Civil Engineering Writing Project - Genre Unit 3

Geotechnical Site Investigation Report

What is a geotechnical site investigation report and why do engineers use them?

One of the most common tasks for geotechnical engineers is to investigate the characteristics of the soils and rocks at a potential construction site and make recommendations to the owner or designer of the construction project. Because the conditions at every site are unique, the geotechnical engineer must conduct an investigation of the site to gather the information needed to make recommendations. The site investigation report describes the investigation, summarizes the geotechnical conditions found at the site and makes recommendations based on the conditions.

What does a geotechnical site investigation report look like?

Geotechnical site investigation reports can vary in length from 5 pages to several hundred pages. The length of the report will depend upon the complexity of the site and the extent of the investigation. A typical investigation for a small commercial building might require 3-5 borings or soundings and the accompanying report might be 10 to 50 pages. The narrative portion of the report will generally be less than half of the total number of pages with figures, tables and appendices making up the remainder of the report. Any report longer than about 5 pages will include a cover letter. Shorter reports are usually written in the form of a letter report.

The exact sections of site investigation reports can vary from firm to firm, client to client, or project to project to meet the needs of the specific context. However, certain content and organization are typical. Here we compare the typical organization for a geotechnical site investigation to the sections discussed in Language Unit 6 *Sequence of Information in a Report*, which you can consult for more practice:

Geotechnical Site Investigation Report	**General Sequencing of Information from Language Unit 6**
Cover letter (for reports over about 5 pages)	(not covered in Unit 6)
Table of contents (for any report over 10 pages of text)	
Introduction	Introduction, Background
Geotechnical Investigation	Data (especially Data Sources)
Investigation Findings	Data (Sources, Reporting of Data, and Interpretation of Data)
Engineering Analysis	Engineering Analysis or Evaluation, Conclusion
Engineering Recommendations	Recommendations
Limitations	Limitations
Figures and Tables	(not covered in Unit 6)
References	
Appendix	

What goes in each section?

Though technically not part of the report itself, the cover letter is often bound with the report at the very front. Details for preparing a cover letter are presented in another unit of the Civil Engineering Writing Project. The table of contents is formatted as any standard table of contents. The sections are generally numbered hierarchically, and we'll follow that format in this explanation.

1. Introduction

This section serves to outline both the project and the work the geotechnical engineer was hired to perform. At a minimum it contains the following three sections. Depending upon the scope of the investigation, additional introductory sections might be required. For example, projects associated with a large amount of regulatory guidance will have a section summarizing regulatory requirements.

1.1. Project Description—This section describes the larger project which the geotechnical report supports. It summarizes key aspects of the project that affect the geotechnical investigation. For example if the project is for a building, this section will describe the function of the building, the number of stories, the type of construction (steel, masonry, reinforced concrete etc.), the range of column loads expected, and any other parameters that affect the geotechnical investigation. This section also serves as documentation of the project at the time the geotechnical work was conducted in case the project changes over time.

Example project description for a new restaurant
We understand that the proposed project will involve constructing a single-story steel column and masonry building with a slab-on-grade for a new restaurant. Parking and drive areas and a trash bin enclosure will also be constructed. No pylon-type signage is proposed at this time. We have not been provided with structural loads, but it is anticipated that the proposed building will have column loads of 25 to 75 kips and continuous wall loads on the order of 3 to 6 kips per lineal foot. Floor loads are anticipated to be light. Grade changes for the site were not provided to us; however, based on existing topography, we anticipate minimal cut and/or fill will be necessary to develop design grades for this site.
Example project description for a pipeline replacement
This project will involve constructing a new water supply pipeline along the State Route 49 (SR49) corridor between Locksley Lane and Cottage Drive in Auburn, California. The approximate location of the proposed pipeline alignment is shown on the Site Location Map (Figure 1). The project includes two segments. Both segments will be mostly within the undeveloped portion of the Caltrans right of way off the road shoulder of SR49. The northern segment will include the installation of about 950 linear feet of 16-inch inside diameter pipeline beginning on the east side of SR49 at Locksley Lane and then heading south along the east side of SR49 to the tie-in point with an existing pipeline near the Quartz Drive intersection (see Figure 2). This segment will cross Rock Creek and the existing Rock Creek Siphon. The southern segment of the proposed pipeline will include installation of about 2,750 linear feet of 16-inch inside diameter pipeline beginning on the west side of SR49 near Education Street and heading along the west side of SR49 to about 100 feet north of Masters Court. From that point to Cottage Drive, an existing 8-inch inside diameter pipeline will be replaced with 600 feet of 16-inch inside diameter pipeline. We anticipate the depth of cover for the pipelines will be about 3 feet below existing grades except at the trenchless crossings of Rock Creek and SR 49. Pipeline materials may include ductile iron or

high density polyethylene.

Commentary: Project Description

Key items to note:

1. Descriptions are of the overall project not the geotechnical portion of the project.
2. Each description is different because each project is different.
3. The descriptions are concise but contain specific information that is needed to conduct the site investigation such as magnitude of column and wall loads, amount of grading expected, length of pipe replacement, type of pipe to be used, expected depth of pipeline.
4. Project characteristics that will limit the scope of work, such as the absence of a large pylon-type signage for the restaurant, are clearly identified.

1.2. Scope of Services—This section states the tasks the geotechnical engineer was hired to perform. It should link directly to the engineer's obligations under the contract signed for the work.

Example scope of services for pipeline replacement

The purpose of this study is to provide geotechnical information regarding soil and rock conditions along the proposed alignment and to provide geotechnical recommendations for project design and construction. Results of our preliminary reconnaissance investigation, field explorations, laboratory testing, and engineering analyses are summarized in this report, which contains the following:

- Description of the site geologic setting and potential seismic hazards
- Description of the surface and subsurface site conditions encountered during our field investigation
- Brief discussion of the corrosion potential of the near-surface soils (NOTE: ABC Engineering does not practice corrosion engineering and, therefore, detailed analysis of corrosion potential is not included.)
- Recommendations related to the geotechnical aspects of:
    - Site preparation and engineered fill;
    - Pipeline design and construction including trenchless crossings
    - Temporary excavations, shoring, and trench backfill;
    - Temporary dewatering systems;
    - California Building Code (CBC) seismic site coefficients for use in structural analysis;
    - Subsurface structures and walls.

Commentary: Scope of Services

Key items to note:

1. The section starts with a brief statement of the purpose of the investigation.
2. The list of services is specific. It is often useful to itemize the tasks with a bulleted list which also correspond to the parts of the report. However, if the list just repeats a table of contents, omit it.
3. Limitations to the services in the area of corrosion assessment are clearly described to avoid potential confusion and limit liability of the geotechnical engineer.

1.3. Site Conditions—This section contains a short description of the site before the start of your field exploration. Note any significant surficial geologic or hydrologic conditions, the general topography, the current use of the site, and the current state of construction. You should prepare and reference figures showing the site location and site plan for this section.

Example site conditions
The site is located south of Yuma Road between 47th Avenue and S. Alpine Dr. in Buckville, Arizona, (Location Map, Figure 1). The site is currently an abandoned industrial park. The topography is relatively flat and slopes gently to the southwest. No buildings currently exist on site, but there is evidence of demolition of previously existing structures. Approximately one third of the site is covered with asphalt pavement. The remainder of the site is bare soil with little or no vegetation (Site Plan, Figure 2).
Commentary: Site Conditions
Key items to note: 1. The general site location is described and there is a reference to a location map. 2. The description provides a thorough, concise overview of the current state of the site, but does not go beyond what can be observed in a short site visit. 3. A site plan is referenced.

2. Geotechnical Investigation

This section describes the field and laboratory investigations that were performed. This is not a "how to" guide giving blow by blow procedures. It's an overview describing the important aspects of the process. It also serves as evidence that you followed standards for geotechnical investigations.

2.1. Field Exploration—This section briefly describes the drilling and sampling procedures by identifying the number of borings made and the type and approximate number of samples retrieved. If you perform any insitu measurements, such as cone penetration tests, shear wave tests, or vane shear tests, they are included here.

2.2. Laboratory Testing—This section briefly describes the laboratory tests performed and their purposes. You should cite ASTM or other standards used in the testing program.

Excerpts from geotechnical investigation section of a pavement site investigation
2.1 Field Exploration ABC Engineering explored the subsurface conditions along the proposed pipeline alignment using borings drilled with a CME 750x truck mounted drill rig equipped with a 6 or 8-inch diameter hollow stem auger. A total of 12 borings were drilled varying in depth from 10 to 33 feet. . . . Soil samples were taken using a split-barrel sampler with a 3-inch outer diameter, 2.4-inch inner diameter California type or a 2-inch O.D., 1.5-inch I.D. standard split spoon type sampler. Samples were taken approximately every 5 feet. Detailed logs of borings are included in Appendix A. 2.2 Laboratory Testing Sieve analyses and Atterberg Limits, performed on selected soil samples, were used to help classify each material type according to the AASHTO soil classification system. Modified Proctor tests (ASTM D1557) were undertaken to test the optimum moisture content and corresponding maximum dry unit weight of selected samples. Compressibility of the soil was tested using . . . Table 2.2 summarizes the laboratory testing. Complete laboratory test results are provided in Appendix B.
Commentary: Geotechnical Investigation
Key items to note: 1. The type of drilling equipment, the sampling equipment, and the procedures are stated. 2. The section references the appendices that contain details of the boring logs and lab tests. 3. Test standards are cited as needed.

3. Investigation Findings

This section reports the information gathered while preparing the report. The subsections will vary based on the scope of the investigation, but the following subsections are typical.

3.1. Regional and Local Geology—Usually, there is a summary of the geology surrounding the site. This section identifies the geologic features and processes that are important for understanding the subsurface conditions at the site and how they will affect the recommendations. The description typically starts with a description of the regional geology. The regional geology covers an area of hundreds of square miles surrounding the site and describes the major geological features which created or affect the local site geology. The local geology is an area of a few square miles to perhaps tens of square miles surrounding the site. The local geologic description characterizes the types of soil or rock expected to be encountered at the site.

Example geologic background
The project area is located in the Basin and Range physiographic province (Cooley, 1967) of the North American Cordillera (Stern, et al., 1979) of the southwestern United States. The southern portion of the Basin and Range province is situated along the southwestern flank of the Colorado Plateau and is bounded by the Sierra Nevada Mountains to the west. The Basin and Range province is dominated by fault controlled topography. The topography consists of mountain ranges and relatively flat alluviated valleys. These mountain ranges and valleys have evolved from generally complex movements and associated erosional and depositional processes. Surficial geologic conditions mapped in the project vicinity (Richard, et al, 2000) consist of soil deposits associated with modern fluvial systems. These deposits consist primarily of fine-grained, poorly graded sediment on alluvial plains, but also include gravelly channel, terrace, and alluvial fan deposits on middle and upper piedmonts.
Commentary: Geologic Background
Key items to note: 1. The description starts with the regional geology (in this case the Basin and Range District of the North American Cordillera). It then moves to the local geology. 2. The local geologic description describes the types of soils expected at the site but does not contain specific information about the soils found at the site. That information comes later. 3. Sources are cited.

3.2. Field and Laboratory Test Data—This section summarizes the data from field and laboratory tests. The specific organization of the section and amount of material will depend upon the scope of the project. Tables are often used to present the material. Only a summary of the key results is presented. The results of all tests are generally included in an appendix to the report.

Example lab data excerpt for rock testing
Rock Quality Designation (RQD) was measured and calculated by ABC Engineering for all boreholes in which rock coring was completed. The RQD values were calculated by summing the length of core greater than or equal to 4 inches and then dividing by the total core run length. Table 3.2 summarizes the average, maximum, and minimum RQD values for each borehole. Appendix C contains logs of all rock cores.

Table 3.2: Summary of RQD Measurements

Borehole No.	Average RQD (%)	Maximum RQD (%)	Minimum RQD (%)	Rock Type
B-01	62	83	17	Apache Canyon Rhyolite
B-03	67	98	0	
B-04	57	100	0	
B-07	65	95	17	Tertiary Conglomerate
B-08	12	43	0	Quartzite
B-09	21	56	0	Willow Canyon Rhyolite
B-10	20	55	0	

Commentary: Laboratory Test Data

Key items to note:

1. Descriptions of data are concise. They do not exhaustively tell the reader how to perform the test.
2. The table is referred to by its number.
3. The table presents a summary for the reader. Complete results are in an appendix.

3.3. Subsuface Conditions—This section summarizes the results of the field exploration and laboratory testing to provide an overview of the conditions encountered at the site.

Excerpt subsurface conditions from a pavement site investigation

The pavement sections at the boring locations generally consisted of 2 to 3 inches of asphalt concrete underlain by 6 to 12 inches of aggregate base material. Below the base material, the insitu soils included a 4-foot thick soft, sandy clay with some gravel. Below the sandy clay, a highly weathered to decomposed, metavolcanic bedrock was encountered. The depth of this highly weathered to decomposed rock ranged from about 10 feet below ground surface (bgs) in Boring B-8 to about 20 feet bgs in Boring B-10. A geologic cross-section of the site is presented in Figure 3.

Commentary: Subsurface Conditions

Key items to note:

1. The description summarizes the subsurface profile to a level where the reader has a general understanding of the conditions. The summary also serves as the basis for the model of the subsurface conditions used in the analysis. Notice that the reporting sequence mirrors the engineering process: data collection, data analysis, engineering model.
2. The boring logs are specifically cited.
3. A graphical representation of the subsurface conditions has been created and is cited in this section.

3.4. Groundwater Conditions—Because groundwater conditions are so important in geotechnical engineering, this information is often presented in its own section. The section usually includes both information gathered in the field and historic information gathered from research.

Groundwater excerpt

Groundwater measured in test borings at the time of field exploration varied from 35 to 42 feet deep (elevations above MSL of 623 to 630 feet). Groundwater in Boring B-04 was observed for a period of 3 days and did not fluctuate significantly. These observations represent groundwater conditions at the time of the field exploration and may not be indicative of other times or other locations. According to the Los Angele County Department of public works groundwater database

(http://dpw.lacounty.gov/general/wells/), the historic high water table measured in the general area of the site between 1974 and 2014 is at a depth of approximately 23 feet (elevation of 642 feet MSL).
Commentary: Groundwater Conditions
Key items to note: 1. Both measured and historic data are presented. 2. The limitations of the field data are clearly stated.

4. Engineering Analysis

This section presents the engineering calculations and evaluations. It is the link between the results found in the investigation and the recommendations.

Engineering Analysis excerpt a small commercial development project
We calculated an allowable bearing stress of 3,500 psf. This allowable bearing stress is controlled by settlement and will limit total settlement to less than one (1) inch. Using this allowable bearing stress will provide a factor of safety for bearing capacity significantly greater than the required value of 3. These computations were based on the insitu cone penetrometer data taken at the site. This allowable bearing stress is for a continuous footing placed at least 24 inches below finished grade. This analysis assumes that the continuous (wall) footings will have a minimum width of 18 inches and will bear on a minimum of 6 inches of compacted crushed aggregate over prepared subgrade.
Commentary: Engineering Analysis
Key items to note: 1. The statement tells the basis for the result (in this case, settlement controls and computations were based on CPT data). 2. The design criteria (allowable settlement and factor of safety) are explicit. 3. Assumptions and limitations related to the analysis are clearly stated (footing type, minimum footing depth and width and subsurface preparation).

5. Engineering Recommendations

This section states the recommendations for design or construction. The material covered will depend on the scope of work for the investigation; typical reports cover at least earthwork and foundations. The guidance should be direct, unambiguous, concise, and understandable. It should follow directly from the analysis.

Recommendations excerpt for a roadway project
Compaction Requirements Based on the results of field borings and laboratory testing, the onsite soils are suitable for the roadway subgrade. At least 24 inches of subgrade material below the planned elevation of the base course material should excavated and recompacted as engineered fill. Recommended compaction and moisture content criteria for engineered fill materials are based on Modified Proctor standards (ASTM D1557). The engineered fill material should be compacted to 95% the maximum dry unit weight. The soil moisture content at time of compaction should be $\pm$ 2% of the optimum water content. Compaction data for proposed subgrade material is presented in Appendix C.
Recommendations excerpt for a small commercial development project
<u>Recommendations</u> 1. Granular fill as defined in this report should consist of 1 or 3/4-inch minus, clean (less than 5%

passing the #200 sieve), well-graded, crushed gravel or rock.
2. Compact all granular fill placed under footings or slabs to at least 92% of the maximum dry weight based on Modified Proctor standards (ASTM D1557).
3. Design all continuous wall footings and isolated column footings using an allowable bearing pressure of 2,000 psf.
4. Provide a minimum footing width of 18 inches for all continuous wall footings and at least 6 inches of compacted granular fill under all footings.

Commentary: Recommendations

Key items to note:

1. The recommendations are specific and clear; the basis of the recommendations is given.
2. Standards are cited, and supporting data is referenced.
3. Recommendations are usually written with either passive voice and modal verbs like *should* (*subgrade material* ***should be compacted***...) or the command form of verbs (***compact*** *all granular fill*...).
4. The list form of recommendations has advantages: they are easier for writers to proofread and confirm they are complete, and they allow readers to find each recommendation more quickly. Firms vary in their preferences for lists or text paragraphs.

6. Limitations

This section concerns risk mitigation. It is intended to remind the client about limits that apply to the information in the report. The language is carefully crafted with advice of attorneys. Most companies have a very specific wording for this section and it is copied verbatim in every report.

Example Limitations section

This report has been prepared in accordance with generally accepted engineering practices for the project area and at the time of report preparation. The analysis and recommendations presented are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless ABC Engineering reviews the changes and either verifies or modifies the conclusions of this report in writing.

Commentary: Limitations

Key items to note:

1. The first sentence of the section is a reiteration of the professional standard of care required of engineers. While this standard applies whether or not it's explicitly stated, it's often included.
2. The first paragraph reminds the client that the findings are based only on the information gathered during the investigation and that the actual conditions in the field may be different. This point is particularly important for geotechnical investigations.

3. The second paragraph specifies that the findings are appropriate only for the particular site investigated and the project described. If the site or project conditions changes, the geotechnical firm must be asked to review the investigation.

7. Figures and Tables

The figures and tables are usually included as a separate section between the body of the report and the appendices. There are two reasons for this. First, it makes pagination of the report easier. Secondly, technical reports readers often need just the figures or tables. It's more convenient to find and copy them if they're all in one central location. Be sure every figure is numbered and has a title!

8. References

Complete references for all citations in the report are included here.

9. Appendices

By definition, an appendix is something that the general reader doesn't need to understand a report. Supplement would be a good word to describe this material. It supplements or adds to the information in the body of the report. It also serves an important documentation function in case questions later arise about some details of the report. The specific appendices required will vary with the subject of the report. Typical appendices in geotechnical site investigation reports are:

- Boring logs
- Lab data (complete data from lab tests)
- Design calculations

This material is based upon work supported by the National Science Foundation under Grants No. DUE-0837776 and DUE-1323259. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.