California High-Speed Train Project

TECHNICAL MEMORANDUM

Geotechnical Reports Preparation Guidelines
TM 2.9.2

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0	22 May 09	Initial Release, R0

Prepared by

for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memorandums. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

Systems:	_NOT REQUIRED_____	____
	Print Name:	Date
Infrastructure:	*Signed document on file*	_22 May 09_
	Donald P. Richards	Date
Operations:	_NOT REQUIRED_____	____
	Print Name:	Date
Maintenance:	__NOT REQUIRED_____	____
	Print Name:	Date
Rolling Stock:	__NOT REQUIRED_____	____
	Print Name:	Date

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ABSTRACT

This technical memorandum addresses reporting of geotechnical information for phased design and construction of California High-Speed Train Project infrastructure facilities. The geotechnical reports will present the findings of the geotechnical investigations and analyses that are performed during preliminary and final design. The term 'geotechnical report' refers to all design level geotechnical reports, including the geotechnical data report, geotechnical baseline report, and geotechnical design report. These reports will be the basis for geotechnical-related aspects of design and construction of project features including earthwork, foundations, and underground infrastructure facilities.

This technical document presents recommended guidelines for the information to be included in the following reports:

- Geotechnical Data Report
- Geotechnical Baseline Report
- Geotechnical Design Report

Additionally, this technical memorandum provides guidance on the content and format of the reports, including the following:

- Checklist of items to consider
- Recommendations for the content and wording of baseline statements
- Examples of problematic and improved practice in stating geotechnical baselines

This document is intended to improve the clarity, understanding and usefulness these reports and to promote compatibility and consistency between the geotechnical reports and other contract documents. The guidelines for the preparation of geotechnical reports for the CHSTP consider the Design-Build approach that will be implemented for project procurement and delivery.

5.0 SOURCE INFORMATION AND REFERENCES

The development of the Geotechnical Report requirements was based on a review and assessment of available information, including the following:

1. American Society of Civil Engineers (ASCE) reference titled “Geotechnical Baseline Reports for Construction – Suggested Guidelines”, ASCE 2007
2. Caltrans, Guidelines for Preparing Geotechnical Design Reports, version 1.3 December 2006
3. Caltrans, Guidelines for Structures Foundations Reports, version 2.0 March 2006
4. FHWA, Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, FHWA-ED-88-053, 1988, revised February 2003

6.0 DESIGN MANUAL CRITERIA

6.1 GEOTECHNICAL REPORTS

The primary documents for the geotechnical discipline include the Geotechnical Baseline Report (GBR), Geotechnical Data Report (GDR), and Final Geotechnical Design Reports. A summary of the typical contents of these reports is provided in the following sections.

6.1.1 Geotechnical Baseline Reports

The listed elements for GBR reports are adapted from the primary reference document by ASCE.

Introduction

- Project name
- Project Owner
- Design team (and Design Review Board, if any)
- Purpose of report; organization of report
- Contractual precedence relative to the GDR and other Contract Documents (refer to the General Conditions)
- Project constraints and latitudes

Project Description

- Project location
- Project type and purpose
- Physical setting, topography and existing man-made features
- Summary of key project features (dimensions, lengths, cross sections, shapes, orientations, support types, lining types, required construction sequences)
- Reference to specific specification sections and drawings to avoid repeating information from other Contract Documents in GBR

Sources of Geologic and Geotechnical Information

- Reference to GDR
- Designated other available geologic and geotechnical reports
- Include the historical precedence for earlier sources of information

Project Geologic Setting

- Brief overview of geologic and groundwater setting, origin of deposits, with cross-reference to GDR text, maps and figures
- Brief overview of site exploration and testing programs – avoid unnecessary repetition of GDR text
- Surface development and topographic and environmental conditions affecting project layout
- Typical surficial exposures and outcrops
- Geologic profile along tunnel alignment(s) showing generalized stratigraphy and rock/soil units, and with stick logs to indicate drill hole locations, depths, and orientations

Previous Construction Experience (key points only in GBR if detailed in GDR)

- Nearby relevant projects
- Relevant features of past projects, with focus on excavation methods, ground behavior, groundwater conditions, and ground support methods

- Summary of problems during construction and how they were overcome (with qualifiers as appropriate)
- Conditions and circumstances in nearby projects that may be misleading and why

Ground Characterization

- Physical characteristic and occurrences of each distinguishable rock or soil unit, including fill, natural soils, and bedrock; describe degree of weathering/alteration; include near-surface units for foundations/pipelines.
- Groundwater conditions; depth to water table; perched water; confined aquifers and hydrostatic pressures; pH; and other key groundwater chemistry details
- Soil/Rock and groundwater contamination and disposal requirements
- Laboratory and field test results presented in histogram (or some other suitable) format, grouped according to each pertinent distinguishable rock or soil unit; reference to tabular summaries contained in the GDR
- Ranges and values for baseline purposes; explanations for why the histogram distributions (or other presentations) should be considered representative of the range of properties to be encountered, and if not, why not; rationale for selecting the baseline values and ranges
- Blow count data, including correlation factors used to adjust blow counts to Standard Penetration Test (SPT) values, if applicable
- Presence of boulders and other obstructions; baselines for number, frequency (i.e., random or concentrated along geologic contacts), size and strength
- Bulking/swell factors and soil compaction factors
- Baseline descriptions of the depths/thicknesses or various lengths or percentages of each pertinent distinguishable ground type or stratum to be encountered during excavation; properties of each ground type; cross-references to information contained in the drawings or specifications
- Values of ground mass permeability, including direct and indirect measurements of permeability values, with reference to tabular summaries contained in the GDR; basis for any potential occurrence of large localized inflows not indicated by ground mass permeability values
- For tunneling/TBM reaches, interpretations of rock mass properties that will be relevant to boreability and cutter wear estimates for each of the distinguishable rock types, including test results that might affect their performance (avoid explicit penetration rate estimates or advance rate estimates)

Design Considerations – Tunnels and Shafts

- Description of ground classification system(s) utilized for design purposes, including ground behavior nomenclature
- Criteria and methodologies used for the design of ground support and ground stabilization systems, including ground loadings (or reference the drawings/ specifications)
- Criteria and bases for design of final linings (or reference to drawings/ specifications)
- Environmental performance considerations such as limitations on settlement and lowering of groundwater levels (or in specifications)
- The manner in which different support requirements have been developed for different ground types, and, if required, the protocol to be followed in the field for determination of ground support types for payment; reference to specifications for detailed description ground support methods/sequences
- The rationale for ground performance instrumentation included in the drawings and specifications

- Influence of stress concentrations at intersections
- Slope stability issues at tunnel portals
- Seismic considerations in selection of final ground support requirements
- Role of groundwater in final ground support design - i.e. drained or undrained

Design Considerations – Other Excavations and Foundations

- Criteria and methodologies used for the design of retaining walls and excavation support systems, including lateral earth pressure diagrams (or in drawings/specifications) and need to control deflections/deformations, and bearing pressures
- Feasible excavation support systems
- Minimum pile tip elevations for deep foundations
- Refusal criteria for driven piles
- Allowable skin friction for tiebacks
- Environmental considerations such as limitations on settlement and lowering of groundwater levels (or in specifications)
- Rationale for instrumentation/monitoring shown in the drawings and specifications
- Embankment fill and grading/earthwork criteria

Construction Considerations – Tunnels and Shafts

- Anticipated ground behavior in response to construction operations within each soil and rock unit
- Required sequences of construction (or in drawings/specifications)
- Specific anticipated construction difficulties
- Rationale for requirements contained in the specifications that either constrain means and methods considered by the Contractor or prescribe specific means and methods (e.g., the required use of an EPB or slurry shield)
- The rationale for baseline estimates of groundwater inflows to be encountered during construction, with baselines for sustained inflows at the heading, flush inflows at the heading, and cumulative sustained groundwater inflows to be pumped at the portal or shaft
- The rationale behind ground improvement techniques and groundwater control methods included in the Contract
- Potential sources of delay, such as groundwater inflows, shears and faults, boulders, logs, tiebacks, buried utilities, other manmade obstructions, gases, contaminated soils and groundwater, hot water and hot rock, etc.

Construction Considerations – Other Excavations and Foundations

- Anticipated ground behavior in response to required construction operations within each soil and rock unit
- Rippability of rock, till, caliche, or other hard materials, and other excavation considerations including blasting requirements/limitations
- Need for groundwater control and feasible groundwater control methods
- Casing requirements for drilled shafts
- Specific anticipated construction difficulties
- Rationale for requirements contained in the specifications that either constrain means and methods considered by the Contractor or prescribe specific means and methods
- The rationale for baseline estimates of groundwater inflows to be encountered during construction, with baselines for sustained inflows to be pumped from the excavation

- The rationale behind ground improvement techniques and groundwater control methods included in the Contract
- Potential sources of delay, such as groundwater inflows, shears and faults, boulders, buried utilities, manmade obstructions, gases, or contaminated soils or groundwater
- Acceptable fill and backfill material, and compaction requirements

6.1.2 Geotechnical Data Reports

The listed elements for typical GDR reports are adapted from the primary reference documents by FHWA, Caltrans, and the Geotechnical Investigation Guidelines TM.

I. Executive Summary
II. Introduction
    A. Project Description
    B. Purpose and Scope
    C. Available Data and Information
    D. Report Organization
III. Geologic Setting
    A. General
    B. Faulting
IV. Seismic Setting
    A. General Seismic Setting
    B. Fault Rupture Displacement
    C. Soil Profile (Site Class) Types, per NEHRP
    D. Seismic Design Criteria
    E. Seismic Design Ground Motions
V. Hydrogeologic Setting
    A. Regional Cross-Sections
    B. Major Aquitards
    C. Regional Water Levels
    D. Land Subsidence
    E. Artesian Conditions
    F. Presence of Gas
    G. Groundwater Chemistry and Corrosion Potential
VI. Field Investigations
    A. Introduction
        1. 10% and 35% Designs
        2. Organizations of Team
        3. Field Manual
        4. Project Restrictions
    B. Exploratory Boring Program
        1. Overview
        2. Drill Rig and Hammer Types
        3. Sampling Methods and Equipment
            a. Sampler Types
            b. Sampling Interval

4. Handheld Field Tests
5. Groundwater Level Measurements
6. Sample Handling
7. Borehole Completion and Abandonment
8. Boring Log Organization and Presentation
9. Standard Penetration Test (SPT)
10. Extruded Boring Logs
11. SPT Energy Calibration
12. Air and Vapor Monitoring
13. Borehole Water Pressure Tests for Bedrock (fracture) Permeability

C. Field Vane Shear Testing
   1. Field Procedures
   2. Frequency of Testing
   3. Results

D. Pressuremeter Testing
   1. Field Procedures
   2. Frequency of Testing
   3. Results

E. Downhole Geophysical Logging
   1. Field Procedures
   2. Frequency of Testing
   3. Results

F. Vibrating Wire Piezometers
   1. Field Procedures
   2. Frequency of Testing
   3. Results

G. Observation Wells
   1. Field Procedures
   2. Frequency of Testing
   3. Results

H. Pumping Tests and Slug Testing
   1. Field Procedures
   2. Frequency of Testing
   3. Results

I. Cone Penetration Testing Program
   1. Conventional CPTs
      a. Equipment
      b. Procedures
      c. Locations
      d. Results
   2. Seismic CPTs
      a. Equipment
      b. Procedures
      c. Locations

d. Results

3. Hydropunch Testing
   a. Equipment
   b. Procedures
   c. Results
4. Dissipation Testing
   a. Equipment
   b. Procedures
   c. Locations
   d. Results
5. CPT Completion and Abandonment

VII Laboratory Investigations

A. Introduction:
   1. Laboratory Visual Classification
   2. Moisture Content
   3. Unit Weight
   4. Specific Gravity
   5. Sieve and Hydrometer Analysis
   6. Materials Finer than No. 200 Sieve
   7. Atterberg Limits
   8. Shear Strength
   9. Expansion Index
   10. Consolidation
   11. Hydraulic Conductivity
   12. Rock Quality Designation (RQD)
   13. Shear Strength Testing of Rock Samples
   14. Brazilian Test (Indirect Splitting Tensile Test) on Rock
   15. Point Load Strength Index Testing on Rock
   16. Slake Durability (of weak rock samples)

B. Specialty Testing
   1. Shipping and X-ray
   2. Constant Rate of Strain Consolidation Tests
   3. Consolidated Drained Triaxial Tests
   4. Static Direct Simple Shear Tests
   5. K_0-Consolidated Undrained Triaxial Compression and Extension Tests
   6. K_0-Consolidated Undrained Triaxial Compression (Bishop Method) Tests

C. Corrosion Testing

VIII Surface Conditions, and Subsurface (Soil, Rock, and Groundwater) Conditions along the CHST Alignment

A. Surface Conditions and Physical Setting

B. Generalized Subsurface Conditions
   1. Geologic Deposits
   2. Applicable Geotechnical Subsurface Information
   3. Material Sources

4. Groundwater Table Information and Hydrogeology
5. Air and Vapor Monitoring

C. Detailed Stratigraphy (Soil and Bedrock)
1. Geotechnical Study Section 1: Sta. __ to Sta. ___
2. Geotechnical Study Section 2: Sta. __ to Sta. ___
3. Geotechnical Study Section 3: Sta. __ to Sta. ___
4. Geotechnical Study Section 4: Sta. __ to Sta. ___
5. Geotechnical Study Section 5: Sta. __ to Sta. ___

D. Geotechnical Properties – Soil and Bedrock
1. Undrained Shear Strength
   a Field Vane Shear Tests
   b. Pressuremeter Tests
   c. CPT Undrained Shear Strength Calibration and Results
   d. Triaxial Tests
   e. Laboratory Static Direct Simple Shear Tests
2. Effective Shear Strength Parameters
   a. Pressuremeter Tests
   b. CPT Undrained Shear Strength Calibration and Results
   c. SPT Blow Counts
3. Compressibility, Load History and Hydraulic Conductivity
   a. Consolidation Tests
   b. At-Rest Earth Pressure Coefficient
   c. Coefficient of Hydraulic Permeability
4. Stress-Strain Parameters
   a. Initial Tangent Shear Modulus
   b. Secant Modulus
   c. Small-Strain Shear and Compression Velocities (Poisson's Ratio)
5. Rock Parameters
   a. Shear Strength
   b. Durability
   c. Unit Weight
   d. Rock Mass Rating
   e. Bedrock Discontinuities
   f. Geological Strength Index

IX Limitations

X References

6.1.3 Final Geotechnical Design Reports

The listed elements for Final Geotechnical Design Reports are adapted from the primary reference documents by FHWA, Caltrans, and the Geotechnical Investigation Guidelines TM.

Final Geotechnical Design Reports should, at a minimum, contain the following typical elements though not specifically organized in this format:

1. A general description of the project, project elements, and project background
2. Project site surface conditions and current use

3. Regional and site geology. This section should describe the site stress history and depositional/erosional history, bedrock and soil geologic units, etc
4. Regional and site seismicity. This section should identify potential source zones, potential magnitude of shaking, frequency, historical activity, and location of nearby faults. This section is generally only included in reports addressing structural elements (e.g., bridges, walls, marine terminal structures, etc.) and major earthwork projects.
5. A summary of the site data available from project or site records (e.g., final construction records for previous construction activity at the site, as-built bridge or other structure layouts, existing test hole logs, geologic maps, previous or current geologic reconnaissance results, etc.).
6. A summary of the field exploration conducted, if applicable. Here, a description of the methods and standards used is provided, as well as a summary of the number and types of explorations that were conducted. Include also a description of any field instrumentation installed and its purpose. Refer to the detailed logs located in the report appendices.
7. A summary of the laboratory testing conducted, if applicable. Again, a description of the methods and standards used is provided, as well as a summary of the number and types of tests that were conducted. Refer to the detailed laboratory test results in the report appendices.
8. Project Soil/Rock Conditions. This section should include not only a description of the soil/rock units encountered, but also how the units tie into the site geology. Ground water conditions should also be described here, including the identification of any confined aquifers, artesian pressures, perched water tables, and potential seasonal variations, if known, any influences on the ground water levels observed, and direction and gradient of ground water, if known. If rock slopes are present, discuss rock structure, including the results of any field structure mapping (use photographs as needed), joint condition, rock strength, potential for seepage, etc. These descriptions of soil and rock conditions should in general be illustrated with subsurface profiles (i.e., parallel to alignment centerline) and cross-sections (i.e., perpendicular to alignment centerline) of the key project features. A subsurface profile or cross-section is defined as an illustration that assists the reader of the geotechnical report to visualize the spatial distribution of the soil and rock units encountered in the borings and probes for a given project feature (e.g., structure, cut, fill, landslide, etc.). As such, the profile or cross-section will contain the existing and proposed ground line, the structure profile or cross-section if one is present, the boring logs (including SPT values, soil/rock units, etc.), and the location of any water table(s). Interpretive information contained in these illustrations should be kept to a minimum. What appears to be the same soil or rock unit in adjacent borings should not be connected together with stratification lines unless that stratification is reasonably certain. The potential for variability in the stratification shall be conveyed in the report, if a detailed stratification is provided. In general, geologic interpretations should not be included in the profile or cross-section, but should be discussed more generally in the report. A subsurface profile should always be provided for bridges, tunnels, and other significant structures. For retaining walls, subsurface profiles should always be provided for soil nail walls, anchored walls, and non-gravity cantilever walls, and all other walls in which there is more than one boring along the length of the wall. For other wall situations, judgment may be applied to decide whether or not a subsurface profile is needed. For cuts, fills, and landslides, soil profiles should be provided for features of significant length, where multiple borings along the length of the feature are present. Subsurface cross-sections should always be provided for landslides, and for cuts, fills, structures, and walls that are large enough in cross-section to warrant multiple borings to define the subsurface cross-section.
9. Summary of geological hazards identified and their impact on the project design (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards, etc.), if any. Describe the location and extent of the geologic hazard.
10. For analysis of unstable slopes (including existing settlement areas), cuts, and fills, background regarding the following:
    - Analysis approach

- Assessment of failure mechanisms
- Determination of design parameters
- Any agreements with stakeholders regarding the definition of acceptable level of risk

Included in this section would be a description of any back-analyses conducted, the results of those analyses, comparison of those results to any laboratory test data obtained, and the conclusions made regarding the parameters that should be used for final design.

11. Analysis and stability of Tunnels (including mined, bored and cut-and-cover):
    - Analysis approach and assessment of failure mechanisms
    - Determination of design parameters
12. Geotechnical recommendations
    - For *earthwork/sitework* (fill design, cut design, usability of on-site materials as fill). This section should provide embankment design recommendations, if any are present, such as the slope required for stability, any other measures that need to be taken to provide a stable embankment (e.g., geosynthetic reinforcement, wick drains, controlled rate of embankment construction, light weight materials, etc.), embankment settlement magnitude and rate, and the need and extent of removal of any unsuitable materials beneath the proposed fills. Cut design recommendations, if any are present, are also provided in this section, such as the slope required for stability, seepage and piping control, erosion control measures needed, and any special measures required to provide a stable slope. Regarding usability of on-site materials, soil units should be identified as to their feasibility of use as fill material, discussing the type of fill material for which the on-site soils are feasible, the need for aeration, and the effect of weather conditions on its usability, and identification of materials that should definitely be considered as waste. This section should also address site preparation in advance of construction, and whether or not there are needs for in-situ Ground Modification and Improvement (e.g., densification, reinforcement and stiffening, grouting).
    - For *rock slopes and rock excavation*. Such recommendations should include, but are not limited to, stable rock slope, rock bolting/dowelling, and other stabilization requirements, including recommendations to prevent erosion/undermining of intact blocks of rock, internal and external slope drainage requirements, feasible methods of rock removal, etc.
    - For *stabilization of unstable slopes* (e.g., landslides, rockfall areas, debris flows, etc.). This section should provide a discussion of the mitigation options available, and detailed recommendations regarding the most feasible options for mitigating the unstable slope, including a discussion of the advantages, disadvantages, and risks associated with each feasible option.
    - For *bridges, tunnels, hydraulic structures, and other structures*. This section should provide a discussion of foundation options considered, the recommended foundation options, and the reason(s) for the selection of the recommended foundation option(s), foundation design requirements (for strength limit state - ultimate bearing resistance and depth, lateral and uplift resistance, for service limit state - settlement limited bearing, and any special design requirements), seismic design parameters and recommendations (e.g., design acceleration coefficient, soil profile type for standard response spectra development, or develop non-standard response spectra, liquefaction mitigation or ground improvement requirements, extreme event limit state bearing, uplift, and lateral resistance, and soil spring values), design considerations for corrosion or scour when applicable, earth pressures on abutments and walls in buried structures, and recommendations regarding bridge approach slabs.
    - For *retaining walls and reinforced slopes*. This section should provide a discussion of wall/reinforced slope options considered, the recommended wall/reinforced slope options, and the reason(s) for the selection of the recommended option(s), foundation type and design requirements (for strength limit state - ultimate bearing

resistance, lateral and uplift resistance if deep foundations selected, for service limit state - settlement limited bearing, and any special design requirements), seismic design parameters and recommendations (e.g., design acceleration coefficient, extreme event limit state bearing, uplift and lateral resistance if deep foundations selected) for all walls except Standard Plan walls, design considerations for corrosion or scour when applicable, and lateral earth pressure parameters (provide full earth pressure diagram for non-gravity cantilever walls and anchored walls). For non-proprietary walls/reinforced slopes requiring internal stability design (e.g., geosynthetic walls, soil nail walls, all reinforced slopes), provide minimum width for external and overall stability, embedment depth, bearing resistance, and settlement, and also provide soil reinforcement spacing, strength, and length requirements in addition to dimensions to meet external stability requirements. For proprietary walls, provide minimum width for overall stability, embedment depth, bearing resistance, settlement, and design parameters for determining earth pressures. For anchored walls, provide achievable anchor capacity, no load zone dimensions, and design earth pressure distribution.

- For *infiltration/detention facilities*. This section should provide recommendations regarding infiltration rate, impact of infiltration on adjacent facilities, effect of infiltration on slope stability, if the facility is located on a slope, stability of slopes within the pond, and foundation bearing resistance and lateral earth pressures (vaults only).

13. Long-term or construction monitoring needs. In this section, provide recommendations on the types of instrumentation needed to evaluate long-term performance or to provide control during construction, the reading schedule required, how the data should be used to control construction or to evaluate long-term performance, and the zone of influence for each instrument.
14. Construction considerations. Address issues of construction staging, shoring needs and potential installation difficulties, temporary slopes, potential foundation installation problems, earthwork constructability issues, dewatering, etc.
15. Appendices. Typical appendices include design charts for foundation bearing and uplift, P-Y curve input data, design detail figures, layouts showing boring locations relative to the project features and stationing, subsurface profiles and typical cross-sections that illustrate subsurface stratigraphy at key locations, all boring logs used for the project design (includes older borings as well as new borings), including a boring log legend for each type of log, laboratory and field test data obtained, instrumentation measurement results, and special provisions needed.

The detail contained in each of these sections listed above will depend on the size and complexity of the project elements and subsurface conditions. In some cases, design memoranda that do not contain all of the elements described above may be developed prior to developing a final geotechnical report for the project.