 9.3 Liquefaction Potential

10.0 CONSTRUCTION RECOMMENDATIONS

<u>LIST OF REFERENCES</u>
<u>LIST OF FIGURES</u>
<u>APPENDICES</u>

Appendix A Boring Logs
Appendix B Laboratory Test Data
Appendix C Existing Subsurface Information

Figure 11-2. Example *Table of Contents* for a Geotechnical Design Report.

The above issues are but a few of the items that need to be addressed in a geotechnical design report. To aid the engineers with review of geotechnical reports, FHWA has prepared review checklists and technical guidelines (FHWA, 1995). One of the primary purposes of the document is to set forth minimum geotechnical standards/criteria to show transportation agencies and consultants the basic geotechnical information which FHWA recommends be provided in geotechnical reports as well as plans and specification packages. Both technical guidelines for "minimum" site investigation information common to all geotechnical reports for any type of geotechnical feature and basic information and recommendations for specific geotechnical features are provided. Checklists are presented in the from of a question and answer format. Specific geotechnical features include:

- Centerline Cuts and Embankments;
- Embankments Over Soft Ground;
- Landslide Corrections;
- Retaining Walls;
- Structure Foundations (Spread Footings, Piles and Drilled Shafts);
- Borrow Material Sites.

11.1.3 GeoEnvironmental Reports

When the geotechnical investigation indicates the presence of contaminants at the project site, the geotechnical engineer may be requested to prepare a geoenvironmental report outlining the investigation findings and making recommendations for the remediation of the site.

The preparation of such a report usually requires the geotechnical engineer to work with a team of experts, since many aspects of the contamination or the remediation may be beyond his/her expertise. A representative team preparing a geoenvironmental report may be composed of chemists, geologists, hydrogeologists, environmental scientists, toxicologists, air quality and regulatory experts, as well as one or more geotechnical engineers. The report should contain all of the components of the geotechnical investigation report, as discussed above. Additionally, it will have a clear and concise discussion of the nature and extent of contamination, the risk factors involved, if applicable, a contaminant transport model and, if known, the source of the contamination (i.e., landfill, industrial waste water line, broken sanitary sewer, above-ground or underground storage tanks, overturned truck or train derailment, or other).

The team may also be required to present solutions (i.e. removal of the contaminated material, pump and treat the groundwater, installation of slurry cut-off walls, or the abandonment of that portion of the right-of-way, deep soil mixing, biorestoration, electrokinetics) to remediate the site. The geoenvironmental report should also address the regulatory issues pertinent to the specific contaminants found and the proposed site remediation methods.

11.2 DATA PRESENTATION

11.2.1 Boring Logs

Boring logs, rock coring, soundings, and exploration logging should be prepared in accordance with the procedures and formats discussed in Chapters 3 through 5. Test boring logs and exploration test pit records can be prepared using software capable of storing, manipulating, and presenting geotechnical data in simple one-dimensional profiles, or alternatively two-dimensional graphs (subsurface profiles), or three-dimensional representations. These and other similar software allow the orderly storage of project data for future reference. The website: http://www.ggsd.com lists over 40 separate software packages available for preparation of soil boring logs.

For example, one software package in common use is *geotechnical INTegrator*, or gINT (1994). The gINT program (http:www.gcagint.com) can be used to store subsurface exploration data, compute laboratory results, and produce boring logs, laboratory graphs, and tables. It has the capability for importing or exporting ASCII, .WKS, .DAT, and other file formats, including CAD software.

Many new software programs offer a menu-based boring log drafting program. The computer-aided drafting tools let users create custom boring log formats which can include graphic logs, monitoring well details, and data plots. Custom designed legends explaining graphic symbols and containing additional notes can be added to boring logs for greater clarity. These can include a library of soil types, sampler, and well symbols as well as other nomenclature used on boring logs. Geological profiles can be generated by the program and may be annotated with text and drawings.

Similarly, results of cone penetration tests (CPT) can be presented using available commercial software (e.g., CONEPLOT found at http://www.civil.ubc.ca/home/in-situ/software.htm) or from flat plate dilatometer tests (e.g., DMT DILLY software found at http://www.gpe.org). Other packages are available for reducing pressuremeter, vane, seismic cone, and piezocone data (http://www.ggsd.com). Links to many geotechnical software programs may be found at: http://www.usucger.org

Alternatively, it is convenient for the in-situ test data to be reduced directly and simply using a spreadsheet format (e.g., EXCEL, QUATTRO PRO, LOTUS 1-2-3). In many ways, the spreadsheet is a superior approach as it allows the engineer to individually tailor the interpretations to account for specific geologic settings and local formations. The spreadsheet also permits creativity and uniqueness in the graphical presentation of the results, thereby enhancing the abilities and resources available to the geotechnical personnel. Since soils and rocks are complex materials with enumerable variants and facets, a site-specific tailoring of the interpreted profiles and properties can be prudent.

11.2.2 Test Location Plans

A site location plan should be provided for reference on a regional or local scale. This can be handled via use of county or city street maps or USGS topographic quad maps. Topographic information at 20-foot (6-m) contour line intervals is now downloadable from the internet (e.g., www.usgs.gov) or purchased for the entire United States from commercial suppliers (e.g., TopoUSA from www.delorme.com).

The locations of all field tests, sampling, and exploratory studies should be shown clearly on a scaled plan map of the specific site under investigation. Preferably, the plan should be a topographic map with well-delineated elevation contours and a properly-established benchmark. The direction of (magnetic or true) north should be shown. A representative example of a soil test boring location plan is given in Figure 11-3.

A *geographic information system* (GIS) can be utilized on the project to document the test locations in reference to existing facilities on the premises including any and all underground and above-ground utilities, as well as roadways, culverts, buildings, or other structures. Recent advances have been made in portable measuring devices that utilize *global positioning systems* (GPS) to permit quick & approximate determinations of coordinates of test locations and installations.

If multiple types of exploratory methods are used, the legend on the site test location plan should clearly show the different types of soundings. Figure 11-4 shows a proposed test location layout for a combination of soil test borings with SPT, cone penetration test (CPT) soundings, and flat plate dilatometer tests (DMT). A horizontal scale should be presented.

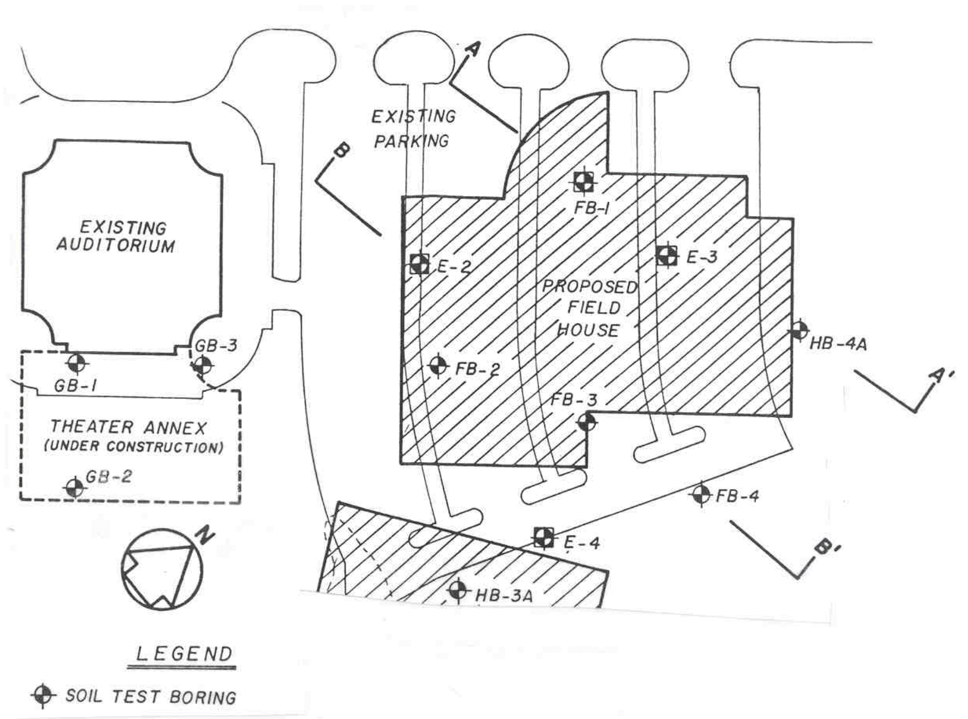

Figure 11-3. Representative Test Location Plan of Completed Soil Boring Locations.
(Note: Horizontal Scale: 1 cm = 10 meters)

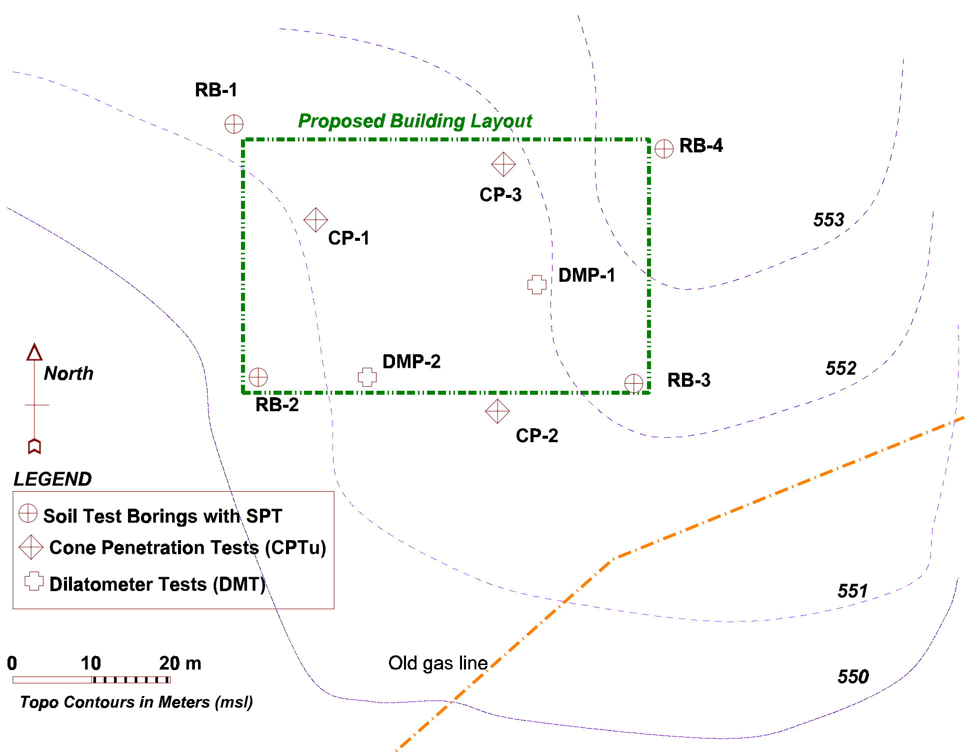

Figure 11-4. Plan Showing Proposed Boring and In-Situ Test Locations.

11.2.3 Subsurface Profiles

Geotechnical reports are normally accompanied by the presentation of subsurface profiles developed from the field and laboratory test data. Longitudinal profiles are typically developed along the roadway or bridge alignment, and a limited number of transverse profiles may be included for key locations such as at major bridge foundations, cut slopes or high embankments. Such profiles provide an effective means of summarizing pertinent subsurface information and illustrating the relationship of the various investigation sites. The subsurface profiles, coupled with judgment and an understanding of the geologic setting, aid the geotechnical engineer in his/her interpretation of subsurface conditions between the investigation sites.

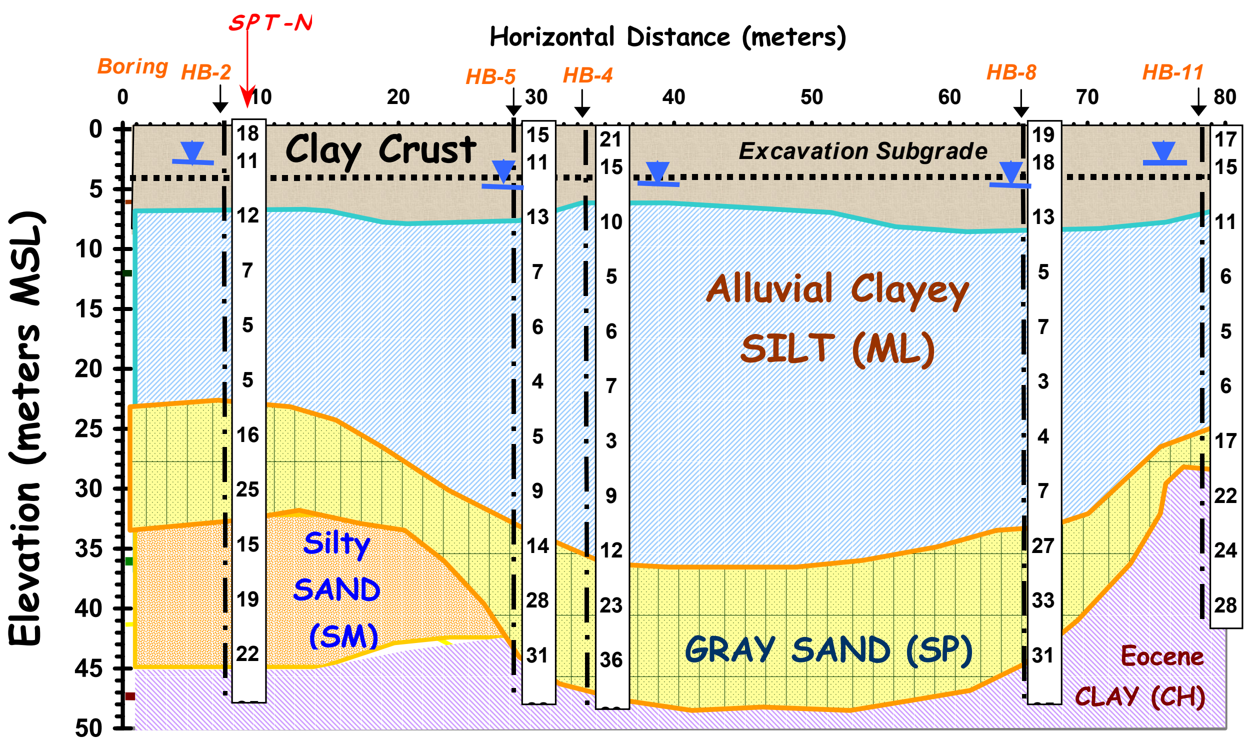

Figure 11-5. Subsurface Profile Based on Boring Data Showing Cross-Sectional View.

In developing a two-dimensional subsurface profile, the profile line (typically the roadway centerline) needs to be defined on the base plan, and the relevant borings projected to this line. Judgment should be exercised in the selection of the borings since projection of the borings, even for short distances, may result in misleading representation of the subsurface conditions in some situations.

The subsurface profile should be presented at a scale appropriate to the depth of the borings, frequency of the borings and soundings, and overall length of the cross-section. Generally, an exaggerated scale of 1(V):10(H) or 1(V):20(H) should be used. A representative example of an interpreted subsurface profile is shown in Figure 11-5.

The subsurface profile can be presented with reasonable accuracy and confidence at the locations of the borings. Generally, however, owners and designers would like the geotechnical engineer to present a continuous subsurface profile that shows an interpretation of the location, extent and nature of subsurface formations or deposits between borings. At a site where rock or soil profiles vary significantly between boring locations, the value of such presentations become questionable. The geotechnical engineer must be very cautious in presenting such data. Such presentations should include clear and simple caveats explaining that the profiles as presented cannot be fully relied upon. Should there be need to provide highly reliable continuous subsurface profiles, the geotechnical engineer should increase the frequency of borings and/or utilize geophysical methods to determine the continuity, or the lack of it, of subsurface conditions.

11.3 LIMITATIONS

Soil and rock exploration and testing have inherent uncertainties. Thus the user of the data who may be unfamiliar with the variability of natural and manmade deposits should be informed in the report of the limitations inherent in the extrapolation of the limited subsurface information obtained from the site investigation. A typical statement, found in geotechnical reports prepared by consultants, that can be included in a geotechnical report is shown below.

> "Professional judgments and recommendations are presented in this report. They are based partly on evaluation of the technical information gathered, partly on historical reports and partly on our general experience with subsurface conditions in the area. We do not guarantee the performance of the project in any respect other than that our engineering work and the judgment rendered meet the standards and care of our profession. It should be noted that the borings may not represent potentially unfavorable subsurface conditions between borings. If during construction soil conditions are encountered that vary from those discussed in this report or historical reports or if design loads and/or configurations change, we should be notified immediately in order that we may evaluate effects, if any, on foundation performance. The recommendations presented in this report are applicable only to this specific site. These data should not be used for other purposes."

The reader is referred to a document entitled "Important Information About Your Geotechnical Engineering Report", which is published by ASFE, The Association of Engineering Firms Practicing In The Geosciences [Phone No. (301) 565-2733]. This document presents suggestions for writing a geotechnical report and observations to help reduce the geotechnical-related delays, cost overruns and other costly headaches that can occur during a construction project.

AASHTO recommends the use of site-specific disclaimer clauses for DOT projects, particularly for construction bids and plans. Specific disclaimer clauses are preferred to the use of general disclaimer clauses which may not be enforceable. Examples of site-specific disclaimers is shown below.

> "The boring logs for BAF-1 through BAF-4 are representative of the conditions at the location where each boring was made but conditions may vary between borings."

> "Although boulders in large quantities were not encountered on this site in the borings that are numbered BAF-1 through BAF-4, previous projects in this area have found large quantities of boulders. Therefore, the contractor should be expected to encounter substantial boulder quantities in excavations. The contractor should include any perceived extra costs for boulder removal in this area in his bid price for Item xxx."

[Blank]