GEOTECHNICAL DESIGN MANUAL - PART 4 OF 4

Main Category:	Civil Engineering
Sub Category:	Geotechnical Engineering
Course #:	GEO-120
Course Content:	91 pgs
PDH/CE Hours:	6

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-120 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. According to the reference material, for round shafts, the standard foundation designs assume for torsional stability that the soil to foundation contact friction angle is 45°, which is typical for concrete cast against soil for moderate strength soils.
    a. True
    b. False
2. Using Table 17-2, Design Parameter Correlations for the Design of Signal, Signs, Sign Bridge, and Luminaire Foundations, what is the allowable lateral bearing pressure of Poor solid with 10 blows/ft?
    a. 1500 psf
    b. 1300 psf
    c. 2900 psf
    d. 2100 psf
3. Using Table 17-3, Allowable Foundation and Lateral Pressure, which of the following martials has an allowable foundation pressure of 3,000 psf.
    a. Crystalline bedrock
    b. Sandy gravel
    c. Silty gravel
    d. Clay
4. Which of the following topics is not listed in the outline for Materials Source Reports according to the reference material?
    a. Slope Stability
    b. Grade of Material
    c. Quality of Material
    d. Quantity of Material

5. Using Table 17-4, Minimum Factors of Safety for ASD Foundation Design, what is the minimum Factor of safety for Wave equation with PDA (min. one per pier and 2 to 5% of the piles?
    a. 3.0
    b. 2.75
    c. 2.5
    d. 2.25
6. According to Chapter 21 of the reference material, which of the following safety factor is associate with Bank yards between 30,000 to 60,000 cubic yards?
    a. 1.35
    b. 1.25
    c. 1.45
    d. 1.70
7. According to Chapter 17 of the reference material, if a building surface area of 1,000-3,000 square feet was being examined, how many explorations points are needed at a minimum?
    a. 1
    b. 2
    c. 3
    d. 4
8. According to Chapter 23 of the reference material, any report can take the memorandum format, instead of the Formal bound report, regardless of subject matter.
    a. True
    b. False
9. According to Chapter 21 of the reference material, to minimize exploration costs representative samples can be collected from existing cut faces for quality testing that includes Specific Gravity, Los Angeles Abrasion, and Degradation
    a. True
    b. False
10. Using Table 17-3, Allowable Foundation and Lateral Pressure, which of the following martials has a lateral bearing of 1,200 psf/ft blow natural grade?
    a. Crystalline bedrock
    b. Sandy gravel
    c. Silty gravel
    d. Clay

Washington State Department of Transportation

Geotechnical Design Manual

M 46-03.14

June 2021

PART 4 OF 4

Environmental and Regional Operations
Construction Division
Geotechnical Office

Chapter 16 Geosynthetic Design

16.1 Overview

This chapter addresses the design of geosynthetics in the following applications:

- Underground drainage, including prefabricated drainage strips
- Soil separation
- Soil stabilization
- Permanent erosion control
- Silt fences
- Base reinforcement for embankments over soft ground
- Geomembranes

Investigation and design of geosynthetic walls and reinforced slopes is addressed in Chapter 15.

16.2 Development of Design Parameters for Geosynthetic Application

For underground drainage design, information regarding the gradation and density of the soil in the vicinity of the geosynthetic drain, as well as details regarding the likely sources of water to the drain, including groundwater, is needed. For shallow systems, hand holes will be adequate for this assessment. For drainage systems behind retaining walls, test holes may be needed. In general, the geotechnical site investigation conducted for the structure itself will be adequate for the drainage design.

In general for soil stabilization and separation, hand holes coupled with Falling Weight Deflectometer (FWD) test results will be adequate for design purposes. For extremely soft subgrade soils, subgrade shear strength data may be needed to allow a subgrade reinforcement design to be conducted.

For permanent erosion control, the gradation characteristics of the soil below the geotextile layer, and measurement of the groundwater, are important to the geosynthetic design. Test holes or test pits will be needed at key locations where permanent erosion control geotextiles are planned to be used.

Investigation for silt fences can generally be done by inspection, as silt fence design is, in general, standardized.

Investigation for base reinforcement of embankments over soft ground is addressed in Chapter 9.

For geomembrane design, groundwater information and soil gradation information is usually needed. If the geomembrane is to be placed on a slope, the geotechnical data needed to investigate slope stability will need to be obtained (see Chapters 7, 9, and 10).

16.3 Design Requirements

For Standard Specification geosynthetic design (underground drainage, separation, soil stabilization, permanent erosion control, silt fences, and prefabricated drainage strips), the *Design Manual* M 22-01 Chapter 630, shall be used for geosynthetic design. For situations where a site specific geosynthetic design is required, FHWA manual No. FHWA HI-95-038 "Geosynthetic Design and Construction Guidelines – Participant Notebook" (Holtz, et al., 1995) shall be used. For base reinforcement of embankments over soft ground, the FHWA manual identified above shall be used for design in addition to the requirements in Chapter 9. For geomembrane design, the above referenced FHWA manual should be used.

16.4 References

Holtz, R. D., Christopher, B. R., and Berg, R. R., 1995, Geosynthetic Design and Construction Guidelines, Federal Highway Administration, FHWA HI-95-038.

Design Manual M 22-01

Chapter 17 Foundation Design for Signals, Signs, Noise Barriers, Culverts, and Buildings

17.1 General

17.1.1 Overview

This chapter covers the geotechnical design of lightly loaded structures which include: noise barriers, sign bridges, cantilevered signs and signals, strain pole standards, luminaires, culverts not supported on foundation elements, and small buildings. Small buildings typically include single story structures such as structures in park and ride lots, rest areas, or WSDOT maintenance facilities. Standard Plan designs found in the *Standard Plans For Road, Bridge and Municipal Construction* M 21-01 have been developed for all of these structures except for small buildings and culverts. Both shallow (e.g. spread footings) and moderately deep foundations (trenches and shafts) have been designed to support these lightly loaded structures in a variety of soil and site conditions. The structural design of these facilities is addressed in the *Bridge Design Manual* and *Design Manual* M 22-01.

17.1.2 Site Reconnaissance

General procedures for site reconnaissance are presented in Chapter 2. Prior to the site reconnaissance, the location of the structures should be staked in the field, or an accurate and up-to-date set of site plans identifying the location of these structures should be available. An office review of all existing data pertinent to the site and the proposed foundations (see Chapter 2) should also be conducted prior to the site reconnaissance.

During the site reconnaissance, observations of the condition of existing slopes (natural and cut) in the immediate vicinity of the structures should be inspected for performance. It is especially important to establish the presence of high ground water and any areas of soft soil. Many of these structures have very shallow foundations and the investigation may only consist of general site reconnaissance with minimal subsurface investigation. The geotechnical designer should have access to detailed plan views showing existing site features, utilities, proposed construction and right-of-way limits. With this information, the geotechnical designer can review structure locations, making sure that survey information agrees reasonably well with observed topography. The geotechnical designer should look for indications of soft soil and unstable ground. Observation of existing slopes should include vegetation, in particular the types of vegetation that may indicate wet soil. Equisetum (horsetail), cattails, blackberry and alder can be used to identity wet or unstable soils. Potential geotechnical hazards such as landslides that could affect the structures should be identified. The identification and extent/condition (i.e., thickness) of existing man-made fills should be noted, because many of these structures may be located in engineered fills. Surface and subsurface conditions that could affect constructability of the foundations, such as the presence of shallow bedrock, or cobbles and boulders, should be identified.

17.1.3 Field Investigation

If the available geotechnical data and information gathered from the site review is not adequate to make a determination of subsurface conditions as required herein, then new subsurface data shall be obtained. Explorations consisting of geotechnical borings, test pits and hand holes or a combination thereof shall be performed to meet the investigation requirements provided herein. As a minimum, the subsurface exploration and laboratory test program should be developed to obtain information to analyze foundation stability, settlement, and constructability with respect to:

- Geological formation(s)
- Location and thickness of soil and rock units
- Engineering properties of soil and rock units such as unit weight, shear strength and compressibility
- Groundwater conditions (seasonal variations)
- Ground surface topography
- Local considerations, (e.g., liquefiable soils, expansive or dispersive soil deposits, underground voids from solution weathering or mining activity, or slope instability potential)

Standard foundations for sign bridges, cantilever signs, cantilever signals and strain pole standards are based on allowable lateral bearing pressure and angle of internal friction of the foundation soils. The determination of these values can be estimated by Standard Penetration Test (SPT). Portable Penetrometer Tests (PPT) may be used to obtain the soil data provided the blow count data is properly converted to an equivalent standard penetrometer "N" value. The designer should refer to Chapter 3 for details regarding the proper conversion factors of PPT to SPT. Every structure foundation location does not need to be drilled. Specific field investigation requirements for the structures addressed in this chapter are summarized in Table 17-1.

<table>
<tr><th>Structure Type</th><th>Field Investigation Requirements</th></tr>
<tr><td>Cantilever signals, strain poles, cantilever signs, sign bridges, and luminaires</td><td>Only a site review is required if the new structures are founded in new or existing embankments known to be constructed of gravel or select borrow and compacted in accordance with Method B or C of the WSDOT Standard Specifications. Otherwise, subsurface conditions should be verified using SPT, or PPT tests and hand augers for shallower foundations) should be performed. For foundations within approximately 75 feet of each other or less, such as at a small to moderate sized intersection, one exploration point for the foundation group is adequate if conditions are relatively uniform. For more widely spaced foundation locations, or for more variable site conditions, one boring near each foundation should be obtained. The depth of the exploration point should be equal to the maximum expected depth of the foundation plus 2 to 5 feet.</td></tr>
<tr><td>Noise barriers</td><td>For noise barriers less than 100 feet in length, the exploration should occur approximately midpoint along the alignment and should be completed on the alignment of the noise barrier face. For noise barriers more than 100 feet in length, exploration points should be spaced every 200 to 400 feet, depending on the uniformity of subsurface conditions. Locate at least one exploration point near the most critical location for stability. Exploration points should be completed as close to the alignment of the noise barrier face as possible. For noise barriers placed on slopes, an additional boring off the wall alignment to investigate overall stability of the wall-slope combination should be obtained.</td></tr>
<tr><td>Building foundations</td><td>The following minimum guidelines for frequency of explorations should be used. Borings should be located to allow the site subsurface stratigraphy to be adequately defined beneath the structure. Additional explorations may be required depending on the variability in site conditions, building geometry and expected loading conditions.
<table>
<tr><th>Building surface area (ft^2)</th><th>Explorationpoints (minimum)</th></tr>
<tr><td><200</td><td>1</td></tr>
<tr><td>200 - 1000</td><td>2</td></tr>
<tr><td>1000 – 3,000</td><td>3</td></tr>
<tr><td>>3,000</td><td>3 - 4</td></tr>
</table>
The depth of the borings will vary depending on the expected loads being applied to the foundation and/or site soil conditions. The borings should be extended to a depth below the bottom elevation of the building foundation a minimum of 2.5 times the width of the spread footing foundation or 1.5 times the length of a deep foundation (i.e., piles or shafts). Exploration depth should be great enough to fully penetrate soft highly compressible soils (e.g., peat, organic silt, soft fine grained soils) into competent material suitable bearing capacity (e.g., stiff to hard cohesive soil, compact dense cohesionless soil or bedrock).</td></tr>
<tr><td>Culverts (without foundation elements)</td><td>If no new fill is being placed, the culvert diameter is 3 feet or less, soft soil is known to not be present immediately below the culvert, and the culvert is installed by excavating through the fill, only a site and office review conducted as described in Chapter 2 is required, plus hand holes to obtain samples for pH and resistivity sampling for corrosion assessment for the culvert. If new fill is being placed, the borings obtained for the design of the fill itself may suffice (see Chapter 9), provided the stratigraphy below the length of the culvert can be defined. Otherwise, a minimum of two borings should be obtained, one near the one-third or one-quarter points toward each end of the culvert. For culverts greater than 300 feet in length, an additional boring near the culvert midpoint should be obtained. Borings should be located to investigate both the subsurface conditions below the culvert, and the characteristics of the fill beside and above the culvert if some existing fill is present at the culvert site. If the culvert is to be jacked through existing fill, borings in the fill and at the jacking and receiving pit locations should be obtained, to a depth of 3 to 5 feet below the culvert for the boring(s) in the fill, and to the anticipated depth of the shoring/reaction frame foundations in the jacking and receiving pits.
Hand holes and portable penetrometer measurements may be used for culverts with a diameter of 3 feet or less, if the depth of exploration required herein can be obtained. Otherwise, SPT and/or CPT borings must be obtained.</td></tr>
</table>

In addition to the exploration requirements in Table 17-1, groundwater measurements conducted in accordance with Chapter 2 should be obtained if groundwater is anticipated within the minimum required depths of the borings as described herein.

Field Investigation Requirements for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, Luminaires, Noise Barriers, and Buildings
Table 17-1

17.2 Foundation Design Requirements for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires - General

The standard foundation designs provided in the Standard Plans for cantilever signals, strain poles, cantilever signs, sign bridges, and luminaires should be used if the applicable soil and slope conditions as described herein for each of these structures are present. If soil or rock conditions not suitable for standard foundations are present, if conditions are marginal, or if nonstandard loadings are applied, a detailed foundation analysis should be conducted. Design for cantilever signals, strain poles, cantilever signs, sign bridges, and luminaires shall be performed in accordance with the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO, 2001).

17.2.1 Design by Correlation for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires

WSDOT standard foundation designs for cantilever signals, strain poles, cantilever signs, sign bridges, and luminaires are based on allowable lateral bearing pressures and soil friction angles developed from correlation (Patterson, 1962) and many years of WSDOT experience for the design of these types of small foundations. The original correlation was based on the measured resistance to pull out a 1.5 inch diameter auger through the foundation soil. The correlation reported by Patterson (1962) ranged from a 200 lbs pullout force in “very soft soil” that was equated to an allowable lateral bearing of 1,000 psf, to a 750 to 1,000 lbs pullout force in “average soil” equated to an allowable lateral bearing of 2,500 psf, and to a pullout force of 2,000 to 2,500 lbs in “very hard soil” equated to an allowable lateral bearing of 4,500 psf. For WSDOT use, this correlation was conservatively related to SPT N values (uncorrected for overburden pressure) using approximate correlations between soil shear strength and SPT N values such as provided in AASHTO (1988). The allowable lateral bearing pressures that resulted from this correlation is presented in Table 17-2. This correlation is based on uncorrected N values (not corrected for overburden pressure).

A friction angle for the soil is also needed for the foundation design for these structures, typically to evaluate torsional stability. See Chapter 5 for the determination of soil friction angles, either from correlation to SPT N values, or from laboratory testing.

Table 17-2 should be used to check if standard foundation designs are applicable for the specific site. The values in Table 17-2 may also be used for special site specific foundation design to adjust depths or dimensions of standard foundations (except noise barriers) to address soil conditions that are marginal or poorer than the conditions assumed by the standard foundation design, or to address nonstandard loadings. In such cases, the values from Table 17-2 should be used as the allowable soil pressure S_1 in Article 13.10 of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO, 2001).

Soil Consistency as Identified in Patterson (1962)	Standard Penetration Test Resistance, N (blows/ft)	Allowable Lateral Bearing Pressure (psf)
Very Soft Soil	2	750
	3	800
	4	900
	5	1000
	6	1100
	7	1200
Poor Soil	8	1300
	9	1400
	10	1500
	11	1700
	12	1900
Average Soil	13	2100
	14	2300
	15	2500
	16	2700
	17	2900
Good Soil	18	3100
	19	3300
	20	3500
Very Hard Soil	25	4200
	30	>4500
	35	>4500

Design Parameter Correlations for the Design of Signal, Signs, Sign Bridge, and Luminaire Foundations
Table 17-2

Some additional requirements regarding characterization of marginal soil conditions are as follows:

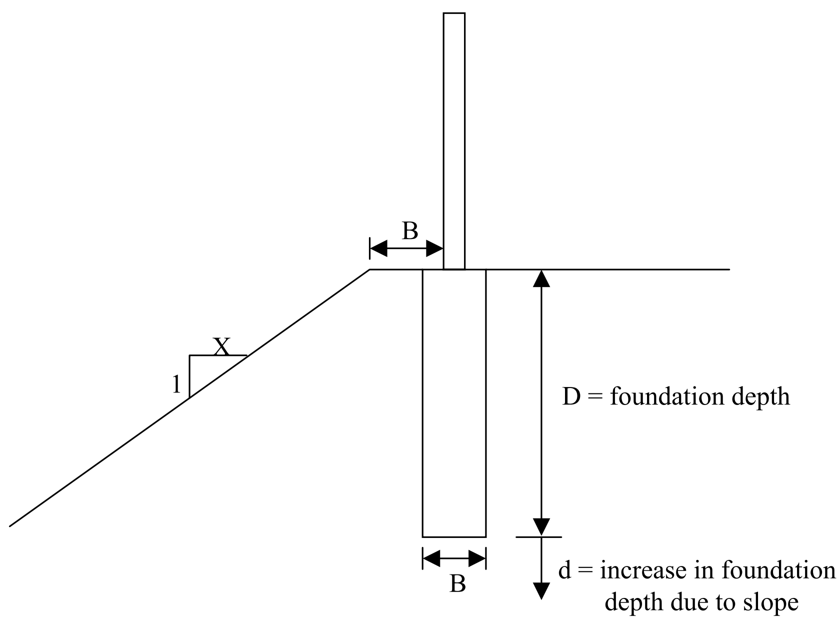
- Consider the soil throughout the entire depth of the proposed foundation. Where the foundation soil is stratified, a weighted average N value should be used to design the foundation. An exception would be where soft soils are encountered at the ground surface, in which case the use of a weighted average is not appropriate.
- For foundations installed in embankments constructed from select or gravel borrow compacted using Method B or C in the WSDOT Standard Specifications, it can generally be assumed that standard foundations can be used, as such embankments will generally have “N” values of 25 or more, which are more than adequate for standard foundations. A standard foundation may also be used where 75% or more of the foundation is to be placed in new fill, provided that the foundation soil below the fill has a SPT of 8 or more. For Common Borrow compacted using Method B or C in the WSDOT Standard Specifications, standard foundations designed allowable lateral bearing pressures of 2,000 psf or less may be used.

- In general, vertical loads for sign, signal, and luminaire structure foundations are very low (i.e., 2 ksf or less) and usually do not control design. However, if it is discovered that very soft silts, clays, or peat (say, N = 4 or less) is present within the bottom 1 to 2 feet or more of the foundation, consideration should also be given to a special foundation design in this case to avoid direct bearing on these very soft soils.

The allowable lateral soil bearing values in Table 17-2 apply only to relatively flat conditions. If sloping ground is present, some special considerations in determining the foundation depth are needed. Always evaluate whether or not the local geometry will affect the foundation design. For all foundations placed in a slope or where the centerline of the foundation is less than 1B for the shoulder of the slope (B = width or diameter of the Standard Foundation), the Standard Plan foundation depths should be increased as follows, and as illustrated in Figure 17-1:

- For slopes 3H:1V or flatter, no additional depth is required.
- For 2H:1V or flatter, add 0.5B to the depth.
- For 1.5H:1V slopes, add 1.0B to the depth.

Interpolation between the values is acceptable. These types of foundations should not be placed on slopes steeper than 1.5H:1V. If the foundation is located on a slope that is part of a drainage ditch, the top of the standard foundation can simply be located at or below the bottom of the drainage ditch.



Foundation Design Detail for Sloping Ground
Figure 17-1

Note that these sloping ground recommendations do not apply to luminaire foundations.

When a nonstandard foundation design using Table 17-2 is required, the geotechnical designer must develop a table identifying the soil units, soil unit boundary elevations, allowable lateral bearing pressure, and soil friction angle for each soil unit. The structural designer will use these data to prepare the nonstandard foundation design.

17.2.2 Special Design for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires

For foundations in rock, a special design is always required, and Table 17-2 is not applicable. Fracturing and jointing in the rock, and its effect on the foundation resistance, must be evaluated. In general, a drilled shaft or anchored footing foundation will be required. Foundation designs based on Table 17-2 are also not applicable if the foundation soil consists of very soft clays, silts, organic silts, or peat. In such cases, a footing designed to “float” above the very soft compressible soils, over-excavation and replacement with higher quality material, or very deep foundations are typically required.

For shaft type foundations in soil, the Broms Method as specified in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO, 2001) or the procedures specified in Chapter 8 for lateral load analysis of deep foundations (e.g., P-y analysis) should be used for conditions where Table 17-2 is not applicable, or as an alternative to Table 17-2 based design. For shafts in rock, nominal lateral resistance should be estimated based on the procedures provided in Chapter 8. This means that for special lateral load design of shaft foundations, the geotechnical designer will need to provide P-y curve data to the structural designer to complete the soil-structure interaction analysis. For spread footing design, the design methods provided in Chapter 8 to estimate nominal bearing resistance and settlement should be used, but instead of the referenced load groups and resistance factors, the AASHTO Standard Specifications for Highway Bridges (2002) combined with a minimum bearing capacity safety factor of 2.3 for Load Factor Design (LFD), or 3.0 for allowable stress or service load design (ASD) should be used for static conditions, and a safety factor of 1.1 should be used for seismic conditions, if seismic conditions are applicable. Note that in general, the foundations for the types of structures addressed in this chapter are not mitigated for liquefaction (see Chapter 6). For anchored footing foundations over bedrock, anchor depth, spacing, and nominal resistance shall be assessed considering the degree of fracturing and jointing in the rock (see Chapters 5, 8, and 12 for design requirements).

17.2.3 Cantilever Signals and Strain Pole Standards

17.2.3.1 Overview

There are eight types of cantilever signal and strain poles standards that are covered in Section J-7 of the WSDOT Standard Plans. Type PPB (pedestrian push bottom pole), PS (pedestrian head standard), Type I/RM (vertical head and ramp meter), Type FB (flashing beacon standard) and Type IV (strain pole standard) are structures that generally consist of a single vertical metal pole member. Type II (mast arm standard), Type III (lighting and mast arm standard) and Type V (lighting and strain pole standard) have a vertical metal pole member with a horizontal mast arm. Lights and/or signals will be suspended from the mast arm. The standard signal foundations designs assume that the foundation soil is capable of withstanding the design lateral soil bearing pressure created by wind and dead loads. The details on the foundation designs can be found in Section J-7 of the *Standard Plans*, in the Signing Foundations Chapter 1020 and Signal Foundations Chapter 1330 of the *Design Manual* M 22-01.

17.2.3.2 Standard Foundation Designs

The standard foundations for these structures consist of square or round shafts that vary in diameter from 1.5 feet to 3.0 feet for square and 2.0 feet to 4.0 feet for round shaft foundations. The standard designs assume a concrete to soil contact. For structure types PPB, PS and I/RM, the foundation depths are quite shallow and vary between 1.5 feet and 3.0 feet in depth. Foundation depths vary from 6 feet to 15 feet for signal structure Types II, III, IV and V. Standard foundations for signal structures Types PPB, PS and I are designed for 1500 psf ($N \geq 10$ bpf) average allowable lateral bearing pressure. Standard foundations for signal structures Types II, III, IV and V have been designed for 1000 psf ($N \geq 5$ bpf), 1500 psf ($N \geq 10$ bpf), and 2500 psf ($N \geq 15$ bpf) average allowable lateral bearing pressure. If the foundation is placed in new compacted fill – standard foundations may be used as specified in Section 17.2.1.

For round shafts, the standard foundation designs assume for torsional stability that the soil to foundation contact friction angle is 30^o, which is typical for concrete cast against soil for moderate strength soils.

17.2.3.3 Construction Considerations

Structures that require short round or square foundations (i.e. < than 9 feet) could be easily formed in an open excavation. The backfill placed around the foundation in the excavation must be compacted in accordance with the WSDOT Standard Specifications M41-10, Section 2-09.3(1)E and using high quality soil backfill. Foundation construction shall be in accordance with the WSDOT Standard Specifications M41-10, Sections 8-20.3(2) and 8-20.3(4). Following the removal of the concrete forms (the forms can be left in place if corrugated metal pipe is used), compacted backfill shall be placed around the shaft to provide containment. If the backfill cannot be properly compacted, then controlled density fill could be used instead.

Deep shaft foundations greater than 9 feet may require the use of temporary casing, slurries or both. Generally in most cases, the temporary casing can be removed. Special foundations designs may be required if the geotechnical designer determines that permanent casing is necessary. In this situation, the structural designer must be informed of this condition. These structures are under lateral and rotational loads. The shear capacity of the foundation under a rotational force is reduced if steel casing remains in the ground. It is important to note here that if the foundation design assumes that the soil around the shaft, assuming the contractor makes an open excavation and then backfills the excavation cavity around the formed foundation, is properly compacted, the degree of compaction is somehow verified in the field. The geotechnical designer needs to make sure that the construction specifications are clear in this regard, and that the project inspectors know what needs to be done to enforce the specifications. If the degree of compaction cannot be verified in the field due to the depth of the open excavation and safety regulations, this needs to be taken into consideration in the selection of soil design parameters. The specifications also need to be clear regarding the removal of temporary forms (e.g., sonotubes) for the foundations. If for some reason they cannot be removed due to the depth of the hole or other reasons, sonotubes should not be used. Instead, corrugated metal pipe should be used so that torsional resistance of the foundation is maintained.

17.2.4 Cantilever and Sign Bridges

17.2.4.1 Overview

Sign bridge foundation details are shown in the WSDOT Standard Plan G-2a. There are three foundations types and they are identified as Type 1, 2 and 3. Type 1 sign bridge foundations consist of a single 3 feet diameter drilled shaft with a shaft length that can vary between 11.5 and 16.5 feet. The shaft length is a function of the sign bridge span length which can vary less than 60 feet to a maximum of 150 feet. Type 2 and 3 foundations consist of massive concrete trench foundations that are 3 feet × 10 feet in plan area with a embedment that can vary between 5.5 feet to 11.5 feet depending on span length. All designs assume a concrete to soil contact.

There are three cantilever sign foundation types in the WSDOT Standard Plans. The structural details are shown in Standard Plan G-3a. These foundations are similar to the sign bridge foundations. Type 1 cantilever sign foundations consist of two 10 feet long drilled shafts. The Type 2 and 3 foundations are a massive concrete trench foundation that is 3 feet × 10 feet in plan area with an embedment that can vary between 8 feet and 12.5 feet. Embedment depth of the foundation is controlled by the total square feet of exposed sign area. All designs assume a concrete to soil contact.

17.2.4.2 Standard Foundation Designs

Standard foundation for cantilevered and sign bridges Types 1 and 2 have been prepared assuming the site soils meet a minimum 2,500 psf allowable lateral bearing pressure. Using the Table 17-2, a soil with a penetration resistance $N \geq 15$ would provide adequate support for these structures. A Type 3 foundation was designed for slightly poorer soils using a lateral bearing pressure of 1,500 psf for structural design. Using Table 17-2, a soil with a penetration resistance of ≥10 bpf would provide adequate lateral resistance for a Type 3 foundation.

17.2.4.3 Construction Considerations

The construction of the trench footings may be performed as a cast-in-place foundation that is poured directly against the soils, or they could be constructed in a large open excavation using wide trench boxes and concrete forms. If a standard foundation design is to be used, but is installed in an open excavation, the backfill placed around the foundation in the excavation must be compacted in accordance with Method C of the WSDOT Standard Specifications and using high quality soil backfill.

The geotechnical designer must evaluate the stability of open excavations. Obviously, high groundwater could affect the stability of the side slopes of the excavation. Casing for drilled shafts or shoring boxes for the trench footing would be required under these conditions. All of these foundations have been designed assuming a concrete to soil contact. Generally in most cases, the temporary casing for drilled shafts can be removed. Special foundations designs may be required if the geotechnical designer determines that permanent casing is necessary. In this situation, the structural engineer must be informed of this condition. These structures are under lateral and rotational loads. The shear capacity of the foundation under a rotational force is reduced if steel casing remains in the ground.

It is important to note here that if the foundation design assumes that the soil around the shaft, assuming the contractor makes an open excavation and then backfills the excavation cavity around the formed foundation, is properly compacted, the degree of compaction is somehow verified in the field. The geotechnical designer needs to make sure that the construction specifications are clear in this regard, and that the project inspectors know what needs to be done to enforce the specifications. If the degree of compaction cannot be verified in the field due to the depth of the open excavation and safety regulations, this needs to be taken into consideration in the selection of soil design parameters. The specifications also need to be clear regarding the removal of temporary forms (e.g., sonotubes) for the foundations. If for some reason they cannot be removed due to the depth of the hole or other reasons, sonotubes should not be used. Instead, corrugated metal pipe should be used so that torsional resistance of the foundation is maintained.

17.2.5 Luminaires (Light Standards)

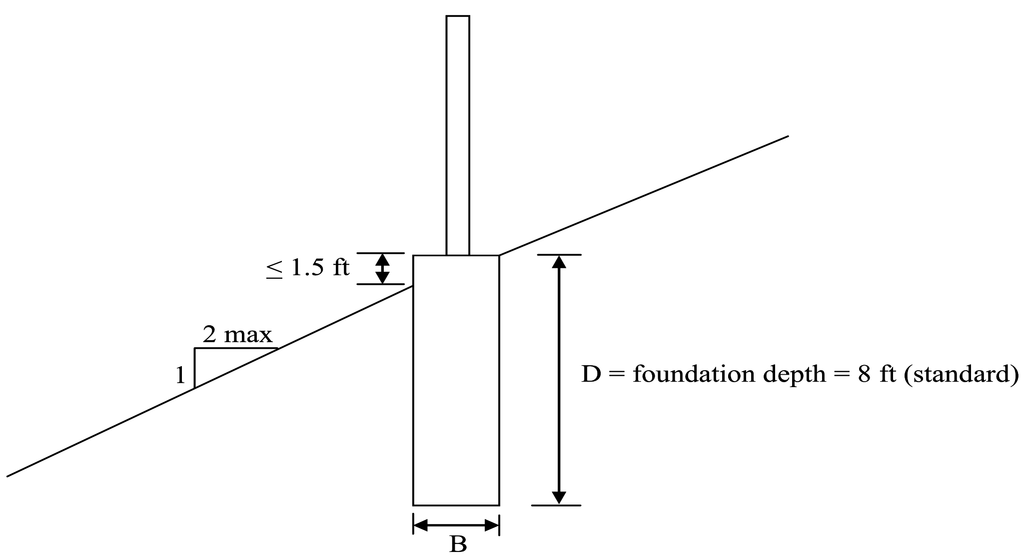
17.2.5.1 Overview

Standard luminaire (light standard) foundations consist of 3 feet diameter round shafts. The foundation details are shown in WSDOT Standard Plan J-1b. The standard foundation depth is 8 feet.

17.2.5.2 Standard Foundation Design

Standard foundations for luminaires (light standards) have been prepared assuming the site soils meet a minimum 1,500 psf allowable lateral bearing pressure. Using the Table 17-2, a soil with a penetration resistance N ≥ 10 would provide adequate support for these structures. The standard foundation design is applicable for foundations on slopes of 2H:1V or flatter as shown in Figure 17-2.

The standard foundation designs assume for torsional stability that the soil to foundation contact friction angle is 30°, which is typical for concrete cast against soil for moderate strength soils.



Luminaire Foundation Design Detail for Sloping Ground
Figure 17-2

17.2.5.3 Construction Considerations

Luminaire foundations could be easily formed in an open excavation. The backfill placed around the foundation in the excavation must be compacted in accordance with the WSDOT Standard Specifications M41-10, Section 2-09.3(1)E and using high quality soil backfill. Foundation construction shall be in accordance with the WSDOT *Standard Specifications* M41-10, Sections 8-20.3(2) and 8-20.3(4). Following the removal of the concrete forms (the forms can be left in place if corrugated metal pipe is used), compacted backfill shall be placed around the shaft to provide containment. If the backfill cannot be properly compacted, then controlled density fill could be used instead.

Deep shaft foundations (i.e., special designs) greater than 9 feet may require the use of temporary casing, slurries or both. Generally, in most cases, the temporary casing can be removed. Special foundations designs may be required if the geotechnical designer determines that permanent casing is necessary. In this situation, the structural designer must be informed of this condition. These structures are under lateral and rotational loads. The shear capacity of the foundation under a rotational force is reduced if steel casing remains in the ground.

It is important to note here that if the foundation design assumes that the soil around the shaft, assuming the contractor makes an open excavation and then backfills the excavation cavity around the formed foundation, is properly compacted, the degree of compaction is somehow verified in the field. The geotechnical designer needs to make sure that the construction specifications are clear in this regard, and that the project inspectors know what needs to be done to enforce the specifications. If the degree of compaction cannot be verified in the field due to the depth of the open excavation and safety regulations, this needs to be taken into consideration in the selection of soil design parameters. The specifications also need to be clear regarding the removal of temporary forms (e.g., sonotubes) for the foundations. If for some reason they cannot be removed due to the depth of the hole or other reasons, sonotubes should not be used. Instead, corrugated metal pipe should be used so that torsional resistance of the foundation is maintained.

17.3 Noise Barriers

17.3.1 Overview

There are 20 standard designs for noise barriers that are covered in WSDOT Standard Plans D-2a through D-2t. The Standard Plans contains detailed designs of seven cast-in-place concrete, seven pre-cast concrete, and five masonry block noise barriers.

Three foundation options are available for the cast-in-place and pre-cast concrete barriers. They include round shafts and spread footings. The spread footing foundation option has two designs. One design consists of an offset panel and a second design consists of a uniform panel where the panel wall bears in the middle of the footing. The following is a summary of the critical design elements of noise barrier walls:

- All noise barrier spread footing standard foundations have been designed assuming an allowable bearing pressure of 2 kips per square foot (ksf).
- The diameter and length of the standard shaft foundations can also vary with soil condition, exposed panel height and loading condition. The lengths vary from 4.75 feet to 13.25 feet, and shaft diameters vary between 1.0 to 2.5 feet.

17.3.2 Foundation Design Requirements for Noise Barriers

Foundation design for noise barrier shall be conducted in accordance with the most current AASHTO Guide Specifications for Structural Design of Sound Barriers, including interims (AASHTO 1989). Currently, design of noise barriers is based on Load Factor Design (LFD). Therefore, the load factors and safety factors specified in the AASHTO manual for sound barrier foundation design, except as specifically required in this chapter of the GDM, should be used.

In addition, the geotechnical designer shall perform a global stability analysis of the noise barrier when the barrier is located on or at the crest of a cut or fill slope. The design slope model must include a surcharge load equal to the footing bearing stress. The minimum slope stability factor of safety of the structure and slope shall be 1.3 or greater for static conditions and 1.1 for seismic conditions. Note that in general, the foundations for noise barriers are not mitigated for liquefaction (see Chapter 6).

All Standard Plan noise barrier structures have been designed to retain a minimal amount of soil that must be no more than 4 feet in height with a level backslope. The retained soil above the noise barrier foundation is assumed to have a friction angle of 34° and a wall interface friction of 0.67ϕ, resulting in a K_a of 0.26 for the retained soil, and a unit weight of 125 pcf. All standard and non-standard noise barrier foundation designs shall include the effects of any differential fill height between the front and back of the wall.

17.3.2.1 Spread Footings

For spread footing design, the design methods provided in Chapter 8 to estimate nominal bearing resistance and settlement should be used, but instead of the referenced load groups and resistance factors, the AASHTO Guide Specifications for Structural Design of Sound Barriers (1989) and AASHTO Standard Specifications for Highway Bridges (2002) combined with a minimum bearing capacity safety factor of 2.3 for Load Factor Design (LFD), or 3.0 for allowable stress or service load design (ASD) should be used for static conditions, and a safety factor of 1.1 should be used for seismic conditions, if seismic conditions are applicable. Note that in general, the foundations for noise barriers are not mitigated for liquefaction (see Chapter 6).

The noise barrier footing shall be designed to be stable for overturning and sliding. The methodology and safety factors provided in the AASHTO Standard Specifications for Highway Bridges (2002) applicable to gravity walls in general for overturning and sliding (FS of 2.0 and 1.5, respectively for static conditions, and 1.5 and 1.1 for seismic conditions), shall be used to assess noise barrier stability for these two limit states, using service loads.

The geotechnical designer will also be responsible to estimate foundation settlement using the appropriate settlement theories and methods as outlined in Chapter 8. The geotechnical designer will report the estimated total and differential settlement.

The soil properties (unit weight, friction and cohesion) shall be determined using the procedures described in Chapter 5.

Noise barrier footings shall be located relative to the final grade to have a minimum soil cover over the top of the footing of 2 feet.

For the Standard Plan noise barrier footing foundation, the geotechnical designer shall use the procedures described above to estimate the allowable bearing resistance for the foundation with consideration to the actual site and subsurface conditions for the wall, and to verify that the allowable bearing resistance is greater than the standard foundation design bearing stress of 2.0 ksf. Note that the standard noise barrier foundations have been designed to resist a PGA of 0.35g. This corresponds to a peak bedrock acceleration (PBA) from Figure 6-6 in Chapter 6 of 0.3g and an amplification factor of 1.18, corresponding to stiff soil.

For nonstandard noise barrier designs, use Mononabe-Okabe analysis in accordance with Chapter 15 to determine the seismic earth pressure if the noise barrier retains soil.

17.3.2.2 Shaft Foundations

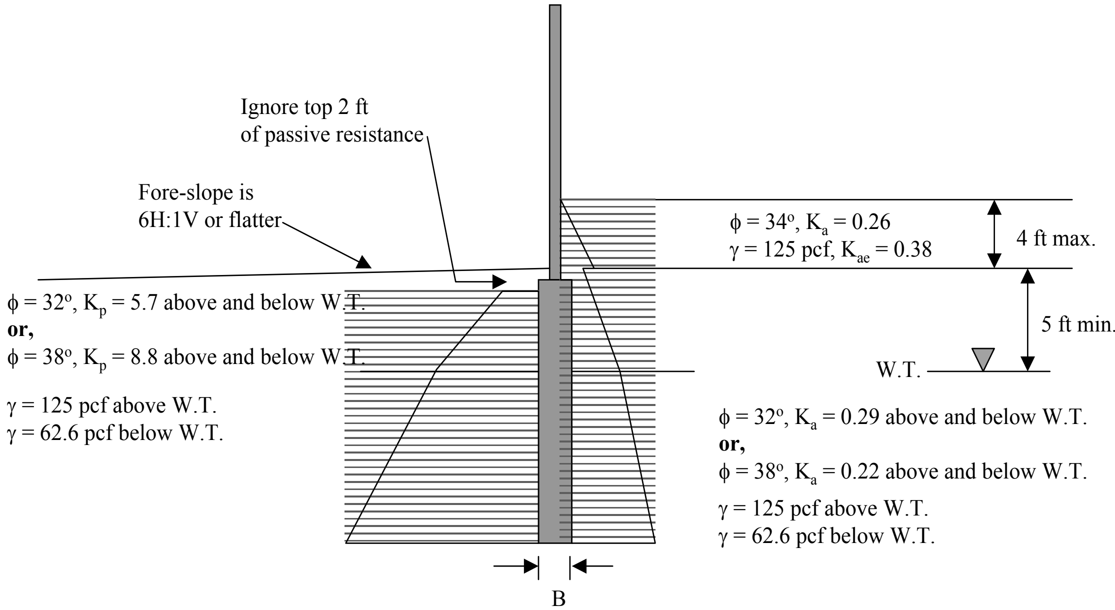
In general, shaft supported noise barriers are treated as non-gravity cantilever walls for foundation design. Shaft foundations have been designed for Standard Plan noise barriers using two soil strength conditions. D1 and D2 trench and shaft foundations have been designed assuming a soil friction of 32 and 38 degrees respectively. The geotechnical designer is responsible to determine the in-situ soil strength parameters using the appropriate field correlations and/or laboratory tests as described in Chapter 5. The geotechnical designer provides recommendations as to which deep foundation(s) is appropriate for inclusion in the contract plans. If the soil strength parameters lie between 32 and 38 degrees, the foundation design based on 32 degrees shall be used if a Standard Plan wall is to be used. If multiple soil layers of varying strength have been identified within the depth of the trench or shaft foundation, soil strength averaging may be used to select the appropriate standard foundation type and depth. For example, if the average soil strength along the length of the shaft is 38^{o} or more, the 38^{o} standard foundation may be used.

The standard foundation designs used for the Standard Plan noise barriers are based on the following assumptions:

- Noise barrier standard foundation designs assume one of the following:
  - The wall is founded at the crest of a 2H:1V slope with a minimum of 3 feet of horizontal distance between the panel face and the slope break. The top 2 feet of passive resistance below the assumed ground surface at the noise barrier face is ignored in the development of the wall pressure diagram. For this case, groundwater must be at or below the bottom of the noise barrier foundation.
  - The wall is founded on a near horizontal slope (i.e., 6H:1V or flatter) with a minimum of 3 feet of horizontal distance between the panel face and the slope break. The top 2 feet of passive resistance below the assumed ground surface at the noise barrier face is ignored in the development of the wall pressure diagram. For this case, groundwater must be at or below 5 feet below the top of the noise barrier foundation.

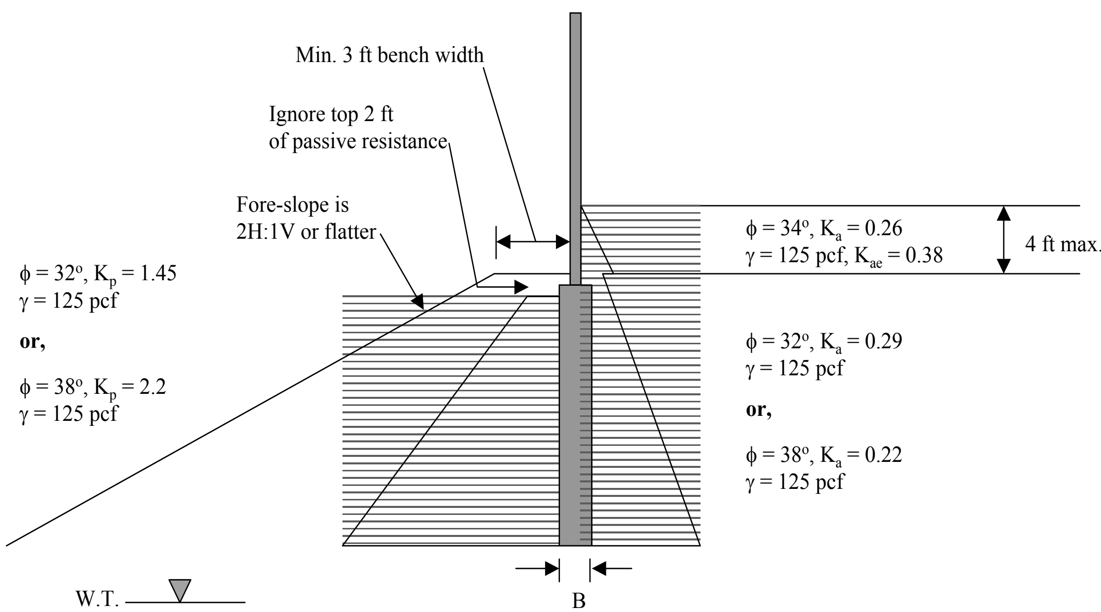
- The standard shaft foundation designs have been designed for two different soil conditions, assuming the slope conditions in front of the wall as indicated above. One design assumes an average soil friction angle of 32 degrees (D1), resulting in a design K_p of 1.45 (2H:1V slope) or 5.7 (near horizontal slope) and K_a of 0.29, and the second design assumes an average soil friction angle of 38 degrees (D2), resulting in a design K_p of 2.2 (2H:1V slope) or 8.8 (near horizontal slope) and K_a of 0.22. All values of K_a and K_p reported above have been corrected to account for the angular deviation of the active or passive force from the horizontal (in these design cases, the correction factor, Cos (δ), where δ is the interface friction angle, is approximately equal to 0.9 to 0.93). The standard shaft foundation designs are based on standard earth pressure theory derived using logarithmic spiral method for K_p and the Coulomb method for K_a, assuming the interface friction between the foundation and the soil to be 0.67φ. A unit weight of 125 pcf was also assumed in the design. This unit weight assumes that the ground water level at the site is below the bottom of the noise barrier foundation. For the case where groundwater is considered, the effective unit weight of the soil is used below the water table (i.e., 62.6 pcf). For the shaft foundation design, it is assumed that the passive earth pressure is applied over a lateral distance along the wall of 3B, where B is the shaft diameter and 3.0 is the magnitude of the isolation factor for discrete shafts, or the center-to-center spacing of the shafts, whichever is less. A factor of safety of 1.5 should also applied to the passive resistance.
- The PGA for seismic design is assumed to be 0.35g. This corresponds to a peak bedrock acceleration (PBA) from Figure 6-6 in Chapter 6 of 0.3g and an amplification factor of 1.18, corresponding to stiff soil. K_{ae}, the seismic lateral earth pressure coefficient, was developed assuming that the acceleration A = 0.5PGA.
- All standard foundation designs assume a concrete to soil contact.
- Figures 17-3 and 17-4 illustrate the assumptions used for the standard trench or shaft foundation designs.

Special designs will be required if the site and soil conditions differ from those conditions assumed for design.



Use $3K_p$ applied to foundation width, B, for discrete foundation units (shafts), and $1.0K_p$ for trench foundation.
Use FS = 1.5 applied to K_p (K_p values shown above have not been factored).
K_a is applied over foundation width, B.

Standard Foundation Design Assumptions for Shaft or Trench Foundations, Assuming Near Level Ground Conditions and Ground Water Above Bottom of Foundation
Figure 17-3



Use $3K_p$ applied to foundation width, B, for discrete foundation units (shafts), and $1.0K_p$ for trench foundation.
Use FS = 1.5 applied to K_p (K_p values shown above have not been factored).
K_a is applied over foundation width, B.

Standard Foundation Design Assumptions for Shaft or Trench Foundations, Assuming 2H:1V Slope in Front of Wall and Ground Water Below Foundation
Figure 17-4

17.3.2.3 Non-Standard Foundation Design

A non-standard foundation design will be required if the site or soil conditions are not consistent with the conditions assumed for the standard foundation designs as described in Section 17.3.4.2. For example, if slopes steeper than 2H:1V are present below the wall, if the soil is weaker than 32°, or if the ground water level is above the bottom of the foundation (Figure 17-4), a non-standard foundation design will be needed. If the foundation must be installed in rock, a non-standard foundation may also be required.

If non-standard foundation designs are required, the geotechnical designer should provide the following information to the structural designer:

- Description of the soil units using Unified Soil Classification System (Chapters 4 and 5).
- Ground elevation and elevation of soil/rock unit boundaries.
- Depth to the water table along the length of the wall.
- Earth pressure diagrams and design parameters developed in accordance with Chapter 15 and this section. Soil unit strength parameters that include effective unit weight, cohesion, φ, K_a, K_p, and K_{ae}. For shaft foundations, passive pressures are assumed to act over 3 shaft diameters, and a factor of safety of 1.5 should be applied to the passive resistance.
- The allowable bearing resistance for spread footings and estimated wall settlement.
- Overall wall stability.
- Any foundation constructability issues resulting from the soil/rock conditions.

The structural designer will use this information to develop a special foundation design for the noise barrier.

17.3.3 Construction Considerations

The presence of a high groundwater table could affect the construction of shaft foundations. The construction of noise barriers with shaft foundations would be especially vulnerable to caving if groundwater is present, or if have lose clean sands or gravels. The concrete in all shaft foundations have been designed to bear directly against the soils. Generally, temporary casing for drilled shafts should be removed. Special foundations designs may be required if the geotechnical designer determines that permanent casing is necessary. In this situation, the structural engineer must be informed of this condition.

17.4 Culverts

17.4.1 Overview

This section only addresses culverts, either flexible or rigid, that do not require foundation elements such as footing or piles. Culverts that require foundation elements are addressed in Chapter 8.

17.4.2 Culvert Design and Construction Considerations

Culvert design shall utilize the LRFD approach. For culverts, the soil loads and design procedures to be used for design shall be as specified in Sections 3 and 12 of the AASHTO LRFD Bridge Design Specifications. The following design situations are typically encountered regarding culverts:

1. The culvert simply needs to be replaced because of performance problems (e.g., leaking, partial collapse, or undersized), or a new culvert is needed, and open excavation is used to remove and replace the culvert, or to install the new culvert, and the excavation is simply backfilled.
2. The culvert simply needs to be replaced because of performance problems (e.g., leaking, partial collapse, or undersized), or a new culvert is needed, and the culvert is installed by “jacking” it through the existing embankment.
3. An existing culvert is extended and new fill is placed over the culvert.

For case 1, little geotechnical design is needed. The soil conditions in the fill and just below the culvert should be investigated, primarily to assess constructability issues such as excavation slopes and shoring design (usually done by the contractor). If soft soils are present near the bottom of the culvert, the feasibility of obtaining stable excavation slopes of reasonable steepness should be assessed. The presence of boulders in the fill or below the fill, depending on the shoring type anticipated, could influence feasibility. However, settlement and bearing issues for the new or replaced culvert should not be significant, since no new load is being placed on the soil below the culvert.

For case 2, the effect of the soil conditions in the fill on the ability to jack the culvert through the fill should be evaluated. Very dense conditions or the presence of obstructions in the fill such as boulders could make jacking infeasible. Ground water within the fill or the presence of clean sands or gravels that could “run” could again make jacking problematic, unless special measures are taken by the contractor to prevent caving. Since a stable jacking platform must be established, along with the shoring required to form the jacking and receiving pits, deeper test hole data adequate for shoring design must be obtained and analyzed to assess earth pressure parameters for shoring design, and to design the reaction frame for the jacking operation.

For case 3, differential and total settlement along the culvert is the key issue that must be evaluated, in addition to the case 1 issue identified above. See Chapter 9 for the estimation of settlement due to new fill.

17.5 Buildings

17.5.1 Overview

The provisions of this section cover the design requirements for small building structures typical of WSDOT rest areas, maintenance and ferry facilities. It is assumed these buildings are not subject to scour or water pressure by wind or wave action. Typically, buildings may be supported on shallow spread footings, or on pile or shaft foundations for conditions where soft compressible soils are present.

17.5.2 Design Requirement for Buildings

Foundations shall be designed in accordance with the provisions outlined in Chapter 18 of the 2003 International Building Code (IBC, 2002). This design code specifies that all foundations be designed using allowable stress design methodology. Table 1804.2 from the IBC provides presumptive values for allowable foundation bearing pressure, lateral pressure for stem walls and earth pressure parameters to assess lateral sliding. Note that these presumptive values account for both shear failure of the soil and settlement or deformation, which has been limited to 1 inch.

Materials	Allowable Foundation Pressure (psf)[d]	Lateral Bearing (psf/ft below natural grade)[d]	Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	-----
2. Sedimentary and foliated rock	4,000	400	0.35	-----
3. Sandy gravel and/or gravel (GW & GP)	3,000	200	0.35	-----
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM, and GC)	2,000	150	0.25	-----
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH	1,500[c]	100	------	130

a. Coefficient to be multiplied by the dead load.

b. Lateral sliding resistance value to be multiplied by the contact area, as limited by Section 1804.3 of the 2003 IBC.

c. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

d. An increase on one-third is permitted when using the alternate load combinations in Section 16.3.2 of the 2003 IBC that include wind or earthquake loads.

Allowable Foundation and Lateral Pressure (as Provided in 2003 IBC, in Table 1804.2)
Table 17-3

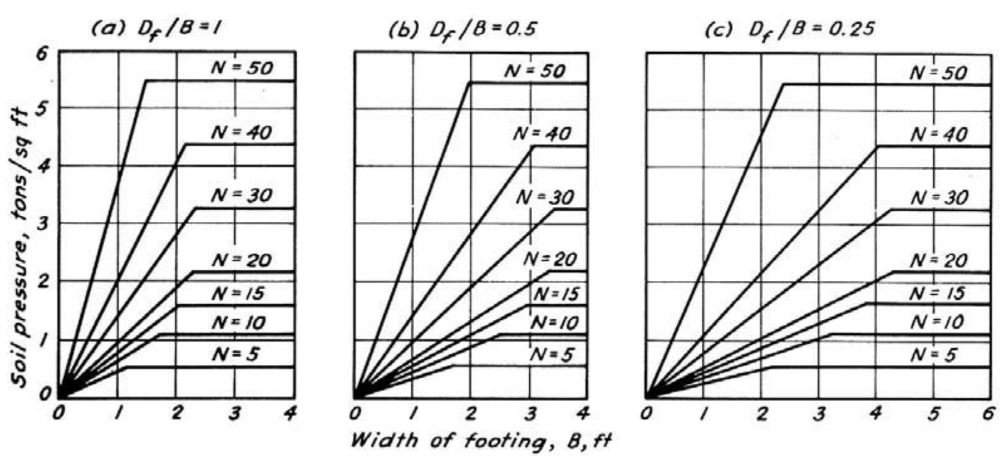
In addition to using the 2003 IBC design code, the geotechnical designer should perform a foundation bearing capacity analyses (including settlement) using the methods outlined in Chapter 8 to obtain nominal resistance values. These design methods will result in ultimate (nominal) capacities. Normally, allowable stress design is conducted for foundations that support buildings and similar structures. Appropriate safety factors must be applied to determine allowable load transfer. Factors of safety to be used for allowable stress design of foundations shall be as follows:

Load Group	Method	*Minimum Geotechnical Factor of Safety, FS		
		Spread Footings	Shafts	Piles
ASD (unfactored DL + LL, or service load level)	Static shear strength analysis from soil/rock properties, compression	3.0	2.5	2.5
	Static analysis from soil/rock properties, uplift		3.0	3.0
	Load test conducted (number of tests depends on uniformity of conditions)		2.0	2.0
	WSDOT driving formula			2.5
	Wave equation with PDA (min. one per pier and 2 to 5% of the piles			2.5
	PDA with CAPWAP (min. one per pier and 2 to 5% of the piles			2.25

Minimum Factors of Safety for ASD Foundation Design
Table 17-4

The results of the ASD foundation bearing capacity analyses, after reducing the foundation bearing capacity by the specified FS from Table 17-4, and further reduced to meet settlement criteria for the foundation (normally, no FS is applied for settlement analysis results), should be checked against the IBC design code, and the most conservative results used.

For allowable stress design, spread footings on sandy soils may alternatively be designed for bearing and settlement by using Figure 17-5. When using Figure 17-5, a FS from Table 17-4 does not need to be applied, as the bearing stresses in the figure represent allowable bearing resistances. The design bearing resistance in Figure 17-5 has been developed assuming footing settlement will be limited to no more than 1 inch. The N-values needed to estimate bearing resistance in the figure should be determined from SPT blow counts that have been corrected for both overburden pressure and hammer efficiency, and hence represent $N1_{60}$ values (see Chapter 5).



Design Chart for Proportioning Shallow Footings on Sand (After Peck, et al., 1974)
Figure 17-5

Note that other issues may need to be addressed regarding the design of buildings and associated structures. For example, significant earthwork may be required. For cut and fill design, see Chapters 9 and 10. For the stabilization of unstable ground, see Chapter 13. If ground improvement is required, see Chapter 11. If retaining walls are required, see Chapter 15.

If septic drain field(s) are needed, local regulations will govern the geotechnical design, including who is qualified to perform the design (i.e., a special license may be required). In general, the permeability of the soil and the maximum seasonal ground water level will need to be assessed for septic system designs.

Note that in general, the foundations for the types of structures addressed in this chapter are not mitigated for liquefaction (see Chapter 6). However, for building foundations, liquefaction and other seismic hazards are at least assessed in terms of the potential impact to the proposed structures. Liquefaction and other seismic hazards are mitigated for building and other structures for which the International Building Code (IBC) governs and mitigation is required by the IBC.

17.6 References

AASHTO, 1988, *AASHTO Manual on Subsurface Investigations*.

AASHTO, 1989, *AASHTO Guide Specifications for Structural Design of Sound Barriers (including 2002 interim)*.

AASHTO, 2001, *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*.

AASHTO, 2002, *Standard Specifications for Highway Bridges,* American Association of State Highway and Transportation Officials, Seventeenth Edition, Washington, D.C., USA, 686 p.

AASHTO, 2004, *LRFD Bridge Design Specifications*, American Association of State Highway and Transportation Officials, Third Edition, Washington, D.C., USA.

International Code Council, Inc., (2002), *2003 International Building Code*. Country Club Hills, IL.

Patterson, D., 1962, *How to Design Pole-Type Buildings*, American Wood Preservers Institute, Chicago, 3rd edition.

Peck, R. B., W. E. Hanson, and T. H. Thornburn. 1974. *Foundation Engineering*. 2nd ed. John Wiley and Sons, Inc., New York, NY, p. 514.

Bridge Design Manual M 23-50

Design Manual M 22-01

Standard Plans For Road, Bridge and Municipal Construction M 21-01

Chapter 18 Geotechnical Design for Marine Structure Foundations

18.1 Overview

This chapter addresses the design of foundations to support marine structures. Such structures include dolphins, wing walls, wharfs, terminal structures and docks, pedestrian ramps, and terminal buildings. Other than the pedestrian ramps and terminal buildings, these structures must handle ship impact loads and wave loads. While this may affect the load groups required, the foundation designs and resistance factors required are the same as for other transportation facilities. Therefore, Chapter 8 shall be used for foundation design for marine structures, other than for terminal buildings, in which case the IBC (2003) should be used as the basis for foundation design.

18.2 Design Philosophy

Normally, structures subject to ship impact loads are designed to fully resist those loads. However, for ferry terminals, the greater risk in terms of financial loss and potential loss of life is the potential to damage the ship. Therefore, ferry terminals subject to ship impact loads need to be designed to be flexible enough to slow down the ship without damaging the ship. If foundation failure occurs, the choice is to have the foundation fail before the ship is damaged. This requires that foundation elements be designed with a lower margin of safety than is required by the current AASHTO specifications and Chapter 8.

18.3 Load and Resistance Factors for Marine Structures Subject to Ship Impact

To be determined.

18.4 References

International Code Council, Inc. (2002). 2003 International Building Code. Country Club Hills, IL.

Chapter 19 Infiltration Facility Design

19.1 Overview

Infiltration facility design includes the design of ponds, trenches and other BMP's designed to encourage infiltration of stormwater back into the ground. Geotechnical design of infiltration facilities includes assessment of the groundwater regime, soil stratigraphy, and hydraulic conductivity of the soil as it affects the hydraulic functioning of the infiltration facility, and the geotechnical stability of the facility (e.g., slope stability, affect of infiltration on stability of adjacent structures and slopes, and design of fills that must retain water for both slope stability and piping failure).

19.2 Geotechnical Investigation and Design for Infiltration Facilities

For infiltration investigation and design, the detailed requirements for the geotechnical site investigation, soil properties needed, groundwater characterization requirements, and design requirements are provided in the WSDOT Highway Runoff Manual (2004), Section 4-5. For geotechnical stability, the site investigation and design requirements provided in Chapters 2, 7, 9, and 10 are applicable.

19.3 References

Highway Runoff Manual M 31-16, 2004

Chapter 20 Unstable Slope Management

20.1 Overview

Unstable slope management provides the ability to rate and prioritize unstable slopes for remediation in consideration of the limitations of funds available to carry out the slope investigation. Actual design requirements for unstable slopes are provided in Chapters 13 and 14. The methodology used to prioritize the slopes based on risk of failure and impact to the public, and the costs and benefits of performing the needed repairs, are provided in the Unstable Slope Management System (USMS) Guidelines, and the article entitled, "Unstable Slope Management in Washington State" by Lowell and Morin (2000).

In the early 1990s WSDOT implemented a new project programming approach for The Highway Construction Program that involved prioritizing and programming projects based on defined service objectives. One of the service objectives within The Highway Construction Program is preserving the existing highway infrastructure in a cost effective manner in order to protect the public investment in the system. One of the action strategies in this service objective is to stabilize known unstable slopes. The funding level for the unstable slope service objectives has been set at $30 million dollars per biennium for 10 biennium (20 years). WSDOT has internally developed a comprehensive management system that can:

- Rationally evaluate all known unstable slopes along WSDOT highway facilities utilizing a numerical rating system for both soil and rock instabilities.
- Develop an unstable slope rank strategy, based on highway functional class that would address highway facilities with the greatest needs.
- Provide for early unstable slope project scoping, conceptual designs for mitigation, and project cost estimates that could be used for cost benefit analysis
- Prioritize the design and mitigation of unstable slope projects, statewide, based on the expected benefit, and ranked rating by highway facilities functional class.

The Unstable Slope Management System (USMS) is central to the process for management of unstable slopes. It is a SQL server database that is one of WSDOT's first truly interactive systems using internet technology and a GIS application. The application and database is designed for all internal WSDOT participants in the unstable slope management process to view and enter data pertaining to their respective job functions.

20.2 References

Lowell, S., and Morin, P., 2000, "Unstable Slope Management Washington State", *TR News 207*, pp 11-15.

Chapter 21 Materials Source Investigation and Report

21.1 Overview

A geotechnical site investigation of WSDOT-owned or -leased materials sources is required in order to determine the quality and quantity of materials available for WSDOT construction projects. These materials include gravel base, crushed surfacing materials, mineral and concrete aggregates, riprap, borrow excavation and gravel borrow, and filler. A Material Source Report (MSR) provides geotechnical documentation of the reconnaissance, exploration, sampling, laboratory testing, and development of the mining plan for the pit site or quarry site. This report includes a legal description of the location of the site and indicates the potential aggregate reserves for the material source. The Material Source Report requires the stamp of a licensed Engineering Geologist. The report is valid for the life of the material source.

Amendments to the MSR provide updates of any changes to the original Material Source Report, such as additional phases of exploration drilling, sampling and testing, mining development, extension of existing property boundaries of the material source, or changes with Department of Natural Resources reclamation permits or any other regulatory permits issued, etc. After a material source is used for project construction, a Pit Evaluation Report form is completed by the Project Engineer and submitted to the Regional Materials Engineer for review. The Pit Evaluation Report form is used to identify the quantity of material removed from the source, and includes comments about the production of the aggregate material extracted from the source for the project construction. This form contains valuable information on the use and production of material from the source.

Any new potential materials source sites considered need to be large enough in acreage to meet the quantity and quality requirements of the immediate construction project with adequate work and storage areas, but also the future construction project needs. It is also desirable that the source has sufficient material to support future maintenance needs in the area. When developing materials source sites, reclamation requirements and aesthetic considerations must be evaluated, to preserve or enhance the visual quality of the highway and local surroundings. This is especially important along scenic highways and adjacent to residential developments. Exposed sites, such as hillside borrow that cannot be visually reclaimed, should not be considered for development as a material source.

21.2 Material Source Geotechnical Investigation

It is preferred that existing approved material sources be used when there are suitable sites available within a reasonable haul distance to the project. When there are no approved WSDOT material sources available, the Regional Materials Engineer requests that the HQ Geotechnical Division conduct a materials source investigation. The materials source investigation typically consists of the following elements:

(a) **Evaluation of Existing Material Source Sites** – Any existing material source data within the project area are collected and reviewed. In project areas where materials sites are presently located, data that should be reviewed includes:

- Site Geology, from existing mapping, reports, etc.
- Aerial photographs, LIDAR coverage
- Past quality testing and production history of the materials source sites
- Surface and subsurface drainage in the site area
- Seasonal fluctuations in the water table, including water wells located on adjacent land that might be affected by those fluctuations, or moisture content of the deposit
- Claims made by adjacent landowners
- Contractor claims, including final settlements
- Maintenance use of the site

(b) **Geologic Field Exploration** – The geologic field exploration phase of the site investigation includes a reconnaissance level review of the material source site to begin the process of developing an understanding of the specific geology at the site, and how the site will be mined with consideration for existing adjacent land use (see Chapter 2). The reconnaissance incorporates the detailed review of the published geologic maps for the area or other published geologic or geophysical information in the vicinity, as well as LIDAR and aerial photographs. The reconnaissance phase review includes mapping existing outcrops and developing the strategy for the exploration drilling and sampling program, and the mine development of the site. During the initial reconnaissance to determine whether a site merits detailed exploration, some specific elements considered include:

- Topography
- Geology
- Test pits
- Test probes
- Test holes
- Representative photographs of the site
- Geologic mapping of existing exposures

Typically, a minimum of three test pits or test holes should be advanced during this phase of investigation. The site investigation should be planned and conducted in accordance with Chapters 2 and 3. The logging of the test pits and test holes should be in accordance with Chapter 4. To minimize exploration costs representative samples can be collected from existing cut faces for quality testing that includes Specific Gravity, Los Angeles Abrasion, and Degradation. A reconnaissance geologic report should be completed describing the site geology, preliminary field exploration and testing results. This report should be transmitted to the Regional Materials Engineer.

(c) **Detailed Site Exploration** – At a request by the Regional Materials Engineer, a detailed site exploration is conducted by the WSDOT Geotechnical Division. The Engineering Geologist submits an exploration plan to the Chief Engineering Geologist for review and concurrence prior to exploration. The test pits and test holes are logged in accordance with Chapter 4. The Engineering Geologist selects representative samples for quality testing. Refer to the *Construction Manual* Chapter 9, for additional discussion about sampling of natural deposits. On the basis of geologic considerations, the number, location, depth, and type of test pits or test borings are determined. In the absence of geological examination, the test pits or test borings are spaced roughly every 150 to 200 feet, on a grid, and extend to the base of the deposit, or to the depth required to provide the needed quantities. A significantly greater spacing (up to 500 feet) is used for nonexclusive leased sites or short-term leases that WSDOT has with other agencies.

For pit site investigations, exploration equipment that allows direct observation and sampling of the subsurface layers is preferred. The equipment can consist of backhoes, bulldozers, large diameter augers, or the Becker Hammer reverse circulation drilling method. Groundwater levels should be recorded during the site investigation. Where significant seasonal groundwater fluctuation is anticipated, observation wells should be installed to monitor water levels.

For quarry site investigations, wet rotary rock coring methods are used to determine subsurface conditions and to obtain samples for testing. Triple-tube core barrels are commonly needed to maximize core recovery. For riprap sources, fracture mapping includes careful measurement of the spacing of fractures to assess rock block sizes that can be produced by blasting. Also, identification of the type and amount of joint infilling is noted. Core samples are reviewed by the Engineering Geologist for assessment for quality testing for riprap or aggregates. If assessment is made on the basis of an existing quarry site face, it may be necessary to core or use geophysical techniques to verify that the nature of the rock does not change behind the face, or at depth.

Geophysical methods employed for material source exploration include seismic refraction surveys, electrical resistivity surveys, and ground penetrating radar. Downhole techniques can also be utilized to identify fracture orientation and condition; and software is available to interpret the fracture orientation in the core. For electrical resistivity surveys typically poor quality rock is denoted with low resistivity and good quality rock is denoted with high resistivity. Faults and fault splays can also be identified using electrical resistivity. Results from these geophysical methods supplies information that is used in developing the mining plan for a material source.

(d) **Special Considerations** – The Engineering Geologist must determine the appropriate shrink/swell factors (see Table 10-1) to convert the needed cubic yards to yards in place (bank yards) at the proposed source. This does not address or account for losses or wastage on construction.

The Engineering Geologist must assess the "indicated" quantity of material that is available in the potential material source. The Engineering Geologist uses knowledge of the mode of occurrence of the deposit in conjunction with the test pits and test borings to determine the surface plane area of the usable material.

The quantity of material reported as "indicated" is defined to mean that quantity of material estimated as being present at the site, including a safety factor. Extrapolation beneath the depth of test borings will not be made for calculation of "indicated" quantities unless well supported by geologic considerations.

A general formula for calculation of "indicated" quantity is:

$$\underline{Q = (LWD) - Cbs}$$
$$SF$$

Where Q is the quantity in cubic yards, L is length in feet, W is width in feet, D is depth in feet, Cbs is the back slope correction, and SF is a safety factor. The back slope correction (Cbs) depends on the slope specified in the reclamation plan or mining plan. ***[Notes: Cbs = ½ (base × height) + perimeter (ft***^{2}***). To convert cubic feet to cubic yards, divide cubic feet by 27.]***

The safety factor (SF) used will vary with the size and type of deposit, the history of other deposits in the area, and the exploration equipment used. In order to determine the SF, calculate the quantity (Q) available without a SF and apply the appropriate SF from the following table.

Bank Yards Available Without Safety Factor	Suggested Safety Factor
0 to 30,000 cubic yards	2.00
30,000 to 60,000 cubic yards	1.70
60,000 to 150,000 cubic yards	1.45
150,000 to 300,000 cubic yards	1.35
300,000 plus cubic yards	1.25

Other considerations are: (1) Determine the surface drainage at the site, noting areas of ponding water, swamps, sloughs, or streams. It is important to determine flooding possibilities or surface flow after periods of heavy rainfall, during spring snow melt, and from artesian conditions. (2) Describe the location of the groundwater table, if known, along with seasonal variations. Identify any springs in the area that will affect the development of the site, or if production operations can impact the water source. (3) For aggregate sources, it is important that the degradation and wear characteristics be determined. The history of use of the aggregate is especially important for aggregates with Los Angeles Wear test values greater than 25 and Degradation test values less than 45. (4) An estimate of oversize material (greater than 10 inches in diameter) determined in percent by volume is necessary. The estimate is given in a percent range, such as, 15 to 25 percent oversize. Also describe the largest size cobble or boulder observed during the site investigation, as well as any glacial erratics.

21.3 Materials Source Report

The Engineering Geologist prepares a Materials Source Report (MSR), following the outline presented below. The MSR provides documentation for the detailed site exploration, sampling and laboratory testing, and subsequent development of a pit or quarry site. The report reviews and discusses the site geology, exploration field data and testing information, slope stability, and groundwater information that has been acquired for the site, and indicates the mining plan for development of the site.

(a) **Introduction** – A brief description of the location of the site including county, state highway, milepost, and haul road access to the site.

(b) **Source Description** – The source description includes the legal description of the property location (e.g., Township, Range, Section, ¼ ¼ sections). The description also includes the size of the material source in acres. Ownership is identified and any pertinent lease information (e.g., leased to WSDOT for exclusive use, or nonexclusive use). Also, any zoning restriction, or other restrictions or constraints are identified. Stockpiles and waste piles are identified on the site plan map with estimated cubic yards (volume).

(c) **Topography, Vegetation and Climate** – The general geomorphology and topography of the area are described, including drainage features. Vegetation and climate should also be discussed.

(d) **Geotechnical Field Exploration** – For quarry site investigations, the number and location of exploratory borings advanced, and drilling methodology should be described (e.g., core drilling with a CME 850 with auto hammer using an HQ core barrel; retrieving a 1/2 inch diameter core sample). The total footage of core retrieved should be identified. For pit site investigations, the number and location of test pits, or Becker Hammer borings advanced should be identified. The test pits and test borehole locations are presented on a site map included in an Appendix. Copies of the boring logs and test pit logs are contained in an Appendix. Color photographs of the rock core or pit samples are included in an Appendix.

(e) **Laboratory Testing** – Representative samples are selected by the engineering geologist from the subsurface exploration drilling for laboratory testing for quality and to verify field visual identification. The preliminary laboratory quality tests include T-85 for Specific Gravity, T-96 for Los Angeles Wear, and WSDOT test method T-113 for degradation. The test results are used to interpret the distribution of the good quality and the poor quality material at the site. The test results are depicted on the geologic cross-sections and included in a table in the Appendix. Other tests may be performed according to the Standard Specifications Manual for specific products to be used in the construction project.

(f) **Regional Geology** – The regional geologic setting includes a description of the processes that occurred for the existing regional geology.

(g) **Site Geology** – Based on the regional geologic setting, the specific geology at the material source site should be described. Surface drainage should be identified and described, including the identification of springs or drainages that are natural or manmade. The depth to ground water and any seasonal changes should be described and discussed. This information should be included as a table in the Appendix. Natural or designed slope stability at the site should be described and discussed.

A stratigraphy for the material source is developed from the site geology, and from the test borings and test pits logs. Geologic cross-sections are developed to demonstrate the distribution and quality of material available at the site. Overburden and waste material encountered in the borings, quality test results, and groundwater should be identified on the geologic cross-sections. Included in the discussion of the stratigraphy should be a description of good and poor quality rock, as identified on each cross-section, and a summary paragraph for each cross-section.

(h) **Groundwater** – Ground water levels encountered during the subsurface investigation are recorded. Where significant seasonal groundwater fluctuation is anticipated, open standpipe piezometers are installed to monitor ground water levels. If appropriate, dataloggers may be installed in the open standpipe piezometers to monitor groundwater fluctuation. Rainfall gauges, or local weather stations can be utilized to gain information about local rainfall events and their effect on groundwater at the source.

(i) **Quality of Material** – The quality of the material at the site is based on the representative samples selected for laboratory testing for quality. The quality tests are typically Los Angeles Wear, Specific Gravity and Degradation, but can include other tests depending on the product to be produced from the material source site. The test results should be presented on the geologic cross-sections as well as in a table in the Appendix.

(j) **Quantity of Material** – The quantity of useable material present at the site is based on the occurrence of the deposit in conjunction with the test pits or borings to the determined depth to a surface plane over a certain area. The quantity of material reported as “indicated” is defined to mean the quantity of material estimated as being present including a safety factor.

(k) **Slope Stability** – Slope stability analyses should be completed to indicate the stability of the slopes of the material source during mining development, and for reclamation.

(l) **Mining Considerations** – The mining plan indicates how the resource will be developed and demonstrates the logic for the excavation and development of the site. The mining plan for the site should indicate which part of the site is to be mined first, second, third, etc. A discussion of any special problems associated with the material present at the site, such as a description of oversize material, including large rock encountered, or excessive overburden. The waste areas for overburden and stripping material should be identified on the mining plan map. The location of haul roads, gates, fences, and the elevation of the mining floor should be included in the mining plan map. Slope angles, based on slope stability analyses, should be designated for interim and final reclamation. For quarry sites, slopes should be designed, based on the rock parameters mapped, and identified specifically at the quarry. Locations of haul road, stockpile storage, waste, overburden and elevation of the pit or quarry floor should be identified on the reclamation plan map.

(j) **Appendices**

- Figures:

  Location MapSite Plan map, with topography, boring and cross section locations Geologic Cross Sections, with boring locations and quality test results Mining Plan Reclamation Plan

- Tables:

  Boreholes identified with depths and laboratory quality testing results

  Boreholes with Groundwater elevations

- Logs of Test Borings (edited for consistency with lab data)
- Laboratory Test Reports
- Calculations of Quantity Determinations
- Photographs of the site, photos of rock core samples, pit samples

Chapter 22 Geotechnical Project Development, Reports, and Support for Design-Build Projects

22-1 Overview

This chapter describes the geotechnical support needed for projects where WSDOT intends to use the Design-Build (DB) method of contract delivery and the geotechnical policies that govern that support.

DB differs from traditional Design-Bid-Build (DBB) projects in that the DB team is responsible for the final design, and the means and methods needed to successfully construct the project compatible with the design. In the DBB contract method of delivery there can be a reasonable anticipation of potential means and methods that may be selected by a contractor. Hence, given a 100% design, establishing a geotechnical baseline with respect to the subsurface and site conditions that may be encountered can be more objectively established. Of significance to the preparation of geotechnical documents for DB is that foundation types and how they are constructed may change, retaining walls may move affecting both height and wall types considered during the development of the project concept, size and location of cuts and fills may change, and any effects on adjacent sensitive structures and utilities may be significantly different than anticipated in the Conceptual Design. Right of way (ROW) lines may also be affected as well as temporary construction easements (TCE).

In DB, the Design-Build team is the responsible Engineer of Record (EOR) and has the latitude in completing the majority of the project design such that it meets the performance requirements and is in compliance with the contract documents. While the WSDOT will always retain primary ownership of the project and its long-term operations and maintenance, the DB contract delivery method allocates the majority of the responsibility and risk for project design and construction to the Design-Builder to foster innovation and creativity.

These differences relative to DBB have a fundamental effect on the type of geotechnical support needed and how it is carried out. The geotechnical support provided by the Headquarters Geotechnical Office or the department's geotechnical consultants includes:

- A geotechnical investigation to identify site geotechnical conditions and to gather the geotechnical information needed to provide a common and consistent basis for bidding.
- Verification of the feasibility of the project Conceptual Design and identification of areas of geotechnical risk.
- The development of geotechnical Technical Requirements to be included in the Request for Proposals (RFP) as well as the Geotechnical Data Report (GDR) and Geotechnical Baseline Report (GBR) to be included as part of the contract.
- The development of Geotechnical Reference and other reference documents.
- Once the contract advertisement begins, a review of proposals, if requested by the project management; this will depend on the importance and complexity of the project geotechnical issues.

- A review of geotechnical Alternative Technical Concepts (ATCs) for consistency with the contract design requirements and WSDOT design policy.
- Review of geotechnical designs, plans, and other geotechnical submittals after award and execution.
- Project office assistance when geotechnical problems occur during the life of the project.

The chapter sections that follow address each of these areas to provide the guidance needed by the Headquarters Geotechnical Office staff and department geotechnical consultant staff to successfully develop and support department DB projects. Since this chapter is for internal geotechnical staff and internal consultant staff, and the department offices who interact with these staff, to develop and carry out DB projects, this chapter should be excluded from the Mandatory Standards that are included in the contract documents.

22-2 Definitions

Geotechnical documents provided as part of or in support of a DB project include the Geotechnical Data Report (GDR), the Geotechnical Baseline Report (GBR), Geotechnical Reference documents, and other related Reference Documents. A GDR only presents factual geotechnical and geological information obtained through site and subsurface investigation, and laboratory testing, for the project, and should not include interpretive information. The GDR is a contract document. The Geotechnical Baseline Report (GBR) is a contract document and a risk allocation document provided to Proposers of DB projects that provides the primary contractual interpretation of geotechnical conditions, in addition to the factual data provided in the GDR, for Proposers to use as the basis for their proposals. The GBR interpretation of geotechnical conditions is based on the factual information in the GDR plus interpretation of the geotechnical conditions that is not strictly based on the available factual information in the GDR. The GBR is also used after contract award for evaluating differing site conditions claims.

This GBR should not refer to any part of a reference document, as doing so will make the reference document contractual and negate its reference document status. Geotechnical Memoranda and other reference documents include other geotechnical information, interpretations, and conceptual designs that were used as the basis for evaluating the feasibility of the project Conceptual Design, and possibly alternatives to the final project Conceptual Design, and to assess areas of geotechnical risk for the project. The Geotechnical Reference documents are not included as Contract Documents, but are made available to Proposers in an appendix of the RFP for information only, not to be used as the basis for their proposal.

The geotechnical information to be included in RFP is project-specific and can include all or only some of the documents identified above. For example, during concept development for the project, it may be determined that the overall geotechnical risks are minimal, warranting only the inclusion of a GDR as a contract document and incorporating a financial allowance to manage any unforeseen risks. The level of the potential financial allowance is a decision made by the project management with input from the HQ Geotechnical and Construction Offices and the project geotechnical team.

22-2.1 Field Investigation Requirements for Pre-Advertisement Design-Build Project Documents

Past experience has demonstrated that an inadequate project geotechnical investigation can lead to excessive risk both in terms of schedule and cost. Therefore, it is important to do the right amount of geotechnical investigation to provide the subsurface information needed to help mitigate those risks. These data can then be used to develop contract information that will provide potential Proposers with a consistent understanding of the site geotechnical conditions and the impact those conditions may have on the project design and the constructability of that design. This section summarizes the level of geotechnical investigation and analysis that should be considered prior to contract advertisement for DB projects. Decisions regarding the level of geotechnical investigation needed should be developed as early in the project as possible with region project office input, including the development of a geotechnical risk profile for the project that is mutually agreed upon by both region and headquarters offices. These early efforts will also be useful to develop a strategy for establishing geotechnical baselines.

The level of geotechnical field investigation necessary for assessment of potential geotechnical risks, with consideration to the baseline configuration for the project, and for preparation of the GDR and GBR should be conducted as early in the project as possible. The goal is to leave enough time in the project development schedule for the Geotechnical Office, the region project office, and possibly others such as the HQ Construction Office and region management, to identify and come to agreement on the level of geotechnical risk WSDOT should be taking and how to allocate that risk. The project baseline configuration geotechnical investigation shall be approved by the State Geotechnical Engineer, or an approved designee. The State Geotechnical Engineer, Region/Headquarters management, and the region project team will review and agree upon the short-term (i.e., during the contract) and long-term (i.e., after the contract is completed to the end of the design life of the facility) project performance risks when determining the initial level of investigation required. During the execution of the field exploration program, field findings may significantly alter those risks and require changes to the field investigation program. The level of geotechnical investigation shall consider the amount of information necessary to develop the Conceptual Design for the DB project and also to provide the appropriate level of confidence in baseline statements and thereby reduce the risk of differing site condition claims. If there is a disagreement regarding the level of geotechnical investigation required, the issue(s) may be escalated to the next higher management level to resolve the disagreement.

The amount of geotechnical investigation needed is project specific, and shall be determined based on the guidelines provided herein.

The goals of the typical geotechnical investigation for DB projects are to:

1. Identify the distribution of soil and rock types for the Conceptual Design, and assess how the material properties will affect the design and construction of the project elements.
2. Define the ground water and surface water regimes for the project concept design. It is especially important to determine the depth, and seasonal and spatial variability, of groundwater or surface water. The locations of confined water bearing zones, artesian pressures, and seasonal or tidal variations should also be identified. The geotechnical investigation will not be sufficient to fully define these groundwater issues, but should be enough to identify potential groundwater problems and risks.
3. Identify and consider any impacts to adjacent facilities that could be caused by the construction of the Conceptual Design.
4. Identify and characterize any geologic hazards that are present within or adjacent to the project limits (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards) that are already known or discovered during the baseline configuration geotechnical investigation that could affect the Conceptual Design as well as adjacent facilities that could be impacted by the construction of the Conceptual Design.
5. Assess the feasibility of the proposed alignments, including the feasibility and conceptual evaluation of retaining walls and slope angles for cuts and fills, and the effect the construction of the Conceptual Design could have on adjacent facilities.
6. Assess potential project stormwater infiltration or detention sites with regard to their feasibility, and to gather at least one year of ground water data in accordance with storm water regulations if possible within the project development schedule.
7. Identify potential suitability of on-site materials as fill, and/or the usability of nearby materials sources.
8. For structures including, but not limited to, bridges and cut-and-cover tunnels, large culverts, walls, bored tunnels, trenchless technology, provide adequate subsurface information to assess feasibility of the Conceptual Design and to help quantify risks.
9. For projects that may include ground improvement to achieve the project Concept Design, provide adequate information to assess feasibility and to assess the potential impacts to adjacent facilities due to the ground improvement.
10. For projects that may include landslides, rockfall areas, and debris flows, provide adequate information to evaluate the feasibility of various stabilization or containment techniques.

To accomplish these goals, the typical geotechnical investigation should consist of the following:

- A review of historical records of previous investigations and construction of existing facilities.
- A geological site reconnaissance of the proposed alignment, focusing on all key project features, and identification of potential hazards within and adjacent to the alignment.
- A subsurface investigation consisting of an appropriate combination of borings, cone probes, field testing, field instrumentation (such as piezometers or inclinometers), geophysical surveys, and laboratory testing.

As a starting point, utilize existing subsurface information from records and augment that information with additional borings, cone probes and/or geophysical surveys to fill in gaps in the existing information.

Typically, to produce a GDR and GBR to support a 15 to 30% project design, a 50 percent or greater level geotechnical subsurface field investigation (including any existing (historical) borings that can be relied upon) is typically needed relative to a full PS&E level geotechnical investigation for final design as defined elsewhere in the GDM and referenced documents. The actual subsurface investigation conducted for a specific project may vary significantly from this target, however, depending on the uncertainty in the details of the Conceptual Design, the potential for variations in alignments and structure locations, the complexity of the site and project, the availability of preexisting subsurface information, and the potential for risk. As stated above, the level of geotechnical investigation undertaken should be developed collaboratively with the Region Project Office, as well as managers in the Region and in Headquarters as needed, based on the level of risk WSDOT should be taking.

Any new boring logs produced shall be consistent with the requirements in Chapter 4.

The geotechnical investigation may also include an assessment of the potential to encounter hazardous waste, since that potential and its location may be strongly tied to the subsurface stratigraphy and ground water regime. However, Environmental Services, and/or the region, or their consultants, have the lead in such investigations, working as a team with the Headquarters Geotechnical Office to complete that work. From a contract standpoint, it is desirable to “baseline” the hazardous/ contaminated materials/water in the same manner that the geotechnical project attributes are baselined. It is also desirable from a contract standpoint that this hazardous/contaminated materials/water information be consolidated in one place in the contract. The decision of whether this is captured in the GBR or an Environmental hazardous/contaminated materials/water baseline report should be coordinated with Environmental Services.

Regarding historical and subsurface investigations to assess the potential to encounter archeological artifacts, such investigations are conducted through environmental Services, the region, or their consultants. In general, the results of archeological investigations will not be included in the GDR, GBR, and Geotechnical Memoranda for WSDOT DB projects, but are contained in a separate report.

It should be recognized that at the time of the field exploration many of the project Conceptual Design features investigated may not be defined. The geotechnical engineer developing the GBR will have to utilize professional judgment in addition to assistance from the WSDOT project team to assess what project elements for the Conceptual Design are to be investigated and where they will likely be located in order to perform an adequate field investigation. When developing the exploration plan to investigate the project Conceptual Design, or other specific concept alternatives requested by the WSDOT project office, ensure that the plan is sufficient to develop an overall characterization of the project corridor, and also sufficient as a basis for pricing the final Conceptual Design portrayed in the RFP.

Risks to be considered that could require a more detailed investigation than what may be considered typical shall include, but not be limited to, the following:

- Liquefaction and other seismic hazards.
- Very soft soils.
- Areas of previous or potential instability (e.g., Landslides, rockfall, severe erosion).
- Site and soil conditions that may affect constructability.
- High groundwater, or complex groundwater regime.
- Shallow bedrock surface that is highly variable either in depth from the surface or in quality/strength.

The degree of investigation necessary to properly define and allocate these risks depends on the nature of the risk, the amount of detailed geotechnical information needed to mitigate that risk, and the impact such risks have on the potential project costs. To determine the amount of geotechnical investigation required, consider the impact of such conditions on the ability of Proposers to adequately estimate project costs and project staging/scheduling. It will remain up to the Design-Builder to assess the limitations in the exploration program provided in the RFP and perform the requisite explorations to be compliant with the GDM and AASHTO requirements during final design.

22-3 Purpose and Content of the Geotechnical Reports Included in the Contract Documents

In general, this section follows the guidelines provided in Essex, et al. (2007) as published by the American Society of Civil Engineers. As specifically applied to WSDOT DB projects, the geotechnical reports included in the contract documents shall be as described in this section.

Geotechnical Data Report (GDR) – The GDR contains all the factual geotechnical data gathered for the project, and shall be included as part of the project contract. The GDR should contain the following information:

- A description of the geotechnical site exploration program, including any explanatory information needed to understand the boring logs and in-situ field test logs.
- The logs of all borings, logs of other subsurface investigation techniques such as cone or geophysical, test pits, and other site investigations, including any existing subsurface geotechnical data.
- Ground water measurements.

- A description of the geologic and seismic setting for the project corridor (at a regional level).
- Results of all field tests conducted, including description and results.
- Installation details, logs, and measurements results of all geotechnical field instrumentation installed for the project or existing geotechnical instrumentation and measurement results usable for the project.
- A description of all laboratory tests conducted and the test results, as well as any previous geotechnical laboratory test results that are relevant for the project.

Existing boring and other subsurface data that are available within the project corridor should not be included in the GDR unless their level of accuracy is consistent with the new subsurface data obtained for the project. This older data should be included in a separate appendix to the RFP as an historical geotechnical reference document that is available to proposers as background information only, not part of the contract, and not be used to determine differing site conditions.

The GDR may also include subsurface profiles and cross-sections at key locations within the project limits, provided that subsurface data interpretations such as interpolation between borings to develop stratigraphy, as well as the geologic interpretation of the strata, are not done. In this case, boring logs are presented in a way that shows spatial relationships between the borings, but no stratagraphic interpretation of the factual data (i.e., the boring logs) is done. This also applies to the boring logs themselves – the boring logs should not contain geological interpretations of the soil and rock units encountered, but should only present the factual observations and test data.

Alternatively, these subsurface profiles and cross-sections that include the stratagraphic and geological interpretations could be included in a separate geotechnical interpretive report (a Geotechnical Reference document) included in an Appendix to the RFP for information only.

Regarding geotechnical field tests reports for exploration methodologies such as pressuremeter testing or geophysical testing, even though the test report will likely contain an interpretation of the raw test data, such test reports should still be included with the GDR. These test interpretations are fairly standardized and are customarily considered to be factual design data in geotechnical practice.

If there is historical information about past construction, the information should be summarized and included in the GDR, especially, for example, if there were geotechnical impacts such as boulders, high groundwater, soft soils, or documented changed conditions.

Geotechnical Baseline Report (GBR) – The GBR is an interpretive geotechnical document used to establish a common understanding between the contractor and the owner (WSDOT) of the subsurface conditions and their potential impact and effect of risk on the design and construction of the project Conceptual Design.

The primary focus of the GBR is to establish baselines regarding geotechnical subsurface conditions present within the project, but specifically focused on the project Conceptual Design as portrayed in the RFP. These baselines should clearly define the specific geotechnical conditions the DB contractor should consider as the basis for developing their price proposal. These baselines are also used to allocate risk between the owner (WSDOT) and the contractor. The GBR baselines are not intended to be used for final design. The GDR and geotechnical data generated by the Design-Builder are used as the basis for final design. The GBR should not contain design or construction requirements; instead, design and construction requirements belong in the RFP and associated mandatory standards.

When establishing baselines in the GBR, it must be recognized that subsurface conditions are inherently variable, and that variability can translate to design and construction risk. The baseline, however, must be as clear, concise, and measurable as possible, conveying to potential Proposers what to assume about the condition being baselined (i.e., essentially, a “line in the sand”) in a way that all Proposers will understand and interpret consistently. Baselines do not necessarily need to be supported by the available technical data. Baselines are engineering interpretations or assumptions about geotechnical conditions that can affect the design of a project feature or its constructability, expressed as contractual representations of anticipated geotechnical conditions (Essex, et al., 2007). The baseline is intended to resolve, at least contractually, the uncertainty in the geotechnical data or its interpretation. Baseline statements are not required to be factual but should address specific risk elements that WSDOT requires the Design-Builder to address or consider. However, baseline statements should not be overly broad or unrepresentative of the conditions such that the risk allocation is excessively shifted to the Design-Builder. It is important that baselines be as realistic as possible.

WSDOT DB contracts allow changes to occur. These changes could occur during the procurement process by the use and approval of an Alternative Technical Concept, or during contract administration by the use of the project changes to the specifications. Both of these options are administered based on the contract documents and each process may or may not include impacts or changes related to baseline assumptions.

Baseline statements should not be considered applicable to alternate locations of the project features that may be proposed by the Design-Builder, or Work that is not in conformance with the anticipated Work. To define the locations for which the baselines are applicable, contractual baseline boundaries should be established to define the area for which the baselines are applicable. This could either be done based on the project Conceptual Design plan feature locations and maximum offsets from those feature locations, or based on a maximum offset from each boring plus an anticipated variance of strata boundaries relative to each boring, or possibly some combination of the two.

Baselines do not need to be provided for every feature in a project that could require geotechnical considerations (e.g., fills or foundations placed on very dense moist or dry soils, small walls, cuts and fills for which the risk and impact of failure is low). Only the higher risk geotechnical features and issues in a project require baselines. What specifically is to be baselined should be determined collaboratively with the project office, and others as needed. The RFP should be clear that for items not baselined, the Design-Builder assumes the risk for bid and design assumptions as well as constructed means, methods, and sequences.

Where possible, baselines should be location and, as much as possible, stratigraphic unit specific, and applicable to the type(s) of construction anticipated with consideration to the Conceptual Design for the project. However, baselines should also avoid getting into specific means and methods. For example, where the need for deep bridge foundations exists in the Conceptual Design for the project, and loose wet sand is present, the baseline should alert proposers that caving conditions are present that may need to be considered. However, the baseline should not tell the proposers to assume that full depth casing will be required to get through the caving soil. An exception to this is possibly to baseline types of construction that are likely to not be successful given the soil/rock conditions. For example, use of sheet piles that must be driven into a soil unit that is very dense or hard, or bouldery, or use of sump pumps in excavations where very permeable water bearing strata will be intersected.

In order to have baselines tied to specific subsurface conditions, a description and depth of soil and rock strata encountered in the borings should be provided. Typically, soil and rock strata locations in each boring can be summarized in a table of specific, interpreted, strata boundary locations in each of the borings. It must be clear that these strata locations are to be used only with respect to the baselines (i.e., these are Baseline Stratigraphic Units, or BSUs), and the proposers should expect the potential for those specific soil and rock strata and their depths will need adjustment for final design once the selected proposer conducts the final geotechnical explorations for the project. Stratigraphic units should not be identified in the boring logs themselves, as the additional subsurface explorations conducted by the Design-Builder for final design could require some adjustments to the stratigraphy.

Stratigraphic profiles or cross-sections in which the boring log specific BSUs discussed above are connected together to provide an overall two-dimensional stratigraphy should not be provided in the GBR. However, if the location, depth, or thickness of a high risk soil stratum in the vicinity of a specific Conceptual Design project feature such as a bridge is highly variable, the geotechnical engineer developing the GBR may need to consider including an assumed depth/location/thickness of the stratum in the baseline. This will be a risk allocation decision and as such, agreement between the Geotechnical Office, the region project design office, and possibly other offices such as Headquarters Construction and the Bridge Office should be sought before including this type of baseline in the GBR.

For project features such as walls and major cuts or fills that are not well defined and subject to significant changes relative to the project Conceptual Design, it may not be feasible to establish locations of BSUs that are specific enough to establish BSU specific baselines. In such cases, it may not even be possible to establish specific baselines, other than for known unstable areas such as landslides, or known locations of obstructions.

The baselines may draw upon data in the GDR as well as in geotechnical reference documents (see Section 22-5). However, the GBR should not specifically reference Geotechnical and other related Reference Documents that are not contractual.

Specific subject areas where baselines may be developed typically include the following, depending on the Conceptual Design and the nature of the project:

- Bridge foundation issues
- Bridge abutment and approach fill issues
- Retaining wall issues

- Seismic design issues, including liquefaction and its effects
- Embankment stability and settlement
- Cut stability
- Stormwater infiltration facilities
- Unstable slope issues and potential mitigation issues
- Ground improvement issues
- Utility impacts
- Noise wall foundation issues
- Groundwater issues
- Excavation and shoring issues, including potential dewatering issues
- Use of excavated materials
- Impact of poor ground, other than as specifically addressed above
- Known and potential obstructions
- Contaminated soils, though this is usually handled separately

In general, geotechnical design parameters (e.g., soil friction angles, earth pressures, permeability values) should not be baselined. If there is a significant risk issue associated with the selection of a geotechnical design parameter that WSDOT cannot afford to be determined by the Design-Builder as the Engineer of Record, the specification of such design parameters shall be approved by the State Geotechnical Engineer and the WSDOT project managers. These geotechnical design parameters should be described or defined in the RFP Section 2.6, and not in the GBR. Examples of this include the seismic ground response parameters for a given site, what soils are to be considered liquefiable, high risk troublesome soils such as glacialacustrine soils as described in GDM Section 5-13.3, high risk landslide deposits, etc. This may be especially important for situations where the geotechnical designer has to use considerable judgment in establishing the design parameters, or where the design procedures and standards of practice are poorly defined.

For extremely large, complex projects, or for specific features that are long and/or uncertain as to their specific location, size, and extent of the geotechnical work needed, it may be too unwieldly to develop specific baselines for everything in the project that have significant geotechnical risks. In that case, the effort and costs expended to develop the GBR need to be strategic so that the most costly risks are addressed in enough detail to clearly apportion those risks. This strategy should be developed in collaboration with the project office and program managers. If it appears necessary to “scale down” the GBR baselines to accommodate these situations, this shall be done in consultation with the State Geotechnical Engineer and the Deputy State Construction Engineer as early as possible in the project, so that there is adequate time to make the course corrections needed for approval of the GBR baseline approach by the State Geotechnical Engineer and the Deputy State Construction Engineer to be obtained so that project development delays are avoided.

See Essex, et al. (2007) for additional guidance on developing GBRs, and their contents.

22-4 Geotechnical and Other Reference Documents

Geotechnical reference documents include interpretive or informational documents that should be made available to bidders, but that should not be considered part of the contract documents. Such documents include, but are not limited to, the following:

- Geotechnical interpretive reports containing results of preliminary geotechnical design used to establish the feasibility of the project design concept and to help quantify geotechnical risks.
- Interpretive geotechnical background information that was used to assess the feasibility of the project Conceptual Design or which could be used by Design-Builders as background information in support of their geotechnical design activities (e.g., geologic stratigraphy).
- As-built information for existing facilities within or adjacent to the project corridor that may or may not be directly affected by the project.
- Detailed construction records for existing facilities within the project corridor.
- Historical information about the project corridor.

The RFP could include as-built information and detailed construction records for existing facilities within the project corridor. In general it has been WSDOT policy to place the risk for the accuracy of as-built documents on the Design-Builder. Therefore, it is important from a contract interpretation standpoint where the as-built information is included in the RFP (e.g., in an appendix), and how it is identified in the RFP. In general, as- built information should not be included in the GBR or GDR, because doing so would place the risk of their accuracy and completeness on WSDOT.

Preliminary geotechnical engineering to develop the Conceptual Design and evaluate its feasibility during the contract development phase should be conducted. Since this is interpretive information developed for the purpose of developing the DB project documents, this information should not be included as part of the contract, but should be made available to Proposers as informational via a reference document.

The focus of any geotechnical analysis or design conducted to develop a DB project should be to evaluate feasibility, and to assess the risk of bidders having wide swings in their bids due to geotechnical issues that have not been adequately defined. For example, if shafts or piles are proposed as foundations for a bridge, the specific foundation loads will not be known accurately enough during GBR and RFP development to determine foundation depths and sizes. Therefore, detailed analysis of foundation skin friction and end bearing resistance would be of little use. The Design- Builder would have to redo such calculations during final design anyway. What is of more use is whether or not shaft or pile foundations are feasible to install, considering impacts to adjacent facilities, ability for equipment of sufficient size to access potential pier locations, etc.

Typically, preliminary geotechnical design to assess feasibility and risk associated with the project Conceptual Design will consist of one or more of the following preliminary geotechnical design activities:

- Feasibility of proposed alignments with consideration to feasible slopes or need for walls, and the potential impact of those fill or cut slopes and walls on adjacent facilities.
- Structure foundation feasibility and risk, and potential impacts to adjacent facilities.
- Conceptual seismic hazard assessment, including site specific ground motion studies (if appropriate for the site and project scope) and the potential for liquefaction and associated seismic hazards caused by liquefaction.
- Preliminary assessment of other existing or potential geologic hazards such as landslides, rockfall, debris flows, etc., as well as the conceptual feasibility of mitigation strategies.
- Potential need for ground improvement to stabilize unstable ground, liquefaction, and excessive settlement, including the feasibility of various ground improvement techniques and their potential impact on adjacent facilities.
- Whether or not on-site materials will be usable as construction materials.
- Feasibility of site conditions present to infiltrate runoff water.
- Need for dewatering, its feasibility, and its potential impact to adjacent facilities.
- Any other preliminary geotechnical design activities needed to assess risks, to help establish baselines that will be included in the GBR, to ensure feasibility of the project Conceptual design, and to assist the WSDOT project office to develop an engineer's estimate for the project.

If there is potential for soil liquefaction at the site, a preliminary assessment of the depth and extent of the liquefiable soils should be considered. A preliminary assessment of the feasibility of potential mitigation schemes may also be considered, as well as an assessment of the impact of liquefaction on the proposed project features, depending on the impact to project feasibility. A more detailed liquefaction investigation and hazard assessment may need to be included in the contract documents to ensure bidding consistency if one or more of the following is true:

- The liquefaction hazard could affect the decision on whether to widen or replace an existing bridge or similar structure.
- The design assumptions and parameters needed to make that liquefaction assessment could vary significantly between proposers such that the project scope could vary significantly (e.g., some proposers feel no stabilization is needed, while others feel that stabilization is necessary or the bridge must be replaced rather than widened).

Similarly, for complex site conditions and large, important structures, it may be necessary to include the results of site specific seismic ground motion or seismic hazard studies in the contract documents rather than just as informational geotechnical reference documents (see Section 22-6).

22-5 Geotechnical RFP Development

The geotechnical portions of the RFP should rely heavily upon the GDM and the AASHTO Bridge Design Specifications. Since the GDM must function as both a practice manual for in-house staff and WSDOT's geotechnical consultants and as a contract document for DB projects, the RFP should clarify how to interpret the GDM for the purposes of the DB contract, to fit the GDM within the context of the project specific contract. Furthermore, the GDM may not cover every geotechnical design situation needed in the DB project, and the RFP may need to include additional design provisions not covered by the GDM, AASHTO, or other available design specifications or manuals. The RFP essentially is contractually establishing the geotechnical engineering design requirements for the DB project.

Table 1-2, defines words used in the GDM to convey design policy (e.g., "should," "shall," "may"). These words also have important contractual implications in the RFP for conveying whether or not the Design-Builder has any options with regard to the specific design requirement. The GDM also identifies design policy issues and options that require specific approval from the State Geotechnical Engineer and/ or Bridge Design Engineer. In such cases, as it applies to DB contracts, the Design-Builder should assume that design provisions requiring approval from the State Geotechnical Engineer and/or the Bridge Design Engineer are not approved, but can only be considered through the Alternative Technical Concepts (ATC) process. Since these address design policy issues, the State Geotechnical Engineer and/or Bridge Design Engineer in this context are not to be considered equivalent to the designer of record for the DB contractor, as decisions on these policy issues are not within the authority of the Engineer of Record.

The GDM is written to augment or supersede the AASHTO Bridge Design Specifications; therefore, if there is an apparent conflict between the GDM and the AASHTO specifications or other referenced documents, the GDM should be considered to be higher in the order of precedence than the AASHTO specifications or other referenced design documents.

With regard to the geotechnical conditions (not design and construction requirements), the GBR should be considered to be highest in the order of precedence in the RFP.

22-6 Geotechnical Investigation During RFP Advertisement

Often with DB, specific project elements cannot be reasonably defined at the time the contract documents are produced. To help minimize contingency costs in the bids and limit risk, it may be desirable to perform supplemental geotechnical investigations after the RFP has been advertised (while the bidders are preparing proposals) to augment the GDR and GBR. Whether or not supplemental geotechnical investigations should be completed during the RFP process is determined by mutual agreement between the State Geotechnical Engineer and Region/Headquarters management prior to advertisement of the RFP. The defined term for this in the RFP is as follows: Supplemental Geotechnical Data Report (SGDR). The Contract Document developed pursuant to ITP Section X.X.X, that contains factual subsurface data collected prior to the Proposal Date, and which is included in Appendix XX. Should supplemental investigation occur, the short-listed Proposers should submit requests for additional information including locations and depths of borings. The State will evaluate the requests and develop an exploration program that eliminates duplication of borings in specific locations. Doing this will eliminate potential conflicts between Proposers, unwanted congestion due to the presence of multiple sets of drilling rigs and multiple crews, and to excessive costs through elimination of duplicated efforts. An example of Instructions to Proposers (ITP) language for a supplementary boring program is provided in Appendix 22-A.

Once the supplemental boring program is completed, the new subsurface data should be included in the GDR through a contract addendum. If the supplemental borings conflict with the GBR, an amendment to the GBR should be developed by the Headquarters Geotechnical Office or the WSDOT Geotechnical Consultant who developed the GBR and included as an addendum to the contract.

22-7 Geotechnical Support for Design-Build Projects During RFP Advertisement and Post-Award

Regarding the geotechnical review of proposals, the focus of this geotechnical support is to evaluate geotechnical aspects of the Proposal in terms of the scoring criteria spelled out in the Instructions to Proposers. Whether or not geotechnical review of bidder proposals is required will depend on the importance and complexity of the geotechnical issues in the project, and if there are any scoring criteria focused on geotechnical issues. Alternative Technical Concepts (ATCs) may also be proposed during the bidding phase. Similarly, the geotechnical support needed includes the assessment of the technical adequacy of the ATC relative to the contract design documents, or that at least the ATC will provide a level of quality that is equal to or better than the contract Conceptual Design and that is consistent with accepted design practice which in general is defined by the RFP.

Once the contract is awarded, geotechnical oversight by the owner (WSDOT) is required to ensure that the final design and its construction meet the contract requirements. This geotechnical oversight is also needed to address unanticipated site conditions (see Differing Site Conditions clause in 1-04.7 of the RFP, i.e., Request for Proposals, in WSDOT projects) and potential ambiguities in the contract specifications, if such problems occur.

From this point forward, owner (WSDOT) geotechnical support is focused on review of contractor design and construction submittals and assisting the project office with oversight to verify that the Design-Builder is appropriately addressing geotechnical design or construction problems as they come up, in accordance with the contract. The geotechnical support person must become intimately familiar with the RFP and referenced contractual documents, as those documents dictate the focus of the geotechnical submittal reviews. The geotechnical support person must consider themselves to be a member of the WSDOT project team, and the findings of their review activities are therefore provided to the WSDOT project managers for implementation. The goal is to provide the WSDOT project management with a technical assessment as to whether or not the Design-Builder met the contract technical requirements, verifying that their Quality Control/Quality Assurance (QC/QA) program with regard to geotechnical issues is being properly implemented and is effective in producing a geotechnical design that meets the contract requirements. The purpose of the geotechnical review is not to provide the DB contractor with QC/QA of their design, as the contractor is responsible for their design QC/QA.

Ordinarily, the DB Contract Technical Requirements will require the Design- Builder to define a process in their Quality Management Plan for recording, logging, tracking, responding to, and resolving WSDOT design review comments. This process is managed by the Design-Builder. Geotechnical comments should be incorporated into this process.

Designer preferences, or differences in opinion between the reviewer's and the Design-Builder's judgments/assumptions, etc., are generally not relevant to these reviews. The focus must be on compliance of the geotechnical design/construction with the contract requirements.

This does not mean that the geotechnical support person is conducting these reviews only at the "30,000 foot level." There may be times when the geotechnical support person must do a comparative design to figure out if the contractor's submittal does meet the contract intent. But in other cases, an evaluation based on the reviewer's geotechnical engineering experience may be sufficient. If problems in the design start to repeat themselves, this may be an indication that either the contractor is not interpreting the contract in a way that is consistent with how WSDOT is interpreting it, or the contractor's design QC/QA is not fully functional. In such cases an oversight review (i.e., a Quality Verification, or QV, review) of the Design-Builder's QA/QC process should be conducted, documenting the review in the Construction Audit Tracking System (CATS), and issuing Non-conforming Issue Reports (NCIs) as appropriate so that the problem can be properly addressed within the provisions of the contract.

The geotechnical support person may also be involved in over-the-shoulder reviews and design task forces of the Design-Builder's work as it progresses. The purpose of such reviews and involvement in the task forces is to not provide design QC/QA or technical direction to the Design-Builder, but simply to work in a cooperative manner with the Design-Builder to head off problems in the design before they get too far along, keeping in mind that the focus is on meeting the contract requirements.

There may be cases where the site conditions encountered by the contractor through additional subsurface explorations or during construction appear to differ from those in the contract documents. Just like any other potential differing site conditions situation, the geotechnical support person should be working with the project management team and Headquarters Construction Office to provide a technical assessment of the claim.

22-8 References

Essex, R. J., 2007, *Geotechnical Baseline Reports for Construction – Suggested Guidelines*, ASCE, Reston, Virginia, 62 pp., http://cedb.asce.org/cgi/wwwdisplay.cgi?0710539.

22-9 Appendices

Appendix 22-A Example Supplemental Geotechnical Boring Program ITP Language

Appendix 22-A Example Supplemental Geotechnical Boring Program ITP Language

Language that may be used in the ITP regarding the availability of a supplemental boring program is provided below. Note that in the first paragraph, this example language allows up to 5 borings to be selected by each of the proposers (typically, three proposers), though for proposed borings that are in close proximity of one another, borings may be combined. This number of supplemental borings (up to 3 × 5 = 15 borings) would typically apply to larger, more complex projects. A smaller number of borings could be used for smaller less complex projects. Ultimately, the number of supplemental borings is a project-specific decision that is made jointly between the Geotechnical Division and the project team.

22-A-1 Supplemental Geotechnical Data Report

Each Proposer is entitled to obtain certain additional geotechnical information by means of a Supplemental Geotechnical Data Report that WSDOT will conduct at WSDOT's own expense. Under the Supplemental Geotechnical Data Report, Proposers may request WSDOT to perform up to five additional test borings and to provide an analysis of the resultant samples.

A request under the Supplemental Geotechnical Data Report must be submitted no later than the Request for Supplemental Boring Deadline set forth in this ITP. Each request shall set forth the location (by station and offset) and highest bottom elevation of the requested borings. Each request shall also include specific requests regarding the frequency and depth of field vane tests; the locations of split-spoon samples and Standard Penetration Tests; the length and diameter of rock cores; the depth of disturbed samples, undisturbed samples, and rock cores sought by the Proposer; and the tests the Proposer desires WSDOT to conduct in relation to the sample gathered.

WSDOT will make reasonable efforts to comply with Proposers' requests under the Supplemental Geotechnical Data Report, but is not obligated to conduct borings at the precise locations requested. To the extent boring locations requested by one or more Proposers are within 20 feet of each other, the locations will be averaged and only one test boring will be conducted. If a Proposer's boring is averaged with another Proposer's boring, neither Proposer will be allowed an additional boring for this supplemental boring program. Survey personnel provided by WSDOT will establish the boring locations and elevations. A qualified inspector working for WSDOT will inspect the borings. WSDOT staff or an independent, qualified drilling contractor will perform the borings. At the option of the Proposers, each Proposer may dispatch a maximum of one person to observe the drilling, sampling, testing, and coring, and shall coordinate transportation of the chosen observer to the drilling site with WSDOT. The Proposers' on-site observers shall not interfere with the operation of the surveyor, driller, or inspector.

The WSDOT drill crew or drilling contractor will conduct the following sampling and testing:

- Split-spoon samples and Standard Penetration Tests at 5-foot intervals and every change in stratum.
- Minimum NQ-size rock cores.
- Minimum 10-foot rock cores with RQD.
- Field vane shear tests in soft clays.
- Electronic cone penetrometer testing.
- Conventional laboratory classification testing on disturbed soil samples.
- Conventional laboratory tests on rock samples.
- Such other tests requested by a Proposer and agreed to by WSDOT at WSDOT's sole discretion.

WSDOT will perform the test borings in whatever manner or sequence it deems appropriate at WSDOT's sole discretion. The Supplemental Geotechnical Data Report, including the final boring logs and laboratory test results, will be provided to all Proposers according to Section 1 of this ITP and is included as Appendix G9 of the RFP. To the extent not consumed by testing, the samples resulting from the Supplemental Geotechnical Data Report will be turned over to the Design-Builder immediately after the Contract is awarded.

WSDOT makes no representation as to whether the Supplemental Geotechnical Data Report will be sufficient for the Proposer to prepare its Proposal. Each Proposer must make this determination independently based upon its own independent judgment and experience. Failure by a Proposer to submit a request for test borings under the Supplemental Geotechnical Data Report constitutes a conclusive presumption that the Proposer has determined that it does not require any additional geotechnical data to properly design, construct, and price the Work, or that it will obtain any necessary geotechnical data at its own expense using its own forces. If permits are required for supplemental borings (in addition to those permits already required for the Project), WSDOT may not be able to permit the borings within the deadline.

Chapter 23 Geotechnical Reporting and Documentation

23.1 Overview and General Requirements

The Geotechnical Office, and consultants working on WSDOT projects, produce geotechnical reports and design memorandums in support of project definition, project design, and final PS&E development (see Chapter 1). Also produced are project specific Special Provisions, plan details, boring logs, Summary of Geotechnical Conditions, and the final project geotechnical documentation. Information developed to support these geotechnical documents are retained in the Geotechnical Office files. The information includes project site data, drilling inspector's field logs, test results, design calculations, and construction support documents. This chapter provides standards for the development and detailed checklists for review of these documents and records, with the exception of borings logs, which are covered in Chapter 4, Materials Source Reports, which are covered in Chapter 21, and Geotechnical Baseline Reports (GBR), which are covered in Chapter 22. The general format, review, and certification requirements for these documents are provided in Chapter 1.

The Region Materials Offices also produce reports that contain geotechnical information and recommendations as discussed in Chapter 1 (e.g., Region Soil Reports). As applicable, the standards contained within this chapter should also be used for the development of these regional reports.

Documents and project geotechnical documentation/records produced by the Geotechnical Office, and consultants working on WSDOT projects, shall meet as applicable the informational requirements listed in the following FHWA manual:

- FHWA, 2003, Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, Publication No. FHWA ED-88-053, Updated edition.

This FHWA manual also includes a PS&E review checklist. The PS&E review checklist contained in this FHWA manual should be used to supplement the WSDOT Geotechnical Office PS&E review checklist provided in Appendix 23-A. These checklists should be used as the basis for evaluating the completeness of the PS&E regarding incorporation of the project geotechnical recommendations and geotechnical data included in the geotechnical report for the project.

23.2 Report Certification and General Format

Table 23-1 provides a listing of reports produced by the Geotechnical Office, the type of certification needed to be consistent with the certification policies provided in Chapter 1 and WSDOT Executive Order E1010.00, and the general format that would typically be used. For formal geotechnical reports, the signatures and stamps will be located on the front of the report. For memorandums, a signature/stamp page will be added to the back of the memorandum. All those involved in the engineering for the project must sign these documents (i.e., the designer(s), the reviewer(s), and the State Geotechnical Engineer, or the individual delegated to act on behalf the State Geotechnical Engineer), and if licensed and as appropriate, certify the documents as summarized in Table 23-1.

For reports that cover individual project elements, a geotechnical design memorandum may suffice, with the exception of bridge reports and major unstable slope design reports, in which case a formal geotechnical report should be issued. For project reports, a formal geotechnical report should be issued. For geotechnical reports that are sent to agencies outside of WSDOT, a letter report format will be used in place of the memorandum format. Alternatively, a formal report transmitted with a letter may be used.

E-mail may be used for geotechnical reporting in certain circumstances. E-mails may be used to transmit review of construction submittals, and Region soil reports sent to the Geotechnical Office for concurrence. E-mails may also be used to transmit conceptual foundation or other conceptual geotechnical recommendations. In both cases, a print-out of the e-mail should be included in the project file. For time critical geotechnical designs sent by e-mail that are not conceptual, the e-mail should be followed up with a stamped memorandum or report as soon as possible. A copy of the e-mail should also be included in the project file.

For reports produced by others outside of WSDOT, the certification requirements described herein are applicable, but the specific report format will be as mutually agreed upon by the Geotechnical Office and those who are producing the report.

Report	General Format	+Type of Certification Required	Who Certifies?		
			Designer and Report Writer	Primary Licensed Technical Reviewer or Supervisor	State Geotech. Engineer (SGE), Chief Foundation Engineer (CFE), or Chief Engineering Geologist (CEG)
Preliminary Bridge Report	Memorandum	PE seal, dated but not signed	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Final Bridge Report	Formal bound report	PE seal, signed and dated (+LEG optional)	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Preliminary Ferry Terminals, Docks, etc.	Memorandum	PE seal, dated but not signed	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Final Ferry Terminals, Docks, etc.	Formal bound report	PE seal, signed and dated (+LEG optional)	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Retaining Wall/ Reinforced Slope Report	Formal bound report	PE seal, signed and dated (+LEG optional)	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Line Work Report (cuts, fills, etc.)	Formal bound report	PE seal, signed and dated, or both PE and LEG seals, depending on geologic complexity	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Small Foundation Report (signals, noise walls, etc.)	Memorandum, unless otherwise requested	PE seal, signed and dated	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Ponds, Environmental Mitigation	Memorandum, unless otherwise requested	PE seal, signed and dated, or both PE and LEG seals, depending on geologic complexity	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level

WSDOT Geotechnical Report Certification and Format Requirements
Table 23-1

Report	General Format	+Type of Certification Required	Who Certifies?		
			Designer and Report Writer	Primary Licensed Technical Reviewer or Supervisor	State Geotech. Engineer (SGE), Chief Foundation Engineer (CFE), or Chief Engineering Geologist (CEG)
Structure Preservation (bridges, walls, etc.) Reports	Memorandum, unless otherwise requested	PE seal, signed and dated (+LEG optional)	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Rockfall, Rockslope Design Reports	Formal bound report	PE or LEG seal, signed and dated	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Landslide Reports	Formal bound report	PE or LEG seal, signed and dated, or both PE and LEG seals if structures are involved	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Pit and Quarry Reports and Reviews	Memo if review only; otherwise, formal bound report	LEG seal, signed and dated, for report; seal required for review memo only if changes to interpretation or design in the report are recommended	Seal if licensed, as noted under Certification Required	Seal, as noted under Certification Required	Seal, as noted under Certification Required, if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Geologic hazard assessments (e.g., for critical area ordinance issues)	Can be a formal report or a letter report	LEG seal, signed and dated (also include PE seal, if structures involved)	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Geology and Soils Discipline and EIS Reports	Usually a formal bound report	PE or LEG seal, signed and dated, or both PE and LEG seals, depending on geologic complexity or if structures are involved	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level

Report	General Format	+Type of Certification Required	Who Certifies?		
			Designer and Report Writer	Primary Licensed Technical Reviewer or Supervisor	State Geotech. Engineer (SGE), Chief Foundation Engineer (CFE), or Chief Engineering Geologist (CEG)
Consultant Report Reviews	Letter to consultant or memo. to Region	None, unless changes to design are recommended, in which case review letter is sealed (signed and dated) by PE, or LEG, or both, depending on geologic complexity	Seal review letter if licensed, as noted under Certification Required	Seal review letter, as noted under Certification Required	Seal review letter if acting as primary technical reviewer, or if final recommendations in review letter are influenced by the review at this level, as noted under Certification Required
Emergency Work	E-mail or memo.	None for preliminary assessment; for final design, PE or LEG seal, signed and dated, or both PE and LEG seals, depending on geologic complexity and if structures are involved	Seal for final design if licensed	Seal for final design	Seal for final design if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
CSL Reports	Memorandum	PE seal, signed and dated	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Construction Support resulting in engineering changes (must result in a change order, and must affect the engineering intent of the contract design)	Memorandum	PE or LEG seal, signed and dated, or both PE and LEG seals, depending on geologic complexity and if structures are involved	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Construction Submittals	Memorandum	None	None	None	N/A

Report	General Format	+Type of Certification Required	Who Certifies?		
			Designer and Report Writer	Primary Licensed Technical Reviewer or Supervisor	State Geotech. Engineer (SGE), Chief Foundation Engineer (CFE), or Chief Engineering Geologist (CEG)
Special Provisions and Summary of Geotechnical Conditions	Usually an appendix to report; memorandum if sent separately	PE or LEG seal, signed and dated, or both PE and LEG seals, depending on nature of Special Provision	Seal if licensed	Seal	Seal if acting as primary technical reviewer, or if final recommendations are influenced by the review at this level
Construction Plans	Plan sheets	PE or LEG seal, signed and dated, or both PE and LEG seals, depending on nature of plan sheets	None	Seal	Seal if acting as primary technical reviewer
Final Geotechnical Project Documentation	Formal bound report	None required, since all subdocuments have been stamped	None	None	N/A

•Some judgment may be used on whether or not to use a memorandum format for small walls, line projects, and small rockfall or rockslope projects.

+Projects that require significant, non-routine, geologic interpretation to provide a correct site characterization and geologic interpretation of design properties may also require a LEG seal.

23.3 Geotechnical Office Report Content Requirements

Design Manual M 22-01 Chapter 610, includes lists of the geotechnical information that should be provided in final geotechnical reports addressing various specific geotechnical subject matters. Specifically addressed in the *Design Manual* M 22-01 Chapter 610 are geotechnical reports providing final recommendations for earthwork, hydraulic structures (including infiltration facilities), foundations for signals, signs, etc., retaining walls, unstable slopes (landslides, rockfall, etc.), rock slopes, bridge foundations, and WSF projects.

A more detailed description of the geotechnical information and types of recommendations that should be provided in geotechnical reports is provided in the sections that follow. Both conceptual level reports and final reports are addressed.

23.3.1 Conceptual or Preliminary Level Geotechnical Reports

Conceptual level geotechnical reports are typically used to provide geotechnical input for the following:

- Developing the project definition
- Development of preliminary bridge and WSF facility layouts
- Conceptual geotechnical studies for environmental permit development activities,
- Reconnaissance level corridor studies,
- Development of EIS discipline studies, and
- Geotechnical Baseline Reports (GBR) for design-build projects (see Chapter 22 for details on the GBR).

Preliminary level geotechnical reports are typically used to provide geotechnical input for the following:

- The determination of preliminary location and size of infiltration facilities,
- Alternative analyses (e.g., TS&L for structures, preliminary grading analyses, etc.)
- Rapid assessment of emergency repair needs (e.g., landslides, rockfall, bridge foundation scour, etc.)

Conceptual level geotechnical reports are in general developed based on a minimum of an office review of existing geotechnical data for the site, and generally consist of feasibility assessment and identification of geologic hazards. Geotechnical design for conceptual level reports is typically based on engineering judgment and experience at the site or similar sites. For preliminary level design, a geological reconnaissance of the project site and a limited subsurface exploration program are usually conducted, as well as some detailed geotechnical analysis to characterize key elements of the design, adequate to assess potential alternatives and estimate preliminary costs. For conceptual level design of more complex projects with potentially unusual subsurface conditions, or potential instability, a geotechnical reconnaissance of the site should be conducted in addition to the office review to assess the site conditions. Note that for preliminary design of infiltration facilities, the seasonal ground water depth should be established early in the project to assess feasibility (i.e., during project definition), since it usually takes a minimum of one season to characterize groundwater conditions. A minimum of one to two test holes, with piezometers installed, are usually required to establish the water table depth for this purpose. Additional test holes may be needed during final design (see Chapter 19 and the WSDOT *Highway Runoff Manual*).

These conceptual or preliminary level reports should contain the following elements:

1. A general description of the project, project elements, and project background.
2. A brief summary of the regional and site geology. The amount of detail included here will depend on whether the report is at the conceptual or preliminary level, and on the type of report. For example, Critical Area Ordinance reports and EIS discipline studies will tend to need a more detailed discussion on site and regional geology than would a conceptual bridge foundation report, an emergency landslide, or a scour repair evaluation report.
3. A summary of the site data available from which the conceptual or preliminary recommendations were made.
4. A summary of the field exploration conducted, if applicable.
5. A summary of the laboratory testing conducted, if applicable.
6. A description of the project soil and rock conditions. The amount of detail included here will depend on whether the report is at the conceptual or preliminary level, and on the type of report. For preliminary design reports in which new borings have been obtained, soil profiles for key project features (e.g., bridges, major walls, etc.) may need to be developed and tied to this description of project soil and rock conditions.
7. A summary of geological hazards identified that may affect the project design (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards, etc.), if any.
8. A summary of the conceptual or preliminary geotechnical recommendations.
9. Appendices that include any boring logs and laboratory test data obtained, soil profiles developed, any field data obtained, and any photographs.

Special requirements for the content of discipline reports for EA and EIS studies are provided in *Environmental Procedures Manual* M 31-11, specifically Chapter 420.

23.3.2 Final Geotechnical Design Reports

Final (PS&E level) geotechnical reports are in general developed based on an office review of existing geotechnical data for the site, a detailed geologic review of the site, and a complete subsurface investigation program meeting AASHTO and FHWA standards, or as augmented in this manual. Final geotechnical reports should contain the following elements:

1. A general description of the project, project elements, and project background.
2. Project site surface conditions and current use.
3. Regional and site geology. This section should describe the site stress history and depositional/erosional history, bedrock and soil geologic units, etc.

4. Regional and site seismicity. This section should identify potential source zones, potential magnitude of shaking, frequency, historical activity, and location of nearby faults. This section is generally only included in reports addressing structural elements (e.g., bridges, walls, marine terminal structures, etc.) and major earthwork projects.
5. A summary of the site data available from project or site records (e.g., final construction records for previous construction activity at the site, as-built bridge or other structure layouts, existing test hole logs, geologic maps, previous or current geologic reconnaissance results, etc.).
6. A summary of the field exploration conducted, if applicable. Here, a description of the methods and standards used is provided, as well as a summary of the number and types of explorations that were conducted. Include also a description of any field instrumentation installed and its purpose. Refer to the detailed logs located in the report appendices.
7. A summary of the laboratory testing conducted, if applicable. Again, a description of the methods and standards used is provided, as well as a summary of the number and types of tests that were conducted. Refer to the detailed laboratory test results in the report appendices.
8. Project Soil/Rock Conditions. This section should include not only a description of the soil/rock units encountered, but also how the units tie into the site geology. Ground water conditions should also be described here, including the identification of any confined aquifers, artesian pressures, perched water tables, potential seasonal variations, if known, any influences on the ground water levels observed, and direction and gradient of ground water, if known. If rock slopes are present, discuss rock structure, including the results of any field structure mapping (use photographs as needed), joint condition, rock strength, potential for seepage, etc.

   These descriptions of soil and rock conditions should in general be illustrated with subsurface profiles (i.e., parallel to roadway centerline) and cross-sections (i.e., perpendicular to roadway centerline) of the key project features. A subsurface profile or cross-section is defined as an illustration that assists the reader of the geotechnical report to visualize the spatial distribution of the soil and rock units encountered in the borings and probes for a given project feature (e.g., structure, cut, fill, landslide, etc.). As such, the profile or cross-section will contain the existing and proposed ground line, the structure profile or cross-section if one is present, the boring logs (including SPT values, soil/rock units, etc.), and the location of any water table(s). Interpretive information contained in these illustrations should be kept to a minimum. What appears to be the same soil or rock unit in adjacent borings should not be connected together with stratification lines unless that stratification is reasonably certain. The potential for variability in the stratification must be conveyed in the report, if a detailed stratification is provided. In general, geologic interpretations (e.g., Vashon till, Vashon recessional, etc.) should not be included in the profile or cross-section, but should be discussed more generally in the report.

A subsurface profile must always be provided for bridges, tunnels, and other significant structures. For retaining walls, subsurface profiles should always be provided for soil nail walls, anchored walls, and non-gravity cantilever walls, and all other walls in which there is more than one boring along the length of the wall. For other wall situations, judgment may be applied to decide whether or not a subsurface profile is needed. For cuts, fills, and landslides, soil profiles should be provided for features of significant length, where multiple borings along the length of the feature are present. Subsurface cross-sections must always be provided for landslides, and for cuts, fills, structures, and walls that are large enough in cross-section to warrant multiple borings to define the subsurface cross-section.

9. Summary of geological hazards identified and their impact on the project design (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards, etc.), if any. Describe the location and extent of the geologic hazard.

10. For analysis of unstable slopes (including existing settlement areas), cuts, and fills, background regarding the following:
    - analysis approach,
    - assessment of failure mechanisms,
    - determination of design parameters, and
    - any agreements with Region or other customers regarding the definition of acceptable level of risk.

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

11. Geotechnical recommendations for earthwork (fill design, cut design, usability of on-site materials as fill). This section should provide embankment design recommendations, if any are present, such as the slope required for stability, any other measures that need to be taken to provide a stable embankment (e.g., geosynthetic reinforcement, wick drains, controlled rate of embankment construction, lightweight materials, etc.), embankment settlement magnitude and rate, and the need and extent of removal of any unsuitable materials beneath the proposed fills.

    Cut design recommendations, if any are present, are also provided in this section, such as the slope required for stability, seepage and piping control, erosion control measures needed (concept only – other WSDOT offices will provide the details on this issue), and any special measures required to provide a stable slope.

    Regarding usability of on-site materials, soil units should be identified as to their feasibility of use as fill material, discussing the type of fill material for which the on-site soils are feasible, the need for aeration, the effect of weather conditions on its usability, and identification of materials that should definitely be considered as waste.

12. Geotechnical recommendations for rock slopes and rock excavation. Such recommendations should include, but are not limited to, stable rock slope, rock bolting/dowelling, and other stabilization requirements, including recommendations to prevent erosion/undermining of intact blocks of rock, internal and external slope drainage requirements, feasible methods of rock removal, etc.
13. Geotechnical recommendations for stabilization of unstable slopes (e.g., landslides, rockfall areas, debris flows, etc.). This section should provide a discussion of the mitigation options available, and detailed recommendations regarding the most feasible options for mitigating the unstable slope, including a discussion of the advantages, disadvantages, and risks associated with each feasible option.
14. Geotechnical recommendations for bridges, tunnels, hydraulic structures, and other structures. This section should provide a discussion of foundation options considered, the recommended foundation options, and the reason(s) for the selection of the recommended foundation option(s), foundation design requirements (for strength limit state - ultimate bearing resistance and depth, lateral and uplift resistance, for service limit state - settlement limited bearing, and any special design requirements), seismic design parameters and recommendations (e.g., design acceleration coefficient, soil profile type for standard AASHTO response spectra development, or develop non-standard response spectra, liquefaction mitigation requirements, extreme event limit state bearing, uplift, and lateral resistance, and soil spring values), design considerations for scour when applicable, earth pressures on abutments and walls in buried structures, and recommendations regarding bridge approach slabs. Detailed reporting requirements for LRFD foundation reports are provided in Section 23.2.3.
15. Geotechnical recommendations for retaining walls and reinforced slopes. This section should provide a discussion of wall/reinforced slope options considered, the recommended wall/reinforced slope options, and the reason(s) for the selection of the recommended option(s), foundation type and design requirements (for strength limit state - ultimate bearing resistance, lateral and uplift resistance if deep foundations selected, for service limit state - settlement limited bearing, and any special design requirements), seismic design parameters and recommendations (e.g., design acceleration coefficient, extreme event limit state bearing, uplift and lateral resistance if deep foundations selected) for all walls except Standard Plan walls, design considerations for scour when applicable, and lateral earth pressure parameters (provide full earth pressure diagram for non-gravity cantilever walls and anchored walls). For nonproprietary walls/reinforced slopes requiring internal stability design (e.g., geosynthetic walls, soil nail walls, all reinforced slopes), provide minimum width for external and overall stability, embedment depth, bearing resistance, and settlement, and also provide soil reinforcement spacing, strength, and length requirements in addition to dimensions to meet external stability requirements. For proprietary walls, provide minimum width for overall stability, embedment depth, bearing resistance, settlement, and design parameters for determining earth pressures. For anchored walls, provide achievable anchor capacity, no load zone dimensions, and design earth pressure distribution. Detailed reporting requirements for LRFD wall reports are provided in Section 23.2.3.

16. Geotechnical recommendations for infiltration/detention facilities. This section should provide recommendations regarding infiltration rate, impact of infiltration on adjacent facilities, effect of infiltration on slope stability, if the facility is located on a slope, stability of slopes within the pond, and foundation bearing resistance and lateral earth pressures (vaults only). See the *Highway Runoff Manual* for additional details on what is required for these types of facilities.
17. Long-term or construction monitoring needs. In this section, provide recommendations on the types of instrumentation needed to evaluate long-term performance or to control construction, the reading schedule required, how the data should be used to control construction or to evaluate long-term performance, and the zone of influence for each instrument.
18. Construction considerations. Address issues of construction staging, shoring needs and potential installation difficulties, temporary slopes, potential foundation installation problems, earthwork constructability issues, dewatering, etc.
19. Appendices. Typical appendices include design charts for foundation bearing and uplift, P-Y curve input data, design detail figures, layouts showing boring locations relative to the project features and stationing, subsurface profiles and typical cross-sections that illustrate subsurface stratigraphy at key locations, all boring logs used for the project design (includes older borings as well as new borings), including a boring log legend for each type of log, laboratory test data obtained, instrumentation measurement results, and special provisions needed.

The detail contained in each of these sections will depend on the size and complexity of the project or project elements and subsurface conditions. All of these report elements may not be applicable to all geotechnical reports, especially if the report is for a specific project element that is limited in geotechnical scope, such as a culvert replacement, a single wall, an infiltration pond, a sign bridge, etc. In such cases, a briefer report is acceptable. Furthermore, design memoranda that do not contain all of the elements described above may be developed prior to developing a final geotechnical report for the project to meet project schedule needs.

23.3.3 Special Reporting Requirements for LRFD Foundation and Wall Designs

The geotechnical designer should provide the following information to the structural designer for Load and Resistance Factor Design (LRFD):

23.3.3.1 Footings

To evaluate bearing resistance, the geotechnical designer provides qn, the unfactored nominal (ultimate) bearing resistance available for the strength and extreme event limit states, and qserv, the settlement limited nominal bearing resistance for the specified settlement (typically 1 inch) for various effective footing widths likely to be used for the service limit state, and resistance factors for each limit state. The amount of settlement on which qserv is based shall be stated. The geotechnical designer also provides embedment depth requirements or footing elevations to obtain the recommended bearing resistance.

To evaluate sliding stability and eccentricity, the geotechnical designer provides resistance factors for both the strength and extreme event limit states for calculating the shear and passive resistance in sliding, as well as the soil parameters ϕ, K_p, γ and depth of soil in front of footing to ignore in calculating the passive resistance, and ϕ, K_a, γ, K_{ae}, and the earth pressure distributions to use for the strength and extreme event (seismic) limit states for calculating active force behind the footing (abutments only – see Section 23.2.3.4 on walls).

To evaluate soil response and development of forces in foundations for the extreme event limit state, the geotechnical designer provides the foundation soil/rock shear modulus values and Poissons ratio (G and μ).

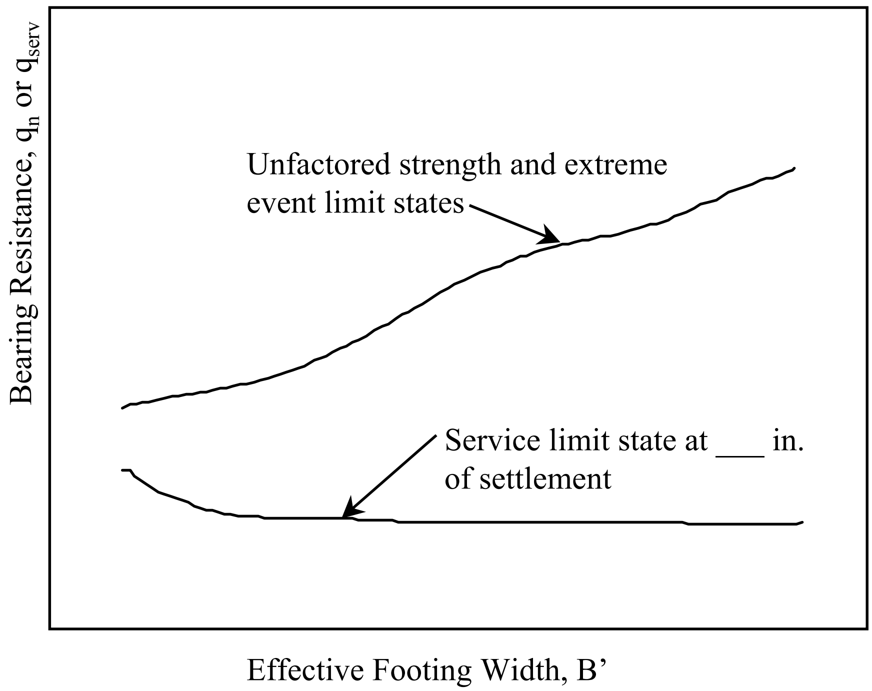
The geotechnical designer evaluates overall stability and provides the maximum (unfactored) footing load which can be applied to the design slope and still maintain an acceptable safety factor (1.5 for the strength and 1.1 for the extreme event limit states, which is the inverse of the resistance factor). A uniform bearing stress as calculated by the Meyerhof method should be assumed for this analysis. An example presentation of the LRFD footing design recommendations to be provided by the geotechnical designer is as shown in Tables 23-2 and 23-3, and Figure 23-1. See Section 23.2.3.4 for examples of the additional information submitted for abutment wall design.

Parameter	Abutment Piers	Interior Piers
Soil Unit Weight, γ (soil above footing base level)	X	X
Soil Friction Angle, φ (soil above footing base level)	X	X
Active Earth Pressure Coefficient, K_a	X	X
Passive Earth Pressure Coefficient, K_p	X	X
Seismic Earth Pressure Coefficient, K_{ae}	X	
Coefficient of Sliding, Tan δ	X	X

Example Presentation of Soil Design Parameters for Sliding and Eccentricity Calculations
Table 23-2

Limit State	Resistance Factor, φ		
	Bearing	Shear Resistance to Sliding	Passive Pressure Resistance to Sliding
Strength	X	X	X
Service	X	X	X
Extreme Event	X	X	X

Example Presentation of Resistance Factors for Footing Design
Table 23-3



Example Presentation of Bearing Resistance Recommendations
Figure 23-1

23.3.3.2 Drilled Shafts

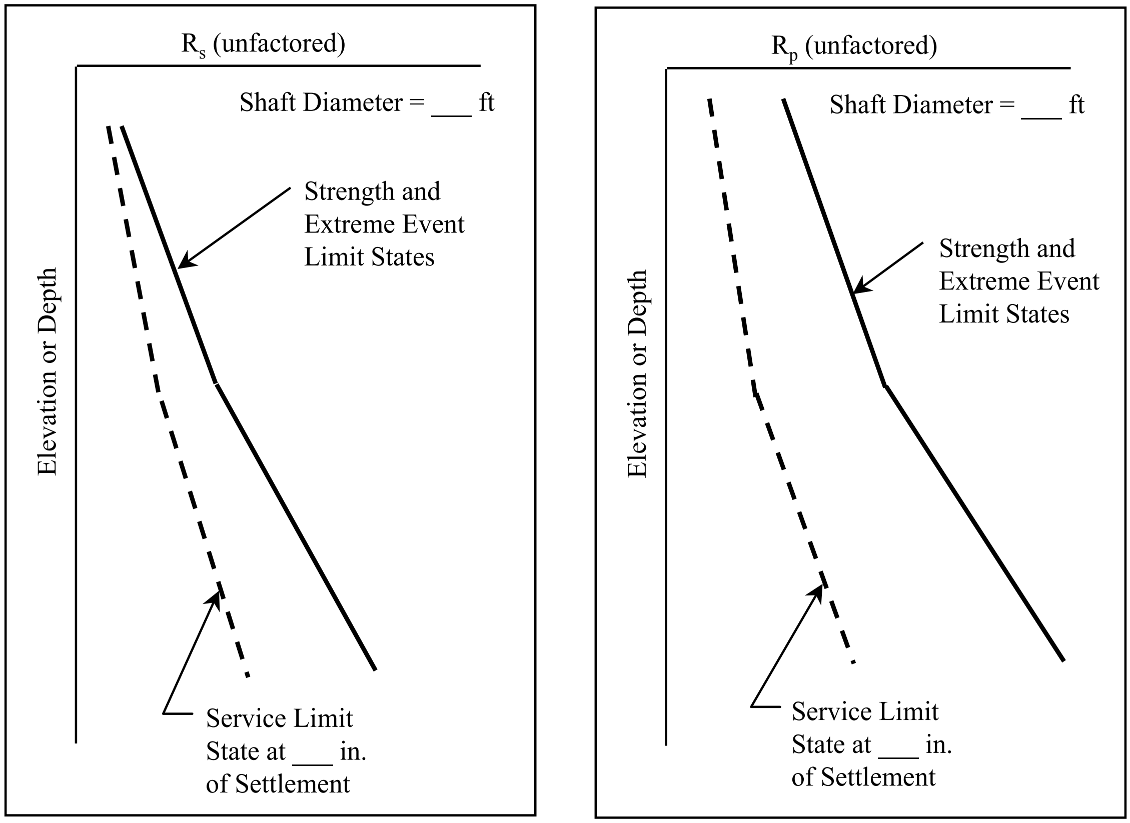
To evaluate bearing resistance, the geotechnical designer provides as a function of depth and at various shaft diameters the unfactored nominal (ultimate) bearing resistance for end bearing, R_p, and side friction, R_s, used to calculate R_n, for strength and extreme event limit state calculations (see example figures below). For the service limit state, the unfactored bearing resistance at a specified settlement, typically 0.5 or 1.0 inch (mobilized end bearing and mobilized side friction) should be provided as a function of depth and shaft diameter. See Figure 23-2 for an example of the shaft bearing resistance information that would be provided. Resistance factors for bearing resistance for all limit states will also be provided, as illustrated in Table 23-4.

If downdrag is an issue, the ultimate downdrag load, DD, as a function of shaft diameter will be provided, as well as the depth zone of the shaft that is affected by downdrag, the downdrag load factor, and the cause of the downdrag (settlement due to vertical stress increase, liquefaction, etc.). If liquefaction occurs, the lost side friction resistance, RSdd, due to downdrag will be provided (see Chapter 8, Figure 8-31).

If scour is an issue, the magnitude and depth of the skin friction lost due to scour, Rscour, will also be provided (see Chapter 8, Figure 8-30).

Limit State	Resistance Factor, φ		
	Skin Friction	**End bearing**	**Uplift**
Strength	X	X	X
Service	X	X	X
Extreme Event	X	X	X

Example Presentation of Resistance Factors for Shaft Design
Table 23-4



Typical Shaft Bearing Resistance Plots (All Limit States)
Figure 23-2

If lateral loads imposed by special soil loading conditions such as landslide forces are present, the nominal (ultimate) lateral soil force or stress distribution, and the load factors to be applied to that force or stress, will be provided.

For evaluating uplift, the geotechnical designer provides, as a function of depth, the nominal (ultimate) uplift resistance, R_n. The skin friction lost due to scour or liquefaction to be applied to the uplift resistance curves should be provided (separately, in tabular form). Resistance factors are also be provided.

The geotechnical designer also provides group reduction factors for bearing resistance and uplift if necessary, as well as the associated resistance factors.

The geotechnical designer also provides soil/rock input data for P-y curve generation or as input for conducting strain wedge analyses (e.g., the computer program S-Shaft) as a function of depth. Resistance factors for lateral load analysis generally do not need to be provided, as the lateral load resistance factors will typically be 1.0.

23.3.3.3 Piles

To evaluate pile resistance, the geotechnical designer provides information regarding pile resistance using one of the following two approaches:

1. A plot of the unfactored nominal (ultimate) bearing resistance (Rn) as a function of depth for various pile types and sizes for strength and extreme event limit state calculations are provided. This design data would be used to determine the feasible ultimate pile resistance and the estimated depth for pile quantity determination. See Figure 23-3 for example of pile data presentation.
2. Only R_n and the estimated depth at which it could be obtained are provided for one or more selected pile types and sizes.

Resistance factors for bearing resistance for all limit states will also be provided (see Table 23-5 for an example).

If downdrag is an issue, the ultimate downdrag load, DD, as a function of pile diameter should be provided, as well as the depth zone of the pile that is affected by downdrag, the downdrag load factor, and the cause of the downdrag (settlement due to vertical stress increase, liquefaction, etc.). If liquefaction occurs, the lost side friction resistance, RSdd, due to downdrag should be provided (see Chapter 8, Figure 8-31).

If scour is an issue, the magnitude and depth of the skin friction lost due to scour, Rscour, should also be provided (see Chapter 8, Figure 8-30).

If lateral loads imposed by special soil loading conditions such as landslide forces are present, the ultimate lateral soil force or stress distribution, and the load factors to be applied to that force or stress, shall be be provided.

For evaluating uplift, the geotechnical designer shall provide, as a function of depth, the nominal (unfactored) uplift resistance, Rn. This is usually be provided as a function of depth, or as a single value for a given minimum tip elevation, depending on the project needs. The skin friction lost due to scour or liquefaction to be applied to the uplift resistance curves shall also be provided (separately, in tabular form). Resistance factors shall be also be provided for strength and extreme event limit states.

The geotechnical designer shall also provide group reduction factors for bearing resistance and uplift if necessary, as well as the associated resistance factors.

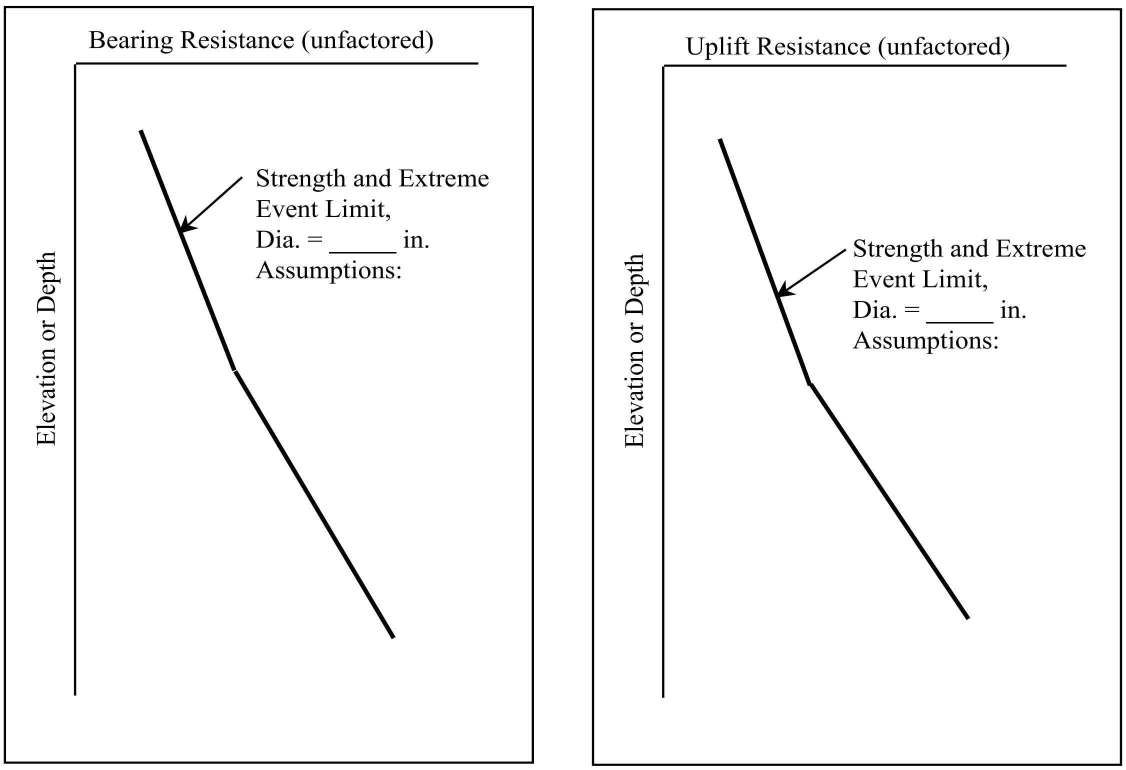
The geotechnical designer shall provide P-Y curve data as a function of depth. Resistance factors for lateral load analysis do not need to be provided, as the lateral load resistance factors will typically be 1.0.

Minimum tip elevations for the pile foundations shall be provided as appropriate. Minimum tip elevations shall be based on pile foundation settlement, and, if uplift loads are available, the depth required to provide adequate uplift resistance (see Section 8.12.6). Minimum pile tip elevations provided in the Geotechnical Report may need to be adjusted depending on the results of the lateral load and uplift load evaluation performed by the structural designer. If adjustment in the minimum tip elevations is necessary, or if the pile diameter needed is different than what was assumed by the geotechnical designer for pile resistance design, the geotechnical designer should be informed so that pile drivability, as discussed below, can be re-evaluated.

Pile drivability shall be evaluated at least conceptually for each project, and if appropriate, a wave equation analysis performed and the results of the analysis provided in terms of special requirements for hammer size and pile wall thickness, etc. The maximum driving resistance required to reach the minimum tip elevation shall also be provided.

	Resistance Factor, φ	
Limit State	**Bearing Resistance**	**Uplift**
Strength	x	x
Service	x	x
Extreme Event	x	x

Example Presentation of Resistance Factors for Pile Design
Table 23-5



Example Presentation of Pile Bearing Resistance and Uplift
Figure 23-3

23.3.3.4 Retaining Walls

To evaluate bearing resistance for footing supported gravity walls, the geotechnical designer provides qn, the unfactored nominal (ultimate) bearing resistance available, and qserv, the settlement limited bearing resistance for the specified settlement for various effective footing widths (i.e., reinforcement length plus facing width for MSE walls) likely to be used, and resistance factors for each limit state. The amount of settlement on which qserv is based shall be stated. The geotechnical designer also provides wall base embedment depth requirements or footing elevations to obtain the recommended bearing resistance.

To evaluate sliding stability, bearing, and eccentricity of gravity walls, the geotechnical designer provides resistance factors for both the strength and extreme event limit states for calculating the shear and passive resistance in sliding. In addition, the geotechnical designer provides the soil parameters ϕ, K_p, and γ, the depth of soil in front of the footing to ignore when calculating passive resistance, the soil parameters ϕ, K_a, and γ used to calculate active force behind the wall, the seismic earth pressure coefficient Kae (see Section 15.4.2.9), the peak ground acceleration (PGA) used to calculate seismic earth pressures, and separate earth pressure diagrams for strength and extreme event (seismic) limit state calculations that include all applicable earth pressures, with the exception of traffic barrier impact loads (traffic barrier impact loads are developed by the structural designer). The geotechnical designer shall also indicate in the report whether or not the wall was assumed to be free to move during seismic loading (e.g., was 0.5xPGA or 1.0.xPGA used to determine K_{ae}).

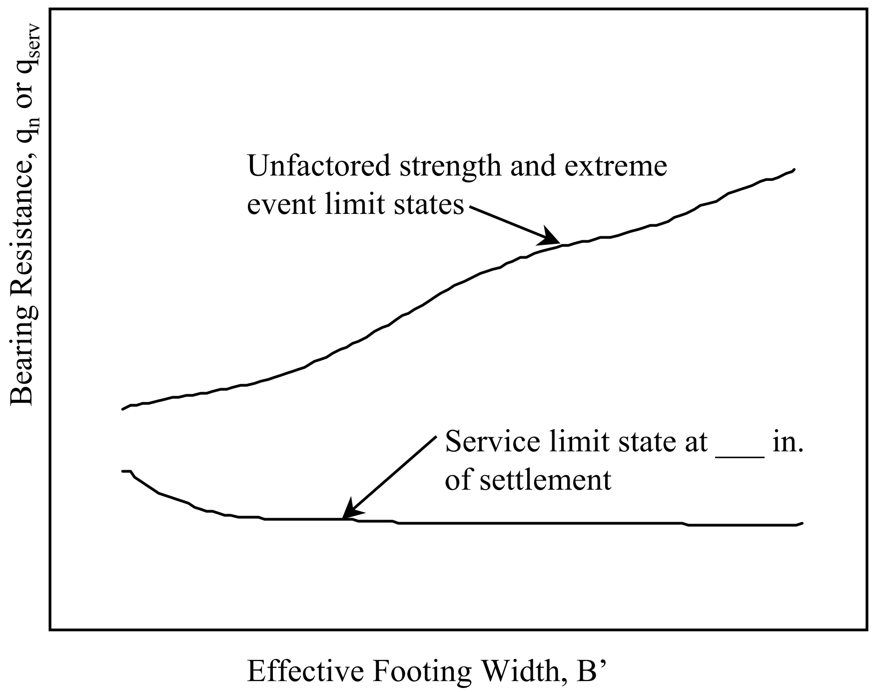
The geotechnical designer shall evaluate overall stability and provide the minimum footing or reinforcement length required to maintain an acceptable safety factor, if overall stability controls the wall width required. An example presentation of the LRFD wall design recommendations to be provided by the geotechnical designer is as shown in tables 23-6 and 23-7, and figures 23-4 and 23-5.

Parameter	Value
Soil Unit Weight, γ (soil above wall footing base level)	X
Soil Friction Angle, φ (soil above wall footing base level)	X
Active Earth Pressure Coefficient, K_a	X
Passive Earth Pressure Coefficient, K_p	X
Seismic Earth Pressure Coefficient, K_{ae}	X
Coefficient of Sliding, Tan δ	X

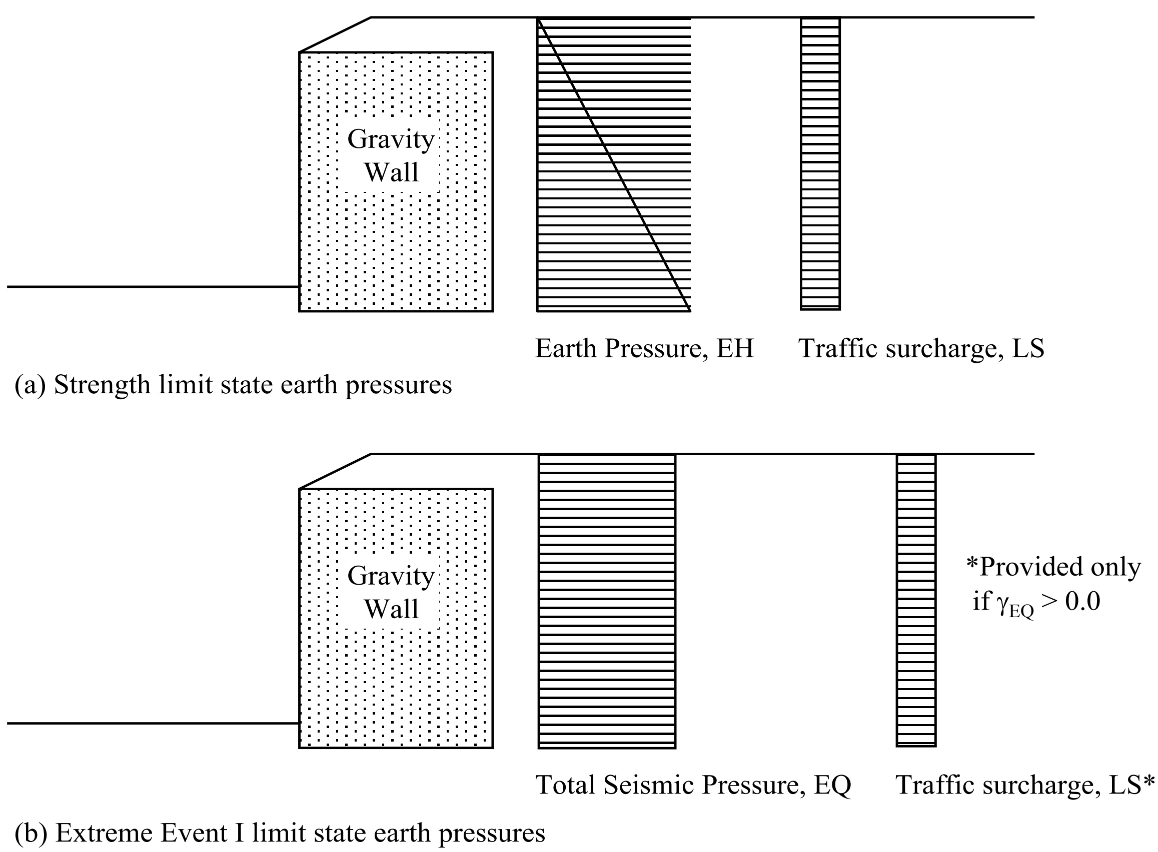
Example Presentation of Soil Design Parameters for Sliding and Eccentricity Calculations for Gravity Walls
Table 23-6

	Resistance Factor, φ		
Limit State	**Bearing**	**Shear Resistance to Sliding**	**Passive Pressure Resistance to Sliding**
Strength	X	X	X
Service	X	X	X
Extreme Event	X	X	X

Example Presentation of Resistance Factors for Wall Design
Table 23-7



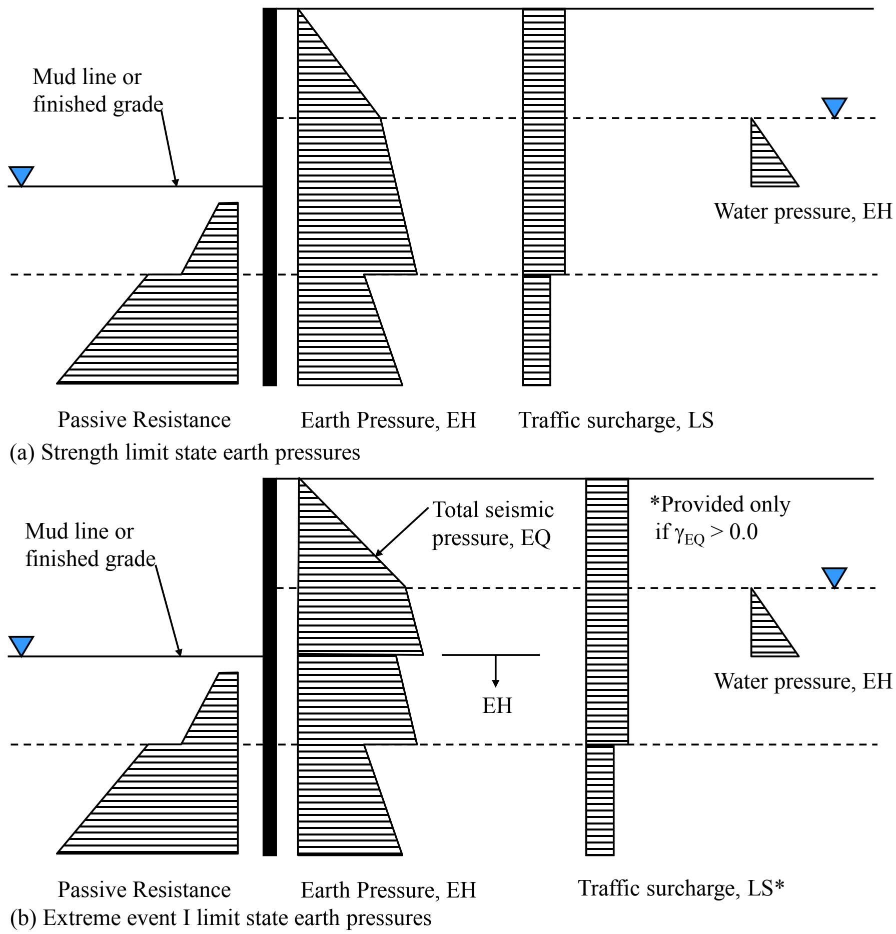
Example Presentation of Bearing Resistance R Ecommendations for Gravity Walls
Figure 23-4



Example Presentation of Lateral Earth Pressures for Gravity Wall Design
Figure 23-5

For non-proprietary MSE walls, the spacing, strength, and length of soil reinforcement should also be provided, as well as the applicable resistance factors.

For non-gravity cantilever walls and anchored walls, ultimate bearing resistance of the soldier piles or drilled shafts as a function of depth (see Section 23.2.3.2, and Figure 23-2), the lateral earth pressure distribution (active and passive), the minimum embedment depth required for overall stability, and the no load zone dimensions, ultimate anchor resistance for anchored walls, and the associated resistance factors shall be provided. Table 23-7 and Figure 23-6 provide an example presentation of earth pressure diagrams for nongravity cantilever and anchored walls to be provided by the geotechnical designer. Note that for the Extreme Event I Limit State (seismic) for anchored walls, the shape of the lateral earth pressure distribution is the same as the Strength Limit State distribution (see AASHTO Article A11.3). Therefore, the active lateral earth pressure for seismic loading for anchored walls may not be triangular as shown in the figure.



Example presentation of lateral earth pressures for non-gravity cantilever and anchored wall design.
Figure 23-6

23.4 Information to Be Provided in the Geotechnical Design File

Documentation that provides details of the basis of recommendations made in the geotechnical report or memorandum is critical not only for review by senior staff, but also for addressing future questions that may come up regarding the basis of the design, to address changes that may occur after the geotechnical design is completed, to address questions regarding the design during construction to address problems or claims, and for background for developing future projects in the same location, such as bridge or fill widenings. Since the engineer who does the original design may not necessarily be the one who deals with any of these future activities, the documentation must be clear and concise, and easy and logical to follow. Anyone who must look at the calculations and related documentation should not have to go to the original designer to understand what was done.

The project documentation should be consistent with FHWA guidelines, as mentioned at the beginning of this chapter, and shall be consistent with the requirements specified in this GDM. Details regarding what this project documentation should contain are provided in the sections that follow.

23.4.1 Documentation for Conceptual Level Geotechnical Design

Document sources of information (including the date) used for the conceptual evaluation. Typical sources include final records, as-built bridge or other structure layouts, existing test hole logs, geologic maps, previous or current geologic reconnaissance results, etc.

If a geologic reconnaissance was or is conducted, the details of that review, including any photos taken that are necessary to illustrate the conditions observed shall be included in this documentation. For structures, provide a description of the foundation support used for the existing structure, including design bearing capacity, if known, and any foundation capacity records such as pile driving logs, load test results, etc. From the final contract records, summarize any known construction problems encountered when building the existing structure. Examples include over-excavation depth and extent, and why it was needed, seepage observed in cuts and excavations, dewatering problems, difficult digging, including obstructions encountered during excavation, obstructions encountered during foundation installation (e.g., for piles or shafts), slope instability during construction, changed conditions or change orders involving the geotechnical features of the project, and anything else that would affect the geotechnical aspects of the project.

For any geotechnical recommendations made, summarize the logic and justification for those recommendations. If the recommendations are based on geotechnical engineering experience and judgment, describe what specific information led to the recommendation(s) made.

23.4.2 Documentation for Final Geotechnical Design

In addition to the information described in Section 23.4.1, the following information shall be documented in the project geotechnical file (or design calculation package submitted by a consultant, contractor, or design builder for WSDOT review as specified in Section 23.5):

1. List or describe all given information and assumptions used, as well as the source of that information. For all calculations, an idealized design cross-section that shows the design element (e.g., wall, footing, pile foundation, buttress, etc.) located in context to the existing and proposed ground lines, and the foundation soil/rock shall be provided. This idealized cross-section should show the soil/rock properties used for design, the soil/rock layer descriptions and thicknesses, the water table location, the existing and proposed ground line, and any other pertinent information. An example design cross-section for a deep foundation is shown in Appendix 23-B. For slope stability, the soil/rock properties used for the design should be shown (handwritten, if necessary) on the computer generated output cross-section.
2. Additional information and/or a narrative shall also be provided which describes the basis for the design soil/rock properties used. The additional details and requirements in Chapter 5 as well as other GDM chapters, applicable to the specific situation, regarding assessment and determination of geotechnical design parameters shall be followed when developing and documenting justification of the selected design parameters. If the properties are from laboratory tests, state where the test results, and the analysis of those test results, can be found in the final geotechnical design documentation and how those test results apply to the specific site conditions and strata encountered, including consideration of site geological history. If using correlations to SPT or cone data, or other measurements, state which correlations were used, the range of applicability of the correlation to the available measurements, the potential uncertainty in the estimated property value due to the use of that correlation, and any corrections to the data made. If using back-analysis based on measurable performance of geotechnical features at the site or near the site in similar geologic conditions and stratigraphy, provide the complete analyses and any assumptions used that are necessary to reduce the number of degrees of freedom in the design model used. When more than one of these approaches to defining design parameters is available and used, the consistency of the results shall be assessed, and the logic used to make the final selection of design parameters obtained from these analyses shall be provided in the documentation. The uncertainty in the design parameters shall also be considered when selecting geotechnical parameters for design. How this uncertainty is addressed shall be documented (e.g., conservative selection of the design parameters or increased overall level of safety used in the design, or both).
3. Identify what is to be determined from these calculations (i.e., what is the objective?). For example, objectives could include foundation bearing resistance, foundation or fill settlement (differential and total), time rate of settlement, the cut or fill slope required, the size of the stabilizing berm required, etc.
4. The design method(s) used shall also be clearly identified for each set of calculations, including any assumptions used to simplify the calculations, if that was done, or to determine input values for variables in the design equation. Write down equation(s) used and meaning of terms used in equation(s), or reference where equation(s) used and/or meaning of terms were obtained. Attach a copy of all curves or tables used in making the calculations and their source, or appropriately reference those tables or figures. Write down or summarize all steps needed to solve the equations and to obtain the desired solution.

5. Identify the load and resistance factors, or safety factors, used for the design. If it is necessary to diverge from the level of safety requirements in the GDM and referenced manuals (e.g., AASHTO), subject to the approval of the State Geotechnical Engineer, identify, and provide justification for, the level of safety used for the design (e.g., load and resistance factors, or safety factors), considering the bias and uncertainty in the design method(s) used, and the uncertainty in the geotechnical design parameters selected for the design.
6. If using computer spreadsheets, provide detailed calculations for one example to demonstrate the basis of the spreadsheet and that the spreadsheet is providing accurate results. Hand calculations are not required for well proven, well documented, and stable programs such as XSTABL or the wave equation. Detailed example calculations that illustrate the basis of the spreadsheet are important for engineering review purposes and for future reference if someone needs to get into the calculations at some time in the future. A computer spreadsheet in itself is not a substitute for that information.
7. Highlight the solutions that form the basis of the engineering recommendations to be found in the project geotechnical report so that they are easy to find. Be sure to write down which locations or piers where the calculations and their results are applicable.
8. Provide a results summary, including a sketch of the final design, if appropriate.

Each set of calculations shall be signed and dated, and the reviewer shall also sign and date the calculations. The name of the designer and reviewer shall also be printed below the signature, to clearly identify these individuals, if their names do not appear on the seals. Calculations and documents shall be sealed in accordance with State Law. Consecutive page numbers should be provided for each set of calculations, and the calculation page numbers for which the stamps and signatures are applicable should be indicated below or beside the stamps.

These requirements also apply to preliminary designs or portions of a project geotechnical design submitted for specific project elements.

23.4.3 Geotechnical File Contents

The geotechnical project file(s) should contain the information necessary for future users of the file to understand the historical geotechnical data available, the scope of the project, the dimensions and locations of the project features understood at the time the geotechnical design was completed, the geotechnical investigation plan and the logic used to develop that plan, the relationship of that plan to what was requested by the Region, Bridge Office, Urban Corridors Office, Washington State Ferries Office, or other office, the geotechnical design conducted, what was recommended, and when and to whom it was recommended. Two types of project files should be maintained: the geotechnical design file(s), and the construction support file(s).

The geotechnical design file should contain the following information (in addition to the final geotechnical report):

- Historical project geotechnical and as-built data (see Section 23.3.1)
- Geotechnical investigation plan development documents
- Geologic reconnaissance results

- Critical end area plots, cross-sections, structure layouts, etc., that demonstrate the scope of the project and project feature geometry as understood at the time of the final design, if such data is not contained in the geotechnical report
- Information that illustrates design constraints, such as right-of-way location, location of critical utilities, location and type of adjacent facilities that could be affected by the design, etc.
- Boring log field notes
- Boring logs
- Lab transmittals
- Lab data, including rock core photos and records
- Field instrumentation measurements
- Final calculations only, unless preliminary calculations are needed to show design development
- Final wave equation runs for pile foundation constructability evaluation
- Key photos (must be identified as to the subject and locations), including CD with photo files
- Key correspondence (including e-mail) that tracks the development of the project – this does not include correspondence that is focused on coordination activities

The geotechnical construction file should contain the following information:

- Change order correspondence and calculations
- Claim correspondence and data
- Construction submittal reviews (retain temporarily only, until it is clear that there will be no construction claims)
- Photos (must be identified as to the subject and locations), including CD with photo files
- CAPWAP reports
- Final wave equation runs and pile driving criteria development
- CSL reports

23.5 Consultant Geotechnical Reports and Documentation Produced on Behalf of WSDOT

Geotechnical reports and documentation produced by geotechnical consultants, including geotechnical work conducted in support of Cost Reduction Incentive proposals (CRIP's), shoring submittals, and design-build projects, shall be subject to the same reporting and documentation requirements as those produced by WSDOT staff, as described in Sections 23.2 and 23.3. The detailed analyses and/or calculations produced by the consultant in support of the geotechnical report development shall be provided to the State.

23.6 Summary of Geotechnical Conditions

The "Summary of Geotechnical Conditions" is generally a 1 to 2 page document 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. A Summary of Geotechnical Conditions is primarily used for design-bid-build projects, as the Geotechnical Baseline Report (Chapter 22) serves the functions described above for design-build projects.

A Summary of Geotechnical Conditions is mandatory for all projects that contain bridges, walls, tunnels, unstable slope repairs, and significant earth work. The Summary of Geotechnical Conditions should specifically contain the following information:

1. Describe subsurface conditions in plain English. Avoid use of jargon and/or nomenclature that contactors will not understand. Identify depths/thicknesses of the soil or rock strata and their moisture state and density condition. Identify the depth/elevation of groundwater and state its nature (e.g. perched, regional, artesian, etc.). If multiple readings over time were obtained, identify dates and depths measured, or as a minimum provide the range of depths measured and the dates the highest and lowest water level readings were obtained. Also briefly describe the method used to obtain the water level (e.g., open standpipe, sealed piezometer, including what soil/rock unit the piezometer was sealed in, etc.). Refer to the boring logs for detailed information. If referring to an anomalous soil, rock or groundwater condition, refer to boring log designation where the anomaly was encountered. Caution should also be exercised when describing strata depths. If depths/thicknesses are based on only one boring, simply refer to the boring log for that information. Comments regarding the potential for variability in the strata thicknesses may be appropriate here. Also note that detailed soil/rock descriptions are not necessary if those conditions will not impact the contractor's construction activities. For example, for fills or walls placed on footings, detailed information is only needed that would support later discussion in this document regarding the workability of the surficial soils, as well as the potential for settlement or instability and their effect on construction.
2. For each structure, if necessary, state the impact the soil, rock or groundwater condition may (will) have on construction. Where feasible, refer to boring log(s) or data that provide the indication of risk. Be sure to mention the potential of risk for:
   - Caving ground
   - Slope instability due to temporary excavation, or as a result of a project element (e.g. buttress, tieback wall, soil nail cuts)
   - Settlement and its effect on how a particular structure or fill needs to be built
   - Potential geotechnical impact of the construction of some elements on the performance of adjacent elements that are, or are not, a part of the construction contract (e.g., ground improvement performed at the toe of a wall could cause movement of that wall)
   - Groundwater flow and control, if anticipated, in construction excavations

- Dense layers (e.g., may inhibit pile driving, shaft or tunnel excavation, drilling for nails, dowels or anchors)
- Obstructions, including cobbles or boulders, if applicable
- Excavation difficulties due to boulders, highly fractured or intact rock, groundwater, or soft soil.

3. Where design assumptions and parameters can be affected by the manner in which the structure is built, or if the assumptions or parameters can impact the contractor's construction methods, draw attention to these issues. This may include:
   - Soil or rock strengths (e.g. point load tests, RQD, UCS, UU, CU tests, etc.)
   - Whether shafts or piles are predominantly friction or end bearing by design
   - The reasons for minimum tip elevations specified in the contract
   - Downdrag loads and the effects on design/construction
   - If certain construction methods are required or prohibited, state the (geotechnical) reason for the requirement
   - Liquefaction potential and impact on design/construction
4. List of geotechnical reports or information. This should include the project specific report and memoranda (copies at the Project Engineer's office) as well as pertinent reports that may be located elsewhere and may be historical or regional in nature.
5. The intent of the Summary is to inform the contractor of what the geotechnical designers know or strongly suspect about the subsurface conditions. The summary should be brief (1 or 2 pages). It should not include tabulations of all available data (e.g. borehole logs, lab tests, etc.). Only that data that are pertinent to the adverse construction conditions anticipated should be mentioned. It should not include sections or commentary about structures or project elements about which the geotechnical designer has no real concerns. It shall also not be used to provide contract special provision material (i.e., statements that direct the contractor to do something). Such requirements should be included in the contract special provisions instead.

Appendix 23-A PS&E Review Checklist

SR- ________ C.S. ________ Project ____

❒ Region PS&E ❒ Bridge PS&E ❒ Office Copy PS&E

Reviewer ______________________________ Date Reviewed ______________________

Earth/Rock Work, Materials, and Geotech. Information Disclosure

Item	Applicable?	Comments
Geotech. Reports Listed?		
Test Hole Locations Shown (structures only)?		
Test Hole Logs Provided?		
Materials Source • Source Approval • Reclaimation Plan • Quantities • Disclosure of Geotechnical Data		
Are Materials Specified Appropriate? • Fill • Backfill for Overex. • Wall Backfill		
Waste Sites		
Cut Slopes		
Fill Slopes		
Berm or Shear Key		
Soil Reinforcement • Location • Length • Strength		

Earth/Rock Work, Materials, and Geotech. Information Disclosure, Cont.

Item	Applicable?	Comments
Unsuitable Excavation		
Ground Modification • Wick Drains • Stone Columns • Vibrocompaction, compaction grouting, etc. • Advisory Specifications?		
Settlement Mitigation • Surcharges • Fill Overbuild • Light Weight Fill • Preload Settlement Period		
Rock Cuts and Blasting • Slopes • Special Provisions - Blasting • Rock Reinforcement		
Slope Drainage Features		

Bridges and Tunnels

Item	Applicable?	Comments
Spread Footings • Elevations/Embed. • Bearing Capacity • Seals • Overexcavation Requirements • Soil Densification Requirements • Advisory Specifications?		
Piles • Quantities • Minimum Tip Elevations • Capacity • Pile Type and Size • Hammer Requirements • Special Pile Tips • Special Material Requirements • Pile Spacing • Advisory Specifications?		
Shafts • Tip Elevations • Shaft Diameter • Casing Requirements • Special Location Requirements for Tip • Shaft Spacing • Advisory Specifications?		
Seismic Design • Acceleration Coefficient • Liquefaction Mitigation Requirements • Special Design requirements		
Abutment and Endslope Design		

Retaining Walls

SR- ________ C.S. ________ Project ____

Item	Applicable?	Comments
Wall Number(s)		
Wall Types Allowed		
Facing Types?		
External Stability • Wall Base Embedment or Elevation • Bearing Capacity • Min. Wall Width • Pile Support Requirements • Shaft Support Requirements • Overexcavation or Soil Densification Requirements • Surcharge Conditions are as Assumed? • Slope Below Wall is as Assumed? • Advisory Specifications?		
Internal Stability • Soil Reinforcement Strength and Spacing Requirements • Reinforcement Type • No Load Zone Requirements • Soil Design Parameters		
Wall Drainage Features		
Wall Backfill Type		
Wall Quantities		
Specifications Appropriate for Wall? • Preapproved? • Construction Tolerances?		

Copy This Page to Wall Database Manager

Miscellaneous Structures

Item	Applicable?	Comments
Noise Walls • Type Appropriate? • Foundation Type • Foundation Size and Depth • Bearing Capacity		
Signals/Signs • Foundation Type • Foundation Size and depth		
Pipe Arches/Culverts • Foundation Type • Foundation Depth • Bearing Capacity • Camber Requirements • Construction Staging • Special Details		
Special Utility Considerations		

Instrumentation

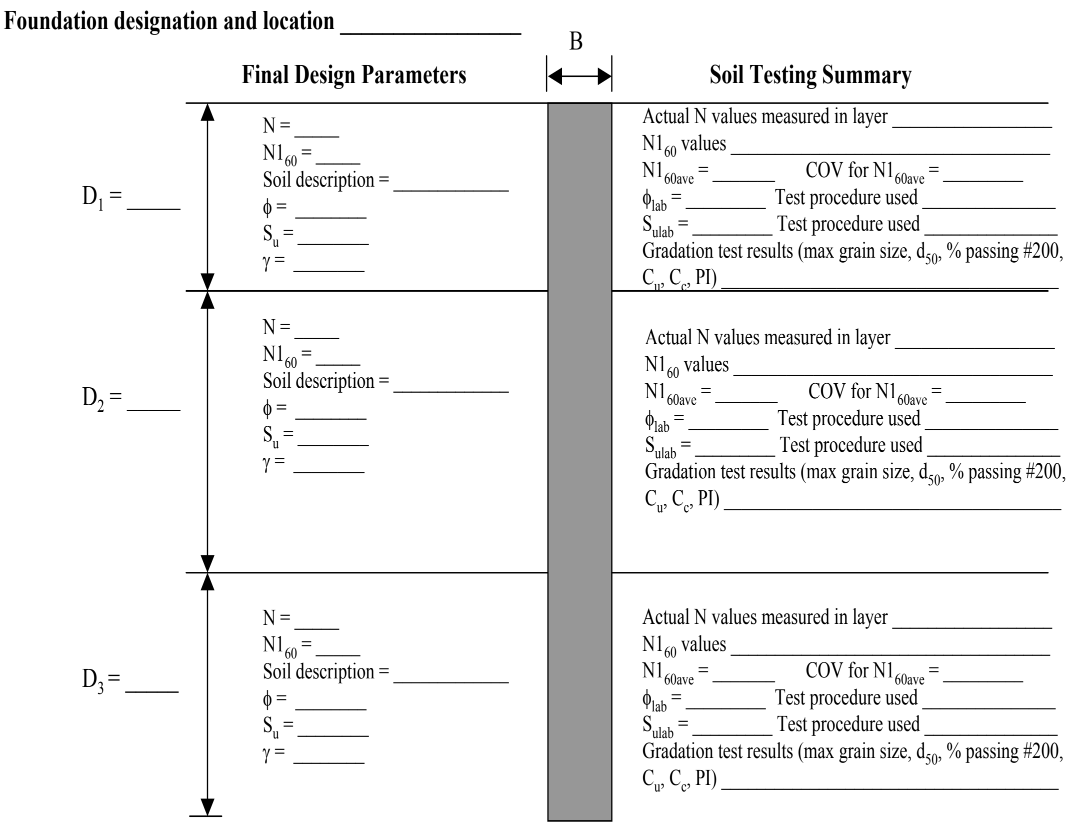
Item	Applicable?	Comments
Types		
Locations		
Zones of Influence		
Purpose and Use of Instrumentation is Clear		

Constructability Issues

Item	Applicable?	Comments
Advisory Specs. Provided? • Obstructions? • Special Excavation Problems? • Wet Weather Construction • Caving Conditions? • Ground Water Conditions • Pile Driveability • Dewatering Issues • Rock Excavation Issues • Pit Development Issues • Others		
Construction Sequence		
Temporary Slope/Shoring Requirements		
Fill Placement		
Soil Reinforcement Installation		
Excavation Restrictions for Stability		
Special Pile Driving Requirements and Criteria		

Appendix 23-B Typical Design Cross-Section for a Deep Foundation

The following figure is an example of a design soil cross-section for a deep foundation. This figure illustrates the types of information that should be included in an idealized cross-section to introduce a foundation design calculation. Depending on the nature of the calculation and type of geotechnical feature, other types of information may be needed to clearly convey to the reviewer what data was used and what was assumed for the design.



Location of boring(s) relative to shaft location ____
If correlations used to estimate ϕ, S_u, and/or γ, indicate which one(s) were used ____________________________
Method used to correct N for overburden and SPT hammer energy __________________________________
Type of SPT hammer, and measured SPT hammer efficiency, if available ______________________________
Water table depth below ground, including identification/thickness/location of confined water bearing zones = ______________
Identify sources of all data included in the form where additional details may be found __________________________