Risk Based Site Characterization

P.K. Robertson

1. Introduction

As described in Chapter 1, risk and uncertainty are characteristics of the ground and are never fully eliminated. This is because only a very small percentage of the ground can be inspected during even the most exhaustive investigation. Different projects have different levels of risk. The extent of an investigation should be based on the level of risk of the project. The level of risk of a project will depend on many factors. The Canadian Standards Association (CSA) (1991) defines risk as "a measure of the probability and severity of an adverse effect to health, property or the environment". As explained in CSA (1991), risk analysis answers three basic questions, namely: "What can go wrong?", "How likely is it?" and "What are the consequences?". The first question is answered by identifying the potential hazards for a given project. CSA (1991) defines a hazard as "a condition with the potential for causing an undesirable consequence". Projects can be classified into low, moderate or high-risk projects, depending on the probability of the associated hazards occurring and the associated consequences. Low risk projects could be projects with few hazards, low probability of occurrence, and limited consequences, whereas high-risk projects would be projects with many hazards, high probability of occurrence, and severe consequences. Additional details regarding risk analysis and assessment can be found in CSA (1991).

Evaluation of the risk of a project in terms of site characterization requires a preliminary site assessment, which is described in detail in Chapter 3. The preliminary site assessment requires a full understanding of the scope of the project and a careful desk study to develop a preliminary geologic and/or hydrogeologic model of the site. Based on this preliminary site evaluation, a preliminary risk assessment can be carried out to estimate the risk level of the project. An important element in the risk assessment for site characterization is the previous experience of the geotechnical engineer in similar ground conditions and for similar projects. A given project may have a slightly higher associated

risk if the engineer designing and supervising the site investigation has limited experience in similar ground for similar projects. Likewise, a given project may have a slightly lower associated risk if the engineer has extensive local experience in the same geologic region with similar projects.

Figure 1 shows a generalized flow chart to illustrate the likely geotechnical ground investigation approach associated with projects of low, moderate and high risk. The following describes the likely approach that should be carried out for geotechnical projects of different risk levels. Details for geoenvironmental projects are given in a later section.

Low-risk geotechnical projects

For low-risk geotechnical projects, the ground investigation and analyses will likely be based on a simple approach using drilling, in-situ tests and some basic laboratory index testing carried out on representative disturbed samples of the main stratigraphic elements. The appropriate in-situ test technique would depend on ground conditions and local practice. For many geotechnical investigations in soil, the common in-situ tests are the Standard Penetration Test (SPT) and the Cone Penetration Test (CPT). Depending on local ground conditions and equipment availability, in-situ testing may also include tests such as the pre-bored pressuremeter (PMT), the flat plate dilatometer (DMT) or the field vane test (FVT). For geotechnical investigations in hard ground such as very stiff soil or rock, borehole geophysical logging techniques may apply. Full details of the test techniques are given in Chapter 4.

Moderate-risk geotechnical projects

For moderate risk geotechnical projects, an initial screening may be carried out using simple methods based on drilling, in-situ testing and basic index laboratory testing, similar to those for a low-risk project. Additional in-situ testing may be required to obtain supporting or detailed evidence of ground conditions and expected ground response. Additional laboratory testing may also be carried out on representative samples of the main stratigraphic elements. The samples would likely have some disturbance,

because truly undisturbed samples can be difficult and expensive to obtain. A common sampling technique for soil is a tube sampler which often has a rather thick wall. The laboratory testing would likely be limited in scope to confirm information from the in-situ testing and provide greater reliability for certain key geotechnical parameters, such as volume change and shear strength characteristics. The results of the laboratory testing should then be linked back to the results of the in-situ tests in order to develop site specific correlations and extrapolate the results across the site.

High-risk geotechnical projects

For high-risk geotechnical projects, a phased approach is generally recommended. The initial ground investigation should identify potentially critical zones for the project based on methods similar to those used for the low to moderate risk projects. If potentially critical zones are identified, a more detailed ground investigation may be required to evaluate the critical zones in more detail. This may include more detailed and careful in-situ testing using more sophisticated techniques as well as more detailed and careful sampling in an effort to obtain undisturbed samples of the ground in the critical zones. The associated laboratory testing on the limited number of high quality samples should be carried out using stress levels and loading conditions which are appropriate for the project. The results of the limited laboratory testing should then be linked back to the results of the in-situ screening tests in order to develop site specific correlations and extrapolate the results across the site.

To illustrate the above concept, the following project examples are given:

An example low risk geotechnical site investigation project would be an investigation for a low-rise warehouse to store non-hazardous products located in an industrial region of a major urban area. The local geology is well understood with no major geologic hazards. The engineer responsible for the investigation has extensive local experience in similar ground and with similar projects. This would likely be classified as a low risk site investigation project and the investigation would likely include a small number of boreholes with SPT using locally available drilling practices. It is unlikely that high

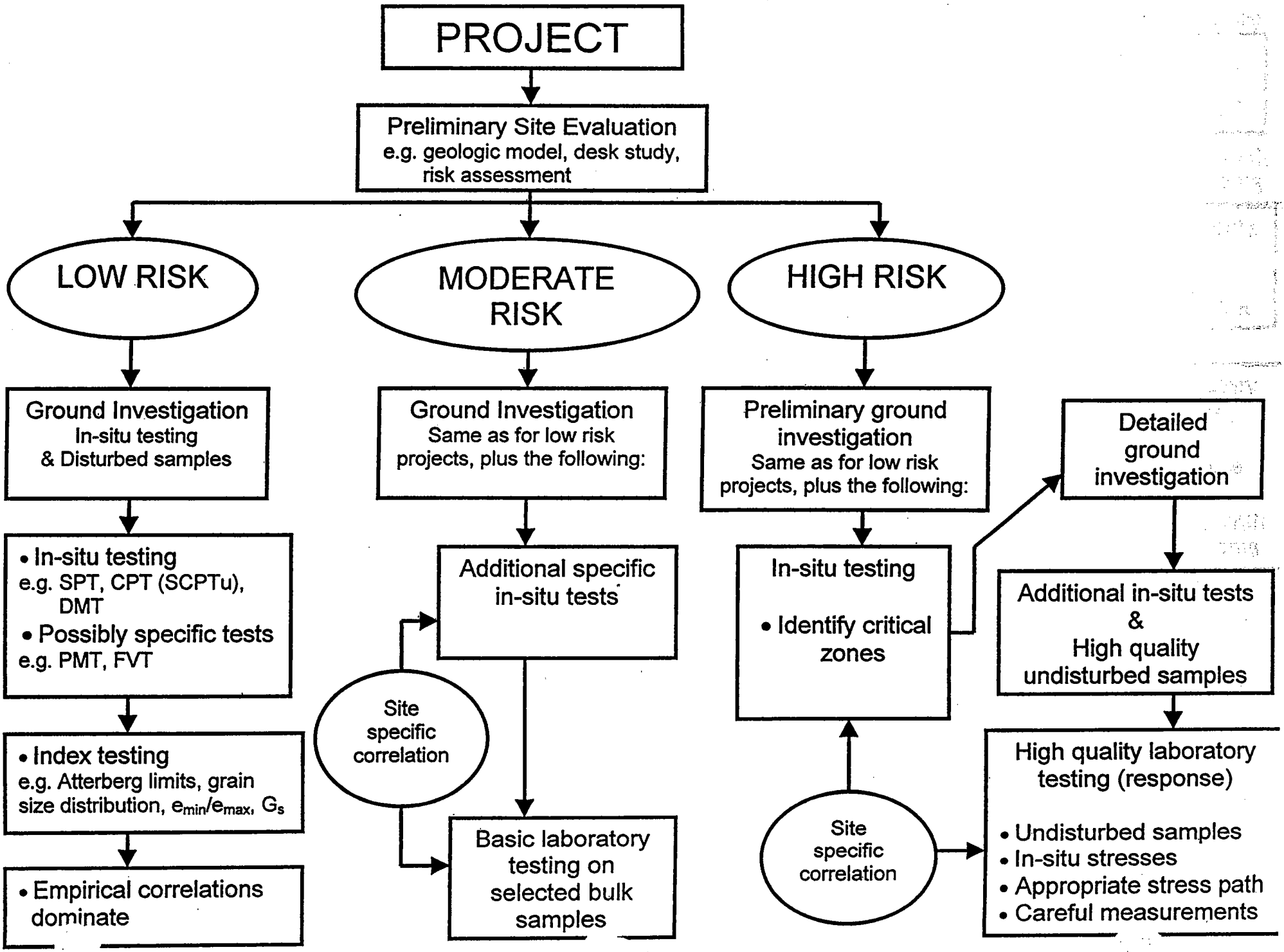
quality undisturbed samples would be obtained. Basic index testing would be performed on the disturbed SPT samples to clarify soil classification. Local correlations would likely be applied to estimate geotechnical parameters for foundation design. If the ground conditions are suitable, CPT may be performed to provide continuous profiles of ground conditions. If extensive local experience exists with the CPT, boreholes may not be required.

An example moderate risk geotechnical site investigation project could be an investigation for the same project described above but located in an isolated region with no previous construction history, such as a remote northern region far from an urban area. The local geology is similar to the low risk project above but less well understood with some potential geologic hazards, such as permafrost. The engineer responsible for the investigation would also likely have little local experience in this ground. This would likely be classified as a moderate risk site investigation project. The investigation would likely include a larger number of boreholes with SPT using more specialized drilling practices and greater supervision, because of the less well understood ground conditions. It is likely that some undisturbed samples would be obtained for performing some laboratory testing to evaluate expected ground response. Basic index testing would also be performed on the disturbed SPT samples to clarify soil classification. If the ground conditions are suitable, additional CPT may be performed to provide continuous profiles of ground conditions. Boreholes should be performed adjacent to some CPT to aid in the soil classification, due to the lack of local experience.

An example high-risk project could be a structure similar to that described above (i.e. a low-rise warehouse), but in this case, the warehouse may need to store a highly toxic material, such as nuclear waste. The warehouse may be located in a major urban area with extensive previous experience. The local geology is well understood, but there are some geologic hazards, such as a design criteria for major earthquake loading. In this case, the consequences of failure would be considerable and a more cautious investigation and design would be warranted. The investigation may include an initial investigation of boreholes, SPT and samples to identify potentially critical zones on the

site. If ground conditions are suitable, the initial screening may involve CPT to provide continuous profiles of ground conditions. Based on the initial screening investigation a more detailed investigation may include additional boreholes with specialized in-situ testing, such as shear wave velocity and other geophysical techniques, self-boring pressuremeter testing, field vane testing, etc. The selection of the appropriate additional in-situ testing would depend on the ground conditions and project design requirements. If appropriate, additional selected sampling may be carried out in the appropriate critical zones to obtain high quality undisturbed samples for careful laboratory testing. The results from the limited careful laboratory testing would then be linked back to the in-situ testing results to allow extrapolation across the site.

These examples are general in nature, but help illustrate the range of activities that should be carried out as part of a site characterization based on the risk of the project. Details would vary depending on the specific project requirements and actual ground conditions. These examples also help illustrate the complementary nature of the role of in-situ testing, sampling and laboratory testing. Each has a role in site characterization depending on the risk of the project and the specific project and ground constraints.


PROJECT
Preliminary Site Evaluation
e.g. geologic model, desk study, risk assessment
LOW RISK
MODERATE RISK
HIGH RISK
Ground Investigation
In-situ testing
& Disturbed samples
Ground Investigation
Same as for low risk projects, plus the following:
Preliminary ground investigation
Same as for low risk projects, plus the following:
• In-situ testing
e.g. SPT, CPT (SCPTu), DMT
• Possibly specific tests
e.g. PMT, FVT
Additional specific in-situ tests
In-situ testing
• Identify critical zones
Detailed ground investigation
Additional in-situ tests & High quality undisturbed samples
• Index testing
e.g. Atterberg limits, grain size distribution, e_{min}/e_{max}, G_s
Site specific correlation
Basic laboratory testing on selected bulk samples
Site specific correlation
High quality laboratory testing (response)
• Undisturbed samples
• In-situ stresses
• Appropriate stress path
• Careful measurements
• Empirical correlations dominate