December 6, 2019

Ann Weckback
Lewis County Public Works
2025 NE Kresky Avenue
Chehalis, Washington 98532

Via email: Ann.Weckback@lewiscountywa.gov

Regarding: Geotechnical Engineering Report
Kruger Road Culvert Replacement
319 Kruger Road
Onalaska, Washington
PBS Project 45013.006

Dear Ms. Weckback:

This report presents results of PBS Engineering and Environmental Inc. (PBS) geotechnical engineering services for the proposed culvert replacement at the crossing of an unnamed tributary to the Middle Fork Newaukum River below Kruger Road, south of Rachel Lane and north of Alger Lane, in Onalaska, Washington (site).

PROJECT UNDERSTANDING

Anticipated plans include the construction of a 24-foot-wide bypass road east of the existing road, replacing the existing culvert with a new, approximately 21-foot-wide, 35-foot-long, and 7- to 10-foot-tall, precast concrete box culvert to improve fish passage beneath the road. The concrete box culvert will have an estimated 1-foot-thick asphalt concrete (AC) and base rock cover. The general site location is shown on the Vicinity Map, Figure 1. The locations of PBS' explorations in relation to existing site features are shown on the Site Plan, Figure 2.

SCOPE OF SERVICES

The purpose of PBS' services was to develop geotechnical design and construction recommendations in support of the planned culvert replacement. This was accomplished by performing the following scope of services.

Literature Review

PBS reviewed various published geologic maps of the area for information regarding geologic conditions and hazards at or near the site.

Subsurface Explorations

Two borings, designated B-1 and B-2, were completed in the roadway on opposite sides of the existing culvert to explore subsurface conditions. A truck-mounted drill rig was used to advance borings to depths of up to 26 feet below the existing ground surface (bgs). In situ, standard penetration tests (SPTs) were performed at 2.5- to 5.0-foot intervals. The borings were logged, and representative soil samples collected by a member of the PBS geotechnical engineering staff. The approximate boring locations are shown on the Site Plan, Figure 2.

Laboratory Testing
Samples were returned to our laboratory and classified in accordance with the Unified Soil Classification System (ASTM D2487) and/or the Visual-Manual Procedure (ASTM D2488). Laboratory tests included natural water contents, particle size analysis, and Atterberg limits.

Geotechnical Engineering Analysis
Data collected during the subsurface exploration, literature research, and testing were used to develop site-specific geotechnical design parameters and construction recommendations.

Report Preparation
This Geotechnical Engineering Report summarizes the results of our explorations, testing, and analyses, including information relating to the following:

- Field exploration logs and site plan showing approximate exploration locations
- Laboratory test results
- Groundwater levels and considerations
- Shallow foundation recommendations:
  - Minimum embedment
  - Estimated settlement
  - Sliding coefficient
- Lateral earth pressures for box culvert wall design including:
  - Active, passive, and at-rest earth pressures
  - Allowable bearing pressure
  - Sliding coefficient
  - Groundwater and drainage considerations
- Earthwork and grading, cut, and fill recommendations:
  - Structural fill materials and preparation, and reuse of on-site soils
  - Utility trench excavation and backfill requirements
  - Slab and pavement subgrade preparation
  - Wet weather considerations
  - Temporary and permanent slope inclinations

SITE CONDITIONS
Surface Description
The site is located along Kruger Road, approximately 0.1 mile south of Rachel Lane and 0.25 mile north of Alger Lane, north of Highway 508 (Main Avenue). The stream crossing is relatively flat, with heavily forested areas on the north and south sides of the crossing along the unnamed tributary to the Middle Fork Newaukum River. Kruger Road is located at an approximate elevation of 617 feet above mean sea level (amsl) and 8 feet above the unnamed tributary to the Middle Fork Newaukum River at the crossing.

Geologic Setting
The site is underlain by Pleistocene age alpine glacial outwash deposits of the Logan Hill Formation (Schasse, 1987).[1] These sediments are described as sand and gravel, with minor interbedded silt and clay of variable thickness, and were deposited over older Tertiary sedimentary and volcanic rocks.

Subsurface Conditions
The site was explored by drilling two borings, designated B-1 and B-2, to depths of 25.5 and 26 feet bgs, respectively. The drilling was performed by Holt Services Inc., of Vancouver, Washington, using mud rotary drilling techniques.

Disturbed soil samples were taken in the borings at 2.5- to 5-foot intervals. Soil samples were obtained using a standard 2-inch outside diameter split-spoon sampler following procedures prescribed for the SPT. Using the SPT, the sampler is driven 18 inches into the soil using a 140-pound hammer dropped 30 inches. The number of blows required to drive the sampler the last 12 inches is defined as the standard penetration resistance (N-value). The N-value provides a measure of the relative density of granular soils, such as sands and gravels, and the consistency of cohesive soils, such as clays and plastic silts. The disturbed soil samples were examined by a member of the PBS geotechnical engineering staff in the field and then sealed in plastic bags for further examination and physical testing in our laboratory.

The boring logs (Figures A1 and A2) show the various types of materials that were encountered in the borings and the depths where the materials and/or characteristics of these materials changed, although the changes may be gradual. Where material types and descriptions changed between samples, the contacts were interpreted. The types of samples taken during drilling, along with their sample identification number, are shown to the right of the classification of materials on the boring logs. The N-values are shown farther to the right.

Initially, soil samples were classified visually in the field. Consistency, color, relative moisture, degree of plasticity and other distinguishing characteristics of the soil samples were noted. Afterward, the samples were reexamined in the PBS laboratory, various standard classification tests were conducted, and the field classifications were modified where necessary. The terminology used in the soil classifications and other modifiers are defined and presented on the attached Tables A-1 and A-2.

PBS has summarized the subsurface units as follows:

ASPHALT: Approximately 6 inches asphalt concrete (AC) pavement was encountered at the surface of borings B-1 and B-2.

BASEROCK: Approximately 12 inches of base rock was encountered beneath the AC in B-1 and B-2.

FILL: Medium stiff to stiff, lean clay fill was encountered beneath the base rock to depths of 6 and 6.5 feet bgs in borings B-1, and B-2, respectively. The fill consisted of lean clay with fine to coarse sand in boring B-2, and with fine to coarse sand and subangular gravel in boring B-1. The fill was brown to olive/red brown and orange, moist, medium plastic, and becomes softer (lower N-value) at 5 feet bgs in boring B-2.

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[1] Schasse, H. W. (1987). Geologic Map of the Centralia Quadrangle, Washington. Washington Division of Geology and Earth Resources, map scale 1:100,000.

SILTY/CLAYEY SAND:	Medium dense to dense, silty or clayey sand with fine to coarse, rounded and subrounded gravel was encountered at approximately 6 to 6.5 feet bgs to depths of 13 and 15 feet bgs in borings B-1 and B-2, respectively. The silty sand portion was gray to olive brown and orange, with fine to coarse sand, and exhibited low plasticity. A 6-inch layer of lean clay with sand interbeds this deposit at 7.5 feet bgs in boring B-1. This deposit was also encountered at 20 and 23 feet bgs to the termination depth in borings B-1 and B-2, respectively. However, the deposit was very dense with high N-values.
SILTY GRAVEL WITH SAND:	A 7- to 8-foot-thick layer of dense to very dense (high N-value), rounded to subrounded, gray, poorly graded gravel with silt, fine to coarse sand, and cobbles was encountered at depths of 13 and 15 feet bgs in borings B-1 and B-2, respectively.

Groundwater

Static groundwater was not measured during our explorations due to mud rotary drilling techniques. However, we anticipate groundwater will be influenced by and reflect the water levels in the creek. Please note that groundwater levels can fluctuate during the year depending on climate, irrigation, extended periods of precipitation, drought, and other factors. Generally, the highest groundwater levels occur in late winter and early spring and the lowest levels in late summer and early fall. We recommend that the contractor determine the actual groundwater levels at the time of construction to determine potential groundwater impacts.

LABORATORY TESTING

Soil samples obtained during our exploration were returned to the laboratory to aid in soil classification and to evaluate the material's general physical properties and engineering characteristics. Laboratory tests included natural moisture contents, particle size analysis, and Atterberg limits. Laboratory test results are presented on the boring logs in Attachment A, and on Figures B1 and B2 in Attachment B.

The applicable ASTM methods were used to perform the laboratory tests and included the following.

Visual Classification

The soils were classified in accordance with the Unified Soil Classification System with certain other terminology, such as the relative density or consistency of the soil deposits, in general accordance with engineering practice. In determining the soil type (that is, gravel, sand, silt, or clay) the term that best described the major portion of the sample was used. Modifying terminology to further describe the samples is defined on the attached Table A-1.

Moisture (Water) Contents

Natural moisture content determinations were made on samples of the fine-grained soils (that is, silts, clays, and silty sands). The natural moisture content is defined as the ratio of the weight of water to dry weight of soil, expressed as a percentage. The results of the moisture content determinations are presented on the exploration logs in Attachment A and on Figure B2 in Attachment B.

Particle Size Analyses

Washed sieve analyses (P200) were completed on samples to determine the portion of soil samples passing the No. 200 Sieve (i.e., silt and clay). The results of the particle size analyses are presented on the exploration logs in Attachment A, and on Figure B2 in Attachment B.

Atterberg Limits

Atterberg limits were determined for select samples for classifying soils into various groups for correlation. The results of the Atterberg limits tests, which included liquid and plastic limits, are plotted on the exploration logs in Attachment A, and Figures B1 and Figure B2 in Attachment B.

CONCLUSIONS AND RECOMMENDATIONS

Geotechnical Design Considerations

Borings B-1 and B-2 encountered undocumented fill beneath the existing pavement. The fill consisted of lean clay with fine to coarse sand and subangular gravel to approximately 6 feet bgs, underlain by 7 to 8.5 feet of medium dense to dense, silty/clayey, poorly graded sand with fine to coarse, rounded to subrounded gravel to depths between 13 and 15 feet bgs. This deposit was also encountered at 20 and 23 feet bgs and was dense to very dense with high N-values. The silty/clayey sand deposits are sandwiched by a 7- to 8-foot layer of dense to very dense, poorly graded gravel with silt and sand. SPT blow count values indicate dense soil conditions below 10 feet in both borings and very dense soil conditions below 15 and 18 feet bgs in borings B-1 and B-2, respectively.

Based on our observations and analyses, foundation support on shallow spread footings is feasible. Excavation with conventional equipment is feasible but may be difficult in the dense and very dense silty/clayey sand and gravel deposits; a large excavator (such as a CAT 235 or larger) may be necessary.

Shallow Foundations

Shallow spread footings, underlain by at least 6 inches of crushed rock over medium dense to dense silty sand or dense to very dense gravel with silt and sand located at about 13 to 15 feet bgs, may be used to support loads associated with the proposed new closed-bottom culvert, provided the following recommendations are followed.

Footing Preparation: Foundation subgrades at a depth of approximately 10 feet bgs at the proposed culvert will likely consist of medium dense to dense, silty/clayey, poorly graded sand with fine to coarse, rounded to subrounded gravel. Due to the location of footings near the current anticipated groundwater elevations and the presence of soils consisting of or containing fine-grained silt or sand, we recommend culvert footings be founded on a minimum 6-inch-thick layer of granular fill. If soft/loose conditions are encountered at this elevation, the crushed rock fill should be underlain by 12 inches of angular pit run rock (6-inch-minus stabilization rock; see the Foundation Base Aggregate section, below) and geotextile stabilization fabric, such as Mirafi 500X, or an approved equivalent.

***Crushed Rock Pads*:** If a silt or clay layer and groundwater is observed at or near the base of the proposed foundation (exposed design subgrade elevation), we recommend over-excavating 12 inches and backfilling with stabilization material in a single lift, and compacting using a large, smooth-drum, non-vibratory roller, until the rock is dense and well keyed. Stabilization rock should be capped with approximately 6 inches of foundation base aggregate (as described in the Construction Considerations section of this report). Crushed rock pads should be planned to extend a minimum of 1 foot laterally beyond the edges of footings. PBS understands the layer of crushed rock may be installed across the entire base of the excavation to act as a working pad for construction traffic. Depending on subsurface and groundwater conditions at the time of construction, increasing the thickness of the crushed rock working pad to support construction traffic and protect the foundation subgrades may be necessary.

A representative from PBS should confirm suitable bearing conditions and evaluate all footing subgrades. Observations should also confirm that loose or soft materials have been removed from new footing excavations. Localized deepening of footing excavations may be required to penetrate soft, wet, or deleterious materials.

Bearing Pressure: Due to the width of the box culvert and limited soil cover, the applied bearing pressure over the base of the culvert will be relatively low, less than 1,000 pounds per square foot (psf). Foundations can be designed using an allowable bearing pressure of 3,500 psf with an effective footing width of 21 feet.

Foundation Static Settlement: Based on the proposed culvert configuration and associated soil removal, no additional load will be applied at the base of the culvert and we estimate post-construction settlement will be less than about 1 inch.

Lateral Resistance: Lateral loads can be resisted by passive earth pressure on the sides of footings and box culvert walls, and by friction at the base of the box culvert foundation. A passive earth pressure calculated using an equivalent fluid weight (EFW) of 250 pounds per cubic foot (pcf) may be used for footings confined by native soils and new structural fills above groundwater and 120 pcf below groundwater or below the ordinary high water (OHW) level in the stream. The allowable passive pressure has been reduced by one-half to account for the large amount of deformation required to mobilize full passive resistance. This should only be applied to the outside of culvert walls. For passive resistance on the inside of the culvert, the depth of possible scour should be considered. For footings supported on crushed rock pads, use a coefficient of friction equal to 0.35 when calculating resistance to sliding and a net normal force (considering uplift below groundwater). These values do not include a factor of safety (FS).

Lateral Earth Pressures: The walls of the proposed new culvert should be designed to resist at-rest earth pressures using an EFW of 60 pcf. Vertical surcharge loads, q, should be considered and be equal to 0.6q, applied as a uniform horizontal surcharge over the full height of the wall. These values assume that the wall is vertical and the backfill behind the wall is horizontal.

CONSTRUCTION CONSIDERATIONS

Site Preparation

Construction of the new culvert will require large areas of cut and subsequent backfill. Based on the estimated depth of the proposed culvert, review of the preliminary design concept, and our understanding that open excavation techniques will be used in construction, we estimate excavation will be on the order of 10 feet deep and about 25 feet wide at the base, and up to 50 feet wide at the road grade, which corresponds to temporary slope inclinations of approximately 1.5H:1V (horizontal to vertical). Based on the results of our geotechnical exploration and analyses, we believe some of the on-site material may be reused as backfill. However, this is dependent on the contractor's ability to dry the soil to within 2 percent of the optimum moisture content, if needed, as well as using adequately sized compaction equipment and applying the required energy during site grading. Reusing the silty sand as backfill is likely feasible. Fill should be benched into excavation side slopes as the lifts are compacted.

Subgrade Verification/Proofrolling

Following site preparation, including excavation for new foundations (box culvert pad) but prior to placing aggregate base for the foundations, the exposed subgrade should be evaluated by a PBS representative. The finished pavement subgrade, following backfill of the culvert, should be proofrolled with a fully loaded dump truck or similar heavy, rubber-tire construction equipment to identify unsuitable areas. If evaluation of the subgrades occurs during wet conditions, or if proofrolling the subgrades will result in disturbance, they should be evaluated by qualified personnel using a steel foundation probe. We recommend that PBS be retained to observe proofrolling and perform the subgrade verifications. Unsuitable areas identified during the field evaluation should be recompacted or be excavated to firm ground and replaced with structural fill.

Wet Weather and Wet Soil Conditions

Due to the presence of fine-grained silty/clayey sand in the near-surface materials at the site, construction equipment may have difficulty operating on the near-surface soils once the pavement has been removed. Protection of the subgrade is the responsibility of the contractor. Soils that have been disturbed during site preparation activities, or unsuitable areas identified during proofrolling or probing, should be removed to firm ground and replaced with compacted structural fill. Our current understanding is that equipment will be staged on the existing AC pavement. Some damage to the existing AC should be anticipated.

Excavation and Temporary Slopes

PBS understands open excavation techniques will be used to install the new culvert. This is acceptable provided the excavation is configured in accordance with the Occupational Safety and Health Administration (OSHA) requirements, groundwater seepage is not present, and with the understanding that some sloughing may occur. The excavation sidewalls should be flattened if sloughing occurs or seepage is present. We recommend 1.5H:1V for temporary slopes.

All excavations should be made in accordance with applicable OSHA and state regulations. The contractor is solely responsible for adherence to the OSHA requirements.

Structural Fill

Excavation required to install the new structure will likely be on the order of 10 feet deep (below existing road grade). Culvert backfill should be placed over subgrades that have been prepared in conformance with the Site Preparation, Wet Weather and Wet Soil Considerations, and Imported Granular Materials sections of this report.

Structural fill and backfill should only be installed on subgrades that have been prepared in accordance with the preceding recommendations. Structural fill material should consist of relatively well-graded soil, or an approved rock product that is free of organic material and debris and contains particles less than 4 inches nominal dimension. The suitability of soil for use as compacted structural fill will depend on the gradation and moisture content of the soil when it is placed. As the amount of fines (material finer than the US Standard No. 200 Sieve) increases, soil becomes increasingly sensitive to small changes in moisture content and compaction becomes more difficult to achieve. Soils containing more than about 5 percent fines cannot consistently be compacted to a dense, non-yielding condition when the water content is significantly greater (or significantly less) than optimum.

A wide range of material may be used as structural fill; however, all material used should be free of organic matter or other unsuitable materials and should meet the specifications provided in the 2020 Standard Specifications for Road, Bridge, and Municipal Construction, Washington State Department of Transportation (WSDOT SS)[2] depending on the application. A brief characterization of some of the acceptable materials and our recommendations for their use as structural fill is provided as follows.

[2] Washington State Department of Transportation (WSDOT SS). (2020). Standard Specifications for Road, Bridge, and Municipal Construction, M 41-10, Olympia, Washington.

On-Site Soil: The soils encountered in our explorations are generally suitable for placement as structural fill during dry weather when moisture content can be maintained by air drying and/or addition of water. However, due to the presence of silty and clayey soils and high moisture contents, reuse of on-site soils for fill may not be feasible. In PBS' opinion, significant drying of soils will be required to achieve optimum moisture content for compaction.

If site soils are used as fill, the material should be free of any organic or deleterious material with grain size less than 4 inches in diameter. The material should be compacted to at least 95 percent of the maximum dry density, as determined by ASTM D1557 (modified proctor) and shall be placed in a maximum uncompacted thickness of 8 inches. Zones of sand and gravel containing variable amounts of silt can be reused as structural fill, provided they meet the specified gradation requirements discussed in the following sections.

Imported Granular Materials: Imported granular material used during periods of wet weather or for haul roads, culvert foundation pad subgrades, staging areas, etc., should be pit or quarry run rock, crushed rock, or crushed gravel and sand, and should meet the specifications provided in WSDOT SS 9-03.14(2) – Select Borrow. However, the imported granular material should also be fairly well graded between course and fine material and of the fraction passing the US Standard No. 4 Sieve, less than 5 percent by dry weight should pass the US Standard No. 200 Sieve.

Imported granular material should be placed in lifts with a maximum uncompacted thickness of 8 inches and be compacted to not less than 95 percent of the maximum dry density, as determined by ASTM D1557.

During wet conditions, where imported granular material is placed over soft-soil subgrades, we recommend a geotextile be placed between the subgrade and imported granular material. Depending on site conditions, the geotextile should meet WSDOT SS 9-33.2 – Geosynthetic Properties for soil separation or stabilization. The geotextile should be installed in conformance with WSDOT SS 2-12.3 – Construction Geosynthetic (Construction Requirements) and, as applicable, WSDOT SS 2-12.3(2) – Separation or WSDOT SS 2-12.3(3) – Stabilization.

Foundation Base Aggregate: Imported granular material placed at the base of excavations for spread footings should be clean, crushed rock or crushed gravel, and sand that is fairly well graded between coarse and fine. The granular materials should contain no deleterious materials, have a maximum particle size of 1 inch, and meet WSDOT SS 9-03.12(1)A – Gravel Backfill for Foundations (Class A). The imported granular material should be placed in one lift and compacted to not less than 95 percent of the maximum dry density, as determined by ASTM D1557.

Pavement Base Aggregate: Imported granular material used as base aggregate (base rock) along roadway alignments should be clean, crushed rock or crushed gravel, and sand that is fairly well graded between coarse and fine. The base aggregate should meet the gradation defined in WSDOT SS 9-03.9(3) – Crushed Surfacing Base Course and Top Course. The base aggregate should be compacted to not less than 95 percent of the maximum dry density, as determined by ASTM D1557.

ADDITIONAL SERVICES AND CONSTRUCTION OBSERVATIONS

In most cases, other services beyond completion of a geotechnical engineering report are necessary or desirable to complete the project. Occasionally, conditions or circumstances arise that require the performance of additional work that was not anticipated when the geotechnical report was written. PBS offers a range of environmental, geological, geotechnical, and construction services to suit the varying needs of our clients.

PBS should be retained to review the plans and specifications for this project before they are finalized. Such a review allows us to verify that our recommendations and concerns have been adequately addressed in the design.

Satisfactory earthwork performance depends on the quality of construction. Sufficient observation of the contractor's activities is a key part of determining that the work is completed in accordance with the construction drawings and specifications. We recommend that PBS be retained to observe general excavation, stripping, fill placement and compaction, and exposed footing and pavement subgrades. Subsurface conditions observed during construction should be compared with those encountered during the subsurface explorations. Recognition of changed conditions requires experience; therefore, qualified personnel should visit the site with sufficient frequency to detect whether subsurface conditions change significantly from those anticipated.

LIMITATIONS

This report has been prepared for the exclusive use of the addressee and their engineers for aiding in the design and construction of the proposed development and is not to be relied upon by other parties. It is not to be photographed, photocopied, or similarly reproduced, in total or in part, without express written consent of the client and PBS. It is the addressee's responsibility to provide this report to the appropriate design professionals, county public works office, and contractors to assure correct implementation of the recommendations.

The opinions, comments, and conclusions presented in this report are based upon information derived from our literature review, field explorations, and laboratory testing. It is possible that soil, rock, or groundwater conditions could vary between or beyond the points explored. If soil, rock, or groundwater conditions are encountered during construction that differ from those described herein, the client is responsible for ensuring that PBS is notified immediately so that we may reevaluate the conclusions of this report.

Unanticipated soil and rock conditions and seasonal soil moisture and groundwater variations are commonly encountered and cannot be fully determined by merely taking soil samples or soil borings. Such variations may result in changes to our recommendations and may require additional funds for expenses to attain a properly constructed project. Therefore, we recommend a contingency fund to accommodate such potential extra costs.

The scope of services for this subsurface exploration and geotechnical report did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous substances in the soil, surface water, or groundwater at this site.

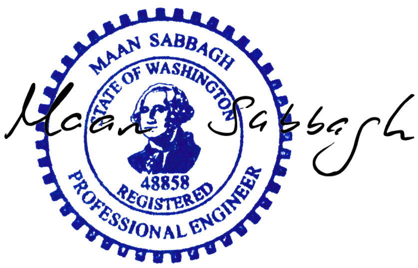
If there is a substantial lapse of time between the submission of this report and the start of work at the site, if conditions have changed due to natural causes or construction operations at or adjacent to the site, or if the basic project scheme is significantly modified from that assumed, this report should be reviewed to determine the applicability of the conclusions and recommendations presented herein. Land use, site conditions (both on and off site), or other factors may change over time and could materially affect our findings; therefore, this report should not be relied upon after three years from its issue, or in the event that the site conditions change.

CLOSING

We trust this Geotechnical Engineering Report meets your current needs. If you have any questions or wish to further discuss our observations, conclusions, and recommendations, please contact Maan Sabbagh at 206.766.7638 or maan.sabbagh@pbsusa.com.

Sincerely,

Prepared by:



12/6/2019

Maan Sabbagh, PE
Senior Geotechnical Engineer
PBS Engineering and Environmental Inc.

Reviewed by:

Ryan White, PE, GE (OR)
Principal/Geotechnical Engineering Group Manager
PBS Engineering and Environmental Inc.

Figures

Figure 1. Vicinity Map
Figure 2. Site Plan

Attachment A: Field Explorations

Table A-1. Terminology Used to Describe Soil
Table A-2. Key to Test Pit and Boring Log Symbols
Figures A1–A2. Logs for Borings B-1 and B-2

Attachment B: Laboratory Testing

Figure B1. Atterberg Limits Test Results
Figure B2. Summary of Laboratory Data

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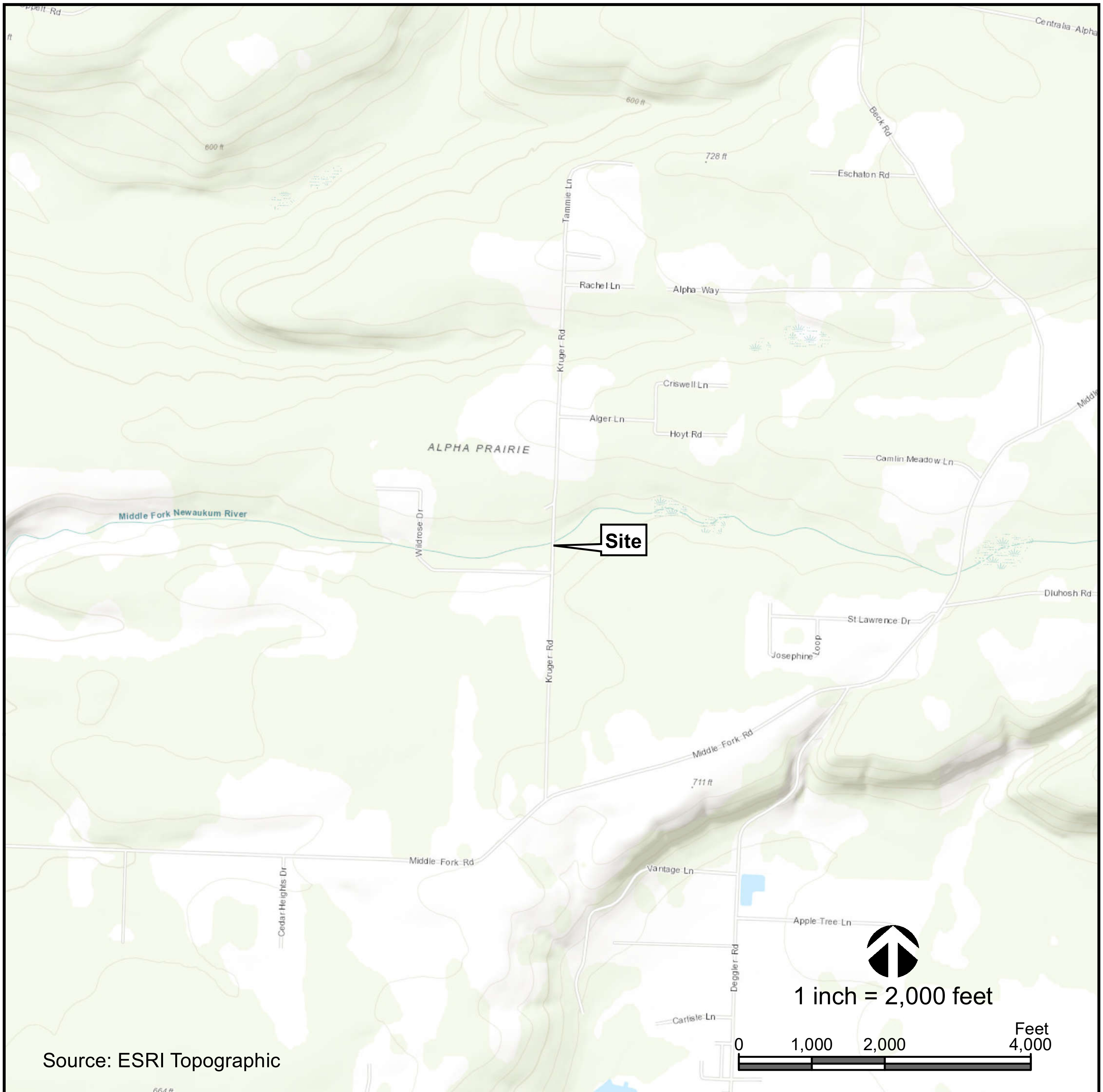
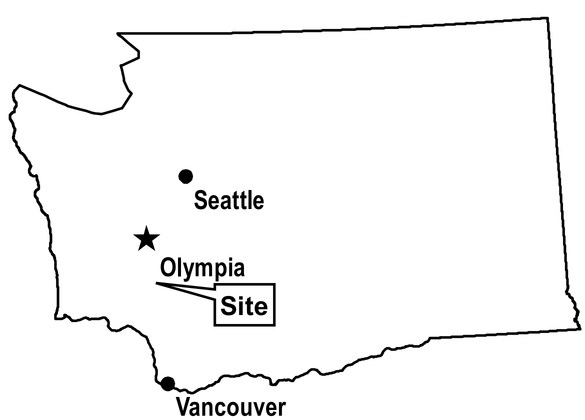
Figures





VICINITY MAP

KRUGER ROAD CULVERT REPLACEMENT
ONALASKA, WASHINGTON

DATE: NOV 2019 · PROJECT: 45013.006

PBS

FIGURE

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EXPLANATION

B-1 - Boring name and approximate location

20-foot elevation contour

Notes: Google Earth imagery, Elevation data from the USGS Onalaska 7.5-minute quadrangle

1 inch = 100 feet

0 50 100 200 Feet

SITE PLAN

KRUGER ROAD CULVERT REPLACEMENT
ONALASKA, WASHINGTON

DATE: NOV 2019 · PROJECT: 45013.006

PBS

FIGURE 2

Attachment A

PBS

Table A-1
Terminology Used to Describe Soil

Soil Descriptions

Soils exist in mixtures with varying proportions of components. The predominant soil, i.e., greater than 50 percent based on total dry weight, is the primary soil type and is capitalized in our log descriptions (SAND, GRAVEL, SILT, or CLAY). Smaller percentages of other constituents in the soil mixture are indicated by use of modifier words in general accordance with the ASTM D2488-06 Visual-Manual Procedure. "General Accordance" means that certain local and common descriptive practices may have been followed. In accordance with ASTM D2488-06, group symbols (such as GP or CH) are applied on the portion of soil passing the 3-inch (75mm) sieve based on visual examination. The following describes the use of soil names and modifying terms used to describe fine- and coarse-grained soils.

Fine-Grained Soils (50% or greater fines passing 0.075 mm, No. 200 sieve)
The primary soil type, i.e., SILT or CLAY is designated through visual-manual procedures to evaluate soil toughness, dilatency, dry strength, and plasticity. The following outlines the terminology used to describe fine-grained soils, and varies from ASTM D2488 terminology in the use of some common terms.

Primary soil NAME, Symbols, and Adjectives			Plasticity Description	Plasticity Index (PI)
SILT (ML & MH)	**CLAY (CL & CH)**	**ORGANIC SOIL (OL & OH)**		
SILT		Organic SILT	Non-plastic	0 – 3
SILT		Organic SILT	Low plasticity	4 – 10
SILT/Elastic SILT	Lean CLAY	Organic SILT/ Organic CLAY	Medium Plasticity	10 – 20
Elastic SILT	Lean/Fat CLAY	Organic CLAY	High Plasticity	20 – 40
Elastic SILT	Fat CLAY	Organic CLAY	Very Plastic	>40

Modifying terms describing secondary constituents, estimated to 5 percent increments, are applied as follows:

Description	% Composition	
With Sand	% Sand ≥ % Gravel	15% to 25% plus No. 200
With Gravel	% Sand < % Gravel	
Sandy	% Sand ≥ % Gravel	≤30% to 50% plus No. 200
Gravelly	% Sand < % Gravel	

Borderline Symbols, for example CH/MH, are used when soils are not distinctly in one category or when variable soil units contain more than one soil type. **Dual Symbols,** for example CL-ML, are used when two symbols are required in accordance with ASTM D2488.

Soil Consistency terms are applied to fine-grained, plastic soils (i.e., PI ≥ 7). Descriptive terms are based on direct measure or correlation to the Standard Penetration Test N-value as determined by ASTM D1586-84, as follows. SILT soils with low to non-plastic behavior (i.e., PI < 7) may be classified using relative density.

Consistency Term	SPT N-value	Unconfined Compressive Strength	
		tsf	**kPa**
Very soft	Less than 2	Less than 0.25	Less than 24
Soft	2 – 4	0.25 – 0.5	24 – 48
Medium stiff	5 – 8	0.5 – 1.0	48 – 96
Stiff	9 – 15	1.0 – 2.0	96 – 192
Very stiff	16 – 30	2.0 – 4.0	192 – 383
Hard	Over 30	Over 4.0	Over 383

Soil Descriptions

Coarse - Grained Soils (less than 50% fines)

Coarse-grained soil descriptions, i.e., SAND or GRAVEL, are based on the portion of materials passing a 3-inch (75mm) sieve. Coarse-grained soil group symbols are applied in accordance with ASTM D2488-06 based on the degree of grading, or distribution of grain sizes of the soil. For example, well-graded sand containing a wide range of grain sizes is designated SW; poorly graded gravel, GP, contains high percentages of only certain grain sizes. Terms applied to grain sizes follow.

Material NAME	Particle Diameter	
	Inches	Millimeters
SAND (SW or SP)	0.003 – 0.19	0.075 – 4.8
GRAVEL (GW or GP)	0.19 – 3	4.8 – 75
Additional Constituents:		
Cobble	3 – 12	75 – 300
Boulder	12 – 120	300 – 3050

The primary soil type is capitalized, and the fines content in the soil are described as indicated by the following examples. Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 percent. Other soil mixtures will have similar descriptive names.

Example: Coarse-Grained Soil Descriptions with Fines

>5% to < 15% fines (Dual Symbols)	≥15% to < 50% fines
Well graded GRAVEL with silt: GW-GM	Silty GRAVEL: GM
Poorly graded SAND with clay: SP-SC	Silty SAND: SM

Additional descriptive terminology applied to coarse-grained soils follow.

Example: Coarse-Grained Soil Descriptions with Other Coarse-Grained Constituents

Coarse-Grained Soil Containing Secondary Constituents	
With sand or with gravel	≥ 15% sand or gravel
With cobbles; with boulders	Any amount of cobbles or boulders.

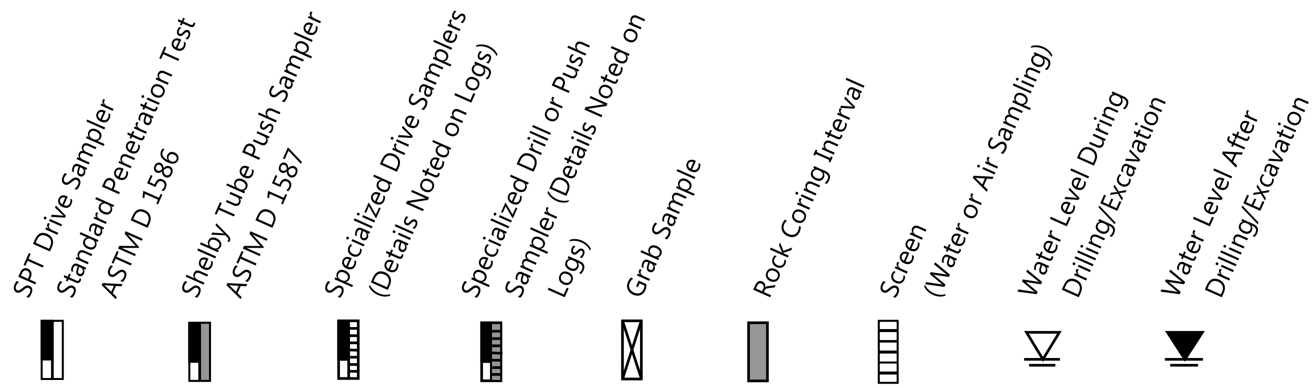
Cobble and boulder deposits may include a description of the matrix soils, as defined above.

Relative Density terms are applied to granular, non-plastic soils based on direct measure or correlation to the Standard Penetration Test N-value as determined by ASTM D1586-84.

Relative Density Term	SPT N-value
Very loose	0 – 4
Loose	5 – 10
Medium dense	11 – 30
Dense	31 – 50
Very dense	> 50

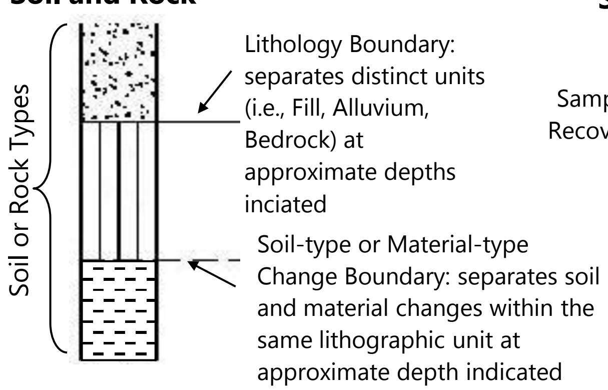
Table A-2
Key To Test Pit and Boring Log Symbols

SAMPLING DESCRIPTIONS

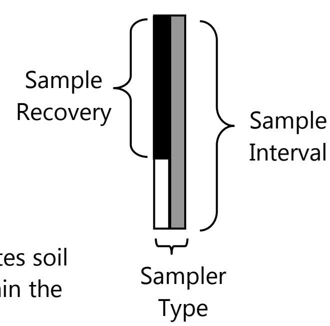


LOG GRAPHICS

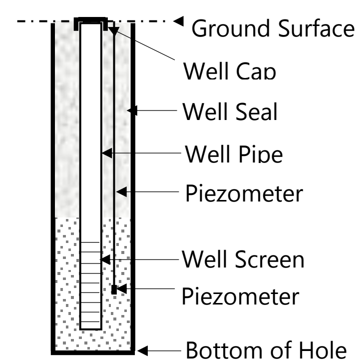
Soil and Rock



Sampling Symbols



Instrumentation Detail



Geotechnical Testing Acronym Explanations

PP	Pocket Penetrometer	HYD	Hydrometer Gradation
TOR	Torvane	SIEV	Sieve Gradation
DCP	Dynamic Cone Penetrometer	DS	Direct Shear
ATT	Atterberg Limits	DD	Dry Density
PL	Plasticity Limit	CBR	California Bearing Ratio
LL	Liquid Limit	RES	Resilient Modulus
PI	Plasticity Index	VS	Vane Shear
P200	Percent Passing US Standard No. 200 Sieve	bgs	Below ground surface
OC	Organic Content	MSL	Mean Sea Level
CON	Consolidation	HCL	Hydrochloric Acid
UC	Unconfined Compressive Strength		

PBS	LEWIS COUNTY CULVERTS KRUGER ROAD ONALASKA, WASHINGTON	**BORING B-1**
	PBS PROJECT NUMBER: 45013.006	APPROX. BORING B-1 LOCATION: 46.610194; -122.729929

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

Legend: ▲ UNCORRECTED N-VALUE; ✦ DYNAMIC CONE PENETROMETER; ● MOISTURE CONTENT %; RQD%; CORE REC%

Surface Conditions: Asphalt

DEPTH (FEET)	MATERIAL DESCRIPTION
0.0–0.5	ASPHALT (6 inches)
0.5–1.5	BASE ROCK (12 inches)
1.5–6.0	Loose, red-brown and orange, clayey SAND (SC) with gravel; medium plasticity fines; fine to coarse sand; fine, subangular gravel; moist **FILL**
6.0–7.5	Medium dense, gray, poorly graded SAND (SP-SM) with silt and gravel; fine to medium sand; fine, rounded gravel; moist
7.5–8.0	Soft, gray, lean CLAY (CL) with sand; medium plasticity; fine sand; moist
8.0–13.0	Dense, gray, clayey SAND (SC) with gravel; low plasticity; fine to medium sand; fine to coarse, rounded gravel; moist
13.0–20.0	Very dense, gray, silty GRAVEL (GM) with sand and cobbles; low plasticity; fine to coarse sand; fine to coarse, rounded gravel; moist
20.0–23.0	Very dense, gray, sandy SILT (ML) with gravel; non-plastic; fine to coarse sand; fine to coarse, rounded to subrounded gravel; moist
23.0–25.5	Very dense, gray, clayey SAND (SC) with gravel; low to medium plasticity; fine to medium sand; fine to coarse, rounded gravel; moist
25.5	Final depth 25.5 feet bgs; boring backfilled with bentonite. Groundwater not measured at time of exploration due to mud rotary drilling.

SAMPLE ID	TESTING	UNCORRECTED N-VALUE	INSTALLATION AND COMMENTS
S-1		9	
S-2	P200	12	P200 = 43%
S-3		10	
S-4		37	
S-5	P200	21-50/4	P200 = 19%
S-6	ATT	50/5	LL = 20 PL = 18 PI = 2
S-7		50/5	

DRILLING METHOD: Mud Rotary - Tricone
DRILLED BY: Holt Services, Inc.
LOGGED BY: D. Eibert

BIT DIAMETER: 4 7/8 inches
HAMMER EFFICIENCY PERCENT: 86.5
LOGGING COMPLETED: 10/22/19

FIGURE A1

PBS

LEWIS COUNTY CULVERTS KRUGER ROAD
ONALASKA, WASHINGTON

BORING B-2

PBS PROJECT NUMBER:
45013.006

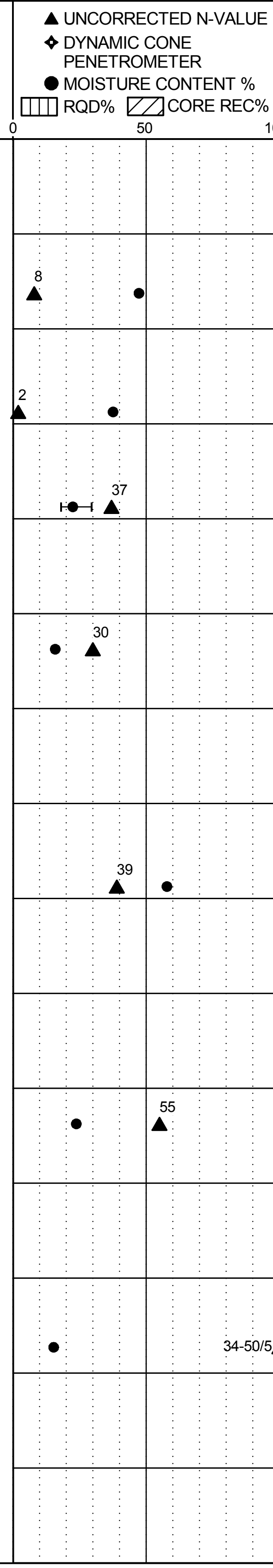
APPROX. BORING B-2 LOCATION:
46.609936; -122.729929

Surface Conditions: Asphalt

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

Depth (feet)	Material Description
0.0–0.5	ASPHALT (6 inches)
0.5–1.5	BASE ROCK (12 inches)
1.5–6.5	Medium stiff, brown to olive brown, lean CLAY (CL) with sand; medium plasticity; fine to coarse sand; moist **FILL** becomes soft, brown to gray; with trace fine to coarse, subangular gravel
6.5–7.0	SILT (ML)
7.0–9.0	Hard, gray to olive brown, sandy CLAY (CL) with gravel; medium plasticity; fine to coarse sand; fine to coarse, subrounded gravel; moist
9.0–15.0	Dense, gray and orange, clayey SAND (SC) with gravel; low plasticity; fine to coarse sand; fine to coarse, rounded to subrounded gravel; moist
15.0–23.0	Dense, gray, poorly graded GRAVEL (GP) with sand; fine to coarse sand; fine to coarse, rounded to subrounded gravel; moist becomes very dense, gray to green
23.0–26.0	Very dense, gray, clayey SAND (SC) with gravel; low to medium plasticity; fine to coarse sand; fine to coarse, rounded to subrounded gravel; moist
26.0	Final depth 26.0 feet bgs; boring backfilled with bentonite. Groundwater not measured at time of exploration due to mud rotary drilling.

Sample ID	Testing	Uncorrected N-Value	Installation and Comments
S-1		8	
S-2		2	
S-3			
S-4	ATT	37	LL = 29 PL = 18 PI = 11
S-5	P200	30	P200 = 24%
S-6		39	
S-7		55	
S-8	P200	34-50/5"	P200 = 26%



DRILLING METHOD: Mud Rotary - Tricone
DRILLED BY: Holt Services, Inc.
LOGGED BY: D. Eibert

BIT DIAMETER: 4 7/8 inches
HAMMER EFFICIENCY PERCENT: 86.5
LOGGING COMPLETED: 10/22/19

FIGURE A2

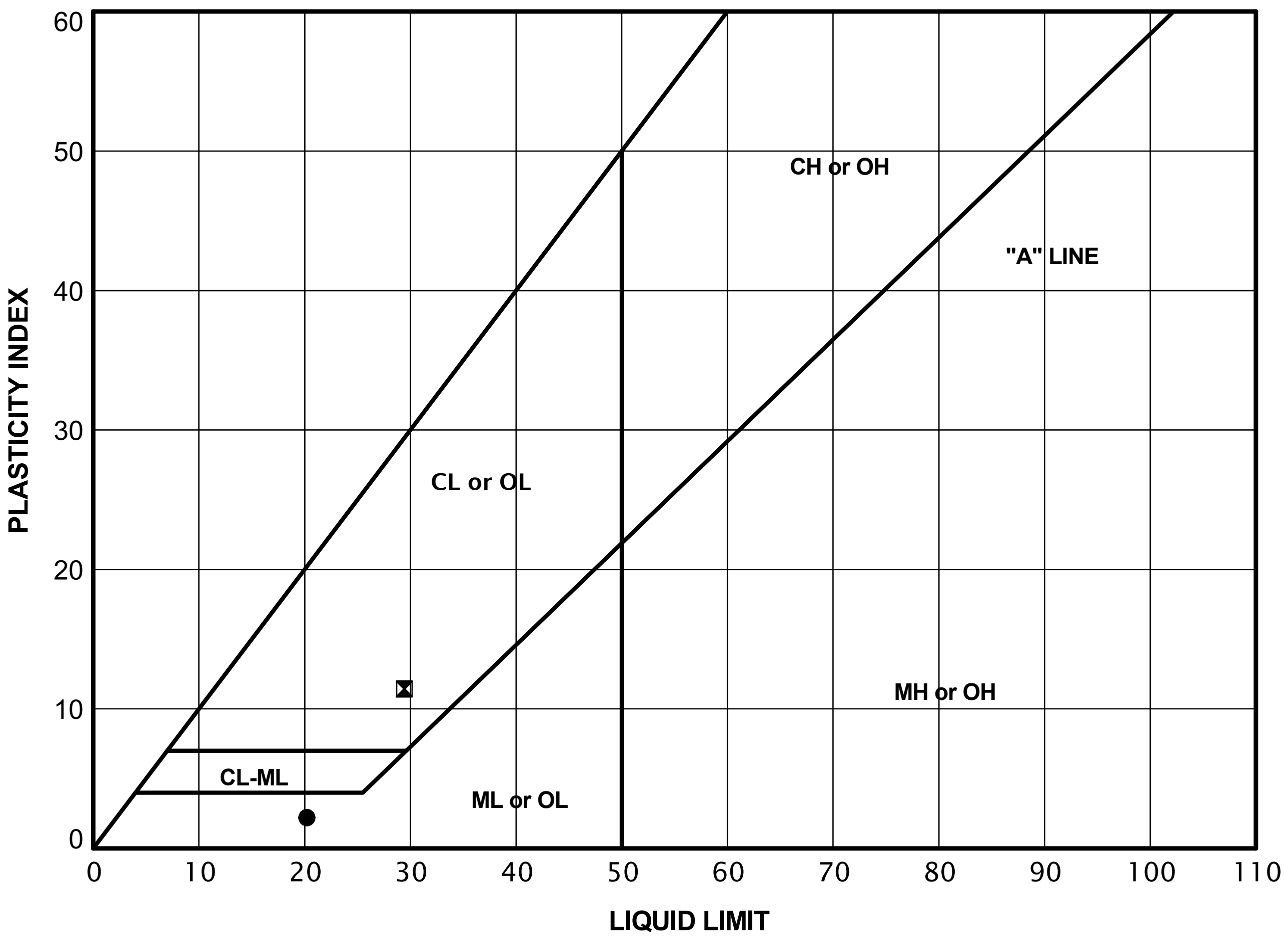
Attachment B

ATTERBERG LIMITS TEST RESULTS

LEWIS COUNTY CULVERTS KRUGER ROAD
ONALASKA, WASHINGTON

PBS PROJECT NUMBER:
45013.006

TEST METHOD: ASTM D4318



KEY	EXPLORATION NUMBER	SAMPLE NUMBER	SAMPLE DEPTH (FEET)	NATURAL MOISTURE CONTENT (PERCENT)	PERCENT PASSING NO. 40 SIEVE (PERCENT)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
●	B-1	S-6	20.0	15.8	NA	20	18	2
⊠	B-2	S-4	7.0	22.4	NA	29	18	11

ATTERBERG LIMITS 45013.006_B1-2_20191029.GPJ PBS_DATATMPL_GEO.GDT PRINT DATE: 11/4/19:RPG

FIGURE B1

SUMMARY OF LABORATORY DATA

LEWIS COUNTY CULVERTS KRUGER ROAD
ONALASKA, WASHINGTON

PBS PROJECT NUMBER:
45013.006

SAMPLE INFORMATION				MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
B-1	S-2	5		30.8				43			
B-1	S-4	10		25.4							
B-1	S-5	15		14.2				19			
B-1	S-6	20		15.8					20	18	2
B-1	S-7	25		18.3							
B-2	S-1	2.5		47.2							
B-2	S-2	5		37.5							
B-2	S-4	7		22.4					29	18	11
B-2	S-5	10		15.8				24			
B-2	S-6	15		57.7							
B-2	S-7	20		23.7							
B-2	S-8	25		15.2				26			

FIGURE B2