Report
Geotechnical Engineering Services
Proposed Commercial Building
Pierce County Parcel No. 728500-0112
Puyallup, Washington

July 20, 2022
ICE File No. 1420-001

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1.0 INTRODUCTION

This report summarizes the results of Icicle Creek Engineers' (ICE's) geotechnical engineering services related to a proposed commercial building located at Pierce County Parcel No. 728500-0112 in Puyallup, Washington (referred to as the Keimig/Castaneda Property in this report). The Keimig/Castaneda Property is shown relative to nearby physical features on the Vicinity Map and Site Plan, Figures 1 and 2, respectively.

Our services were completed in general accordance with our Proposal dated February 14, 2022, and were authorized in writing by Samantha Keimig and Jackson Castaneda, the property owners, on February 21, 2022.

2.0 PROJECT DESCRIPTION

Our project understanding is based on telephone and email correspondence with Ms. Keimig and Mr. Castaneda, Jeff McCann (the Land Use Consultant), and Brandon Loucks, PE with ESM Consulting Engineers, LLC (ESM). Information and documentation related to this project is referenced as follows:

- Cascade Land Surveying, May 8, 2014, *Surveyed For: Robert & Karen Trail*, two sheets.
- ESM, undated, *Jackson Castaneda & Samantha Keimig, 5th St CUP, Basemap,* scale 1 inch = 30 feet.

Based on our review of the above-referenced information and our correspondence with the project team, we understand that the preliminary plan for development of the Keimig/Castaneda Property includes a single-story, approximately 3,200-square-feet commercial building, along with a pedestrian plaza and parking areas as conceptually shown on Figure 2. The Keimig/Castaneda Property is nearly-level and unvegetated; we expect clearing and grading will be limited.

We expect that underground utilities may be installed below pavement and/or building areas; details about underground utility locations or depths are not known at this time. We understand that the preliminary plan for stormwater disposal from the roof and paved areas is infiltration (if feasible), or tying in with the street drainage collection system if infiltration is infeasible.

3.0 SCOPE OF SERVICES

The purpose of our services was to explore and evaluate subsurface soil and groundwater conditions as a basis for evaluating foundation support and stormwater infiltration feasibility. Specifically, our services included the following:

- Review readily available geologic and geotechnical information in the vicinity of the Keimig/Castaneda Property.
- Complete a visit to the Keimig/Castaneda Property to observe existing surface conditions.
- Explore subsurface soil and groundwater conditions by drilling two test borings to depths of about 20 and 31.5 feet.
- Install a groundwater monitoring well (piezometer) in one of the test borings.
- Complete laboratory testing (moisture content determination and grain size analysis) on soil samples obtained from the test borings.
- Evaluate pertinent physical and engineering characteristics of the soils based on the results of the test borings, laboratory testing and our experience.
- Describe and characterize soil and groundwater conditions at the Keimig/Castaneda Property.
- Provide a preliminary evaluation of liquefaction potential for the Keimig/Castaneda Property, based on the shallow subsurface conditions observed in the test borings and our general knowledge of deeper soil and groundwater conditions in the Puyallup valley.
- Provide recommendations for the proposed building regarding earthwork including site preparation and overexcavation and replacement of any unsuitable soils (compressible or weak near-surface soils), structural fill placement and compaction and subgrade preparation requirements, and suitability of on-site soils for use as structural fill. This includes evaluation of the effects of weather and/or construction equipment on the workability of site soils.
- Develop recommendations for shallow foundation design, including allowable soil bearing pressures and settlement estimates.
- Provide preliminary recommendations for reducing post-construction settlements due to static loads and liquefaction.
- Provide recommendations for slab-on-grade floor.
- Provide seismic design criteria, including Seismic Site Class (American Society of Civil Engineers) and other seismic design criteria.
- Evaluate soil infiltration characteristics using the Soil Grain Size Analysis Method (Volume 5, Section 5.4) as described in Washington State Department of Ecology's (Ecology's) 2019 Stormwater Management Manual for Western Washington (SMMWW).
- Provide an evaluation of feasibility of stormwater infiltration. If feasible, provide recommendations for short-term (field) and long-term (design) infiltration rate(s) based on the Soil Grain Size Analysis.

4.0 REGULATORY CONSIDERATIONS

Based on our review of the Puyallup Municipal Code (PMC) section 21.06.1210.3.c, the Keimig/Castaneda Property may be considered a Seismic Hazard Area. PMC section 21.06.1250.2 requires that "*Construction of new buildings and additions to existing buildings within a seismic hazard area shall conform to the International Building Code standards for seismic protection*."

5.0 SITE CONDITIONS

5.1 GENERAL

Shane Markus, PE, LEG of ICE completed site visits to the Keimig/Castaneda Property on February 24, 2022 to mark the locations of two test borings (Borings B-1 and B-2) for the purpose of the underground utility locate and for site reconnaissance, and on March 2, 2022 to observe the drilling of two test borings.

Our understanding of the Keimig/Castaneda Property is based on our review of in-house geological information, review of nearby subsurface explorations (from in-house sources, Washington State Department of Natural Resources (DNR; https://www.dnr.wa.gov/geologyportal), and the Ecology Well Report Viewer), geologic map review (DNR), historic aerial photograph review (US Army Corps of Engineers, US Geological Survey EarthExplorer – https://earthexplorer. usgs.gov/, and Google Earth), surface reconnaissance of the Keimig/Castaneda Property, observations of subsurface conditions in the two test borings at the Keimig/Castaneda Property, and our laboratory testing program.

5.2 GEOGRAPHIC AND TOPOGRAPHIC SETTING

The approximately 10,000-square-feet Keimig/Castaneda Property is located in the Puyallup River valley. The property is nearly-level, varying from about Elevation 49.5 to 51 feet, based on LiDAR-based Digital Terrain Model (DTM) data (Pierce 2011 acquisition; https://lidarportal.dnr.wa.gov/), processed by ICE for 1-foot topographic contours using Environmental Systems Research Institute (Esri) ArcGIS 10.6. The Keimig/Castaneda Property is bordered to the west, north and east by parking lots, alleyways and urban commercial development (single-story retail and warehouse structures). The Keimig/Castaneda Property is bordered to the south by a double-track main rail line elevated about 2- to 3-feet above the property on an embankment of railroad ballast (clean 2- to 4-inch rock).

5.3 GEOLOGIC SETTING

The surficial geology of the Keimig/Castaneda Property has been mapped by the DNR (November 2015, *Geologic Map of the Tacoma 1:100,000-scale Quadrangle, Washington*, Map Series 2015-03) as underlain by Alluvium. Alluvium typically consists of stratified (layered) silt and sand with variable amounts of gravel, typically in a loose/soft to medium dense/medium stiff condition.

Subsequent modifications of the ground surface may have resulted in the placement of fill of varying character in the vicinity of the Keimig/Castaneda Property, considering the extended history of site use in nearby areas (commercial development and construction/use of the rail line).

5.4 SITE OBSERVATIONS

The Keimig/Castaneda Property is currently undeveloped and gravel-surfaced, with grass growing up through the gravel. The Keimig/Castaneda Property is nearly level, with the embankment for the rail line rising abruptly along the south property boundary. Construction materials are stockpiled in local parts of the site. The Keimig/Castaneda Property is surrounded by a temporary chain-link fence. We observed storm drains in the alley and parking lots surrounding the site.

5.5 SUBSURFACE CONDITIONS

5.5.1 Geotechnical Test Borings

Subsurface conditions at the Keimig/Castaneda Property were explored by drilling two test borings (Borings B-1 and B-2) to depths of 20 and 31.5 feet (respectively) on March 2, 2022 using a CME 55LCX rubber-tracked hollow-stem auger drill rig, owned and operated by Gregory Drilling, Inc. of North Bend, Washington. The locations of the test borings are shown on Figure 2.

Disturbed soil samples were obtained at approximately 2½- and 5-foot depth intervals using a split-spoon sampler. The sampler was driven 18 inches using a 140-pound hammer falling 30 inches (Standard Penetration Test – SPT). The number of blows required to drive the sampler the last 12 inches or other specified interval was recorded on the boring log.

The borings were continuously observed by Mr. Markus who classified the soils encountered, observed groundwater conditions and prepared a detailed log of the borings. After completion, a groundwater monitoring well (piezometer) was installed in Boring B-1. Piezometer installation was completed in general accordance with Ecology requirements; installation details are shown on the boring log. Boring B-2 was backfilled in general accordance with Ecology guidelines.

An explanation for the boring logs is presented in Figure 3. The boring logs are presented in Figures 4 and 5. The soil consistencies noted on the boring logs are based on the conditions observed, our experience and judgement, and blow count data obtained during drilling. The depth to groundwater was measured during drilling using a water level meter lowered into the hollow-stem auger once samples appeared saturated; the water level was allowed to stabilize in the auger prior to the measurement being recorded.

The soil samples obtained from the test borings were visually examined in our soils laboratory and selected samples were tested to evaluate pertinent physical characteristics. The testing program included moisture content by ASTM Test Method D 2216, and grain size analysis (particle size distribution) by ASTM Test Methods C 117 and C 136. The moisture content test results are shown on the boring logs. The particle size distribution reports are shown on Figures 6 and 7.

Soils encountered were classified in general accordance with the classification system described in Figure 3. The boring logs are based on our interpretation of the field and laboratory data. The boring logs also indicate the depths at which the soil characteristics change, although the change might be gradual. If the change occurred between samples in the boring, it was interpreted. The boring locations as shown on Figure 2 were measured in the field relative to existing site features, supplemented with a geo-referenced map and hand-held GPS device (cell phone). Elevations of the test borings were estimated using 1-foot topographic contours from LiDAR DTM data (Pierce 2011 acquisition; https://lidarportal.dnr.wa.gov/), processed by ICE using Esri ArcGIS 10.6.

The soil types encountered in each test boring is described below. The native soil conditions encountered in the test borings were consistent with the DNR (2015) mapping of Alluvium.

Boring B-1: Boring B-1 encountered about 1½ feet of Fill, consisting of loose gravel with silt and sand. Coarse-grained Alluvium was encountered from about 1½ to 6 feet, consisting of loose fine to medium sand with silt. Fine-grained Alluvium was encountered from about 6 to 7½ feet, consisting of soft silt. Coarse-grained Alluvium was encountered from about 7½ to 17 feet, consisting of very loose to loose silty sand. Fine-grained Alluvium was encountered from about 17 to 20 feet at the completion depth of Boring B-1, consisting of medium stiff silt with sand.

Boring B-2: Boring B-2 encountered about ½ foot of Fill, consisting of 5/8-inch-minus crushed rock. Coarse-grained Alluvium was encountered from about ½ to 3½ feet, consisting of very loose silty sand with gravel. Fine-grained Alluvium was encountered from about 3½ to 6 feet, consisting of soft silt with sand. Coarse-grained Alluvium was encountered from about 6 to 15½ feet, consisting of very loose to medium dense sand with occasional fine gravel. Fine-grained Alluvium was encountered from about 15½ to 22½ feet, consisting of stiff silt with sand. Coarse-grained Alluvium was encountered from about 22½ to 31½ feet at the completion depth of Boring B-2, consisting of medium dense sand with silt grading to silty sand at about 27½ feet.

At the time of drilling, groundwater was encountered in Borings B-1 and B-2 at depths of about 4.4 feet and 4.8 feet, respectively.

5.5.2 Supplemental Subsurface Information

As part of this evaluation, we reviewed nearby subsurface explorations from in-house sources, from the DNR (https://www.dnr.wa.gov/geologyportal), and from the Ecology Well Report Viewer to evaluate expected conditions deeper than the maximum depths of our borings. Geotechnical test borings are available about 1- to 1½-miles north and northwest of the Keimig/Castaneda Property, on the north side of the Puyallup River but still within the Puyallup River valley bottom. Based on our review of these geotechnical test borings, similar interlayering of very loose to medium dense sand and soft to medium stiff silt is present to the completion depths of these borings at 50 to 100 plus feet. Based on our review of Well Reports from the immediate vicinity of the Keimig/Castaneda Property, groundwater was consistently encountered at relatively shallow depths (less than about 10-feet-deep).

5.6 SEISMIC SETTING

The Puget Sound lowland is located in the forearc of the Cascadia Subduction Zone. Seismicity of this region is attributed primarily to the subduction zone interaction between the Juan de Fuca plate, the continental forearc of the North American plate, and the landward continental arc. The Juan de Fuca plate is subducting beneath the North American plate.

The majority of historical earthquakes in this region have occurred at depths of 20 miles or less. Most major earthquakes (magnitudes greater than 8.5) occur within the deep, subcrustal zone (greater than 20-mile depth). Thick deposits of glacial and non-glacial sediments occur throughout most of the Puget Sound area. Due to the thick sediment cover, little is known regarding the nature of faults in the underlying bedrock. The Seattle Fault, the Southern Whidbey Island Fault and the Tacoma Fault zones are structural geology features that have indicated ground displacement in the Quaternary-age glacial, interglacial and post-glacial sediments in the Puget Sound region.

An abbreviated list of major (great than magnitude 5) earthquake events in the Puget Sound region according to the Pacific Northwest Seismic Network is presented below:

Summary of Major Seismic Events in the Puget Sound Region			
Seismic Event	**Date**	**Location**	**Richter Magnitude**
Cascadia Earthquake	January 26, 1700	Cascadia Sub. Zone	8.7 – 9.2*
North Cascades Earthquake	December 15, 1872	Chelan, WA	6.8*
Pickering Passage Earthquake	February 15, 1946	Olympia, WA	5.8
Strait of Georgia Earthquake	June 23, 1946	Courtenay, BC	7.4
Olympia Earthquake	April 13, 1949	Olympia, WA	7.1
Seattle-Tacoma Earthquake	April 29, 1965	SeaTac, WA	6.5
Duvall Earthquake	May 3, 1996	Duvall, WA	5.4
Satsop Earthquake	July 3, 1999	Satsop, WA	5.7
Nisqually Earthquake	February 28, 2001	Olympia, WA	6.8
* Estimated from historical information.			

Based on our review of the USGS Unified Hazard Tool (https://earthquake.usgs.gov/hazards/interactive/), the most significant contributor to the seismic hazard at the Keimig/Castaneda Property is a potential Cascadia Subduction Zone earthquake about 50 to 90 miles away with a very high intensity (magnitude 9). Another earthquake contributing to the seismic hazard at the Keimig/Castaneda Property includes a shallow local (about 20-miles away) crustal earthquake with a moderate intensity (up to magnitude 7).

6.0 PRELIMINARY INFILTRATION EVALUATION

We completed a preliminary evaluation of infiltration rates in general accordance with Ecology's 2019 SMMWW (Volume 5, Section 5.4, *Option 3: Soil Grain Size Analysis*). Grain size analyses were completed on selected soil samples obtained from the test borings; the particle size distribution reports are presented as Figures 6 and 7. The following is a summary of our preliminary infiltration analysis results (short-term and long-term rates):

Test Boring Number/Sample Number	Sample Depth (feet)	Geologic Unit	Soil Type	Soil Infiltration Rate (short-term / long-term(1)) (inches per hour - iph)
B-1 / S-1	3.5	Alluvium (coarse-grained)	SP-SM – sand with silt	31 / 8.4
B-2 / S-2 & S-3	4 & 5.5	Alluvium (fine-grained)	ML – silt with sand	0.6 / 0.16

(1) The long-term infiltration rate includes correction factors to account for in-situ density, test method, maintenance and biofouling. The long-term infiltration rate should be used for sizing infiltration facilities.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 GENERAL

Based on our information review, site observations, and the results of our subsurface exploration and laboratory testing program, it is our opinion that the proposed building at the Keimig/Castaneda Property is feasible from a geotechnical standpoint. However, the Keimig/Castaneda Property is underlain by zones of loose or soft Alluvium with a relatively high groundwater level which are conditions that need to be considered in the building design, as described in the remainder of this report.

7.2 SEISMIC CONSIDERATIONS

7.2.1 Seismic Design Criteria

Based on our review of PMC section 17.04.030 which refers to Washington Administrative Code (WAC) Chapter 51-50, we understand that the 2018 International Building Code (IBC) will be the adopted building code of reference at the time of design and permitting for the proposed building.

The 2018 IBC both presents requirements for seismic design criteria and refers to requirements of the 2016 American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 7-16 (Minimum Design Loads for Buildings and Other Structures). Both the 2018 IBC and ASCE 7-16 require structures to be designed for earthquake ground motions with a two percent probability of exceedance in 50 years, corresponding to a target risk of structural collapse of one percent in 50 years considering a generic structural fragility factor.

Because of the presence of potentially liquefiable soils, the subsurface conditions at the Keimig/Castaneda Property correspond to Site Class F, as defined by ASCE/SEI 7-16 Section 20.3.1. Within Site Class F, ASCE/SEI 7-16 requires that a site-specific ground response analysis be completed, with the exception of structures with fundamental periods of vibration equal to or less than 0.5 seconds; these structures may be assigned Seismic Site Class using ASCE/SEI 7-16 Section 20.3 and designed accordingly using methods in 2018 IBC Section 1613. Because only one story is planned, we assume the proposed building at the Keimig/Castaneda Property will have a fundamental period of less than 0.5 seconds.

Based on our analysis of boring logs and our review of available geologic information, we interpret the on-site conditions at the Keimig/Castaneda Property to correspond to Seismic Site Class E ("Soft Clay Soil"). The Seismic Site Class was developed based on the recommended procedure using SPT N-values (Standard Penetration Test blow count), as described in ASCE/SEI 7-16 Section 20.4.2. We considered SPT N-values from Borings B-1 and B-2 and reviewed supplemental geotechnical test borings in the area for this evaluation.

We recommend the following seismic parameters for use in design of structures for the project.

Seismic Design Parameters	
Site Class[1]	E
Site-Modified Peak Ground Acceleration (PGA_M)[2]	0.600
Design-Level PGA[3]	0.400
Short Period Spectral Response Acceleration, S_S[4]	1.269
1-Second Period Spectral Response Acceleration, S_1[4]	0.437
Site Coefficient, F_a[5]	1.2
Site Coefficient, F_v[5]	2.326
Short Period Design-Level Spectral Response Acceleration, S_{DS}[6]	1.015
1-Second Period Design-Level Spectral Response Acceleration, S_{D1}[6]	0.676

(1) The subsurface conditions correspond to Site Class F, but, assuming a structural fundamental period of less than 0.5 seconds, Site Class E was determined using average N-values (ASCE/SEI 7-16 Section 20.4.2).
(2) Based on the Maximum Considered Earthquake – Geometric Mean (MCE_G) Seismic Ground Motion Maps in ASCE 7-16 (Figure 22-9), adjusted for the Site Coefficient F_{PGA} = 1.2 (Table 11.8-1).
(3) Two-thirds of the PGA_M (2018 IBC Section 1613.2.4).
(4) Based on the Risk-Targeted Maximum Considered Earthquake (MCE_R) Ground Motion Response Acceleration Maps in the 2018 IBC (Figures 1613.2.1(1) and 16.13.2.1(2)), adjusted following 2018 IBC Sections 1613.2.3 and 1613.2.4.
(5) From 2018 IBC Table 1613.2.3(1) and Table 1613.2.3(2).
(6) ASCE 7-16 Section 11.4.8 Exception 3 was assumed; the requirements of the exception should be reviewed by the structural engineer.

7.2.2 Liquefaction Susceptibility

Soil liquefaction is a phenomenon where soils experience a rapid loss of shear strength as pore water pressures increase in response to strong ground shaking. Loss of soil strength and migration of water can result in soils that flow, deform or erupt. Soil liquefaction may cause ground settlement, lateral deformation, excessive ground oscillation, and/or sand boils or soil eruptions, potentially resulting in structural damage.

Liquefaction generally occurs in loose to medium dense sand deposits, though recent studies have shown that gravels, silty sands and non-plastic sandy silts may also be susceptible to liquefaction. Additionally, soil saturation (groundwater) is a necessary component of liquefaction susceptibility.

The potential for liquefaction to initiate is typically quantified by comparing the Cyclic Stress Ratio (CSR – the driving forces of liquefaction, which are based on ground shaking amplitude, frequency content and duration) to the Cyclic Resistance Ratio (CRR – the resisting forces to liquefaction, which are related to soil strength and grain size distribution). Procedures for determining the CSR and CRR are outlined in Idriss and Boulanger (2004, *Semi-Empirical Procedures for Evaluating Liquefaction Potential During Earthquakes*). To determine the CSR, we used the site-adjusted MCE_G PGA of 0.600g (see section **7.2.1** of this report), and an earthquake magnitude M_W of 7.83 (obtained as the mean magnitude from the USGS Unified Hazard deaggregation tool). To determine the CRR, we used correlations between SPT blow-count (N) value and the CRR, adjusted for the fines content of the soil (based on sample observations and laboratory test results).

Based on our evaluation of the subsurface soil and groundwater conditions, and our analysis using Idriss and Boulanger (2004), **the very loose to medium dense sand and very soft to soft silt layers (where non-plastic) below the groundwater table (4.4- to 4.8-feet) of the soil profile are moderately to highly susceptible to soil liquefaction** during a design ground motion (earthquake/seismic event) prescribed by IBC 2018 and ASCE 7-16 Seismic Design Maps.

7.2.3 Seismically-Induced Settlements and Lateral Spreading

Based on empirical methods described by Tokimatsu and Seed (1987, *Evaluations of settlements in sand due to earthquake shaking*) and Ishihara and Yoshimine (1992, *Evaluation of settlements in sand deposits following liquefaction during earthquakes*), which correlate the SPT N value and ground motion to expected ground settlements, **we estimate that liquefaction-induced ground settlements in the area of the Keimig/Castaneda Property could be on the order of several inches** during design ground motions prescribed by IBC 2018 and ASCE 7-16 Seismic Design Maps. We expect that liquefaction may be initiated uniformly across the Keimig/Castaneda Property, but there is also a risk of differential seismically-induced settlement (if unmitigated).

Lateral spreading is the phenomenon wherein the ground surface displaces toward a gentle slope or free face during liquefaction, resulting in permanent lateral deformation. An approximately 20-feet-high free face is located about 1,100-feet northeast of the Keimig/Castaneda Property, along the banks of the Puyallup River. Based on Youd and Bartlett (1994, *Empirical Prediction of Liquefaction-Induced Lateral Spread*) and Youd *et al.* (2002, *Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement*), **lateral spreading (horizontal displacement) is possible toward the free face along the Puyallup River on the order of several inches** during design ground motions prescribed by IBC 2018 and ASCE 7-16 Seismic Design Maps.

7.3 GEOTECHNICAL DESIGN RECOMMENDATIONS

7.3.1 Foundation Support

As previously described, the Keimig/Castaneda Property is underlain by very loose/soft to medium dense/ stiff Alluvium (silt and sand). In our opinion, these soils are not suitable for directly supporting the proposed building on conventional shallow foundations, due to the risk of unacceptable differential settlements during a design seismic event and/or static loading; however, the design recommendation provided below should acceptably mitigate the potential for seismic and/or static differential settlement and should improve bearing support.

We recommend that the proposed building be founded on shallow footings that bear on a pad of Structural Fill (referred to as a “Bearing Pad”) placed over the native soils across the entire structure footprint. We recommend overexcavating at least 2-feet below footing subgrade elevation across the entirety of the building footprint. The bearing pad should extend at least 2-feet out from the edges of the spread footings to accommodate the “zone of influence” of footing stress. We recommend that the overexcavated subgrade be compacted in place (if compactible as Structural Fill – see section **7.4.2** of this report) or covered with a woven reinforcing geosynthetic (such as Tencate Mirafi® RS380i or equal). We recommend that the Bearing Pad fill be composed of well-drained sand, gravel and cobbles (Washington State Department of Transportation (WSDOT) 2022 Standard Specifications 9-03.14(1) Gravel Borrow). Alternatively, Crushed Surfacing Base Course (CSBC) could be used for the Bearing Pad as described in WSDOT 2022 Standard Specifications 9-03.9(3). The Bearing Pad should be placed and compacted as described in section **7.4.2** of this report.

Conventional spread footings are adequate if the Bearing Pad is constructed as described. The Bearing Pad mitigates the risk of static and seismic differential settlement by serving as a diaphragm to buffer the effects of an earthquake event, and by dissipating foundation stresses uniformly across the building footprint, thereby mitigating both static and seismic differential settlements.

We recommend that exterior footings be embedded a minimum of 18-inches below the adjacent ground surface for frost protection; interior footings can be embedded 12 inches. We recommend that continuous and isolated column footings have minimum widths of 16 and 24 inches, respectively. We anticipate that footings may be designed using an **allowable soil bearing pressure of 1,500 pounds per square foot** (psf) for dead plus long-term live loads. This value may be increased by one-third when considering transient loads, such as wind or seismic.

We estimate that post-construction static settlement of shallow footings, constructed as recommended on a Bearing Pad, will be on the order of ½ to ¾ inch for the assumed loading conditions. Static differential settlements should not exceed about ½ inch over 50 feet. We expect static settlements to occur relatively quickly (mostly within about 1 month of construction). We expect liquefaction-induced differential settlements to be minimized if the Bearing Pad and shallow footings are constructed as recommended, but the risk of liquefaction-induced differential settlement cannot be eliminated.

7.3.2 Slab-on-Grade Support

The slab-on-grade subgrade should be prepared in accordance with section **7.4.1** of this report. We recommend that the subgrade surface be compacted so that a minimum compaction of 95 percent of the Maximum Dry Density (MDD) is obtained in accordance with ASTM Test Method D 1557 before placing Structural Fill or capillary break material.

We recommend that a 6-inch-thick layer of medium to coarse sand and gravel containing less than 3-percent fines (material passing the US Standard No. 200 sieve) by weight based on the fraction of the material passing the ¾-inch sieve be placed below the bottom elevation of the floor slab to provide uniform support and a capillary break. A vapor retarder and/or waterproofing should be provided if there is a potential for surface or shallow groundwater to occur or migrate under the slab.

Post-construction static slab settlements for a 150 psf live load are expected to be less than ¾ inch. In addition, the on-grade slabs could experience seismically-induced settlements on the order of several inches during a major earthquake.

We expect that liquefaction may be initiated uniformly across the Keimig/Castaneda Property, but there is also a risk of differential seismically-induced settlement, which is minimized with the use of the Bearing Pad. We expect liquefaction-induced differential settlements to be minimized if the Bearing Pad and slab-on-grades are constructed as recommended, but the risk of liquefaction-induced differential settlement cannot be eliminated.

7.3.3 Stormwater Disposal

As described in section **6.0** of this report, we completed a preliminary evaluation of infiltration rates of select soil samples in general accordance with Ecology's 2019 SMMWW (Volume 5, Section 5.4, *Option 3: Soil Grain Size Analysis*).

Based on this evaluation, the shallower coarse-grained Alluvium (extending from near-surface to about 6 to 3.5 feet in Borings B-1 and B-2, respectively) is relatively permeable. The underlying fine-grained Alluvium (below about 6- and 3.5-feet in Borings B-1 and B-2, respectively) is relatively impermeable. These depths are described in the table below. As described in section **5.5.1** of this report, groundwater was encountered at depths of about 4.4 and 4.8 feet in Borings B-1 and B-2, respectively.

Soil Type	Approximate Depth of Layer (Boring B-1) (feet)	Approximate Depth of Layer (Boring B-2) (feet)	Preliminary Soil Infiltration Rate (short-term / long-term) (inches per hour – iph[(1)])
Alluvium (coarse-grained)	1.5 to 6	0.5 to 3.5	31 / 8.4
Alluvium (fine-grained)	6 to 7.5	3.5 to 6	0.6 / 0.16

(1) The long-term (design) infiltration rate includes correction factors to account for in-situ density, test method, maintenance and biofouling. The long-term infiltration rate should be used for design (sizing) infiltration facilities.

We recommend using the long-term (design) infiltration rates for each soil type for sizing infiltration facilities. Due to the relatively shallow groundwater table and the relatively shallow depth to low-permeability soil, we expect that disposal of stormwater by infiltration may be infeasible at the Keimig/Castaneda Property. We understand that permeable pavement is being considered; permeable pavement may be feasible depending on the elevation of the final subgrade and the ponding depth within the base course (refer to Ecology's 2019 SMMWW).

7.4 EARTHWORK CONSIDERATIONS

7.4.1 Site Preparation

Sod and Topsoil should be stripped and removed from pavement areas. Fill can be evaluated on a case-by-case basis for support of pavements. Stripping should be minimized to the extent that only the footprint of these areas is affected. We expect that the stripping depth will be 6 to 12 inches for pavement areas. Greater stripping depths may be necessary where organic or very soft/loose soils are observed. Individual roots larger than 1-inch diameter should be grubbed to at least 12-inches below the design subgrade.

As previously described, we recommend a 2-feet-deep overexcavation (total 3-feet-deep excavation including the 1 foot recommended embedment) within the footprint of the proposed building (slab-on-grade and footing areas).

Following stripping, the exposed pavement, slab-on-grade and footing subgrade areas should be thoroughly proofrolled in dry weather and probed in wet weather to evaluate areas of soft, loose, or otherwise unsuitable subgrade areas.

In pavement areas, soft, loose or wet soils identified during proofrolling or probing should be removed and replaced with Structural Fill (as described in section **7.4.2** of this report) up to about 3 feet below final subgrade elevation. Where soft, loose, or wet soils are present below 3 feet, we recommend that a woven geotextile fabric, such as Tencate Mirafi® RS380i or equal, be placed in the bottom of the excavation prior to backfilling with Structural Fill.

Within the building footprint, organic soils identified during proofrolling or probing should be removed and replaced with Structural Fill (as described in section **7.4.2** of this report), regardless of depth.

7.4.2 Structural Fill

The term "Structural Fill" refers to any fill material placed under pavements, slab-on-grades, building foundations, or other load-bearing and settlement-sensitive features. We recommend that all fill used in these applications at the Keimig/Castaneda Property meet the following criteria regarding composition, placement and compaction of Structural Fill.

Structural Fill should be free of organic material or debris and have a maximum particle size of 6 inches. The material should contain less than five percent fines (soil particles passing the US Standard No. 200

sieve) by weight relative to the portion finer than the ¾-inch sieve. If earthwork is done during generally dry weather conditions, the fines content may be increased.

As a guideline, Structural Fill should be placed in horizontal lifts which are 12 inches or less in loose thickness. The actual lift thickness depends on the quality of the fill material and the size of the compaction equipment.

We recommend that Structural Fill placed in the pavement, slab-on-grade and footing areas be uniformly compacted to at least 95 percent of the MDD obtained in general accordance with ASTM Test Method D 1557. Materials such as pea gravel, washed rock, quarry spalls, Controlled Density Fill (CDF) and lean mix concrete do not require the same rigorous placement and compaction procedures, but they should be placed in a manner suitable for the purpose. Nonstructural fill placed in landscape areas need only be compacted to the degree required for trafficability of construction equipment and effective surface drainage.

We expect that the Fill and coarse-grained Alluvium (provided no abundant roots or organic fragments) that are excavated may be reused for Structural Fill during periods of extended dry weather. During wet weather, it may be necessary to import soil containing less than five percent fines (soil particles passing the US Standard No. 200 sieve). Moisture conditioning (wetting or drying) may be required, especially where silt contents are higher. Fine-grained Alluvium may not be easily compactible to 95 percent of the MDD. As previously described, Structural Fill for the Bearing Pad should be composed of well-drained sand, gravel and cobbles as described in WSDOT 2022 Standard Specifications 9-03.14(1) Gravel Borrow. Alternatively, CSBC could be used for the Bearing Pad as described in WSDOT 2022 Standard Specifications 9-03.9(3).

7.4.3 Excavation Considerations

Based on our geotechnical test borings, we expect excavatability of the site soils using conventional heavy construction equipment to be relatively easy. Temporary cut slopes greater than 4-feet deep should be made at an inclination of 1H:1V (horizontal to vertical) or flatter. Flatter slopes may be needed if instability is observed. All temporary cut slopes must comply with the provisions of Title 296 Washington Administrative Code (WAC), Part N, *Excavation, Trenching and Shoring*. We recommend that cut slopes for temporary excavations be made the responsibility of the contractor. The contractor is present at the site continuously and is best able to observe changes in site and soil conditions and to monitor the performance of excavations.

We recommend that all excavations extending below groundwater be fully dewatered.

7.5 DRAINAGE

We recommend that perimeter footing drains be installed adjacent to the exterior footings of the proposed building. These drains should consist of 4-inch diameter, perforated, smooth-walled pipe bedded in at least 6 inches of 1¼-inch uniform washed rock, with the base of the pipe at the base of any adjacent footings. The bedding should be enclosed within a nonwoven geotextile fabric such as Tencate Mirafi® 160N to reduce the potential for infiltration of fines into the drainage material from the native soils. The pipe should be placed with the perforations down. The perforated pipe should be connected to a tightline collection system that discharges away from structures. The ground surface surrounding the proposed building should be sloped down and away from the structure.

7.6 GEOTECHNICAL OBSERVATION DURING CONSTRUCTION

A representative from ICE should observe preparation for, placement and compaction of Structural Fill, including completing an adequate number of in-place density tests in the Structural Fill to evaluate if the desired degree of compaction is being achieved. A representative from ICE should also be present to observe pavement, slab-on-grade, footing and Bearing Pad subgrade preparation and advise on the extent of any remedial action needed. A representative from ICE should observe the base of infiltration facilities, if used, after excavation to subgrade to evaluate whether the native materials at the base of the facilities are as expected and that the provided long-term (design) infiltration rates are applicable.

8.0 USE OF THIS REPORT

We have prepared this report for use by Samantha Keimig and Jackson Castaneda. The data and report should be provided to prospective contractors for bidding or estimating purposes and to permitting agencies, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

When the design has been finalized, we recommend that the final design drawings and specifications be reviewed by our firm to confirm that our recommendations have been interpreted and implemented as intended.

There is the possibility that subsurface conditions could vary with location across the Keimig/Castaneda Property, as well as with time. A contingency for unexpected conditions should be included in the project budget and schedule. Sufficient observation, testing and consultation should be provided by our firm during construction to evaluate whether the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions encountered during the work differ from those anticipated, and to evaluate whether or not earthwork and foundation installation activities comply with the contract plans and specifications.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express or implied, should be understood.

****

We appreciate the opportunity to be of service to Samantha Keimig and Jackson Castaneda on this project. If you have any questions concerning this report or if we can provide additional services, please call.

Yours very truly,
Icicle Creek Engineers, Inc.

Shane J. Markus, PE, LEG
Project Engineer/Geologist

Brian R. Beaman, PE, LEG, LHG
Principal Engineer/Geologist/Hydrogeologist

Document ID: 1420001.Report
Attachments: Vicinity Map – Figure 1
Site Plan – Figure 2
Explanation for Boring Logs – Figure 3
Boring Logs – Figures 4 and 5
Particle Size Distribution Reports – Figures 6 and 7

Submitted via email

FIGURES

Notes: 1) Aerial Photograph dated March 3, 2021 obtained from Esri ArcGIS World Imagery layer.
2) Parcel boundary based on Pierce County GIS data.

0 500 1,000
Approximate Scale in Feet

VICINITY MAP	ICICLECREEK ENGINEERS	SCALE: As Shown	ICE FILE NO.	
PROPOSED COMMERCIAL BUILDING PIERCE COUNTY PARCEL NO. 728500-0112, PUYALLUP, WASHINGTON	29335 NE 20th Street Carnation, Washington 98014 (425) 333-0093	DESIGNED: --- DRAWN: BRB CHECKED: KSK DATE: 07/20/2022	1420-001 Figure 1	

EXPLANATION

B-1 Test Boring Location - "p" indicates installation of a monitor well

Keimig/Castaneda Property - Pierce County Parcel No. 728500-0112

Notes: 1) Aerial Photograph dated August 14, 2020 obtained from Google Earth.
2) LiDAR-based Digital Terrain Model (DTM) data (Pierce 2011 acquisition) obtained from the Washington State Department of Natural Resources, Washington LiDAR Portal (https://lidarportal.dnr.wa.gov/); processed by ICE for 1-foot topographic contour intervals using Environmental Systems Research Institute (Esri) ArcGIS 10.6.
3) Preliminary locations of parking pad and commercial building are based on our review of the ESM site plan (ESM, undated, *Jackson Castaneda & Samantha Keimig, 5th St CUP, Basemap*, scale 1 inch = 30 feet).
3) Parcel boundary obtained from Pierce County GIS data.

0 25 50

Approximate Scale in Feet

SITE PLAN

PROPOSED COMMERCIAL BUILDING

PIERCE COUNTY PARCEL NO. 728500-0112, PUYALLUP, WASHINGTON

ICICLECREEK ENGINEERS
29335 NE 20th Street
Carnation, Washington 98014
(425) 333-0093

SCALE: As Shown

DESIGNED: ---

DRAWN: SJM

CHECKED: BRB/KSK

DATE: 07/20/2022

ICE FILE NO.

1420-001

Figure

2

Unified Soil Classification System

MAJOR DIVISIONS			Soil Classification and Generalized Group Description	
Coarse-Grained Soils More than 50% retained on the No. 200 sieve	GRAVEL More than 50% of coarse fraction retained on the No. 4 sieve	CLEAN GRAVEL	GW	Well-graded gravels
			GP	Poorly-graded gravels
		GRAVEL WITH FINES	GM	Gravel and silt mixtures
			GC	Gravel and clay mixtures
	SAND More than 50% of coarse fraction passes the No. 4 sieve	CLEAN SAND	SW	Well-graded sand
			SP	Poorly-graded sand
		SAND WITH FINES	SM	Sand and silt mixtures
			SC	Sand and clay mixtures
Fine-Grained Soils More than 50% passing the No. 200 sieve	SILT AND CLAY Liquid Limit less than 50	INORGANIC	ML	Low-plasticity silts
			CL	Low-plasticity clays
		ORGANIC	OL	Low plasicity organic silts and organic clays
	SILT AND CLAY Liquid Limit greater than 50	INORGANIC	MH	High-plasticity silts
			CH	High-plasticity clays
		ORGANIC	OH	High-plasticity organic silts and organic clays
Highly Organic Soils	Primarily organic material with organic odor		PT	Peat

Notes: 1) Soil classification based on visual classification of soil is based on ASTM Test Method D 2488.
2) Soil classification using laboratory tests is based on ASTM Test Method D 2487.
3) Description of soil density or consistency is based on interpretation of blow count data and/or test data.

Soil Particle Size Definitions

Component	Size Range
Boulders	Coarser than 12 inch
Cobbles	3 inch to 12 inch
Gravel	3 inch to No. 4 (4.78 mm)
Coarse	3 inch to 3/4 inch
Fine	3/4 inch to No. 4 (4.78 mm)
Sand	No. 4 (4.78 mm) to No. 200 (0.074mm)
Coarse	No. 4 (4.78 mm) to No. 10 (2.0 mm)
Medium	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Finer than No. 200 (0.074 mm)

Soil Moisture Modifiers

Soil Moisture	Description
Dry	Absence of moisture
Moist	Damp, but no visible water
Wet	Visible water

Key to Boring Log Symbols

Sampling Method	Boring Log Symbol	Description
Blows required to drive a 2.4 inch I.D. split-barrel sampler 12-inches or other indicated distance using a 300-pound hammer falling 30 inches.	34	Location of relatively undisturbed sample
	12	Location of disturbed sample
	21	Location of sample attempt with no recovery
Blows required to drive a 1.5-inch I.D. split barrel sampler (SPT - Standard Penetration Test) 12-inches or other indicated distance using a 140-pound hammer falling 30 inches.	14	Location of sample obtained in general accordance with Standard Penetration Test (ASTM D-1586) test procedures.
	30	Location of SPT sampling attempt with no recovery.
Pushed Sampler	P	Sampler pushed with the weight of the hammer or against weight of the drilling rig.
Grab Sample	G	Sample obtained from drill cuttings.

Note: The lines separating soil types on the logs represents approximate boundaries only. The actual boundaries may vary or be gradual.

Laboratory Tests

Test	Symbol
Moisture Content	MC
Density	DN
Grain Size	GS
Percent Fines	PF
Atterberg Limits	AL
Hydrometer Analysis	HA
Consolidation	CN
Compaction	CP
Permeability	PM
Unconfined Compression	UC
Unconsolidated Undrained TX	UU
Consolidated Undrained TX	CU
Consolidated Drained TX	CD
Chemical Analysis	CA

EXPLANATION FOR BORING LOGS

PROPOSED COMMERCIAL BUILDING
PIERCE COUNTY PARCEL NO. 728500-0112, PUYALLUP, WASHINGTON

ICICLECREEK ENGINEERS
29335 NE 20th Street
Carnation, Washington 98014
(425) 333-0093

SCALE: None
DESIGNED: --
DRAWN: SJM
CHECKED: BRB/KSK
DATE: 07/20/2022

ICE FILE NO. 1420-001
Figure 3

Boring B-1

Latitude 47.191302; Longitude -122.286816

Approximate Ground Surface Elevation: 50 feet

SJM: 03/02/22

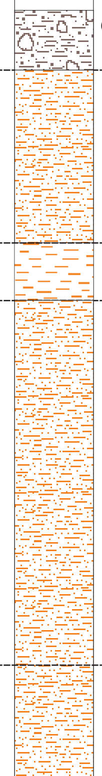
Logged by: SJM

Project Name: Proposed Commercial Building, Pierce County Parcel No. 728500-0112

ICE File No. 1420-001

Depth in Feet	Description (Soil Profile)	Group Symbol	Blow Count	Laboratory Testing
0	Grayish-brown fine to coarse GRAVEL with silt and sand (loose, moist) (Fill)	GP-GM		
	Grayish-brown fine to medium SAND with silt (loose, moist) (Alluvium)			
		SP-SM	10	MC/ GSD
	grades to wet at about 4.4 feet			
5		SP-SM	2	MC
	Mottled gray and brown SILT (soft, moist) (Alluvium)	ML		
	Grayish-brown silty fine to medium SAND (very loose, wet) (Alluvium)	SM	2	MC
10	grades to loose at about 10 feet	SM	9	MC
15		SM	5	MC
	Grayish-brown SILT with sand (medium stiff, moist) (Alluvium)	ML		MC
20	Boring completed at about 20 feet on March 2, 2022.			
25				
30				
35				
40				

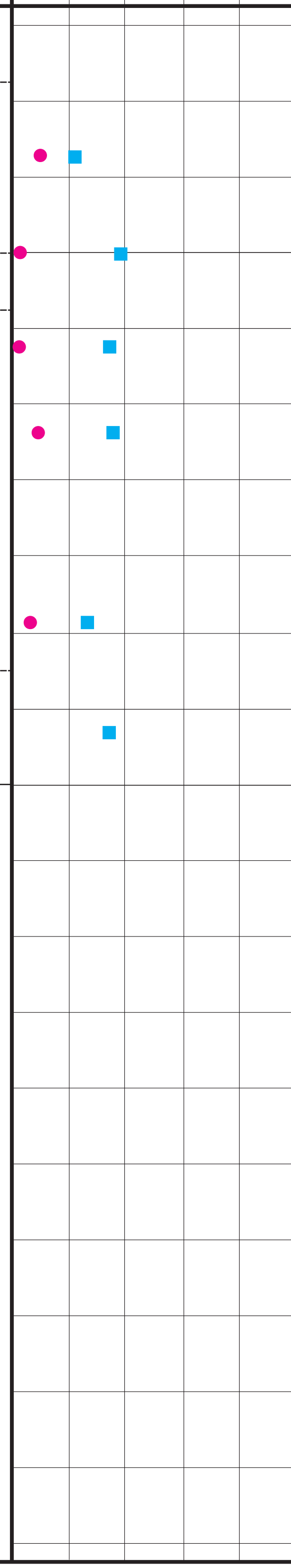
Graphic Log



Sample Location

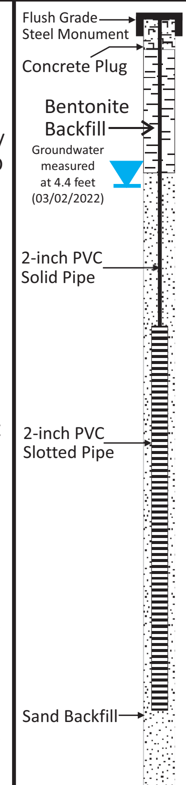
Penetration Resistance (Blows/foot - ●)

Moisture Content (Percent - ■)



Comments/ Groundwater Observations

Ecology Well Tag ID #BMS-984



See Figure 3 for explanation of symbols

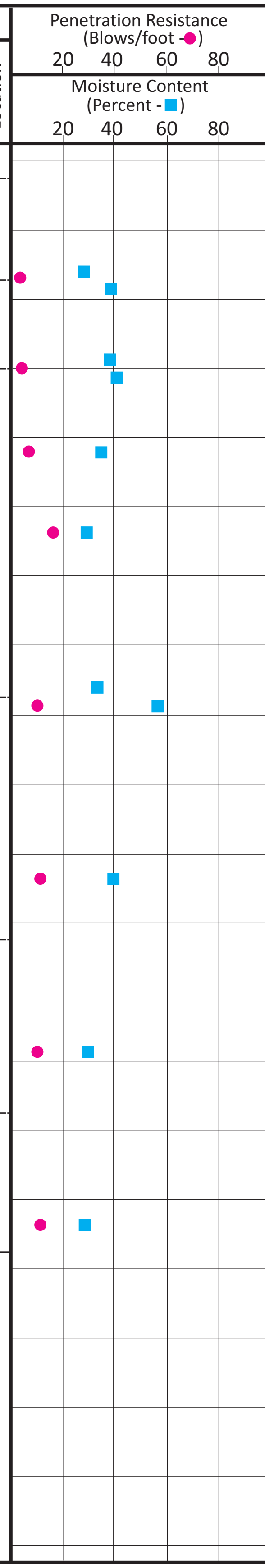
Boring B-2

Latitude 47.191277; Longitude -122.286539

Approximate Ground Surface Elevation: 49.5 feet

Logged by: SJM

Depth in Feet	Description	Group Symbol	Blow Count	Laboratory Testing	Comments/ Groundwater Observations
0	5/8-inch-minus crushed rock (loose, moist) (Fill)	GM			
	Dark brown silty fine to medium SAND with gravel (very loose, moist) (Alluvium)	SM	2	MC	
	Mottled gray and brown SILT with sand (soft, moist) (Alluvium)	ML		MC/ GSD	Groundwater measured at about 4.8 feet at the time of drilling
5		ML	3	MC/ GSD	
	Brown silty fine to medium SAND with occasional fine gravel (very loose, wet)	SM		MC	
	grades to grayish-brown, loose at about 7.5 feet	SM	5	MC	
10	grades to medium dense at about 10 feet	SM	16	MC	Bentonite Backfill
15		SM			
	Grayish-brown SILT with sand (stiff, moist) (Alluvium)	ML	10	MC	
20	grades to gray, with wood and root fragments at about 20 feet	ML	12	MC	
	Gray fine to coarse SAND with silt (medium dense, wet) (Alluvium)				
25		SP-SM	10	MC	
	Gray silty fine to medium SAND (medium dense, wet) (Alluvium)				
30		SM	12	MC	
	Boring completed at about 31.5 feet on March 2, 2022.				
35					
40					

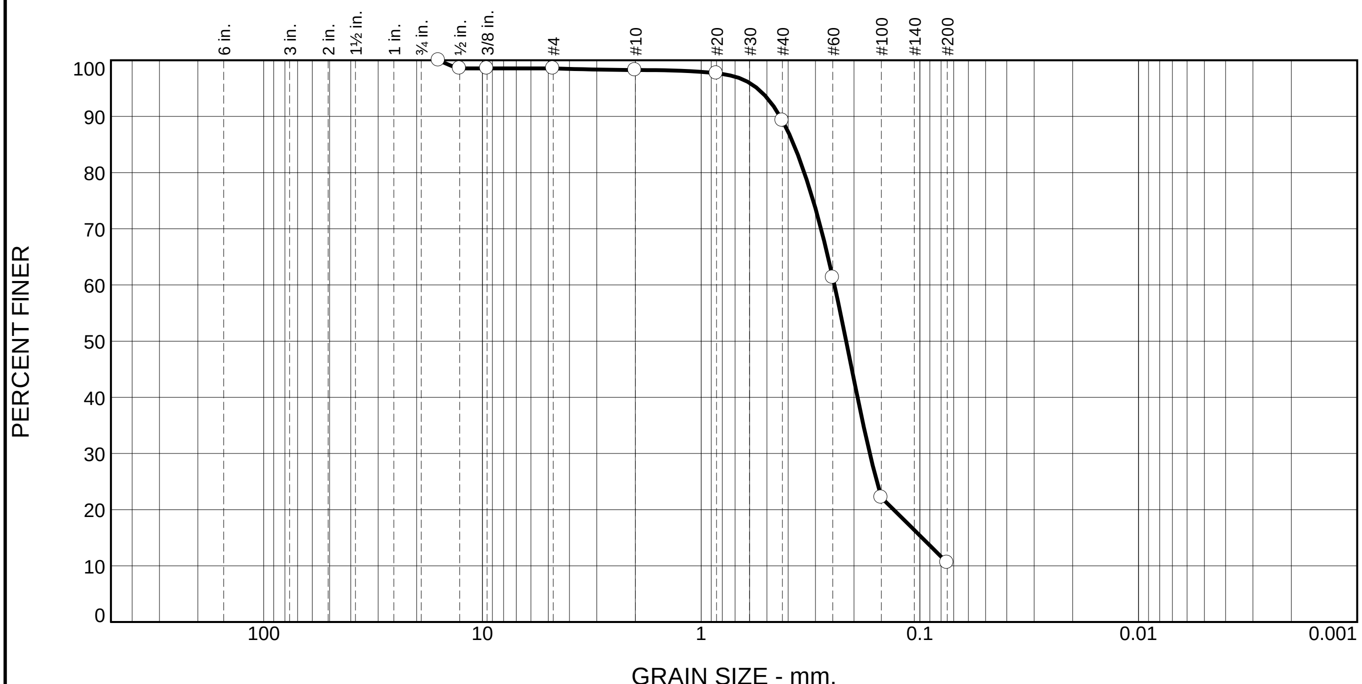


Project Name: Proposed Commercial Building, Pierce County Parcel No. 728500-0112

ICE File No. 1420-001

See Figure 3 for explanation of symbols

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.4	0.3	9.0	78.7	10.6	

TEST RESULTS			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
5/8	100.0		
1/2	98.6		
3/8	98.6		
#4	98.6		
#10	98.3		
#20	97.7		
#40	89.3		
#60	61.3		
#100	22.2		
#200	10.6		

* (no specification provided)

Material Description

Grayish-brown fine to medium SAND with silt (Alluvium)

Atterberg Limits (ASTM D 4318)

PL= **LL=** NV **PI=**

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 0.4354 D_{85}= 0.3769 D_{60}= 0.2458
D_{50}= 0.2172 D_{30}= 0.1693 D_{15}= 0.0977
D_{10}= C_u= C_c=

Remarks

MC = 21%

Date Received: 03/21/2022 **Date Tested:** 03/28/2022
Tested By: CEN
Checked By: SJM
Title: Project Engineer/Geologist

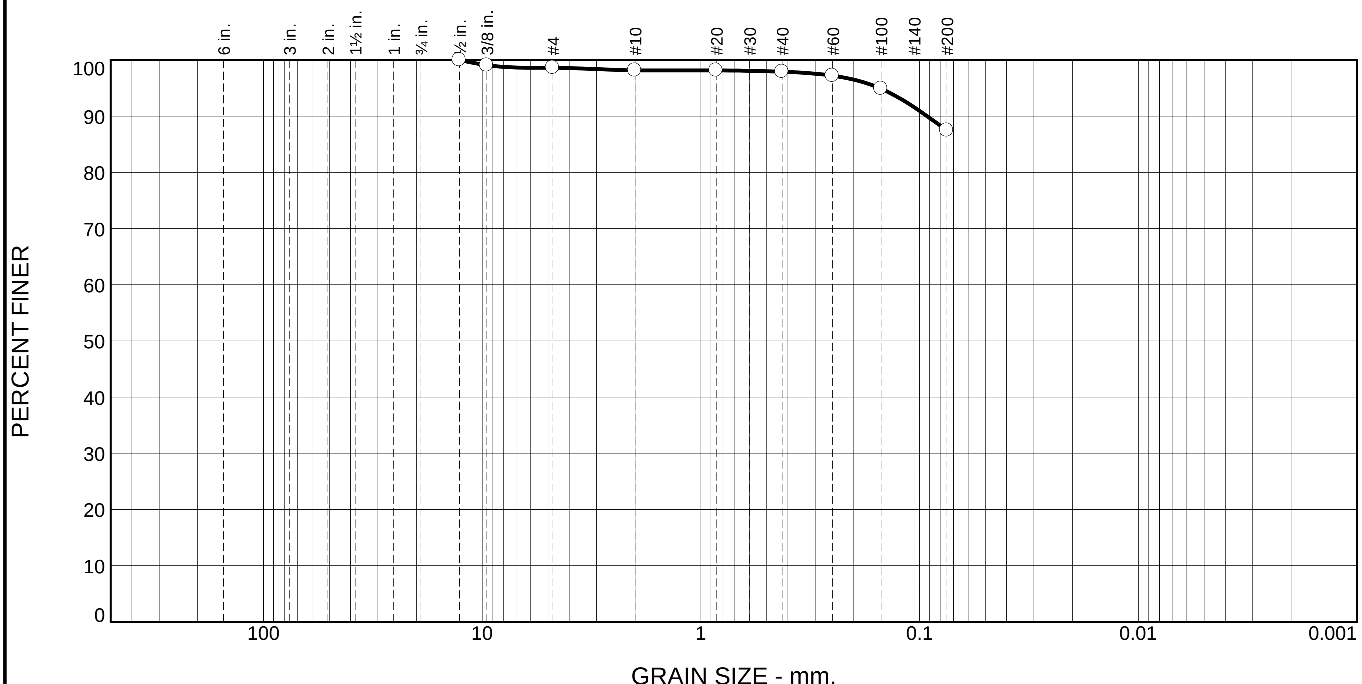
Source of Sample: Boring Data **Depth:** 3.5 feet **Date Sampled:** 03/02/2022
Sample Number: B-1, S-1

ICICLE CREEK ENGINEERS, INC.

Carnation, WA

Client: Samantha Keimig and Jackson Castaneda
Project: Proposed Commercial Building
Pierce County Parcel No. 728500-0112
Project No: 1420-001 **Figure** 6

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.4	0.5	0.2	10.4	87.5	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1/2	100.0		
3/8	99.1		
#4	98.6		
#10	98.1		
#20	98.1		
#40	97.9		
#60	97.2		
#100	94.9		
#200	87.5		

* (no specification provided)

Material Description

Mottled gray and brown SILT with sand (Alluvium)

Atterberg Limits (ASTM D 4318)

PL= **LL=** NV **PI=**

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.0923 D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

MC = 39%

Date Received: 03/21/2022 **Date Tested:** 03/28/2022
Tested By: CEN
Checked By: SJM
Title: Project Engineer/Geologist

Source of Sample: Boring Data **Depth:** 4/5.5 feet **Date Sampled:** 03/02/2022
Sample Number: B-2,S-2/S-3

ICICLE CREEK ENGINEERS, INC.

Carnation, WA

Client: Samantha Keimig and Jackson Castaneda
Project: Proposed Commercial Building
Pierce County Parcel No. 728500-0112
Project No: 1420-001 **Figure** 7