Alberta Infrastructure

Geotechnical Investigation Guidelines for Alberta Infrastructure Projects

Version 1.0

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Technical Services & Procurement Branch

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1 Introduction

1.1 Purpose of Guidelines

The Guidelines have been prepared to set out the standards of practice which geotechnical consultants should meet and follow while providing professional engineering services for Alberta Infrastructure projects.

Following are the specific objectives of these guidelines:

1. Describe the standard of practice that Engineering Professionals should follow when providing professional services related to geotechnical professional activities.
2. Specify the tasks and/or services that Engineering Professionals should complete or provide to meet the appropriate standard of practice and fulfill their professional obligations under the Act. These obligations include the Engineering Professional's primary duty to protect the safety, health, and welfare of the public and the environment.
3. Describe the roles and responsibilities of the various participants/stakeholders involved in these professional activities. The document should assist in delineating the roles and responsibilities of the various participants/stakeholders, which may include the Registered Professional of Record, the Geotechnical Engineer of Record (GER), Province, Authorities Having Jurisdiction, Supporting Registered Professionals, and contractors.
4. Define the skill sets that are consistent with the training and experience required to carry out these professional activities.

1.2 Geotechnical Engineering

Geotechnical engineering is to study the behaviour of soils and rock under the influence of loading forces and soil-water interactions. This knowledge is applied to the design of site grading (cut/fill), foundations, retaining walls, earth dams, and the stability of natural and man-made slopes, and etc.

Geotechnical investigation is performed by geotechnical engineers to obtain the subsurface information of a proposed development site. It helps to understand the foundation requirements and constraints posed by soil and groundwater conditions for construction of any new infrastructures, underground utilities, parking lots, and roads. A geotechnical investigation is required for all new infrastructure projects. Insufficient geotechnical information is the main cause of project's delays, disputes, claims, and cost overruns. Inadequate information of

subsurface conditions could cause a significant, over-designed solution (high cost) or under-designed solution (potential failures).

The geotechnical report is a communication tool used by geotechnical engineers to provide site specific design parameters, and construction recommendations related to the geotechnical component of the project, such as foundations, excavation, groundwater conditions, retaining walls, ground anchors, earth works, utility installation, etc.

2 Roles and Responsibilities

The geotechnical engineer, working for the Province, must be licensed by the Association of Professional Engineers and Geoscientists of Alberta (APEGA) to practice in Alberta, and must be qualified, based on experience in the profession, to provide geotechnical engineering services.

2.1 Project Organization and Delivery Methods

Project organizations vary according to the needs of the project and the parties. The Geotechnical Engineer of Record (GER) is usually engaged by the Province, but may be engaged by the Province's Coordinating Registered Professional, the Structural Engineer of Record, a design/build contractor, or other persons responsible for the delivery of part or the entire project. The common forms of project organization / delivery methods are:

1. Design-Bid-Build Delivery
2. Design-Build Delivery
3. Construction Management
4. Public Private Partnership Delivery

2.2 Responsibilities

2.2.1 The Province

In order that the design and construction of the project is carried out in a manner that meets appropriate standards of public safety and requirements of applicable codes and regulation, the Province should:

1. Retain or cause to be retained qualified Professional Engineers including a Prime Consultant and a GER with responsibility for providing the necessary geotechnical design parameters used in foundation design and construction;
2. Cooperate with GER to set out a written description of the scope of GER's services and adequate written description of the project;
3. Before the commencement of the GER's services, finalize a written agreement with GER and other Professional Engineers. It specifies the agreed scope of services, schedules, deliverables, and associated compensation;
4. Authorize in writing any additional services that may be beyond the original scope of the GER's services, based on recommendations from the GER or other members of the project team;
5. Ensure that all required approvals, licences and permits from the Authorities Having Jurisdiction are obtained;
6. Provide the GER with the right of entry onto the project site for exploration purpose;
7. Recognize that drawings, specifications and other documents prepared by the GER are specific to the project and site and shall not be used or copied for other projects;
8. Disclose fully and promptly all information that may affect the GER's analysis, work, scheduling of tasks, design, or payment for services, including among other things, any existing geotechnical reports or data, any situations that may require special testing or equipment, and all known potential environmentally sensitive or hazardous site conditions;
9. Recognize that geotechnical investigations surveyed the subsurface and that unanticipated conditions may be encountered and a reasonable contingency should be included in the Province's budget; and
10. If the original GER is replaced, the new GER may require additional resources beyond which were originally budgeted and scheduled.

2.2.2 Prime Consultant

To enable the GER to perform his duties properly, the Prime Consultant should do the following, but not limited to:

1. Interpret and define the needs of the Province. The Prime Consultant should identify any special design criteria and advise the GER accordingly;
2. Outline the scope of assignment to each design professional for design, preparation of contract documents, review of work during construction and contract administration;
3. Provide timely information in sufficient detail required by the GER to adequately perform GER's duties;
4. Coordinate and review the designs, drawings and other contract documents produced by all participants of the design team;

5. Coordinate communication of information between the Province, the contractor and the design professionals, including the GER, so that the work proceeds in a manner that complies with applicable codes and regulations and meets the Province's needs.

2.2.3 Geotechnical Engineer of Record (GER)

The GER should work with the Province to develop a scope of work that allows the GER to meet the design and field review requirements of these guidelines, applicable codes and regulations.

Overall, the GER has responsibilities for, but not limited to:

1. Selecting investigation methods and testing soil samples to assess physical characteristics or properties, such as strength and compressibility;
2. Providing geotechnical and foundation parameters on which the geotechnical aspects are designed;
3. Ensuring that the design parameters provided meet acceptable engineering standards;
4. Reviewing final design to determine if the information and parameters provided have been correctly interpreted.

The GER may also provide recommendations for other elements of a building project or other types of projects requiring geotechnical expertise, such as slope stability, earthworks, pavement structures, criteria for design of temporary or permanent earth-retention systems, etc.

If the Province or Prime Consultant fails or refuses to carry out the obligations as set out in sections 2.2.1 and 2.2.2, the GER should consider giving written notice to the Province advising the Province of what GER requires in order to properly perform their duties.

2.2.4 General Contractor

It is not the mandate of this guideline to stipulate the responsibilities of the General Contractor, however, following should be clearly stated in the Contract Documents:

1. The General Contractor is responsible for all labour, materials, and equipment required to completed the work;
2. The General Contractor is responsible for the construction methods, techniques, sequences, procedures, safety precautions and programs associated with the construction work, all as set out in the Contract Documents;
3. The General Contractor is responsible for coordinating the work of the sub-contractors and for checking the sub-contractor's work;

4. The General Contractor is responsible for providing reasonable notice to the GER when the work is ready for field inspection and testing;
5. The General Contractor is responsible for providing safe access to the GER or their delegates to and within the site for review, inspection, material sampling and testing; and
6. The GER's field inspection and testing does not relieve the General Contractor from his responsibilities to complete the work in conformance with the Contract Documents.

3 Guidelines for Providing Geotechnical Engineering Services

This section outlines the services the Geotechnical Engineer of Record (GER) should consider providing as part of good practice. These guidelines should not be considered to be exhaustive and interpreted to limit the GER's responsibilities.

3.1 Scope of Services

Before commencement of design services, the GER should meet with the Province to:

- Determine the terms of reference and the scope of work for basic services and additional services;
- Clarify the required design life of proposed structure;
- Clarify the professional responsibilities for geotechnical design and field review in order to satisfy Occupational Health and Safety Alberta (OHSA) since they relate to excavation and shoring safety;
- Reach agreement on fees, payment schedule, and professional liability insurance coverage; and
- Reach agreement on other contractual terms and conditions.

3.2 Basic Geotechnical Engineering Services

The typical components of the basic geotechnical services, as discussed below, are generally organized in an agreement according to the sequential stages of a typical geotechnical investigation project.

3.2.1 Desktop Study

During the conceptual planning of a project, a desktop study should be carried out. The GER may attend, as required, periodic meetings with the Province and design team to obtain the Province's instructions regarding project requirements. For the desktop study, the GER may provide the following:

3.2.1.1 Air Photo Interpretation

The following might be indicated on the air photographs for the site and surrounding area terrain:

1. General drainage patterns;
2. General surficial soil types (fill or native material);
3. General slopes and ranges of gradient;
4. Bedrock outcrops, where present;
5. Poorly drained or bog areas (peat or muskeg);
6. Erosion features;
7. Old or potential slope failure areas; and
8. Previous land use history: Identify what were the previous uses of the site including but not limited to the following within the area of the site:
    a. Mining activity;
    b. Abandoned mines; and
    c. Landfills.

Some specific projects may also require the review of LiDAR images.

Summarize any risks associated with the above findings regarding the proposed project.

3.2.1.2 Literature Search

The following information may be searched:

1. The geology of the area;
2. Physiographical data;
3. Previous site investigation data; and
4. Available water well records.

3.2.1.3 Site Reconnaissance

A preliminary site reconnaissance may be made to physically examine land forms, drainage, erosion features, and site access constraints. In addition, hand auger holes may be put down to confirm the general surficial soil conditions.

3.2.2 Extent of Investigation

Upon completion of the desktop study, the GER may attend, if required, meetings with the Province and design team to review the data and plan the field investigation. The extent of the ground investigation is determined by the expected soil type, variability of soils and groundwater conditions, the type of project, and the amount of existing information.

3.2.2.1 Methods of Investigation

There are many different methods available for geotechnical investigation. However, this section summarizes the general local practice in Alberta.

Borehole drilling:

In Alberta, boreholes in the overburden are typically drilled with solid-stem augers. In some areas where boreholes must be cased to remain open due to the presence of high groundwater levels and soft or loose soils, hollow-stem auger drilling may be required. Other forms of drilling may at times be feasible depending on site condition such as: wash boring, air-rotary, sonic, CPTu, and etc.

Drilling into bedrock and retrieving bedrock core samples is typically carried out using rotary diamond drilling equipment.

Test pits:

Test pits excavated by a backhoe can often provide valuable information on soil characteristics at shallow depth. ‘Grab’ samples can be obtained from the sides of the test pits or from the excavated spoil. Extra caution should be taken if test pits are excavated in loose sands, soft clays, or close to the water table.

3.2.2.2 Depth and spacing of boreholes

The depth of investigation is determined by many factors, including the type of structure and the associated magnitude of the loading, the subsurface conditions and their variability, the depth of planned excavation, and the types of foundations to be constructed. It is recommended that the site investigation should be carried to a depth that the entire zone of soil affected by changes caused by the structure and construction. However, the foundation type and design may not be finalized or unknown at the beginning of the site investigation, it is prudent to drill holes deeper than originally estimated to allow some variation during project development.

The spacing of boreholes is based on variability of site conditions, size/footprint of structure, type of project, performance requirements, past experiences, and judgement. For less developed areas where previous experiences are limited, more boreholes and closer spacing are generally recommended.

Table 1 Guidelines for Depth and Spacing of Boreholes

Development	Test Spacing	Approximate Depth of Investigation
Building	20 m – 50 m (A minimum of three boreholes is required)	• The depth of investigation will depend on the expected load and site condition: Low rise (≤2 Storeys): 8-10 m depth Mid rise (3 to 5 storeys): 10-15 m depth High rise (≥ 6 storeys): ≥ 20 m depth (*If the structure has a basement or underground parkade, deeper holes may be required*.) • Canadian Foundation Engineering Manual (4th Edition, 2006) recommends to extend the boreholes to such a depth that the net increase in soil stress under the weight of the structure is less than 10% of the applied load, or less than 5% of the effective stress in the soil at that depth, whichever is less. A reduction in the depth may be considered if bedrock or dense soil is encountered within the minimum depth. If very compressible normally consolidated clay soil is encountered, it is recommended extending boreholes deeper than determined by the 10% and 5% rules.
Pavements /roads	250 m to 500 m	5 m below existing surface

Local roads < 150 m	2 to 3 locations	
Local roads >150 m	50 m to 100 m (3 minimum)	
Parking lot	2Bhs for <50 parks 3Bhs for 50-100 4Bhs for 100-200 5Bhs for 200-400	5 m below existing surface

Note: Bhs = Boreholes

3.2.2.3 Soil Sampling and In-Situ Testing of Soil

Exploration and field sampling work must be carried out in accordance with the Canadian Foundation Engineering Manual, ASTM, and CSA Standards.

3.2.2.3.1 Field Sampling

The frequency and type of sampling may be varied by the requirements of the project and site condition.

In local practice, for investigation by boreholes, soil sampling is typically obtained by grabbing from drilling auger and using split spoon in conjunction with the Standard Penetration Test. Relatively undisturbed samples can be obtained using Shelby tube samplers.

Standard sampling frequency:

- Grab disturbed samples from auger at 0.75 m depth interval and at changes in strata;
- Obtain samples using split spoon at 1.5 m depth intervals; and
- Obtain undisturbed samples at depths recommended by GER.

In test pit excavation, it is good practice to obtain at least one (grab) sample per test pit and / or one sample per strata encountered in each test pit.

3.2.2.3.2 In-Situ Testing

Field testing must be carried out in accordance with ASTM or CSA Standards or special instructions set out by the equipment manufacturer.

The common field tests are:

1. Standard Penetration Test
2. Pocket Penetrometer Test
3. Cone Penetration Test
4. Field Vane test
5. Pressuremeter test
6. Dilatometer test

Field tests must be carried out properly and at the appropriate place to obtain in-situ soils or bedrock parameters.

Where possible, Standard Penetration Tests should be carried out at 1.5 m depth interval in all boreholes.

3.2.2.4 Groundwater Monitoring

Groundwater level is expected to fluctuate with seasonal variations and rainfall events. The groundwater level should be monitored by standpipes installed during geotechnical investigation. The installation of such instrument should be in accordance with recognized standards and as directed by GER.

It is essential that the field logs record all observations of encountered water seepage, sloughing, and initial water percolation into test pits. The rate of inflow and rise of water levels should be recorded at the time of the initial observations to assess the apparent influence. The water flow may have impact on the project design and construction procedures.

The number of wells required depends on the geology, uniformity, topography and hydrological. It is recommended to complete 50% of the boreholes for short term groundwater monitoring. A minimum of three groundwater monitoring wells is required.

For standpipes in lower permeability soils, the groundwater levels could take up to two weeks to stabilize. The groundwater levels should be measured after stabilization is reached.

Standpipes shall be decommissioned after groundwater levels have been measured by filling the standpipes with Bentonite chips and then removing the top 300 mm (from the ground surface) of the standpipes.

3.2.2.5 Laboratory Testing

It is required that representative samples from the field investigation be tested in the laboratory for the determination of soil properties essential to the preparation of the geotechnical report. After completing the laboratory testing program, the report and recommendations should be provided based on the results obtained.

Conventional laboratory testing includes:

- Visual inspection on all soil samples including disturbed and relatively undisturbed samples;
- Water content;
- Atterberg limits;
- Grain size distribution;
- Laboratory oedometer consolidation testing on compressible clay soils;
- unconfined compressive strength;
- Soil water-soluble sulphate; and
- Soil corrosivity.

All tests must be carried out in accordance with standard procedures outlined by ASTM and CSA Standards. Laboratory testing can only be performed by trained and qualified technicians working under supervision of an experienced GER.

Only necessary tests required to provide data for the geotechnical analyses should be carried out.

3.2.2.6 Frost Penetration:

Provide 50 year return period frost penetration depth/burial depth for both heated and unheated structure, and utility lines that are susceptible to freezing.

3.2.2.7 Geotechnical Reports

Geotechnical report should be clear, concise, and accurate. An adequate, and comprehensive geotechnical report is necessary to carry out a safe, cost-effective project.

A geotechnical report summarizes the results of the site work, laboratory work, and analyses. And it should include recommendations for the geotechnical aspects of design and construction of the project. Generally, the report shall contain:

1. An Executive summary including potential risks for the proposed development;
2. A description of the site location, current land use, and topography;

3. A description of the planned development, including the proposed buildings, site grading (if known), and any significant excavations;
4. A summary of desktop study results;
5. A description of site investigation (e.g., borehole drilling and sampling, in situ testing, laboratory testing, and groundwater condition);
6. A summary of the subsurface conditions on the site and the results of the in situ and laboratory testing;
7. A scaled plan showing the site and the locations of the boreholes and test pits;
8. Drawings or tables showing the findings of the investigation;
9. Drawings or tables showing the factual results of the laboratory testing;
10. Geotechnical recommendations for:
    a. Site grading / surface drainage;
    b. Subgrade preparation;
    c. Foundation options and feasibility;
    d. Design parameters for shallow foundations (bearing capacity for strip and spread footings, minimum depth of burial);
    e. Design parameters for deep foundations;
    f. Design and construction provisions for groundwater control;
    g. Grade-supported floor slab including sub-grade preparation required to limit the slab settlement to a maximum of 25 mm
    h. Subsurface drainage;
    i. Design and construction of excavation support system;
    j. Soil swelling and frost heaving mitigation measures;
    k. Lateral earth pressure parameters for basement and retaining walls if required;
    l. Backfill material and compaction;
    m. Cement type related to soluble sulphate concentrations, freeze-thaw cycles from groundwater level fluctuations;
    n. 1-in-50 year frost penetration depth for both heated and unheated structures, and deep utilities;
    o. Pavement design and construction, including surfacing type(granular, concrete, asphalt);
    p. Seismic considerations – seismic site class and potential for ground liquefaction
    q. Earthworks related to site servicing; and
    r. Slope stability and retaining walls (if required).
11. Appendices containing:
    a. A list of references;
    b. Borehole and test pits logs;
    c. Site photographs;
    d. Laboratory test result sheets;
    e. Plan drawing with borehole locations; and

f. Two (2) stratigraphic cross-sections (along the major and minor axes of the footprint of the proposed development).

Geotechnical report should be prepared, signed, and sealed by a qualified geotechnical engineer licensed in the Province of Alberta.

3.2.3 Services During Construction

Further to the carrying out of a geotechnical investigation and provide a geotechnical report, the GER should also be involved in various supplementary activities during the construction phase. The supplementary services might include, but not limited to:

1. Foundation Subgrade Inspection
   The GER or a qualified and experienced technician under the supervision of the GER should inspect the foundation bearing materials during construction. The GER should verify the expected soil conditions at the bottom of the excavation and confirm that no part of the excavation encounters soil conditions substantially different than anticipated. The foundation designer or structural engineer should verify that the specified bearing values have been achieved at the foundation level.

2. Pile Installation Inspection
   During pile installation, an independent inspection should be carried out by a qualified and experienced technician under the supervision of the GER to ensure installations are in accordance with specifications.

3. Pile Load Test Supervision
   The GER and the Structural Engineer of Record provide recommendations on whether a pile load test should be carried out for the proposed project. The pile load testing should be carried out under the supervision of an engineer working for the GER. All load tests should be carried out in accordance with ASTM. (ASTM-D1143, ASTM-D3689, and ASTM-D3966, as applicable)

4. Fill Compaction Testing
   If fill placement is required, a qualified, experienced technician under supervision of the GER should inspect and test the soil and provide recommendation on whether the fill materials are acceptable or not. Where standards of compaction are required, the physical testing of the fill material should be carried out by a qualified and experienced technician under the supervision of the GER. A report should be submitted to the Province indicating acceptance or rejection of the work as it is performed.

5. Pavement Subgrade Testing
   Road and parking lot subgrade should be inspected and tested by a qualified, experienced technician under supervision of the GER to ensure the soil condition is consistent with what is encountered during investigation. Pavement subgrade tests shall include laboratory testing of samples recovered from the site and in-situ testing of the subgrade in its prepared condition.

6. Slope Stability Monitoring (if required)
   Slope stability monitoring prior to, during and following construction of civil works is essential to the safety of the facility. The installation and monitoring of slope indicators should only be carried out by qualified and experienced engineering technicians under the supervision of a GER.

7. Field Instrumentation-Settlement (if required)
   The GER is frequently required to provide the monitoring of instrumentation established during construction to determine settlement and stress changes. This work should be carried out by qualified experienced technicians acting under the supervision of a GER.

3.3 Additional Geotechnical Engineering Services

In addition to the Basic Services, the GER may provide the following additional services if the GER and the Province reach appropriate mutual agreements. The additional services are not considered intrinsic parts of the basic geotechnical design services as discussed in the Section 3.2.

Examples of Additional Services are:

1. Review of design drawings and / or specifications prepared by others to determine suitability;
2. Geotechnical engineering work resulting from changes to the project as originally described and agreed to under the contract between the GER and Province, such as changes in scope, complexity, diversity or magnitude of the project;
3. Work related to preparation of documents for tendering segregated contracts, pre-tendered contracts, phased or fast-track construction;
4. Review of alternative designs or products after completion of the Contract Documents;
5. Special dynamic analysis beyond that required by codes such as ground-foundation response;
6. Field investigation of existing buildings and structures including surveys of existing construction;

7. Design review or field observations of shoring or bracing for excavation and building or under pinning of adjacent structures;
8. Work resulting from corrections or revisions required because of errors or omissions in construction by the contractor;
9. Extra work arising from disputes due to problems outside the control of the GER;
10. Review of the contractor's methods, procedures and construction equipment with respect to the effect on the project;
11. Work due to extended time schedules for design or construction, beyond the control of the Prime Consultant or GER;
12. Services as an expert witness in connection with any public hearing, arbitration, or court proceedings concerning the project, including attendant preparation for same;
13. Work resulting from damage as the result of fires, flood, man-made disasters or natural disasters;
14. Overtime work requiring premium pay when authorized;
15. Travelling time outside of normal requirements;
16. Provision of special clauses to be included in the specifications where unusual soil, bedrock or groundwater conditions exist and where special expertise is required;
17. Provision of special sketches for drainage, special foundation measures, safe slopes and shoring requirements; and
18. Attendance at special site meetings to review problems of an unforeseen nature that have arisen during foundation or earthworks construction.