GEO CONSULTANTS NORTHWEST

March 26, 2020

Riverside Homes, LLC
17933 NW Evergreen Place, Ste. 370
Beaverton, OR 97006

Attn: Niki Munson

Subject: Geotechnical Site Evaluation
Cedar Creek Subdivision
GCN Project 1497

This report presents our Geotechnical Site Evaluation for the proposed Cedar Creek Subdivision, a single-family home development in Sherwood, Oregon. The report summarizes the work accomplished and provides our conclusions and recommendations for site development. It has been prepared in accordance with Riverside's Independent Contractor Agreement dated February 10, 2020.

PROJECT INFORMATION

The approximate 10.5-acre property is located at 17433 Brookman Road and is currently developed with a single-family home and several outbuildings. About 60 percent of the property is developable, the southern 40 percent or so is within the 100-year flood plain or flood plain buffer zone. The eastern and southern portions of the site are heavily wooded. All the buildings and most of the trees will be removed when the property is developed.

You provided us with a preliminary grading plan prepared by Pioneer Design Group that shows the general site layout. The proposed development will include a public roadway, underground utilities, and a detention pond. The detention pond will outfall to Cedar Creek.

The proposed homes are expected to be supported on shallow spread foundations with crawl

The site relative to surrounding features is shown in Figure 1.

SCOPE OF WORK

The purpose of our services was to explore the site and provide recommendations for design and construction. The following describes our specific scope of services:

- Coordinate and manage the field investigation, including utility locates, authorization for site access, access preparation, scheduling of contractors and GCN staff.
- Observe excavation of 5 test pits to depths up to 11 feet below the existing ground surface. The test pits were made using a small tracked excavator.
- Maintain a log of soil, rock, and groundwater, as encountered, and obtain soil samples to be classified in the field and returned to our lab for further evaluation and testing. We classify soil in general accordance with the Unified Soil Classification System.
- Determine the moisture content and dry unit weight of selected soil samples in general accordance with ASTM D2216 and D4318, respectively.

- Provide a written Geotechnical Report summarizing our explorations, geotechnical analysis, conclusions, and recommendations that include:
  - A discussion on the geologic conditions and the seismic setting of the site including general geologic features, tectonic faulting in the area, and seismic design criteria in accordance with the Oregon Structural Specialty Code.
  - Recommendations for site preparation, grading and drainage, compaction criteria, and wet-weather earthwork procedures.
  - Recommendations for excavation, utility trenches, backfill materials, and backfill compaction.
  - Recommendations for design and construction of shallow-spread foundations, including allowable design bearing pressures, minimum footing depth and width, lateral resistance to sliding, and estimates of settlement.
  - Geotechnical engineering recommendations for the design and construction of concrete floor slabs, including an anticipated value for subgrade modulus.
  - Recommendations for asphalt pavement including, soil subgrade condition and preparation, asphalt and base rock thickness, asphalt mix design, and construction testing.
  - A discussion of groundwater conditions on the site and recommendations for subsurface drainage of foundations, floor slabs, and pavement.

SITE CONDITIONS

The site is in a relatively flat uplands plateau at the base of Parrot Mountain in Sherwood. The following paragraphs describe the area geology, surface, and subsurface features.

SITE GEOLOGY

The most recent geologic material in the site vicinity Quaternary sediment consisting of is silt and sand placed during episodic, cataclysmic, flooding in the Quaternary age Missoula Floods. The deposits are several hundred feet thick in portions of the Tualatin Basin. Bedrock that underlies the area is basalt of the Columbia River Basalt flows that was deposited 15 to 16 million years ago.[1]

SURFACE CONDITIONS

The project site is located at the foot of Parrot Mountain in an area of large wooded properties. The site is currently improved with a single family home and several small outbuildings. The site access and driveway are paved with gravel. The northwest portion of the site is covered with pasture grass and most of the remaining area is forested with small to large trees. The area immediately around the home is landscaped with lawn and grass and shrubs. There are two vegetable garden areas and a separate graveled driveway area.

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[1] Lina Ma, Ian P. Madin, Serin Duplantis, and Kendra J. Williams, "Lidar-Based Surficial Geologic Map and Database of the Greater Portland Area, Clackamas, Columbia, Marion, Multnomah, Washington, and Yamhill Counties, Oregon, and Clark County,:100,000quadrangle, Washington, Multnomah, Clackamas, and Marion Counties Washington ", 1:63,360,Oregon: State of Oregon Department of Geology and Mineral Industries, Open File Report O-12-02.

Site grades show the site slopes downward to the south from elevation 210 to 178 feet above mean sea level. The site layout is shown in Figure 2.

SUBSURFACE CONDITIONS

We explored subsurface conditions at the site by observing excavation five test pits (TP-1through TP-5) to depths up to 11 feet below the ground surface (bgs) on March 23, 2020. The exploration locations are shown in Figure 2.

Soil samples obtained from the test pits were returned to our laboratory for additional evaluation and testing. Selected samples were used to determine the natural soil moisture content. Descriptions of field and laboratory procedures and the exploration logs are included in Attachment A.

We encountered an approximate one-foot thick zone of soft topsoil at the ground surface in all five of the test pit explorations. The topsoil included a heavily rooted organic zone about 2 inches thick in both pasture and forested areas. The forest areas included dense tree roots that extend to several feet bgs. The dry unit weight of the topsoil obtained from a Shelby tube sample collected in test pit TP-2 varied from 75 to 81 pounds per cubic foot.

The topsoil surficial layer was underlain by stiff to very stiff silt to the depth of our explorations. The moisture content of the silt varied from 28 to 40 percent. The dry unit weight of the silt obtained from a Shelby tube sample collected in test pit TP-2 varied from 86 to 87 pounds per cubic foot.

We encountered slow ground groundwater seepage in test pit TP-2 at 11 feet bgs. The color of soil observed in the test pits indicated that the depth of perched groundwater on the site is at about 10 feet bgs in the driest months of the year and within 2 feet of the ground surface during the wet season.

SEISMIC SETTING

The Portland area is subject to seismic events stemming from three possible sources: the Cascadia Subduction Zone (CSZ), intraslab faults within the Juan de Fuca Plate, and crustal faults

There are three faults within 10 miles of the site: the Beaverton Fault Zone 8.9 miles to the north, the Newberg Fault 6.4 miles to the southeast, and the Canby-Molalla Fault 6 miles to the northwest[2]. The USGS considers the faults to be greater than 150,000 years old and are considered inactive.

The contribution of potential earthquake-induced ground motion from all known sources, including the faults described above, are included in probabilistic ground motion maps developed by the USGS. Based on site explorations and geologic mapping, the site falls into Site Class E for seismic design. Seismic design parameters for the project site are provided in Table 1.

[2]United States Geological Survey, 2019, Quaternary Fault and Fold Database of the United States; USGS Earthquake Hazards Program.

TABLE 1 – SEISMIC DESIGN PARAMETERS

2019 IBC CODE BASED RESPONSE SPECTRUM MCER GROUND MOTION - 5% DAMPING 1% IN 50 YEARS PROBABILITY OF COLLAPSE			
LAT	45.345	LON	-122.856
S_S		0.832g	
S_1		0.395g	
MAPPED MAXIMUM CONSIDERED EARTHQUAKE SPECTRAL RESPONSE ACCELERATION PARAMETER (SITE CLASS E)			
F_A		1.3	
F_V		SEE ASCE 7-16 SECTION 11.4.8*	
S_{MS}		1.082g	
S_{M1}		SEE ASCE 7-16 SECTION 11.4.8*	
DESIGN SPECTRAL RESPONSE ACCELERATION PARAMETER			
S_{DS}		0.721g	
S_{D1}		SEE ASCE 7-16 SECTION 11.4.8*	

* Factors dependent on structural design.

The site is not subject to liquefaction.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of our field explorations and our engineering analysis, it is our opinion that the site can be developed as proposed. On-site soil conditions are favorable for mass grading in dry weather conditions. It can be expected that extra costs will accrue if earthwork is planned for the winter months.

The presence of soft agricultural and forest topsoil on the site is a geotechnical concern. Soft surficial soil that will remain at the base of structures will need to be scarified and compacted to support the intended loads.

Our specific recommendations for site development are provided in the following paragraphs.

CONSTRUCTION CONSIDERATIONS

Fine-grained soils on the site are easily disturbed during the wet season. If not carefully executed, site preparation, utility trench work, and roadway excavation can create extensive soft areas and significant repair costs can result. Earthwork should be planned and executed to minimize subgrade disturbance.

The base rock thickness for project streets, as described below in the section titled "Pavement Recommendations," are intended to support post construction design traffic loads. The base rock thickness determined for post construction traffic will not support construction traffic or pavement construction when the subgrade soils are wet. Accordingly, if construction is planned for periods when the subgrade soils are not dry and firm, then an increased thickness of base rock or other methods to support construction traffic could be required.

If construction occurs during wet conditions, site preparation activities may need to be accomplished using track-mounted equipment, loading removed material into trucks supported on granular haul roads. The use of granular haul roads or staging areas will be necessary for support of construction traffic during wet conditions.

The imported granular material should be placed in one lift over the prepared or undisturbed subgrade and compacted using a smooth drum, non-vibratory roller. We recommend that geotextile be placed as a barrier between the subgrade and imported fill in areas of repeated construction traffic. The geotextile should have a minimum Mullen burst strength of 250 pounds per square inch (psi) for puncture resistance and an apparent opening size between the U.S. Standard No. 70 and No. 100 Sieve to minimize migration of fines into the imported granular material.

We recommend that a minimum of 2-inch thickness of lightly compacted granular material be placed at the base of footing excavations made in wet weather conditions. The granular material reduces water softening of subgrade soils and reduces subgrade disturbance during placement of forms and reinforcement.

TOPSOIL ZONE

Much of the site includes an approximate 12 inch thick tilled zone from agricultural use. The till zone should be scarified to a depth of 12 inches and compacted as structural fill in areas that will be occupied by buildings, roadways, new fill, or other structures. These measures may be omitted where; 1) mass grading will remove the upper 12 inches of soil or ; 2) building footings or other structural elements will penetrate the eventual ground surface to a depth greater than the till zone depth.

The on-site silt can be sensitive to small changes in moisture content and may be difficult to compact during wet weather. Accordingly, scarification and compaction of the subgrade may only be possible during extended dry periods and following moisture conditioning of the soil.

As an alternative, amendment of the tilled zone materials with lime or portland cement is possible. Recommendations for soil amendment are provided in the "Structural Fill" section of this report.

SITE PREPARATION

The existing heavily rooted zone that cover the ground surface should be removed from building and structural areas to the depth of firm compacted fill or native soil. We estimate the stripping depth will generally be 2 to 4 inches. The actual stripping depth should be based on field observations at the time of construction. Stripped material should be transported off site for disposal or used in landscaping areas.

Trees, shrubs, and brush should be removed from all building and paved areas. Root balls should be grubbed out to a depth such that roots greater than ½-inch in diameter are removed. The depth of excavation to remove root balls of trees could exceed 5 feet bgs.

Depending on the methods used, considerable disturbance and loosening of the subgrade could occur during grubbing and stripping. Soil disturbed during these operations should be removed to expose firm undisturbed subgrade. The resulting excavations should be backfilled with structural fill.

The existing building footings, floor slabs, septic tanks and drain fields and other structural elements should be removed from the site. Remaining utilities should be abandoned by removing the conduit and backfilling with granular structural fill. Soil disturbed during building demolition and grubbing operations be removed to expose firm undisturbed subgrade. The resulting excavations should be backfilled with structural fill.

If basements are present, they should be backfilled with granular structural fill after breaking and removing the sidewalls. The basement floors may be left in place but should be broken with an excavator bucket to allow movement of groundwater.

We recommend proof rolling the subgrade with a fully loaded dump truck or similar size, rubber-tire construction equipment after stripping, scarification and required site cutting have been completed. The proof rolling should be observed by a member of our geotechnical staff to identify areas of excessive yielding. Areas of excessive yielding should be excavated and replaced with compacted materials recommended for structural fill. Areas that appear to be too wet and soft to support proof rolling equipment should be prepared in accordance with the recommendations for wet weather construction presented in the following section of this report.

The test pits were backfilled using little compactive effort and soft spots can be expected at these locations. We recommend that these soft soils be removed from the test pits that are located within the proposed building and paved areas to a depth of 3 feet below finished subgrade. The resulting excavation should be brought back to grade with structural fill.

UTILITY TRENCH EXCAVATIONS

Trench construction and maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. Local, state, and federal safety codes should be followed. Temporary excavations should either be shored or sloped in accordance with Safety Standards for Excavation, Oregon Administrative Rules (OARs) 1926.650.

The on-site silt soil, if groundwater or seepage is not present, is classified as soil type A per Appendix A of OAR 1926.650. For planning purposes, this type of soil should be sloped no steeper than 3/4 H:1V of the unshored portion of the trench or excavation. Depending on actual site conditions, flatter slopes may be necessary.

Trench backfill should consist of well-graded granular material with a maximum particle size of ¾-inch and less than 8 percent by weight passing the U.S. Standard No. 200 Sieve. The material should be free of roots, organic matter, and other unsuitable materials.

Trench backfill in the bedding zone and pipe zone should be placed and compacted in maximum lifts of 6 inches. Trench backfill above the pipe zone should be placed and compacted with a minimum of two lifts. A minimum cover of 3 feet over the top of the pipe should be placed before compacting with a hydraulic plate compactor (hoe-pack).

Trench backfill should be compacted to at least 90 percent of the maximum dry density at depths greater than 4 feet below finished grade and to 95 percent of the maximum dry density within 4 feet of finished grade. Compaction is based on ASTM D698/AASHTO T-99, the standard proctor test, or as recommended by the pipe manufacturer.

PERMANENT SLOPES

Permanent cut and fill slopes should not exceed a grade of 2H:1V (Horizontal to Vertical). Slopes that will be maintained by mowing should not be constructed steeper than 3H:1V. Structures and paved surfaces should be located at least 5 feet from the slope face.

The slopes should be planted with vegetation to provide protection against erosion. Surface water runoff should be collected and directed away from slopes steeper than 3H:1V to prevent water from running down the face of the slope.

STRUCTURAL FILL

General: Fill within building, pavement, and sidewalk areas should be placed as compacted structural fill. Structural fill should be compacted to at least 95percent of the maximum dry density as determined by ASTM D 698.

The earthwork contractor's compactive effort should be evaluated based on field observations. Lift thicknesses should be adjusted to meet compaction requirements. The moisture content for compaction should be within 3 percent of optimum.

Brush, roots, construction debris, and other deleterious material should not be placed in the structural fill. Additional information regarding specific types of fill is provided below.

On-Site Silt: The on-site soil is suitable for use as structural fill provided it can be moisture-conditioned, separated from concentrations of organics and other unsuitable material, and compacted to the specified density. The fill should be placed in lifts with a maximum loose thickness of 8 inches.

Imported Granular Material: Imported granular fill material may include sand, gravel, fragmented rock, or recycled crushed concrete with a maximum size of 4 inches and with not more than about 8 percent passing the No. 200 sieve (washed analysis). Material satisfying these requirements can usually be placed during periods of wet weather. The first lift of granular fill placed over a fine-grained subgrade should be about 18 inches thick and subsequent lifts about 12 inches thick when using medium- to heavy-weight vibratory rollers. Granular structural fill should be limited to a maximum size of about 1-½ inches when compacted with hand-operated equipment. Lift thicknesses should be limited to less than 8 inches when using hand-operated vibratory plate compactors.

Free-Draining Fill: Free-draining material should have less than 2 percent passing the No. 200 sieve (washed analysis). Examples of materials that would satisfy this requirement include ¾ to ¼ inch, 1½ to ¾ inch, or 3- to 1-inch crushed rock.

Cement Amended Fill: Portland cement can be used to stabilize and strengthen soils, to stabilize expansive soil, or to permit use of native soils when moisture contents are above optimum. The amount of cement used to amend the soils generally varies with moisture content and clay content. For planning purposes, we expect acceptable soil strength will be obtained using an amendment rate of 5 pounds portland cement placed per square foot of area, tilled to a depth of 12 inches.

The permeability of amended soil is extremely low. Amendment should not be completed in landscape areas or the amended material should be removed from landscape areas prior to planting.

SHALLOW FOUNDATIONS

In our opinion, the proposed structures can be supported on continuous or isolated column footings founded on new structural fill, or on undisturbed native silt.

Continuous wall and spread footings and retaining wall footings should be proportioned for an allowable bearing pressure of 1,500 pounds per square foot (psf). For this allowable bearing pressure, foundations should be at least 14 inches wide. Footing embedment should be as required by the Oregon Structural Specialty Code.

The recommended allowable bearing pressure applies to the total of dead plus long-term live loads. The allowable bearing pressure may be increased by a factor of 1/3 for short-term wind or seismic loads.

Differential and total settlement of footings is anticipated to be less than ½ inch and 1-inch under static conditions, respectively.

SLAB-ON-GRADE FLOORS

Satisfactory subgrade support for lightly loaded building floor slabs can be obtained on the undisturbed native soil or on engineered structural fill. A subgrade modulus of 100 pounds per cubic inch may be used to design floor slabs.

A minimum 4-inch-thick layer of free draining fill should be placed and compacted over the prepared subgrade to assist as a capillary break and blanket drain. The free draining fill layer may be capped with a 1- to 2-inch-thick layer of clean ¾ inch minus crushed rock that contains no more than 5 percent fines.

A vapor retarder manufactured for use beneath floor slabs should be installed above the free draining fill in inhabited spaces and spaces that will receive floor coverings. Careful attention should be made during construction to prevent perforating the retarder and to seal edges and utility penetrations. We recommend following ACI 302.1, Chapter 3 with regard to installing a vapor retarder.

RETAINING WALLS & EMBEDDED BUILDING WALLS

The following recommendations assume that the walls are less than 12 feet in height, backfill extends a distance behind the wall equal to the wall height, and that the backfill is well drained and meets the requirements detailed above for imported granular material. Reevaluation of our recommendations will be required if retaining walls vary from these assumptions.

In general, cantilever retaining walls yield under lateral loads and should be designed with active lateral earth pressures. Restrained walls, such as embedded building walls and vaults should be designed to withstand at-rest lateral earth pressures. We recommend using the lateral earth pressures shown in Table 2. The loads are provided as equivalent fluid density (G). Diagrams showing use of the lateral earth pressures in design calculations are provided in Figure 3.

TABLE 2 – EQUIVALENT FLUID DENSITY (G) ACTING ON RETAINING WALLS

WALL TYPE	BACKFILL CONDITION	BACKFILL COMPONENT (PCF)	SURCHARGE COMPONENT (PSF)	SEISMIC COMPONENT (PCF)
YIELDING WALL	FLAT	30	80	15
	2H:1V	45		28
NON-YIELDING WALL	FLAT	50	120	15
	2H:1V	70		28

Static lateral earth pressures acting on a retaining wall should be increased to account for surcharge loadings resulting from any traffic, construction equipment, material stockpiles, or structures located within a horizontal distance equal to the wall height. We have included lateral earth pressures for surcharge loads up to 250 psf placed as a distributed load within the distance H from the wall face.

Retaining wall drains should consist of a perforated drainpipe embedded in a minimum 1-foot-wide zone of free draining fill that is wrapped 360 degrees around by a geotextile filter that overlaps a minimum of 6 inches. The geotextile filter should be placed between the granular materials and the native soil to prevent movement of fines into the clean granular material. The geotextile filter should be a non-woven fabric with an apparent opening size between the U.S. Standard No. 70 and No. 100 Sieve sizes and a water permittivity of greater than 1.5 sec^{-1}.

Backfill for retaining walls should extend a horizontal distance of H/2 from the back of wall, where H is the embedded height, and compacted as recommended for structural fill, except for backfill placed immediately adjacent to walls. To reduce pressure on walls, backfill located within a horizontal distance of 3 feet from retaining walls should be compacted to approximately 90 percent of the maximum dry density, as determined by ASTM D698, and should be compacted in lifts less than 6 inches thick using hand-operated tamping equipment (such as a jumping jack or vibratory plate compactor).

LATERAL RESISTANCE

Lateral loads of buildings and retaining walls can be resisted by passive earth pressure on the sides of footings or by friction on the base of the footings but not both. We recommend using the equivalent fluid pressures and coefficients of friction provided in Table 3.

TABLE 3 – LATERAL RESISTANCE FACTORS

SOIL TYPE	EQUIVALENT FLUID PRESSURE (Ɣ – PCF)	FRICTION COEFFICIENT (μ)
ON-SITE SILT	300	0.35
IMPORTED CRUSHED ROCK	800	0.45

In order to develop the tabulated capacity for passive resistance using on-site silt, concrete must be placed directly against the walls of the footing excavations. When using the value for imported crushed rock, the rock should extend a minimum horizontal distance equal to half the footing embedment and should be compacted to not less than 95 percent of the dry density as determined by ASTM D698. Adjacent floor slabs, pavements, or the upper 12-inch depth of adjacent, unpaved areas should not be considered when calculating passive resistance.

SITE DRAINAGE

Foundation and crawl space drainage should be sloped to drain to a sump or low point drain outlet. Water should not be allowed to pond within crawl spaces.

Roof drains should be connected to a tightline drainpipe leading to storm drain outlet facilities. Pavement surfaces and open space areas should be sloped such that surface water runoff is collected and routed to suitable discharge points. Ground surfaces adjacent to buildings should be sloped to drain away from the buildings.

ASPHALT PAVEMENT

The pavement subgrade should be prepared in accordance with the previously described recommendations described in the "Construction Considerations", and "Structural Fill" sections of this report.

We recommend using the minimum pavement section specified by the City of Sherwood as shown in Table 4 which includes thicknesses for both wet and dry weather construction.

TABLE 4: ACC PAVEMENT SECTION THICKNESSES

CONSTRUCTION CONDITION	ACC THICKNESS (IN)	AGGREGATE BASE (IN)	COMPACTED SUBGRADE (IN)
DRY WEATHER	4 (2+2)	10 (2 + 8)	12
WET WEATHER	4 (2+2)	13 (2 + 11)	0

The City of Sherwood requires the upper 12-inch thickness of subgrade be improved by compaction to not less than 95 percent of the maximum density as determined by AASHTO T-99. When it is not possible to compact subgrade soil, primarily due to wet weather conditions, the value of subgrade stiffness added by improvement may be substituted with additional crushed rock base. As shown in Table 4, pavement subgrade preparation when the subgrade cannot be improved by compaction will required an additional 3inches of crushed rock base.

The aggregate base should conform to Section 02630 of the Standard Specification for Highway Construction, Oregon Highway Specifications.

Aggregate subbase base should be placed in one lift and compacted to not less than 90 percent of the maximum dry density as determined by AASHTO T-99. Aggregate base should be compacted to not less than 95 percent of the maximum. A separation fabric is required between the silt subgrade and the aggregate subbase. Aggregate base contaminated with soil during construction should be removed and replaced before paving.

The AC pavement should conform to Section 00744 of the specifications. We recommend half inch dense graded Hot Mix Asphalt Concrete for Design Level 2 using Performance Grade Asphalt PG-70-22.

Pavement construction in wet weather conditions may require additional base rock over and above the minimum shown in Table 4.

ADDITIONAL SERVICES

Because the future performance and integrity of the structural elements will depend largely on proper site preparation, drainage, fill placement, and construction procedures, monitoring and testing (geotechnical special inspection) by experienced geotechnical personnel should be considered an integral part of the design and construction process. Consequently, we recommend that GCN be retained to provide the following post-investigation services:

- Review construction plans and specifications to verify that our design criteria presented in this report have been properly integrated into the design.
- Attend a pre-construction conference with the design team and contractor to discuss geotechnical related construction issues.
- Observe site preparation before placement of fill.
- Observe placement and conduct density testing of structural fill.
- Conduct density testing of underground utility backfill.
- Observe proof rolling of pavement and curb line base rock and compaction of asphalt pavement as it is placed.
- Observe footing subgrade before footings are constructed in order to verify the soil conditions.
- Prepare a post-construction letter-of-compliance summarizing our field observations, inspections, and test results.

LIMITATIONS

This report was prepared for the exclusive use of Riverside Homes, LLC and members of the design team for this specific project. It should be made available to prospective contractors for information on the factual data only, and not as a warranty of subsurface conditions, such as those interpreted from the explorations and discussed in this report.

The recommendations contained in this report are preliminary, and are based on information derived through site reconnaissance, subsurface testing, and knowledge of the site area. Variation of conditions within the area and the presence of unsuitable materials are possible and cannot be determined until exposed during construction. Accordingly, GCN's recommendations can be finalized only through GCN's observation of the project's earthwork construction. GCN accepts no responsibility or liability for any party's reliance on GCN's preliminary recommendations.

Unanticipated soil conditions are commonly encountered and cannot fully be determined by exploratory methods. Such unexpected conditions frequently require that additional expenditures be made to attain properly constructed projects. Therefore, a contingency fund is recommended to accommodate the potential for extra costs.

Within the limitations of the scope of work, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this report was prepared. We make no warranty, either express or implied.

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We appreciate the opportunity to be of continued service to you. Please call if you have questions concerning this report or if we can provide additional services.

Sincerely,
GEO Consultants Northwest, Inc.

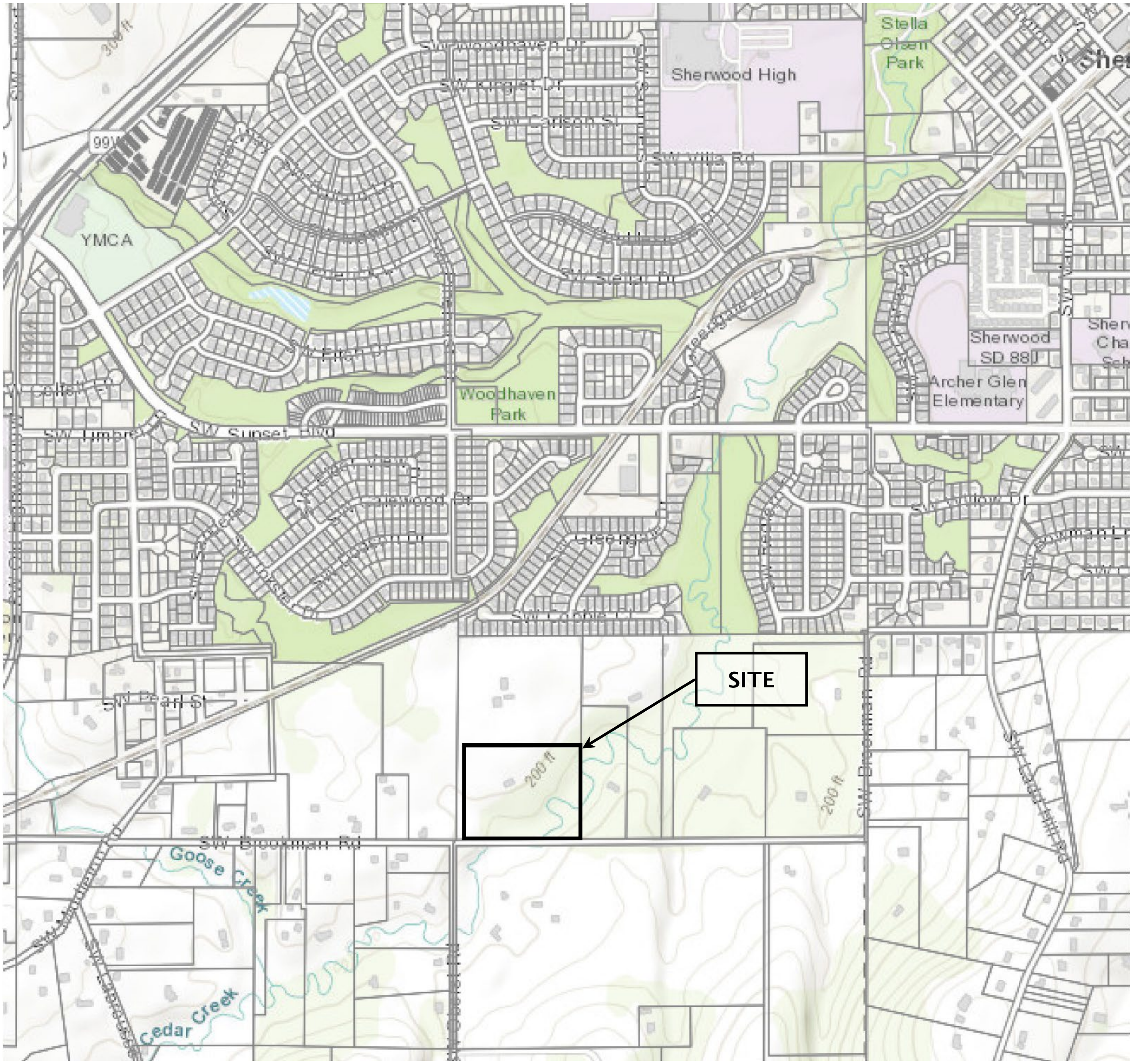
EXPIRES 06/30/2021

Brad L. Hupy
Managing Principal

Randall S. Goode, PE
Geotechnical Engineer

Figures: Figure 1 – Site Vicinity
Figure 2 – Preliminary Site Layout with Explorations
Figure 3 – Retaining Wall Pressures

Attachments: Attachment A – Field Exploration and Laboratory Testing

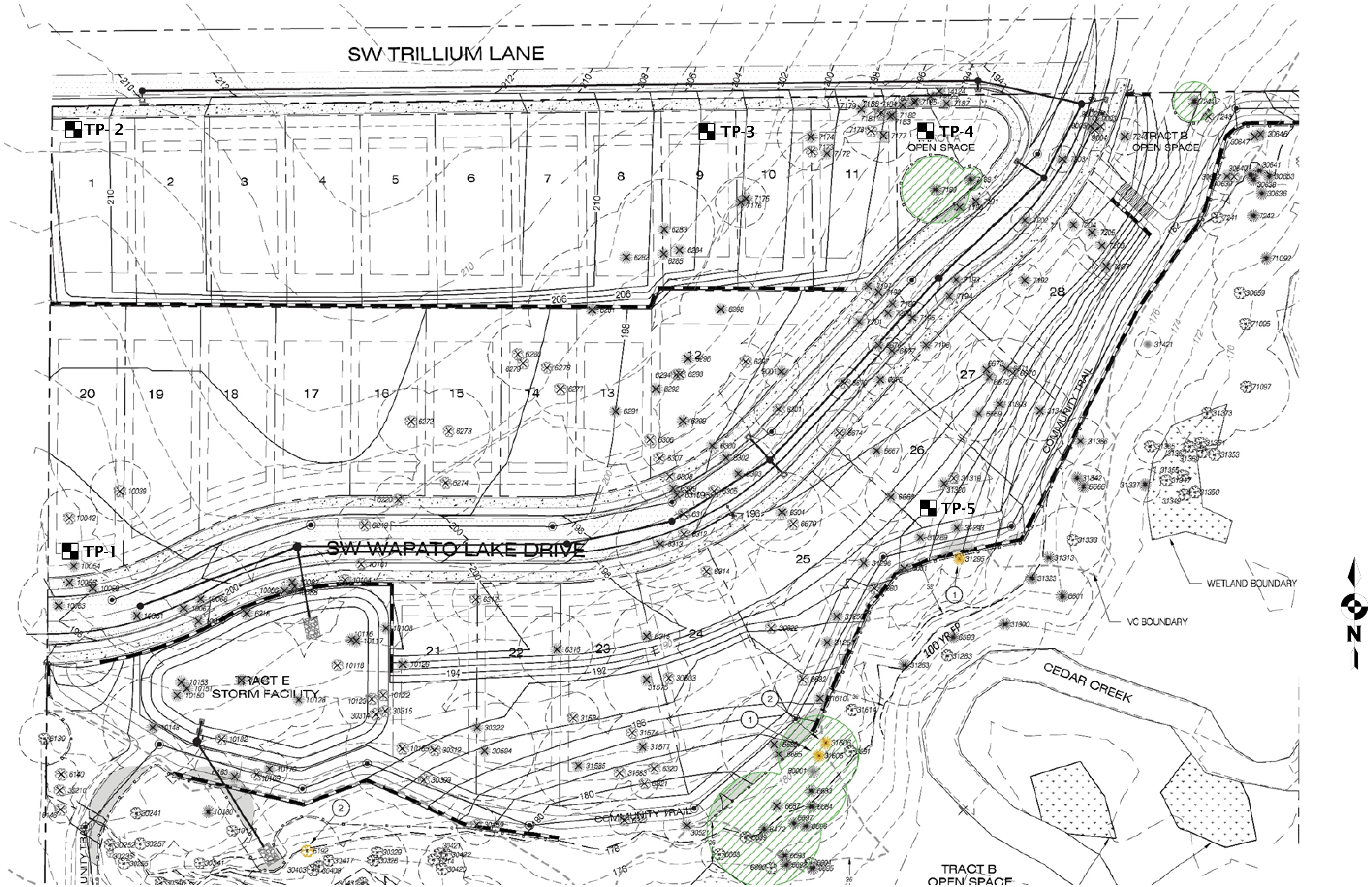


PROVIDED BY OREGONMETRO.GOV

17433 SW BROOKMAN ROAD

LAT 45.345N, LON 122.856 W; TOWNSHIP 3S RANGE 1W SECTION 6

GEO CONSULTANTS NORTHWEST	PROJECT 1497	**RIVERSIDE HOMES CEDAR CREEK SUBDIVISION**
2839 SE Milwaukie Avenue Portland, OR 97202	MAR 2020 Drawn By: blh	**SITE VICINITY** — **FIGURE 1**

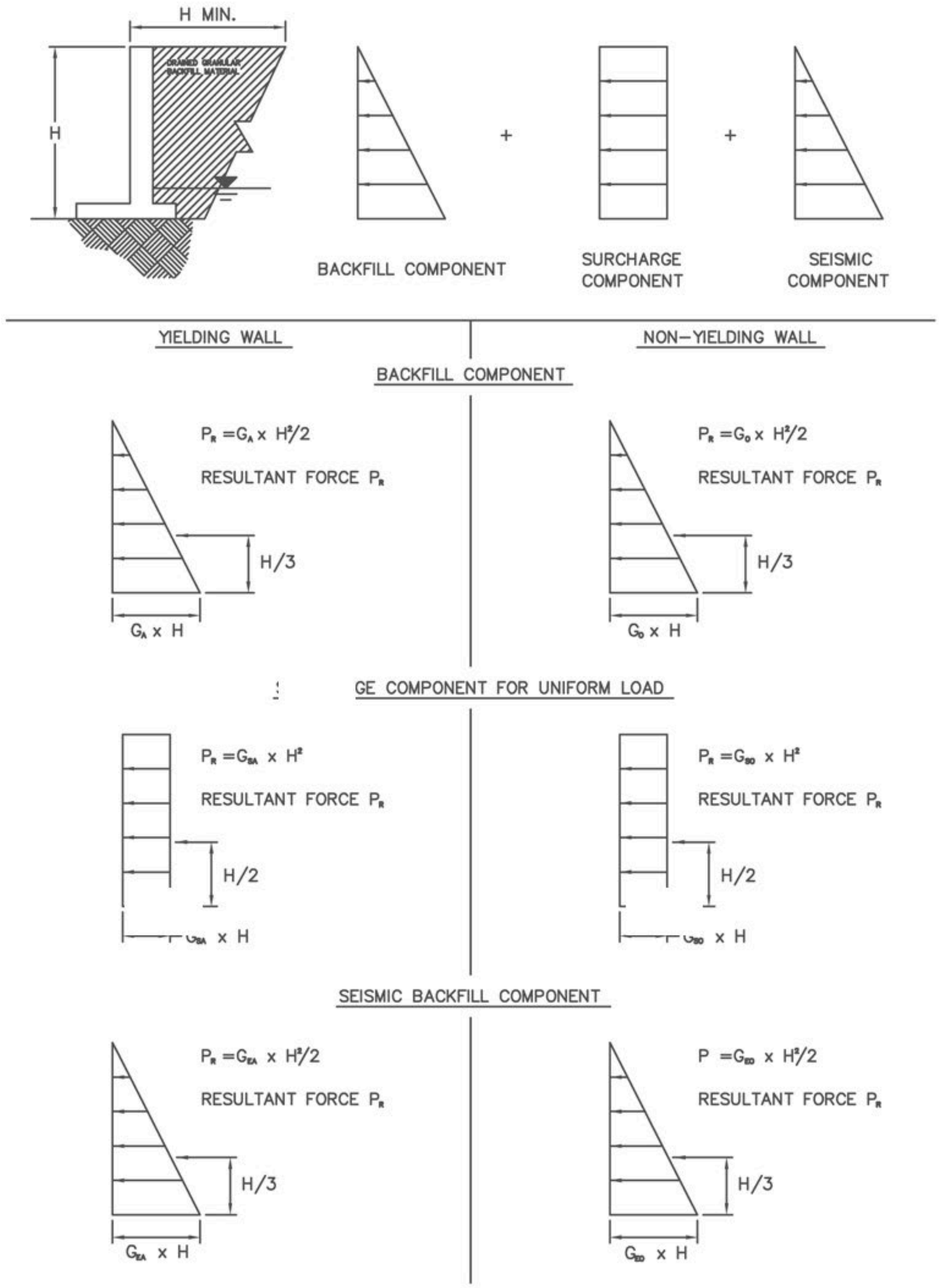


TP-1 ▪ TEST PITS EXCAVATED MARCH 23, 2020 – LOCATIONS APPROXIMATE

BASE DRAWING "PRELIMINARY GRADING AND EROSION CONTROL PLAN"

PREPARED BY PIONEERDESIGN GROUP, DATED DECEMBER 6, 2019

GEO CONSULTANTS NORTHWEST	PROJECT 1497	RIVERSIDE HOMES CEDAR CREEK SUBDIVISION	
2839 SE Milwaukie Avenue Portland, OR 97202	MAR 2020 Drawn By: blh	SITE LAYOUT AND EXPLORATIONS	FIGURE #



NOTE:

1. SEE REPORT TEXT FOR VALUE OF G.

A: ACTIVE O: AT–REST S: SURCHARGE E: EARTHQUAKE

GEO CONSULTANTS NORTHWEST	PROJECT 1497	RIVERSIDE HOMES CEDAR CREEK SUBDIVISION	
2839 SE Milwaukie Avenue Portland, OR 97202	MAR 2020 Drawn By: blh	RETAINING WALL PRESSURES	FIGURE 3

ATTACHMENT A

FIELD EXPLORATION PROCEDURES

LABORATORY TESTING PROCEDURES

KEY TO BORING AND TEST PIT LOGS

TEST PIT LOGS

FIELD EXPLORATION PROCEDURES

GENERAL

Subsurface conditions were explored on March 23, 2020 using shallow test pits with a rubber-tired backhoe owned and operated by Dan Fisher Excavation of Forest Grove, Oregon. A member of GCN's geotechnical staff observed subsurface explorations to record the soil, rock, and groundwater conditions and to obtain soil samples for laboratory testing.

SOIL SAMPLING

Representative grab samples of the soil observed in the explorations were obtained from the test pit walls and/or base using the excavator bucket. Relatively undisturbed soil samples were obtained using a standard Shelby tube in general accordance with guidelines presented in ASTM D 1587, the Standard Practice for Thin-walled Tube Sampling of Soils. Samples obtained in the exploration were sealed in airtight, plastic bags or the Shelby tubes to retain moisture and returned to our laboratory for additional examination and testing. The test pits were loosely backfilled.

FIELD CLASSIFICATION

Soil samples were initially classified visually in the field. Consistency, color, relative moisture, degree of plasticity, peculiar odors, and other distinguishing characteristics of the soil samples were noted. The terminology used is described in the key and glossary that follow.

POCKET PENETROMETER TESTING

The undrained shear strength of fine-grained soil (silt and clay) was estimated with a pocket penetrometer applied to the sidewalls of the test pits. A pocket penetrometer is a hand-held device that indicates undrained compressive strength in tons per square foot. The test method is approximate and applicable only to fine-grained soil.

SUMMARY EXPLORATION LOGS

Results from the test pits are show in the summary exploration logs. The left-hand portion of a log provides our interpretation of the soil encountered, sample depths, and groundwater information. The right-hand, graphic portion of a log shows the results of pocket penetrometer and laboratory testing. Soil descriptions and interfaces between soil types shown in summary logs are interpretive, and actual transitions may be gradual.

LABORATORY TESTING PROCEDURES

Soil samples obtained during field explorations are examined in our laboratory, and representative samples may be selected for further testing. The testing program included visual-manual classification and natural moisture content.

VISUAL-MANUAL CLASSIFICATION

Soil samples are classified in general accordance with guidelines presented in ASTM D2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*. The physical characteristics of the samples are noted, and the field classifications are modified, where necessary, in accordance with ASTM terminology, though certain terminology that incorporates current local engineering practice may be used. The term which best described the major portion of the sample is used to describe the soil type.

NATURAL MOISTURE CONTENT

Natural moisture content is determined in general accordance with guidelines presented in ASTM D2216, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*. The natural moisture content is the ratio, expressed as a percentage, of the weight of water in a given amount of soil to the weight of solid particles.

DRY UNIT WEIGHT (IN-PLACE DRY DENSITY)

Dry unit weight (in-place dry density) testing is performed in general accordance with guidelines presented in ASTM D2937, *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method*. The dry unit weight is defined as the ratio of the dry weight of the soil sample to the volume of that sample. The dry unit weight typically is expressed in pounds per cubic foot.

BORING AND TEST PIT LOGS

DISTINCTION BETWEEN FIELD LOGS AND FINAL LOGS

A field log is prepared for exploration by our field representative. The log contains information concerning soil and groundwater encountered, sampling depths, sampler types used and identification of samples selected for laboratory analysis. The final logs presented in this report represent our interpretation of subsurface conditions based on the contents of the field logs, observations made during explorations, and the results of laboratory testing. Our recommendations are based on the contents of the final logs and the information contained therein, and not on the field logs.

SOIL CLASSIFICATION SYSTEM

Soil samples are classified in the field in general accordance with the United Soil Classification System (USCS) presented in ASTM D2488 "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)." Final logs reflect field soil classifications and laboratory testing results. A summary of the USCS is provided on page 3. Classifications and sampling intervals are shown in the logs.

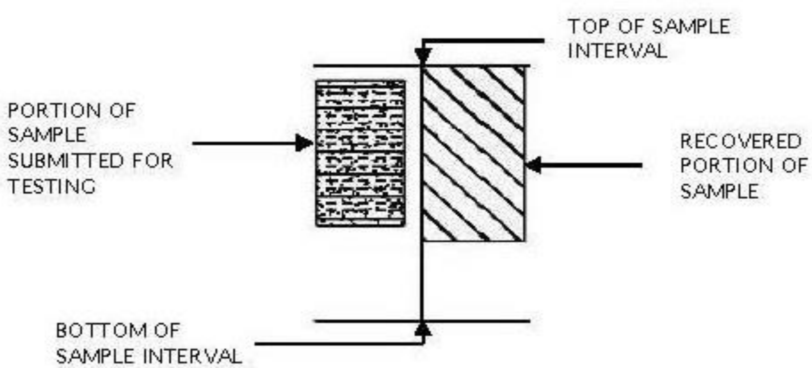
VARIATION OF SOIL BETWEEN EXPLORATIONS

The final logs and related information depict subsurface conditions only at the specific location and on the date(s) indicated. Those using the information contained herein should be aware that soil conditions at other locations or on other dates may differ.

TRANSITION BETWEEN SOIL AND ROCK CLASSIFICATIONS

The lines designating the interface between soil, fill, or rock on the final logs and on the subsurface profiles presented in the report are determined by interpolation and are, therefore, approximate. The transition between the materials may be abrupt or gradual. Only at specific exploration locations should profiles be considered as reasonably accurate and then only to the degree implied by the notes.

BORING LOG SAMPLES



GEO CONSULTANTS NORTHWEST	2019	KEY TO BORING AND TEST PIT LOGS	
2839 SE Milwaukie Avenue Portland, OR 97202	Drawn By: GCN	GENERAL INFORMATION	1/5

EXPLORATION LOG SYMBOLS

- Sample Location with No Sample Recovery
- Sample Location Using Direct Push Sampler (ASTM D 6282)
- Sample Location Using Ring-Lined Barrel Sampler (ASTM D 3550)
- Sample Location Using Split-Barrel Sampler (ASTM D 1586)
- Sample Location Using Thin-Walled Tube Sampler (ASTM D 1587)
- Rock Core Interval
- Grab Sample Location
- Soil Sample Submitted for Chemical Testing
- Soil Sample Submitted for Physical Property Testing
- Water Sample Screened Interval
- Water Sample Submitted for Chemical Testing
- Water Sample Tested in the Field
- Groundwater Level Encountered While Drilling
- Static Groundwater Level
- Perched Groundwater
- Groundwater Level at Time of Sampling

SOIL CHARACTER

Granular Soil		Cohesive Soil		
Density	Standard Penetration Test *	Consistency	Standard Penetration Test*	Unconfined Compressive Strength (tsf)
Very Loose	0 - 4	Very Soft	Less Than 2	Less Than 0.25
Loose	4 - 10	Soft	2 - 4	0.25 - 0.5
Medium Dense	10 - 30	Medium Stiff	4 - 8	0.50 - 1.0
Dense	30 - 50	Stiff	8 - 16	1.0 - 2.0
Very Dense	Greater Than 50	Very Stiff	16 - 32	2.0 - 4.0
Blows Required to Drive a Split-Barrel Sampler 12 inches		Hard	Greater Than 32	Greater Than 4.0

DEFINITIONS AND ABBREVIATIONS

AT	ATTERBERG LIMITS TEST	ND	NON DETECT	PPB	PARTS PER BILLION
BGS	BELOW GROUND SURFACE	NEG	NEGATIVE RESULT	PPM	PARTS PER MILLION
CO	CONSOLIDATION TEST	NS	NO VISIBLE SHEEN	PSF	POUNDS PER SQUARE FOOT
DS	DIRECT SHEAR TEST	OC	ORGANIC CONTENT	RS	SOIL RESISTIVITY TEST
DW	DRY UNIT WEIGHT	P	PUSHED SAMPLE	S4	SUDAN IV SOIL TEST
GS	MECHANICAL GRAIN SIZE TEST	P200	P200 FINES CONTENT TEST	SG	SPECIFIC GRAVITY TEST
HS	HEAVY SHEEN	PCF	POUNDS PER CUBIC FOOT	SPT	STD. PENETRATION TEST
HYD	HYDROMETER TEST	PH	SOIL pH	SS	SLIGHT SHEEN
MC	MOISTURE CONTENT	PID	PHOTOIONIZATION DETECTOR	TO	TOREVANE
MG/KG	MILLIGRAMS PER KILOGRAM	POS	POSITIVE RESULT	TSF	TONS PER SQUARE FOOT
MS	MODERATE SHEEN	PP	POCKET PENETROMETER	UV	ULTRAVIOLET LIGHT TEST

GRAIN SIZE DEFINITIONS			MINOR FRACTIONS IN FINE GRAINED SOIL		GROUNDWATER SEEPAGE	
SAND	FINE	No. 200 to No. 40	No Mention (CLAY, SILT)	< 15 percent	Slow	< 1 gpm
	MEDIUM	No. 40 to No. 10	With Sand, With Gravel	15 to 30 percent	Moderate	1-3 gpm
	COARSE	No. 10 to No. 4	Sandy, Gravelly	30 to 49 percent	Rapid	> 3 gpm
GRAVEL	FINE	No. 4 to 3/4-inch	FIELD MOISTURE OBSERVATION		CAVING	
	COARSE	3/4- to 3-inch	Dry	Absence of moisture, dusty, dry to touch	Minor	
COBBLE		3-inches to 12-inches	Moist	Damp but no visible water.	Moderate	
BOULDER		> 12-inches	Wet	Saturated, below groundwater	Severe	

GEO CONSULTANTS NORTHWEST	2019	KEY TO BORING AND TEST PIT LOGS

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Drawn By: GCN

SYMBOLS AND ABBREVIATIONS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

GEO CONSULTANTS NORTHWEST	2019	KEY TO BORING AND TEST PIT LOGS	
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ROCK CLASSIFICATION GUIDELINES

HARDNESS		DESCRIPTION
Very soft	(RH-0)	For plastic material only
Soft	(RH-1)	Carved or gouged with a knife
Moderate	(RH-2)	Scratched with a knife
Hard	(RH-3)	Difficult to scratch with a knife
Very hard	(RH-4)	Rock scratches metal; rock cannot be scratched with a knife

STRENGTH	DESCRIPTION
Plastic	Easily deformable with finger pressure
Friable	Crumbles by rubbing with fingers
Weak	Crumbles only under light hammer blows
Moderately Strong	Few heavy hammer blows before breaking
Strong	Withstands few heavy hammer blows and yields large fragments
Very Strong	Withstands many heavy hammer blows, yields dust and small fragments

WEATHERING	DESCRIPTION
Severe	Rock decomposed; thorough discoloration; all fractures extensively coated with clay, oxides, or carbonates.
Moderate	Intense localized discoloration of rock; fracture surfaces coated with weathering minerals.
Little	Slight and intermittent discoloration of rock; few stains on fracture surfaces.
Fresh	Rock unaffected by weathering

FRACTURING	FRACTURE SPACING
Crushed	Less than 5/8 inch to contains clay
Highly Fractured	5/8 inch to 2 inches
Closely Fractured	2 inches to 6 inches
Moderately fractured	6 inches to 1 foot
Little Fractured	1 foot to 4 feet
Massive	Greater than 4 feet

JOINT SPACING	DESCRIPTION
Papery	Less than 1/8 inch
Shaley or Platey	1/8 inch to 5/8 inch
Very Close	5/8 inch to 3 inches
Close	3 inches to 2 feet
Blocky	2 to 4 feet
Massive	Greater than 4 feet

GLOSSARY

Alluvial – Made up of or found in the materials that are left by the water of rivers, streams, floods, etc.

Bearing pressure – The total stress transferred from the structure to the foundation, then to the soil below the foundation.

Bulk density (Soil density) – The total mass of water and soil particles contained in a unit volume of soil: lb/ft^3.

Coefficient of active earth pressure – The ratio of the minimum horizontal effective stress of a soil to the vertical effective stress at a single point in a soil mass retained by a retaining wall as the wall moves away from the soil.

Cohesive soil – Clay type soil with angles of internal friction close to zero. Cohesion is the force that holds together molecules or like-particles within a substance.

Colluvium – A loose accumulation of soil and rock fragments deposited through the action of gravity, such as erosion and soil creep.

Differential settlement – The vertical displacement due to settlement of one point in a foundation with respect to another point of the foundation.

Engineered fill – Soil used as fill, such as retaining wall backfill, foundation support, dams, slopes, etc., that are to be placed in accordance with engineered specifications. These specifications may delineate soil grain-size, plasticity, moisture, compaction, angularity, and many other index properties depending on the application.

Excess pore pressure – That increment of pore water pressures greater than hydro-static values, produced by consolidation stresses in compressible materials or by shear strain; excess pore pressure is dissipated during consolidation.

Factor of safety – The ratio of a limiting value of a quantity to the design value of that quantity.

Fines – Material by weight passing the U.S. Standard No. 200 Sieve by washed analysis.

Fluvial – Produced by the action of rivers or streams.

Homogenous soil – A mass of soil where the soil is of one characteristic having the same engineering and index properties.

In situ – Undisturbed, existing field conditions.

Lacustrine – Of a lake, e.g., the depositional environment of a lake.

Liquefaction – The sudden, large decrease of shear strength of cohesionless soil caused by collapse of the soil structure, produced by small shear strains associated with sudden but temporary increase of pore water pressure. Usually a problem in submerged, poorly graded sands within the upper 50 feet of subgrade in earthquake-prone environments.

Maximum dry density – A soil property obtained in the laboratory from a Proctor test. Density of soil at 100% compaction.

Overbank deposit – Sediment that has been deposited on the floodplain of a river or stream by flood waters that have broken through or overtopped the banks.

Permeability – A measure of continuous voids in a soil. The property which allows the flow of water through a soil. See also coefficient of permeability.

Porosity (Pore space) – The ratio of the volume of voids to the total volume: unitless or expressed as a percentage.

Residual soil – Soil that has been formed in place by rock decay.

Shear strength – The maximum shear stress which a soil can sustain under a given set of conditions. For clay, shear strength = cohesion. For sand, shear strength = the product of effective stress and the tangent of the angle of internal friction.

Surcharge – An additional force applied at the exposed upper surface of a restrained soil.

Tuff – An igneous rock (from molten material) that forms from the debris ejected by an explosive volcanic eruption.

Unit weight – The ratio of the total weight of soil to the total volume of a unit of soil: lb/ft^3.

DEPTH (feet bgs)	GRAPHIC LOG	USCS SYMBOL	SOIL DESCRIPTION	SAMPLE	WATER CONTENT (%)	GROUND WATER	FIELD TESTING	TESTING AND LABORATORY DATA
0		ML	Soft, brown SILT with trace fine sand (forest topsoil); moist. (2-inch heavily rooted zone at the ground surface)					
		ML	Stiff, brown SILT with trace fine sand; moist.	1	38		1.5	
			Becomes gray mottled brown at 3 feet.				1.0	
				2	31		1.5	
5								
			Becomes gray at 8 feet.					
10				3	36			
			End at 11 feet in stiff silt.					
			No caving and no groundwater to the depth explored.					
15								
20								

Station:

LOGGED BY: Brad Hupy

Approximate Elevation: 200

Excavator: CASE Backhoe

Excavation Started: 3/23/2020

Excavation Completed: 3/23/2020

1497 Riverside - Cedar Creek

GEO Consultants Northwest
2839 SE Milwaukie Avenue
Portland OR 97202
Tel 503-616-9425
Fax 1-866-293-9037

GEO CONSULTANTS NORTHWEST

LOG OF TEST PIT

TP-1

DEPTH (feet bgs)	GRAPHIC LOG	USCS SYMBOL	SOIL DESCRIPTION	SAMPLE	WATER CONTENT (%)	GROUND WATER	FIELD TESTING	TESTING AND LABORATORY DATA
0		ML	Soft, brown SILT with trace fine sand (forest topsoil); moist. (2-inch heavily rooted zone at the ground surface)	1	35			DW=75pcf
					28			DW=81pcf
		ML	Very stiff, gray motled brown SILT with trace fine sand; moist.		28			DW=87pcf
					26			DW=86pcf
				2	35		2.5	
				3	36		5.0	
							5.0	
5								
10						▼		
			End at 11 1/2 feet in very stiff silt. No caving to the depth explored. Slow groundwater seepage at 11 feet.					
15								
20								

Station:

Approximate Elevation: 209

Excavation Started: 3/23/2020

LOGGED BY: Brad Hupy

Excavator: CASE Backhoe

Excavation Completed: 3/23/2020

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GEO CONSULTANTS NORTHWEST

LOG OF TEST PIT

TP-2

DEPTH (feet bgs)	GRAPHIC LOG	USCS SYMBOL	SOIL DESCRIPTION	SAMPLE	WATER CONTENT (%)	GROUND WATER	FIELD TESTING	TESTING AND LABORATORY DATA
0			Soft, brown SILT (forest topsoil); moist. (2-inch heavily rooted zone at the ground surface)					
			Stiff, brown SILT with trace fine sand; moist.	1	28			
							1.5	
							2.0	
				2	37		2.5	
5							3.0	
		ML						
		ML						
10			Becomes gray at 10 feet.					
				3	34			
			End at 11 1/2 feet in stiff silt. No caving and no groundwater to the depth explored.					
15								
20								

Station:

LOGGED BY: Brad Hupy

Approximate Elevation: 204

Excavator: CASE Backhoe

Excavation Started: 3/23/2020

Excavation Completed: 3/23/2020

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LOG OF TEST PIT

TP-3

DEPTH (feet bgs)	GRAPHIC LOG	USCS SYMBOL	SOIL DESCRIPTION	SAMPLE	WATER CONTENT (%)	GROUND WATER	FIELD TESTING	TESTING AND LABORATORY DATA
0		ML	Medium stiff, brown SILT with trace fine sand (forest topsoil); moist. (2-inch heavily rooted zone at the ground surface)				1.0	
		ML	Very stiff, brown SILT with trace fine sand; moist.	2	25		2.5	
							4.0	
5				3	30		4.0	
10			Becomes gray at 10 feet.	1	34			
			End at 11 feet in very stiff silt. No caving and no groundwater to the depth explored.					
15								
20								

Station:

LOGGED BY: Brad Hupy

Approximate Elevation: 194

Excavator: CASE Backhoe

Excavation Started: 3/23/2020

Excavation Completed: 3/23/2020

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GEO CONSULTANTS NORTHWEST

LOG OF TEST PIT

TP-4

DEPTH (feet bgs)	GRAPHIC LOG	USCS SYMBOL	SOIL DESCRIPTION	SAMPLE	WATER CONTENT (%)	GROUND WATER	FIELD TESTING	TESTING AND LABORATORY DATA
0		ML	Soft, brown SILT with trace fine sand (forest topsoil); moist. (2-inch heavily rooted zone at the ground surface)					
		ML	Very stiff, brown SILT with trace fine sand; moist.				2.5	
				1	26		3.0	
							3.5	
				2	35		4.0	
5								
				3	40			
10			End at 9 feet in very stiff silt. No caving and no groundwater to the depth explored.					
15								
20								

Station:

LOGGED BY: Brad Hupy

Approximate Elevation: 188

Excavator: CASE Backhoe

Excavation Started: 3/23/2020

Excavation Completed: 3/23/2020

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LOG OF TEST PIT

TP-5