ENGINEERING-PDH.com
ONLINE CONTINUING EDUCATION

GEOTECHNICAL DESIGN MANUAL - PART 1 OF 4

Main Category:	Civil Engineering
Sub Category:	Geotechnical Engineering
Course #:	GEO-117
Course Content:	113 pgs
PDH/CE Hours:	7

OFFICIAL COURSE/EXAM

(SEE INSTRUCTIONS ON NEXT PAGE)

WWW.ENGINEERING-PDH.COM
TOLL FREE (US & CA): 1-833-ENGR-PDH (1-833-364-7734)
SUPPORT@ENGINEERING-PDH.COM

GEO-117 EXAM PREVIEW

- TAKE EXAM! -

Instructions:

- At your convenience and own pace, review the course material below. When ready, click "Take Exam!" above to complete the live graded exam. (Note it may take a few seconds for the link to pull up the exam.) You will be able to re-take the exam as many times as needed to pass.
- Upon a satisfactory completion of the course exam, which is a score of 70% or better, you will be provided with your course completion certificate. Be sure to download and print your certificates to keep for your records.

Exam Preview:

1. The State Geotechnical Engineer is the final approval authority for geotechnical policy, and for geotechnical investigations and designs conducted statewide.
   a. True
   b. False
2. According to the reference material, in this phase that the Region office, or civil consultant, refines and defines the project's alignment, sets profiles and grade, and identifies specific project elements to be addressed by specialty groups within the state DOT, or other consultants.
   a. Project definition phase
   b. Project design phase
   c. PS&E development phase
   d. Project completion phase
3. Using Table 1-1, Geotechnical Items in Master Deliverables List, which of the following WBS code corresponds to Project Site Data.
   a. PC-21.04
   b. PC-21.05
   c. PC-21.06
   d. PC-21.01
4. According to the reference material, it is not justifiable to spend additional money on explorations and related testing and engineering beyond the standards as identified in this manual.
   a. True
   b. False
5. According to the reference material, which of the following quality control checks is defined as: performed by a person's supervisor or another individual not involved in the technical details.

a. QC
b. QA
c. QP
d. QV

6. According to the reference material, which of the following site exploration techniques is useful for determining if a landslide has occurred in the region of interest?
    a. Geologic maps
    b. Topographic maps
    c. Ariel photos
    d. Soil surveys
7. According to the reference material, cone probes can be a rapid and cost-effective means to reduce the number of conventional borings yet provide additional data that cannot be obtained from conventional test hole drilling and sampling.
    a. True
    b. False
8. Which of the following subsurface exploration techniques was NOT outlined in the reference material?
    a. Geotechnical soil borings
    b. Slope inclinometers
    c. Excavating test pits
    d. Ultrasonic ground imaging
9. According to the reference material, which of the following ASTM Standards is used to outline the Standard Practices for persevering and Transporting Rock Core Samples?
    a. D5079-02
    b. D2573-01
    c. D5092-02
    d. D3550-01
10. According to the reference material, calibration to determine specific hammer system efficiencies shall be developed in general accordance with ASTM D4600 for dynamic analysis of driven piles or other accepted procedure.
    a. True
    b. False

Washington State
Department of Transportation

Geotechnical Design Manual

M 46-03.14

June 2021

PART 1 OF 4

Environmental and Regional Operations
Construction Division
Geotechnical Office

Contents

Chapter 1 Geotechnical Operations and Administration

1.1 Scope of Geotechnical Design, Construction, and Maintenance Support

The focus of geotechnical design, construction, and maintenance support within the context of WSDOT is to ensure that the soil or rock beneath the ground surface can support the loads and conditions placed on it by transportation facilities. Typical geotechnical activities include the following:

- subsurface field investigations
- geologic site characterization, laboratory testing of soil and rock
- structure foundation and retaining wall design
- soil cut and fill stability design
- subsurface ground improvement
- seismic site characterization and design
- rock slope design
- unstable slope management
- unstable slope (e.g., rock fall, landslides, debris flow, etc.) mitigation
- infiltration, subsurface drainage and related hydrogeologic design
- material source (pits and quarries) evaluation
- long-term site monitoring for geotechnical engineering purposes
- support to Regional construction staff regarding geotechnical issues and contractor claims
- support to Regional maintenance staff as geotechnical problems (e.g., landslides, rock fall, earthquake or flood damage, etc.) arise on transportation facilities throughout the state

A geotechnical investigation is conducted on all projects that involve significant grading quantities (including state owned materials source development), unstable ground, foundations for structures, and ground water impacts (including infiltration). The goal of the geotechnical investigation is to preserve the safety of the public who use the facility, as well as to preserve the economic investment by the State of Washington.

As defined in this manual, geotechnical engineering is inclusive of all the aspects of design and construction support as described above, and includes the disciplines of foundation engineering and engineering geology. Geotechnical engineering shall be conducted by engineers or engineering geologists who possess adequate geotechnical training and experience. Geotechnical engineering shall be conducted in accordance with regionally or nationally accepted geotechnical practice, and the geotechnical engineering practice as defined by this manual. Geotechnical engineering shall be performed by, or under the direct supervision of, a person licensed to perform such work in the state of Washington, who is qualified by education or experience in this technical specialty of engineering per WAC 196-27A. For work that does or does not require certification by a professional engineer, but does require certification by a licensed engineering geologist (LEG), such work also shall be performed by, or under the direct supervision of, a person licensed to perform such work in the state of Washington, who is qualified by education or experience in this technical specialty per WAC 308-15.

1.1.1 Geotechnical Design Objectives for Project Definition Phase

For the project definition phase, the geotechnical recommendations provided will be at the conceptual/feasibility level, for the purpose of developing a project estimate to establish the transportation construction program to be approved by the legislature. The investigation for this phase usually consists of a field reconnaissance by the geotechnical designer and a review of the existing records, geologic maps, and so forth. For projects that lack significant geotechnical information or are complex, test pits/borings may be completed and/or geophysical investigation performed at critical locations for development of the project definition with approval of the State Geotechnical Engineer.

A key role of the geotechnical designer in this stage of a project is to identify potential fatal flaws with the project, potential constructability issues, and geotechnical hazards such as earthquake sources and faults, liquefaction, landslides, rockfall, and soft ground, for example. The geotechnical designer shall provide conceptual hazard avoidance or mitigation plans to address all the identified geotechnical issues. An assessment of the effect geotechnical issues have on construction staging and project constructability must be made at this time. Future geotechnical design services needed in terms of time, cost, and the need for special permits to perform the geotechnical investigation (critical areas ordinances), are determined at this time. This preliminary geotechnical information is intended to inform where significant modifications to the preliminary design should be considered prior to advancing to the design stage and where significant cost impacts may be realized, such as relocation of the alignment, horizontal and vertical alignment changes, addition or elimination of structures, etc. Geologic/geotechnical input during this initial project phase is critical for complex projects.

1.1.2 Geotechnical Design Objectives for Project Design Phase

It is in this phase that the Region office, or civil consultant, refines and defines the project's alignment, sets profiles and grade, and identifies specific project elements to be addressed by specialty groups within WSDOT, or other consultants. Once the preliminary project elements and alignments for the project are established, the geotechnical designer will assess feasible cut and fill slopes to enable the Region or civil consultant to establish the right-of-way needs for the project. Where walls may be needed, using approximate wall locations and heights identified by the Region, an assessment of feasible wall types is performed by the geotechnical designer, primarily to establish right-of-way and easement needs (as is true for slopes).

The Region will identify potential locations for infiltration/detention facilities, and the geotechnical designer shall begin investigating and assessing if the selected sites are suitable for infiltration. The geotechnical data and analysis needed to assess infiltration/detention facility size and feasibility, including the seasonal ground water measurements necessary to meet the requirements in the *Highway Runoff Manual*

(HRM) are also obtained. Sizing of the infiltration/detention facilities is conducted at this time to make sure enough right-of-way is available to address the project storm-water requirements.

Conceptual and/or more detailed preliminary bridge foundation design, for example, Type, Size, & Location (TS&L), if required, may be conducted during this phase, if it was not conducted during project definition, to evaluate bridge alternatives and develop a more accurate estimate of cost.

Before the end of this phase, the geotechnical data necessary to allow future completion of the PS&E level design work is gathered (final geometric data, test hole data, and so forth.)

1.1.3 Geotechnical Design Objectives for PS&E Development Phase

It is in this phase that final design of all geotechnical project features is accomplished. Recommendations for these designs, as well as special provisions and plan details to incorporate the geotechnical design recommendations in the PS&E, are provided in the geotechnical reports and memorandums prepared by the geotechnical designer. This manual, AASHTO Specifications, and WSDOT's various engineering publications provide specific design requirements for this phase of design. Detailed recommendations for the staging and constructability of the project geotechnical features are also provided.

1.2 Role of Offices Providing In-House Geotechnical Design, Construction, and Maintenance Support

1.2.1 Lead Role for WSDOT Regarding Geotechnical Policy and Design

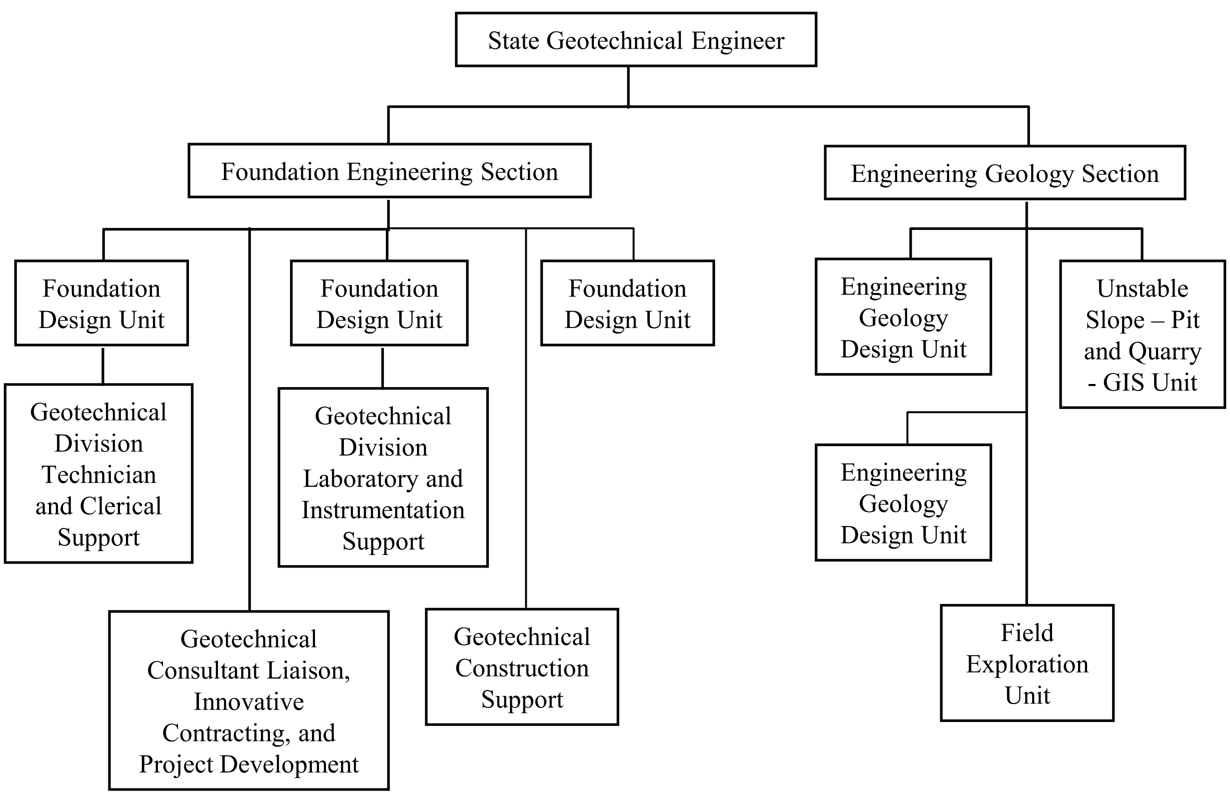
Based on an executive level policy decision initiated in 1980, formally implemented in 1983, and later formally documented in the *Design Manual* M 22-01, geotechnical design, construction support, and maintenance support functions are centralized as a Headquarters function. As a result of this executive decision, the Headquarters (HQ) Materials Laboratory was directed to begin obtaining staff with specialized geotechnical expertise and to maintain that specialized expertise. The regions were directed to retain the Region Materials Engineer position, and that Region Materials staff be trained in the area of soils to the degree possible to be able to function as an effective liaison with the HQ Materials Laboratory geotechnical personnel. However, the major geotechnical work (see Section 1.2.2) is to be conducted by the HQ's staff, based on this executive policy.

The Geotechnical Office, within the Construction Division, hereinafter referred to as the Geotechnical Office, is the State's expert for all geotechnical design and construction work. The Geotechnical Office provides direct geotechnical design, technical oversight for all consultant geotechnical design, and quality verification on design-build projects.

How the geotechnical design will be accomplished will be identified in the Project Management Plan (PMP) at the initiation of a project. The PMP will include the initial scope, schedule and budget of the geotechnical design work. As the project develops, scope schedule and budget may be revised through the change management plan. The PMP will also include how the project manager, Region Materials Lab and the Geotechnical Office will work together to provide the oversight and expertise necessary to retain a strong owner role, thus ensuring a geotechnical design product that is consistent with WSDOT policy and developed in the best interest of the state.

The Geotechnical Office provides the lead regarding the development and implementation of geotechnical design policy for WSDOT. The State Geotechnical Engineer is the final approval authority for geotechnical policy, and for geotechnical investigations and designs conducted statewide for WSDOT projects. Geotechnical policies are contained in the *Design Manual* (e.g., Chapters 610, 630, and 730), the Standard Plans, the Standard Specifications, and in General Special Provisions in addition to this *Geotechnical Design Manual*. The State Geotechnical Engineer is also the final approval authority regarding geotechnical designs conducted by others (e.g., local agencies, developers, etc.) that result in modification to transportation facilities that are under the jurisdiction of WSDOT or otherwise impact WSDOT facilities. For cases where geotechnical design is being conducted by others on behalf of WSDOT, such as by consultants working directly for WSDOT and geotechnical consultants working for design-builders, where this GDM states that approval of the WSDOT State Geotechnical Engineer is required, that approval authority is not transferrable to the designer of record (e.g., for a design-builder). Where this GDM states that approval by the State Geotechnical Engineer is required, these are WSDOT design policy issues, not designer of record design decisions. See Section 22.6 for additional discussion on this issue as it applies to design-build contracts.

The functional structure of the Geotechnical Office is provided in Figure 1-1.



Functional Organization of the WSDOT Geotechnical Office
Figure 1-1

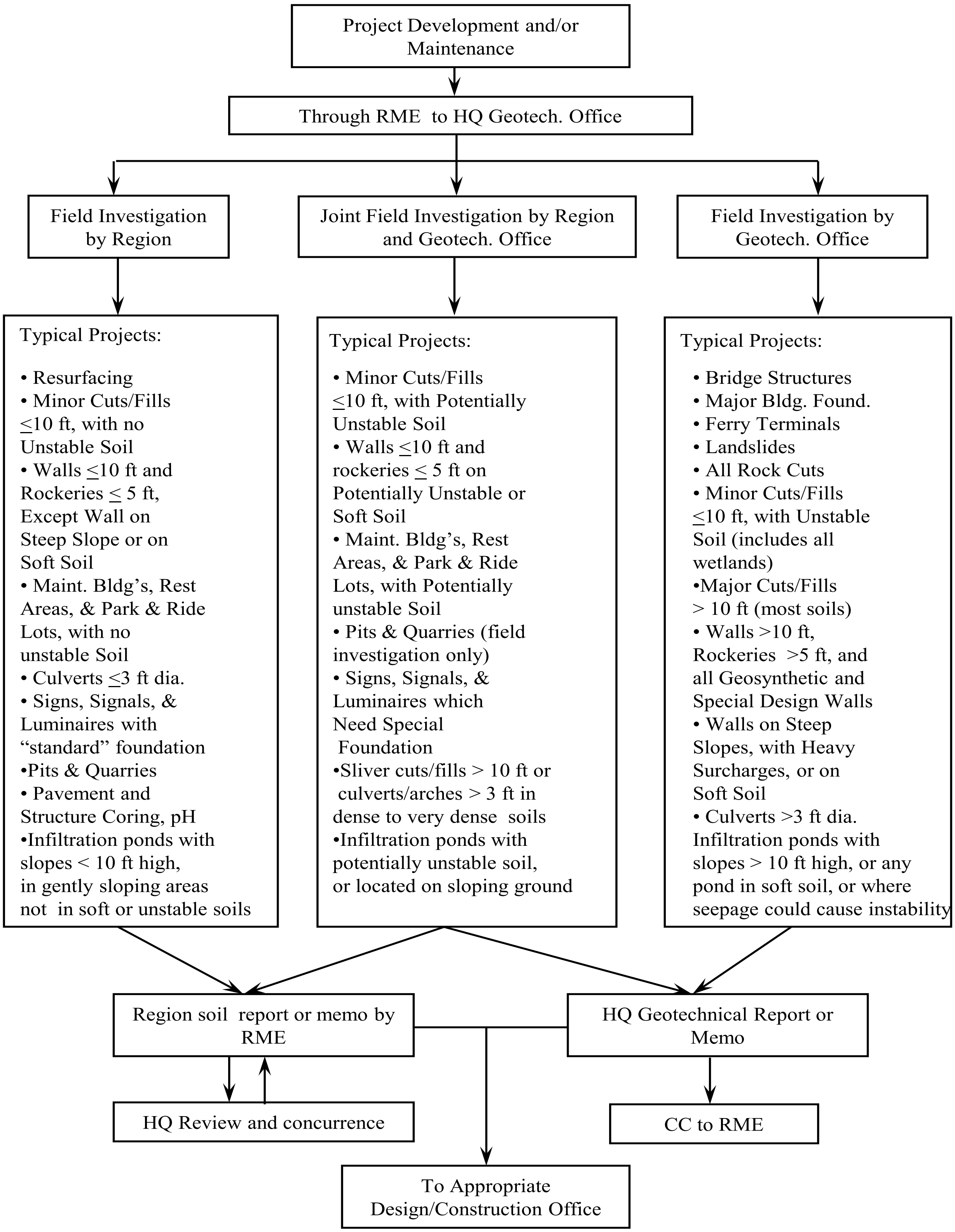
1.2.2 Geotechnical Functions Delegated to the Regions

Some geotechnical functions have been delegated to the Region Materials Engineers (RME), as described in the *Design Manual* M 22-01 Chapter 610. In general, the RME functions as the initial point of contact for all geotechnical work, with the exception of Bridge Office, Washington State Ferries (WSF), and Urban Corridors Office (UCO) projects. If the geotechnical work required is relatively straightforward (in that the ground is stable and relatively firm, bedrock is not involved, the design is not complicated by high ground water or seepage, and the design of the project geotechnical elements does not require specialized geotechnical design expertise), the RME takes the lead in conducting the geotechnical work. If this is not the case, the RME asks for the involvement and services of the Geotechnical Office. The Geotechnical Office responds to and provides recommendations directly to the WSDOT Office responsible for the project, but always keeps the RME informed. For structural projects (bridges and tunnels, for example), the Bridge and Structures Office works directly with the Geotechnical Office. For WSF projects, the Terminal Engineering Office works directly with the RME or the Geotechnical Office, depending on the nature of the project. For UCO projects, the Geotechnical Office handles all geotechnical work.

General guidelines and requirements regarding coordination of geotechnical work are provided in the *Design Manual* M 22-01 Section 610.04. Figure 1-2 illustrates the division of geotechnical design responsibility between the region materials offices and the Geotechnical Office and is consistent with the *Design Manual.* The Region Materials Engineers (RME) and their staff, and the Geotechnical Office personnel should communicate on a regular basis as projects requiring geotechnical input develop. The RME should be viewed as the Geotechnical Office's representative in the region. The RME's function as the initial point of contact for geotechnical work in their respective regions in that the RME will be evaluating the projects included in the construction program within their respective regions at the beginning of the design phase for those projects, and deciding if the nature of the work included in those projects will require Geotechnical Office involvement and design support. Similarly, during the project definition phase, the RME functions as the initial point of contact regarding geotechnical issues. If it appears the nature of the geotechnical issues that need to be addressed to develop an accurate project definition will require Geotechnical Office assistance, the RME is responsible to contact the Geotechnical Office to obtain geotechnical input for the project. Figure 1-2 should be used as a guide for this purpose for project definition, design, and PS&E development, but some judgment will be required, as specific projects and/or conditions may not completely fit the project categories listed in Figure 1-2. The RME office and the Geotechnical Office must view themselves as a team to get the geotechnical work accomplished from project inception to completion of the construction. If the RME is not sure if Geotechnical Office involvement is needed, the RME and Geotechnical Office should discuss the project needs together.

For geotechnical work that is clearly the responsibility of the RME to complete based on Figure 1-2, the RME should complete the geotechnical subsurface site investigation plan, perform the design, and complete the region soils report. For those regions that do not have the resources (i.e., drill crews) to carry out the geotechnical subsurface site investigation, the RME submits the plan to the State Geotechnical Engineer, or the individual delegated to act on behalf of the State Geotechnical Engineer. In this case, the subsurface site investigation is carried out by the Geotechnical Office's Field Exploration Unit. If the results of the site investigation demonstrate that the project geotechnical design is still a RME responsibility, the data from the site investigation will be provided to the RME and the RME will complete the geotechnical design and report. If the subsurface conditions are such that HQ involvement is required, the Geotechnical Office will discuss the design responsibility with the RME. If, due to the nature of the project or the potential subsurface conditions, it is not clear if the design will be a HQ or region responsibility, the RME should contact the Geotechnical Office for assistance in planning, and if necessary to carry out, the geotechnical investigation and design.

With regard to division of work between the Geotechnical Office and the RME, Figure 1-2 indicates that HQ involvement is required if the soils appear to be soft or unstable. As a general guide, granular soils classified as loose or very loose (i.e., $N \leq 10$ blows/ft) and clays classified as very soft to stiff ($N \leq 15$ blows/ft) should be considered potentially unstable, especially if they are wet or are exhibiting signs of instability such as cracking or slumping. When such soils are encountered by the RME, whether or not the work should be retained by the RME should be discussed with the Geotechnical Office to determine of more detailed input from HQ regarding the stability of the soils encountered is needed.



Geotechnical Design Workflow and Division of Responsibility
Figure 1-2

1.2.3 Coordination between HQ's and Region Regarding Emergency Response

The need for emergency geotechnical response is primarily the result of slope failure, rockfall events, flooding, or earthquakes. For the case of slope failure (including retaining walls) and rockfall events, and slope failure caused by flooding or earthquakes, the following process should be used:

1. Once the failure occurs, Region Maintenance conducts an initial evaluation of the site.
2. If there is any question as to the stability of the affected slope and the potential for future slope movement or rockfall, the Region Maintenance Office should contact the Regional Materials Engineer (RME).
3. The RME performs a site review as soon as possible to assess the magnitude of the problem, and to determine if Geotechnical Office assistance is needed. To save time, the RME may, at the RME's discretion, skip the RME field review and transfer the field review and all design responsibilities fully to the Geotechnical Office, if it is obvious that HQ involvement will be needed. If it is determined that a detailed geotechnical evaluation by the Geotechnical Office is not needed (e.g., conditions are not geologically complex, the failure is limited in extent, and the risk of continued slope movement or instability is low, and slope stabilization methods are not required), the RME provides recommendations to complete the cleanup and facility repair.
4. If it is determined that there is a real threat of continued slope movement, instability, or rockfall, there are geological complexities at the site that will require a more detailed geotechnical analysis to assess the potential threat, or if an engineered slope stability mitigation may be required, the RME immediately contacts the Geotechnical Office to complete the initial evaluation. This contact may initially take the form of a phone call and/or e-mail with photos, and as soon as possible a joint site review, if the Geotechnical Office feels it is warranted.
5. The Geotechnical Office specialist(s) responds as soon as possible and comes to site to make an initial assessment. The specialist provides the Region (on site) with that assessment and the risk(s) associated with that assessment. The assessment includes evaluation of the cause(s) of the instability, the potential for future instability, whether or not the threat of future instability is immediate, the potential threat to public and worker safety, and the need for slope stabilization measures.
6. The Region (typically a project office) should use the field recommendations provided by the Geotechnical Office specialist to begin developing a scope of work and cost estimate to complete the emergency work concurrently with Geotechnical Office management review of the field recommendations, and will immediately contact the region if any changes in the recommendations are needed as a result of the technical review of the recommendations.

7. Based on the assessment and recommendations, the Region evaluates risk(s) and cost to mitigate the problem. The Region then makes a decision to either immediately repair the slope and facility, opening up the facility to the public, or to close, maintain closure, or otherwise limit facility public access. If the risk is too high to immediately repair the facility and/or open it up to full public access, the Region requests the Geotechnical Office for a more complete evaluation and stabilization recommendation.
8. Once stabilization recommendations are developed, the slope is stabilized, and the facility is reopened. During the stabilization construction activities, the point of contact to address any problems that occur and to review the acceptability of the finished stabilization measures is the office which developed the stabilization recommendations.
9. Since multiple activities conducted by several offices must occur simultaneously to address an emergency slope problem, frequent stakeholder meetings or conference calls should be conducted throughout the duration of the emergency project (design and construction) to keep all stakeholders informed and to make intermediate decisions as needed. These stakeholder meetings or conference calls should occur at key junctures in the development of the project, or as needed based on the specific needs and duration of the project.

Flood or seismic events can also result in emergency conditions that need geotechnical evaluation. Other than the slope stability issues addressed above, such events can affect the integrity of bridges and other structures. In these situations, other than keeping the RME informed of the situation, the process for geotechnical evaluation primarily involves the Bridge Office. If the structure is under the jurisdiction of WSF, then WSF would be responsible to initiate the geotechnical investigation instead of the Bridge Office. In these cases, the process is generally as follows:

1. Once the failure or structure distress occurs and becomes known, the Bridge Office (or WSF for marine and terminal work) conducts an initial evaluation of the structure.
2. If there is damage or potential damage to the structure foundation, the Bridge Office or WSF contacts the Geotechnical Office to conduct an initial evaluation to assess the problem, identify potential risks to the structure and the public, and develop preliminary solutions. The HQ Geotechnical Office should notify the RME regarding the problem at this point, and discuss with the RME any involvement the Region Materials Office may need to have.
3. Based on this initial evaluation, the Bridge Office, in concert with the Region, or WSF in the case of marine or terminal facilities, determines whether or not to restrict public access, or to close the facility, and whether or not to proceed with a more complete geotechnical investigation to develop a repair or replacement for the structure foundation.
4. If it is determined that a more complete geotechnical investigation is needed, the Geotechnical Office proceeds with the investigation and develops design recommendations.

1.3 Geotechnical Support within the WSDOT Project Management Process (PMP)

By Executive Order E1032.00, all phases of WSDOT capital transportation projects are to be delivered according to the principles and practices of the Project Management Process (PMP). In general, the PMP includes five main steps. These steps are "Initiate and Align," "Plan the Work," "Endorse the Plan," "Work the Plan," and "Transition and Closure."

Prior to or during the initiate-and-align step, the project manager should contact the RME to determine if the nature of the project could require Geotechnical Office involvement. If it appears that Geotechnical Office involvement may be required, the RME should make arrangements to have a Geotechnical Office representative included in PMP activities. Note that at this point, detailed project site data will likely not be available. Therefore, this determination by the RME will likely need to be made based on conceptual project data, and possibly a project site review. This determination must be made early in the project development process. For example, if the project is defined for PMP to include the development of the project definition (see Section 1.1.1), this determination must be made at the beginning of the project definition phase. If the project is defined instead to include only the project design and PS&E development phases (see Sections 1.1.2 and 1.1.3), this determination must be made at the beginning of the project design phase, as the office responsible for the geotechnical design work should be included in the planning for the project.

1.3.1 Initiate and Align

Assuming geotechnical design services will be needed to complete the project, during the "Initiate and Align" step, the individual/office responsible to provide geotechnical support (i.e., either the Geotechnical Office, the RME Office, or both) should be included in the project team by the project manager. Once included in the team, the geotechnical PMP team member (in general, this individual is also the geotechnical designer for the project) should, as a minimum, participate in the "Initiate and Align" efforts to provide input regarding roles and responsibilities, boundaries, and measures of success.

1.3.2 Plan the Work

During the "Plan the Work" step, the geotechnical PMP team member should provide input to the team regarding the project specific Work Breakdown Structure (WBS) developed from the Master Deliverables List (MDL), and the input necessary to develop the project budget and schedule. This would include a detailed analysis of how long it will take to perform the geotechnical tasks needed to complete the project, any individual task dependencies that affect task sequencing and the interrelationship between the geotechnical tasks and tasks to be completed by other team members, and how much it will cost to complete those tasks. It is the responsibility of the geotechnical PMP team member to coordinate the resource needs for the subject project with the resource needs of other projects that require geotechnical input, so that the proposed project delivery schedule can be achieved. The geotechnical PMP team member will also coordinate with the project team and with the Geotechnical Office management regarding the decision to use geotechnical consultants, if required to achieve the desired project schedule milestones. The geotechnical PMP team member also provides technical oversight of and coordination with any geotechnical consultants being used for the project.

The geotechnical PMP team member should also provide input to the team regarding potential risks or changes in the geotechnical area that could affect project schedule, budget, or scope, and provide a strategy to deal with those risks or changes. Examples of geotechnical risk include potential difficulties in getting drilling permits or right-of-entry, uncertainties in the scope of the geotechnical investigation required due to unknown subsurface conditions, mitigation of unstable ground, liquefaction or other seismic hazards, etc.

The geotechnical PMP team member should also provide the team with a plan regarding how geotechnical investigation and design quality, as well as how the accuracy of geotechnical design schedule and budget, will be assured.

1.3.3 Endorse the Plan

Once the work has been planned, the next step is to "Endorse the Plan." In this step, the geotechnical aspects of the Project Management Plan should be endorsed by the management of the office responsible to carry out the geotechnical work (e.g., if the Geotechnical Office is responsible for completing geotechnical work for the project, the Geotechnical Office management should endorse the plan). Note: The Project Management Plan must be reviewed and endorsed by Region Management.

1.3.4 Work the Plan

In the "Work the Plan" step, the geotechnical PMP team member will track the schedule and budget for the geotechnical work as it progresses, keeping the project team informed regarding the progress of the geotechnical work as identified in the project Communication Plan. If changes in the geotechnical schedule and/or budget are likely due to unanticipated problems, scope changes, or other inaccuracies in the geotechnical schedule or budget, the geotechnical PMP team member is responsible to inform the project team as far in advance as possible so that adjustments can be made. The frequency of reporting to the team on the progress of the work is identified in the Communication Plan and should be decided based on the needs of the project, recognizing that excessive progress reporting can, in itself, impact the schedule and budget for the work due to the time it takes to develop the interim reports. As problems or changes occur in the project, the geotechnical PMP team member assists the project team to address those problems or changes.

In general for this step, the geotechnical PMP team member completes, or arranges for the completion, of the geotechnical report for the project, and assists the team in the development of contract documents needed to construct the project. In the case of design-build projects, see Chapter 22 regarding the deliverables needed.

1.3.5 Transition and Closure

The geotechnical PMP team member should coordinate with the project team regarding the "Transition and Closure" activities that require geotechnical input and assistance. This may include documenting the geotechnical design decisions made, and identifying construction contract specifications that need to be reevaluated at a later time, should the project PS&E be put on the shelf until adequate funding is available. The geotechnical PMP team member should also make the geotechnical project file ready for long-term storage, making sure that if another geotechnical designer must work on the project, that the calculations and logic for the decisions made are easy to follow.

1.3.6 Application of the PMP to Construction

If possible, the geotechnical PMP team member should continue to provide geotechnical support to the project through construction, functioning as the Geotechnical Advisor for the construction project, to minimize any transition issues between the design and construction phases. The Geotechnical Advisor would become part of the construction project team in the initiate and align step, and would participate with the team to define roles and responsibilities, boundaries, and Measures of Success, assist in planning for risk and/or change, assist in the quality assurance and control of the project geotechnical features, and help the project team to manage risks and change as they occur.

1.3.7 Master Deliverables to be Considered

The geotechnical PMP team member will need to provide information regarding the geotechnical deliverables and tasks in the Master Deliverables List (MDL) (see Table 1-1) to the project team for consideration in developing the project schedule. For many deliverables, the region Project Office will need to provide information before the geotechnical work can begin. The master deliverables provided in Table 1-1 are current as of August 2006. Note that scoping (termed "Project Definition" in Section 1.1.1), Design, and PS & E are combined into one phase, "Preconstruction", in the MDL.

All tasks and subtasks under WBS Code PC-21 in Table 1-1 are used to accomplish the geotechnical work needed to complete the project definition (see Section 1.1.1). Regarding “Preliminary Site Data” (WBS Code PC-21.01), this information should be provided by the Project Office to the RME to be consistent with the process described in Sections 1.2.2 and 1.3. Refer to the *Design Manual* M 22-01, Section 610.04 for specifics regarding what information is to be submitted. Note that for the bigger, more complex projects where some limited field explorations may be needed, this task would also require the project office to obtain, or to make arrangements to obtain, drilling permits and right-of-entry. Supplying the necessary site data and permits should be considered a predecessor task to MDL task PC-21.03.

If it appears that Geotechnical Office involvement may be required, the RME should make arrangements to have a Geotechnical Office representative included in the geotechnical work to complete the project definition as discussed previously. Each office that is involved provides input data for these deliverables in terms of time and cost to complete the task, and the deliverables themselves. If both offices are involved, the Project Office will need to add the cost required to accomplish the work from both offices to obtain the total cost for each task.

Regarding the schedule to complete PC-21.03, the RME and Geotechnical Office efforts can, in general, be conducted concurrently. Regarding the “Conceptual Geotechnical Report,” up to two reports may need to be produced, one for the RME work and one for the Geotechnical Office work, if both offices need to be involved in this project phase for the given project. This deliverable should contain the cost estimate, schedule, and scope of work to complete the final project design through PS&E, and should discuss the potential geotechnical risk issues that need to be addressed to construct the project, to establish the scope and budget to construct the overall project.

WBS Code	Task Name	Task Description	Work Op
PC-18.03	Discipline Reports - Earth (Geology & Soils)	*Environmental Procedures Manual* Section 420 Earth (Geology & Soils)	0136
PC-20.03	Materials Source Report	A report on a specific WSDOT material source that verifies the quality and quantity of the material requested	0156
PC-21	Geotechnical Evaluations	Development of Geotechnical reports for project.	
PC-21.01	Preliminary Site Data	Project design office is to provide a project description and location of work to be performed to Region Materials Engineer. See *Design Manual* M 22-01 Chapter 610.	0140
PC-21.02	Environmental Permit for Field Exploration	Field exploration may require permits to complete. Permits need to be provided by the Project Office to Geotechnical Office/Region Materials Office to enable required field work to be started.	0138
PC-21.03	Conceptual Geotechnical Report	RME/Geotechnical Office will provide recommendations at the conceptual / feasibility level. Some soil borings may be drilled at this time depending upon project scope and available information.	0140
PC-21.04	Project Site Data	Site information provided to RME by the project design office (specific to the type of project) to initiate geotechnical work on a project during the design and PS&E phases. See *Design Manual* M 22-01 Chapter 610.	0140
PC-21.05	RME Geotech Report(s)	Region Geotechnical Report containing geotechnical recommendations and information applicable to the project. There is a possibility of multiple reports, depending upon the scope and complexity of the project.	0140
PC-21.06	HQ Geotechnical Report(s)	HQ Geotechnical Report containing geotechnical recommendations and information applicable to the project. There is a possibility of multiple reports, depending upon the scope and complexity of the project.	0140
PC-37.02	Summary of Geotechnical Conditions	Geotechnical Office and/or Region Materials prepares summary of geotechnical conditions for inclusion into the PS&E as Appendix B.	0140
PC-43.03	Project Geotechnical Documentation Package	Printing of pertinent geotechnical reports for sale to prospective bidders. Prepared by Geotechnical Office and/or Region Materials and printed by HQ Printing Services.	0140

Geotechnical Items in Master Deliverables List (MDL)
Table 1-1

WBS codes PC-21.04, PC-21.05, PC-21.06 and WBS codes PC-37.02 and PC-43.03) in Table 1-1 are used to accomplish the geotechnical work to complete the project design and final PS&E (see Sections *1.1.2* and 1.1.3). Regarding "Project Site Data" (WSB code PC-21.04), the Project Office provides the site data to the office designated to take the lead (i.e., the Geotechnical Office, the RME, or both) regarding the geotechnical work, as determined during the "Initiate and Align" step for the project.

Refer to the *Design Manual* M 22-01 Section 610.04 for specifics regarding the information to be submitted. This task would also require the project office to obtain, or to make arrangements to obtain, drilling permits and right-of-entry, if the necessary permits were not obtained in WBS code PC-21.02 or if they need to be amended. Supplying the necessary site data and permits should be considered a predecessor task to MDL tasks PC-21.05 and PC-21.06. The RME and Geotechnical Office efforts can, in general, be conducted concurrently. Note that WBS Codes PC-21.05 and PC-21.06 must be completed before WBS Codes PC-37.02 and PC-43.03.

1.4 Geotechnical Report Review Process, Certification and Approval Requirements

The following sections provide minimum requirements to insure the quality of the geotechnical work conducted by or for WSDOT.

The following terms are used herein:

Quality Control (QC) -- QC is performed by the individual performing the work while the work is being performed and includes all activities performed to control the level of quality produced in the end product. It consists of self-checking to ensure that work is completed in conformance with this manual and standards of practice. It includes checking for errors, omissions, and making sure that all the project elements work together coherently.

Quality Assurance (QA) -- Is performed by a person's supervisor or another individual not involved in the technical details. It is a system of external review and audit procedures conducted as an independent objective review by a third party to assess the effectiveness of the QC program and the quality, completeness, accuracy, and precision of the work being performed, and that it is consistent with design standards.

Quality Verification (QV) – Is performed prior to releasing geotechnical work products to their intended recipients for geotechnical work performed internal to WSDOT. For work performed outside WSDOT (e.g., consultants), this step is performed by WSDOT prior to acceptance of the final work products. The purpose of this step in the quality process is to verify that the QC/QA process used by the designer was effective for producing a geotechnical work product of acceptable quality that meets design standards. If, through conducting the QV it appears that the QC/QA process was not fully followed or if it appears that design standards may not have been met, QV may include a more detailed review of the design, including, as needed, comparative QV geotechnical analyses, to help identify the specific concerns.

All individuals, regardless if they are WSDOT staff or not, who are involved in geotechnical design are responsible for QC self-checking of their work. Each individual shall check their own work for compliance with this manual, standards of practice, errors, and omissions. Individuals are to correct their work before sending their work to the next individual(s) in the process of producing final geotechnical products.

The following sections define and describe the Quality Control/Quality Assurance (QC/QA) process that should be used.

1.4.1 Quality Control/Quality Assurance/Quality Verification for Geotechnical Work Produced by the RME's

The RME is fully responsible for the QC/QA of the geotechnical work they perform. The RME completes their geotechnical recommendations, certifies them as described in Section 1.4.3, and sends them to the Geotechnical Office for QV review and concurrence. If the Geotechnical Office finds the recommendations are not consistent with department policy or a significant error appears to have occurred (i.e., the QC/QA process appears to have not been followed), the Geotechnical Office may require that the RME produce an amendment to the recommendations.

1.4.2 Quality Control/Quality Assurance/Quality Verification for Geotechnical WorkProduced by the Geotechnical Office

Geotechnical Project Managers (GPM) not only have a QC role for their own work, they also have a QA role for the work of geotechnical design staff, support staff, and peers who may be assisting them with portions of their projects. The GPM is tasked with ensuring that the geotechnical work for their project is complete, thorough, accurate, and error free. To accomplish this task, the GPM shall perform QA review of the work that is performed by others in support of the project. If there are issues with the work that is performed, the GPM is responsible to ensure that the issue is resolved by working with the other individuals on the team and their supervisors. If necessary, the GPM will escalate issues upward through the supervisory chain to achieve successful resolution.

It is expected that GPM's will seek QA review from their supervisors, peers, or from other subject matter experts within the Office to ensure that the work they perform is of the highest quality. A peer review process or subject-matter-expert review is encouraged for unusual or highly technical project elements. After supervisory, peer, or subject-matter-expert review is completed, QV review will be performed by senior staff and the State Geotechnical Engineer prior to work being released to office customers.

For emergency projects or projects requiring preliminary information to keep moving forward, QC, QA, and QV reviews shall not be neglected.

Field Exploration Plans

The GPM is responsible for developing the field exploration plan (See Section 2.3). Before these plans are implemented, the project manager's supervisor is responsible to provide quality assurance for these plans to make sure they are complete, that they consider the available existing data, and that they meet the standards applicable to the structure or facility to be designed. For highly complex project plans, the State Geotechnical Engineer should be consulted for QV.

Boring Logs

For boring logs, the Field Exploration Inspector is responsible to make sure that the draft electronic field boring logs as entered are free of errors and consistent with the handwritten field logs (QC). To make sure that the inspector sees the final draft electronic field boring logs, the office staff in the Geotechnical Office will produce a PDF of each log sent in by the inspector and e-mail them back to the inspector for review. The inspector will provide any comments to correct errors in the electronic logs back to the office staff, with a copy to the inspector's supervisor to ensure that the log review process has been followed and done correctly, for production of the final field logs and confirm that they have been reviewed. The geotechnical project manager is responsible to perform a QA check of the final draft edited boring logs produced by the technical staff.

Laboratory Testing

Once the drilling is completed, the GPM is responsible to develop the laboratory testing plan (see Section 2.4). Once the geotechnical project manager who is assigned the project has received the draft field logs, has selected soil and rock samples for testing, and if rock core is obtained, has reviewed the rock cores, and quality assurance of the laboratory testing plan has been conducted, the laboratory evaluation begins. Laboratory testing of soil and rock shall meet the quality control requirements in Section 5.6.1, and as applicable the AASHTO accreditation program requirements. Once the laboratory technicians have completed the specified testing and documentation and have checked their own work for errors, the supervisor in charge of the laboratory shall check the test results and reports for errors and incorrect interpretations and document that the data has been reviewed – once determined to be free of errors and omissions, the laboratory data are provided to the geotechnical project manager for use in the project, and also provided to the staff responsible to produce final draft edited boring logs based on the laboratory test results. The geotechnical project manager is responsible to check the laboratory test results for accuracy.

Geotechnical Reports and Memorandums

For geotechnical reports produced by the Geotechnical Office, senior-level review is required at the following key project junctures:

- The letter/memo transmitting the estimate of the scope of work and estimated costs for the geotechnical services needed,
- The subsurface investigation plan,
- The laboratory testing plan, and
- The draft/final geotechnical report.

Typically, three levels of review are conducted at each of these project junctures:

- a detailed review by the immediate supervisor (who is licensed) and at other intermediate times as needed to guide the design (including a detailed review of the draft report and supporting calculations, and a spot check of the boring logs and laboratory test data),
- A detailed review by the Chief Foundation Engineer or Chief Engineering Geologist of the final geotechnical product (e.g., geotechnical report, design memorandum, or Summary of Geotechnical Conditions) and a spot check of the calculations and other supporting information, and
- A spot check review and review for consistency with design policy and standards of practice by the State Geotechnical Engineer.

The State Geotechnical Engineer may delegate final review authority to the chief or senior level. For the subsurface investigation and laboratory testing plans, formal review by the State Geotechnical Engineer is generally not required. A minimum of one level of review by a licensed professional with the necessary geotechnical or engineering geology experience must be conducted in all cases, however. Licensed professionals performing design shall seek peer review and shall obtain the State Geotechnical Engineer's approval, or the review and approval of the individual to whom final review authority has been delegated by the State Geotechnical Engineer, prior to issuing design recommendations. "Design recommendations" include those that are considered final, and those that are considered preliminary if the preliminary recommendations will result in significant design effort being expended by those who use the recommendations to perform their designs, or if they could otherwise end up being treated as final recommendations. For those design recommendations that are clearly identified as being preliminary and subject to change, and for which all parties receiving those recommendations fully understand that the recommendations are subject to change and are only to be used for preliminary alternative and scope development purposes (with the exception of EIS discipline reports, critical area ordinance reports, or similar documents), final review authority is delegated to the Chief Foundation Engineer and Chief Engineering Geologist level.

Some projects require significant input by both engineering geologists and foundation engineers (e.g., landslides contained within a bigger interchange or line project, bridges or walls founded on soils or rock in which the site geology is very complex, retaining walls used to stabilize landslides, drainage or infiltration designs where the groundwater regime is complex, etc.). In such cases, a foundation engineer/ engineering geologist team (i.e., one individual from each Section of the Geotechnical Office) should perform the design, and as a minimum, senior-level review by the Chief Foundation Engineer and the Chief Engineering Geologist, in addition to a spot check review and review for consistency with design policy and standards of practice by the State Geotechnical Engineer, shall be conducted at each of the key project junctures identified above.

1.4.3 Report Certification

In general, the individual who did the design, if he/she possesses a PE or LEG, and the first line reviewer who is licensed, will stamp the report, as required by the applicable RCW's and WAC's. If the second line supervisor/manager, or above (e.g., the State Geotechnical Engineer, Chief Foundation Engineer, or Chief Engineering Geologist), through the review process, requires that changes be made in the design and/or recommendations provided in the report, otherwise provides significant input into the design, or is the primary reviewer of the report, consistent with the definition of direct supervision in WAC 196-23 and WAC 308-15-070, the second line supervisor/ manager, or above, will also stamp the report/memorandum. For reports produced by the Engineering Geology Section that require a Professional Engineer's stamp, and which have been produced and reviewed by individuals that do not possess a Professional Engineer's license, the State Geotechnical Engineer, or the licensed professional engineer delegated to act on behalf of the State Geotechnical Engineer, will provide a detailed review of the design and report, consistent with the definition of direct supervision in WAC 196-23, and stamp the report. For plan sheets in construction contracts, the first line manager/supervisor, or above, who has functioned as the primary reviewer of the geotechnical work as defined above will stamp the plans, but only if the plan sheets fully and accurately reflect the recommendations provided in the geotechnical report upon which the plan sheets are based.

1.4.4 Approval of Reports Produced by the Geotechnical Office

The State Geotechnical Engineer, or the individual delegated to act on behalf of the State Geotechnical Engineer, must sign the geotechnical report or memorandum, as the designated approval authority for WSDOT regarding geotechnical design (this includes engineering geology reports). The signature of the approval authority indicates that the report or memorandum is in compliance with WSDOT geotechnical standards and policies. This policy also applies to design recommendations that are sent out informally to other offices (e.g., the WSDOT Bridge and Structures Office, Washington State Ferries Offices, Region Project Engineer Offices, etc.) for their use in design and PS&E development prior to issuance of the final geotechnical report for the project or project element.

1.5 Reports Produced by Consultants or other Agencies for WSDOT

The Geotechnical Office reviews and accepts all geotechnical reports and design letters/memorandums produced for WSDOT projects, consistent with the division of geotechnical work as described in Section 1.2.2. However, the consultant/other agency producing the report shall take full responsibility for the accuracy of the report and its engineering recommendations.

The Geotechnical Project Manager assigned the project being designed by a consultant is responsible to develop the scope of work for the consultant task assignment, or for consultants hired through the region project office, to work with the region to develop the scope of work. The geotechnical project manager is then responsible to:

- work with the consultant to make sure that the geotechnical work is carried out in accordance with the scope of work,
- work with the consultant (and region project office as needed) to address any changes in scope of work that occur during the life of the project,
- to verify that the work is carried out in accordance with department geotechnical policies, and
- to provide an overall quality verification (QV) evaluation of the adequacy of the geotechnical work with regard to WSDOT's geotechnical policies.

As a minimum, the geotechnical project manager should review the consultant's work and recommendations regarding the subsurface investigation plan, and for the draft/final geotechnical report. If there are questions about the adequacy/accuracy of the design, the geotechnical project manager should also request and spot check the consultant's geotechnical calculations. However, the geotechnical consultant is responsible for QC/QA for their design and report. The consultant liaison for the Geotechnical Office is only responsible to assist the geotechnical project manager with setting up the consultant task assignment and other consultant administration tasks during the life of the task assignment. See Section 1.6 for a more complete description of geotechnical consultant administration.

For reports or design letters/memorandums that cover only the level of geotechnical work that is clearly region responsibility per Section 1.2.2, the RME reviews and accepts the report or design letter/memorandum, but still forwards a copy of the consultant report to the Geotechnical Office for concurrence, consistent with Section 1.2.2 for regional soils reports. Acceptance of the report or design letter/memorandum produced by consultants or other agencies shall not be considered to constitute acceptance of professional responsibility on the part of WSDOT, as well as the reviewer, for the contents and recommendations contained therein, consistent with professional responsibility as prescribed by law. Acceptance only indicates that the contractual obligations under which the report or design letter/memorandum have been met and that the contents and recommendations appear to meet the applicable WSDOT, regional, and national standards of practice.

Geotechnical reports produced by consultants shall be certified in accordance with the principles described above in Section 1.4.1 and 1.4.3, and as required by the applicable RCW's and WAC's. Note that this review and acceptance process and associated considerations also apply to reports produced by consultants for developers building facilities that impact WSDOT facilities.

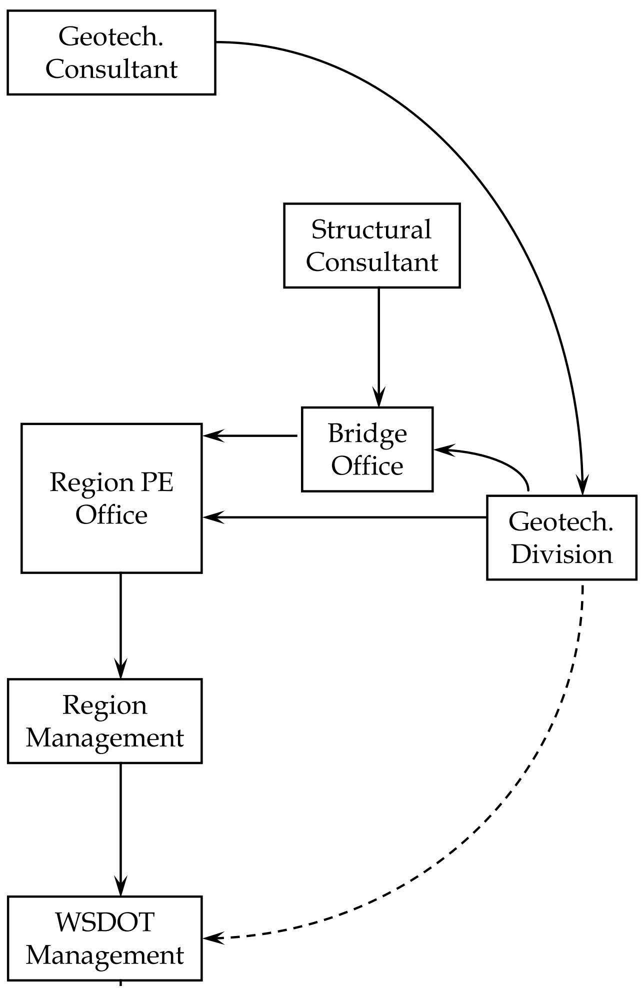
For geotechnical reports and documents produced by Design-Builders, see Chapter 22.

1.6 Geotechnical Consultant Administration

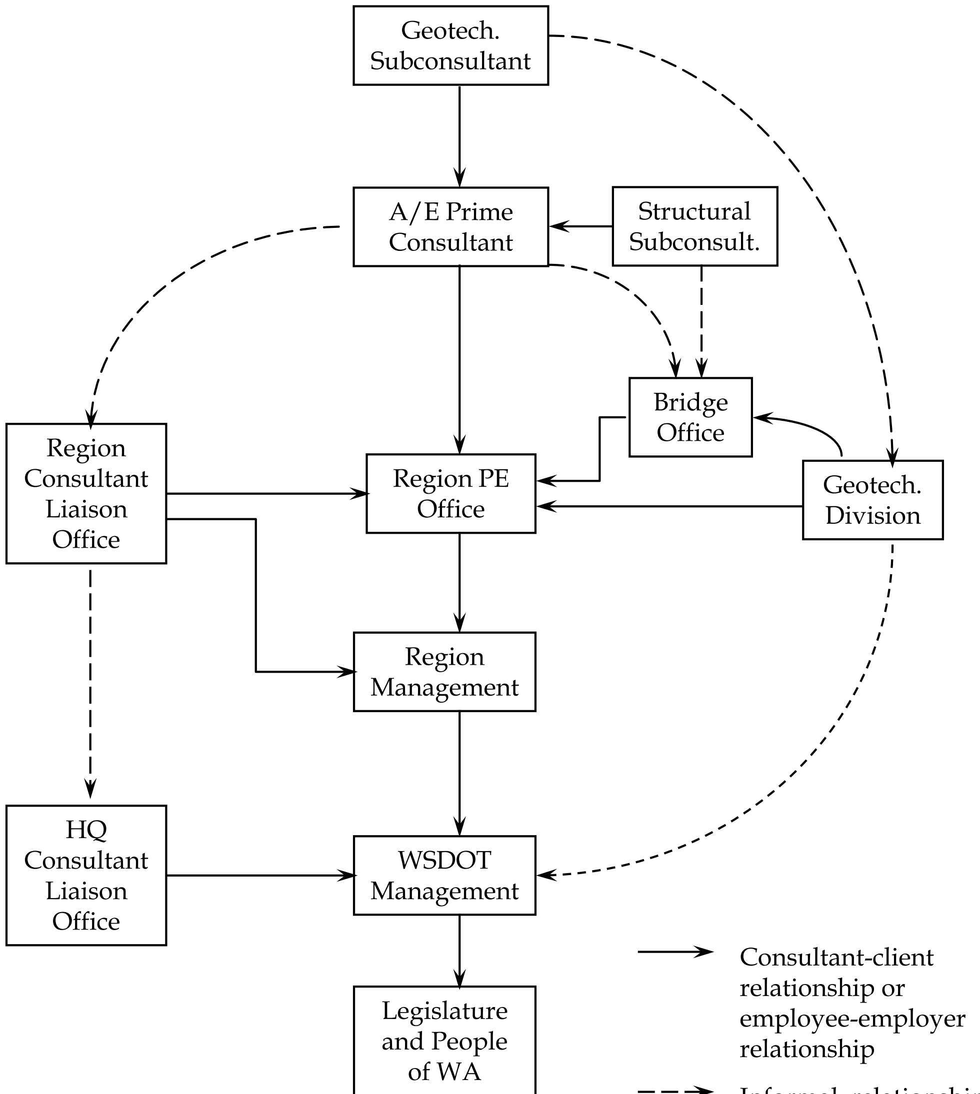
This section addresses geotechnical consultants working directly for the Geotechnical Office, and geotechnical consultants working for a prime consultant through a region, or other WSDOT office, contract. Geotechnical consultants are used to handle peak load work, or to obtain specialized expertise not contained within the Geotechnical Office. If a geotechnical consultant is needed, the first choice is to utilize a consultant working directly for the Geotechnical Office, as the communication lines are more straightforward than would be the case if the geotechnical consultant is working for a prime consultant, who in turn is working for another office in WSDOT. This is illustrated in Figures 1-3 and 1-4.

In general, consultants working directly for the Geotechnical Office will do so through an on-call master agreement in which the consultant is assigned project specific tasks. Through these tasks, the consultant is typically responsible to develop the detailed geotechnical investigation plan, perform the testing and design, and produce a geotechnical report. For these assignments, the consultant is viewed as an extension of the Geotechnical Office staff and is therefore subject to the same standards of design and review as in-house Office staff. The review and certification process for consultant geotechnical work mirrors that for in-house geotechnical work, as described in Section 1.5, except that the final certification of the report is done by the consultant rather than WSDOT staff, with WSDOT functioning in a review capacity. Frequent communication between the Geotechnical Office staff and the consultant is essential to a successful project. For this contractual scenario, the Geotechnical Office is responsible to oversee and administer the consultant agreement and task assignments.

If it is determined by the Region or other WSDOT office that a general civil or structural consultant is needed to handle the design work normally handled by that WSDOT office, the Geotechnical Office and Region Materials Office shall be contacted prior to sub-consulting the geotechnical portion of the project. Both the Region Materials Office and Geotechnical Office may have staff available to perform the geotechnical design for the project. If it is determined that a geotechnical subconsultant is needed, the Geotechnical Office will need to assist in the development of the geotechnical scope and estimate for the project, so that the consultant contract is appropriate. A typical consultant scope of work for preliminary design is provided in Appendix 1-A, and a typical consultant scope of work to complete the geotechnical work for a PS&E level design is provided in Appendix 1-B. These typical scopes of work for geotechnical subconsultants may need adjustment or augmentation to adapt them to the specific project. A team meeting between the consultant team, the Region or other WSDOT Office (depending on whose project it is), and the Geotechnical Office is conducted early in the project to develop technical communication lines and relationships. Good proactive communication between all members of the project team is crucial to the success of the project due to the complex consultant-client relationships (see Figure 1-4).



WSDOT Consultant Relationship for
Consultants Working Directly for the Geotechnical Office
Figure 1-3



WSDOT-Consultant Relationship for Consultants Working for a Prime Consultant for Other WSDOT Offices
Figure 1-4

1.7 Geotechnical Information Provided to Bidders

1.7.1 Final Geotechnical Project Documentation

The Final Geotechnical Project Documentation for a project shall consist of all geotechnical reports and memorandums, in their entirety, produced by WSDOT or consultants that are pertinent to the final PS&E for the project. Outdated or otherwise superseded geotechnical reports and memorandums should not be included in the Final Geotechnical Project Documentation. In such cases where a small portion of a geotechnical report has been superseded, the entire report should be included with the superseded text clearly identified along with the superseding document. Reports produced by the RME are generally kept under separate cover, but are included in the final publication package as described below.

1.7.2 Final Geotechnical Documentation Publication

Once a project PS&E is near completion, the Final Geotechnical Project Documentation is to be published for the use of prospective bidders. Materials Source Reports should also be included as part of the package published for bidders. The Region Project Development Office (or Terminal Engineering Department for Washington State Ferries) is responsible to notify the Geotechnical Office at least 12 to 14 weeks in advance of the Ad or Shelf Date when the final project geotechnical documentation is due in the Region (or Washington State Ferries), and which projects require final project geotechnical documentation. The Region Project Development Office (or Terminal Engineering Department for the Washington State Ferries) will also identify at that time who they have designated to receive the report to handle or continue the publication process. In general, it is desirable that the final geotechnical documentation be available for printing 10 weeks prior to the Ad or Shelf Date, but absolutely must be available no later than two Fridays prior to the Ad or Shelf date. This compiled geotechnical documentation package is typically sent to the Region Project Engineer Office (or Terminal Engineering Office for Washington State Ferries projects) by the Geotechnical Office. When transmitting the final project geotechnical documentation, the Geotechnical Office will specifically identify the geotechnical documentation as final for the project and as camera-ready. Likewise, the Region Materials Office will concurrently send a camera-ready final copy of any Region-generated reports (e.g., the Region Soils Report), as applicable, to the Region Project Engineer Office to be included as part of the geotechnical documentation for the project.

1.7.3 Geotechnical Information to be Included as Part of the Contract

Geotechnical information included as part of the contract (as an appendix) for design-bid-build projects will generally consist of the final project boring logs, and, as appropriate for the project, a Summary of Geotechnical Conditions. Both of these items are, in general, provided by the Geotechnical Office. If a Region Soils Report has been produced by the RME, the RME must provide the final boring logs and may be required to complete portions of the Summary of Geotechnical Conditions to include the information provided in the Region Soils Report. Note that Chapter 22 covers what geotechnical information is to be included in the Request for Proposals for design-build projects.

All boring logs used as the basis for the geotechnical design for the project should be included in an appendix to the contract. A legend sheet that defines the terms and symbols used in the boring logs shall always be included with the boring logs. The Geotechnical Office will provide a legend for logs they have produced. Consultants shall also provide a legend along with their logs in their geotechnical reports. The locations of all boring logs included with the contract should be shown on the contract plan sheets.

Based on specific project needs, other types of geotechnical data may also need to be included in the contract documents. Such additional data may include geophysical test results, and subsurface profiles and cross-sections for specific geotechnical project features. The goal of such data is to provide potential bidders a more complete picture of the conditions as necessary for accurate bidding, when that information cannot be conveyed by the boring logs alone.

A "Summary of Geotechnical Conditions," provided by the Geotechnical Office for most projects that contain significant geotechnical features, should also be included in the contract with the boring logs. This Summary of Geotechnical Conditions" is generally a 1 to 2 page document (see Chapter 23) that briefly summarizes the subsurface and ground water conditions for key areas of the project where foundations, cuts, fills, etc., are to be constructed. This document also describes the impact of these subsurface conditions on the construction of these foundations, cuts, fills, etc., to provide a common basis for interpretation of the conditions and bidding.

1.8 Sample Retention and Chain of Custody

In general, there are three types of samples obtained by the Geotechnical Office and geotechnical consultants: disturbed soil samples (includes sack samples from test pits), undisturbed soil samples, and rock cores. Disturbed soil samples are typically used for soil classification purposes, though on occasion they may be used for more sophisticated testing. Undisturbed soil samples are primarily used for more sophisticated testing, though they may also be used for evaluation of detailed soil structure. Undisturbed samples typically degrade significantly and are not useful for testing purposes after about 3 to 6 months. Disturbed and undisturbed soil samples that have not been tested by the Geotechnical Office or Consultant will be retained for a minimum of 90 days after the geotechnical report is completed, after which time they will be disposed. Prior to disposal, the Consultant shall contact the Geotechnical Office so that they may take possession of the samples, if they choose to do so.

Rock core is generally retained until after the construction project is complete and it is clear that claims related to the rock are not forthcoming. After construction, the core will be disposed. Rock core obtained by consultants shall be delivered to the Geotechnical Office as part of the deliverables associated with the Geotechnical Report. Subject to prior approval of the WSDOT State Geotechnical Engineer, rock core may be disposed prior to project construction if it is determined that the risk of claims related to rock quality issues is sufficiently low, if the rock core is degraded and therefore not useful for visual inspection or testing, or possibly other reasons that cause the risk of early core disposal to be low. In all cases, whether or not early disposal of the core is conducted, all rock core shall be photographed at high resolution and in color correct light, to provide a permanent record of the core.

All samples of soil or rock that are obtained on behalf of WSDOT by consultants and transported to the State Materials Laboratory Geotechnical Office shall become the property of WSDOT.

1.9 Geotechnical Design Policies and their Basis

Technical policies and design requirements provided in this manual have been derived from national standards such as those produced by AASHTO. FHWA and other nationally recognized geotechnical design manuals and publications have been used in the *Geotechnical Design Manual* to address areas not specifically covered by the AASHTO manuals. The following manuals, listed in hierarchical order, shall be the primary source of geotechnical design policy for WSDOT:

1. This *Geotechnical Design Manual* (GDM)

2. AASHTO Guide Specifications for LRFD Seismic Bridge Design
3. AASHTO LRFD Bridge Design Specifications, most current edition plus interims
4. AASHTO Standard Practice for Conducting Geotechnical Subsurface Investigations, R 13-03, 2007
5. AASHTO Manual on Subsurface Investigations (1988)

If a publication date is shown, that version shall be used to supplement the geotechnical design policies provided in this GDM. If no date is shown, the most current version, including interim publications of the referenced manuals, as of the GDM publication date shall be used. This is not a comprehensive list; other publications are referenced in this GDM and shall be used where so directed herein. FHWA geotechnical design manuals, or other nationally recognized design manuals, are considered secondary relative this GDM and to the AASHTO manuals listed above for establishing WSDOT geotechnical design policy.

Where justified by research or local experience, the design policies and requirements provided in the GDM deviate from the AASHTO and FHWA design specifications and guidelines, and shall supersede the requirements and guidelines within the AASHTO and FHWA manuals.

For foundation and wall design, the load and resistance factor design (LRFD) approach shall be used, to be consistent with WSDOT Bridge Office structural design policy. For aspects of foundation and wall design that have not yet been developed in the LRFD format, allowable stress (ASD) or load factor design (LFD) will be used until such time the LRFD approach has been developed. Therefore, for those aspects of foundation and wall design for which the LRFD approach is available, alternative ASD or LFD design formats are not presented in this manual.

In the chapters that follow, as well as within this chapter, and in the referenced AASHTO Manuals, the terms, and their definitions, provided in Table 1-2 are used to convey geotechnical policy.

Term	Definition
Shall	The associated provisions must be used. There is no acceptable alternative.
Should	The associated provisions must be used unless strong justification is available and based on well-established regional or national practice, and if supported by widely accepted research results.
May	The associated provisions are recommended, but alternative methods or approaches that are consistent with the intent of the provisions are acceptable.
Evaluate, evaluated, address, or addressed	The associated issue must be evaluated or addressed through detailed analysis and the results documented.
Consider, considered	The associated recommended provisions must be evaluated, and the reasons and analyses used to decide whether or not to implement the recommended provisions must be documented.
Geotechnical designer	The geotechnical engineer or engineering geologist who has been given responsibility to coordinate and complete the geotechnical design activities for the project

Terms Used to Convey Geotechnical Policy
Table 1-2

With regard to "should" in Table 1-2, "strong justification" relates to the veracity and consistency of the information used to justify the alternative approach or procedures, and how the data are to be interpreted or the analysis methodology is to be used based on widely accepted design codes, regional practices, manuals, published research results, etc. In order to meet the requirement for "well established regional or national practice", the practice must be demonstrably relevant to the specific project conditions and applications in question. To meet the requirement for "well-established", the practice must be defined in regionally or nationally accepted design manuals, text books, or codes of practice. Examples that meet these requirements are as follows:

1. FHWA engineering manuals.
2. AASHTO LRFD Bridge Design Specifications.
3. Widely accepted text books.
4. Practices that have been widely and successfully used by the geotechnical design firms in the region, provided they are applicable to the project conditions and applications in question, and provided that each of the following are convincingly demonstrated: details of the practice, long-term success, soil/rock conditions, and applicability.

In order to meet the requirement for "widely accepted research" the research must be published in a peer-reviewed national or international engineering journal, such as the ASCE Journal of Geotechnical and Geoenvironmental Engineering; the Canadian Geotechnical Journal; or Ground Improvement. Furthermore, the research must be demonstrably relevant to the project-specific conditions and applications in question. What would not be considered widely accepted research includes, for example, conference articles (while sometimes peer reviewed, such peer reviews are usually not thorough or rigorous); PhD theses; trade magazine articles; and any article, even if peer reviewed, that directly conflicts with the design requirements of this Geotechnical Design Manual and other documents referenced by this manual.

Justification to deviate from the policies and design requirements outlined in this manual shall not rely solely on "engineering judgment". Furthermore, strong justification must consider all the available data that applies to the site and design, not just portions of it.

1.10 Geotechnical Construction Support Policies

1.10.1 Division of Responsibilities for Construction Support of Design-Bid-Build Projects

The division of responsibilities between the Geotechnical Office and the Region Materials Office for response to geotechnical construction problems for design-bid-build projects is generally consistent with Section 1.2, which means that the RME, at least theoretically, functions as the clearing house to address geotechnical construction problems. The division of work shown in Figure 1-2 applies to construction assistance as well. However, it must also be recognized that most geotechnical construction problems need to be addressed quickly to prevent construction contract impacts. To minimize delays in getting geotechnical construction problems addressed, if it is obvious that HQ input will be required anyway (e.g., foundation construction issues, retaining wall geotechnical construction problems, shoring wall stability or excessive deformation problems, rockslope construction issues, etc.) the Region Project Office should contact the Geotechnical Office directly. In that case, the Geotechnical Office should keep the RME informed as to the request and the nature of the problem as soon as practical. Typically, a construction project geotechnical advisor will be assigned to the project and is the first point of contact for assistance from the Geotechnical Office. For construction emergencies, such as slope failures, the process described in Section 1.2.3 should be followed, except that the Region Project Office functions as the maintenance office in that process.

There are some types of geotechnical construction issues for which the RME should always provide the first response. These include, for example:

- Evaluation of fill compaction problems;
- Evaluation of material source and borrow problems;
- Pavement subgrade problems; and
- Evaluation of the soil at the base of spread footing excavations to check for consistency with boring logs.

For the specific issues identified above, the RME will enlist the help of the Geotechnical Office if complications arise.

For evaluation of differing site conditions claims, the Geotechnical Office should always provide the geotechnical evaluation and will work directly with the HQ Construction Office to provide the geotechnical support they need.

Note that for consultant designed projects, the Geotechnical Office may request that the designer of record (i.e., the consultant) get involved to recommend a solution to WSDOT regarding the problem.

1.10.2 Division of Responsibilities for Construction Support of Design-Build Projects

For design-build projects, the first responder for geotechnical construction problems is the geotechnical designer of record for the design-builder. The next point of contact, if action on behalf of the contracting agency (i.e., WSDOT) is required in accordance with the contract RFP, is the geotechnical advisor assigned to the project from the Geotechnical Office. If it turns out that the RME should provide a response or if the RME could provide a more rapid response, considering the nature of the problem, the geotechnical advisor will contact the RME to enlist their assistance.

1.10.3 Geotechnical Office Roles and Communication Protocols for Construction Support

Geotechnical Office support to HQ Construction, Region Construction, and Region Project offices must always be technical in nature, leaving construction administration issues to the construction offices the Geotechnical Office is supporting. Since the technical support the Geotechnical Office provides could affect the construction contract, it is extremely important to contact HQ Construction as soon as possible to let them know of the situation, in addition to the specific regional offices being supported. Direct communication and directions to the contractor should be avoided, unless the boundaries of such communication have been approved in advance by the Region Project Office and as appropriate, HQ Construction. Any communication in writing, including e-mail correspondence, must be written in a way that communicates only technical issues and does not compromise WSDOT's ability to effectively administer the contract. This is especially important if potential contractor claims are involved.

If potential contractor claims are involved in the construction problem, the Geotechnical Office role is to provide assistance to the HQ Construction Office. For example, with changed conditions claims, the Geotechnical Office's professional evaluation of the situation should focus on determining and describing the geotechnical conditions observed during construction in comparison to what was expected based on the data available at time of bidding. The Geotechnical Office is not to determine or even imply the merits of the contractor's claim. HQ Construction will do that.

Evaluations of contractor claims, as well as geotechnical recommendations for the redesign of a geotechnical element in a contract, must be put in a formal written format suitable for sealing as discussed in Section 1.4.1. E-mail should not be used as a communication vehicle for this type of information. Furthermore, the State Geotechnical Engineer, or the individual delegated to act on behalf of the State Geotechnical Engineer, must review and approve such documents before they are distributed. Memorandums that provide an evaluation of a contractor claim should be addressed to the HQ Construction Office, and a copy shall not be sent to the Region Project Engineer in this case. The HQ Construction Office will forward the Geotechnical Office response to the Region Project Engineer with their final determination of the validity of the claim. If a claim evaluation is not involved and only technical recommendations in support of a contract redesign are being provided, address the letter to the HQ Construction Office, with a copy to the Region Project Office and others as necessary (e.g., the Bridge Office). If the resulting change order will be within the Region authority to approve, the memorandum should be addressed to the Region Project Office with a copy to HQ Construction and the Region Operations or Construction Office.

1.11 Geotechnical Construction Submittal Review Policies

Most construction contract submittals include information that both the Bridge and Structures Office and the Geotechnical Office must review. Blasting plan and rock slope submittals (e.g., rock bolting) are an exception to this, in that their technical review are purely a Geotechnical Office function.

For construction submittals that involve structures or support of structures or bridge approach fills, policies on coordination of submittal review are as follows:

1.11.1 Proprietary Retaining Walls

- All pre-approved wall manufacturer submittals required by the contract shall be reviewed by the Bridge Office. The Bridge Office shall send a copy of the submittal to the Geotechnical Office for review when the submittal is distributed to the appropriate Bridge Office Design Unit. Details of specifically what will be reviewed are provided in Appendix 15B.
- The Geotechnical Office shall respond directly to the Construction Support Unit of the Bridge Office with their submittal review comments. The Bridge Office Construction Support Unit is responsible for the response back to the Region Project Engineer, and shall attach or include Geotechnical Office comments verbatim.
- After both the Bridge Office Design Unit and the Geotechnical Office have submitted their comments back to the Bridge Office Construction Support Unit, they will be circulated to the Bridge Office Wall Specialist for this review for completeness and consistency.
- Returns for Corrections (RFC's) and Change Order Notifications will require that a copy of the submittal go to the HQ Construction Office.
- Proprietary retaining walls that have been completely detailed in the Contract Plans and Special Provisions (including manufacturer shop plans) need not come to the Bridge Office for review. The Region's Project Engineer's Office is responsible for the review of the contractor's walls in accordance with the contract documents.

1.11.2 Other Construction Submittals (Non-Proprietary walls, Excavation and Shoring, Soldier Piles, Ground Anchors, Shafts, Piles, Ground Improvement, etc.)

- Geosynthetic shoring walls without structural facing do not require Bridge Office review. These walls shall be sent directly to the Geotechnical Office for their review. To provide consistency in the review process, the review comments should be sent back to the Bridge Office Construction Support Unit in the same manner as any other submittal for forwarding to the region project engineer.
- The Bridge Office Construction Support Unit will determine the need for geotechnical input when reviewing contractor shoring submittals. If geotechnical input is needed, the Construction Support Unit will coordinate with the Geotechnical Office to obtain review comments and will submit the compiled comments from both offices to the region project office.
- For all other construction submittals with geotechnical items received by the Bridge Office, the Bridge Office Construction Support Unit will send a copy of the submittal to the Geotechnical Office for review. The Geotechnical Office shall respond directly to the Construction Support Unit of the Bridge Office with their submittal review comments. The Bridge Office Construction Support Unit is responsible for the response back to the region project engineer, and shall attach or include Geotechnical Office comments verbatim. Returns for Corrections (RFC's) and Change Order Notifications will require that a copy of the submittal go to the HQ Construction Office.

- The geotechnical designer's main emphasis in review of the shaft submittals is to ensure that the proposed construction procedure will result in a shaft that meets the assumptions used during the design phase. Casing limits, construction joints, shaft diameter(s), and surface casing installation, as well as, backfilling are areas that typically need review. For soldier piles, substitution of another pile section or possible over-stressing of the pile anchor stressing should be checked. These items will generally be flagged by the geotechnical designer.
- The Bridge Office shall in general be the clearinghouse for transmittals of submittal reviews back to the region project engineer. The Geotechnical Office will return comments to the Bridge Office only, except when previously agreed to respond separately.

1-12 References

AASHTO, 2012, LRFD Bridge Design Specifications, American Association of State Highway and Transportation Officials, Sixth Edition, Washington, D.C., USA. (Note: Most current edition shall be used)

AASHTO, 2011, AASHTO Guide Specifications for LRFD Seismic Bridge Design, Second Edition, LRFDSEIS-2, Washington DC, USA. (Note: Most current edition shall be used)

AASHTO, 2007, Standard Practice for Conducting Geotechnical Subsurface Investigations, R 13-03, Washington DC, USA.

AASHTO, 1988, Manual on Subsurface Investigations, First Edition, MSI-1, Washington, DC, USA.

Design Manual M 22-01, 2012, (Note: Most current edition shall be used)

WAC 196-27A Rules of Professional Conduct and Practice

WAC 196-23 Stamping and Seals

WAC 308-15 Geologist Licensing Services

Appendix 1-A Preliminary Geotechnical Engineering Services Scope of Work

The CONSULTANT shall provide all PRELIMINARY geotechnical services that would normally be provided by the STATE's geotechnical engineering personnel to the project office responsible for the design and preparation of plans, specifications, and estimates (PS&E) for this PROJECT. The preliminary recommendations are to identify critical design elements and provide a basis for developing a scope of work for preparing design-level (PS&E) geotechnical recommendations. Based on the information obtained and the preliminary recommendations, the Geotechnical Scope may be supplemented by the STATE to have the CONSULTANT provide detailed design recommendations for PS&E.

The CONSULTANT shall cooperate and coordinate with the STATE's Geotechnical Office, other STATE personnel, and Municipal Agencies as necessary and under the direction of the STATE Geotechnical Engineer to facilitate the completion of the PROJECT. The CONSULTANT shall:

Review Available Information
The CONSULTANT shall collect and review readily available geotechnical and geologic data for the project including, but not limited to, geologic maps from the U.S. Geologic Survey, WSDOT construction records, soils and geotechnical reports from WSDOT, Federal, Community, City or County officials, groups or individuals, and geotechnical information within the project limits that may be in the CONSULTANT's files.

For projects where the geotechnical elements of the project have not been fully defined by the STATE, the CONSULTANT shall review the project and available information to identify areas within the project limits that may require detailed geotechnical recommendations or areas that have geotechnical elements that are complex. The CONSULTANT shall identify areas of significant cuts in soil or rock, large fills, areas of soft compressible soils, potential retaining wall locations and suitable wall types.

Perform a Site Review
The CONSULTANT shall perform an on-site geologic reconnaissance of the project to identify critical design elements. The CONSULTANT shall determine general site conditions, access for exploration, conditions of existing transportation features, and identify areas of potential fills or cuts, walls, culverts or culvert extensions, and bridges or bridge widen-ings.

Summarize Project Geology
The CONSULTANT shall summarize the regional geology and geology of the projects limits based on available existing information and the site reconnaissance. Geotechnical hazards, such as liquefaction and landslides, shall be assessed and the potential impacts to the project shall be discussed for identified hazards.

Prepare a report that Provides Preliminary Geotechnical Recommendations

The CONSULTANT shall identify critical design elements and provide a basis for geotechnical recommendations. As a minimum the CONSULTANT shall address or identify the following:

1. Locations of potential cuts, fills, soft compressible soils, soils susceptible to liquefaction, landslides, and faults close to or at the site.
2. Preliminary maximum cut and fill slope inclinations shall be recommended to ensure overall stability for cut slopes, embankments, structures, and to provide a basis for right-of-way acquisition.
3. For structures, suitable foundation types shall be identified. The report shall also indicate whether the foundation bearing capacities are anticipated to be low, indicating marginal bearing conditions, or high, indicating good to excellent bearing conditions.
4. Feasible retaining wall types shall be discussed.
5. The report shall include available site maps, cross sections, end areas, and subsurface profiles, and the available subsurface information.

The CONSULTANT shall prepare a Draft Preliminary Geotechnical Recommendations Report for the project. The CONSULTANT shall prepare three copies of the Draft Geotechnical Report and submit them to the STATE for review and comment. The STATE will review the Geotechnical Report and provide written comments within three weeks. The CONSULTANT shall respond to comments from the project team and WSDOT, revise the draft report, and submit three (3) copies of the final report. Additional Draft reports may be requested by the STATE prior to completing the FINAL report until the STATE's review comments are adequately addressed.

Instructions for Preparation of the Scope of Work for Project Specific Application
The **Preliminary Geotechnical Engineering Services Scope of Work** is to be used when the civil engineering portion of the project is not defined before consultant services are requested. In general, new soil borings are not required for conceptual-level recommendations except where subsurface information is not available within the project limits and if project elements are geotechnically complex. The Geotechnical Office is available to assist in the determination of whether or not borings are required. If the Region and the Geotechnical Office determine that borings are required to adequately develop preliminary recommendations, the Geotechnical Office will provide an additional section to be included in the scope of work for the drilling of new borings.

The Geotechnical Office should be contacted to provide a cost estimate for the work anticipated. The Geotechnical Office estimate should be used to complete negotiations with the consultant. At the Region's request, the Geotechnical Office can review the consultant's estimate and provided guidance for negotiation.

Once preliminary geotechnical recommendations are provided, the prime Consultant or Region can define the civil engineering portion of the project. Once the civil engineering portion is defined, a supplement can be prepared to have the Geotechnical Consultant provide detailed PS&E level recommendations. The **Geotechnical Engineering Services Scope of Work** should be used for the supplement.

The CONSULTANT shall provide all geotechnical services that would normally be provided by the STATE's geotechnical engineering personnel to the project office responsible for the design and preparation of plans, specifications, and estimates (PS&E) for this PROJECT. The STATE will provide support services to the CONSULTANT, as described in the text below. The CONSULTANT shall cooperate and coordinate with the STATE's Geotechnical Office, other STATE personnel, and Municipal Agencies as necessary and in accordance with the policy of the STATE Geotechnical Engineer to facilitate the completion of the PROJECT.

State Furnished Services, Information and Items

Throughout the duration of the project the STATE will perform services and furnish information and items as necessary to provide ongoing support for the CONSULTANT and the PS&E preparation process.

The following services will be performed by the STATE:

1. The STATE will handle public information.
2. The STATE will accomplish field survey work as required to complete the project, unless the STATE resources are not available. The CONSULTANT may request any necessary survey work, giving a minimum of 14-calendar-days notice prior to need. The CONSULTANT shall furnish information for the locations and the type of work required.

The following information and items shall be made available by the STATE to the CONSULTANT:

1. The STATE will provide or make available information from its files and answer questions.
2. Existing utility plan sheets.
3. Right of way and access plans.
4. Agreements between the STATE and utilities or any other agency where the agreements affect the project.

Geotechnical Consultant Engineering Services

The CONSULTANT shall provide to the STATE all geotechnical engineering services required by the STATE in order to design and prepare PS&E. The following is an outline of anticipated areas of significant CONSULTANT work:

Project Review and Scoping

The CONSULTANT shall collect and review readily available geotechnical and geologic data for the project including, but not limited to; Geologic maps from the U.S. Geologic Survey, WSDOT construction records, soils and geotechnical reports from WSDOT, Federal, Community, City or County officials, groups or individuals, and geotechnical information within the project limits that may be in the CONSULTANT's files.

Site Review

The CONSULTANT shall perform an on-site geologic reconnaissance of the project. The CONSULTANT shall determine general site conditions, access for exploration, and condition of existing transportation features.

Project Geology

The CONSULTANT shall summarize the regional geology and geology of the project limits. The CONSULTANT shall review the site seismicity and provide recommendations for suitable response spectra and the design acceleration. Geotechnical hazards shall be assessed and the potential impacts to the project shall be discussed. Recommendations for mitigating the hazards shall be provided at the STATE's request. Liquefaction potential shall be assessed and liquefaction mitigation methods shall be provided at the STATE's request.

Field Exploration

The CONSULTANT shall, in consultation and coordination with the STATE, plan and conduct a subsurface investigation program utilizing exploratory borings, test pits, geophysical methods, and insitu tests to provide information relative to soil, groundwater, and other geologic conditions along the project alignment. The CONSULTANT shall develop an exploration plan showing the locations of existing information, the locations for new explorations, the anticipated depths and sampling requirements for the borings, and field instrumentation requirements. Existing subsurface information shall be fully utilized and considered when preparing the field exploration plan. The CONSULTANT shall submit the plan to the region project engineer and the Geotechnical Office for review and approval. Upon approval, the CONSULTANT shall stake all boring locations in the field.

The STATE will provide all traffic control for the field exploration. The CONSULTANT shall obtain utility locates prior to field investigations requiring digging or boring and shall field locate the borings or test pits relative to station, offset, and elevation.

The __________ shall perform the field investigation, and the ________________ shall secure Right of Entry for the field exploration.

If the STATE will perform all subsurface exploration drilling and taking of cores, the CONSULTANT shall provide a Drilling Inspector to obtain samples, and keep records. The STATE will commence drilling or coring operations as soon as practical after approval of the CONSULTANT's drilling plan.

All soil samples from drilling operations will become the property of the CONSULTANT. The CONSULTANT shall retain the samples for a period of 90 days after submittal of the final geotechnical report, at which time the samples may be disposed of unless the STATE requests that they be made available for pick-up at the CONSULTANT's office. All rock cores from drilling operations will become the property of the STATE and shall be delivered to the Geotechnical Office with, or prior to, the final geotechnical report. The CONSULTANT shall provide logs for the borings and test pits. The logs shall be edited based on laboratory or field tests in accordance with WSDOT Soil And Rock Classification Guidelines.

The results of the field exploration and all of the equipment used shall be summarized. Down hole hammers or wire-line operated hammers shall not be used for Standard Penetration Tests (SPT). Boring logs with station, offset, elevation, groundwater elevations, uncorrected SPT test results with blows per 6 inches shall be provided. Soil units encountered in the field exploration shall be described and their extent and limits shall be identified. Soils profiles shall be developed and shown for all structures or significant cut and fill slopes. Plan views shall be prepared that show the actual locations of the borings in relation to project elements.

Testing

The CONSULTANT shall conduct field and laboratory tests in general accordance with appropriate American Society for Testing Materials (ASTM) and WSDOT standards, including Standard Penetration Tests (SPT's), natural moisture content, grain size analysis, Atterberg limits, moisture/density (Proctor) relationships, resilient modulus for use in pavement design, pH, and resistivity and specialized geotechnical tests such as triaxial tests, direct shear tests, point load tests, and soil consolidation. All test results shall be included in the Geotechnical Report.

Instrumentation

The CONSULTANT shall provide the STATE with recommendations for field instrumentation to be installed in the exploratory borings of the project to monitor water levels and slope movements during both design and construction. If necessary, the CONSULTANT shall provide the STATE with recommendations for instrumentation for construction control of the project, e.g., monitoring slope movement, wall movement, pore pressure, settlement, and settlement rates. Included shall be the recommended instrument types, locations, installation requirements, zones of influence, and critical readings or levels. The CONSULTANT shall coordinate with the Geotechnical Office to ensure that recommended instruments are compatible with STATE readout/recording devices. During design, all instruments shall be installed and monitored by the CONSULTANT. The STATE shall monitor all instrumentation during construction or if long term monitoring is required.

Engineering Analysis

The CONSULTANT shall perform necessary geotechnical engineering analysis to identify critical design elements and provide a basis for geotechnical recommendations. Descriptions of the analysis and/or calculations shall be provided at the STATE's request. Comprehensive geotechnical engineering design recommendations shall be provided for preparation of project PS&E documents. The recommendations shall be detailed and complete for use by STATE engineering personnel or other CONSULTANTs in design of structures, cut slopes, fill slopes, embankments, drainage facilities, rock fall control, and landslide correction. As a minimum the CONSULTANT shall address the following:

1. Overall stability for cut slopes, embankments, and structures shall be assessed. For structures, minimum foundation widths, embedments, over-excavation, and ground improvement shall be addressed to satisfy overall stability requirements. Maximum cut and fill slope inclinations shall be recommended. Any mitigating measures needed to obtain the required level of safety for slopes shall be fully developed for the PS&E.

2. For structures, suitable foundation types shall be assessed and alternate foundation types recommended. For spread footings, allowable bearing capacity and settlement shall be provided. For seismic design of spread footings, ultimate bearing capacity and shear modulus values shall be provided for strain levels of 0.2% and 0.02%. For piles and shafts, ultimate capacity figures shall be developed that show the capacity in relation to tip elevation for both compression and tension. Settlement shall be assessed and group reduction factors shall be recommended. Downdrag and lateral squeeze shall be reviewed. Parameters for P-y curve development using L-Pile or COM624 shall be provided. Minimum tip elevations, casing requirements, and estimates of overdrive shall be provided. For piles with maximum driving resistances of 300 tons or more, wave equation analysis shall be performed to assess driveability, pile stress, and hammer requirements.
3. Suitable retaining wall types shall be recommended. For all walls (including standard, preapproved proprietary, and non-preapproved proprietary walls), bearing capacity, settlement, construction considerations, and external stability shall be addressed. For non-standard, non-proprietary walls, internal stability shall be addressed.
4. Earthwork recommendations shall be provided including subgrade preparation, material requirements, compaction criteria, and settlement estimates. In areas where compressible soils are encountered, overexcavation, staged construction, instrumentation, settlement, and creep characteristics and estimates shall be addressed as well as details of any mitigating measures needed to keep embankment performance within project constraints.
5. At stream crossings, evaluation of alternatives and recommendations shall be provided for extending the existing culvert, pipe jacking a new culvert, installing a bottomless culvert, or constructing of a bridge structure. Pipe bedding, subgrade preparation, bearing capacity, and settlement shall be addressed. For pipe jacking, jacking pit construction shall be assessed along with the potential for caving soils.
6. General drainage, groundwater, pH, and resistivity values as they apply to the project.
7. For signals, illumination, and sign structures, allowable lateral bearing capacity shall be evaluated. Where poor soils are present design recommendations for special design foundations shall be prepared. These shall address bearing capacity, lateral capacity, rotational capacity, settlement, and construction of the foundations.
8. Where possible, design recommendations shall be provided in tabular or graphical form.

Construction Considerations

Construction considerations shall be addressed. Temporary slopes and shoring limits shall be identified for estimating purposes. Advisory Special Provisions shall be prepared for elements that may encounter difficult ground conditions or that may require non-typical construction methods. Over-excavation recommendations and backfill requirements shall be discussed and details prepared for the PS&E. Construction staging requirements, where applicable, shall be addressed. Wet weather construction and temporary construction water control shall be discussed.

State Standards

Whenever possible, the CONSULTANT's recommendations shall provide for the use of WSDOT standard material, construction methods, and test procedures as given in the current *Standard Specifications for Road, Bridge, and Municipal Construction*. The CONSULTANT shall follow AASHTO Guide Specifications in design except where STATE design methods are applicable. State design methods are provided in the *Design Manual, Bridge Design Manual, Construction Manual, Hydraulics Manual*, and Standard Plans.

Report

The CONSULTANT shall prepare a Draft Geotechnical Report for the project summarizing the Geotechnical recommendations for the areas of significant CONSULTANT work as discussed under **Geotechnical Consultant Engineering Services** above.

Prior to Draft report submittal, the CONSULTANT shall meet with the Geotechnical Office to discuss the recommendations, assumptions, and design methodology used in preparation of the report. After the meeting, the CONSULTANT shall incorporate or address WSDOT's comments in the Draft Report. The CONSULTANT shall prepare three copies of the Draft Geotechnical Report and submit them to the STATE for review and comment. The STATE will review the Geotechnical Report and provide written comments within three weeks. The CONSULTANT shall respond to comments from the project team and WSDOT, revise the draft report, and submit ten (10) copies of the final geotechnical report. In addition, the CONSULTANT shall provide one unbound, camera ready copy of the report so that the report can be reproduced with the bid documents. Additional Draft reports may be requested by the STATE prior to completing the FINAL report until the STATE's review comments are adequately addressed.

Special Provisions and Plans

Where elements of geotechnical complexity are identified, the CONSULTANT in cooperation and coordination with the STATE shall develop or modify Special Provisions as appropriate to meet the project construction requirements. Wherever possible, the CONSULTANT shall utilize existing STATE specifications. All recommended Special Provisions shall be included in the geotechnical report as an appendix. All details necessary for design and construction of the project elements shall be included in the Geotechnical Report such as earth pressure diagrams, over-excavation details, wall details, and staged construction details. Details developed by the geotechnical engineer shall be provided in electronic form to the STATE or other CONSULTANTs for incorporation into the PS&E.

Instructions for Preparation of the Scope of Work for Project Specific Application
The **Geotechnical Engineering Services Scope of Work** is to be used when the civil engineering portion of the project is well defined before consultant services are requested. The following elements of the project should be well defined or guidelines should be available as to what is acceptable to WSDOT:

1. Right of way
2. Wetland boundaries and limits
3. Roadway alignments and roadway sections
4. Retaining wall locations, profiles, cross sections, and aesthetic requirements
5. Structure preliminary plans

There are fill-ins that need to be completed to designate who will perform the drilling and secure Right of Entry. Region Materials should be contacted to determine availability for drilling prior to completing the fill-in.

The Geotechnical Office should be contacted to provide a cost estimate for the work anticipated. The Geotechnical Office estimate should be used to complete negotiations with the consultant. At the Region's request, the Geotechnical Office can review the consultant's estimate and provided guidance for negotiation.

2.1 Overview

This chapter addresses geotechnical planning for projects that involve significant grading or foundations for structures, from the project definition or conceptual phase through the project design phase to preparation for the PS&E development phase. Final design for the PS&E development will be covered in other chapters of this manual specific to each project element.

The design objectives of the different phases of a project and guidance on the general level of geotechnical investigation for each phase were discussed in Chapter 1. The *Design Manual* M 22-01 Chapter 510 and Chapter 1 provide guidance concerning the roles and responsibilities of the Region Materials Engineer and the Geotechnical Office, as well as information on initiating geotechnical work, scheduling and site data and permits needed for each stage of a project. Geotechnical design for WSDOT projects is generally provided by the Region Materials Engineer and the Geotechnical Office or geotechnical consultants working either on behalf of these groups or as part of a consultant design team.

This chapter includes general guidelines for geotechnical investigations conducted for project definition and design phases (see Sections 1.1.1 and 1.1.2), and preparation of the subsurface exploration plan for the PS&E phase. Specific information on the number and types of explorations for PS&E level design is provided in the chapters for the specific design elements.

To assure success of a project, it is important for the geotechnical designer to become involved in the project at an early stage. The usual process starts with studying the preliminary project plans, gathering existing site data, determining the critical features of the project, and visiting the site, preferably with the project and structural engineer. Good communication throughout the project between the geotechnical designer, the structural designer, and the region project engineer is essential.

2.2 Preliminary Project Planning

2.2.1 Overview

The goal in the initial planning stages is to develop an efficient investigation plan and to identify any potential fatal flaws that could impact design or construction as soon in the project as possible. An effort should be made to maximize the amount of information obtained during each phase of the investigation process and minimize the number of site visits required to obtain information.

For larger projects, it may be beneficial to conduct the field exploration in a phased sequence, consisting of a reconnaissance investigation and a preliminary subsurface investigation during the project definition phase and more detailed exploration conducted during the project design and PS&E development phases. If the subsurface exploration can be conducted in phases, it allows information obtained in the preliminary phase to be used in planning the exploration program for the detailed design phase. This can be cost effective in maximizing the efficiency of the explorations in the subsequent phases. That is, the likely depths of the test borings are known, problem soil layers can be identified and sampled in subsequent phases, and the lab testing program can be planned with greater efficiency.

The location of the site will play a part in the way the investigation is planned. For projects where mobilization costs for drilling equipment are high, the number of subsurface investigation phases should be minimized, even on fairly large projects.

The studies and activities performed during the planning stage should be documented. A list of references should be developed, citing nearby explorations, notes from field visits and conversations with design engineers and construction engineers from nearby projects. Any critical issues that are identified during the planning stages should be documented, such as geohazards that are identified. At a minimum, enough documentation should be maintained so that another engineer picking up the project would not have to go through the same search for information.

2.2.2 Office Review

The geotechnical designer should become completely familiar with the proposed project elements by studying the preliminary plans provided by the region project design office. Location and size of structures, embankments and cuts should be determined. Discuss with the structural designers the amount of flexibility in the location of structures and determine the approximate magnitude of the loads to be transmitted.

Site exploration begins by identifying the major geologic processes that have affected the project site. Soils deposited by a particular geologic process assume characteristic topographic features or landforms that can be readily identified by the geotechnical designer. A landform contains soils with generally similar engineering properties and typically extends irregularly over wide areas of a project alignment. Early identification of landforms is used to optimize the subsurface exploration program.

Many of the soils in the state of Washington fall into geologic provinces with distinct soil types typical of the province. For example much of the Puget Sound lowland has been glaciated, and the soils are typically related to glacial processes. Eastern Washington geology generally consists of basalt flows capped by glacial flood and loess deposits.

The general geology of a project may also give indications of soil conditions that may or may not be encountered in test borings, for instance boulders and large cobbles in glacially deposited or glacial flood deposits, buried trees in debris flow deposits, or relatively fresh rock encountered in residual soils deposits in the coast range.

One of the objects of the office review is to plan site reconnaissance and prepare a conceptual plan for subsurface exploration.

2.2.2.1 Site Geology and Seismicity

Topographic Maps – Topographic maps are generally readily available at a scale of 1:24,000 (7.5 minute) for the all of Washington State. These maps are prepared by the U.S. Geological Survey (USGS). The maps provide information on the overall topography of the site including drainage patterns, slope inclinations, wetlands and general accessibility for field exploration. Used in conjunction with geologic maps and aerial photos, easily recognized geologic features can sometimes be identified. The headscarps and hummocky terrain of landslides can often be identified from topographic maps.

Geologic Maps – The Department of Natural Resources (DNR) Division of Geology and Earth Resource has geologic map coverage of most of the state at 1:100,000 scale. The maps show the distribution of the basic geologic units and provide a brief description of each deposit and rock type including depositional environment and relative age. The maps also include a list of references that may provide more information on a particular area.

The DNR also has published maps showing the extent of geohazards in selected areas of the state. These maps give an indication of the potential problem areas. The maps showing slope stability and liquefiable soils are particularly useful. The DNR has published liquefaction susceptibility maps for several areas in the Puget Sound Region. These maps give a general indication of the extent of liquefiable soils in the region.

Geologic maps are also available from the USGS. Coverage of Washington is not complete, but the maps are readily available from USGS and may be available from the DNR Library. Seismic acceleration maps are also available from the USGS and can be found on their website. The peak ground acceleration map provided in Chapter 6 has been adapted from the USGS maps.

Some local agencies have developed geohazard maps depicting flood plains or areas of steep slopes. These maps are available from the individual cities and counties.

Aerial Photos – Aerial photos along the state route alignments can generally be obtained from the WSDOT Geographic Services Office in Tumwater. Aerial photos can be one of the most useful sources of information for planning the subsurface exploration program. When used with a general understanding of the geology of the site and limited subsurface information, the extent of geologic deposits on the site can often be determined. Using stereo-pairs of photos can greatly enhance the interpretation of landforms.

The identification of a landform as a dune, terrace deposit, alluvial fan, esker, moraine, or other type of deposit often permits the general subsurface conditions to be established within given limits and thus yields the initial appraisal of the situation. Drainage patterns can also aid in the identification of soil type and in the structural characteristics of the underlying rock. The maximum amount of information will be obtained when aerial photos are used in conjunction with field investigations that can verify and correct interpretations.

Landslides are often recognizable in aerial photos by slide formed features or conditions, including hillside scars; disturbed or disrupted soil and vegetation patterns; distinctive changes in slope or drainage patterns; irregular, hummucky surfaces; small undrained depressions; step-like terraces; and steep hillside scarps.

Although one of the more difficult features to evaluate, vegetation is often indicative of subsurface conditions. The relationship between vegetation soil type, moisture content, topography and other pertinent factors may be important and any variations should be checked in the field.

Aerial photos may be available in both black and white or in color. Color photographs are generally preferred because objects are easier to identify when they appear in their natural color. Fine details and small objects can be identified more positively than on black and white photographs at the same scale and the cause of tonal variations is more readily established.

Aerial photos from different years can give an indication of the history and previous use of the site. A complete set of air photos from the oldest available to the most recent can give an indication of the previous site use, as well as significant changes in topography or landforms due to the more rapid geologic processes such as stream channel migration, beach erosion, landslides, or rockfall.

Remote Sensing – Satellite imagery such as Landsat can often be used for regional interpretations of geologic features and drainage patterns. The AASHTO Manual on Subsurface Investigations (1988) provides a more detailed discussion on the types and availability of satellite imagery. LiDAR (Light Detection And Ranging) mapping uses a laser to measure distances to specific points and is capable of rapidly generating digital elevation data similar to that obtained by traditional photogrammetry techniques. The equipment can be mounted in a small plane or helicopter and can produce accurate digital topographic maps of the terrain beneath the path of the aircraft. One of the advantages of LiDAR is that vegetation can be removed from the database to reveal a “bare earth” model. Landforms that are typically obscured by western Washington’s heavy vegetation are often apparent on the “bare earth” view. Similar technology using land based equipment is also becoming available. These techniques are being more widely used for mapping river morphology and flood plains, and geologic hazard such as landslides and may be available from local agencies

Soil Surveys – Agricultural soil surveys in the United States have been conducted by the Department of Agriculture (USDA) in conjunction with state agencies since the early 1900’s. The results of the surveys are presented in the form of reports and maps which commonly cover a complete county. The reports, in general, contain a description of the aerial extent, physiography, relief, drainage patterns, climate, and vegetation, as well as the soil deposits of the area covered. The maps show the extent and derivation of the various deposits. The surveys give some information on the slope inclination and erosion hazards that may be common. The reports also provide engineering classifications of the near surface soil and sometimes information on the suitability of the soils for various construction uses as well as an indication of the general drainage characteristics.

The surveys are regional in aspect and only provide information on the top several feet of soil. They should not be used for more than providing some preliminary soil information.

Other Sources – WSDOT's unstable slope data base should be reviewed for any historic problems with slope instability or rock fall problems.

Hydrogeologic surveys can provide regional information on the presence and depth of groundwater. Both the DNR and USGS have completed hydrogeologic surveys in parts of Washington.

Scientific articles and reports on geology in Washington may also be available, through the DNR and university libraries.

2.2.2.2 Previous Site Exploration Data

Most highway transportation projects are on or near existing alignments, and previous subsurface information might be available. For WSDOT projects the Geotechnical Office maintains files at the Materials Lab in Tumwater. Files are generally available for existing bridges, retaining walls, or significant cuts and embankments. Materials reports and source reports that were prepared for alignment studies might also be available either from the Geotechnical Office or the Region Materials Engineer.

Water well records are available from the Department of Ecology. Many logs can be obtained from their website. The soil descriptions are generally not very reliable; however, information on groundwater levels and presence of bedrock can be obtained from them.

The City of Seattle has developed an existing boring database in conjunction with the University of Washington. The database includes borings completed for local agency projects as well as data provided by consultants. The database is available on-line and includes a map showing exploration locations along with PDF images of the boring logs.

2.2.2.3 Previous Site Use

Environmental Impact Statements (EIS) will probably have been completed and will indicate the most recent land use of the area. Note that a review of land use records or reports that describe previous site uses, especially those that could identify the potential for hazardous waste will be contained in a separate report produced by the Environmental Affairs Office (EAO) or their consultant.

Note that identification of potential hazardous subsurface materials could affect the subsurface investigation approach for the geotechnical design. This issue may need to be considered, therefore, in the planning for the geotechnical subsurface investigation. The geotechnical investigation approach will also need to be adjusted during the subsurface investigation if potentially hazardous materials are retrieved during the subsurface investigation, both for crew safety purposes and to comply with environmental regulations.

If, during the office review or during subsequent subsurface investigation potentially hazardous materials are discovered, the EAO should be notified. The EAO will investigate the potential for hazardous waste, defining its nature and extent, and how to address it for the project.

Other site uses may also affect the site investigation approach and possibly the timing of the investigation. Especially important is whether or not the site is historically or archeologically significant, and whether or not there is potential for artifacts to be discovered at the site. The investigation for this type of previous site use should be conducted prior to beginning the geotechnical site investigation. In general, the region project office is responsible for making sure that this investigation is carried out.

While the geotechnical designer is not responsible to specifically carry out a detailed investigation regarding the potential to encounter hazardous subsurface materials or archeological artifacts, the geotechnical designer is responsible to know whether or not such investigations have taken place, to communicate this information to the Field Exploration Manager (FEM), and to adjust the geotechnical site exploration program accordingly.

2.2.2.4 Construction Records

Many WSDOT projects consist of improvement or replacement of existing alignments or facilities. Construction records and existing geotechnical or materials reports are often available from WSDOT files. Headquarters Final Records has the most complete collection of construction records.

Generally the Region Materials Engineer will be the primary contact to obtain any construction records from the Region Project offices. The Geotechnical Office also has some construction records. All three offices should be contacted for available construction records.

Consultation with WSDOT project engineers who may have completed work on similar structures in the same general area should be utilized to gain general information on the soil, foundation, and groundwater conditions. Previous experience may also reveal acceptable foundation conditions for the problems at hand.

Many of the county and city agencies also maintain records of investigations and construction, and these are generally available through each agency.

2.2.3 Site Reconnaissance

2.2.3.1 General

Before the site reconnaissance is performed, the geotechnical designer should have performed the office review as described in Section 2.2.2, as well as given some thought to the field exploration plan. The review of available data should be done prior to the field reconnaissance to establish what to look for at the site. The field reconnaissance should also be done with the preliminary plans in hand. Cross sections rovided with the preliminary plans should be field checked. The cross sections are often generated by photogrammetry and may not accurately represent the existing ground surface. If available, the project design engineer, structural engineer and field exploration supervisor should also participate in the site visit.

Note the location, type and depth of any existing structures or abandoned foundations that may infringe on the new structure. Inspect any nearby structures to determine their performance. If settlement or lateral movement is suspected, obtain the original structure plans and arrange to have the structure surveyed using the original benchmark, if possible.

For water crossings, inspect structure footings and the stream banks up and down stream for evidence of scour. Riprap present around the bridge foundation may indicate a past scour problem, could impact the location of test borings and will need to be dealt with during construction. Take note of the streambed material. Often large cobbles and boulders are exposed in the stream bed, but not encountered in the borings or noted on the boring logs. The boulders are an indication of unexpected subsurface obstructions to deep foundation installation.

Relate site conditions to proposed boring locations. Check access for exploration equipment and make an initial determination of what type of equipment might be best suited to the site conditions. If site preparation is necessary, note the type of equipment, such as a bulldozer, that may be needed for drilling equipment access. Note potential problems with utilities such as overhead and underground power, site access, private property or other obstructions. While utility clearances will need to be obtained before the subsurface exploration begins, the locations will influence where explorations can be located. Note any water sources that could be used during drilling. Also note traffic control needs to accomplish the field exploration program, considering the practical aspects of the proposed drilling plan with regard to impact to the public. If borings are to be located in a stream bed, the reconnaissance should note the size of the barge best suited for the job, details of anchoring, depth of water, locations for launching the barge, etc. Notes should be made as to which type of drilling is best suited to the site. Also note potential problems with borings such as shallow groundwater table, loose or heaving sands, cobbles and boulders, etc. Availability of water, if coring or mud rotary methods are anticipated, should be determined. Special sampling equipment needed, such as undisturbed sampling equipment, should be noted. This evaluation of field investigation logistics should be done with the assistance of the geotechnical field exploration manager or supervisors to take advantage of their expertise in working with geotechnical exploration equipment and in conducting a geotechnical field investigation (see Section 3.2).

Right of Entry on WSDOT projects is generally obtained through the project office. However, note proximity of residences and buildings for possible difficulties due to noise and other disturbances during the subsurface exploration. Local residents can often provide some information on the history of the site.

Compare the topography of the site with that shown on maps and try to confirm the assumptions made during the office review concerning the site geology. Observe and note natural occurring exposures such as river banks, natural escarpments, quarries, highway or railway cuts and rock outcrops. Measure the inclination of any existing steep slopes. Note and describe the type and amount of fill that has been placed on the site.

Note the extent of any existing unstable slopes or erosion features. For unstable slopes or landslides note the length and width of the area affected. Note any other indications of instability such as pistol butting of trees, hummocky terrain or springs. Note types of vegetation present. Full investigation of these issues will require review of the site conditions well above and below the facility alignment, and may extend on to private property. Right of entry may be needed in such cases to complete the site reconnaissance. If steep slopes must be accessed to fully investigate the site, safety issues will need to be addressed before attempting to access the area, or alternative means of getting into the position to make the necessary observations should be considered (e.g., a man-lift, or use of a helicopter).

Note the presence of any wetland or other surface water.

Hand holes or probes may be useful to obtain information on depth of soft soils.

Photographs are valuable records of the site visit and should be labeled with the approximate stationing, direction of view, date, and a brief title. Photos should be obtained of all the site features listed above and of the probable exploration locations.

A record of the field visit should be kept and included in the project file. Measures should be taken to permanently archive any photographs taken. The record should list and describe significant site features as discussed above along with approximate stationing. An example field reconnaissance report form is included in the FHWA Soil and Foundations Workshop Manual (Samtani and Nowatzki, 2006).

Special site reconnaissance requirements for investigation of rock slopes are provided, by reference, in Chapter 12.

2.3 Development of the Subsurface Exploration Plan

2.3.1 General Considerations for Preparation of the Exploration Plan

If the site reconnaissance is performed as part of a project definition phase investigation, the results will be used to develop the project definition conceptual level geotechnical report in accordance with Chapter 23. Otherwise, the site reconnaissance and office review results are used to develop the project design and/or PS&E phase field investigation.

A description of the site data needed for each type of project is provided in the Design Manual Chapters 510 and 1130. The sections that follow expand on the considerations required for the preparation of the subsurface exploration plan. Development of exploration plans for geotechnical baseline reports is covered in Chapter 22.

2.3.2 Criteria for Development

The goal of the geotechnical investigation program is to obtain the engineering properties of the soil or rock and to define the aerial extent, depth, and thickness of each identifiable soil/rock stratum, within a depth that could affect the design of the structure, fill, cut, landslide, or other project element, dependent on the size and nature of the element. Typical properties and conditions to be evaluated include permeability, compressibility, shear strength, the location of groundwater and the presence and magnitude of artesian pressures, if present. Regarding the determination of properties for design, the focus of the exploration and testing program should be on the geologic unit/stratum, and the number of measurements of each critical design property in each unit/stratum to have a reasonable degree of confidence in the property measured (see Chapter 5). The geotechnical investigation at the PS&E level should be adequate to fully define the subsurface conditions for design and construction purposes, and shall be consistent with the national standards of practice identified in this manual and as specifically augmented in this manual, subject to adjustment based on the variability of the site conditions and the potential impact of site condition variability as determined based on the judgment of an experienced geotechnical engineer or engineering geologist.

The type, location, size and depth of the explorations and testing are dependent upon the nature and size of the project and on the degree of complexity and critical nature of the subsurface conditions. In general, it is justifiable to spend additional money on explorations and related testing and engineering beyond the standards as identified in this manual as long as sufficient savings can be realized in the project construction costs. Consideration should be given to the small cost of a boring in relation to the foundation cost. A test boring will typically cost less than one driven pile. Yet the knowledge gained from the boring may permit a more efficient design that may allow elimination of one or more piles for that structure.

Consideration should be given to how sensitive the structure or embankment is to variations in subsurface conditions when planning the geotechnical investigation. Embankments can generally tolerate several inches of settlement while a structure may be limited to less than one inch. Embankment loads are spread over a wide area while structure loads are concentrated.

Some consideration should be given to the amount of risk that unknown soil conditions could bring to the project (e.g., what is the risk to the constructability and functioning of the facility if detailed subsurface information at a specific location is not obtained?). There are times when soil conditions may be understood fairly well for the geotechnical design, but that unknown soil conditions could affect the cost of the project. Generally if rock is encountered at the foundation grade in a boring at a pier location, the location and quality of the rock should be explored at the other side of the pier. If rock may fall off towards the river, make sure the borings explore the rock contact on the front side of the footing.

Specific requirements for boring spacing, depth, and sampling frequency are provided in Chapter 8 for foundations and hydraulic structures, Chapter 9 for embankments, Chapter 10 for cuts, Chapter 15 for walls, Chapter 17 for noise walls, signal and sign foundations, culverts, and buildings, and by reference to other documents/ manuals in Chapters 11, 12, 13, and 19 for ground improvement, rock cuts, landslides and infiltration facilities, respectively. While engineering judgment will need to be applied by a licensed and experienced geotechnical professional to adapt the exploration program to the foundation types and depths needed and to the variability in the subsurface conditions observed, the intent of specific requirements provided in the chapters identified above regarding the minimum level of exploration needed should be carried out.

The specific exploration requirements identified in the chapters identified above should be used only as a first step in estimating the number of borings for a particular design, as actual boring spacings will depend upon the project type and geologic environment. In areas underlain by heterogeneous soil deposits and/or rock formations, it will probably be necessary to drill more frequently and/or deeper than the minimum guidelines provided in these chapters to capture variations in soil and/or rock type and to assess consistency across the site area. Even the best and most detailed subsurface exploration programs may not identify every important subsurface problem condition if conditions are highly variable. The goal of the subsurface exploration program, however, is to reduce the risk of such problems to an acceptable minimum.

In a laterally homogeneous area, drilling or advancing a large number of borings may be redundant, since each sample tested would exhibit similar engineering properties. Furthermore, in areas where soil or rock conditions are known to be very favorable to the construction and performance of the foundation type likely to be used (e.g., footings on very dense soil, and groundwater is deep enough to not be a factor), obtaining fewer borings than specified in the chapters identified above may be justified.

Test borings are typically the primary means used to obtain the needed subsurface information and samples for laboratory testing. However, other means of obtaining subsurface data should be considered to provide a more complete picture of the subsurface conditions and to help reduce exploration costs.

Cone probes can be a rapid and cost effective means to reduce the number of conventional borings, yet provide additional data that cannot be obtained from conventional test hole drilling and sampling. Cone data can be especially effective in defining the finer stratigraphy of geologic units, to obtain pore pressure measurements and in-situ permeability and shear wave velocities, as well as obtain data that can be directly correlated to a variety of soil properties. However, the cone is not very useful in dense to very dense soils or soils with larger gravels and cobbles (due to inability to penetrate such soils). The cone can be especially useful in comparison to conventional borings when heaving sands are present. If cone probes are used to supplement a subsurface exploration program, some conventional test hole data are necessary to correlate readings from the probe to physical samples of the soil (since the cone is not capable of retrieving physical soil samples, as well as to obtain soil samples for laboratory measurement of soil properties.

Similarly, in-situ testing devices such as the pressuremeter and vane shear can be conducted to supplement conventional test hole drilling to obtain specific in-situ properties. For example, the pressuremeter is useful for obtaining in-situ soil stiffness properties that can be used to more accurately assess settlement or lateral load response of foundations. Shear vane testing can be useful to obtain in-situ undrained shear strength of soft cohesive soils. See FHWA Geotechnical Engineering Circular 5 (Sabatini, et al., 2002) for additional information on these types of in-situ tests and their use.

Geophysical techniques should also be considered to fill in the gaps between test holes and to potentially reduce the cost of the geotechnical subsurface investigation. Geophysical techniques are especially useful for defining geologic stratigraphy, and can be useful to identify buried erosion channels, detailed rock surface location, overall rock quality, buried obstructions or cavities, etc., as well as to define certain properties.

Geophysical testing should be used in combination with information from direct methods of exploration, such as SPT, CPT, etc. to establish stratification of the subsurface materials, the profile of the top of bedrock and bedrock quality, depth to groundwater, limits of types of soil deposits, the presence of voids, anomalous deposits, buried pipes, and depths of existing foundations. Geophysical tests shall be selected and conducted in accordance with available ASTM standards. For those cases where ASTM standards are not available, other widely accepted detailed guidelines, such as Sabatini, et al. (2002), AASHTO Manual on Subsurface

Investigations (1988), Arman, et al. (1997) and Campanella (1994), and Sirles (2006) should be used.

Geophysical testing offers some notable advantages and some disadvantages that should be considered before the technique is recommended for a specific application. The advantages are summarized as follows:

- Many geophysical tests are noninvasive and thus, offer, significant benefits in cases where conventional drilling, testing and sampling are difficult (e.g. deposits of gravel, talus deposits) or where potentially contaminated subsurface soils may occur.
- In general, geophysical testing covers a relatively large area, thus providing the opportunity to generally characterize large areas in order to optimize the locations and types of in-situ testing and sampling. Geophysical methods are particularly well suited to projects that have large longitudinal extent compared to lateral extent (such as for new highway construction).
- Geophysical measurement assesses the characteristics of soil and rock at very small strains, typically on the order of 0.001%, thus providing information on truly elastic properties, which are used to evaluate service limit states.
- For the purpose of obtaining subsurface information, geophysical methods are relatively inexpensive when considering cost relative to the large areas over which information can be obtained.

Some of the disadvantages of geophysical methods include:

- Most methods work best for situations in which there is a large difference in stiffness or conductivity between adjacent subsurface units.
- It is difficult to develop good stratigraphic profiling if the general stratigraphy consists of hard material over soft material or resistive material over conductive material.
- Results are generally interpreted qualitatively and, therefore, only an experienced engineer or geologist familiar with the particular testing method can obtain useful results.
- Specialized equipment is required (compared to more conventional subsurface exploration tools).
- Since evaluation is performed at very low strains (or no strain at all), information regarding ultimate strength for evaluation of strength limit states is only obtained by correlation.

There are a number of different geophysical in-situ tests that can be used for stratigraphic information and determination of engineering properties. These methods can be combined with each other and/or combined with the in-situ tests presented in Section 5.4 to provide additional resolution and accuracy. ASTM D 6429, "Standard Guide for Selecting Surface Geophysical Methods" provides additional guidance on selection of suitable methods.

Sampling requirements will depend on the type of soil or rock encountered and the nature of the project element to be designed and the properties necessary for the geotechnical design of that project element. Properties needed for design, and how those properties can best be obtained, should be identified as part of the geotechnical investigation planning process. For example, if soft to stiff cohesive soils are present, an adequate number of undisturbed samples will need to be obtained to perform the laboratory shear strength and consolidation testing to define the shear strength and compressibility properties needed for design, considering the potential variability of these properties in each geologic unit, as well as to account for problem samples that are discovered to not be usable for testing. The degree of sample disturbance acceptable should also be considered, as well as the ability of the specific sampling technique to retain the high quality undisturbed soils needed (see Chapter 3 regarding sampling techniques). The disturbed sampling technique selected to obtain representative samples for classification and characterization will depend on the size of the bigger particles anticipated. For example, SPT sampling is generally not suitable for soils that contain a large percentage of medium to coarse gravel – in such cases, a Becker hammer sampler may be more appropriate. If the gravelly soils of interest are close enough to the surface, it may be possible to obtain more representative bag samples through test pit techniques. For large projects where shaft foundations are anticipated, and if permits and access can be obtained far enough in advance of when the final design is due, larger diameter augers could be used to install test shafts to evaluate the soils and evaluate shaft constructability. If detailed stratigraphy is needed, for example, to identify potential unstable zones or surfaces, Shelby tube samples or triple tube coring techniques can be used to get a continuous soil or rock sample for visual assessment.

Field instrumentation planning is also crucial to the development of a complete field exploration program. Ground water measurement in terms of its location, pieziometric head, extent across the site, gradient, and connection to surface water features is typically important for most geotechnical designs, and its measurement should always be a part of any geotechnical investigation planning effort. Elimination of ground water measurement from the geotechnical investigation plan must be justified by strong evidence that there is no groundwater present within the depths of interest, or that the presence of ground water will have no effect on the geotechnical design of the project element or its construction. Note that measurement of ground water in the drilled hole at the time of drilling is generally not considered to be adequate for ground water measurement. In granular soil with medium to high permeability, reliable groundwater levels can sometimes be obtained in the drilled hole. At a minimum, groundwater levels should be obtained at completion of drilling after the water level has stabilized and 12 hours after drilling is completed. However, since the presence of drilling fluids and the time required for ground water levels to reach equilibrium after drilling can be significant, measurements of ground water at time of drilling can be misleading. It is generally necessary to install some type of piezometer to make such measurements. The extent of the ground water measurement program shall be capable of evaluating both design and constructability needs (note that this does not mean that the piezometers need to be available for use during construction of the project element, but only means that constructability issues can be assessed). Seasonal or tidal variations in the ground water levels should also be assessed to the extent feasible given the project design schedule. Continuous monitoring of groundwater can be achieved by using electrical piezometers such as vibrating wire type in conjunction with digital data loggers. Additional information on ground water monitoring as part of the field investigation is provided in Mayne, et al. (2002).

Other field instrumentation may be needed as part of a geotechnical investigation for certain situations. For example, where instability is anticipated, inclinometers placed at strategic locations to define the potential failure surface should be installed. The inclinometer should be installed deep enough to be firmly fixed in stable soil. For forensic analysis of existing structures, tilt meters and/or extensometers can be useful for determining the direction and location of structure movement. Setting up survey control of key points on the structure as part of the geotechnical investigation can also be of use in some cases.

2.3.3 Preparing the Exploration Plan

It is important to be confident of the accuracy of the site data provided by the office requesting the geotechnical services, and to clearly understand the scope of services being requested. The office requesting the geotechnical services should also clearly understand what affect approximations in the site data could have on the geotechnical design, and the need to go back later and redo some of the geotechnical work if the impact of such approximations on the geotechnical design is significant. Any geotechnical concerns that are likely to develop, or the need for contingencies, should also be communicated at this time. Communication between the geotechnical designer and the project office is essential throughout the geotechnical investigation. The geotechnical designer is defined as the geotechnical engineer or engineering geologist who has been given responsibility to coordinate and complete the geotechnical design activities for the project. Early communication of potential complications due to geotechnical concerns will result in more cost effective and constructible designs. Any impact to project schedule resulting from the geotechnical investigation as it progresses should also be communicated to the project office promptly. It is the geotechnical designer's responsibility to make sure that this communication takes place.

Once the geotechnical investigation plan has been developed and approved (see Chapter 1), a proposed budget for field exploration, laboratory testing and engineering should be developed and provided to the project office. The basis of this budget, including a description of the scope of work as the geotechnical designer understands it, the date and source of the site data upon which the geotechnical investigation plan was based, and the potential for changes to the plan that could occur once some of the geotechnical subsurface data becomes available must be clearly documented in the letter transmitting the geotechnical project budget.

The proposed locations of the borings should have been checked for accessibility during the site reconnaissance (normally, the drilling supervisor will check for this). It may be necessary to shift the locations of some explorations due to local conditions, such as utilities, encountering obstacles such as boulders during drilling, or changes in engineering plans. The revised locations of these holes should be carefully plotted on the layout by the drill inspector, and the reason for the shift should be noted on the field log. Some tolerance in location of the explorations should be expected and communicated to the drill crew. The amount of tolerance will depend on the topography at the site, the expected soil conditions, stage of exploration, and type of structure. For example, for explorations made during the project definition phase or for cut slope design, exact locations might not be critical. On the other hand, if the test boring is being made to define the rock contact beneath a spread footing, moving the boring 10 feet might be too much. If the location of the exploration is critical, it may be justified to mobilize a different type of drill rig. Costs incurred during construction because of differing site conditions are generally much greater than the cost of an additional mobilization.

Communication between the geotechnical designer and the drilling inspector during the field exploration is also crucial. The drilling inspector should be briefed as to what subsurface conditions to expect and should contact the geotechnical designer if any significant changes are encountered. It may be necessary to adjust the sampling intervals of depth of explorations or add explorations, if the subsurface conditions are different than expected. If it becomes apparent that such changes that will significantly impact the project budget or schedule, it is important to immediately contact the project office to discuss the situation with them, and come to an agreement on the best course of action, but without impacting the progress of the field crews in accomplishing the work.

The information needed on the drilling request form should be as complete as possible to make efficient use of the exploration crew's time. They need to know how to get to the site, where to drill, what equipment to take, and what difficulties to expect. The drill crew's time should be spent in drilling and sampling and not in sending back for more equipment.

A copy of the WSDOT Field Exploration Request Form is attached in Appendix 2-A. Other examples are available in the National Highway Institute (NHI) Course manuals.

Below is a partial list of information to be included on the field exploration request by the geotechnical designer. Other information should be included as appropriate.

Field Exploration Check List:

- Type of explorations required.
- Sequence of drilling to allow for adjustment in the plan. For example, explorations in areas where soil conditions are unknown or problem soils are expected to be present should be performed in the first stages of the program, to allow for adjustment in sampling intervals or additional explorations to be added.
- Expected soil conditions. Attach field logs from nearby explorations, if available.
- Sampling intervals and types of samples to be obtained.
- Instrumentation and procedures for installation.
- Criteria for ending borings - depth, refusal, thickness of bearing layer, etc. If at all possible, the depth of all explorations should be estimated prior to doing the fieldwork. However, that is not always practical in situations where no previous subsurface information is available and some criteria should be stated on the exploration plan. A criteria recommended for typical use is to have a minimum of 30 feet of material with blow counts of 30 blows per foot or greater, or a minimum of 10 feet into bedrock, and for deep foundations, the boring depth should be at least as deep as the estimated foundation depth plus 20 feet. Note that without communication between the geotechnical designer and drilling inspector, these criteria can sometimes result in borings that are drilled deeper than necessary.
- Coordination of drilling inspector and geotechnical designer regarding when and at what stages of the field exploration communication should take place.

The field exploration supervisor is responsible to obtain the following information, either through field review of the investigation plan, or with the help of the appropriate Region offices:

- Equipment required and access needs
- Known permits required and regulations
- Known utilities
- Special traffic control requirements
- Cost of field exploration services.

Coordination between the field exploration supervisor and the geotechnical designer is necessary to implement the field investigation program, to make sure that there are no logistical problems with the plan implementation.

2.4 Development of the Laboratory Testing Plan

The laboratory testing plan shall be developed in accordance with Section 5.6.2. The laboratory testing plan includes classification and index testing, and soil/rock property tests that can be used directly to assess design parameters. The development of the testing plan shall address the properties needed for geotechnical design, and shall consider the in-situ (field) test data available such that the results from both field and laboratory testing can complement one another to provide a consistent and complete assessment of the properties of the soil and rock strata encountered.

For soil classification/index testing, the plan shall consider the following:

- Enough samples shall be selected in each soil stratum to assess the consistency of each soil stratum,
- When samples are available from more than one test hole for a given soil stratum, samples from more than one test hole should be tested to verify spatial consistency of the soil properties,
- For soil samples with a significant fines content, Atterberg limits tests should at least be attempted to determine the plasticity of the fines.

For performance level laboratory tests, the plan shall consider the following:

- Availability of samples suitable for testing – note that the field exploration plan should address the laboratory sample needs,
- The number of performance tests for each property required for the geotechnical design needed to assess the potential variability in the property within a given geologic stratum, though it is recognized that it will generally not be possible to obtain enough test results to develop meaningful statistics for the property,
- The laboratory testing should be conducted in a way that best represents the in-situ conditions from which the tested samples were taken, and the stresses and moisture conditions to which the soil/rock being characterized through the tests will be subjected based on the geotechnical design anticipated,
- Minimization of sample disturbance, when testing is conducted on undisturbed samples,
- Classification/index testing to be conducted on the samples subjected to performance level tests.

The laboratory testing plan shall identify the following information and testing requirements:

- All tests shall be clearly identified as to the location within the borings from which samples to be tested will be taken.
- The specific test procedures to be used shall be identified, including any special sample preparation requirements and specific testing parameters, such as stress levels. If the test procedures have options, the specific options to be used shall be specified.
- The classification/index tests to be conducted on each sample subjected to performance level testing.

2.5 References

Arman, A., Samtani, N., Castelli, R., Munfakh, G., 1997, *Subsurface Investigations: Training Course in Geotechnical and Foundation Engineering*. Report No. FHWA-HI-97-021. Federal Highway Administration, U.S. Department of Transportation.

Campanella, R.G. 1994. "Field Methods for Dynamic Geotechnical Testing: An Overview of Capabilities and Needs." *Dynamic Geotechnical Testing II, Special Technical Publication No. 1213*, ASTM, Philadelphia, PA, pp. 3-23.

Mayne, P. W., Christopher, B.R., and DeJong, J., 2002, *Subsurface Investigations – Geotechnical Site Characterization*, Publication No. FHWA NHI-01-031, National Highway Institute, Federal Highway Administration, Washington, DC, 300 pp.

Sabatini, P.J, Bachus, R.C, Mayne, P.W., Schneider, J.A., Zettler, T.E. (2002), Geotechnical Engineering Circular 5 (GEC5) - Evaluation of Soil and Rock Properties. Report No FHWA-IF-02-034. Federal Highway Administration, U.S. Department of Transportation.

Samtani, N. C., and Nowatzki, E. A., 2006. Soils and Foundations Workshop Reference Manual, Volumes 1 and 2. Washington, DC, National Highway Institute Publication NHI-06-088 and NHI-06-089, Federal Highway Administration, 1056 pp.

Sirles, P. C., 2006. *Use of Geophysics for Transportation Projects – A Synthesis of Highway Practice*, NCHRP Synthesis 357, Transportation Research Board, Washington, DC, 108 pp.

FIELD EXPLORATION REQUEST

DATE: **REVIEWED BY:** ____________________

REGION: **SR:** ________ **C.S.:** ________ **JOB No.:** ____________

PROJECT NAME:

PROJ. CONTACT: ____________________________ **PHONE:** ____________________

PROJECT TYPE:

☐ CENTERLINE ☐ STRUCTURE ☐ LANDSLIDE ☐ PIT/QUARRY

NUMBER OF TEST BORINGS: ____

ESTIMATED DRILL FOOTAGE: ____

TYPE OF TEST HOLE:

☐ STANDARD TEST HOLE
☐ CPT
☐ STANDARD TEST HOLE AND CPT
☐ OTHER ____

INSITU TESTING:	FREQUENCY OF TESTING:
☐ VANE SHEAR	________________________________
☐ CPT PORE PRESSURE DISAPATION	________________________________
☐ CPT SEISMIC VELOCITY	________________________________
☐ OTHER	________________________________

INSTRUMENTATION:

☐ OPEN STANDPIPE PIEZO ☐ PNEUMATIC PIEZO
☐ SLOPE INCLINOMETER ☐ OTHER ______________________________

SAMPLING FREQUENCY:

☐ STANDARD SPT AT 5 FOOT INTERVALS
☐ WSDOT UNDISTURBED SAMPLES
☐ SHELBY TUBE UNDISTURBED SAMPLES
☐ LONGYEAR UNDISTURBED SAMPLES
☐ PISTON SAMPLER UNDISTURBED SAMPLES
☐ CONTINUOUS SAMPLING
☐ OTHER ____

Special Instructions

Chapter 3 Field Investigation

3-1 Overview

This chapter addresses subsurface exploration activities performed as part of a geotechnical investigation. Subsurface explorations may include:

- Performing geotechnical soil borings
- Excavating test pits
- Performing field testing (e.g., Standard Penetration Testing (SPT), cone penetration tests, downhole seismic testing, etc.)
- Installing standpipe piezometers (i.e. observation wells) or vibrating wire piezometers
- Other geotechnical instrumentation such as slope inclinometers.

This chapter is organized by activities and policies involved prior to, during, and after exploration. Also addressed, through appendices included with this chapter, are best management practices (BMPs) for erosion and spill prevention during geotechnical field investigations, as well as other potential impacts to the natural environment in the vicinity of the geotechnical investigation site (Appendices 3-C and 3-D), and the handling, and disposing of, contaminated and potentially contaminated materials/samples obtained during the geotechnical field investigation (Appendices 3-E and 3-F). Appendix 3-G provides a listing of the information required to track wells as defined in RCW 18.104.020 and WAC 173-160-111 and which is included in the WSDOT database of well installations. This is information that shall be submitted to WSDOT for any "well" installed on WSDOT property or in connection with WSDOT Projects, regardless of who installs it.

3-2 Activities and Policies – Before Exploration

3-2.1 Field Exploration Plan Development and Permissions

A geotechnical field exploration plan should be formulated as described in Chapter 2. The Geotechnical Project Manager (GPM) assigned to the project is responsible to coordinate with the Region or Washington State Ferries (WSF) Project Office (PO) to prepare the way for the field exploration crews to implement the field exploration program. The GPM also functions as the primary liaison between the Region, Megaprograms, or WSF and the Field Exploration Manager (FEM), to keep the FEM informed as the Region or WSF completes the necessary preparations to begin implementation of the field exploration plan.

Specifically, the GPM should do the following before submitting the final field exploration request to the FEM:

1. Make sure senior Geotechnical Office management agrees with the proposed exploration plan (see Section 1-4).
2. Make sure that the Project Office has provided adequate site data to locate test holes and key project features on paper and in the field.

3. Make sure that the project office has asked for (preferably obtained) an environmental assessment of the site to determine whether or not there is potential to encounter hazardous subsurface materials. The GPM is responsible to have a basic knowledge of previous site use as well.
4. Make sure that the project office has asked for (preferably obtained) an archeological assessment of the site to determine if there is potential to encounter Native American or other artifacts.
5. Coordinate with the project office to make sure any right-of-entry's needed are obtained for the proposed drilling.
6. Coordinate with the project office to make sure the necessary permits are obtained (especially with regard to wetlands and other environmentally sensitive areas).
7. Coordinate with the Field Exploration Supervisor (FES) who will be assigned to the project, and the project office, to conduct a joint field review to evaluate access and other issues related to setting up and finalizing the field exploration program.
8. Act as the liaison between the Field Exploration Manager (FEM) and the project office to make sure the FEM knows when all the tasks have been completed and to inform the FEM of the results so that the exploration program can be properly estimated.

To obtain permits and right-of-entry, a preliminary field exploration plan will likely be needed by the Region (or WSF) before the final exploration plan is completed and turned in. Therefore, the development of the field exploration plan may require a somewhat iterative process. Once enough field exploration plan details have been developed, the GPM should request that those who will be directly negotiating with local owners to obtain right-of entry (if needed) invite the FEM or FES to assist in those negotiations. This generally makes the negotiations go much smoother.

If the GPM recognizes, either through an environmental assessment or through general knowledge of the previous site use, that there is a potential to encounter hazardous materials during the geotechnical field exploration, it is important that the GPM make the FEM aware of this as soon as possible in the development of the exploration plan. This will enable the FEM to be prepared to meet the requirements as specified in Appendices 3-C and 3-D, as well as to initiate procedures provided in Appendices 3-E and 3-F. The potential to encounter hazardous subsurface materials can completely change the approach, cost, and scheduling for the site exploration activities.

A preliminary field exploration plan is also needed for use as the basis for conducting the joint field review mentioned above. This field review should be used to determine how each individual exploration site will be accessed, the type of drill equipment best suited for the site, areas for utility locates, required traffic control, and to identify any permit, right-of-entry, and environmental issues. Adjustments to the specific locations of exploration points can be made as needed during the field review to address the above issues.

During the field review, the FES will stake the borings if they have not already been located and if right-of-entry (if needed) has been obtained. The FES should also assess the traffic control needs for the exploration work at this time. The FES will coordinate directly with the Maintenance Office for traffic control. After staking borings, the FES is responsible for calling all utility locates a minimum of 48 hours prior to the start of explorations.

The final field exploration plan shall be developed as described in Chapter 2. The plan should include provisions and costs to decommission installed wells. Once the final field exploration plan has been completed, the FEM will provide a cost estimate to the GPM to complete the field exploration plan. Once the expenditure for the field exploration has been authorized, the GPM must then notify the FEM to commence with the field exploration. Once the exploration plan has been executed, any subsequent requests to modify the plan should be provided in writing by the GPM to the FES. The FES will respond with an updated estimate and schedule for requested plan change.

If the geotechnical design is to be conducted by a geotechnical consultant, the WSDOT GPM who is overseeing the consultant task assignment or agreement is responsible to make sure that the consultant accomplishes the tasks described above and to assist in the coordination between the consultant and the FEM. If the consultant needs changes to the field exploration plan, the GPM is responsible to provide input to the FES or FEM as to the acceptability of the changes. The FES or FEM is not to act on the requested changes to the field exploration plan without input from the GPM.

While the GPM is responsible to coordinate between the project office and the FEM or FES regarding permits, the project office is ultimately responsible to perform or provide right-of-entry, hazardous materials assessment and archeological evaluation for the site, and to provide adequate site data to locate the exploration points for exploration plan development and for location in the field.

Currently, WSDOT has a five-year General Hydraulic Project Approval (HPA) for performing geotechnical exploration in both marine and fresh waters statewide. Once again the FEM or FES should be involved early in the process to define all technical questions for each project. For all barge projects, the drilling shall be in compliance with the provisions described in the general HPA from the Washington Department of Fish & Wildlife (WDFW).

The FEM (or as delegated to a FES) will assign the project to a drill inspector(s) and a drill crew. The drill inspector will then initiate a meeting with the GPM to discuss the objectives and any particulars of the exploration plan. Either the FES or the drill inspector should notify the GPM of the anticipated start date of the requested work.

3-2.2 Department of Ecology Requirements for Wells

Well definitions, and submittal, construction, protection, and decommissioning requirements as specified in RCW 18.104 and WAC 173-160 shall be followed.

In accordance with RCW 18.104.020 and WAC 173-160-111, a well is defined as a water well, resource protection well, dewatering well, and geotechnical soil boring. Specifically, RCW 18.104.020(8) defines *"geotechnical soil boring"* or *"boring"* as *"a well drilled for the purpose of obtaining soil samples or information to ascertain structural properties of the subsurface"*.

A "resource protection well" is defined as *"a cased boring intended or used to collect subsurface information or to determine the existence or migration of pollutants within an underground formation. Resource protection wells include monitoring wells, observation wells, piezometers, spill response wells, remediation wells, environmental investigation wells, vapor extraction wells, ground source heat pump boring, grounding wells, and instrumentation wells."* Note that these definitions of a well do not apply to *"excavations made for the purpose of … inserting any device or instrument less than 10 feet in depth into the soil for the sole purpose of performing soil or water testing or analysis or establishing soil moisture content as long as there is no withdrawal of water in any quantity other than as necessary to perform the intended testing or analysis."*

Reports required for wells by the Washington State Department of Ecology (hereinafter referred to as Ecology) in accordance with the RCWs and WACs include Notice of Intent (NOI) and water well reports for both the construction and decommissioning of wells.

The following sections provide the most relevant RCWs and WACs for wells. The WACs and RCWs identified herein are not intended to be an exhaustive list. Other RCWs and WACs may also be applicable.

3-2.2.1 *RCWs and WACs for Geotechnical Soil Borings*

Given the definition of "well" provided above, the following RCWs and WACs are applicable to geotechnical borings:

WAC 173-160-101: General standards that apply to all water wells

RCW 18.104.050: Reports of well construction or decommissioning

WAC 173-160-141: Requirements regarding water well reports

RCW 18.104.048: Prior notice of well construction, reconstruction, or decommissioning

WAC 173-160-151: Prior notice to the Department of Ecology and fees regarding well construction, reconstruction, and decommissioning

WAC 173-160-181: Requirements for preserving the natural barriers to groundwater movement between aquifers

WAC 173-160-191: Design and construction requirements for completing wells

WAC 173-160-311: Well tagging requirements

WAC 173-160-381: Standards for decommissioning a well

WAC 173-160-420: General construction requirements for resource protection wells

WAC 173-160-460: Decommissioning process for resource protection wells

For a geotechnical boring, an NOI as described in WAC 173-160-151 shall be provided to Ecology, with a copy to the WSDOT Geotechnical Office, at least 72 hours prior to drilling the boring. If the boring is not left open or cased after it is drilled, the well report(s) developed in accordance with WAC 173-160-141 for both conducting the boring and its decommissioning can be provided at the same time. In this case, a well tag (i.e., per WAC 173-160-311) is not required.

For a geotechnical boring that is not decommissioned immediately after the boring is completed, but is left open or cased after it is drilled to provide opportunity to monitor ground water, movements, or access for future testing (i.e., a resource protection well as previously defined), a NOI as described in WAC 173-160-151 shall be provided to Ecology, with a copy to the WSDOT Geotechnical Office, at least 72 hours prior to drilling the boring. A well report describing the well construction shall be provided to Ecology after the boring is complete in accordance with WAC 173-160-141.

Resource protection wells shall be physically identified with a well identification tag provided by Ecology in accordance with WAC 173-160-311 and WAC 173-160-420. The well identification tag must be placed in a secure, visible location. Per WAC 173-160-311 and WAC 173-160-420, the well tag shall be permanently attached to the outer well casing or other prominent well feature and be visible above land surface.

3-2.2.2 *Definition and Responsibilities of the Well Contractor and Well Owner*

RCW 18.104.020 defines the "well contractor" as "any person, firm, partnership, copartnership, corporation, association, or other entity, licensed and bonded under chapter 18.27 RCW, engaged in the business of constructing water wells." RCW 18.104.020 also applies this definition to resource protection well contractors.

Wells, as defined in RCW 18.104.020 and WAC 173-160-111, which includes geotechnical borings and resource protection wells, shall be drilled by a licensed resource protection well operator as specified in RCW 18.104.095, RCW 18.104.097, and WAC 173-162. A resource protection well operator with a training license (i.e., as specified in RCW 18.104.097) may operate the drilling rig to conduct the well construction, including geotechnical borings, under the supervision of a licensed operator as allowed in that RCW. Licenses shall be kept current as specified in RCW 18.104.100.

RCW 18.104.020 defines the "well owner" as the "person, firm, partnership, co-partnership, corporation, association, other entity, or any combination of these, who owns the property on which the well is or will be constructed or has the right to the well by means of an easement, covenant, or other enforceable legal instrument for the purpose of benefiting from the well." In general, responsibilities of the well owner include making sure that NOIs, well reports, and fees are properly submitted to Ecology in a timely manner, that the well is protected from damage and contamination, and that it is properly decommissioned.

As applied to the various situations in which wells are constructed on WSDOT right-of-way or other property where WSDOT may be considered the "well owner" as defined under RCW 18.104.020 by WSDOT or other entities, the application of this definition and the associated responsibilities are as follows:

- For all wells that are constructed by WSDOT drill crews (including headquarters crews and NW Region crews), and private sector contract drill crews hired by WSDOT, WSDOT will fulfill the responsibilities of the well owner, making sure that NOIs, well reports, and fees are properly submitted to Ecology in a timely manner, that the well is protected from damage and contamination, and that it is properly decommissioned.
- For all wells constructed by consultants and their subcontracted drill crews, the consultant shall be responsible to make sure that, for each well, survey coordinates, NOIs, well reports, and fees are properly submitted to the Ecology in a timely manner and to make sure that a copy of those documents are provided to the WSDOT Geotechnical Office for its records. WSDOT will maintain primary responsibility to make sure that the well is protected from damage and contamination, and that it is properly decommissioned.
- For all wells constructed by design-build contractors, the design-builder shall be responsible to submit NOIs, well reports, and fees to Ecology, to make sure wells are properly tagged, and shall be responsible to make sure that the well is protected from damage and contamination and that it is properly decommissioned. In addition, for each well, the design-builder shall submit copies of survey coordinates, the NOIs, and well reports submitted to Ecology to the WSDOT Geotechnical Office for its records. WSDOT, as the well owner, will provide oversight to make sure that the design-builder carries out its responsibilities regarding wells.
- For all wells as defined above constructed by another agency or private sector developer within WSDOT right-of-way, the responsibility for the wells shall be as defined in the Subterranean Monitoring Permit (see also the WSDOT Development Services Manual, Section 5.4.05). The developer, or other agency, shall be responsible to submit, for each well, survey coordinates, NOIs, well reports, and fees to Ecology, to make sure wells are properly tagged, and shall be responsible to make sure that the well is protected from damage and contamination and that it is properly decommissioned. In addition, the other agency or private developer shall submit a copy of the survey coordinates, NOIs and well reports submitted to Ecology to the WSDOT Geotechnical Office for its records. WSDOT, as the well owner, will provide oversight to make sure that the other agency or private sector developer carries out its responsibilities regarding wells.
- For land purchased by WSDOT that contains wells, WSDOT becomes the owner of the wells and is responsible to protect the wells from contamination and damage. WSDOT becomes responsible to decommission the wells, unless WSDOT requires the previous landowner to decommission the wells through the purchase agreement. If the prior landowner is required to decommission the wells, it shall provide the required decommissioning notices and reports to Ecology, with copies to WSDOT.

Protection of wells between well construction and decommissioning shall meet the requirements in WAC 173-160-101 and WAC 173-160-420.

3-2.2.3 *Submittal and Tracking Requirements for Wells*

WSDOT will maintain a database of all well installations on WSDOT property made by WSDOT, its contract drill crews, consultants, design-builders, other agencies, and private sector developers. Consultants, design-builders, and other agencies shall provide pertinent information as listed in Appendix 3-G for the database in addition to the following documents for each installed well:

- A copy of all NOIs submitted Ecology, both for constructing the well and its decommissioning
- A copy of the well report submitted to Ecology, both for constructing the well and for its decommissioning

The above documents will be stored by the WSDOT Geotechnical Office, and a link to these documents will be included in the database for easy retrieval.

3-3 Activities and Policies – During Exploration

The drill inspector will maintain regular contact with the GPM. The drill inspector shall contact the GPM, for example, when unanticipated conditions or difficulties are encountered, significant schedule delays are anticipated, and prior to terminating the exploration and installing instrumentation. The driller is required to complete a daily drill report at the end of each workday. This is also required of any contract driller working for WSDOT. The drilling inspector is also required to complete a daily inspector's report at the end of each workday. At the completion of each workweek these reports shall be turned in to the FES and put in the project file. Examples for both the daily drill and inspector reports that show the minimum required documentation are included in Appendix 3-A.

Exploration activities during drilling must adhere to the Geotechnical Office's Best Management Practices to mitigate for sediment/erosion control and spill prevention (see Appendix 3-C).

Methods for advancing geotechnical borings should be in accordance with the following ASTM standards:

- D6151-97(2003) Standard Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
- D5876-95(2000) Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
- D2113-99 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

Hollow-stem augers are not to be used for assessment of liquefaction potential; wet rotary methods should be used. Further, care must be exercised during drilling with hollow-stem augers to mitigate for heave and loosening of saturated, liquefiable soils.

Sampling of subsurface materials should be in accordance with the following ASTM standards:

- D1586-99 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils

- D3550-01 Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
- D1587-00 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
- D4823-95(2003)e1 Standard Guide for Core Sampling Submerged, Unconsolidated Sediments

In addition to the methods described above for sampling for soft, fine-grained sediments, WSDOT utilizes a thick-walled sampler referred to as the Washington undisturbed sampler. This sampler is lined with 2-inch (I.D.) extrudible brass tubes. The sampler is intended for stiffer fine-grained deposits than what would be suitable for Shelby tubes.

Down-the-hole hammers are not allowed for use in performing Standard Penetration Tests.

Samples should be handled in accordance with the following ASTM standards:

- D4220-95(2000) Standard Practices for Preserving and Transporting Soil Samples
- D5079-02 Standard Practices for Preserving and Transporting Rock Core Samples

Disturbed soil samples should be placed in watertight plastic bags. For moisture- critical geotechnical issues, a portion of the sample should be placed in a moisture tin and sealed with tape. Extreme care must be exercised when handling and transporting undisturbed samples of soft/loose soil; undisturbed samples must also be kept from freezing. Rock cores of soft/weak rock should be wrapped in plastic to preserve in situ moisture conditions. Rock cores should be placed in core boxes from highest to lowest elevation and from left to right. Coring intervals should be clearly labeled and separated. Core breaks made to fit the core in the box must be clearly marked on the core. All soil and rock samples should be removed from the drill site at the end each day of drilling and transported to the laboratory as soon as possible.

In situ testing methods commonly employed in geotechnical investigations should be in accordance with the following ASTM standards:

- D2573-01 Standard Test Method for Field Vane Shear Test in Cohesive Soil
- D5778-95(2000) Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils

Groundwater monitoring and in situ characterization methods commonly employed in geotechnical investigations should be in accordance with the following ASTM standards:

- D5092-02 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers
- D4750-87(2001) Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
- D4044-96(2002) Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

Additional information on ground water investigation and monitoring is provided in Mayne, et al. (2002).

As described herein, the term "piezometer" includes the use of open standpipe piezometers and pore pressure transducers (pneumatic or vibrating wire). RCW 18.104.020/WAC 173.160.111 defines these as observation or monitoring wells, and when pressure transducers are used, as an instrumentation well. As a minimum, groundwater levels should be measured/recorded prior to the daily commencement of drilling activities and upon completion of piezometer installation. Subsequent monitoring is at the discretion of the GPM. Prior to constructing a piezometer, the boring should be thoroughly purged of drill fluids using clean, potable water. The GPM should provide design input on the construction of the piezometer, specifically regarding the screened interval and seals. Piezometers shall be constructed in accordance with Ecology regulations (RCW 18.104/WAC 173.160) governing water wells. Following completion of the piezometer, the piezometer should be repeatedly surged or bailed to develop the well screen and optimize hydraulic connectivity with the formation. Furthermore, the piezometer should be sealed within the aquifer of interest, not hydraulically linking multiple aquifers.

Slope inclinometers are routinely employed for slope stability investigations. The installation and monitoring of slope inclinometers should be in accordance with the following ASTM Standard:

- D6230-98 Standard Test Method for Monitoring Ground Movement Using Probe-Type Inclinometers

Explorations using hand equipment such as augers and drive probes may also be useful for some geotechnical investigations, such as to define lateral and vertical extent of soft/loose, near-surface deposits. The WSDOT portable penetrometer consists of 1.75 inch diameter rod which tapers to a rounded 0.5 inch tip over a 4.5 inch length, and which is driven in the ground with a 35 lb weight dropped from a 25.5 inch height. Detailed procedures for portable penetrometer testing are provided in Appendix 3-B. Standard Penetration Test correlations for the WSDOT portable penetrometer (PP) are approximated as follows:

Soil Type	SPT Correlation
Clay	# PP blows/4
Silt	# PP blows/3
Sand/Gravel	# PP blows/2

The excavation of test pits can provide valuable subsurface information not determinable or well characterized by test borings. Extreme care should be exercised around open excavations, and access within them should adhere to Washington Administrative Code (WAC) sections 296-155-655 and 296-155-657. Prior to de- mobilizing, the drill inspector should ensure location information (e.g., station, offset, elevation and/or state plane coordinates) of all the explorations are recorded on the field logs. If exact location information is unavailable upon completion of field activities, a sketch of each exploration location should be made indicating relationship to observable features (i.e., bridge/structure, mile post, etc.). This information should be provided with the field logs to the GPM. In addition to providing field logs for all explorations, required documentation for test pits should include a scale drawing of the excavation and photographs of the excavated faces. Sampling methods and in situ measurement devices such as pocket penetrometers should also be documented. Detailed requirements for boring logs are provided in Chapter 4.

3-4 Activities and Policies – After Exploration

3-4.1 Field Notes, Finished Log, and Sample Handling

Upon completion, the drilling inspector shall transmit recovered samples to the State Materials Lab and provide both the original copy of the field notes and a finished log for all explorations to the GPM. If the samples to be transmitted to the lab are known to be contaminated or are potentially contaminated, the procedures provided in Appendices 3-E and 3-F shall be followed.

Upon completion of the subsurface explorations, a finished well report that meets the requirements of WAC 173-160-141 shall be submitted to Ecology within 30 days of completion of the last boring for the project or the end of the calendar year, whichever occurs first.

3-4.2 Well Protection and Decommissioning Requirements

The primary goals of the policies and procedures outlined in this section are to ensure proper protection of wells in service, timely decommissioning of all wells, decrease the potential for incomplete documentation of well installation and decommissioning with Ecology, and increase the degree to which complete documentation is verified with Ecology.

Protection of wells between well construction and decommissioning shall meet the requirements in WAC 173-160-101 and WAC 173-160-420. With assistance from the FES in charge of the well installations, the GPM should coordinate with the local WSDOT maintenance office to make sure they are aware of any wells located within their jurisdiction.

RCW 18.104.020 defines "decommission" as *"filling or plugging a well so that it will not produce water, serve as a channel for movement of water or pollution, or allow the entry of pollutants into the well or aquifers".* Well decommissioning shall be carried out in accordance with WAC 173-160-420 and WAC 173-160-460 (see Section 3-2.2). The GPM will make the request for decommissioning to the FEM, updating the original field exploration request as needed (initial estimate will be in the original estimate for the drilling). The GPM is responsible to coordinate the well decommissioning with the Region Project Office, and for wells preserved for longer term monitoring, also with the Geotechnical Design and Project Development Engineer.

The timing of decommissioning is determined as follows:

Design-Bid-Build – For these projects, decommissioning of wells is scheduled by the assigned GPM when the project reaches final PS&E review, or sooner, if possible. The GPM is responsible for reaching out to the Project Office, informing them of the need to decommission and making appropriate arrangements with the FEM. In addition to less formal notification to the Project Office (email, etc.), a comment indicating the need for well decommissioning should also be provided as part of PS&E review. If the geotechnical design work is conducted by either a HQ or region consultant, the WSDOT staff assigned to review the consultant's work will make sure any wells installed are properly decommissioned. Ideally, well decommissioning should be included in the consultant's scope of work, but if not the HQ GPM will do the coordination with the FEM to make sure the wells get decommissioned.

Design Build – For these projects, for wells installed during project development, the GPM is responsible for informing the WSDOT Project Office during final review of the RFP of the need to decommission prior to RFP advertisement. For wells installed by the Design-Builder, the Design-Builder shall decommission the wells prior to contract physical completion. The GPM should make sure that specifications requiring decommissioning by the Design-Builder are included in the RFP.

For either type of project (i.e., Design-Bid-Build or Design-Build), if the GPM feels that the well(s) should be maintained for long-term monitoring through project construction (e.g., for landslides or ground water monitoring), the GPM shall notify the WSDOT FEM and the Geotechnical Design and Project Development Engineer so that the well can be tracked for future decommissioning. The GPM is also responsible for informing the WSDOT Project Office of the need for special provisions or RFP language to handle both the protection-in-place of the wells and their decommissioning. In addition, the locations of wells to be protected will be clearly shown on the project plans. Standard Specification language is already in place to require the Contractor to protect the wells and not disturb them as a result of any construction activity. Decommissioning of these wells should occur at or about Contract Physical Completion, unless other arrangements are made to leave the wells in place longer term, and will be triggered by the Construction Project Engineer notifying the Geotechnical Office. If left in place longer term, the GPM is responsible to request and arrange for the proper decommissioning of the wells and all Ecology reporting requirements.

Historic Wells – During project development, construction, or maintenance activities, previously installed, historic wells may be encountered. During project development, the GPM should attempt to locate and positively identify all such wells, determine whether or not they have been properly decommissioned, that records for those wells are available, and that those records have been submitted to Ecology. If the well has not been decommissioned, or if the records for the well are lacking, the GPM should work with the FES to make sure that the well is properly decommissioned. If the region Project Office discovers the historic wells, the GPM assigned to the project should be notified as soon as practical.

At least 72 hours prior to well decommissioning, a NOI as described in WAC 173-160-151 shall be provided to Ecology. Once the decommissioning is completed, a well report documenting the decommissioning shall be submitted to Ecology in accordance with WAC 173-160-141 and WAC 173-160-420. In both cases, a copy of the NOI and well report for decommissioning shall be retained by the WSDOT Geotechnical Office for its records if drilled by state forces or its drilling contractors, or shall be submitted to the WSDOT Geotechnical Office for its records if drilled by others (e.g., consultants, design-build contractors, other governmental agencies, developers).

3-5 Standard Penetration Test (SPT) Calibration

Calibration to determine specific hammer system efficiencies shall be developed in general accordance with ASTM D4633 for dynamic analysis of driven piles or other accepted procedure. In general, hammers should be tested annually, and may be tested on a project specific basis if deemed necessary and staff are available to do the testing. Measured hammer efficiencies for WSDOT drilling equipment can be obtained by contacting the WSDOT Geotechnical Office.

3-6 References

Mayne, P. W., Christopher, B.R., and DeJong, J., 2002, *Subsurface Investigations – Geotechnical Site Characterization*, Publication No. FHWA NHI-01-031, National Highway Institute, Federal Highway Administration, Washington, DC, 300 pp.

3-7 Appendices

Appendix 3-A	Daily Drill Report Form
Appendix 3-B	Portable Penetrometer Test Procedures
Appendix 3-C	Field Investigation Best Management Practices for Erosion and Spill Prevention
Appendix 3-D	Department of Natural Resources Memorandum of Understanding: Drilling Operations – State Owned Aquatic Lands
Appendix 3-E	Geotechnical Field Investigation and Contaminated Drilling Waste Management Procedures
Appendix 3-F	State Materials Laboratory Sample- Handling Policy for Contaminated and Potentially Contaminated Samples
Appendix 3-G	WSDOT Well Tracking Database Information to be Tracked

Appendix 3-A Daily Drill Report Form

Washington State Department of Transportation

Daily Drill Report

SR	CS	Date
Project		Project No.
Drill		Drill No.

☐ Structure ☐ Line ☐ Landslide ☐ Materials Source

Hole No	Size	Angle	From	To	Soil	Rock	Total

Item	Hours	Item	Hours
Mobilization and Demobilization		Water Haul: Mileage	
On Site Moving/Rigging		Equipment Downtime Explain:	
Drill Site Preparation			
Soil Drilling		Standby for Hole Survey and Other Delays Explain:	
Rock Drilling			
Reaming Hole		Installation of Instrumentation Type:	
Placing and Removing Casing			
Hole Stabilization		Special Testing Type:	
Install and Maintain Water System			
Water Delay		Travel Time	

Expendables

Core Boxes	Piezo Pipe	Slope Incl	Cement	Bentonite	Additives

Other

Support Equipment	No.	Job	Yard	O Serv.

Remarks

	Reg.	OT	Comp	Total
Inspector				0
Driller				0
Helper				0

Shift Start	Shift Finish	Service Codes

DOT Form 350-152
Revised 07/2012

Appendix 3-B Portable Penetrometer Test Procedures

Background

The WSDOT portable penetrometer (PP) is a field test used in highway and small foundation design. The test may be used in both cohesive (clay) and cohesionless (sands & gravels) soils. The test values (i.e., blow count per foot of penetration) are dependent upon the effective overburden pressure of granular soils and shear strength of cohesionless soils. However, since all equations and correlations related to use of blow count values are approximate, sound engineering judgment is necessary for accurate interpretation of the test results.

The PP test is a derivative of the Standard Penetration Test (SPT), the most widely used method for determining soil conditions in the world. The SPT is both a dynamic penetration test and a method of obtaining disturbed samples. For the SPT test, a split-spoon sampler attached to drill steel is driven downward by the impact of a falling weight on the steel. In the SPT test, a 140 lb. weight falls a distance of 30 inches per blow. In the PP test method, a 35 lb weight falls an approximate distance of 25.5 inches. In the SPT test, as a split-spoon sampler is driven downward, it fills with disturbed soil. In the PP test, no sample is obtained as a solid, cone-shaped tip is driven downward by a falling weight. However, the PP method requires excavation of a test hole, and samples should be obtained with each change in soil strata.

Equipment

Performance of portable penetrometer testing requires two groups of equipment. The first group is associated with preparation of a drilled borehole, backhoe test pit, or hand-excavated test hole. This group includes the tools used to dig the hole, with a hand auger employed most frequently in a PP test application. A list of equipment used for excavation of a test hole with a hand auger follows:

- Shovel with pointed end for breaking up turf and vegetation at the surface.
- Posthole digger for assistance in establishing the test hole excavated using the hand auger.
- Hand auger to include: auger, pipe extensions (± 3 feet lengths), and handle.
- Steel bar to loosen up hard pack soil and assist in the removal of rock or gravel from the test hole.
- Tarp for collecting representative samples of soil strata.
- Field notebook and pencil for recording location of test holes, numbers and descriptions of distinct soil layers encountered, and other information relative to a review of site characteristics and conditions.
- Sample bags with ties for preservation of samples of material encountered with changes of soil strata.
- Marker for writing on sample bags or tags to delineate test hole and depth of sample collection.
- Pocket or rag tape to be used to locate the test hole relative to some reference point, grid, or proposed alignment and for measurement of depth below surface of distinct soil strata and depth of exploration.

The PP device and accessories form the second group of equipment required for geotechnical investigation of proposed highway or small foundation designs. A list of the equipment necessary for this group follows:

- Portable penetrometer to include cone-shaped tip; drill rod sections (A-rod - 1.75 in. pipe OD & 22.5 in. lengths); falling weight section (length of bar for sliding weight up and down); the 35-lb weight; and the coupling devices used for connecting the tip – drill rod sections – falling weight section – falling weight stop.
- Pipe wrenches (2) used to loosen connections when breaking down the portable penetrometer.
- Lathe or another "straight-edge" useful for establishing a surface reference elevation.
- Construction crayon or marker used for marking three 6 inch intervals on the penetrometer in order to clearly delineate displacement as the penetrometer is driven into the ground.
- Rags to wipe down equipment, removing moisture and dirt, prior to packing away equipment.

Test Procedure

1. Using a shovel or other hand tool, strip away sod or surface vegetation and set aside for future restoration of the location. Using a posthole digger or a 6 in diameter or greater hand auger, dig down approximately 2 feet, noting the depth of topsoil, subsoil, and other changes in soil strata. Describe soil conditions such as color, texture, and moisture content of the soils encountered in the bore log. Collect samples for lab soil classification, grain size determination, or Atterberg limits determination.
2. Assemble the PP device for evaluation of soils near the surface. Use threaded coupling devices to connect the cone-shaped tip, drill rod sections, and falling weight slide section.
3. Measure the distance from the bottom of the test hole to the surface and record. From the tip of the penetrometer, measure this distance on the body of the testing device and annotate a reference line on the body of the device. From this line measure and mark three intervals, each 6 inches in length.
4. Lift up the PP device and place the tip at the bottom of the test hole. Insure that the bottom or base line mark lines up with the approximate ground surface. Place a lathe or other straight edge on the ground surface so that any downward displacement of the PP device may be measured accurately.
5. Lift the 35 lb weight up and lower it down on to the upper, slide portion of the testing device. Screw on the threaded stop at the upper end of the slide section.

6. Performance of PP testing requires a minimum of two people. One person should be responsible for steadying the PP device in the test hole, counting the number of times the weight drops, and watching the reference line in order to stop the process every time the device is displaced downward a total of 6 inches. The second person is responsible for raising and dropping the weight in as smooth and controlled manner as possible. Raising the weight upward of fifty times per 6 inch interval can prove to be a workout. Additional personnel can be employed to relieve the person responsible for lifting the weight and assist in the manual work requirements of test hole excavation.
7. For each "blow", the 35 lb weight drops a distance of approximately 25.5 in. The number of blows required to drive the cone penetrometer through three 6 inch intervals is recorded. The count for the initial 6 inch interval is noted but isn't used to compute a test value because it reflects the seating of the PP device. The sum of the blows for the last two 6 inch intervals is recorded. This sum of the blows represents the blow count for that 1 foot interval below the surface.
8. Upon completion of PP testing at a specific depth, the device is unseated by thrusting the weight against the stop at the end of the slide. Repeating this action should loosen the tip and permit removal of the device from the test hole.
9. Employ the hand auger to remove material "disturbed" by the action of the PP. Place this affected material on the tarp and obtain a sample for lab testing. Associate PP test results with material sampled from the proper test hole and elevation.
10. Continue advancing the auger into the soil, emptying soil and repeating the procedure until the desired depth is reached. Advances from one PP test to the next lower level test are usually in 2 feet increments. Monitor the condition and properties of the soil, noting any changes in strata. Obtain samples as necessary.
11. To prepare the PP device for the next test at a lower test hole level, remove the weight stop, 35 1b weight, and slide section to permit the attachment of additional drill rod sections. Re-attach the slide section to the penetrometer. Measure the distance from the bottom of the test hole to the surface. Mark this distance on the body of the testing device by measuring from the tip and annotating a base line corresponding to the distance on the PP device.
12. With assistance, lift the PP into the test hole, properly seat it in the center of the hole, and insure that the base line corresponds with the ground surface.
13. Lift the weight up and onto the slide section and screw in the threaded stop at the top end of the slide.
14. Perform PP test procedure and sampling as described previously.
15. Monitor changes in soil strata as the hand auger advances downward in the test hole. In general, sample only when there are obvious changes in soil strata. Use engineering judgment to guide whether additional sampling and testing are warranted. As the degree of geologic complexity increases, the degree of sampling and testing increases as well.

Figures 3-B-1 through 3-B-8 illustrate the equipment and procedures used for conducting the Portable Penetrometer test.

Figure 3-B-1

Perform a field reconnaissance of the site of the geotechnical investigation. Insure that the proposed design is tied to an established coordinate system, datum, or permanent monument.

Figure 3-B-2

Hand augers used in conjunction with the PP test.

Figure 3-B-3

Porta-Pen equipment. Clockwise from the top left: tape measure above cone-shaped tips (2); 22.5-inch lengths (9); threaded coupling devices used to connect PP components (10); threaded coupler used to stop weight (1); falling-weight slide section above pipe wrenches (2); 35 lb. weight; and threaded coupling devices used with small cone tips (not shown).

Figure 3-B-4

The vicinity of the test hole is cleared of vegetation using a shovel or posthole digger. Left photo shows using the auger to advance the hole to the desired depth. Right photo shows placing soil on the tarp prior to sampling.

Figure 3-B-5

Photo of PP device in the process of being assembled. The threaded coupling devices on the left side of the box are used to connect the cone-shaped tip to lengths forming the body of the penetrometer. The lengths forming the body of the penetrometer are then connected to the section on which the weight slides.

Figure 3-B-6

Marking a base line on the body of the penetrometer. This will line up with the top of the test hole. In addition, also mark three 6 inch intervals, measured from this base line, to track the downward displacement when the falling weight is applied.

Figure 3-B-7

PP testing in progress. Lathe is used to mark the surface of the test hole excavation. In this instance, one person is steadying the equipment, another is lifting and dropping the 35 lb weight, and a third is observing downward displacement and counting blows.

Figure 3-B-8

This PP testing can be tiring. Photo shows another person providing relief for the falling weight task.

Appendix 3-C Field Investigation Best Management Practices for Erosion and Spill Prevention

The Washington State Department of Transportation (WSDOT) is dedicated to protecting the environment when conducting field exploration projects. This memo outlines the erosion/sediment control and spill prevention best management practices (BMPs) that will be followed for all drilling activities.

The two distinct scenarios for drilling include pavement and vegetated areas. The variety of erosion and sediment control BMPs may vary between the two scenarios, but the philosophy of minimizing site disturbance, reducing waste materials, trapping sediment, and stabilizing the site, remains the same.

Disturbance Minimizing BMPs:

- Select the smallest rig capable for the job
- Use elevated scaffolding for driller and assistant when necessary

Waste Reduction BMPs:

- Re-circulate drilling slurry
- Minimize volume of water for drilling

Sediment Trapping BMPs:

- Baffled mud tub (sealed with bentonite to prevent fluid loss)
- Polyacrylamide (PAM) for flocculation (must meet ANSI/NSF Standard 60)
- Silt fence (trenched, below drill, and on contour)
- Sand bag barrier (washed gravel, below drill, two rows high, and on contour)
- Straw bale barrier (trenched, staked, below drill, and on contour)
- Catch basin insert (pre-fabricated type, above or below grate)
- Storage of slurry in locked drums

Site Stabilization BMPs:

- Seed with pasture grass
- Straw mulch (2” maximum for seeded areas)

All BMPs will be installed and a thorough inspection for sensitive areas (wetlands, streams, aquifer recharge, etc.) and stormwater conveyances will be conducted, prior to starting drilling activities. At no time shall drilling slurry or cuttings be allowed to enter Water Bodies of the State of Washington.

When sensitive resources or conveyances to these areas exist, all slurry and cuttings will be stored in lockable drums and disposed of off-site. If not, the slurry will slowly be infiltrated into the ground using surrounding vegetated areas and the cuttings will be stored and disposed of off-site.

Removal of sediment control BMPs will be performed immediately after drilling is completed. Place trapped sediment with cuttings in drums. If significant soil disturbance occurs during drilling, the BMPs will be left in place until the site is stabilized with grass or mulch.

The drill crew will have a copy of the HPA, issued by WDFW on-site for all work adjacent to or over water. The General HPAs are available on the HPA webpage (https://wsdot.wa.gov/environment/technical/permits-approvals/hydraulic-project-approval). The Supervisor will discuss the HPA permit provision requirements with the crew prior to each project, which include BMPs to protect fish habitat, water quality, and riparian vegetation. All of the provisions in each HPA will be strictly followed until the completion of said project. The previously defined erosion/ sediment control philosophy and BMPs will be implemented in these conditions

The approach to protecting surface and ground water is focused on prevention. The drill shaft will be filled with bentonite clay to prevent mixing of aquifers and eliminating the route for surface contaminants. In addition, the following Spill Prevention Control & Countermeasures (SPCC) BMPs will be used when applicable:

Minimize Risk:

- Visually inspect equipment for leaks or worn hoses on a daily basis
- Fix equipment leaks as soon as possible to minimize cleanup
- Use proper equipment to transfer materials
- Reduce the overall volume of fuel and chemicals on site
- Remove as many sources of spills as possible from the site when not working (evenings/weekends)
- Use environmentally-friendly chemicals whenever possible
- Store all chemicals with lids closed and keep containers under cover
- Have secondary containment devices underneath potential spill sources when applicable (e.g. 5 gallon bucket)

Maximize Response:

- Each drilling operation will have at least one emergency spill response kit on site at all times
- Know who to call in case of emergency spill

If an incidental spill (less than 1 gallon/small equipment leak) occurs, immediately collect contaminated soil and store it in label storage drum. Do not mix soils with different contaminants together. Report spill to your supervisor, as they are aware of reporting requirements.

If a major spill (more than 1 gallon) to water occurs, control the source of the leak if possible and contact the Washington State Emergency Management Division (800-258-5990) and the National Response Center (800-424-8802). If a major spill to soil occurs and there is immediate risk to human health and/or the environment, control the source of the leak if possible and contact Ecology (800-407-7170). Then contact your supervisor, as they are aware of reporting requirements.

Appendix 3-D Department of Natural Resources Memorandum of Understanding: Drilling Operations – State Owned Aquatic Lands

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
PETER GOLDMARK, Commissioner of Public Lands

MEMORANDUM OF UNDERSTANDING

MOU No. 92-091209

This Memorandum of Understanding (MOU) is between the State of Washington, acting through its Department of Natural Resources, referred to as DNR, and the State of Washington, acting through its Department of Transportation, referred to as WSDOT.

The DNR is entering into this Agreement under authority of Chapter 39.34 RCW of Washington State, Interlocal Cooperation Act.

The DNR is the steward of 2.6 million acres of state-owned aquatic lands. DNR manages the aquatic lands beneath Puget Sound, the coast, navigable rivers and lakes to encourage direct public use and access, foster water dependent uses, ensure environmental protection, and to utilize renewable resources.

The WSDOT is responsible to keep people and business moving by operating and improving the state's transportation system vital to our taxpayers and communities. A key institutional linkage between DNR and WSDOT is a mandate to ensure environmental protection.

This MOU formally recognizes the connection between marine and freshwater sediment test drilling and State Owned Aquatic Lands habitat function, and it increases coordination between the DNR aquatic lands leasing and WSDOT Geotechnical Services Division programs. This MOU defines a streamlined process for DNR to authorize WSDOT access to state-owned aquatic land for the purposes of temporarily installing test drilling equipment and collecting geotechnical survey data. This increased coordination and streamlined process will result in better environmental protection of State Owned Aquatic Lands at a cost savings to the state.

We agree to the provisions and statements outlined below.

1.01 Definitions.

DNR – an agency of the state of Washington

WSDOT – an agency of the state of Washington

Memorandum of Understanding - The DNR and WSDOT enter into this memorandum of understanding, in good faith, to collaborate on and/or coordinate programs, and to define institutional linkages along broad areas of concern. Memoranda of understanding are not legal contracts and do not strictly obligate the resources of the Department.

Drilling operations may consist of several different types of drilling methods and equipment such as portable aluminum pontoon barge with a skid mounted drill. The ultimate goal is to collect geotechnical data necessary to determine the sub-surface composition for the purpose of structure and roadway design. This memorandum of understanding applies only to work that is conducted consistent with the activities described in Exhibit A. Any work proposed to be conducted on State Owned Aquatic Lands that is outside of the activities described in Exhibit A will require the submission of a completed application for use authorization and possibly a separate use authorization before access to State Owned Aquatic Lands is granted.

Access to State Owned Aquatic Lands – After satisfying all the procedural requirements triggered by this type of work and securing all other applicable federal, state and local permits, and receiving written confirmation that no conflicts exist with aquatic habitats, sediment contamination, navigation and public access, or any prior rights granted on State Owned Aquatic Lands at a proposed drilling site, WSDOT is granted access to State Owned Aquatic Lands for the purpose of temporarily installing marine and freshwater sediment test drilling equipment to collect geotechnical data. In authorizing access to WSDOT for this specific purpose, DNR conveys no rights in property. Access to State Owned Aquatic Lands may be revoked by DNR with thirty (30) day notice to WSDOT.

2.01 Objectives.

- Create a formal cooperative agreement between DNR and WSDOT that encourages joint planning and operations in support of the WSDOT's Field Exploration Unit.
- Create a streamlined process to grant WSDOT access to State Owned Aquatic Lands for the purpose of installing marine or freshwater sediment test drilling equipment and collecting geotechnical data while ensuring environmental protection of State Owned Aquatic Lands.
- Build collaboration between DNR and WSDOT that will establish a forum for communication regarding geotechnical surveys.

3.01 Work Activities.

See Attachment A

4.01 Functions/Roles/Tasks of Agencies/Parties.

DNR shall:

- Review WSDOT proposed sediment test drilling work descriptions and locations for potential conflicts on State Owned Aquatic Lands and consistency with activities described in Exhibit A.
- Provide written notification to WSDOT granting or denying access to State Owned Aquatic Lands for temporarily installing marine and freshwater sediment test drilling equipment to collect geotechnical. Written notification will be provided to WSDOT via email or fax, within fifteen (15) working days of receipt of notice of any proposed work. Written DNR approval does not exempt WSDOT from regulatory permits.
- Maintain communication with WSDOT regarding marine and freshwater sediment test drilling results on State Owned Aquatic Lands.

WSDOT shall:

- Contact DNR at least thirty (30) days before installing drilling devices with a description and anticipated duration of the proposed work and a description of the location in the form of a vicinity map depicting Section, Township, Range and accompanying GPS coordinates. WSDOT will not proceed with the proposed work until receiving written confirmation from the DNR project coordinator that there are no conflicts after and obtaining and fulfilling all other local, state, and federal permits and permit requirements.
- Maintain communication with DNR regarding marine and freshwater sediment test drilling results and implications to potential management activities on State Owned Aquatic Lands.
- Upon request, provide to DNR all sediment quality results and any other data, results, conclusions or findings WSDOT obtains from any of the work completed under this MOU.

5.01 Terms and Conditions.

(1) Effective Dates. This MOU is effective between May 1, 2014 and May 1, 2019. This agreement will be reviewed every two years.

(2) Amendments. This MOU shall be amended only by written mutual consent of the

(2) Amendments. This MOU shall be amended only by written mutual consent of the parties.

(3) Termination. Either party may terminate this MOU by notifying the other party, at the addresses given, of the termination and specifying the termination date. The terminating party shall deliver the notice at least fifteen (15) days prior to the termination date.

6.01 Project Coordinators.

(1) The Project Coordinator for the DNR is Linda Farr, Telephone Number (360) 902-1065.

(2) The Project Manager for the WSDOT is Cyndi Booze, Property & Acquisition Specialist, Telephone Number (360) 705-7377.

STATE OF WASHINGTON
DEPARTMENT OF TRANSPORTATION

Dated: 5-19, 2014

By: [signature]

Title: Acquisition Prog. Mgr

Address: PO Box 47338, Olympia WA 98504

Phone: 360-705-7312

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES

Dated: 5/21, 2014

By: [signature]

Title: AQR Division Manager

Address: PO Box 47027, Olympia WA 98504-7027

Form Date07/01 4 of 6 Agreement No. 92-091209

Attachment A

WORK ACTIVITIES

Habitat Stewardship Measures and Best Management Practices:

(1) Species work windows will be used for the timing of any in-water construction and operational activities. This includes protection of forage fish, forage fish spawn, and associated spawning areas, as applicable.

(2) Avoid impacts to aquatic vegetation and fish spawning habitat/vulnerable life history stages. WSDOT will avoid drilling in Puget Sound eelgrass beds.

  (i) Fuels and other toxic materials must be stored in a location where they do not pose a risk of contaminating intertidal or nearshore areas.

    1. Maintaining pumps, boat motors, and other equipment in good condition, without leaks.
    2. Storing equipment free of fuel or in secure containment areas where any accidental leaks will be contained.
    3. Containing and cleaning up spills of fuels or other fluids without delay. Absorbent materials must be available onsite for this purpose.
    4. Removing broken-down vehicles promptly from beaches and intertidal areas.

(3) Floating structures and boats must not rest on the substrate. Boat moorage systems must be deployed in a manner that prevents dragging of the vessel or line. NOTE: When drilling location is in a confirmed forage fish spawning beach area, either use of the portable or large barge method is required for sediment test drilling and geotechnical surveys. However, deployment needs to be from a designated boat launch or beach void of suitable forage fish spawning habitat. Only in areas where successful avoidance of forage fish, their spawn and associated spawning areas is achieved, can other methods be deployed (i.e., truck or track mounted drill).

After satisfying all requirements triggered by this type of work, the WSDOT project coordinator will provide a description and anticipated duration of the proposed work and a description of the location in the form of a vicinity map depicting Section, Township, Range and accompanying GPS coordinates to the DNR project coordinator. The DNR project coordinator will review these proposals for potential conflicts on State Owned Aquatic Lands and provide written notification to the WSDOT project coordinator within 15 days granting access to State Owned Aquatic Lands for the sole purpose of conducting marine and freshwater sediment testing activities. WSDOT projects the length of time at each location to be approximately 1-60 days.

Marine and freshwater sediment test drilling and geotechnical surveys are necessary to determine the sub-surface composition for the purpose of structure and roadway design, hazardous materials detection, and other information necessary in the design roadway structures such as bridges.

Form Date07/01 5 of 6 Agreement No. 92-091209

WSDOT sampling procedure is as follows:

A 4 inch casing is sealed into the lake or river bottom. The test boring is advanced through that casing with a 3 inch casing. At every 5 foot interval a split spoon sampler is lowered on a 2 1/4 inch rod through the 3 inch casing to the bottom of the hole for taking soil samples. This process is repeated to the required depth of the soil investigation.

TRUCK MOUNTED DRILL
The truck mounted drill will access boring locations that are on relatively flat, easy to access sites. Each drill will have a support truck for water, tooling, and other required supplies.

TRACK MOUNTED DRILL
The track mounted drill is a low ground pressure (2.5 pounds per square inch rubber and steel track vehicle). It is used to access soft ground areas and sites with uneven or rough terrain. Each drill will have a support truck for water, tooling, and other required supplies.

PORTABLE BARGE
The Portable Barge is used when access is needed to an area within the waterbody where none of the above methods will work. It consists of hauling transportable pontoons to the vicinity by trailer and setting them into the water with a boom truck for assembly into a barge. Drills and support equipment are placed on the barge on moved into position for the drilling operation. The barge is held in place by four anchors.

For operations in deep water, a truck mounted drill is placed on a large barge rented. Tug boats are used to maneuver the barge.

CONE PENETROMETER TEST TRUCK
The Cone Penetrometer test truck is used to send sound waves into the ground to determine the density of material underground. It use an electronic instrumented cone assembly, hollow core sounding rods, a 20 ton hydraulic thrust frame, and a computer data acquisition/processing system to perform the analysis. This is a self-contained unit mounted on a truck. The system can be used from a barge for testing when there is deep soft sediment.

Form Date07/01 6 of 6 Agreement No. 92-091209

Appendix 3-E Geotechnical Field Investigation and Contaminated Drilling Waste Management Procedures

Requirements for handling, storage, and disposal of hazardous materials encountered during geotechnical drilling are provided at the following website: https://wsdot.wa.gov/environment/technical/disciplines/hazardous-materials/investigation-sampling-document

Appendix 3-F State Materials Laboratory Sample-Handling Policy for Contaminated and Potentially Contaminated Samples

On a project level, if any contaminated sites are brought to the attention of the (GPM), he/she shall immediately notify and forward all contaminant information to the Structural Materials Testing Engineer (SMTE) of the State Materials Laboratory (SML) and the Field Exploration Manager (FEM). Similarly, if the FEM, FE Supervisor, or FE crew is made aware of or suspects the presence of contaminants on a project, they shall immediately notify the GPM and the SMTE. This information shall include the project number, project name, location, boring (if applicable), and the types and scale of the contamination.

The SMTE shall pass this information to the SML geotechnical lab employees. Three situations are anticipated with regard to contaminated or potentially contaminated samples. The sample handling and disposal protocol applicable to the situation shall be followed. These situations, and the protocols associated with those situations, are described in the sections that follow.

Situation 1: Contaminated Soils Encountered in the Field

Soils (or rock) encountered in the field known or suspected to be contaminated shall not be submitted to the lab for standard sample processing and testing. In the event suspected or known contaminated soils/rock are encountered in the field, the following protocol shall be followed:

1. The FE crew shall immediately stop drilling/sampling operations and call the FEM, Supervisor and GPM for direction.
2. The FEM and/or GPM shall then contact the Environmental Services Office (ESO) for direction.
3. Utilizing appropriate PPE, any samples suspected or known to be contaminated shall be marked as contaminated and placed in the contaminated holding area or drum, as directed by the ESO. Labeling should be in the form of a single (~4”) strip of black and yellow striped tape and be placed on all samples (across the baggie, or over the cap of a Shelby tube). All drill cuttings and fluids from the boring shall also be placed in sealed drums. All samples from a suspected contaminated boring should be kept together until they have been cleared for testing.
4. If the ESO determines that a suitable secure and offsite storage area is not available or not necessary, they may direct the suspected/known contaminated materials to be transported to the SML for disposal characterization. The FEM or GPM shall then notify the SMTE that suspected/known contaminated samples are being transported to the SML.
5. The FEM shall establish a secure area outside of the main SML building, where the FE crew shall place the samples while they await disposal characterization by the ESO. The FEM shall then notify the ESO of the receipt of samples and request their direction on disposition.

6. Once analytical test results have been obtained, the ESO will direct the soil/rock samples and cuttings to be disposed of properly (protocols for what this entails shall be provided by the ESO) or make them available for geotechnical testing if contamination test(s) indicate they are suitable for geotechnical testing.
7. The samples shall not have geotechnical testing performed on them without being cleared to be tested by the ESO and Safety Office. The ESO/Safety Office shall determine the appropriate safety level for any subsequent testing/handling to be performed by SML employees. It is understood that at this time, only soils/rock not exceeding regulatory cleanup levels, and that have been cleared by the ESO Office, shall be suitable for geotechnical testing to be performed at the SML. Samples not cleared for testing at the SML should not enter the building.
8. Samples cleared for geotechnical testing by the ESO/Safety Office shall be labelled with additional green tape prior to delivery to the SML, indicating that the samples have been cleared for testing but extra precaution should be used. The black and yellow tape shall remain on the samples.

Situation 2: Screened Samples - Known Contaminants Exist in a Boring, but Samples are Screened in the Field and Deemed Safe for Geotechnical Testing

1. All samples from a contaminated boring should be kept together until they have been cleared for testing.
2. Upon direction from the ESO, samples that have been retained at a secure offsite location and confirmed to not exceed regulatory cleanup levels through analytical testing may be transmitted to the SML for geotechnical testing. Prior to transmitting the samples to the SML for geotechnical testing, the ESO shall notify the FEM, who in turn will notify the GPM and SMTE, that the soil samples are marginally contaminated and that they may be safely processed for geotechnical testing using appropriate PPE.
3. All such contaminated samples shall be properly labeled before being taken to the SML.
4. Labeling should be in the form of a single (~4”) strip of green tape placed on all samples (across the baggie, core box, or over the cap of a Shelby tube), indicating that the sample has been cleared for testing but extra precaution should be used.
5. All lab employees handling such marked samples shall use proper PPE and be at a heightened awareness for the possibility of contaminants to exist in these samples.
6. PPE for marginally contaminated materials includes latex/rubber gloves, eye protection, and other equipment or handling methods as deemed necessary by the ESO (which will vary based on the types of contaminants encountered).
7. Once cleared samples have been tested by the SML Soils Lab, at the direction of the GPM they may be disposed of in the same manner as non-contaminated soils.

Situation 3: Unexpected Contaminated Samples Discovered in the SML

If samples inadvertently make it to the SML that are suspected by lab personnel to be contaminated, lab personnel shall immediately secure all samples from the entire boring in an airtight container, label the container as having suspected contaminated samples, and notify the SMTE and the FEM, who shall then contact the ESO for direction.

If any tests have been performed on a sample and contamination is suspected after the fact, the SMTE and FEM should be notified immediately to determine how to proceed. Any equipment that came into contact with the contaminated sample should be identified and addressed (segregated, cleaned) according to ESO recommendations.

Detailing proper disposal for samples determined by ESO to be contaminated and not suitable for geotechnical testing is deemed outside the scope of this protocol. The ESO will convey the disposal requirements to the FEM or, in his absence, the FE Supervisors, and the FE personnel shall follow those disposal procedures accordingly.

Appendix 3-G WSDOT Well Tracking Database Information to be Tracked

Table 3-G-1 Well Data to be Tracked.

Field Name	Definition
WellTrackingDetail ID	An auto incremented number that serves as the primary key for the WellTrackingDetail table.
ECYRegionName	Ecology Region Name
WSDOTRegionName	The textual description of the geographic and administrative areas of responsibility of the Washington State Department of Transportation within the State of Washington as described in the Chart Of Accounts.
COUNTY	The name of a political and administrative division of a state, providing certain local governmental services. This name does not include the word 'County'.
ControlSectionNumber	A code that identifies a location, either a Roadway Segment, state owned facility or Ferry, established for the purpose of tracking project costs with the location's associated tax base.
TownshipNumber	The numeric designation that identifies a unit of survey of the public lands. Townships run north and south. In Washington Township numbers range from 1 north in Clark and Skamania counties to 40 North across our northern border: 1N-41N
RangeNumber	Ranges run east and west and Range numbers go from 16 West in Clallam County to 45 East along the Idaho border: 1E-47E or 1W-16W
SectionNumber	The full designation of a location based on the US Public Land Survey System in the format of Township, Township Direction, Range, Range Direction, Section. Each Township is divided into a grid of 36 sections. Each section is approximately 1 mile square. About 5% of the townships use section numbers greater than 36 (37-50).
SectionQuarter	Each section is divided into four 1/4 sections. They are defined by their quadrant name. NW - Northwest quadrant NE - the Northeast quadrant SW - the Southwest quadrant SE - the Southeast quadrant.
SectionQuarterQuarter	Each Quarter is divided into four 40-acre parts called a Quarter-Quarter. They are defined by their quadrant name. NW is for the Northwest quadrant of the Northwest quadrant, NE for the Northeast quadrant of the Northeast quadrant, SW for the Southwest quadrant of the Southwest quadrant, and SE for the Southeast quadrant of the Southeast quadrant.
DrillerFirstName	The first name of a WA State licensed well operator
DrillerLastName	The last name of a WA State licensed well operator

Table 3-G-1 Well Data to be Tracked.

Field Name	Definition
DrillerLicenseNumber	Alfa numeric License number driller is required to be licensed with the Washington state Department of Ecology to provide well construction
DecommissionCardNumber	Decommission Card Number - NOI number for a well decommission
DecommissionLicenseNumber	Alfa numeric License number driller is required to be licensed with the Washington state Department of Ecology to provide well decomission
WorkOrderNumber	The number that identifies the central collection point or cost center for managing costs associated with projects. It identifies a written order authorizing work to be performed on a Work Item Phase. It is the first 6 characters of the Job Number.
WorkOrderDescription	The title of the Work Order authorizing work to be accomplished on the Work Item. This field is reporting from TRAINS and cannot be modified in CPMS.
Phase	Phase
Group	Group
StateRouteNumber	The Number assigned to the State Route and enacted into law

Chapter 4 Soil and Rock Classification and Logging

4.1 Overview

The detailed description and classification of soil and rock are an essential part of the geologic interpretation process and the geotechnical information developed to support design and construction. The description and classification of soil and rock includes consideration of the physical characteristics and engineering properties of the material. The soil and rock descriptions that are contained on the field logs should be based on factual information. Interpretive information *should not* be included on the field logs, but provided elsewhere, such as in the text of geological, and geotechnical reports. This chapter provides standards for describing and logging soil and rock.

The Unified Soil Classification System, as outlined in ASTM 2488 – "Standard Practices for Description of Soils (Visual – Manual Procedure)", provides a conventional system for classifying soils. However, it alone does not provide adequate descriptive terminology and criteria for identifying soils for engineering purposes. Therefore, the ASTM Standard has been modified to account for these additional descriptive terms and criteria. It is not intended to replace the standard but to improve upon it, and make it better understood.

There are numerous rock classification systems, but none of these is universally used. This chapter provides a composite of those classification systems that incorporates the significant descriptive terminology relevant to geotechnical design and construction.

An important facet of soil and rock classification is the determination of what constitutes *"rock"*, as opposed to extremely weathered, partially cemented, or altered material that approaches soil in its character and engineering characteristics. Extremely soft or decomposed rock that is friable (easily crumbled), and can be reduced to gravel size or smaller by normal hand pressure, should be classified as a soil.

4.2 Soil Classification

Soil classification, for engineering purposes, is based on the *distribution* and *behavior* of the fine-grained and coarse-grained soil constituents. Soil descriptions that are contained on the field exploration logs are based on *modified* procedures as outlined in ASTM 2488. The visual - manual procedure provided in this standard utilizes visual observation and simple field index tests to identify the characteristics of the soil constituents. Definitions for the various soil constituents can be found in Table 4-1. In addition, soil properties that address angularity, consistency/relative density, color, moisture, structure, etc. have been defined.

Soils are divided into four broad categories. These soil categories are coarse-grained soils, fine-grained inorganic soils, organic soils, and peat. The first step in identifying soil is to make a determination regarding which of the four broad categories the soil belongs. The definitions for these broad categories are as follows:

- Coarse Grained Soils: Soils that contain 50 % or less of soil particles passing a 0.0030 in. (0.075 mm) opening.

- Fine Grained Inorganic Soils: Soils that contain more than 50 % of soil particles passing a 0.0030 in. (0.075 mm) opening.
- Fine Grained Organic Soils: Soils that contain enough organic particles to influence the soil properties.
- Peat: Soils that are composed primarily of vegetative tissue in various stages of decomposition that has a fibrous to amorphous texture, usually dark brown to black, and an organic odor are designated as a highly organic soil called peat. Once a soil has been identified as a peat (group symbol **PT**), the soil should not be subjected to any further identification procedures.

Soil Constituent	Description
Boulder	Particles of rock that will not pass through a 12 in. opening.
Cobble	Particles of rock that will pass through a 12 in. opening, but will not pass through a 3 in. opening.
Gravel	Particles of rock that will pass through a 3 in. opening, but will not pass a 0.19 in. (4.75 mm) opening.
Sand	Particles of rock that will pass through a 0.19 in. (4.75 mm) opening, but will not pass a 0.003 in. (0.075 mm) opening.
Silt	Soil that will pass through a 0.003 in. (0.075 mm) opening that is *non-plastic* or very slightly plastic and exhibits *little or no strength* when air-dried.
Clay	Soil that will pass through a 0.003 in. (0.075 mm) opening that can be made to exhibit *plasticity* (putty-like properties) within a range of water contents, and exhibits *considerable strength* when air-dried.
Organic Soil	Soil that contains enough organic particles to influence the soil properties.
Peat	Soil that is composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

Soil Constituent Definition
Table 4-1

4.2.1 Coarse Grained Soils

Coarse grained soils are classified as either a gravel or a sand, depending on whether or not the percentage of the coarse grains are larger or smaller than a 0.19 in. (4.75 mm) opening. A soil is defined as a ***gravel*** when the estimated percentage of the gravel size particles is greater than the sand size particles. A soil is defined as a ***sand*** when the estimated percentage of the sand size particles are greater than the gravel size particles.

If the soil is classified as a gravel, it is then identified as either clean or dirty. *Dirty* means that the gravel contains an appreciable (greater than 10 %) amount of material that passes a 0.003 in. (0.075 mm) opening (fines), and *clean* means that the gravel is essentially free of fines (less than 10 %). The use of the terms clean and dirty are for distinction purposes only and *should not* be utilized in the description contained on the field log.

If the gravel is *clean* then gradation criteria apply, and the gravel is classified as either well graded (GW) or poorly graded (GP). *Well graded* is defined as a soil that has a wide range of particle sizes and a substantial amount of the intermediate particle sizes. *Poorly graded* is defined as a soil that consists predominately of one particle size (uniformly graded), or has a wide range of particle sizes with some sizes obviously missing (gap graded). Once the grading determination has been made, the classification can be further refined by estimating the percentage of the sand size particles present in the sample.

If the gravel is *dirty* then it will be important to determine whether the fines are either silt or clay. If the fines are determined to be *silt* then the gravel will be classified as a silty gravel (GM). If the fines are determined to be *clay* then the gravel will be classified as a clayey gravel (GC). Once the determination has been made whether the fines are silt or clay, the classification can be further refined by estimating the percentage of sand size particles present in the sample.

If the soil is classified as a sand, the same criteria that were applied to gravels are used - clean or dirty. If the sand is *clean*, the gradation a criterion is examined in terms of well-graded sand (SW) versus poorly graded sand (SP). Once the grading determination has been made, the classification can be further refined by estimating the percentage of gravel size particles present in the sample. If the sand is *dirty*, then it will be important to determine whether the fines are silt or clay. If the fines are determined to be silt, then the sand will be classified as a silty sand (SM); conversely, if the fines are determined to be clay, then the sand will be classified as a clayey sand (SC). Once the determination has been made whether the fines are silt or clay the classification can be further refined by estimating the percentage of gravel size particles present in the sample. Table 4-2 should be used when identifying coarse grained soils.

The coarse-grained soil classification as outlined in Table 4-2 does not take into account the presence of cobbles and boulders within the soil mass. When cobbles and/ or boulders are detected, either visually within a test pit or as indicated by drilling action/core recovery, they should be reported on the field logs after the main soil description. The descriptor to be used should be as follows:

with cobbles - when only cobbles are present

with boulders - when only boulders are present

with cobbles and boulders - when both cobbles and boulders are present

	Fines	Grading	Silt or Clay	Group Symbol	Sand or Gravel	Description
Gravel	<10%	Well Graded		GW	< 15% Sand	Well graded GRAVEL
	< 10%	Well Graded		GW	≥ 15% Sand	Well graded GRAVEL with sand
	< 10%	Poorly Graded		GP	< 15% Sand	Poorly graded GRAVEL
	< 10%	Poorly Graded		GP	≥ 15% Sand	Poorly graded GRAVEL with sand
	> 10%		Silt	GM	< 15% Sand	Silty GRAVEL
	> 10%		Silt	GM	≥ 15% Sand	Silty GRAVEL with sand
	> 10%		Clay	GP	< 15% Sand	Clayey GRAVEL
	> 10%		Clay	GP	≥ 15% Sand	Clayey GRAVEL with sand
Sand	< 10%	Well Graded		SW	< 15% Gravel	Well graded SAND
	< 10%	Well Graded		SW	≥ 15% Gravel	Well graded SAND with gravel
	< 10%	Poorly Graded		SP	< 15% Gravel	Poorly graded SAND
	< 10%	Poorly Graded		SP	≥ 15% Gravel	Poorly graded SAND with gravel
	> 10%		Silt	SM	< 15% Gravel	Silty SAND
	> 10%		Silt	SM	≥ 15% Gravel	Silty SAND with gravel
	> 10%		Clay	SC	< 15% Gravel	Clayey SAND
	> 10%		Clay	SC	≥ 15% Gravel	Clayey SAND with gravel

Field Description of Coarse Grained Soil Classification
Table 4-2

4.2.2 Fine-Grained Inorganic Soils

Fine-grained inorganic soils are classified into four basic groups based on physical characteristics of dry strength, dilatancy, toughness, and plasticity. These physical characteristics are summarized in Table 4-3. The index tests used to determine these physical characteristics are described in ASTM 2488. Soils that appear to be similar can be grouped together. To accomplish this, one sample is completely described, and the other samples in the group are identified as *similar* to the completely described sample.

When describing and identifying *similar* soil samples, it is generally not necessary to follow all of the procedures for index testing as outlined in ASTM 2488 for those samples.

Soil Group	Dry Strength	Dilantancy	Toughness	Plasticity
Silt (ML)	None to Low	Slow to Rapid	Low	Non-plastic
Elastic Silt (MH)	Low to Medium	None to Slow	Low to Medium	Low to Medium
Lean Clay (CL)	Medium to High	None to Slow	Medium	Medium
Fat Clay (CH)	High to Very High	None	High	High

Field Identification of Fine Grained Inorganic Soils
Table 4-3

Once the major soil group has been determined, fine grained inorganic soils can be further described by estimating the percentages of fines, sand and gravel contained in the field sample. Tables 4-4 through 4-7 should be used in describing fine-grained inorganic soils.

4.2.3 Organic Fine Grained Soils

If the soil contains enough organic particles to influence the soil properties, it should be identified as an organic fine-grained soil. Organic soils (OL/OH) usually have a dark brown to black color and may have an organic odor. Often, organic soils will change colors, for example black to brown, when exposed to the air. Organic soils will not have a high toughness or plasticity. The thread for the toughness test will be spongy. It will be difficult to differentiate between an organic silt and an organic clay. Once it has been determined that the soil is a organic fine grained soil, the soil can be further described by estimating the percentage of fines, sand, and gravel in the field sample. Table 4-8 should be used in describing an organic fine-grained soil.

Fines	Coarseness	Sand or Gravel	Description
> 70%	< 15% Plus 0.075 mm		SILT
> 70%	15 to 25 % Plus 0.075 mm	% Sand > % Gravel	SILT with Sand
> 70 %	15 to 25 % Plus 0.075 mm	% Sand < % Gravel	SILT with Gravel
< 70%	% Sand > % Gravel	< 15 % Gravel	Sandy SILT
< 70 %	% Sand > % Gravel	> 15% Gravel	Sandy SILT with gravel
< 70 %	% Sand < % Gravel	< 15 % Sand	Gravelly SILT
< 70 %	% Sand < % Gravel	> 15 % Sand	Gravelly SILT with Sand

Field Descriptions of Silt Group (ML) Soils
Table 4-4

Fines	Coarseness	Sand or Gravel	Description
> 70 %	< 15 % Plus 0.003 in. (0.075 mm)		Elastic SILT
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand > % Gravel	Elastic SILT with Sand
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand < % Gravel	Elastic SILT with Gravel
< 70 %	% Sand > % Gravel	< 15 % Gravel	Sandy Elastic SILT
< 70 %	% Sand > % Gravel	> 15 % Gravel	Sandy Elastic SILT with Gravel
< 70 %	% Sand < % Gravel	< 15 % Sand	Gravelly Elastic SILT
< 70 %	% Sand < % Gravel	> 15 % Sand	Gravelly Elastic SILT with Sand

Field Descriptions of Elastic Silt (MH) Group Soils
Table 4-5

Fines	Coarseness	Sand or Gravel	Description
> 70 %	< 15 % Plus 0.003 in. (0.075 mm)		Lean CLAY
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand > % Gravel	Lean CLAY with Sand
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand < % Gravel	Lean CLAY with Gravel
< 70 %	% Sand > % Gravel	< 15 % Gravel	Sandy Lean CLAY
< 70 %	% Sand > % Gravel	> 15 % Gravel	Sandy Lean CLAY with Gravel
< 70 %	% Sand < % Gravel	< 15 % Sand	Gravelly Lean CLAY
< 70 %	% Sand < % Gravel	> 15 % Sand	Gravelly Lean CLAY with Sand

Field Descriptions of Lean Clay Group (CL) Soils
Table 4-6

Fines	Coarseness	Sand or Gravel	Description
> 70 %	< 15 % Plus 0.003 in. (0.075 mm)		Fat CLAY
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand > % Gravel	Fat CLAY with Sand
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand < % Gravel	Fat CLAY with Gravel
< 70 %	% Sand > % Gravel	< 15 % Gravel	Sandy Fat CLAY
< 70 %	% Sand > % Gravel	> 15 % Gravel	Sandy Fat CLAY with Gravel
< 70 %	% Sand < % Gravel	< 15 % Sand	Gravelly Fat CLAY
< 70 %	% Sand < % Gravel	> 15 % Sand	Gravelly Fat CLAY with Sand

Field Description of Fat Clay Group (CH) Soils
Table 4-7

Fines	Coarseness	Sand or Gravel	Description
> 70 %	< 15 % Plus 0.003 in. (0.075 mm)		ORGANIC SOIL
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand > % Gravel	ORGANIC SOIL with Sand
> 70 %	15 to 25 % Plus 0.003 in. (0.075 mm)	% Sand < % Gravel	ORGANIC SOIL with Gravel
< 70 %	% Sand > % Gravel	< 15 % Gravel	Sandy ORGANIC SOIL
< 70 %	% Sand > % Gravel	> 15 % Gravel	Sandy ORGANIC SOIL with Gravel
< 70 %	% Sand < % Gravel	< 15 % Sand	Gravelly ORGANIC SOIL
< 70 %	% Sand < % Gravel	> 15 % Sand	Gravelly ORGANIC SOIL with Sand

Field Description of Organic Fine Grained Soil (OL/OH) Group
Table 4-8

4.2.4 Angularity

The field description of angularity of the coarse size particles of a soil (gravel, cobbles and sand) should conform to the criteria as outlined in Table 4-9.

Description	Criteria
Angular	Coarse grained particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Coarse grained particles are similar to angular description but have rounded edges
Subrounded	Coarse grained particles have nearly plane sides but have well rounded corners and edges
Rounded	Coarse grained particles have smoothly curved sides and no edges

Criteria for the Field Description of Angularity
Table 4-9

4.2.5 Consistency and Relative Density

An important index property of cohesive (plastic) soils is its consistency, and is expressed by terms such as very soft, soft, medium stiff, stiff, very stiff, hard, and very hard. Similarly, a significant index property of cohesionless (non-plastic) soils is its relative density, which is expressed by terms such as very loose, loose, medium dense, dense, and very dense. The standard penetration test (ASTM 1586) is an in-situ field test that is widely used to define cohesive soil consistency, and cohesionless soil density. Tables 4-10 and 4-11 should be used to describe consistency, or relative density.

SPT N (Blows/Foot)	Consistency
0 to 1	Very Soft
2 to 4	Soft
5 to 8	Medium Stiff
9 to 15	Stiff
16 to 30	Very Stiff
31 to 60	Hard
Over 60	Very Hard

Consistency of Cohesive Soils
Table 4-10

SPT N (Blows/Foot)	Relative Density
0 to 4	Very Loose
5 to 10	Loose
11 to 24	Medium Dense
25 to 50	Dense
Over 50	Very Dense

Relative Density of Cohesionless Soils
Table 4-11

4.2.6 Color

Soil color is not in itself a specific engineering property, but may be an indicator of other significant geologic processes that may be occurring within the soil mass. Color may also aid in the subsurface correlation of soil units. Soil color should be determined in the field at their natural moisture content. The predominant color of the soil should be based on the *Munsell Soil Color Charts.*

4.2.7 Moisture

A visual estimation of the relative moisture content of the soil should be made during the field classification. The field moisture content of the soil should be based on the criteria outlined in Table 4-12.

Moisture Description	Criteria
Dry	Absence of moisture; dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

Criteria for Describing Moisture Condition
Table 4-12

4.2.8 Structure

Soils often contain depositional or physical features that are referred to as soil structure. These features should be described following the criteria as outlined in Table 4-13.

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 0.25 in. thick; note thickness and inclination.
Laminated	Alternating layers of varying material or color with layers less than 0.25 in. thick; note thickness and inclination
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into smaller angular lumps which resists further breakdown.
Disrupted	Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris.
Homogeneous	Same color and appearance throughout.

Criteria for Describing Soil Structure
Table 4-13

4.2.9 HCl Reaction

Calcium carbonate is a common cementing agent in soils. To test for the presence of this cementing agent the soil sample should be tested with dilute hydrochloric acid (HCL). The reaction of the soil sample with HCL should be reported in accordance with the criteria outlined in Table 4-14.

HCL Reaction Description	Criteria
No HCL Reaction	No visible reaction
Weak HCL Reaction	Some reaction with bubbles forming slowly
Strong HCL Reaction	Violent reaction with bubbles forming immediately

Soil Reaction to Hydrochloric Acid
Table 4-14

4.2.10 Test Hole Logging

The protocol for field logging the test hole is to describe the soil properties in the following order:

Soil Description ⇒ Angularity ⇒ Density ⇒ Color ⇒ Moisture ⇒ Structure ⇒ HCL Reaction

Some examples of this field logging protocol are as follows:

- Well graded Gravel, with cobbles and boulders, sub-rounded, very dense, light brown, wet, homogeneous, no HCL reaction.
- Sandy SILT, medium dense, light gray, moist, laminated, no HCL reaction
- Fat CLAY with sand, medium stiff, dark gray, wet, blocky, no HCL reaction

4.3 Rock Classification

Rock classification for engineering purposes consists of two basic assessments; one based on the *intact* properties of the rock, and the other based on the *in situ* (engineering) features of the rock mass.

- **Intact properties** – This assessment is based on the character of the intact rock (hand specimens and rock core) in terms of its genetic origin, mineralogical make-up, texture, and degree of chemical alteration and/or physical weathering.
- **In situ properties** – This assessment is based on the engineering characteristics (orientation, spacing, etc.) of the bounding discontinuities (bedding, joints, foliation planes, shear zones, faults etc.) within the rockmass.

Both assessments are essential engineering characterization of the rock mass, and are the basis for rock slope design and excavation, foundation design on rock, rock anchorage, and characterizing rock quarries.

4.3.1 Intact Properties

Rocks are divided into three general categories based on genetic origin. These categories are *igneous rocks, sedimentary rocks, and metamorphic rocks.*

4.3.1.1 Igneous Rocks

Igneous rocks are those rocks that have been formed by the solidification of molten or partially molten material. Typically, they are classified based on mineralogy and genetic occurrence (intrusive or extrusive). See Table 4-15 for examples. Texture is the most conspicuous feature (key indicator) of genetic origin (see Table 4-16).

In general, coarser grained igneous rocks are intrusive having been formed (solidified) before the molten material has reached the surface; while the finer grained igneous rocks are extrusive and have formed (solidified) after the molten material has reached the surface. Although this generality is true in most cases, it must be stressed that there is no clear line between the two.

A special, but common, class of igneous rock is pyroclastic rocks (See Table 4-17). These rocks have been derived from volcanic material that has been explosively or aerially ejected from a volcanic vent.

Intrusive (Coarse-grained)	Primary Minerals	Common Accessory Minerals	Extrusive (Fine Grained)
Granite	Quartz, K-feldspar	Plagioclase, Mica, Amphibole, Pyroxene	Rhyolite
Quartz Diorite	Quartz Plagioclase	Hornblende, Pyroxene, Mica	Dacite
Diorite	Plagioclase	Mica, Amphibole, Pyroxene	Andesite
Gabbro	Plagioclase, Pyroxene	Amphibole	Basalt

Common Igneous Rocks
Table 4-15

Texture	Grain Size	Genetic Origin
Pegmatitic	Very large; diameters greater than 0.8 in.	Intrusive
Phaneritic	Can be seen with the naked eye	Intrusive or Extrusive
Porphyritic	Grained of two widely different sizes	Intrusive or Extrusive
Aphanitic	Cannot be seen with the naked eye	Extrusive or Intrusive
Glassy	No grains present	Extrusive

Igneous Rock Textures
Table 4-16

Table 4-16 should be used only as an aid in determining the possible genetic origin (intrusive versus extrusive) of the igneous rock. For grain size determination and descriptors use Table 4-23.

Rock Name	Characteristics
Pyroclastic Breccia	Pyroclastic rock whose average pyroclast size exceeds 2.5 inches and in which *angular* pyroclasts predominate.
Agglomerate	Pyroclastic rock whose average pyroclast size exceeds 2.5 inches and in which *rounded* pyroclasts predominate.
Lapilli Tuff	Pyroclastic rock whose average pyroclast size is 0.08 to 2.5 inches.
Ash Tuff	Pyroclastic rock whose average pyroclast size is less than 0.08 inches.

Pryoclastic Rocks
Table 4-17

Some extrusive volcanic rocks contain small sub-rounded to rounded cavities (vesicles) formed by the expansion of gas or steam during the solidification process of the rock. The occurrence of these vesicles are to be reported using an estimate of the relative area that the vesicles occupy in relationship to the total area of the sample and the designation as outlined in Table 4-18.

Designation	Percentage (by volume) of Total Sample
Slightly Vesicular	5 to 10 Percent
Moderately Vesicular	10 to 25 Percent
Highly Vesicular	25 to 50 Percent
Scoriaceous	Greater than 50 Percent

Degree of Vesicularity
Table 4-18

4.3.1.2 Sedimentary Rocks

Sedimentary rocks are formed from preexisting rocks. They are formed by the deposition and lithification of sediments such as gravels, sands, silts, and clays; or rocks formed by the chemical precipitation from solutions (rock salt), or from secretion of organisms (limestone). As indicated above sedimentary rocks are classified based on whether they are derived from clastic sediments or from chemical precipitates/ organisms. See Tables 4-19 and 4-20 for their classification.

Rock Name	Original Sediment
Conglomerate	Sand, Gravel, Cobbles, and Boulders
Sandstone	Sand
Siltstone	Silt
Claystone	Clay
Shale	Laminated Clay and Silt

Clastic Sedimentary Rocks
Table 4-19

Rock Name	Primary Mineral
Limestone	Calcite
Dolomite	Dolomite
Chert	Quartz

Non-Clastic Sedimentary Rocks
Table 4-20

4.3.1.3 Metamorphic Rocks

Metamorphic rocks are those rocks that have been formed from *pre-existing* rocks when mineral in the rocks have been re-crystallized to form new minerals in response to changes in temperature and/or pressure. Metamorphic rocks are classified based on two general categories; foliated and non-foliated metamorphic rocks. Foliated metamorphic rocks contain laminated structure resulting from the segregation of different minerals into layers parallel to schistosity. Non-foliated metamorphic rocks are generally re-crystallized and equigranular.

Rock Name	Texture	Formed From	Primary Minerals
Slate	Platy, fine grained	Shale, Claystone	Quartz, Mica
Phyllite	Platy, fine grained with silky sheen	Shale, Claystone, Fine grained pyroclastic	Quartz, Mica
Schist	Medium grained, with irregular layers	Sedimentary and Igneous Rocks	Mica, Quartz, Feldspar, Amphibole
Gneiss	Layered, medium to coarse grained	Sedimentary and Igneous Rocks	Mica, Quartz, Feldspar, Amphibole

Foliated Metamorphic Rocks
Table 4-21

Rock Name	Texture	Formed From	Primary Minerals
Greenstone	Crystalline	Volcanics, Intermediate - Mafic Igneous	Mica, Hornblende, Epidote
Marble	Crystalline	Limestone, Dolomite	Calcite, Dolomite
Quartzite	Crystalline	Sandstone, Chert	Quartz
Amphibolite	Crystalline	Mafic Igneous, Calcium - Iron Bearing Sediments	Hornblende, Plagioclase

Non-Foliated Metamorphic Rocks
Table 4-22

4.3.1.4 Rock Color

Rock color is not in itself a specific engineering property, but may be an indicator of the influence of other significant geologic processes that may be occurring in the rock mass (e.g. fracture flow of water, weathering, alteration, etc.). Color may also aid in the subsurface correlation of rock units. The color of the rock is based on the ***Geological Society of America Rock Color Charts***. Rock color should be determined as soon as the core has been recovered from the test hole.

4.3.1.5 Grain Size

Grain size is defined as the size of the particles or mineral crystals that make up the intact portion of the rockmass. The description of grain size should follow the criteria as set forth in Table 4-23.

Grain Size	Description	Criteria
Less than 0.04 inches	Fine grained	Few crystal boundaries/ grains distinguishable in the field or with a hand lens.
0.04 to 0.2 inches	Medium grained	Most crystal boundaries/ grains distinguishable with the aid of a hand lens.
Greater than 0.2 inches	Coarse grained	Most crystal boundaries/ grains distinguishable with the naked eye.

Grain Size
Table 4-23

4.3.1.6 Weathered State of Rock

Weathering is the process of mechanical and/or chemical degradation of the rock mass through exposure to the elements (e.g. rain, wind, ground water, ice, change in temperature etc.). In general, the strength of the rock tends to decrease as the degree of weathering increases. In the earliest stages of weathering only discoloration and slight change in texture occur. As the weathering of the rock advances significant changes occur in the physical properties of the rock mass, until ultimately the rock is decomposed to soil.

The classification of the weathered state of the rock mass is based on six weathering classes (See Table 4-24) developed by the International Society of Rock Mechanics (ISRM).

Term	Description	Grade
Fresh	No visible signs of rock material weathering; perhaps slight discoloration in major discontinuity surfaces.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering, and may be somewhat weaker externally than in its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as discontinuous framework or as corestone.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric is destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Weathered State of Rock
Table 4-24

Alteration is the process that applies *specifically* to the changes in the chemical or mineral composition of the rock due to hydrothermal or metamorphic activities. Alteration may occur in zones or pockets, and can be found at depths far below that of normal weathering. Alteration does not strictly infer that there is a degradation of the rockmass or an associated loss in strength.

Where there has been a degradation of the rockmass due to alteration, Table 4-24 may be used to describe the alteration by simply substituting the word *"altered"* for the word "*weathered*" for Grade II through Grade V.

4.3.1.6 Relative Rock Strength

Rock strength is controlled by many factors including degree of induration, cementation, crystal bonding, degree of weathering or alteration, etc. Determination of relative rock strength can be estimated by simple field tests, which can be refined, if required, through laboratory testing. The relative rock strength should be determined based on the ISRM method outlined in Table 4-25. Due to the potential for variable rock conditions, multiple relative strength designations may be required for each core run.

Grade	Description	Field Identification	Uniaxial Compressive Strength (Approx)
R0	Extremely Weak Rock	Indented by thumbnail	0.04 to 0.15 ksi
R1	Very Weak Rock	Specimen crumbles under sharp blow with point of geological hammer, and can be cut with a pocket knife.	0.15 to 3.6 ksi
R2	Moderately Weak Rock	Shallow cuts or scrapes can be made in a specimen with a pocket knife. Geological hammer point indents deeply with firm blow.	3.6 to 7.3 ksi
R3	Moderately Strong Rock	Specimen cannot be scraped or cut with a pocket knife, shallow indentation can be made under firm blows from a hammer point.	7.3 to 15 ksi
R4	Strong Rock	Specimen breaks with one firm blow from the hammer end of a geological hammer.	15 to 29 ksi
R5	Very Strong Rock	Specimen requires many blows of a geological hammer to break intact sample.	Greater than 29 ksi

Relative Rock Strength
Table 4-25

4.3.1.7 Slaking

Slaking is defined as the disintegration of a rock under conditions of wetting and drying, or when exposed to air. This behavior is related primarily to the chemical composition of the rock. It can be identified in the field if samples shrink and crack, or otherwise degrade upon drying, or being exposed to air for several hours. If degradation of the rock sample occurs, and slaking is suspected; an air-dried sample may be placed in clean water to observe a reaction. The greater the tendency for slaking, the more rapid the reaction will be when immersed in water. This tendency should be expressed on the field logs as *"potential for slaking"*, and can be confirmed through laboratory testing.

4.3.2 In Situ Properties

The in-situ properties of a rock mass are based on the engineering properties of the bounding structure within the rockmass. Structure refers to large-scale (megascopic) planar features which separate intact rock blocks, and impact the overall strength, permeability, and breakage characteristics of the rock mass. Common planar features within the rockmass include joints, bedding, and faults; collectively called **discontinuities**. These common planar features are defined as follows:

Joints – Joints are fractures within the rockmass along which there has been no identifiable displacement.

Bedding – Bedding is the regular layering in sedimentary rocks marking the boundaries of small lithological units or beds.

Faults – Faults are fractures or fracture zones within the rockmass along which there has been significant shear displacement of the sides relative to each other. The presence of gouge and/ or slickensides *may* be indicators of movement.

When defining the in-situ properties of these planar features (discontinuities) within the rockmass, the recovered rock core from the borehole is examined, and the following information recorded:

- Discontinuity Spacing
- Discontinuity Condition
- Core Recovery
- Rock Quality Designation (RQD)
- Fractures Frequency (FF)
- Voids

4.3.2.1 Discontinuity Spacing

Discontinuity spacing is the distance between *natural* discontinuities as measured along the borehole. An evaluation of discontinuity spacing within each core run should be made, and reported on the field logs in conformance with the criteria set forth in Table 4-26. Mechanical breaks caused by drilling or handling should *not* be included in the discontinuity spacing evaluation.

Description	Spacing of Discontinuity
Very Widely Spaced	Greater than 10 feet
Widely Spaced	3 feet to 10 feet
Moderately Spaced	1 feet to 3 feet
Closely Spaced	2 inches to 12 inches
Very Closely Spaced	Less than 2 inches

Discontinuity Spacing
Table 4-26

4.3.2.2 Discontinuity Condition

The surface properties of discontinuities, in terms of roughness, wall hardness, and / or gouge thickness, affects the shear strength of the discontinuity. An assessment of the discontinuities within each core run should be made, and reported on the field logs in conformance with the descriptions and conditions set forth in Table 4-27.

Condition	Description
Excellent Condition	Very rough surfaces, no separation, hard discontinuity wall.
Good Condition	Slightly rough surfaces, separation less than 0.05 inches, hard discontinuity wall.
Fair Condition	Slightly rough surface, separation greater than 0.05 inches, soft discontinuity wall.
Poor Condition	Slickensided surfaces, or soft gouge less than 0.2 inches thick, or open discontinuities 0.05 to 0.2 inches.
Very Poor Condition	Soft gouge greater than 0.2 inches, or open discontinuities greater than 0.2 inches.

Discontinuity Condition
Table 4-27

4.3.2.3 Core Recovery (CR)

Core recovery is defined as the ratio of core recovered to the run length expressed as a percentage. Therefore:

$$\frac{\text{Core Recovery (\%)} = 100 \times \text{Length of Core Recovered}}{\text{Length of Core Run}}$$

These values should be recorded on the field logs on a core run by core run basis.

4.3.2.4 Rock Quality Designation (RQD)

The RQD provides a subjective estimate of rock mass quality based on a modified core recovery percentage from a double or triple tube diamond core barrel. The RQD is defined as the percentage of rock core recovered in intact pieces of 4 inches or more in length in the length of a core run, generally 6 feet in length. Therefore:

$$\frac{\text{RQD (\%)} = 100 \times \text{Length of Core in pieces} > 4 \text{ inches}}{\text{Length of Core Barrel}}$$

Mechanical breaks caused by drilling or handling should not be included in the RQD calculation. Vertical fractures in the core should not be utilized in the RQD calculation.

4.3.2.5 Fracture Frequency (FF)

Fracture frequency is defined as the number of *natural* fractures per unit of length of core recovered. The fracture frequency is measured for each core run, and recorded on the field logs as fractures per foot. Mechanical breaks caused by drilling or handling should *not* be included in the fracture frequency count. In addition, vertical fractures in the core should *not* be utilized in the fracture frequency determination.

4.3.2.6 Voids

Voids are defined as relatively large open spaces within the rockmass caused by chemical dissolution or the action of subterranean water within the rockmass. In addition, voids can be a result of subsurface mining activities. Voids, when encountered, should be recorded on the field logs. Attempts should be made to determine the size of the void by drilling action, water loss, etc.

4.3.3 Test Hole Logging

The protocol for field logging the test hole is to first describe the *intact* properties if the rockmass followed by the description of the *in-situ* properties:

[Intact Properties] Rock Name ⇒ Rock Color ⇒ Grain Size ⇒ Weathered State ⇒ Relative Rock Strength. *then* [In-situ Properties] Discontinuity Spacing ⇒ Discontinuity Condition ⇒ Core Recovery ⇒ RQD ⇒ Fracture Frequency.

Some examples of this field logging protocol are as follows:

Diorite, medium light grey (N6), medium grained, slightly weathered, moderately strong rock (R3). [***Intact Properties***] Discontinuities are widely spaced, and in fair condition. CR = 100%, RQD = 80%, FF = 2. [***In-situ Properties***]

Basalt, highly vesicular, dark grey (N3), very fined grained, slightly weathered, fresh, strong rock (R4). [***Intact Properties***] Discontinuities are closely spaced, and in poor condition. CR = 65%, RQD = 40%, FF = 20. [***In-situ Properties***]

SILTSTONE, medium dark grey (N4), very fine grained, slightly weathered, very weak rock (R1), potential for slaking. [***Intact Properties***] Discontinuities are widely spaced, and in fair condition. CR = 100%, RQD = 100%, FF = 1. [***In-situ Properties***]

The standard legend for WSDOT boring logs is provided in Appendix 4-A.

4.4 References

Munsell Soil Color Charts, 2000, GretagMacbeth, New Windsor, NY.

Geological Society of America, 1991, *Rock Color Charts*, Boulder, CO.

Washington State
Department of Transportation

Boring and Test Pit Legend

Page 1 of 2

Sampler Symbols

Standard Penetration Test
Non-Standard Sized Penetration Test
Shelby Tube
Piston Sample
Washington Undisturbed
Vane Shear Test
Core
Becker Hammer
Bag Sample

Well Symbols

Cement Surface Seal
Piezometer Pipe in Granular Bentonite Seal
Piezometer Pipe in Sand
Well Screen in Sand
Granular Bentonite Seal
Inclinometer Casing or PVC Pipe in Cement Bentonite Grout
Sand
Vibe Wire in Grout
Miscellaneous, noted on boring log

Laboratory Testing Codes

UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
UC	Unconfined Compression Test
DS	Direct Shear Test
CN	Consolidation Test
GS	Grain Size Distribution
MC	Moisture Content
SG	Specific Gravity
OR	Organic Content
DN	Density
AL	Atterberg Limits
PT	Point Load Compressive Test
SL	Slake Test
DG	Degradation
LA	LA Abrasion
HT	Hydrometer Test
RS	Ring Shear Test
LOI	Loss on Ignition
CSS	Cyclic Simple Shear
DSS	Direct Simple Shear
RSM	Resilient Modulus

Soil Density Modifiers

Gravel, Sand & Non-plastic Silt		Elastic Silts and Clay	
SPT Blows/ft	Density	SPT Blows/ft	Consistency
0-4	Very Loose	0-1	Very Soft
5-10	Loose	2-4	Soft
11-24	Medium Dense	5-8	Medium Stiff
25-50	Dense	9-15	Stiff
>50	Very Dense	16-30	Very Stiff
(REF)	Refusal	31-60	Hard
		>60	Very Hard

Angularity of Gravel & Cobbles

Angular	Coarse particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Coarse grained particles are similar to angular but have rounded edges.
Subrounded	Coarse grained particles have nearly plane sides but have well rounded corners and edges.
Rounded	Coarse grained particles have smoothly curved sides and no edges.

Soil Moisture Modifiers

Dry	Absence of moisture; dusty, dry to touch
Moist	Damp but no visible water
Wet	Visible free water

Soil Structure

Stratified	Alternating layers of varying material or color at least 6mm thick; note thickness and inclination.
Laminated	Alternating layers of varying material or color less than 6mm thick; note thickness and inclination.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into smaller angular lumps which resist further breakdown.
Disrupted	Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris.
Homogeneous	Same color and appearance throughout.

HCL Reaction

No HCL Reaction	No visible reaction.
Weak HCL Reaction	Some reaction with bubbles forming slowly.
Strong HCL Reaction	Violent reaction with bubbles forming immediately.

Degree of Vesicularity of Pyroclastic Rocks

Slightly Vesicular	5 to 10 percent of total
Moderately Vesicular	10 to 25 percent of total
Highly Vesicular	25 to 50 percent of total
Scoriaceous	Greater than 50 percent of total

Washington State
Department of Transportation

Boring and Test Pit Legend

Page 2 of 2

Grain Size

Fine Grained	< 0.04 in	Few crystal boundaries/grains are distinguishable in the field or with hand lens.
Medium Grained	0.04 to 0.2 in	Most crystal boundaries/grains are distinguishable with the aid of a hand lens.
Coarse Grained	> 0.2 in	Most crystal boundaries/grains are distinguishable with the naked eye.

Weathered State

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discoloration in major discontinuity surfaces.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as core stones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as discontinuous framework or as core stone.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric is destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Relative Rock Strength

Grade	Description	Field Identification	Uniaxial Compressive Strength approx
R1	Very Weak	Specimen crumbles under sharp blow from point of geological hammer, and can be cut with a pocket knife.	0.15 to 3.6 ksi
R2	Moderately Weak	Shallow cuts or scrapes can be made in a specimen with a pocket knife. Geological hammer point indents deeply with firm blow.	3.6 to 7.3 ksi
R3	Moderately Strong	Specimen cannot be scraped or cut with a pocket knife, shallow indentation can be made under firm blows from a hammer.	7.3 to 15 ksi
R4	Strong	Specimen breaks with one firm blow from the hammer end of a geological hammer.	15 to 29 ksi
R5	Very Strong	Specimen requires many blows of a geological hammer to break intact sample.	Greater than 29 ksi

Discontinuities

Spacing	
Very Widely	Greater than 10 ft
Widely	3 ft to 10 ft
Moderately	1 ft to 3 ft
Closely	2 inches to 12 inches
Very Closely	Less than 2 inches

RQD (%)

$$\frac{100(\text{length of core in pieces} > 100\text{mm})}{\text{Length of core run}}$$

Condition	
Excellent	Very rough surfaces, no separation, hard discontinuity wall
Good	Slightly rough surfaces, separation less than 0.05 in, hard discontinuity wall.
Fair	Slightly rough surfaces, separation greater than 0.05 in, soft discontinuity wall.
Poor	Slickensided surfaces, or soft gouge less than 0.2 in thick, or open discontinuities 0.05 to 0.2 in.
Very Poor	Soft gouge greater than 0.2 in thick, or open discontinuities greater than 0.2 in.

Fracture Frequency (FF) is the average number of fractures per 1 ft of core. This does not include mechanical breaks caused by drilling or handling.

Datum:
NAD 83/91 HARN = North American Datum of 1983/1991 High Accuracy Reference Network
NAVD88 = North American Vertical Datum of 1988
SPN (ft) = State Plane North (ft)
SPS (ft) = State Plane South (ft)