Camas Water System Well 13 PFAS Treatment Design

Geotechnical Engineering Report

March 2025

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Table of Contents

List of Tables

List of Figures

Appendices

Distribution

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1.0 Introduction

1.1 Background

The City of Camas (City) is developing a strategy to address the public health concerns associated with per- and polyfluoroakyl substances (PFAS) in its drinking water. PFAS has been detected in groundwater at the City's Lower Washougal Wellfield (LWWF) and impacts the quality and quantity of its primary supply source. PFAS levels from LWWF Well 13 exceeds Washington State Action Levels (SAL), and other LWWF wells have yielded results that exceed the United States Environmental Protection Agency's (USEPA) proposed maximum contaminant levels (MCL).

The City developed a Water System Plan Addendum to advance the PFAS mitigation strategy. With this project, the City intends to 'fast track' the planning and implementation of wellfield development, treatment, funding, and an outreach approach that addresses the near-term water quality and quantity needs while establishing a sustainable and equitable approach for long-term PFAS mitigation.

1.2 Project Description

Carollo Engineers, Inc. (Carollo) has been contracted by the City for the Design, Planning, and Bidding efforts of the Project. Based on our communications with the City and Carollo, preliminary plans for the PFAS mitigation will include construction of a new facility that will include treatment for PFAS at the existing Well 13 site located at 1250 East 1st Avenue, Camas, Washington. Figures 1 and 2 show the general site location.

The new treatment facility and associated improvements at the site are expected to include new tanks, piping, increased supply capacities, and electrical upgrades at the site. A specific layout of the site improvements, including volume capacities, tank dimensions and elevations, and a hydraulic profile have not been developed during this preliminary design phase. As the project design phases continue, we should be provided an opportunity to review and possibly revise recommendations included in this report.

1.3 Purpose and Scope of Work

Carollo retained Delve Underground to evaluate the subsurface conditions and to provide preliminary geotechnical engineering design and construction recommendations for subsequent use by the design team in support of the Project. Specifically, our scope of work includes the following:

- *Geotechnical Visual Reconnaissance and Background Information Review*: Visit the site to evaluate existing and surrounding conditions and identify geologic hazards, if present.

Review available geologic publications to assess the subsurface conditions and potential geologic hazards.

- *Geotechnical Investigation*: Complete a geotechnical investigation at the Well 13 site consisting of one soil boring extending to a depth of 50 feet below ground surface. Our investigation included laboratory testing for the purpose of further defining the subsurface soils and for use in our geotechnical analyses. Infiltration testing was also performed at the site.
- *Geotechnical Analyses*:
  - Evaluate the Well 13 site for liquefaction potential, and liquefaction-induced effects such as seismic-induced settlements, lateral spreading, and potential reduction in bearing capacities.
  - Assess soil seismic profile (site classification) and site response parameters in accordance with the 2021 Washington State Building Code and the 2021 International Building Code. If the site is potentially liquefiable, the seismic profile will include those facilities with seismic periods less than 0.5 seconds.
  - Evaluate and provide recommendations for static and seismic soil bearing capacity, subgrade modulus, and total and differential settlement for potential foundations.
  - Recommendations and preliminary design criteria for the preferred foundation type, or preliminary ground improvement recommendations to mitigate potential site hazards or conditions.
  - Recommendations for shoring and dewatering of excavations.
  - Recommendations for site preparation, grading, drainage, and wet weather earthwork procedures.
  - Recommendations for engineered fill and compaction criteria for foundations, or ground improvement if deemed necessary.
- *Summarize the Above in this Geotechnical Engineering Report.*

2.0 Geotechnical Investigation

2.1 Exploratory Boring

The subsurface exploration was completed in the presence of a Delve Staff Engineer who directed the drilling operations, collected samples, and provided continuous observation and logging of the explorations. Soil materials were classified in the field in accordance with ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedures). Sample depths, stratigraphy, groundwater occurrence, and soil characteristics were also recorded. The stratigraphic contacts indicated in the boring logs represent the approximate boundaries between soil types; actual transitions between soil units may be more gradual than shown. A log of the exploration is included in Appendix A.

To evaluate the subsurface conditions at the site, we completed one exploratory boring, B-1, advanced by Western States Soil Conservation (WSSC) of Hubbard, Oregon using a truck mounted CME 75 drill rig. The boring was advanced to a depth of 50 feet below ground surface (bgs) using mud rotary techniques. The approximate location of B-1 is shown in Figure 3.

Disturbed soil samples were obtained in our investigation. Split spoon samples were obtained in general accordance with ASTM D1586, "Standard Test Method for Standard Penetration Test (SPT) and Split Barrel Sampling of Soils." This procedure uses a 140-lb hammer dropped from a height of 30 inches to advance a 2-inch diameter split barrel sampler 18 inches. The number of hammer-blows for each 6 inches of penetration was recorded. The standard penetration resistance (designated as the "N-value") of the soil is the sum of the number of blows required for the final 12 inches of sampler penetration. The N-value is an indication of the relative density of granular soils and the relative consistency of cohesive soils. SPT N-values of 50 or more blows per 6 inches or less of penetration is defined as "refusal." Uncorrected, field-recorded N-values are presented in the boring log in Appendix A. An automatic hammer was used in our exploration. WSSC provided a Report of SPT hammer efficiencies (Shannon and Wilson 2023) which cite an energy transfer ratio (efficiency) of 90.6 and a Correction Factor of 1.51 for the automatic hammer used in our investigation.

Disturbed samples were also obtained using a 3-inch diameter, "Modified California" sampler. Blow counts to drive the sampler with the 140-lb hammer three 6-inch increments were recorded. The total number blows to drive the 3-inch sampler the final 12 inches were correlated to an N-value that would be obtained from the SPT method previously described using the Caltrans Geotechnical Manual Soil Correlations section (March 2021).

2.2 Laboratory Testing

Soil samples obtained from the exploration borings were re-examined and classified independently of field boring log descriptions to provide a quality control check of the field classifications. Representative soil samples were selected for laboratory testing. The laboratory testing program included the following tests:

- Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216);
- Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing Amount of Material Finer than U.S. No. 200 Sieve (ASTM D1140);
- Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318);

- Standard Test Method for Particle-Size Analysis of Soils (ASTM D422, Mechanical Analysis Only).

Laboratory testing was performed by Breccia Geotechnical of Tigard, Oregon. Laboratory test results were used to characterize soil properties and refine soil classifications. The boring log in Appendix A includes the results for the laboratory index tests. The report provided by the testing laboratory is included in Appendix B.

2.3 Infiltration Testing

We performed infiltration testing at the Well 13 site. The testing was performed by a Delve Underground Staff Engineer in accordance with Section 6.6 of the Clark County Stormwater Manual (November 2009). The testing was done inside a 4.5-inch inside diameter (ID) hollow stem auger at an approximate depth of 6.25 feet bgs. The soil surface in contact with the hollow stem auger at the test depth were fine grained Missoula Flood Deposits.

Prior to testing, the soil was soaked for a four-hour period. Water levels inside the auger were observed in 15 and 30-minute intervals following the presoaking period. These observations continued over a period of 2 hours when consistent rates were observed. Our infiltration testing results are reported in Section 3.5.

After testing was complete, the auger was removed using the drill rig and the bored hole was backfilled with bentonite chips and the previously excavated soils.

3.0 Site Conditions

3.1 Surface Conditions

The address for the Well 13 property is 1250 East 1st Avenue in Camas, Washington. The property is rectangular, about 0.4 acres and located southwest of the intersection of East 1st Avenue and East Cramer Lane. The property is amongst a mostly residential community with a one-story single-family home located at the west and a two-story apartment building located at the east.

The property includes two existing structures, each is an above ground, one-story building constructed using Cement Masonry Units (CMUs). The structures were built in 1965 and 2007 and roughly have footprints of 400 and 1730 square feet, respectively, according to Clark County Property Maps (Clark County 2024).

The Well 13 property is mostly level and includes an asphalt paved driveway accessing the larger structure from East Cramer Lane. The asphalt paved East Cramer Lane transitions to a gravel surface lane which crosses the adjacent property at the south. Otherwise, the ground surface surrounding each of the Well 13 facilities is grass-surfaced. The property is landscaped with shrubs and bushes adjacent to East 1st Avenue.

The southern extent of Lacamas Creek and its confluence with the Washougal River is about 100 feet south of the Well 13 site. Although not located on the subject property, there are steep banks trending down to Lacamas Creek on the order of 1 Horizontal : 1 Vertical (H:V). This ground slope is currently wooded with young and mature trees and thick underbrush. The ground surface elevation at the property is about 60 feet and slopes down to about 14 feet, the approximate water surface of Lacamas Creek.

3.2 Local Geology

The Well 13 site is located within the Portland Basin at the mouth of the Columbia River Gorge. A recently published geologic map of the Camas Quadrangle at a scale of 1:24,000 shows the Well 13 site is underlain by the gravel facies of cataclysmic floods referred to as the Missoula floods (Evarts and O'Connor, 2008). During the glacial periods of the late Pleistocene, several lakes developed behind ice dams at the margins of the continental glaciers in northeastern Washington, Idaho, and western Montana—the largest of which was Glacial Lake Missoula. Periodic failure of these ice dams caused a series of flood episodes on the Columbia River system. These massive floods scoured the Columbia River Gorge before spreading into the Portland Basin and through to the Willamette Valley. As the flood waters repeatedly entered the basin they cut flood channels, scoured the bedrock in areas, such as nearby Lacamas Lake, and left behind massive sediment deposits such as the gravel deposit near the mouth of the Washougal River in Camas (Burns and Coe, 2012). When the flood waters stopped, the water would flow from the Willamette Valley and other tributary valleys back into the Portland Basin leaving temporary lakes, where fine-grained sediments would settle, and the water would eventually drain to the ocean. The Missoula floods are believed to have occurred during a 2,000 to 3,000-year period between approximately 15,500 and 13,000 years before present (Waitt, et al., 2009; Allen, et al., 2009).

The Missoula-flood deposits-gravel facies (Qfg) are described by Evarts and O'Conner (2008) as "unconsolidated, gray, stratified, bouldery to cobbly gravel and sand." The gravel is texturally and compositionally variable. The unit includes local sand deposits that were likely deposited by smaller late-episode floods. The thickness of the unit at the Well 13 site is not known but a similar deposit to the west of the Camas Slough is estimated on the map cross-section to be around 100 feet thick. The bedrock adjacent to the site is mapped as Basaltic Andesite of Elkhorn Mountain.

Recent fine-grained alluvium derived from the Washougal River overbank deposits mantles the site.

3.3 Subsurface Conditions

The subsurface conditions at the Project site were explored with one geotechnical boring to 51.5 feet (B-1) in depth and one shallow boring to 6.5 feet (I-1) in depth for use with infiltration testing. We grouped the subsurface materials encountered into three based on their engineering properties, geologic origins, and their distribution in the subsurface: Fill, Recent Alluvium, and Coarse-Grained Catastrophic Flood Deposits. Variations in subsurface conditions may exist across the footprint of the Project. Contacts between the geotechnical units are approximate and may be more gradational than shown on the exploration log in Appendix A.

The following sections provide a discussion of soil unit characteristics, including a summary of soil index testing results and soil density/consistency for each unit based on data from the recent geotechnical exploration.

3.3.1 Fill

Fill was encountered from the surface in B-1 and I-1. At the surface, the soils were a clayey silt with fine to coarse sand, fine to coarse gravel, and rootlets from the surficial grasses, and was approximately 2 inches thick. Low plasticity silt (ML) with trace fine to coarse sand was present beneath this surficial layer. Although no particular manmade materials were observed in the auger cuttings (IT-1) or SPT samples (B-1), based on the general level site topography and inconsistent texture of the material, it is very likely that the fill soils at the site extend to about 18 inches below ground surface.

3.3.2 Recent Alluvium

Beneath the fill at about 18 inches bgs, we encountered similar fine-grained alluvial deposits comprised of silt (ML) with varying amounts of sand. The fine-grained alluvial deposits extended to about 5 feet bgs in B-1 and 6.5 feet bgs in I-1. Three SPT samples were obtained within this unit resulted in N-values of 1, 2, and 6 blows per foot, indicating very soft to medium stiff consistency.

Laboratory moisture content tests completed on the two samples within this unit resulted in 23 and 30 and 51 percent moisture. One fines content (ASTM D1140) was completed and resulted in 67% passing the No. 200 sieve, indicating a sandy silt (ML) soil classification per the Unified Soil Classification System (USCS, ASTM D2487).

3.3.3 Coarse Grained Catastrophic Flood Deposits

Gravel was encountered beneath the native fine-grained unit at a depth of approximately 5 feet bgs and extended to a depth of 50 feet bgs. The unit generally consisted of clayey gravel (GC), well graded gravel (GW), and poorly graded gravel (GP), each with varying amounts of sand. At the terminal depth of Boring B-1, 50 feet bgs, we encountered very dense, micaceous poorly graded sand (SP).

This consistency of this unit ranged from medium dense to very dense conditions and primarily gray to gray-brown in color.

A composite of the samples in boring B-1 at 10 and 12.5 feet bgs was tested for particle size analysis. A plot of the testing results is included in Appendix B. The results of this testing are summarized below:

- Coarse Gravel – 5 percent
- Fine Grave – 40 percent
- Coarse Sand – 26 percent
- Medium Sand – 13 percent
- Fine Sand – 5 percent
- Fines – 11 percent

3.4 Groundwater

Mud rotary drilling was used to drill soil boring B-1 for this project. The mud rotary method involves the circulation of drilling fluids; therefore, the presence or absence of groundwater could not be confidently determined. Groundwater was not encountered while advancing the infiltration test boring I-1 to about 6.5 feet bgs using hollow stem auger methods.

Water Well Reports maintained by the Washington State Department of Ecology cite a groundwater surface located 67.6 feet bgs at Louis Block Park in February 2006. Louis Block Park is located about 650 feet west of the Well 13 property and has a ground surface elevation approximately 10 feet higher than the subject property.

Several Resource Protection Well Reports at a site located at NE 3rd Avenue and NE 3rd Place, about 500 feet northwest of the Well 13 property, did not indicate groundwater was encountered during hollow stem auger soil borings drilled between 15 and 20 feet below the ground surface in December 2013.

The Water Well Reports referenced in this report section are provided in Appendix C.

Groundwater levels vary with precipitation, the time of year, and other factors. Generally, groundwater highs occur near the end of the wet season in late spring or early summer and groundwater lows occur near the end of the dry season in the early fall.

3.5 Infiltration Testing Results

We completed infiltration testing at one location at the site, shown as I-1 in Figure 2. The testing was performed inside a 4.25-inch (inside) diameter hollow stem auger at a depth of approximately 6.25 feet bgs. After presoaking for 4 hours, the testing was performed for a 2-hour period when consistent results were observed. The infiltration rate was 1.0 inch per hour. Per the Clark County Stormwater Manual (2006), the coefficient of permeability, k, was 0.0162 inches per hour for the auger borehole method.

4.0 Seismic and Geologic Hazards Evaluation

We performed a seismic hazards evaluation in general accordance with the 2021 Washington State Building Code (WSBC) which references the 2021 International Building Code (IBC) and ASCE's Minimum Design Loads and Associated Criteria for Buildings and Other Structures, 2017 Edition (ASCE/SEI 7-16). We evaluated the seismic hazards for the Maximum Considered Earthquake (MCE) having a 2 percent probability of exceedance in a 50-year period (2,475 year return period).

4.1 Seismic Setting

4.1.1 Regional Seismicity

The Pacific Northwest is a seismically active region. Earthquakes in the Pacific Northwest occur in response to active convergence of the Juan de Fuca oceanic plate and the North America continental plate. Stress builds within the colliding plates, resisted by friction at the contact between the plates. Periodically, the stress exceeds the friction and fault rupture occurs. Faulting can occur both between the plates (interplate) and within the plates (intraplate). In northwest Oregon, earthquakes can be generated from three primary sources:

- The Cascadia Subduction Zone (CSZ), which represents the interface between the subducting Juan de Fuca Plate and the overriding North American Plate;
- The CSZ intraslab within the deep subducted portion of the Juan de Fuca Plate; and
- Shallow intraplate crustal faults that form in the continental crust and accretionary wedge of sediments that accumulate along continental shelf and slope.

Background earthquakes not associated with known geologic structures, or on faults that do not exhibit surface expression or are not identified, are accounted for as grid sources in the seismic hazard analysis. Grid sources are used to account for seismic activity occurring in uncharacterized and unrecognized faults or seismic structures, and to include the effect of what has been described as a "floating earthquake."

The three primary sources above and the grid sources are included in the development of design ground motion parameters discussed in Section 4.3.

4.1.2 Cascadia Subduction Zone Seismic Sources

The CSZ extends from Vancouver Island to Northern California (about 754 km [469 mi]) and forms the boundary between the overriding North American plate and the subducting Juan de Fuca Plate. The interface and slab sources are associated with the CSZ and are described below:

- *Subduction Zone Megathrust Interface Source*: Large subduction zone (megathrust) earthquakes occur within the upper approximately 30 kilometers (18.6 mi) of the contact between the two plates (Pacific Northwest Seismic Network [PNSN], 2020). As the Juan de Fuca Plate subducts beneath the North American Plate through this zone, the plates are locked together by friction (PNSN, 2020). Stress slowly builds as the plates converge until the frictional resistance is exceeded and the plates rapidly slip past each other, resulting in a megathrust earthquake. The subduction zone dips between 9 and 11 degrees eastward and has a slip rate of less than 5 mm/year (Personius and Nelson, 2006). Geologic evidence indicates a recurrence interval for major subduction zone earthquakes of 250 to 650 years, with the last major event occurring in 1700 (Atwater et. al., 1995). The interface source generates earthquakes that range from 8 to 9.3 M on the interface between the Juan de Fuca and North American Plates. The 2021 WSBC

- *Subduction Zone Intraplate Source*: Below depths of approximately 30 kilometers, the plate interface does not appear to be locked by friction and the plates slowly slide past each other. The curvature of the subducted plate increases as the advancing edge moves east, creating extensional forces within the plate. Normal faulting occurs in response to these extensional forces. This region of maximum curvature and faulting of the subducting plate is where large intraplate (intraslab) earthquakes are expected and is located at approximate depths ranging from 30 to 60 kilometers (18.6–37.3 mi) (Geomatrix Consultants 1993, 1995; and Kirby et al., 2002). Intraplate earthquakes generally originate below depths of 30 kilometers and are typically less than M7.5 (Cascadia Region Earthquake Workshop, 2008).

4.1.3 Shallow Crustal Source

Crustal sources typically occur at depths ranging from approximately 14 to 40 kilometers (8.7–24.9 mi) below ground surface (Geomatrix Consultants, 1995). The US Geologic Survey (USGS) uses four class definitions to classify Quaternary-age faults (e.g., faults that have generated tectonic movement within the past 2.6 million years). These classes are defined as follows (Crone and Wheeler 2000):

- *Class A* – Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction or other deformational features.
- *Class B* – Geologic evidence demonstrates existence of a fault or suggests Quaternary deformation, but the fault may not extend deep enough to be a potential source of significant earthquakes, or the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
- *Class C* – Geologic evidence is insufficient to demonstrate (1) the existence of a tectonic fault or (2) a Quaternary slip or deformation associated with the feature.
- *Class D* – Geologic evidence demonstrates that the feature is not a tectonic fault or feature; this category includes features such as demonstrated joints or joint zones, landslides, erosional or fluvial scarps, or landforms resembling fault scarps, but of demonstrable non-tectonic origin.

The USGS online Interactive Quaternary Faults database (USGS, 2024) catalogs known, Class A crustal seismic sources. The Class A faults within 20 km of the site are presented in Table 4-1.

Table 4-1. USGS Class A Faults Within 20 km (12.5 miles) of the Project Site

USGS Fault ID.	Fault Name	Type of Fault	Slip Rate (mm/year)	Distance & Direction from Site
878	Grant Butte Fault	Normal	>0.2	11.0 km Southwest
879	Damascus-Tickle Creek Fault Zone	Right Lateral, Left Lateral, Reverse	>0.2	10.4 km South
880	Lacamas Lake Fault	Right Lateral, Normal	>0.2	0.6 km Northeast

Although not included in the USGS Fault and Fold Database, the northeast trending Prune Hill Fault and the northwest trending Blue Lake Fault about 4 km northwest and 4 km southwest of the site, respectively according to Evarts and O'Connor (2008).

The Washington State Department of Natural Resources (WSDNR) Division of Geology and Earth Resources (2024) identifies frequent seismic activity within the Saint Helens Fault Zone which southern extent is about 54 miles north of the site. The WSDNR Division of Geology and Earth Resources (2024) also archives historic seismic activity southwest of the Lacamas Lake Fault, about 0.5 km west of the Project site, with 6 noted events with Magnitude (M) 2.0 to 3.0 and two events between M 3.0 and 6.8.

The Pacific Northwest Seismic Network (PNSN) catalogs historic seismic events throughout the northwest. Within 5 km of the Project site the PNSN identifies more than 90 events between May 1988 and August 2022, with most occurring northwest of the site. The strongest event, M 2.8, occurred on September 7, 1996. These mapped locations of the events are bound by the Prune Hill Fault, Lacamas Lake Fault, and Blue Lake Fault previously described.

4.2 Site Classification

We assigned a seismic site class for the Project site following code-based procedures in Section 1613.2.2 of the Internation Building Code, which references the ASCE/SEI 7-16, Chapter 20 (2017). Site class is used to categorize common subsurface conditions into broad classes to which ground motion attenuation and amplification effects are assigned. Site classification is based on the weighted average of the shear wave velocity or Standard Penetration Test (SPT) blow counts (N-value) in the upper 100 feet of subsurface profile. Based on the SPT N-values in boring B-1, a Site Class D is appropriate for design purposes.

4.3 Seismic Design Parameters

The 2021 WSBC with its two amendments (WSBC 2023 and WSBC 2024) requires that spectral response accelerations be developed based on the ASCE 7-16 procedures. To develop spectral response accelerations, we used the online ASCE 7 Hazard Tool, which follows ASCE 7-16 and is based on the USGS 2014 National Seismic Hazard Mapping Project (NSHMP) developed for the Maximum Considered Earthquake (MCE) (Peterson et. al., 2014). The MCE consists of ground motions (accelerations) with a 2-percent probability of exceedance in 50 years (return period of 2,475 years). The mean earthquake magnitude and the mean site-to-source distance for the zero-second period of vibration (e.g., PGA) are 7.39 and 60.89 km, respectively, for the MCE. The recommended spectral acceleration parameters for use in structural design are provided in Table 4-2.

Table 4-2. MCE Spectral Acceleration Parameters for Site Class D

Parameter	0.2-Second Period	1-Second Period
Mapped MCE_R (Rock site)	S_S = 0.807g	S_1 = 0.350g
Site Coefficients	F_a = 1.177	F_v = 1.95
Site-Adjusted MCE_R	S_{MS} = 0.950g	S_{M1} = 0.682
Design MCE_R	S_{DS} = 0.633g	S_{D1} = 0.455
Mapped MCE PGA (Rock Site)	0.363g	
Site Coefficient F_{PGA}	1.237	
Site-adjusted MCE PGA_M	0.449g	

It is important to note that Section 11.4.8 of ASCE 7-16 requires a site-specific ground motion hazard analysis be performed on structures on Site Class D sites with a 1-second spectral response acceleration parameter (S_1) greater than 0.2g. However, Exception No. 2 in Section 11.4.8 states that a site-specific ground motion hazard analysis is not required at Site Class D site if the structure's fundamental period of vibration T is less than $1.5T_s$ and the seismic response coefficient C_s is used for design. We assume structures for the Project will be single story or below grade. Therefore, we anticipate the fundamental period of vibration T will be less than 0.5-second.

4.4 Seismic Sources and Hazard Deaggregation

We used the online USGS Unified Hazard Tool (USGS 2024b) to perform a deaggregation of the Uniform Hazard Spectrum at the site. Table 4-3 summarizes the results of the MCE hazard deaggregation for the zero-second period of vibration (e.g., PGA). The deaggregation data identify the earthquake sources, magnitudes, and site-to-source distances that contribute to the mean source event acceleration parameters summarized in Table 4-3 below.

Table 4-3. Deaggregation Results for 2,475-year Mean Source Event (MCE), PGA Period

Source	Moment Magnitude, M_W[1]	Site-to-Source Distance[2] (km)	% Contribution to Hazard
CSZ Interface	8.99	116.64	40.2
CSZ Intraslab	7.01	77.35	11.2
Crustal Faults[3]	6.04 to 6.33	7.81 to 12.94	48.6

Notes:
1. M_W values represent the mean value from each type of earthquake source.
2. Site-to-Source distances represent the mean value from each type of earthquake source.
3. Crustal faults source include gridded seismic sources that represent earthquakes that do not occur on known, mapped faults.

4.5 Liquefaction and Lateral Spreading

Liquefaction is the phenomenon whereby saturated cohesionless soils (e.g., sands, gravels, and non-plastic to low-plasticity silts) undergo significant strength loss and stiffness when subjected to vibration or large cyclic ground motions produced by earthquakes. Saturated granular and low-plasticity soils (i.e., gravels, sands, and silts) are most susceptible to liquefaction.

Because of the very dense gravelly conditions encountered, we conclude that the risk of liquefaction is very low at the site. This concurs with hazards maps provided by Washington State Department of Natural Resources Division of Geology and Earth Resources (Palmer et. al, 2004).

Lateral spreading is a liquefaction-related phenomenon that results in ground displacement during an earthquake and occurs in sloping ground or flat ground with free face (i.e., a creek bank or channel). Although these are steep creek banks to the south trending toward the south extent of Lacamas Creek, we consider the risk of lateral spreading low due to the lack of liquefiable soils encountered and the distance between the slope and the planned site improvements (which is more than 200 feet from the top of the nearest site slope).

4.6 Slope Stability

The Washington Geologic Information Portal (Washington DNR 2024) does not show any known landslides at the Project site. The nearest mapped landslide mass is about 1,200 feet north of the site along the banks of Lacamas Creek. This movement is reported to have occurred within the last 150 years and has a failure depth of 43 feet and a headscarp height of 50 feet. We confirmed these features by available LIDAR imagery.

A large slide mass is mapped about 1,800 feet west of the site along the steep slopes of Northwest 6th Avenue. This feature is reported to be fan material from a deep-seated slide mass with a failure depth of have a failure depth of 87 feet. This feature is located along the south slopes of Prune Hill bound at the north by Forest Home Road and is approximately 320 acres in size (Washington Geologic Portal, 2024).

The Well 13 site is relatively level. However, there are steep banks trending down to the confluence of Lacamas Creek and the Washougal River. These slopes are generally 1H:1V and wooded. During our site reconnaissance in April 2024, we did not observe clearly indicative signs of instability along this slope face, such as pistol butted tree trunks, surficial cracking, or soil raveling. Our review of available Lidar imagery (Washington Geologic Information Portal) confirms our observations. Although we do not interpret previous soil movement from Lidar imagery provided by WS DNR (Washington Geologic Information Portal 2024), the imagery could be interpreted to include erosional characteristics along the slope near the south terminus of East Cramer Lane.

In general, we anticipate that the risk of the creek bank failure and landslide affecting the proposed improvements is low.

4.7 Flood Hazard

The Federal Emergency Management Agency (FEMA) shows the site adjacent to Zone AE (Floodway) near the south banks to the Lacamas Creek (FEMA 2018). A flood water surface elevation is reported to be 35 feet at the site. The ground surface of the site is approximately between 50 and 60 feet.

4.8 Other Hazards

Other geologic and seismic hazards, including debris flows, fault rupture, and tsunamis/seiches are not considered risks to the project.

5.0 Conclusions

Based on the results of our geotechnical investigation, laboratory testing, seismic hazards evaluation, new site structures associated with the Project can be supported on shallow foundations, provided the recommendations in Section 6 are incorporated.

The layout, size, and elevations for new structures/facilities have not been established at this stage of the Project. At this preliminary stage of the Project, we assume the location of the site improvements will be in the north, undeveloped section of the property near East 1st Avenue.

There are two primary geotechnical-related considerations at the project site:

- *Soft Surficial Soils:* We encountered a 5- to 6.5-foot-thick mantle of very soft to soft fine-grained soils at the site that overlie dense gravely soil. Foundations bearing on the soft soils are highly likely to settle over time. Bearing surfaces of new foundations should be within the gravel stratum underlying these soft soils. Therefore, we recommend the foundation subgrade, if founded within the upper 5 feet, be overexcavated and replaced with structural fill.

- *Slope Setback*: The slopes down to the confluence of Lacamas Creek and the Washougal River are up to 1H:1V. Based on the dense gravelly subsurface conditions encountered, we do not expect new structures/facilities over 200 feet from the top of these slopes to be impacted from the potential slope erosion and instability conditions. However, we recommend a setback of at least 50 feet from the top of the slopes for any other possible project improvements. Stormwater generated by site improvements should be managed so that there is no discharge or open channel flow down these existing slopes and all stormwater management facilities should be setback the minimal distance recommended.

6.0 Design Recommendations

We are providing geotechnical design recommendations for the planning and layout of the site improvements that provide PFAS treatment at the site. We understand the new structure(s) will house and support tanks needed for the treatment processes. At this phase of the project, the layout, elevations, size, and of the new tanks and other equipment have not been established and our recommendations should be considered preliminary.

6.1 Slab-on-Grade Foundations

We recommend a modulus of subgrade reaction of 250 pounds per cubic inch (pci) for the design of concrete slab-on-grade foundations which will be supported on structural fills placed on native gravelly subgrade soils which should be prepared as recommended in Section 6.1.1

below. The recommended modulus of subgrade reaction represents the anticipated value, which would be obtained in a standard in situ plate test with a 1-foot square plate. Use of this subgrade modulus for design should include appropriate modifications based on dimensions as necessary.

We anticipate concrete slabs-on-grade will have a total static settlement up to ½ inch when designed in accordance with our recommendations. Differential settlement is expected to be one-half of this amount, or up to ¼-inch. We recommend allowing for an additional ½-inch total settlement and ¼-inch differential settlement under seismic conditions.

6.1.1 Subgrade Preparation

Subgrade soils supporting concrete slab foundations should consist of the native gravelly soils encountered beneath the surficial soft fine-grained soils about 5 to 6.5 feet bgs in our investigation. The subgrade should be excavated using a smooth bucket. After excavating to the proposed subgrade level, the subgrade surface should be observed by Delve Underground or their representative. Due to the soft surficial conditions at the site, we recommend assessing subgrade suitability by subgrade probing rather than proof rolling with a fully-loaded dump truck or equivalent. Soils that are observed to be unsuitable should be overexcavated and replaced with structural fill (see Section 7.2.1) at the direction of the Delve Underground Geotechnical Engineer, or their representative.

The exposed subgrade should be mechanically compacted to unyielding conditions and should be overlayed by a layer of separation geotextile (see section 7.3) prior to the placement of structural fill.

The structural fill should be capped by a 6-inch thick leveling coarse on which the slab-on-grade and footing foundations can be placed. The prepared subgrade, geotextile, and structural fill should extend a minimum of 2 feet outside the perimeter of the concrete slab.

6.2 Continuous, Strip, and Spread Footings

Although locations and depths of new structures are not shown at this phase of the design, those structures can be supported by shallow foundations, such as conventional strip, continuous, or spread footings bearing on the native gravelly soils. Preliminary recommendations for the design of shallow foundations are provided in Table 6-1.

Table 6-1. Foundation Design Recommendations

Parameter	Value
Net Allowable Bearing Pressure (psf)	2,500
Friction Coefficient, Pre-Cast Concrete Foundations	0.30
Friction Coefficient, Cast-in-Place Concrete Foundations	0.45
Passive Pressure (psf)	200D[1]

Note:

1. D: embedment depth; passive pressure value includes a factor of safety of 2.

The net allowable bearing pressure applies to the total of dead and long-term loads and may be increased by one-third when considering seismic loads. We recommend disregarding the effects of the upper 12 inches of soil in calculating passive resistance due to the likelihood of soil disturbance in this area.

Based on our analysis, the total static settlement is anticipated to be less than 1/2 inch. We estimate minimal total dynamic settlement, which will be about 0.1-inch. We estimate differential settlement to be up to one-half the total settlement under each condition.

6.2.1 Subgrade Preparation

The design parameters provided in Table 6-1 assume the foundations are bearing on prepared subgrade, as recommended in Section 6.1.1.

6.3 Lateral Earth Pressures on Embedded Walls

Below grade structures at the site can be designed to resist the lateral earth pressures provided in Figure 4.

7.0 Construction Recommendations

The following are preliminary recommendations intended for use during the construction phase. Once the Project design phase progresses, we can provide additional or revised recommendations based on the new information.

7.1 Site Preparation

All existing utilities should be identified prior to excavation. If applicable, demolition of any existing structures should include complete removal of all structural elements, including foundations, and concrete slabs. Abandoned buried utilities should similarly be removed or fully grouted.

7.2 Backfill Materials and Compaction Criteria

7.2.1 Structural Fill

Structural fill should be used under foundations and slabs. Structural fill should consist of imported, crushed rock conforming to Washington State Department of Transportation (WSDOT) 2025 Standard Specifications, M 41-10 (WSDOT 2025) Class B Gravel Backfill for Foundations, Section 9-03.12(1)B. Unless otherwise noted, structural fill below structures should be compacted to a minimum 95% of the maximum dry density determined by ASTM D698.

Structural fill placed within 5 feet around embedded walls should be compacted to no more than 95% of dry density determined by ASTM D698. The structural fill should be placed in maximum lifts of 8 inches of loose material. Each lift of structural fill should be tested prior to placement of subsequent lifts.

7.2.2 Embedded Wall Backfill

The walls of fully-embedded structures should be backfilled with free-draining granular materials the requirements of WSDOT 2025 Standard Specification, M 41-10 Section 9.03.12(2) for Gravel Backfill for Walls. The backfill placed within 3 feet of the wall for the structure should be compacted to not more than 92 percent of the maximum dry density per ASTM D698.

Large and heavy equipment, particularly compaction equipment, should not be allowed to operate near the walls during construction. The compaction equipment used within 3 feet of the wall should be hand compaction equipment, walk-behind, or self-propelled rollers with a limit static weight of less than 1,000 pounds. Loose lift thickness may need to be reduced where hand compaction equipment is used.

7.3 Separation Geotextiles

Separation geotextile placed on foundation subgrade should be installed over the prepared subgrade to prevent fines migration of the imported structural fill material into the prepared native gravel subgrade. The separation geotextile should be installed per the manufacturer's instructions. Separation geotextiles should meet the requirements for Separation Geotextile in Table 3 of WSDOT Standard Specification, M 41-10, Section 9-33.2(1).

7.4 Temporary Shoring

At this stage the locations, size and depths of the new Project structure are not known.

Selection of shoring systems and the safety of temporary excavation and cut slopes is solely the responsibility of the Contractor. The Contractor must submit an excavation and shoring plan to the Engineer prior to construction. The plan should show the design of the shoring, bracing, sloping, or other provisions to be made for worker protection from the hazard of caving ground for excavations over 4 feet in depth. The Contractor should be aware of, and familiar with, applicable local, state, and federal safety regulations, including the current Occupational Safety and Health Administration (OSHA) Excavation and Trench Safety Standards. The shoring plan must be prepared and stamped by a Professional Engineer in the State of Washington.

7.5 Groundwater Control

Static groundwater is not expected to be encountered within anticipated excavation depths (up to 10 feet). Therefore, we anticipate that any groundwater inflow to the excavation can be controlled using sumps.

7.6 Temporary Cuts

If cut slopes are required, maximum cut slope inclinations must be made in accordance with OSHA regulations. Based on the subsurface conditions encountered at the project site, an OSHA Type C soil type should be used in the upper 5 feet for temporary excavation layout. Below 5 feet, Type B soils can be used for the underlying gravelly conditions. For excavations up to 20 feet, ground cuts should not exceed 1H:1V in the site gravels and not exceed 1.5H:1V in the upper fine-grained silt soils.

Temporary slope recommendations do not consider site constraints such as groundwater, surcharge, or nearby structures. Temporary slopes should be evaluated on a case-by-case basis and incorporate groundwater conditions, soil classification, and site constraints. Cut slopes should be inspected and maintained as required by OSHA.

With time, the presence of seepage, and precipitation, temporary cut slope stability can be compromised. Therefore, temporary slopes kept open during construction should be protected from erosion by installing a surface water diversion ditch or berm at the top of the slope and covering the cut face with well-anchored plastic sheets. In addition, the Contractor should monitor the stability of the temporary cut slopes and adjust the construction schedule and slope inclination accordingly. Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the Contractor and all excavations must comply with current federal, state, and local requirements.

7.7 Wet Weather Construction

Soil conditions should be evaluated in the field by the geotechnical engineer or their representative at the initial stage of site preparation to determine whether the recommendations within this section should be incorporated into construction. If earthwork is performed during extended periods of wet weather or in wet conditions, we recommend the following:

- Excavations should be protected from surface water runoff by placing sandbags or by other means to direct runoff of precipitation away from work areas and to prevent ponding of water in excavations.
- Plastic covers, sloping, ditching, sumps, dewatering, and other measures should be employed in work areas as necessary to permit timely completion of work. Bales of straw and/or geotextile silt fences should be used to control surface soil movement and erosion.
- Excavation or the removal of unsuitable soil should be followed promptly by placement and compaction of structural fill.

8.0 Closure

This report has been prepared for the exclusive use for Carollo Engineers for the PFAS Evaluation and Well 13 Treatment Design for the City of Camas, Washington. The data presented in this report is based on the subsurface conditions encountered during our site explorations and is intended to support the design of the proposed improvements. Delve Underground is not responsible for the interpretation of the data contained in this report by anyone; as such interpretations are dependent on each person's subjectivity.

In the performance of geotechnical work, specific information is obtained at specific locations at specific times, and geologic conditions can change over time. It should be acknowledged that variations in soil conditions may exist between exploration and exposed locations and this report does not necessarily reflect variations between different explorations. The nature and extent of variation may not become evident until construction. If, during construction, conditions observed or encountered differ from those disclosed by this report, Delve Underground should be advised at once so we can observe and review these conditions and reconsider our recommendations where necessary.

The geotechnical engineering evaluations and interpretations are completed within the limitations of Delve Underground's approved scope of work, schedule and budget. The services rendered by Delve Underground have been performed in a manner consistent with the level of care and skill ordinarily exercised by members of the profession currently practicing under similar conditions in the same area. The construction recommendations are considered preliminary and provided for planning purposes only. Delve Underground is not responsible for the use of this report in connection with anything other than the project at the location described above.

Delve Underground

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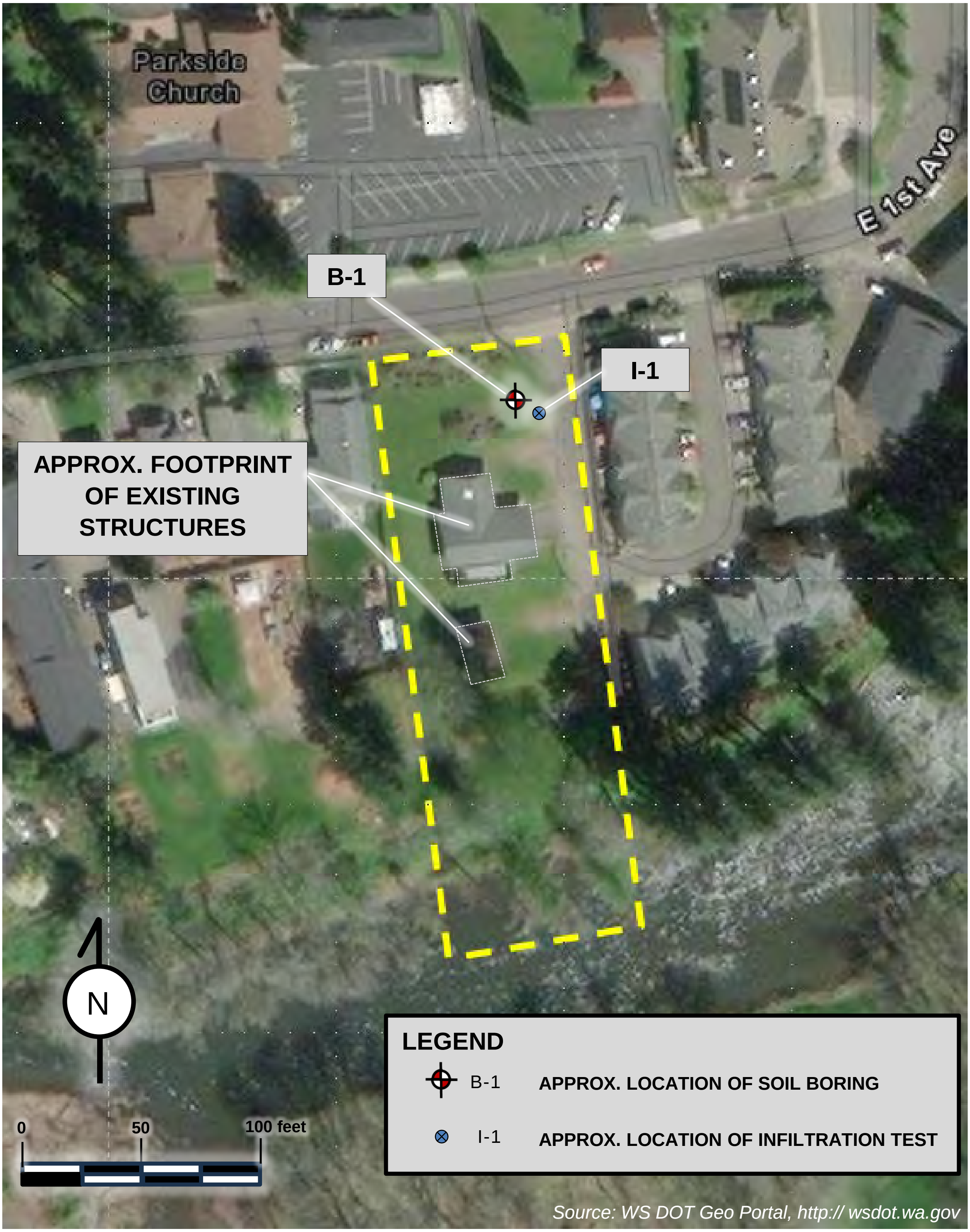
Source: https://databasin.org/maps/

DELVE underground

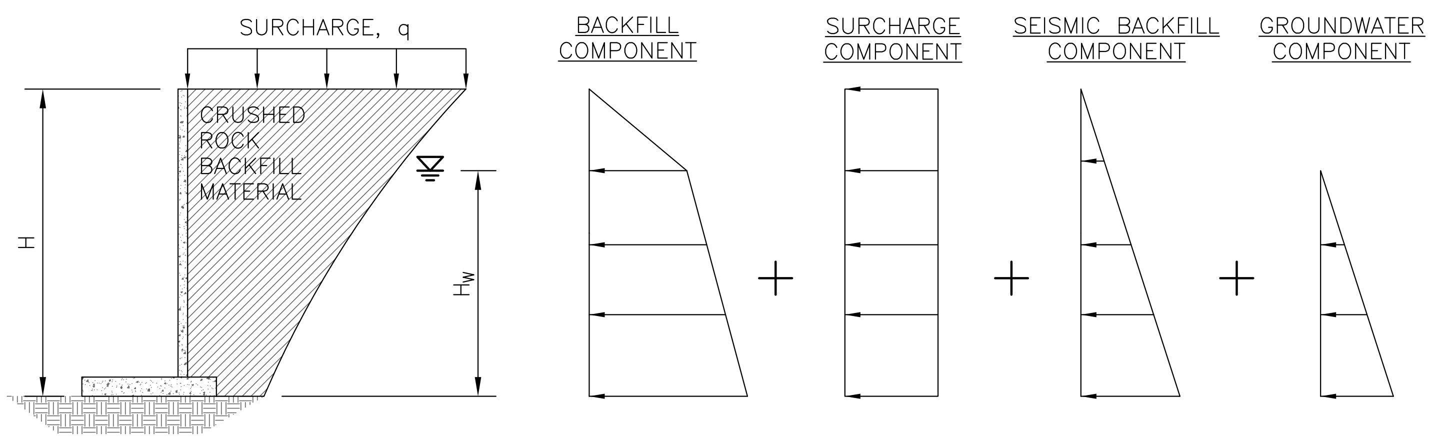
CAMAS WATER SYSTEM WELL 13 PFAS TREATMENT DESIGN	FIG 1
SITE VICINITY PLAN	MARCH 2025

DELVE underground	CAMAS WATER SYSTEM WELL 13 PFAS TREATMENT DESIGN	FIG 2
	SITE LOCATION PLAN	MARCH 2025



DELVE underground	CAMAS WATER SYSTEM WELL 13 PFAS TREATMENT DESIGN	FIG 3
	SITE EXPLORATION PLAN	MARCH 2025

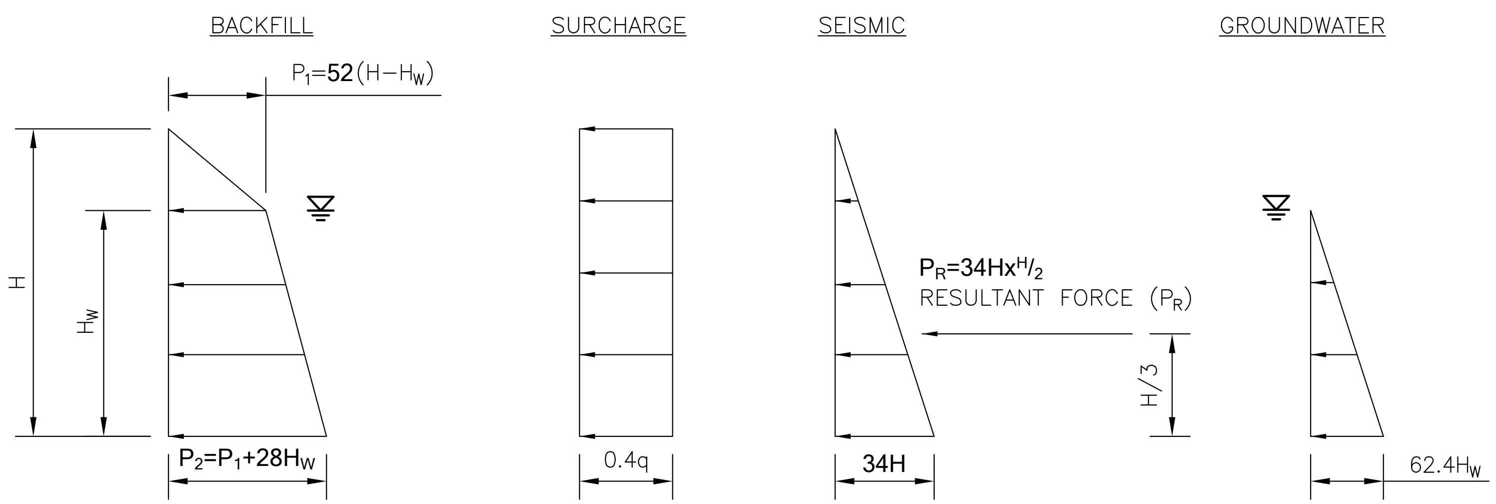
LATERAL EARTH PRESSURES ON EMBEDDED WALLS & STRUCTURES



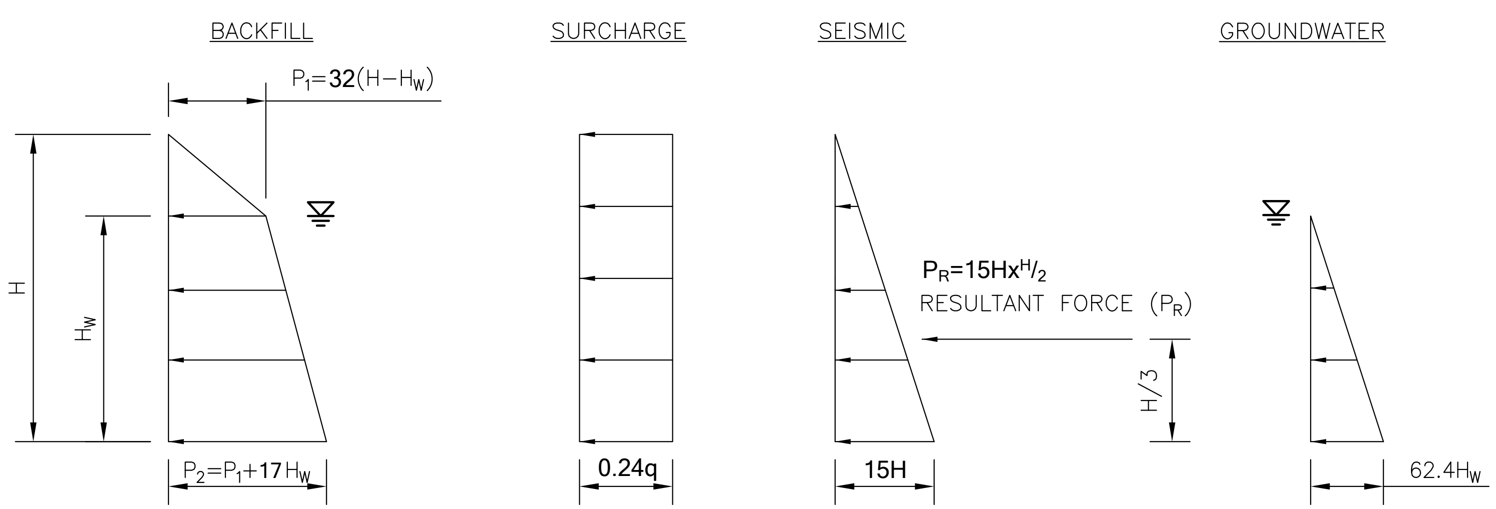
NOTES:

1. UNITS ARE POUNDS PER SQUARE FOOT (PSF).
2. PRESSURES BASED ON WALL BACKFILL PER WSDOT 2024 STANDARD SPECIFICATIONS M41-10 SECTION 9.03.12(2)

RESTRAINED (NON–YIELDING) EMBEDDED WALLS & STRUCTURES



NON-RESTRAINED (YIELDING) EMBEDDED WALLS & STRUCTURES



DELVE underground	CITY OF CAMAS WELL 13 PFAS TREATMENT DESIGN GEOTECHNICAL ENGINEERING REPORT LATERAL EARTH PRESSURES FOR EMBEDDED WALLS	FIG.4 MARCH 2025

Appendix A Soil Boring Logs

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Project: Camas Water System WELL 13 PFAS Treatment Design
Project Location: Camas, Washington
Project Number: 6571.0

Log of Boring

B-1

Date(s) Drilled	05/01/2024	Client	Carollo Engineers	Final Depth	51.5 ft bgs
Coordinates	Lat. 45.58795°, Lon. -122.39343°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 75
Surface Elevation	60.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.78 in
Location	45 ft. South of sidewalk, ~12 ft off SE Cramer Rd.	Logged by/ Checked by	N. Lambing / A. Havekost	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 / ○ MC (%) —— LL/PL 20 40 60 80	USCS GRAPHIC	USCS	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
		0–1.5							ML	Soft, moist, brown, SILT (ML); trace fine to coarse sand, low plasticity. **FILL**		
		2										
		3		67	0-0-1 (N=1)	S-01	■ 1		ML	Very soft, moist, brown (SILT (ML); trace fine to coarse sand, trace mica. **RECENT ALLUVIUM**		
		4										
55		5										
		6		6	4-3-26 (N=29)	S-02	■ 29		GW-GC	Medium dense, moist, brown fines, gray gravel, Well Graded GRAVEL with Clay (GW-GC); fine to coarse gravel, fine to coarse sand. **COARSE GRAINED CATASTROPHIC FLOOD DEPOSITS**		
		7.5		0	50/1" (Refusal)	S-00				*(7.5 ft. bgs) Refusal, no recovery at S-00*		
		8										
50		10										
		11		61	9-12-13 (N=25)	S-03	■ 25		GC	Medium dense, moist, brown to gray, CLAYEY GRAVEL (GC); mostly coarse subrounded to subangular gravel, fine to coarse sand, medium plasticity fines.		
		12									Modified California sampler for S-4., and S-6 through S-13. Hammer blow counts are as observed and uncorrected.	
		13		56	18-27-27	S-04			GC	Dense, wet, brown fines and sand, gray gravel, red and red-brown clasts, CLAYEY GRAVEL (GC); fine to coarse gravel, fine to coarse sand, coarse sand/fine gravel red clasts, occassional charcoal, subrounded to angular gravel.		
		14										
45		15										
		16		45	14-16-14 (N=30)	S-05	■ 30		GP	Medium dense, gray, wet, well Poorly Graded GRAVEL (GP); fine to coarse sand, fine to coarse gravel, angular to subangular gravel.		
		17									(~17 ft. bgs) Drill rig chatter.	
		18		56	13-16-17	S-06				*(17.5 ft bgs) Encountered red, coarse gravel-sized weak clasts.*		

NOTES: AL: Atterberg limits; N: Penetration resistance; MC: Moisture content; SA: Sieve analysis; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: USGS Camas Quadrangle 7.5 Min. Topo; NAD83 ; Coordinate System: WGS84

DELVE underground

Boring B-1

Project: Camas Water System WELL 13 PFAS Treatment Design
Project Location: Camas, Washington
Project Number: 6571.0

Log of Boring

B-1

Date(s) Drilled	05/01/2024	Client	Carollo Engineers	Final Depth	51.5 ft bgs
Coordinates	Lat. 45.58795°, Lon. -122.39343°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 75
Surface Elevation	60.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.78 in
Location	45 ft. South of sidewalk, ~12 ft off SE Cramer Rd.	Logged by/ Checked by	N. Lambing / A. Havekost	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 / ○ MC (%) — LL/PL 20 40 60 80	USCS GRAPHIC	USCS	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
				67	19-37-49	S-07				Very dense, wet, gray with light brown gravel fragments, Well Graded GRAVEL with Sand (GW); fine to coarse sand, fine to coarse gravel, angular (recently fractured) to subangular gravel, trace green-gray gravel. *(20 ft. bgs) Becomes very dense. Fine gravel clasts present.*		
		22										
		24										
35				100	75/5"	S-08			GW			
		26										
		28										
30		30		100	75/6"	S-09				Very dense, moist, gray and gray brown with red clasts, Poorly Graded GRAVEL with Sand (GP); mostly fine subrounded to angular gravel, fine to coarse sand.		
		32							GP			
		34										
25				100	29-75/1"	S-10				Very dense, moist, gray, Well Graded GRAVEL (GW); fine to coarse sand, fine to coarse gravel, subrounded to angular gravel, recently broken subrounded gravels present.		
		36										
		38							GW			

DELVE underground

NOTES: AL: Atterberg limits; N: Penetration resistance; MC: Moisture content; SA: Sieve analysis; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: USGS Camas Quadrangle 7.5 Min. Topo; NAD83 ; Coordinate System: WGS84

Boring B-1

Project: Camas Water System WELL 13 PFAS Treatment Design
Project Location: Camas, Washington
Project Number: 6571.0

Log of Boring

B-1

Date(s) Drilled	05/01/2024	Client	Carollo Engineers	Final Depth	51.5 ft bgs
Coordinates	Lat. 45.58795°, Lon. -122.39343°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	Mud Rotary CME 75
Surface Elevation	60.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	4.78 in
Location	45 ft. South of sidewalk, ~12 ft off SE Cramer Rd.	Logged by/ Checked by	N. Lambing / A. Havekost	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 / ○ MC (%) — LL/PL 20 40 60 80	USCS GRAPHIC	USCS	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
			67	40-75/12 "	S-11			GP	Very dense, wet, gray to brown, Poorly Graded GRAVEL (GP); fine to coarse sand, fine gravel, occasional coarse gravel.		
	42										
	44							GP	Very dense, moist-gray-brown, dark red, red-orange, and light gray, Poorly Graded GRAVEL with Sand (GP); mostly fine gravel, fine to coarse sand.		
15											
	46		67	43-75/12 "	S-12						
	48										
10	50		100	45-62-65	S-13			SP	Very dense, moist, gray and gray-brown, Poorly Graded SAND (SP); red, brown and light brown sand visible, micacous.		
	52									Borehole completed at 51.5 feet below ground surface (bgs).	
	54										
5											
	56										
	58										

DELVE underground

NOTES: AL: Atterberg limits; N: Penetration resistance; MC: Moisture content; SA: Sieve analysis; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: USGS Camas Quadrangle 7.5 Min. Topo; NAD83 ; Coordinate System: WGS84

Boring B-1

Project: Camas Water System WELL 13 PFAS Treatment Design
Project Location: Camas, Washington
Project Number: 6571.0

Log of Boring

I-1

Date(s) Drilled	05/01/2024	Client	Carollo Engineers	Final Depth	6.5 ft bgs
Coordinates	Lat. 45.58795°, Lon. -122.39343°	Geotechnical Consultant	Delve Underground	Method/ Rig Type	4.25" HSA CME 55
Surface Elevation	60.0 ft.	Drilling Contractor	Western States Soil Conservation, Inc.	Hole Diameter	6.00 in
Location	~35 ft. South of sidewalk, ~12 ft off SE Cramer Rd.	Logged by/ Checked by	N. Lambing / A. Havekost	Hammer Type	140 lb / 30 in / Automatic

ELEV. (FT)	WATER LEVEL	DEPTH (FT)	SAMPLE TYPE	RECOVERY (%)	BLOW COUNTS	SAMPLE NUMBER	■ N (blows/ft) 10 20 30 40 / ○ MC (%) — LL/PL 20 40 60 80	USCS GRAPHIC	USCS	MATERIAL DESCRIPTION	REMARKS AND TESTS	BACKFILL/INSTALL.
		0–1.5							ML	Moist, brown SILT (ML), trace fine to coarse sand, low plasticity. **FILL**		
		2								Moist, brown SANDY SILT (ML); trace fine sand, low plasticity. **RECENT ALLUVIUM**		
		3–4		67	1-1-1 (N=2)	S-01			ML			
55		5								Moist, brown SILT with SAND (ML); fine to coarse sand, low plasticity, coarse gravel fragment in shoe of split spoon		
		6		67	2-2-4 (N=6)	S-02			ML	*Perform infiltration test. Pre-soak for 4 hours. Take two hours of measurements, adding additional water at each interval.*	Borehole completed at 6.5 feet below ground surface (bgs).	
		8										
50		10										
		12										
		14										
45		16										
		18										

DELVE underground

NOTES: AL: Atterberg limits; N: Penetration resistance; MC: Moisture content; SA: Sieve analysis; LL/PL: Atterberg liquid/plastic limits
Location and Elevation Source:
Vertical Datum: USGS Camas Quadrangle 7.5 Min. Topo; NAD83 ; Coordinate System: WGS84

Boring I-1

Appendix B Laboratory Testing Results

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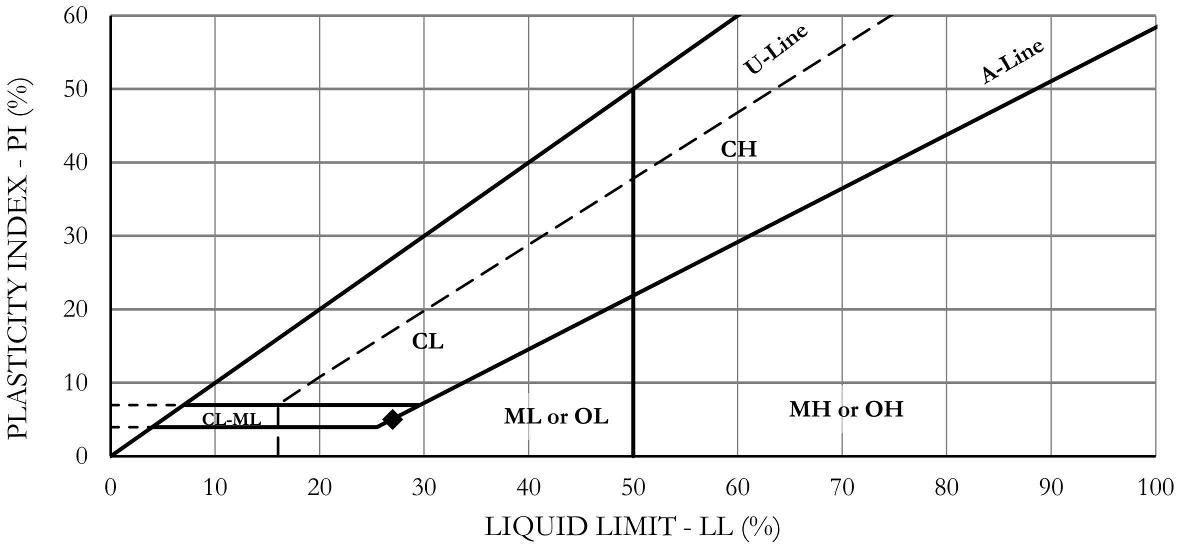
Breccia Geotechnical Testing, LLC.	Percent Fines (ASTM D1140)

Client:	Delve Underground	By:	FS
Project Name:	Camas Water System PFAS Evaluation	Date:	5/24/2024
Project Number:	6571.0		

Exploration ID	I-1					
Samples ID	S-2					
Samples Depth (ft.)	5					
Moisture Content (%)	30.3					
Percent Fines (%)	66.6					

ATTERBERG LIMITS TEST RESULTS (ASTM D4318)



	Boring ID	Sample ID	Depth (feet)	Moisture Content (%)	Atterberg Limits LL	PL	PI	%Pass #200	USCS
◆	I-1	S-1	2.5	22.6	27	22	5	--	ML

Remarks

Project: Camas Water System PFAS Evaluation
Project No.: 6571.0
Location: Camas, WA

Breccia Geotechnical Testing, LLC.
Brecciageolab@gmail.com
Tel: 971-246-1324

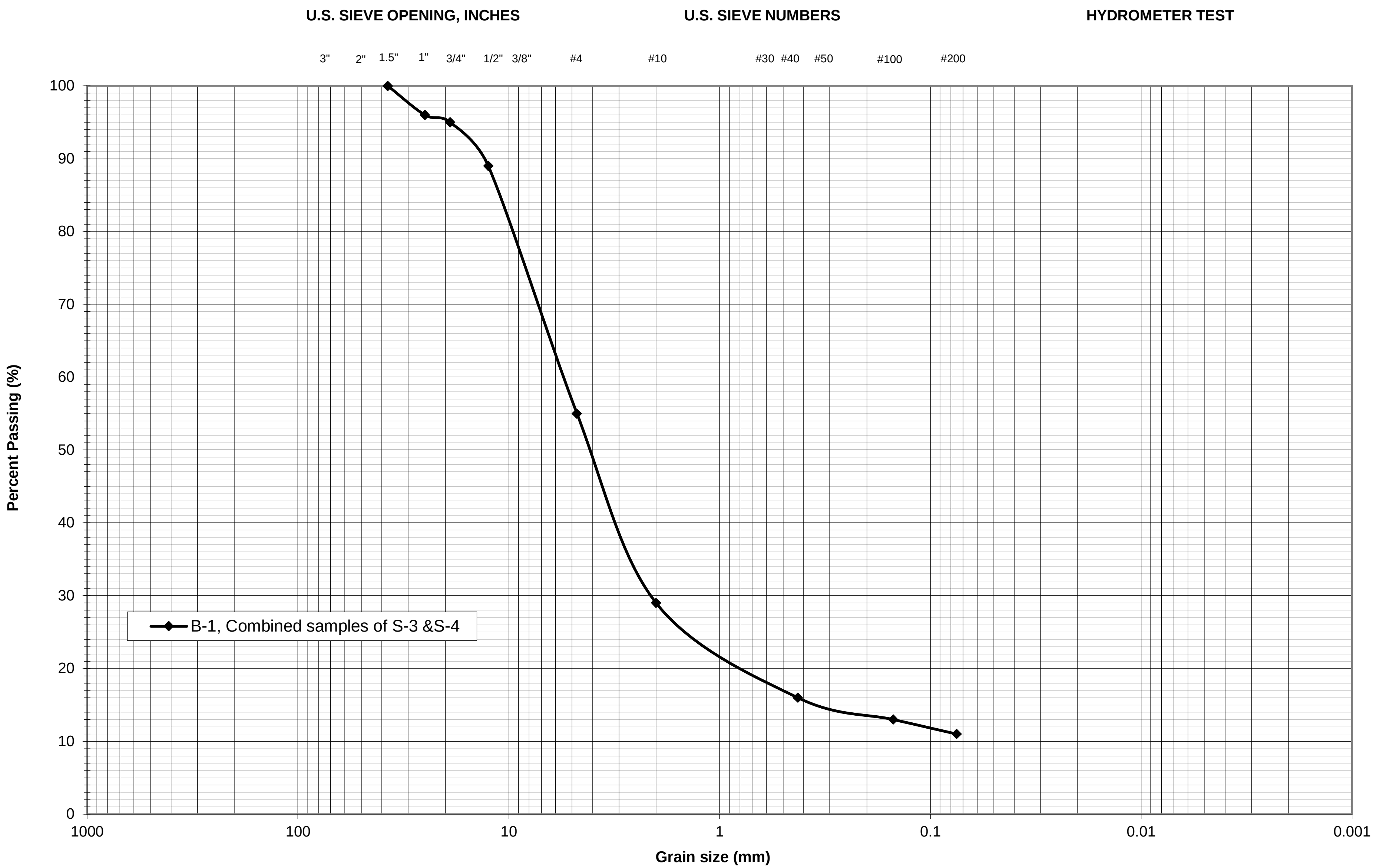
Breccia Geotechnical Testing, LLC.	**Particle-Size Analysis of Soils (ASTM D422) -** ***Mechanical Analysis without Hydrometer Test***

Client:	Delve Underground	By:	FS
Project Name:	Camas Water System PFAS Evaluation	Date:	5/24/2024
Project Number:	6571.0		

Exploration ID	B-1					
Samples ID	S-3&S-4					
Samples Depth (ft.)	10&12.5					
Sieve Size	Percent Passing					
1-1/2"	100					
1"	96					
3/4"	95					
1/2"	89					
No. 4	55					
No. 10	29					
No. 40	16					
No. 100	13					
No. 200	11					

% Coarse Gravel	5.0					
% Fine Gravel	40.0					
% Coarse Sand	26.0					
% Medium Sand	13.0					
% Fine Sand	5.0					
% Fines	11.0					

Note: Samples prepared by washing over No. 200 sieve



U.S. SIEVE OPENING, INCHES
U.S. SIEVE NUMBERS
HYDROMETER TEST
3"
2"
1.5"
1"
3/4"
1/2"
3/8"
#4
#10
#30
#40
#50
#100
#200
Percent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
1000
100
10
1
0.1
0.01
0.001
Grain size (mm)
B-1, Combined samples of S-3 &S-4

Appendix C Water Well Reports

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File Original with Department of Ecology
Second Copy - Owner's Copy
Third Copy - Driller's Copy
193881

WATER WELL REPORT

STATE OF WASHINGTON

Notice of Intent W241453
UNIQUE WELL I.D. # ~~ALL~~ ALL-996
Water Right Permit No.

(1) OWNER: Name City of Camas Address PO Box 1055, Camas, WA 98607

(2) LOCATION OF WELL: County Clark SE 1/4 NE 1/4 Sec 11 T 1 N.R. 3E WM

(2a) STREET ADDRESS OF WELL: (or nearest address) Lou Block Park - NE 1st Ave

TAX PARCEL NO.: 090988-000

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☒ Test Well ☐ Other ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) TW-1
☒ New Well ☐ Deepened ☐ Reconditioned ☐ Decommission
Method: ☐ Dug ☐ Bored ☒ Cable ☐ Driven ☐ Rotary ☐ Jetted

(5) DIMENSIONS: Diameter of well 8 inches
Drilled 138 feet. Depth of completed well 138 ft.

(6) CONSTRUCTION DETAILS
Casing Installed:
☒ Welded 8" Diam. from +2 ft. to 138 ft.
☐ Liner installed ___" Diam. from ___ ft. to ___ ft.
☐ Threaded ___" Diam. from ___ ft. to ___ ft.

Perforations: ☒ Yes ☐ No
Type of perforator used Mills Knife
SIZE of perforations 1/4" in. by 4" in.
60 perforations from 95 ft. to 110 ft.

Screens: ☐ Yes ☒ No ☐ K-Pac Location
Manufacturer's Name
Type Model No.
Diam. Slot Size from ft. to ft.
Diam. Slot Size from ft. to ft.

Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand
Material placed from ft. to ft.

Surface seal: ☒ Yes ☐ No To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level 70 ft.
Static level 61.6 ft. below top of well Date 2/8/06
Artesian pressure lbs. per square inch Date
Artesian water is controlled by
(Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(10) WELL LOG or DECOMMISSIONING PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. Indicate all water encountered.

MATERIAL	FROM	TO
Brown silty Sand & Clay	0	10
Brown siltbound Sand, Gravel and Boulders	10	29
Brown siltbound Sand, Gravel and Cobbles	29	40
Brown siltbound Sand & Gravel	40	49
Brown very silty Sand and Gravel	49	58
Brown silty Sand & Gravel	58	80
Brown Sand & Gravel w/minor cobbles and siltbound interbeds	80	92
Brown Sand & Gravel	92	111
Brown fine Sand	111	120
Brown silty to very silty fine Sand	120	132
Tan Clay	132	136
Reddish-brown clay and Rockfrags. (weathered bedrock)	136	138

RECEIVED FEB 11 2003 Washington State Department of Ecology
RECEIVED APR 17 2006 Washington State Department of Ecology

Work Started 10/26/2005 Completed 2/15/2005

WELL CONSTRUCTION CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

Type or Print Name Randy Holt License No. 1099
(Licensed Driller/Engineer)

Trainee Name License No.

Drilling Company Holt Drilling / Boart Longyear

(Signed) Randy Holt License No. 1099
(Licensed Driller/Engineer)

Address Po Box 1890 Milton WA 98354

Contractor's Registration No. BOARTLL055 PZ Date 4/04/06

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (360) 407-6600. The TDD number is (360) 407-6006.

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Please print, sign and return to the Department of Ecology

RESOURCE PROTECTION WELL REPORT

CURRENT Notice of Intent No. RE09349

(SUBMIT ONE WELL REPORT PER WELL INSTALLED)

Construction/Decommission *("x" in box)*
☒ Construction
☐ Decommission

ORIGINAL INSTALLATION Notice of Intent Number:

Consulting Firm
Unique Ecology Well IDTag No. BCM274

Type of Well *("x" in box)*
☒ Resource Protection
☐ Geotech Soil Boring

499829

Property Owner City of Camas
Site Address NE 3rd Ave + NE 3rd Pl
City Camas County Clark
Location SE 1/4-1/4 NE 1/4 Sec 11 Twn 1N R 3E
EWM ☒ or WWM ☐

Lat/Long (s, t, r still REQUIRED) Lat Deg ______ Min ______ Sec ______
Long Deg ______ Min ______ Sec ______

Tax Parcel No.

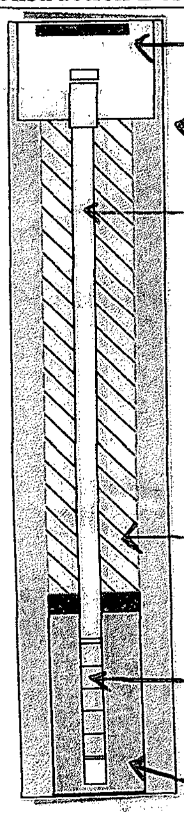
Cased or Uncased Diameter 5" Static Level none
Work/Decommission Start Date 12/6/13
Work/Decommission Completed Date 12/6/13

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee
Name (Print Last, First Name) Dennis, James
Driller/Engineer /Trainee Signature James Dennis
Driller or Trainee License No. 3145

If trainee, licensed driller's Signature and License Number:

Construction Design



Well Data

MONUMENT/VAULT Below Ground
From 0 To 1

BORE HOLE
Diameter 5" From 0 To 20

CASING
Dia. 1" From ☐ 0 To 10
Gauge 580 Wld Thrd
Material ◯Steel ⊗Plastic ☐ ☒

LINER
Dia. ______ From ☐ ______ To ______
Gauge ______ Wld Thrd
Material ◯Steel ◯Plastic ☐ ☐

SEAL
From 1 To 9
Material Bent Chips
Amount 23 Grout weight ______

SCREEN
Casing/Liner ______ Material PVC
Diameter 1" From 10 To 20
Slot Size .010

FILTER
Material Silica Sand Size of pack 10/20
From 9 To 20

Formation Description

Cibbles 0-3'
Sandy Silt/Gravels 3-7'
Boulders 7-9'
Cobbles 9-20'

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DEC 23 2013
WA State Department of Ecology (SWRO)

SCALE: 1"= ______ PAGE ______ OF ______

Please print, sign and return to the Department of Ecology

RESOURCE PROTECTION WELL REPORT

CURRENT Notice of Intent No. SE50012

(SUBMIT ONE WELL REPORT PER WELL INSTALLED)

Construction/Decommission *("x" in box)*
☒ Construction
☐ Decommission

ORIGINAL INSTALLATION Notice of Intent Number: ______

Consulting Firm ______

Unique Ecology Well IDTag No. ______

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

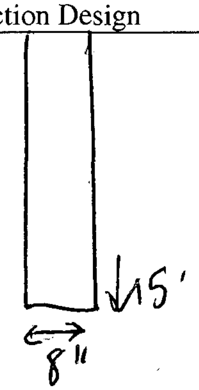
☒ Driller ☐ Engineer ☐ Trainee
Name (Print Last, First Name) Dennis, James
Driller/Engineer /Trainee Signature James Dennis
Driller or Trainee License No. 3145

If trainee, licensed driller's Signature and License Number: ______

Type of Well *("x in box)*
☐ Resource Protection
☒ Geotech Soil Boring

499848

Property Owner City of Camas
Site Address NE 3rd Ave & NE 3rd Pl
City Camas County Clark
Location SE1/4-1/4 NE1/4 Sec 11 Twn 1N R 3E
EWM ☒ or WWM ☐
Lat/Long (s, t, r still REQUIRED) Lat Deg ______ Min ______ Sec ______
Long Deg ______ Min ______ Sec ______
Tax Parcel No. ______
Cased or Uncased Diameter 8" Static Level None
Work/Decommission Start Date 12/05/2013
Work/Decommission Completed Date 12/05/2013

Construction Design	Well Data	Formation Description
	Drilled (1) 15' hollow stem auger boring for geotechnical purposes.	Asphalt 0-6" Sand 6"-15'

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DEC 23 2013
WA State Department of Ecology (SWRO)

SCALE: 1"= 10 PAGE ____ OF 8

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RESOURCE PROTECTION WELL REPORT

CURRENT Notice of Intent No. AE24763

(SUBMIT ONE WELL REPORT PER WELL INSTALLED)

Construction/Decommission *("x" in box)*
- ☐ Construction
- ☒ Decommission

ORIGINAL INSTALLATION Notice of Intent Number: SE50012

Consulting Firm ____________

Unique Ecology Well IDTag No. ____________

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

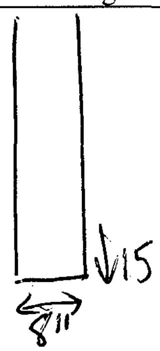
☒ Driller ☐ Engineer ☐ Trainee
Name (Print Last, First Name) Dennis, James
Driller/Engineer /Trainee Signature James Dennis
Driller or Trainee License No. 3145

If trainee, licensed driller's Signature and License Number: ____________

Type of Well *("x in box)*
- ☐ Resource Protection
- ☒ Geotech Soil Boring

499849

Property Owner City of Camas
Site Address NE 3rd Ave & NE 3rd Pl
City Camas County Clark
Location SE1/4-1/4 NE1/4 Sec 11 Twn 1N R 3E
EWM ☒ or WWM ☐
Lat/Long (s, t, r still REQUIRED) Lat Deg ____ Min ____ Sec ____ Long Deg ____ Min ____ Sec ____
Tax Parcel No. ____________
Cased or Uncased Diameter 8" Static Level None
Work/Decommission Start Date 12/05/2013
Work/Decommission Completed Date 12/05/2013

Construction Design	Well Data	Formation Description
	Decommissioned (1) 15' hollow stem auger boring using (6) 50lb sack bentonite chips 15-2', gravel 2-6", Asphalt 6"-0'	Asphalt 0-6" Sand 6"-15' Boring decommssioned as described under well data.

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WA State Department of Ecology (SWRO)

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RESOURCE PROTECTION WELL REPORT

CURRENT Notice of Intent No. AE24763

(SUBMIT ONE WELL REPORT PER WELL INSTALLED)

Construction/Decommission *("x" in box)*
☐ Construction
☒ Decommission

Type of Well *("x in box)*
☐ Resource Protection
☒ Geotech Soil Boring

499853

ORIGINAL INSTALLATION Notice of Intent Number: SE50012

Consulting Firm ____

Unique Ecology Well IDTag No. ____

Property Owner City of Camas

Site Address NE 3rd Ave & NE 3rd Pl

City Camas County Clark

Location SE1/4-1/4 NE1/4 Sec 11 Twn 1N R 3E

EWM ☒ or WWM ☐

Lat/Long (s, t, r still REQUIRED) Lat Deg ____ Min ____ Sec ____
Long Deg ____ Min ____ Sec ____

Tax Parcel No. ____

Cased or Uncased Diameter 8" Static Level None

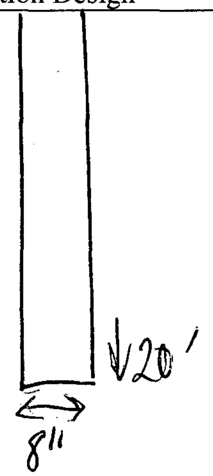
Work/Decommission Start Date 12/05/2013

Work/Decommission Completed Date 12/05/2013

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee
Name (Print Last, First Name) Dennis, James
Driller/Engineer /Trainee Signature James Dennis
Driller or Trainee License No. 3145

If trainee, licensed driller's Signature and License Number:

Construction Design	Well Data	Formation Description
	Decommissioned (1) 20' hollow stem auger boring using (8) 50lb sack bentonite chips 20-2', gravel 2-6", Asphalt 6"-0'	Asphalt 0-1' Gravel 1-1.5' Sand 1.5-20' Boring decommssioned as described under well data. RECEIVED DEC 23 2013 WA State Department of Ecology (SWRO)

SCALE: 1"= 10 PAGE ____ OF 8