

**GUIDELINES**  
For Preparing  
**GEOTECHNICAL DESIGN REPORTS**

**VERSION 1.3**

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**DIVISION OF ENGINEERING SERVICES**  
**GEOTECHNICAL SERVICES**

# INTRODUCTION TO GDR GUIDELINES

The following guidelines were developed by Geotechnical Services, Division of Engineering Services for the preparation of Geotechnical Design Reports (GDRs). Geotechnical Services is responsible for performing geotechnical investigations and report preparation, in addition to providing oversight and review of consultant geotechnical work for the California Department of Transportation (Caltrans).

These guidelines are intended to be a reference for persons involved in preparing, overseeing, or reviewing these reports. They are intended to provide guidance by outlining and describing the various elements that may be needed in a GDR for a detailed geotechnical investigation.

The Geotechnical Design Report documents the project site subsurface geotechnical conditions and are usually based on the results of subsurface exploration drilling. The GDR analyzes those conditions as they relate to the project, assesses impacts of the geotechnical conditions on the construction of the project, and provides recommendations for both designing and constructing the roadway portions of projects. The primary audience for the report consists of roadway designers, construction personnel, bidders and contractors. As a final design report, the Geotechnical Design Report will document the anticipated subsurface conditions based upon field exploration, testing, and analyses. From that information the report will present project designers with final geotechnical design recommendations and specifications for the specific design features.

Prior to preparation of the Geotechnical Design Report the District Preliminary Geotechnical Report (DPGR) is usually prepared. It is prepared to document anticipated subsurface conditions based upon site reconnaissance and available sources of data for the various alignments and/or alternatives under consideration. It will contain geotechnical information needed during the planning phase for preparation of the Project Study Report and for preparing preliminary cost estimates. The preparation of the DPGR follows guidelines established in the Guidelines For District Preliminary Geotechnical Reports prepared by Geotechnical Services.

Geotechnical information is also required for the design and construction of structure foundations such as bridge foundations, tunnels, major culverts, retaining walls on deep foundations, etc. The preparation of structure Foundation Reports follow guidelines established in the Guidelines For Structure Foundations Reports prepared by Geotechnical Services.

## GDR Outline/ Table of Contents

i.	Title Sheet.....	5
ii.	Letter of Transmittal.....	5
iii.	Table of Contents.....	6
iv.	List of Figures .....	6
v.	List of Tables.....	6
1.	Introduction .....	7
2	Existing Facilities and Proposed Improvements .....	7
3.	Pertinent Reports and Investigations .....	8
4.	Physical Setting.....	8
4.1	Climate .....	8
4.2	Topography & Drainage.....	8
4.3	Man-made and Natural Features of Engineering and Construction Significance.....	9
4.4	Regional Geology and Seismicity .....	9
4.5	Soil Survey Mapping .....	9
5.	Exploration .....	10
5.1	Drilling and Sampling.....	10
5.2	Geologic Mapping .....	11
5.3	Geophysical Studies.....	11
5.4	Instrumentation.....	11
5.5	Exploration Notes .....	12
6.	Geotechnical Testing.....	12
6.1	In Situ Testing.....	12
6.2	Laboratory Testing.....	12

<b>7.</b>	<b>Geotechnical Conditions .....</b>	<b>12</b>
7.1	Site Geology .....	13
7.1.1	Lithology .....	13
7.1.2	Structure .....	13
7.1.3	Natural Slope Stability .....	13
7.2	Soil and Ground Water Conditions .....	13
7.3	Water .....	14
7.3.1	Surface Water .....	14
7.3.1.1	Scour .....	14
7.3.1.2	Erosion .....	15
7.3.2	Ground Water .....	15
7.4	Project Site Seismicity .....	15
7.4.1	Ground Motions .....	15
7.4.2	Ground Rupture .....	15
<b>8.</b>	<b>Geotechnical Analysis and Design .....</b>	<b>15</b>
8.1	Dynamic Analysis .....	17
8.1.1	Parameter Selection .....	17
8.1.2	Analysis .....	18
8.2	Cuts and Excavations .....	18
8.2.1	Stability .....	18
8.2.2	Rippability .....	19
8.2.3	Grading Factors .....	19
8.3	Embankments .....	20
8.4	Earth Retaining Systems .....	20
8.5	Culvert Foundations .....	21
8.6	Minor Structure Foundations .....	22
8.7	Others .....	22

9.	Material Sources.....	22
10.	Material Disposal.....	23
11.	Construction Considerations .....	23
11.1	Construction Advisories .....	23
11.2	Construction Considerations that Influence Design .....	23
11.3	Construction Considerations that Influence Specifications.....	24
11.4	Construction Monitoring and Instrumentation .....	24
11.5	Hazardous Waste Considerations.....	24
11.6	Differing Site Conditions.....	25
12.	Recommendations and Specifications.....	25
13.	Appendix .....	26
13.1	Location of Borings/Geologic Map.....	26
13.2	Geologic Cross-Sections & Soil Profiles .....	26
13.3	Profile Grade Sheets.....	26
13.4	Boring Legend.....	26
13.5	Boring Logs .....	26
14.6	Logs of Test Borings .....	26
13.7	Geophysical Data .....	26
13.8	Stereonet .....	26
13.9	In Situ Test Data .....	26
13.10	Laboratory Test Data .....	26
13.11	Corrosion Test Reports .....	26
13.12	References.....	26
13.13	Photographs .....	26
13.14	Calculations.....	26
13.15	Correspondence.....	26

**i. Title Sheet**

The first page of the Geotechnical Design Report will be a title sheet containing all the information necessary to identify the report and locate the project. Show:

- The title, "Geotechnical Design Report"
  - The project title and the limits of the facility addressed by the report (e.g., "Truck Climbing Lanes On Route 5 from 1.2 miles south of the Rio River Bridge to 5.4 miles north of River Road")
  - Complete, standard Caltrans project identification (i.e., District-County-Route-Post Mile designation and the Expenditure Authorization for the project)
    - The date the report was issued
    - The name of the Caltrans office in Geotechnical Services responsible for preparing the report
- or
- If prepared by a consultant, the consultant's company name, address of the office that prepared the report, telephone number and the consultant's project number

**ii. Letter of Transmittal**

Immediately following the title sheet, include a transmittal letter addressed to the Division Chief, Office Chief, or Branch Chief of the district that requested the report. The date of the letter should match that of the title sheet. The transmittal letter shall identify the project and include the following statement: "This report defines the geotechnical conditions as evaluated from field and laboratory test data and used in the development of the geotechnical design. It provides recommendations and specifications for project design and construction."

Affix signatures of geotechnical personnel responsible for the project to the transmittal memo, not to the report itself. Geotechnical Design Reports must bear the signature, registration seal, license number, and license expiration date of the Registered Civil Engineer in responsible charge of the geotechnical engineering for the project. When the Geotechnical Design Report contains geologic information, analysis, or recommendations beyond the scope of responsible charge of the Registered Civil Engineer, the report shall also be signed by the Certified Engineering Geologist in responsible charge of the engineering geology for the project.

The names, titles, registration information and signatures (if desired) of others working under the Registered Civil Engineer's and Engineering Geologist's direction and having significant input to the preparation of the

report should also be presented on the letter of transmittal. List the distribution of the report copies after the signatures.

For projects prepared by consultants, add a separate page immediately following the letter of transmittal. The purpose of this page is to retain the legal protection of design immunity for the State, in general accordance with Deputy Director Richard P. Weaver's January 28, 1993 memorandum. The added page shall contain the following statement:

"Approved as to impact on State facilities and conformance with applicable State standards and practices, and that technical oversight was performed as described in the California Department of Transportation A&E Consultant Services Manual."

The Caltrans Registered Civil Engineer and Certified Engineering Geologist who had responsibility for geotechnical oversight shall sign this page on spaces provided immediately below the statement. Type the names, registration numbers and titles of these individuals below the spaces and include spaces for the date of signature. The oversight engineer and geologist shall affix their professional seals to the signed page.

**iii. Table of Contents**

In a Table of Contents, show the starting page number for each section and subsection in the report. List all the Appendices that appear at the back of the report. A Table of Contents is not necessary for a memorandum style report.

**iv. List of Figures**

Provide a list of all figures used in the body of the report. These include vicinity maps, location maps, photographs, charts, flow diagrams, graphs, etc. Include figures within the body of the text close to the point where they are referenced.

**v. List of Tables**

Provide a list of all tables used in the body of the report. On the list, include page numbers showing where the tables are located in the text. Locate tables close to their point of reference in the text.

## 1. Introduction

Open this section of the report with a brief description of the proposed project and the scope of the geotechnical services that were performed:

- Identify the location and type of proposed project (e.g., safety improvement, capacity enhancement, landslide correction, etc.) and describe the type of facility being proposed (e.g., curve correction, widening, buttress fill, etc.). Present a Vicinity Map to help orient the reader to the area of the State being discussed.
- Note the investigative techniques and exploration methodology used (e.g., review of published data, site reconnaissance and mapping, subsurface exploration, laboratory testing, analyses, etc.).

Follow with these statements:

"The purpose of this report is to document subsurface geotechnical conditions, provide analyses of anticipated site conditions as they pertain to the project described herein, and to recommend design and construction criteria for the roadway portions of the project. This report also establishes a geotechnical baseline to be used in assessing the existence and scope of changed site conditions.

This report is intended for use by the project design engineer, construction personnel, bidders and contractors."

## 2. Existing Facilities and Proposed Improvements

With the aid of a Site Plan, describe the proposed improvement. Define the geometric base line upon which the report is based. Also describe depths/heights, thicknesses and slope ratios of proposed cuts and fills.

Readers should be able to read this description and recognize whether or not the report addresses the same profile and alignment (center line, station line, etc.) used as a basis for the construction plans. Include the line names for the main alignment and major connector roads, station equations, and key location coordinates based on the California Coordinate System. It is recommended that this information be presented as a Site Plan showing the proposed improvements relative to local streets and facilities.

Describe existing facilities that may be relevant to the proposed improvement. For example, describe the heights, slope ratios, constituent materials and performance of existing cut and fill slopes. Note the performance of cut, fill, and natural slopes in the vicinity with respect to erosion. Pavement condition can be an indicator of geotechnical problems so note the type, performance, and condition of existing pavements. Include a



description of the present foundation and its performance for a project to replace an existing feature.

Document any project or site details that have changed since preparation of the Preliminary Geotechnical Report.

Include information about existing reinforced concrete structures or Mechanically Stabilized Earth walls (material type, condition, age, name and bridge number, etc.) and describe any visible evidence of distress caused by the environment. For example, the evidence of distress can be described by a simple statement such as: "concrete cracking and rust stains in substructure."

### **3. Pertinent Reports and Investigations**

List additional reports that pertain to this project. Include information describing authorship and dates of completion.

Document the literature used in researching the geotechnical conditions for this project. The literature may be geologic maps, topographic maps, aerial photographs, previously completed reports for this or adjacent projects, regional geology reports, "as-built" plans, construction completion reports, or others. Include pertinent maps in the appendix if they are of particular value to understanding the project's geotechnical conditions and copies can either be purchased or made with permission from the map publishers.

If an Initial Site Assessment Report was completed prior to the Project Study Report, or if any other information is available on the presence of hazardous waste within the project limits, cite these references here. Mention the Preliminary Geotechnical Report prepared for this project.

### **4. Physical Setting**

#### **4.1 Climate**

Describe climatic conditions that will have an effect on the project design, construction or maintenance. Present the range of temperatures in the vicinity of the project noting nighttime conditions if night construction work is a possibility. Note average annual rainfall in inches. Describe seasonal conditions such as heavy rain, snow or fog that could limit construction seasons, the ability to reduce the moisture content of construction materials, affect traffic control, etc. Note the potential for frost heave, if appropriate.

#### **4.2 Topography & Drainage**

Describe the topography and the drainage patterns through which the project will pass. For example, discuss hills and ridges which will require cuts for the project alignment and the approximate depths of the cuts. Describe valleys to be traversed by embankment, and slopes to receive

sidehill cuts or fills. Note drainage patterns including creeks, intermittent streams, and rivers.

Include a topographic map showing the project alignment. Consider using United States Geological Survey topographic mapping if other, more project specific mapping, is not available.

#### **4.3 Man-made and Natural Features of Engineering and Construction Significance**

At times, the project may abut or parallel certain features that, although outside the proposed right of way, could be adversely affected by the project. For example, retaining walls or flood control channel linings may have been designed to retain bedding plane loads. Embankment placed upslope of the wall may surcharge the wall, even though the toe of fill is located well back from the wall. As another example, cuts which remove support from bedding planes or which remove confinement from old fills can reduce the lateral support of materials or facilities well outside the right of way. Identify such situations in this part of the report for later consideration.

Similarly, there may be certain natural features such as specimen trees or wetlands which require added clearance through retained or steeper cut and fill slopes. Describe such features.

Include information on the presence of any major underground utilities (e.g., petroleum lines, natural gas pipelines, large water supply lines, etc.) or light rail facilities, noting existing corrosion protection provisions as well as features for geotechnical consideration.

#### **4.4 Regional Geology and Seismicity**

Describe the regional geologic setting of the project area. Include geomorphic province, major topographic features (such as mountain ranges and valleys) and major characteristics such as depth of alluvium over basement rock, basic rock types, etc.

Describe the regional seismic setting, including names of known active faults, distances and directions from the project site, and maximum credible earthquake magnitudes. Provide a map at a suitable scale to show the regional faulting within 100± km with the appropriate annotation showing the relative proximity of the project location.

Do not discuss ground rupture potential, shaking and estimated recurrence intervals in Section 4.4 because they are addressed later in the report.

#### **4.5 Soil Survey Mapping**

Discuss soil survey mapping, if any, used to further characterize the project location (e.g., California Soil/Vegetation Survey, USDA Soil

Survey). When the mapping describes the soils as erodible, provide information from the mapping regarding depth of erodible soil, engineering classification and lateral distribution relative to the project. Give a full reference for any mapping used.

## **5. Exploration**

In this section of the Geotechnical Design Report, describe what was done during the field investigation. Include a summary description of the type, scope, and purpose of the field investigations. Include a section on problems encountered during the exploration program which may have design or construction implications.

If some portion of the planned or desired field work could not be done for some reason (right-of-entry refused by property owner, for example), state what work was desired, why it could not be done, and possible consequences of its not being done. In Section 7.2, "Subsurface Soil Conditions," discuss the assumptions that had to be made as a result of the omitted field work.

### **5.1 Drilling and Sampling**

Briefly describe the number, type and depths of borings, trenches and test pits made for the field study. Describe the drill rig type and model, and the sampler type and weight. Indicate the specific duration of the exploratory drilling. Locate borings, trenches, and test pits on a Geologic Map or a topographic based Location of Borings Map and include the map in the Appendix. Also include the boring or test pit logs in the Appendix. Provide a general statement about the types of samples taken (bulk, undisturbed, SPT, etc.) and the reasons for each type. Show sample locations on the boring or test pit logs. State whether the samples were taken to the laboratory, are in storage, or were discarded. Also include a statement about how drill holes or pits were filled (grouted, converted to an observation well, backfilled and compacted, etc.).

Soil and water corrosivity testing, analysis and recommendations for culvert studies will be addressed by the District Materials Engineer (DME) and presented in a separate report. For minor structures, subsurface drainage, and where culverts will be in cuts or areas too deep to be sampled by the DME, deep samples will continue to be taken by geotechnical staff during the subsurface exploration phase. These samples may be tested by either the DME (where the testing capability resides in the district) or by the Corrosion Technology Branch of Materials Engineering and Testing Services (METS). Field sampling of soil and water for corrosion studies shall conform to the requirements of California Tests 643 and/or 532. (See Corrosion Technology's "Corrosion

Guidelines" for further information on corrosion issues.) Note in the geotechnical design report if samples were obtained and delivered to the DME or METS. For Mechanically Stabilized Embankment (MSE) reinforcement element design, for minor structure foundation/wall design, and for subsurface drainage designs, include the corrosion test results from the DME or METS in the Appendix.

## **5.2 Geologic Mapping**

Describe and append any geologic mapping done for the project. Include information on the base map used (for example, USGS 7.5 Minute Quadrangle topographic map blown up to 1" = 100'), and the level of mapping – reconnaissance or detailed. If the mapping effort consisted of verifying a published or pre-existing geologic map, give a full reference for that map. On the map, show the layout of the proposed project to define the relationship between the proposed features and the local geology. Use of geologic cross sections is highly recommended where they would further illustrate the relationship of geologic conditions to the proposed project. Show the locations of any geologic cross-sections on the geologic map.

The mapping should cover a sufficiently large area to show geologic features outside the project that may have significance to the project (for example, a landslide which could adversely affect the project if it were to fail). Mapping should be sufficiently detailed to show geologic structure and features of importance to analyses - such as faults, bedding and major joint attitudes, folds, etc.

## **5.3 Geophysical Studies**

Describe the type, scope, general locations and intended purpose of any geophysical studies performed. Indicate the locations of field data collection sites/lines on a Geologic Map or a Location of Borings Map. Present the data, including all graphs and interpretations made from raw field data, in the Appendix and reference the data in this section. Include a statement about the storage location of the raw data in case anyone wishes to look at it.

## **5.4 Instrumentation**

Describe any instrumentation installed during the field exploration (e.g., slope inclinometers, extensimeters, piezometers and observation wells). Indicate their locations on a Geologic Map or a Location of Borings Map. State why each was installed and present summaries of the data in the Appendix. If a monitoring program needs to be continued, provide a schedule and duration. Present and discuss relevant data from

instrumentation monitored during original construction or from previous exploration programs of relevance to the present project.

### **5.5 Exploration Notes**

Describe and briefly discuss any aspect of the exploration program that may affect design or construction. Include such items as caving or squeezing in the borings, extremely hard drilling or alternating hard and soft drilling, problems with access to certain sites, or gaps in the exploration program. The intent of this section is to disclose conditions that may not be addressed in the "analyses and recommendations" sections, but which may nevertheless be indicative of potential geotechnical behavior during construction.

## **6. Geotechnical Testing**

### **6.1 In Situ Testing**

Describe the in situ testing performed for the subsurface exploration program (e.g., vane shear tests, pressuremeter tests, electronic cone penetration tests, in situ permeabilities, etc.) Reference the test methods used. Include modifications of existing test methods or unpublished test methods in the appendix. Explain why that method was used instead of a published method. Where the in situ test results lend themselves to a concise summary (i.e. general data in the form of result ranges) include the summary here, otherwise summarize as appropriate in the appendix. Include the data and examples of necessary calculations in the Appendix.

### **6.2 Laboratory Testing**

Describe laboratory testing performed for this report. Include a listing of the testing performed such as consolidation tests, triaxial tests, Atterberg Limit tests, mechanical analyses, etc. Test methods used are to be referenced. Include modifications of existing test methods or unpublished test methods in the Appendix. Explain why that method was used instead of a published method.

Where the laboratory test results lend themselves to a concise summary (i.e. general data in the form of result ranges) include the summary in this section. Otherwise, summarize as appropriate in the Appendix. Include data and examples of necessary calculations in the Appendix.

## **7. Geotechnical Conditions**

Drawn from field observation, literature study, instrumentation, exploration, testing and professional judgment, this section presents the geotechnical and ground water conditions assigned for use in analysis and design. The discussion in the following subsections is also a statement of the

conditions that Caltrans expects will be encountered in the field and which will influence project performance.

## **7.1 Site Geology**

Describe the geology of the project site and an area surrounding the project site sufficiently large to include geologic features of potential significance to the project. Provide enough detail that needed analyses and decisions can be made. Preparation of a geologic map is recommended in foothill (hillside) or mountainous terrain. Emphasize properties or condition of the rock materials that will have a bearing on design or construction of the project.

### **7.1.1 Lithology**

Describe in detail the geologic units present, giving priority to rock units. Soils and other unconsolidated units will be described in detail in Section 7.2. Give formational names and describe rock types, bedding, contacts, special features such as solution cavities, etc. Emphasize characteristics of engineering significance. Lateral variation in the type or character of units as shown on the geologic map is important so describe the distribution of rock types along the project alignment by providing station limits and offsets.

### **7.1.2 Structure**

Describe the structure of the geologic units. Include bedding, folds, faults, fractures and jointing, foliation and any other structure. Refer to specific project features or stationing when describing the extent of structural features. For example: "Bedding in the area of cuts between Stations 345+00 and 356+50 dips 38 to 45 degrees toward the west..."

### **7.1.3 Natural Slope Stability**

Discuss existing natural slopes including slope inclinations and observed instabilities. Describe instabilities giving the type (mudflow, toppling, rotational, etc.) and locations by station and offsets. Note springs, seepage and phreatophytes or other vegetative indicators of excessive moisture, creep or instability. Include slopes adjacent to the project site since they may be indicators of onsite conditions or, in the case of an instability problem, may impact project features.

## **7.2 Soil and Ground Water Conditions**

Summarize the existing soil and ground water conditions based on information from the boring logs, in situ tests, and laboratory tests. Often

the soils within definable areas of a project will have similar engineering characteristics. Describe the soils in general, by classifications, consistency (hard, soft etc.), degree of moisture, color, structure etc. Develop soil profiles and cross sections as needed to conduct engineering evaluations and include them as attachments to the report.

Describe the anticipated behavior of the soils during construction. Give descriptions of anticipated ground behavior as determined from drilling operations (e.g., difficulty of drilling, caving, loss of drilling fluid etc.) and define the limits of the affected areas. Describe the characteristics of the materials within generalized areas that would require attention in the design or construction (e.g., collapsible soils, expansive soils, liquefiable soils, contaminated or otherwise unsuitable soils, etc.). Define areas of specific construction interest (such as areas needing remedial grading) by depth and location either through plan and profile or by table showing station limits, offsets, and depth.

At times, field observations may only hint at problem soil behavior during construction. Potential construction difficulties may not actually be forecast until analyses and calculations, contained later in the report, are prepared. In such cases, note the potential problems in Section 7.2 "Soil and Ground Water Conditions" and note that the condition is further analyzed in a later section.

### **7.3 Water**

In this section of the report, describe surface and ground water conditions which might have an impact on project design or construction.

#### **7.3.1 Surface Water**

Describe the surface drainage patterns, including their density (are there many or few drainage channels), general shape (for example, are they deeply incised with steep banks, or broad with flatter banks), gradients, estimations of runoff volumes (is this a channel which may carry large floods or just small volumes), and any other information which could be needed to design drainage or other site facilities.

##### **7.3.1.1 Scour**

Describe the potential for scour in drainages, which can impact the proposed facilities. Include historical data where appropriate. Reference pertinent field data whether obtained for this report or for other reports such as a Structure Foundation Report.

### **7.3.1.2 Erosion**

Describe the natural erosion of stream banks that may affect project features along or across drainages. Also describe debris and bed loads which can influence design of culverts, retaining structures, etc.

Note the performance of existing cut, fill and natural slopes, describing the slope soil/rock composition, slope inclination, height, runoff control features such as terrace drains, degree of rilling and compass orientation of problem slopes.

### **7.3.2 Ground Water**

Describe in detail the ground water regime of the project site and surrounding area that may influence, or be influenced by, project construction. Include presence of ground water in borings, wells or pits, general depths and flow directions (if known), local use of the water, and artesian or perched water conditions. Discuss water quality data including presence of contaminants (if known) if pertinent to the proposed project.

## **7.4 Project Site Seismicity**

This section is to describe seismic considerations that must be used for design of project features.

### **7.4.1 Ground Motions**

Describe the regional faults of potential impact to the site. Tabulate their relation to the site (distance and direction), their estimated Maximum Credible and Maximum Probable magnitudes, recurrence intervals, anticipated bedrock accelerations and durations. Provide references or reasoning for these estimates.

### **7.4.2 Ground Rupture**

Describe known or suspected faults that are present within the project site. Provide estimates of activity, recurrence intervals and the potential for ground rupture. Estimate vertical and horizontal offsets from ground rupture during the Maximum Credible Event on each fault. Provide references or reasoning for these estimates.

## **8. Geotechnical Analysis and Design**

The purpose of this section is to provide enough supporting analyses, computations, reasoning and discussion so that the basis for the geotechnical conclusions is clear to the reader. Discuss each feature (cut or fill slope,



retaining wall, embankment foundation, etc.) that was designed, either through mathematical calculation or through exercise of geotechnical reasoning.

Corrosion issues for most project features and structure foundations will be addressed by either the Foundation Reports for structure foundations, or by the District Materials Engineers for culverts. However, consider corrosion in the Geotechnical Design Report for such items as minor structure foundations, retaining walls, and subsurface drainage facilities. Corrosion Technology of METS has prepared "Corrosion Guidelines" to assist in these studies. Summarize the results of corrosion tests that are applicable to such features. Particularly note test results such as low pH, low minimum resistivity, high chlorides and high sulfates which are indicative of aggressive corrosion potential. In the Appendix, include a copy of the corrosion test reports that were performed by others but which relate to features addressed in the Geotechnical Design Report. Describe the corrosion mitigation analysis procedures used and present the results.

Other circumstances and conditions which were of concern or interest at some point during the geotechnical study may also have been analyzed or studied and found to have no impact on the project or surrounding environs. Alternatives to various portions of the project design which were rejected for geotechnical reasons, and the conditions mentioned in Section 4.3 "Man-made and Natural Features of Engineering and Construction Significance," can be examples of such conditions. Even though such features are not reflected in the design recommendations, include the analyses or considerations given to them that led to rejecting each alternative or which led to the decision not to provide design recommendations for a certain situation. In other words, show why those features proved not to be of consequence to the project and why the alternatives were rejected.

Identify the methods of analyses, such as Bishop's Method for stability analysis or Terzaghi's One-Dimensional Consolidation Theory for settlement analysis. Discuss selection of design parameters and whether values are determined by laboratory/field testing or through other approaches such as correlations. Discuss any assumptions that were made when generating input for calculations or for analysis by reasoning.

Calculation results should be summarized in this section, but place the actual calculations in the appendix. For repetitive analyses, append one complete set of the calculations for the final design, such as the calculations for a critical failure surface for a given slope and set of subsurface conditions. Calculations for additional failure surfaces analyzed need only be summarized. Place the summary in the Appendix following the calculation for the primary analysis.

The topics in the following sections can be organized in the report either by analysis type (settlement, slope stability, dynamic analysis, etc.), by feature analyzed (embankment, embankment foundation, etc.), or by location (e.g., Embankment - Station 0+00 to 1+00). Project designers prefer organization by location.

## **8.1 Dynamic Analysis**

### **8.1.1 Parameter Selection**

Provide a concise summary of the design seismic conditions assumed for the site. In Section 7.4.2 "Shaking," data on numerous faults which could affect the site was described and tabulated. In this section (8.1.1), summarize the parameters for the controlling event. Include a complete description of all data, assumptions, and resources utilized to develop the ground motion parameters. This information will include both the fault characteristics and the site-specific historical data compiled in Sections 4.4 and 7.4 as well as in Section 7.5 of the Preliminary Geotechnical Report, plus any site-specific design ground motions developed for the site.

Seismic design parameters are needed to evaluate liquefaction potential and remediation measures, and to conduct dynamic analyses of slope stability, embankments, and retaining walls as part of the Geotechnical Design Report. For compatibility between reports, units preparing Geotechnical Design Reports must coordinate their efforts with the Earthquake Engineering Section.

The effort required to develop the basic ground motion parameters for dynamic earthwork analyses varies. For most slope stability and liquefaction studies, examination of standard maps and evaluation of simple attenuation relationships should be sufficient to generate the required peak ground acceleration. However, exceptions might arise such as where liquefaction under a fill could cause a shear failure disrupting nearby foundations. In such instances, it may be desirable to do a detailed, site specific analysis.

Due to variations in project scope, one or more sets of design parameters may be required for a particular project. For instance, a small project consisting of a single embankment placed on deep alluvium may use ground-surface accelerations based on map or attenuation-relationship values for analysis of both liquefaction potential and all stability studies. In contrast, a larger project involving earthwork and several structures, each spanning different subsurface conditions, may require development of separate site-specific ground motion parameters for some features, while literature based project parameters can be used for less

rigorous analyses such as the stability of the cuts and fills. Whatever the degree of analysis used to select design input parameters, discuss and provide the reasoning behind the selection.

### **8.1.2 Analysis**

In this section of the report, discuss analytic methods and the analyses performed to address dynamic conditions. Describe assumptions and reasons for selecting methods of analysis.

The project scope and site conditions will determine the area(s) of the project subject to dynamic analysis. Organize the discussion accordingly. For example, a liquefaction analysis might address an entire site. Discussion of the calculations would therefore be appropriate in the Dynamic Analysis section of the report. On the other hand, a project with several cut and fill areas may entail numerous static and dynamic stability analyses for each cut and fill. It would likely be easier to include the dynamic analysis portion of such studies in Section 8.2.1, "Stability" or Section 8.3, "Embankment" of the report as set forth later in this outline.

Dynamic analysis may show a certain earthquake effect, such as liquefaction, to be probable. Economics and other considerations, however, may lead to the conclusion that treatment to mitigate the conditions will not be incorporated into the project. Include the rationale/philosophy behind such a conclusion. For some types of projects, it may be decided not to study or not to design treatments for considerations such as liquefaction. Include the rationale and/or philosophy behind these decisions.

## **8.2 Cuts and Excavations**

This section presents the analyses used to determine the stability, rippability, and grading factors of materials in proposed cuts or excavations.

### **8.2.1 Stability**

Consider proposed cuts and excavations in terms of temporary, short-term and long-term stability. Perform stability analyses for cuts that, in the opinion of the engineer or geologist, have a potential for instability. Analyze gross stability, surficial stability and stability under seismic loading as appropriate. Use a level of analysis consistent with the consequences of slope failure. Give special attention to very high cuts, steep cuts, cuts with adverse geologic structure, and temporary cuts that may have construction personnel working under them.

The stability analyses used must be appropriate for the slope conditions. For example, a circular failure model should not be used to analyze a cut in rock where discontinuities will control the stability. State the method of analysis, the input data and any assumptions used. If stereographic analyses are used, append the stereonets and summarize the results of the analyses.

A good way to present the data and assumptions used to assess a cut is to show this information on geologic cross sections through the proposed cut area. Soil profiles, ground water surfaces, bedrock profiles, geologic structure, etc. can be depicted along with the proposed cut surface. These may be the same cross-sections presented in the Appendix (Section 13.2).

### **8.2.2 Rippability**

Analyze rippability based on geophysical data, geologic conditions, boring data, experience with the same or similar material, or other methods. State the basis for rippability estimates and include supporting data here or reference the data here and include it in the Appendix.

### **8.2.3 Grading Factors**

Provide the basis for estimating grading factors. Include calculations utilizing relative compaction comparisons based on laboratory test data, geophysical data, boring data or a statement of experience with similar materials.

Considerable uncertainty exists in selecting a specific value of grading factor. Actual earthwork volumes will vary due to subsidence, imprecision in constructing slopes to the designed surface plane, compaction to a greater density than considered in the grading factor calculation, etc. These variations can result in the need to export or import borrow on planned balanced earthwork projects, or change the amount of import/export on other projects, conceivably leading to a contract claim or construction cost overrun.

Although the grading factor selected may be imprecise, it is best not to discuss the possible imprecision unless there is a specific reason to do so. The intent of a Geotechnical Design Report is to assign a specific value so that all bidders can base their bids on that number, knowing that the assigned value will be the baseline against which actual conditions will be measured. The Standard Specifications provide for contract item over- and underruns. Therefore, it is best not to introduce ambiguity in the grading factor by discussing its imprecision in the report.

### **8.3 Embankments**

In this section, describe the analysis and design of embankments and related items. Design of embankment features such as zoning, slope ratios, the foundation, and subsurface drainage would include analysis of settlement, slope stability, groundwater conditions, subsidence, compaction characteristics and problems with the materials to be used in embankment, etc. Discuss design considerations such as the performance requirements of the features and include a description of design parameters selected, the method of analysis used, and comments on the assumptions made during the analysis. Describe alternatives considered. Also, discuss the geotechnical, construction, and maintenance constraints that control the design.

In some areas, slag aggregate is plentiful and inexpensive. Because of its corrosive properties, this material should not be used on projects, but may already be in place in existing fills or backfill. Identify areas where slag aggregate has been used as a construction material and include safeguards to mitigate corrosive properties of these materials.

### **8.4 Earth Retaining Systems**

For earth retaining systems, Geotechnical Design Report should be checked against Memo to Designer, Section 5-20, "Foundation Report / Geotechnical Design Report Checklist for Earth Retaining Systems" for thoroughness of the information provided.

Present the design and analysis of State designed earth retaining systems (see Topic 210 of the Highway Design Manual). These systems, often taken from the standard plans, include Type 1 to 6 retaining walls on spread footings, crib walls, gabion walls, etc. For sites requiring deep wall foundations or other special design walls as discussed in Topic 210, a special foundation design is required and is to be presented in a Structure Foundation Report.

Analyze the assumed foundation characteristics and materials plus the loading conditions for each wall. Present bearing capacity analysis calculations together with the wall geometry, the geotechnical parameters, and the assumptions needed to perform the calculations. Discuss or analyze the frictional sliding resistance and both passive and active pressure conditions relative to the assumptions on which Standard Plan Walls are based. Make particular note of ground water assumptions; surcharges due to superjacent slopes, structural loads and geologic structure; slopes descending from the footing, and other features pertinent to the analysis. Address the global stability of the retaining wall system.

Discuss the stability of the temporary cut needed to install the wall. Safety of temporary cuts and design of shoring is the responsibility of the contractor, however project design personnel need to know if the wall can be installed without shoring for cost estimating purposes.

For geotextile reinforced embankments, present the underlying design assumptions, describe the analysis and present the results. Show the calculations for reinforcement spacing, type selection, global and local stability, etc. in the Appendix.

Refer to the results of corrosion tests pertinent to the proposed retaining systems. Describe the procedures used to analyze the need for corrosion mitigation measures, and present the results of the analysis. When proposed cut areas might be used as a source of backfill for MSE structures, include a discussion of the corrosion characteristics of the potential borrow and the requirements for minimum resistivity, chlorides, sulfates, etc.

## **8.5 Culvert Foundations**

In those instances where geotechnical analyses are conducted for culverts, a description of the analysis and results shall be presented in this section of the GDR. If a geotechnical investigation is not performed, provide the rationale for not completing one. Selection of culvert materials for corrosion resistance is a function of the District Materials Engineer and will not be addressed in the GDR.

Small diameter culverts (300 mm to less than 600 mm) for on-site drainage generally do not require a geotechnical investigation.

Geotechnical investigation, analysis, and design for culverts whose footing pressures exceed 144 kPa or with a diameter or span exceeding 3 m shall be presented in a Structure Foundations Report.

Culverts 600 to 2700 mm in diameter for which Standard Plans and Standard Specifications provide structural and construction details may not require a geotechnical investigation. The decision to investigate this category of culverts is made by the geotechnical designer unless a request for an investigation is made by the project engineer.

When culvert geotechnical investigations are performed, describe the field exploration, testing and analyses of the settlement under the design loading conditions. The goal of the geotechnical design is to limit non-uniform settlement of the culvert. Address the bearing capacity of the foundation soils when required by the Highway Design Manual for the type of culvert being considered.

### **8.6 Minor Structure Foundations**

Provide geotechnical analysis and foundation design recommendations for minor structures such as soundwalls, cantilevered signs, light standards on soft soils, etc. Foundation designs for soundwalls are largely governed by Division of Structures Memo to Designers, Section 22. Coordinate work on soundwalls with the Structure Foundations Branch to avoid duplication of effort.

For each structure site, refer to the boring logs pertaining to each specific structure. Also, summarize the design data (including corrosion data) in this section. Note particularly high groundwater conditions that might affect installation of CIDH piles for soundwall or sign support. For piles subjected to lateral loads, provide analysis to show how the pile diameter and depth were selected. Address allowable bearing capacity.

### **8.7 Others** (*such as drainage galleries, dewatering studies, expansive soil stabilization*)

## **9. Material Sources**

In general, location, testing, analysis, discussion, and preparation of factual data tabulations for materials sources will be done by the District Materials Engineer. Engineering geologists, exploration equipment and drilling staff may assist the DME on request in assessing off-site materials sources, but the resulting data will not be presented in the Geotechnical Design Report.

On occasion, however, materials which could be put to higher use than common borrow will be found in proposed roadway excavation areas or elsewhere within a project's limits. Also, groundwater of some quantity and quality may be available on site. In these instances, the geotechnical staff should coordinate exploration and reporting of the material with the District Materials Engineer.

Identify such sources in this section of the Geotechnical Design Report. Define the limits of the source relative to the proposed construction. Describe the approximate quantity of material available, the amount of overburden to be stripped, and material excavation characteristics. Describe the material as it exists in its natural state, tell what construction material it might be used for, and refer the reader to the Materials Report or Materials Information Handout for further information. It is likely that exploration and test data generated by investigating the on-site materials source will also be relevant to understanding the geotechnical conditions of the project as a whole. Therefore, incorporate the exploration and test data in the Geotechnical Design Report Appendix even if the DME will be publishing the same data in a different report.

## **10. Material Disposal**

For projects with a potential surplus of material (net export projects), note on-site or nearby disposal sites, along with any geotechnical constraints on their use. Also note areas, either on the site or nearby, that may appear to be ideal for disposal, but for which distinct geotechnical reasons exist for not using them. For example, it may not be advisable to fill a hollow with excess material if the hollow is the topographic expression of the head of an ancient landslide.

## **11. Construction Considerations**

### **11.1 Construction Advisories**

In this section provide geotechnical information that might be of use in deciding how to bid and how to construct the project. Include a listing/discussion advising construction personnel of anticipated water, soil, or rock conditions that might affect construction operations, sequences and/or methods. These conditions might include quick soils, extremely fractured rock which could affect construction cuts, massive rock which could affect rippability, high moisture soils which will need to be dried prior to placement in fills or that would affect movement of construction equipment, material availability or conditions that would affect a haul plan, boulders in existing fills which might affect pipe jacking, etc.

Discuss possible constraints due to major underground utilities such as petroleum lines, natural gas pipelines and large water supply lines within or adjacent to the right of way.

### **11.2 Construction Considerations that Influence Design**

In this section, summarize the construction related factors that influenced the analyses and designs discussed in Section 8. Identify design features that were specifically included to address geotechnical conditions during construction. Tell why they were included, emphasizing the repercussions on the construction process, the project, and the project area if they are altered or deleted. For example, the section might include a discussion of soft foundation soils that required placing working tables and/or geotextiles prior to embankment construction or structural section placement in order to avoid a pumping subgrade. Or, it may include a temporary dewatering plan designed to preclude damage to nearby structures due to groundwater draw down. In another instance, the plans may require a culvert to be located near the edge of pavement rather than at the edge of shoulder because the culvert trench would remove support from an adjoining slope.



### **11.3 Construction Considerations that Influence Specifications**

Identify the special provisions that have been written as the result of geotechnical conditions that will impact construction. Discuss the reasons for and intent of these specifications. For example, on soft foundation soil projects, a special provision may state that certain locations cannot be used for stockpiling imported borrow or other materials because the weight of the stockpile could cause adverse settlement or failure of features adjacent to or beneath the stockpile. Or, the special provisions may limit fill placement rates so that a failure does not occur in weak foundation soils. On buttress fill projects, special provisions may be used to preclude stockpiling materials upslope of the temporary cut for the key in order to avoid surcharging the temporary cut slope.

Occasionally, specifications are written that vary on the basis of field performance during construction. Instrumentation may be specified to monitor the field performance and/or potential movement of adjacent facilities. Discuss instrumentation data (see Section 12.4) that would alert the Resident Engineer to request changes in the construction operation or schedule, and note how the specifications are written to allow for these changes.

### **11.4 Construction Monitoring and Instrumentation**

Occasionally geotechnical conditions mandate an instrumentation program to monitor soil and rock behavior and/or potential movement of adjacent facilities during and after construction. An instrumentation program may be included for safety during construction, for verification of design assumptions, for study of short term as well as long-term performance, for verification of the contractor's compliance with specifications, or for legal reasons.

If an instrumentation program is to be conducted, list the various devices planned. Show the locations for the instruments on a map and the elevations at which they will be installed on cross-sections. State the parties responsible for monitoring the instrumentation and for collecting and analyzing the data. If the responsible party is other than the Geotechnical Services, describe the methods and frequency of collecting data and also the types of data that will be collected. Contractor responsibility for installations, maintenance, repair/replacement, etc. shall be stated in the project specifications.

### **11.5 Hazardous Waste Considerations**

For sites on which hazardous waste or material was found, cite the hazardous waste assessment report in Section 3 and reference it here. In

this section, highlight the impacts on construction processes and/or scheduling.

### **11.6 Differing Site Conditions**

Differing site conditions consist of subsurface or latent physical conditions encountered at the site that differ materially from those indicated in the contract, and/or, unknown physical conditions of an unusual nature that are encountered which differ materially from those ordinarily encountered and that are generally recognized as inherent in the work provided for in the contract. The subsurface conditions "in the contract" are those defined by the Geotechnical Design Report.

Emphasize the need for early communication between the Resident Engineer, the Contractor and the Geotechnical Professionals as soon as conditions that differ from those established by the GDR are recognized by any of the parties.

## **12. Recommendations and Specifications**

Present a concise listing of the geotechnical design and construction recommendations and specifications. Where appropriate, tabulate recommendations or present them as bulleted items.

At the beginning of this section, include a brief paragraph stating how to resolve difficulties that may arise over the stated recommendations. An example paragraph is:

"If designers have questions or problems with any of these recommendations, or, if conditions are found to be different during construction, contact the geotechnical staff who prepared this report. Additional field work, analysis or changes in recommendations may be required."

By this point the reader of the Geotechnical Design Report should be well aware of the geotechnical setting and constraints of the project. This section is provided for the geotechnical designer(s) to concisely present, and for interested reader(s) to easily find, recommendations and specifications for the design and construction of the project. Discussion is to be nonexistent or kept to a minimum. Therefore, rather than discussing reasons for the recommendations here, refer the reader to preceding sections of the report for further detail or explanation.

Do not repeat recommendations automatically included as part of the Standard Specifications. Definitely state any recommendations that revise or delete portions of the Standard Specifications as these will have to be presented as Special Provisions. In this case, be thorough in making the recommendation. It will probably be necessary to include a draft wording for the special provision.

List Standard Special Provisions to be included by number and subject. Concisely state any editing to be done to the "Specials" such as adding or deleting paragraphs. Give numbers or phrases that may be necessary to fill in blanks in certain Standard Special Provisions.

Construction recommendations need to be included. During the design phase, construction conditions may be anticipated that require a clear specification telling the contractor what to do, or what not to do. For example, rather than allow a temporary cut slope to build a retaining wall, it might be necessary to tell the designer (and therefore the contractor), "Shore the cut." Or, during construction of a buttress fill, a special provision saying, "Do not stockpile materials on the slope above the proposed buttress," may be needed.

13. **Appendix** (numbering and contents may change depending on the project)
  - 13.1 **Geologic and/or Location of Borings Map**
  - 13.2 **Geologic Cross-Sections & Soil Profiles**
  - 13.3 **Profile Grade Sheets**
  - 13.4 **Boring Legend**
  - 13.5 **Boring Logs**
  - 13.6 **Logs of Test Borings**
  - 13.7 **Geophysical Data**
  - 13.8 **Stereonet**
  - 13.9 **In Situ Test Data**
  - 13.10 **Laboratory Test Data**
  - 13.11 **Corrosion Test Reports**
  - 13.12 **References**
  - 13.13 **Photographs**
  - 13.14 **Calculations**
  - 13.15 **Correspondence**

If previous correspondence transmitted information that would otherwise be presented as sections of the GDR, then append that correspondence.