## Geotechnical Investigations

This module addresses geotechnical investigations. The information presented is general in that it applies to most geotechnical investigations regardless of the purpose or type(s) of proposed improvement(s). Specifics on the appropriate types and extent of explorations are provided in the individual design modules.

The three references cited at the end of this module contain relevant information that is not provided here, and it is recommended that the Geoprofessional (GP) become familiar with their contents as they may serve as valuable references for investigation work.

This module documents the standards and procedures for both planning (K and 0 phase) investigations and design (1 phase) investigations. Geotechnical investigations are conducted in the office and at the project site, generally in the following order:

- Office work (As-built/Literature review)
- Site investigation (Planning Phase)
- Site investigation (Design Phase)

Office investigations consist largely of literature reviews and discussions with other staff. Site investigations consist of activities performed at the project site to acquire information such as surface mapping, or subsurface investigations using drilling, geophysics, or the Cone Penetration Test (CPT).

In some cases, more than one GP from more than one design branch may be performing investigations on the same project. If more than one GP is working on the project, communicate and coordinate the investigative work with all parties to maximize efficiency.

## Investigation Process

The geotechnical investigation for a project typically begins with a request for a District or Structure Preliminary Geotechnical Report (DPGR or SPGR). The information presented in these planning-phase reports is typically based on the results of a literature review, conversations with knowledgeable staff such as other GPs or Maintenance personnel, and a limited site investigation. Reports prepared during the 0-phase and 1-phase, such as the Preliminary Geotechnical Design Report (PGDR), Geotechnical Design Report (GDR), Preliminary Foundation Report (PFR) and Foundation Report (FR), are based on the findings of the planning-phase work and the site investigation, which may include drilling, sampling, testing, geophysical testing, or the CPT.

### Office Work

The GP should become familiar with the proposed project, and specific geotechnical work requested, by reviewing the request and plans, and meeting or speaking with the client to review the work request. Location and size of structures, embankments, and cuts should be understood. Discuss the amount of flexibility in the location of structures or other works and determine the approximate loads.

Consult with other GPs who have worked in the area or perhaps even on that project. Contact the local Maintenance supervisor to inquire about their experience with the site and invite them to the site visit. They may have information that will be useful in planning the geotechnical investigation and/or that will be documented in the report, e.g., landslide or rockfall history.

The GP should perform a thorough literature search to become familiar with all pertinent information. Review the relevant design module(s) to identify the types of information needed and the reporting requirements. The following resources should be reviewed during the literature search and prior to the site investigation.

*Publicly available resources:*

- Geotechnical reports, laboratory tests, and Log of Test Borings (LOTB)
  - Digital Archive of Geotechnical Data (GeoDOG)
- Geology and topography
  - California Geological Survey
  - US Geological Survey
  - Google Maps
  - Topozone
  - Historic Aerials
- Groundwater data
  - California Department of Water Resources
  - Los Angeles County Wells
  - Groundwater Level Maps
  - Water Data Library
  - Groundwater Ambient Monitoring and Assessment Program
  - GeoTracker
  - National Water Information System
  - National Geologic Map Database
  - EnviroStor
- Soil surveys
  - Natural Resources Conservation Service.
- Liquefaction maps (Association of Bay Area Governments)
- California fault maps (e.g., Alquist-Priolo Earthquake Fault Zone Maps)
  - California Geological Survey.
- Seismic information: ARS Online

*Caltrans Internal Information*

- Virtual drive-by: Pathweb
- Bridge As-built plans (including LOTB) and maintenance records
  - Bridge Inspection Records Information System (BIRIS)
- District roadway and maintenance records
  - Document Retrieval System
- Aerial photographs
  - Digital Highway Inventory Photography Program
- Standpipe Piezometer Database in Geotechnical Services Project Tracking
- Geotechnical Design Project Records Management System

The Caltrans Library at 1120 N Street Sacramento, as well as the California Geological Survey Library (801 K St. 14th Floor, Sacramento) have many reports and references, and can facilitate interlibrary loans.

**Site Investigation for K Phase**

Subsurface investigations utilizing drilling, CPT, or geophysical testing are typically not performed in the K phase, or for non-programmed work. However, if project needs justify these or other non-resourced work, the GP should propose the work to the Project Engineer (PE) and Project Manager and communicate resource needs through DES Program Project Management to the District. An example would be a proposed bridge site with no available subsurface information but where liquefaction is suspected and would impact foundation and structure types.

The purpose of the planning-phase site investigation is to gather existing site information, evaluate if the proposed work is appropriate, and to support preliminary recommendations. The site investigation is typically limited to a site visit, observations, mapping, and hand measurements such as lengths, heights, and slope angles. If there are anticipated challenges relating to the design-phase site work, invite the appropriate support representatives along to plan future work. The Project Engineer and the local Maintenance supervisor should be invited.

Specific observations or measurements made will depend on the types of improvements proposed. Read the relevant design and reporting modules to identify the information needed. During the planning-phase site investigation:

- Field-check preliminary plans for accuracy, ideally with the Project Engineer.
- Assess the performance of existing structures and improvements (e.g., scour, slope stability, erosion, and rock fall) as they relate to the proposed work.
- Decide whether the proposed work is constructible as planned. Identify suitable foundation types and need for ground improvement or other items that could impact on the scope of work.

- Walk the site with Maintenance. Ask them to identify any problems in the area and their availability to assist with future site work such as traffic control or access road construction.
- Select potential boring locations and related access.
- Determine geophysical testing needs.
- With the PE and Caltrans personnel involved in obtaining permits, determine the need for permits and when to start the permit process.
- Determine potential task order needs and discuss with the PE and Project Manager (PM).
- Photograph or video relevant site features and probable exploration locations.
- If drilling is to be performed during the planning phase, refer to the following sections on planning a subsurface investigation for the design phase.

## Site Investigation for 0 or 1 Phase

The 0 or 1 phase geotechnical investigation begins with a request for a Preliminary Geotechnical Design Report (DPGR), Geotechnical Design Report (GDR), Preliminary Foundation Report (PFR), or Foundation Report (FR). The purpose of the 0 or 1-phase site investigation program is to obtain the engineering properties of the soil or rock and to determine the areal extent, depth, and thickness of each identifiable soil/rock unit that could affect the design of the project, while minimizing exploration costs.

The geotechnical investigation for design should adequately define the subsurface conditions for design purposes and be consistent with the standards of practice identified in this manual. The extent of the exploration and testing, and the number of measurements of each critical design property in each unit/stratum must give a reasonable degree of confidence in the property measured. Specifics of information needed for design are presented in the applicable design module(s) of the Geotechnical Manual and their references.

The GP may or may not have been involved in the K-phase investigation for the project, so the amount of literature review necessary at this time will vary.

### *Preparing for Site Visit*

To prepare for the site visit:

- Review work request for completeness. See the applicable design module, Bridge Memo to Designers (MTD) 1-35 for bridge foundations, or MTD 5-19 for earth retaining structures for the required content. The request must provide adequate information to allow for effective planning of the investigation.
- Speak with the requestor to establish a working relationship and to review the work request. Invite the client to the site visit.
- Review literature and all K- and 0-phase reports. Speak with the report authors, if available.

- Submit a *Site Assessment Questionnaire* to the District Environmental Coordinator. Hazardous subsurface materials could affect the investigation and therefore need to be identified as early as possible. The specifics of hazardous materials present at the site will determine if GS staff can perform the drilling, CPT, or other investigative work, and determine special precautions needed. If GS cannot perform the site work, then the GP must arrange for a Task Order to have a consultant perform the site work.
- Speak to and invite the local Maintenance supervisor to the site visit.
- If permits are anticipated invite the appropriate district personnel (Right of Way, Environmental, etc.)
- Contact District Surveys to obtain a benchmark close to the project.

***Site Visit***

The objective of the site visit is to prepare for a successful site investigation. In many cases multiple site visits may be necessary to prepare for the subsurface investigation work. The GP should:

- Meet with personnel who will support the site investigation, such as the project engineer, maintenance supervisor, and environmental coordinator.
- Review the site and plans with the project engineer. Confirm that the planned work is appropriate. Use of a handheld GPS to locate proposed improvements is helpful.
- Field-check plans, layouts, and cross sections for accuracy with the project engineer.
- Assess the performance of existing structures and improvements (scour, slope stability, erosion, rock fall, etc.) as it relates to the current work. Do not limit observations to just the footprint of the structure, wall, or other improvements being considered. Make note of relevant geologic features within a reasonable distance of the site. Ask the maintenance supervisor for their insight and experience with the site.
- Estimate the type and variability of subsurface conditions. What's expected will help determine the appropriate investigation tools to be used, the number and location of borings, and the sampling needs.
- Identify site investigation methods to be used (drilling, CPT, geophysics) and the preferred order (or staging) of the work. See *Selection of the Appropriate Investigation Method* and *Choosing Boring Locations and Depth* below.
- Look for conditions that will affect the location of borings such as:
    - Wetland or surface water
    - Environmentally sensitive areas
    - Underground or overhead utilities
    - Active rockfall areas
- Evaluate site access, the need for permits and timing of work. Talk with designer about potential for changes to alignments, support locations, wall lengths, etc, and consider these when applying for permits and determining access routes

(see the Offices of Geotechnical Design – Quality Management Plan, *Permitting* section).

- Working with Maintenance and Drilling Services, check access for exploration equipment and determine the best suited equipment type for the site. If site preparation is necessary, determine the type of equipment, such as a bulldozer, that may be needed for drilling equipment access. Note exploration locations and access details on the Layout Plan Sheet and submit this with the *Drilling Request*. District Environmental will need to be involved in any plans to do grading work for site access.
- For projects adjacent to rivers or lakes inquire with the District Environmental if water can be pumped and used for drilling. This will eliminate idle time associated with water resupply.
- Determine the need for traffic control to accomplish the site exploration program (see *Choosing Boring Locations and Depth*).
- Locate the benchmark(s) to be used (see *Borehole Location* module). Create a temporary benchmark closer to the planned exploration locations to make the borehole location task easier on the day of drilling, especially for night drilling.
- Identify geophysical testing needs.
- Mark for utility clearance (see Offices of Geotechnical Design – Quality Management Plan, *Utility Clearance* section) and ask Maintenance to mark irrigation and electrical lines at all proposed boring locations.

### ***Follow-up work to the site visit***

This may include the following, depending on the nature of the planned site investigation work:

- Submit Drilling Request, CPT Request, or Geophysics Request.
- Work with Maintenance to finalize site access and traffic control needs.
- Submit pertinent information for permitting to the district.
- Obtain utility clearance.

## Selection of the Appropriate Investigation Method

The purpose of the investigation is to acquire the information needed to design the project. The GP should evaluate As-built information and utilize it for planning the investigation. This may reduce or eliminate site work. It is often possible to obtain information in several ways. The specific method used can vary depending on equipment availability, access, timing, site conditions, and the planned work. For example, a foundation investigation for a bridge using driven standard plan piles could use mud rotary drilling, augering, CPT, or the dynamic penetrometer. Sampling could range from none in CPT and penetrometer holes, to visual descriptions and on-site testing of samples using pocket penetrometer, torvane and vane shear, to detailed laboratory testing.

Consider the cost of the investigation including time and dollars, safety, and effects on traffic and maintenance operations. Rather than planning many conventional borings with Standard Penetration Test (SPT) borings, consider using many CPT holes in conjunction with a few conventional borings with SPT. If piles are to be founded on rock or dense soils, consider dynamic penetrometer holes or geophysical testing to delineate the bearing surface. For the cost of one SPT boring it is possible to push about 5 CPT soundings or 20 dynamic penetrometer holes. Weigh the effort versus the cost and desired outcome. Consider Wacker-driven 1-inch soil tubes instead of truck mounted drilling, if clearing new access roads are required for the latter. Instead of drilling in lane closures or at night, consider drilling on city streets, even if it requires an extra boring or two.

Caltrans can drill borings using wireline/conventional rotary drilling, hollow stem augers, dynamic penetrometer, hand-drilled soil tubes, and CPT. For more details, refer to the Drilling Services webpage or contact the appropriate Drilling Services liaison. In some situations, hand or backhoe trenches, geophysical measurements, and surface mapping can replace drilling. Exposure of workers to traffic can be minimized by choosing the CPT and/or dynamic penetrometer (DP) in high traffic areas and correlating results with conventional drilling performed in safer areas. The CPT is considered safer because the operator is protected by the truck, and dynamic penetrometer may be safer because holes are completed in minutes rather than hours.

When developing a subsurface investigation, consider the various drill methods and sampling needed to achieve the project goals. Augering is cheap for relatively shallow holes and provides instant groundwater information, but it is not suitable for SPT work below the water table or when borehole geophysical measurements are planned. Wireline (self-casing) drilling makes it easy for the drillers to maintain stability of the holes and is ideal for borehole geophysics, but their use may mask hole instability. If CIDH piles are being contemplated for the design, then consider at least one hole not using a self-casing drilling method to determine if caving is a problem. All methods have limitations. The CPT cannot penetrate very hard/dense layers or retrieve samples. Augers cannot penetrate hard rock. The dynamic penetrometer provides only relative data. SPT holes require truck or trailer mounted equipment which may require construction of access roads. But each method has its use.

Testing should also be appropriate for the foundations and design methods being considered (refer to the relevant design module). In situ and site testing are often quicker and cheaper than lab testing. Where appropriate, use vane shear, pocket penetrometer, and torvane to determine cohesive shear strength. The pressure meter or dilatometer can determine rock strength at the site.

Consult with the Geophysics and Geology Branch to determine what they can do to reduce the effort (time, cost) and uncertainties. Geophysics cannot provide a description of the soil or rock; however, it can be used to evaluate variability of soil and rock and can provide in situ material properties such as bulk density, shear modulus, and porosity. Shear wave velocity can be obtained directly from a down-hole instrument placed in a borehole at the end of drilling operations, or indirectly from surface wave measurements. Geophysics can be cost-effective for small projects where specific targets are needed (e.g., landslide imaging, borehole geophysics for in situ properties, void detection, subsurface utilities, and rock rippability). For large projects, it may be useful to perform geophysical investigations to determine the uniformity of the subsurface conditions. Based on those results, the number or location of boreholes may be adjusted.

CPT can provide shear wave velocity measurements more cheaply than PS Suspension logging. Consider using the seismic cone even if measurements cannot be made to a depth of 100 feet. Surface wave velocity measurements can also be used in lieu of drilling and CPT in areas with restricted access or rocky conditions.

If a required investigative method is not available in-house, the GP should work with the appropriate support branch to acquire consultant services.

### Choosing Boring Locations and Depth

Boreholes should be located as close as possible to the planned improvement and in accordance with the applicable module. The exact location of the borehole(s) will rely on many factors including but not limited to the variability of the subsurface conditions, the type of foundation or project component, equipment accessibility, permit restrictions and impacts to traffic. Whenever possible, the borehole locations should be chosen so that the drilling does not require lane closures or expose personnel to traffic. Maintenance can remove barrier rails to allow access to potential boring locations. Drilling on city streets and frontage roads is safer than drilling on highways and freeways. Consider drilling two holes slightly off-site rather than one exactly on-site to lessen exposure to traffic.

Depth of drilling is a function of the project and the geology. If the project foundations are well established, e.g., it is certain that Class 90 Alternative “X” piles will be used, then it makes sense to drill 10 to 20 feet deeper than the estimated pile tip. On the other hand, if there is a reasonable possibility that the proposed pile group foundation may be replaced with single CIDH or CISS piles, then at least some of the exploration borings should be deep enough for design of the CISS or CIDH piles. Consideration of the geology is also important. Where the geology is well exposed and uniform, drilling may not be necessary. For example, even if $V_{S30}$ is required for a seismic analysis and the site is homogeneous granite, it may not be necessary to drill a 100-foot-deep hole to establish the shear wave velocity. The design modules provide general guidance for drilling depths. However, consideration of the geology and project parameters must take precedence.

Minimize encroachment on environmentally sensitive areas (ESA) to save the time and extra work needed to address the special needs of the area. Locations of ESAs are typically shown on the project layout plans. The PE, or the project’s environmental staff, should be able to locate the ESAs during the site visit. The Categorical Exemption/Categorical Exclusion (CE) obtained from District Environmental prior to drilling will identify the ESAs and special requirements needed during the drilling process.

Drilling through a bridge deck may be more efficient than using a barge. Drilling through a bridge deck requires the approval of the Bridge Maintenance Engineer to assure that critical structural elements are not damaged by the coring operations.

Refer to AASHTO LRFD BDS Section 10.4.2, *Subsurface Exploration*, for more information about the number, locations, and depths of exploratory borings.

## References

1. "*Subsurface Investigations – Geotechnical Site Characterization*", FHWA NHI-01-031, May 2002
2. Geotechnical Engineering Circular No. 5, Geotechnical Site Characterization, FHWA NHI-16-072, April 2017
3. "*Manual on Subsurface Investigations*", AASHTO 1988
4. AASHTO LRFD BDS Section 10.4.2, *Subsurface Exploration*, 8th Edition, 2017