DAVID EVANS AND ASSOCIATES INC

Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study

Design Concept Alternatives Report

Prepared for:

CLACKAMAS COUNTY

County Project No. 22265

Submitted by

David Evans and Associates, Inc.

DAVID EVANS AND ASSOCIATES INC

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PROJECT PURPOSE, NEED AND DESIGN SOLUTION

The goal of the project is to study the feasibility of extending the Trolley Trail, a shared-use path for bicycles and pedestrians, across the Clackamas River at the site of an abandoned trolley bridge that collapsed in 2014. The project would include a new bridge structure and approach paths, creating an exciting new active transportation link and providing pedestrians and bicyclists with a safe and convenient route between the communities of Gladstone and Oregon City. The purpose of this report is to evaluate alternatives, determine a recommended alternative, and produce conceptual bridge plans and cost estimate. Funding for final design and construction has not yet been secured.

EXISTING CONDITIONS AND DESIGN STANDARDS

The Project site follows an alignment beginning in Gladstone, extending southeasterly along Portland Avenue, from the south edge of Arlington Street, through the old rail and bridge corridor, to a tie-in point on the Clackamas River Greenway Trail south of the Clackamas River in Oregon City. The project study area is shown in the figure below.

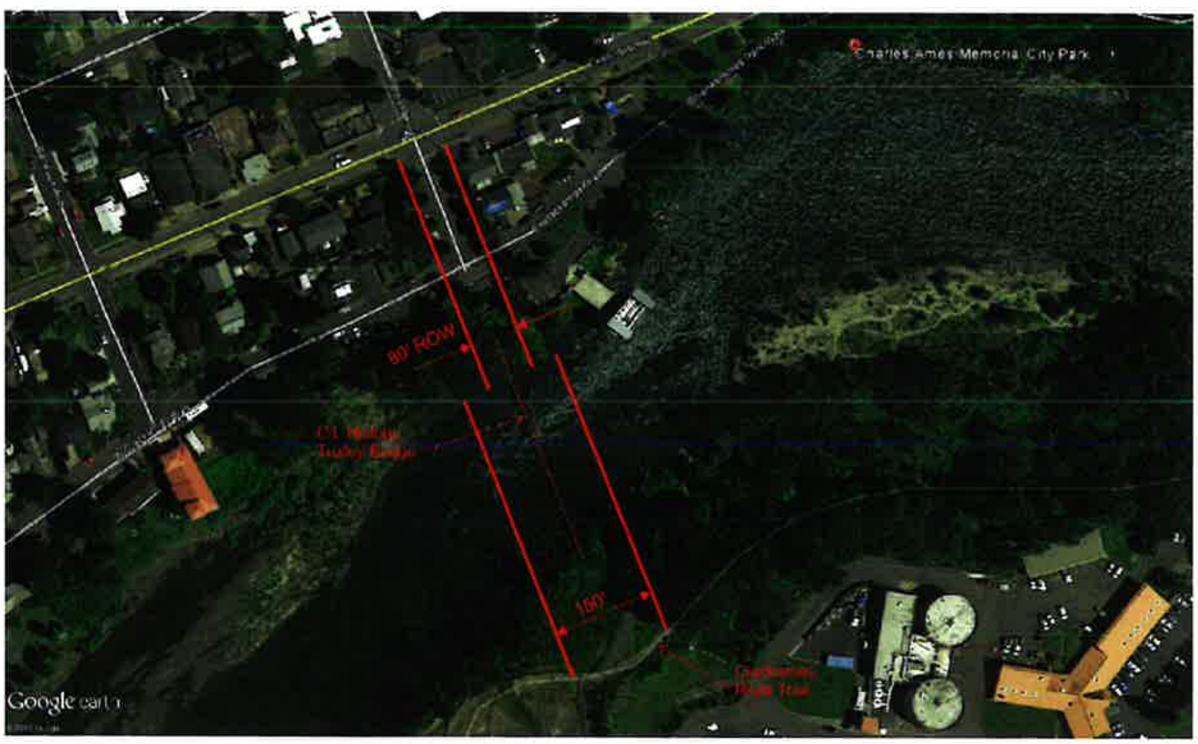


Figure 1: Trolley Trail Bridge Project Study Area

Path Design Criteria

The multiuse path will be 12 feet wide with 2-foot shoulders, meeting guidelines in the 2011 Oregon Bicycle and Pedestrian Design Guide and the AASHTO Bicycle Facilities Guide. This width will also accommodate emergency and maintenance vehicles. The maximum cross slope will be 2% and the maximum longitudinal grade will be 5%, meeting guidelines in the 2011 Oregon Bicycle and Pedestrian Design Guide as well as the Americans with Disabilities Act Accessibility Guidelines.

The full design criteria for all of the path alternatives is shown in the Design Criteria Matrix, see Appendix A.

Structure Design Criteria:

The following structural design criteria summary has been established for all of the structure alternatives.

- Accommodate a 12-foot wide path with two 2-foot shoulders for a total clear width of 16-feet.
- Support pedestrian live load of 90 pounds per square foot
- Support a 12 ton emergency vehicle live load (H12)
- Overhead vertical clearance 16 feet minimum (for emergency vehicles)
- Deflection under pedestrian live load shall not exceed 1/360 of the span length

Design Standards:

The design standards which will govern bridge design are:

- AASHTO LRFD Bridge Design Specifications, 8th Edition
- AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges, 1st Edition
- ODOT Bridge Design Manual (BDM), current edition
- ODOT Geotechnical Design Manual, current edition

DESIGN EXCEPTIONS

No design exceptions are proposed for this project.

MULTIUSE PATH ALTERNATIVES CONSIDERED

The existing ground on the north bank of the Clackamas River is higher than the south bank, so the transition from the bridge end to existing ground will be relatively short on the Gladstone side. On the Oregon City side, the grade will need to be raised to meet the end of the bridge, with the amount of grade increase and transition length varying for each of the bridge alternatives. The fill section will utilize 2:1 side slopes.

Full vertical profiles have been developed to correspond with Bridge Alternatives No. 1 and 3. Bridge Alternatives No. 4 and 5 can utilize the same profile and Alternative No. 1. A full profile was not developed for Bridge Alternative No. 2, since it requires the most fill and seems like the least desirable alternative. Conceptual plans of each alternative can be found in Appendix B.

Alternative 1

The alignment is tangent from the starting point at Clackamas Blvd. and Portland Ave. to a point just south of bridge. The alignment then curves to the west to provide a meeting point with the Clackamas River Trail. The existing ground on the north bank of the Clackamas River is higher than the south bank, so there will be a grade of 1.93% on the bridge. The vertical profile transitions from the bridge end to existing ground with a 3.59% grade. The fill section in this area will utilize 2:1 side slopes.

This alternative requires a less steep grade for the transition at the south end of the bridge compared to Alternative 3. The amount of fill and right of way footprint required is also less. The horizontal and vertical alignments meet all applicable standards.

Alternative 3

The horizontal alignment for Alternative 3 is the same as Alternative 1. The existing ground on the north bank of the Clackamas River is higher than the south bank, so there will be a grade of 1.18% on the bridge. The vertical profile transitions from the bridge end to existing ground with a 4.61% grade. There will also be a small raise in elevation required for the existing Clackamas River Trail. The fill section in this area will utilize 2:1 side slopes. The horizontal and vertical alignments meet all applicable standards.

This alternative requires a steeper grade for the transition at the south end of the bridge compared to Alternative 1. The amount of fill and right of way footprint required is also greater.

STRUCTURE CONCEPT ALTERNATIVES CONSIDERED

The following bridge structural alternatives have been investigated:

- Alternative 1 – Single span steel truss

- Alternative 2 – 3-span prestressed concrete girder
- Alternative 3 – 3-span steel girder
- Alternative 4 – Single span tied steel arch
- Alternative 5 – 3-span steel truss

Alternative 1 is a steel through truss structure with a single 365-foot span. This bridge type places the path between the trusses, therefore minimizing the depth of the structure and the amount of fill required for the adjoining path to match the bridge. The bridge will have a concrete deck. The structure depth from top of path to bottom chord is assumed to be 2'-0". The total height of the truss is assumed to be 36 feet.

Alternative 2 is a 3-span bulb-tee prestressed concrete girder structure with span lengths of 112.5'-140'-112.5'. The bridge will have a concrete deck. The structure depth from top of path to bottom of girder is assumed to be 6'-3".

Alternative 3 is a 3-span steel plate girder structure with span lengths of 112.5'-140'-112.5'. The bridge will have a concrete deck. The structure depth from top of path to bottom of girder is assumed to be 4'-9".

Alternative 4 is a tied steel through arch structure with a single 365-foot span. This bridge type places the path between the arches, therefore minimizing the depth of the structure and the amount of fill required for the adjoining path to match the bridge. The bridge will have a concrete deck. The structure depth from top of path to bottom chord is assumed to be 2'-0". The total height of the arch is assumed to be 52 feet.

Alternative 5 is a steel through truss structure with a three 121.7-foot spans. This bridge type places the path between the trusses, therefore minimizing the depth of the structure and the amount of fill required for the adjoining path to match the bridge. The bridge will have a concrete deck. The structure depth from top of path to bottom chord is assumed to be 2'-0". The total height of the truss is assumed to be 18 feet.

The substructure consists of the abutments, and in the case of the multi-span alternatives, the interior bents. The substructure elements must support the loads from the superstructure while considering the effects of scour and seismic events.

The abutments would be similar for all of the alternatives, although the single span alternatives would require larger foundation components to support the larger loads from the longer single span. The abutments would be short, stub type with wingwalls to retain fill at the end of the bridge. The abutments are likely to utilize driven pile foundations.

For the multi-span alternatives, the interior bents are likely to consist of a drilled shaft foundation supporting a formed single column and cap.

Conceptual plans of the five alternatives can be found in Appendix B.

PROJECT CONSTRAINTS

The proposed location and layout of the bridge alternatives were strongly influenced by the following considerations:

- The bridge alignment matches Portland Avenue, providing a direct and logical link to the existing Trolley Trail.
- The alignment avoids impacting the existing electrical lines spanning the Clackamas River to the east.
- The alignment matches the historic Trolley Trail Bridge location, which means the bridge can be considered a replacement of an existing structure for permitting purposes.
- The alignment crosses the Clackamas River at a moderate skew, which does not significantly increase the required bridge length.
- For permitting, it is desirable to minimize any structures within the floodway. The abutments have been placed outside of the floodway for all alternatives.
- The north abutment has been placed behind the existing abutment from the historic Trolley Trail Bridge to avoid interference with existing deep foundation components that may be present.
- For the multi-span alternatives, the intermediate bents were located to provide a larger clear opening in the center of the river, with shorter end spans on each side.
- The superstructure provides 3 feet minimum clearance above the 100-yr flood.
- Structure depth from top of path to bottom of structure should be minimized to reduce fill requirements for the adjoining path on the south side of the river.
- The U.S. Coast Guard has confirmed that the Clackamas River is not considered to be navigable waters at the project site and therefore there is no minimum navigational height that must be maintained and a Coast Guard permit will not be required.

ENVIRONMENTAL IMPACTS AND PERMITTING REQUIREMENTS

The section of the Clackamas River to be crossed has several endangered species of fish. No other threatened or endangered species are believed to be present in the project vicinity. See Biological Resources Memorandum for more detail.

The Ordinary High Water Mark (OHWM) has been determined to be at Elev. 20.5 NAVD88. The OHWM is the jurisdictional boundary for the Clackamas River, which is regulated under Oregon's Fill-Removal law and Section 404 of the Clean Water Act. No other wetlands or regulated waters were observed in the project area. See Wetland/Water Reconnaissance Memorandum for more detail.

Based on a literature review and field reconnaissance, historic and pre-historic artifacts have been previously found in the project vicinity on the north side of the river. Archeological test excavations and monitoring are recommended in this portion of the project area. Because the project area on the south side of the river has previously been extensively disturbed by construction activities, it is unlikely that intact archeological will be found and additional testing does not appear to be necessary. See the Archaeological Review and Reconnaissance for the Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study report for more information.

Based on a review of available environmental records and historic information, there is a potential for petroleum, heavy metals, pesticide, and herbicide contamination in the groundwater and soils in the project area on both sides of the river. Any contaminated soil that is removed for the project will need to be disposed of in an appropriate, permitted landfill. Further exploration and sampling are recommended. See the Preliminary Hazardous Materials Corridor Assessment report for more information.

A Clean Water Act Section 404 permit is required for any temporary or permanent fill within jurisdictional waters, except for temporary piling. A Clean Water Act Section 401 Water Quality Certification will be required along with a Section 404 permit. A State Removal/Fill Permit will also be required for any temporary or permanent fill. The Oregon Department of Fish and Wildlife will require a Fish Passage Plan. The project will likely need to meet Endangered Species Act (ESA) and Magnuson-Stevenson Act (MSA) requirements because the project area is designated as Essential Fish Habitat for Chinook and coho salmon. Assuming the pedestrian bridge is placed in the same alignment as the collapsed structure, FHWA is likely to consider this action to fit within a Categorical Exclusion (CE) and thus require CE or Programmatic CE documentation to be completed for NEPA compliance. However, further conversations with FHWA should confirm this assumption.

It is possible that the project can be designed to fit within the criteria for NMFS's programmatic biological opinions, either the Federal Aid Highway Program (FAHP) or Standard Local Operating Procedures for Endangered Species (SLOPES). The FAHP biological opinion can only be used for projects funded by the Federal Highway Administration (FHWA) and administered by Oregon Dept. of Transportation. Without FHWA funding, SLOPES can be used if there is a USACE nexus through a Section 404 permit. A bridge that clear-spans the entire channel will probably be able to use either the FAHP or SLOPES programmatic biological opinion to meet these requirements. A multi-span bridge with piers in the water will probably need an individual Biological

Opinion. See the Environmental Compliance and Permitting Strategy memo for more detail.

UTILITIES

Utility locations have been identified through surveyed utility locates, field observation, as-built drawings provided by the utilities and email correspondence. A brief discussion of the utilities is provided below:

1. Portland General Electric (PGE)

PGE has both aerial transmission and distribution lines crossing the Clackamas River to the east of the proposed bridge. No impact are anticipated on the Gladstone side of the river. On the Oregon City side the side slope for the proposed embankment will impact the PGE utility pole and could result in adjustments being required to multiple poles and not only the one directly affected by the fill. PGE also has a large vault on the Oregon City side that will be impacted due to the project fill limits and would need to be relocated.

The property on the Oregon City side is outside of road right of way. Based on discussions with PGE it expected that their facilities are within a private easement. Any relocation or adjustments to PGE's facilities on the Oregon City side will be reimbursable and paid for by the project.

2. Northwest Natural Gas (NWN)

NWN has facilities within Portland Avenue on the Gladstone side of the proposed bridge. A 4-inch gas line is located within Clackamas Blvd at the north end of the project area. A valve may need adjusted for the proposed multiuse path. No other conflict is anticipated.

3. City of Gladstone: water & sanitary

The City of Gladstone has water facilities within the project area on the north side of the proposed bridge. The multiuse path impacts a fire hydrant and a water meter that would need to be relocated. Manhole lids and valves would also need to be adjusted for any grade change with new pavement.

The City of Gladstone expressed an interest in using the new bridge to carry an 18-inch gravity sewer line. However, the gravity sewer is about 12' deep at Clackamas Blvd. This means the sewer would need to hang below the structure and cross the river at an elevation considerably below the design flood elevation, which is not feasible.

4. City of Lake Oswego: water

The water main transporting water to Lake Oswego is adjacent to the project area, but no impacts are anticipated.

5. Comcast

Comcast has aerial facilities along Portland Ave on the Gladstone side that drop to underground and turn east toward Lake Oswego's water intake. No impacts are anticipated based on the concept design.

6. CenturyLink

CenturyLink has aerial facilities along Portland Ave and Clackamas Blvd providing service drops to homes on Clackamas Blvd. No Impacts are anticipated.

7. Verizon

Currently Verizon is looking at a capital expansion and have an aerial crossing proposed on the PGE pole adjacent to the proposed bridge. This should be tracked if the Trolley Trail Bridge project goes forward.

8. Clackamas County DOT

Clackamas County has aerial communication facilities are attached to the poles used by PGE on the Oregon City side of the bridge. The facilities transition from aerial to underground at the pole closest to the proposed bridge location with a vault located near the pole. These facilities would be impacted by the fill needed for the bridge and would need to be relocated.

PUBLIC INVOLVEMENT

A presentation on the project was given and comments were solicited at the Clackamas County Pedestrian and Bikeway Advisory Committee meeting on October 1, 2019. A public presentation of the project was made to interested citizens at the City of Gladstone's Council Chambers on October 30, 2019. Comments received on the proposed structure types recommended a single-span structure and truss bridge type, reflecting the previous railroad bridge.

GEOTECHNICAL

A geotechnical investigation was conducted which included a review of available existing information, one geotechnical boring, one infiltration test, laboratory testing, preliminary geotechnical analysis, evaluation of subsurface conditions and seismic hazards, and recommended bridge foundation alternatives and lateral earth pressures for design. The boring and infiltration test were located on the south bank of the Clackamas River, near the proposed location of the south bridge abutment. Based on previous studies and the current investigation, the subsurface material at the project site was categorized into geotechnical layers that include fill, sand alluvium, gravel alluvium, Sandy River Mudstone and Columbia River Basalt.

The primary seismic hazard is ground shaking. The potential for liquefaction at the bridge abutments is considered to be low, although the potential for liquefaction may exist at the interior river bents. In accordance with the 2018 Oregon Department of Transportation Geotechnical Design Manual, seismic design parameters were developed for two design events:

- A "Life Safety" event with a 1000-yr return period, in which the bridge, approach structures and foundations may sustain some damage but will not collapse.
- An "Operational" event, defined as a full rupture Cascadia Subduction Zone Earthquake. Under this level of shaking, the bridge and approach sections are designed to remain in service shortly after the event to provide access for emergency vehicles.

The recommended foundation types are driven steel H-piles for the abutments and 6-foot or 8-foot diameter drilled shafts for interior bents in the river. Additional details, including foundation design resistance and lateral earth pressures, are shown in the Preliminary Geotechnical Report. Additional subsurface investigations are recommended at the north abutment and any interior river bents to develop the final design.

STORMWATER MANAGEMENT/DRAINAGE FEATURES

Stormwater from the bridge will flow to the Oregon City side. The project will add over 10,000 square-feet of new impervious area. Stormwater management was evaluated based on Oregon City's "Stormwater and Grading Design Standards" dated February 2015 and updated in 2019. Pedestrian and bicycle improvements do not require water quality treatment according to the standards. Additionally, projects are exempt from the flow control requirement when they are located within the 100-year floodplain or up to 10 feet above the design flood elevation. The project area is within the 100-year floodplain of the Clackamas River. Therefore, no treatment or flow control standards are required for this project.

In addition, the ODOT 2014 *Hydraulics Manual* and Federal Aid Highway Program Programmatic Biological Opinion (FAHP) were reviewed for stormwater management criteria. Projects discharging directly into the Clackamas River are exempt from flow control requirements by both the ODOT *Hydraulic Manual* and FAHP. FAHP does not require water quality for bicycle and pedestrian bridges not associated with a highway.

Although not required for stormwater quality or quantity control, a small rain garden is proposed to provide stormwater infiltration and flow dissipation into the vegetated corridor. Rain gardens are landscaped reservoirs that collect and treat stormwater runoff through vegetation and soil media. The rain garden will be placed near the bridge to allow for stormwater runoff from the bridge to be directed to the rain garden. See the Stormwater Management Concept Design Memorandum for more information.

HYDRAULICS

A hydraulic analysis and scour evaluation were conducted for the proposed bridge alternatives. Seven cross sections were surveyed for this project: two sections downstream of the bridge, one each at the upstream and downstream face of the bridge, and three sections upstream of the bridge. Nine additional cross sections were available from a previous survey conducted by WEST Consultants, Inc. (WEST) and KPFF Consulting Engineers for the Clackamette Park Boat Ramp Project located approximately 1,200 ft downstream of the project site. The cross sections were incorporated into the study to account for backwater associated with the Willamette River and the Highway 99E bridge.

Alternatives 1 and 4 are the same for hydraulic purposes and represent one hydraulic condition, while Alternatives 2, 3 and 5 represent a second hydraulic condition. The governing design condition is the 100-yr flood because the site is in a FEMA floodplain. The existing conditions hydraulic model has been developed, with the following conclusions:

- Upstream face water surface elevation = 48.4 ft. (NAVD88) (backwater condition from Willamette River governs)
- Recommended freeboard = 3 feet due to heavy debris load
- The FEMA Floodway boundary is Elevation 45.6 (NAVD88)
- The FEMA Floodplain boundary is Elevation 47.8 (NAVD88)

Hydraulic evaluations for the proposed bridge alternatives over the Clackamas River demonstrated that neither the 100-year base (design) flood nor the 500-year check flood will overtop the superstructure for any of the proposed alternatives. However, the bottom chord of the superstructure would be submerged approximately 4.5 feet below the 500-year check flood elevation at the south abutment. The 100-year flood is 3.2 and 3.1 feet below the low chord of the bridge for Alternatives 1/4 and 2/3/5, respectively, for the with-backwater conditions. Both Alternatives 1/4 and 2/3/5 will not result in an increase in the FEMA 100-year base flood elevations ("no-rise" condition).

The sediment transport capacity of the Clackamas River is not significantly altered by the proposed bridge alternatives compared to natural (no bridge) conditions. Scour calculations were conducted for 500-year recurrence interval flood. The calculated total scour depth is 8.2 feet for Alternatives 1/4 and 22.8 feet for Alternatives 2/3/5. Bridge substructure will be designed for the appropriate calculated scour depth.

Abutment protection consisting of ODOT Class 2000 riprap is considered necessary for the south abutment. The north abutment will be founded on siltstone bedrock that is moderately resistant to erosion. The stability of the north bank should be evaluated by a geotechnical engineer to determine if additional erosion protection is needed for this location.

See the Bridge Hydraulic Design and Scour Assessment Detailed Report for more information.

RIGHT OF WAY

On the north side of the Clackamas River, the project path will fall within existing right of way along Portland Avenue from Clackamas Blvd. to the river. On the south side of the river, the proposed path falls on land owned by both Water Environmental Services and Urban Renewal Agency of Oregon City, which would need to be acquired for the project. The outlines of the estimated ROW needs are shown on the Concept Plan and Profile sheets. A programming cost estimate for these parcels has been performed.

The State of Oregon Division of State Lands (DSL) requires easements for use of State-owned submersible and submerged land, including uses such as bridges and utility lines. State ownership is determined as navigable and tidally influenced waterways that generally extend from ordinary high water on each side of the waterway. A determination by DSL was made in 2014 that the Clackamas River was tidally influenced up to the Historic Trolley Bridge location. In a conversation with Justin Russel, a Proprietary Coordinator with DSL, DSL confirmed that it does not manage ownership of the Clackamas River at the Historic Trolley Bridge location and a DSL easement will be required.

LOCAL PERMIT NEEDS

The Project would install a new bridge that would span the Clackamas River to carry the Trolley Trail from the City of Gladstone (Gladstone) south to the City of Oregon City (Oregon City). The Project is entirely within the Portland Metro UGB and crosses the Clackamas River floodplain. It crosses two local jurisdictions: Gladstone north of the Clackamas River and Oregon City south of the river. Land use permits from each of these two jurisdictions will be required for the Project. Zoning designations are Single-Family Residential (R-5) and Open Space (OS) in Gladstone; in Oregon City the zoning designations are Mixed Use Downtown (MUD) and General Industrial (GI).

The Project area is located primarily within the floodplain of the Clackamas River and therefore will require avoidance of and mitigation for the natural resources present. Per Title 44 of the Code of Federal Regulations, Section 60.3(d)(3), a local regulatory agency shall prohibit encroachments into the regulatory floodway (100-year floodplain) of a water body "unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the [100-year] flood discharge." Therefore, the Project should complete a no-rise statement supported by technical data and signed and stamped by a registered professional engineer. It is noted that Oregon City's flood management area includes all of the following:

- The area of inundation of the February 1996 flood
- The one hundred-year floodplain, flood area and floodway mapped on the June 17, 2008 FEMA FIRM maps
- Other areas that have physical or documented evidence of flooding (i.e. from aerial photos, etc)

The following permits are anticipated to be required by the City of Gladstone:

- Design Review Permit - §17.80
- Habitat Conservation Area District Development Permit - §17.25
- Flood Management District Development Permit - §17.29
- Water Quality Resource Area District Permit - §17.27

The following permits are anticipated to be required by the City of Oregon City:

- Natural Resouces Overlay District Permit (Type II or III) - §17.49
- Flood Management Area Development Permit (Type II or III) - §17.42
- Removal of trees should demonstrate conformance with Oregon City Municipal Code Chapter 17.41, Tree Protection, Preservation, Removal and Replanting Standards

See the Land Use Permitting Memorandum (Appendix C) for more information.

AESTHETICS

The truss bridge type provides an iconic style that is reminiscent of the historic trolley bridge. Various truss configurations are possible to achieve different aesthetic effects. A constant depth Warren-type truss has been shown, which is consistent with the historic trolley bridge design. The multi-span truss alternative provides a similar aesthetic, but with a shorter height will be less impressive than the very tall truss for the single span alternative.

The multi-span girder bridge alternatives are similar to most typical highway bridges and present a lower degree of inherent aesthetic appeal. The steel girder alternative, with its reduced structure depth, would probably be slightly preferred over the concrete girder alternative. The aesthetic appeal of these structures can be improved with decorative railing designs and the addition of special features such as pylons at the bridge ends and haunched girders. Weathering steel girders naturally develop a pleasing uniform dark brown color over time.

The arch bridge type provides a more dramatic signature style that is generally considered to be visually appealing. An arch bridge would also echo the style of the OR99E bridge over the Clackamas River, just downstream from the project. The visual effect of the arches can be enhanced by tilting the plane of the arches inward or outward.

OTHER CONSIDERATIONS

It is assumed that retaining walls will not be required to support the raised path elevation, other than the wingwalls that are part of the abutments.

Site access and construction activities required for each structure type need to be evaluated to make sure they are constructible. The evaluation of site access needs to consider any limitations of the vehicle size and delivery route for materials that can feasibly be delivered to the site. This evaluation should be included in the final design phase so that potential access routes can be included in the bid documents and permit applications.

Cranes will need to be placed near the bridge ends to facilitate construction of the abutments erection of structure components. Careful placement of the cranes will be required to avoid interference with the power lines located near the bridge. For the intermediate bents in the water, temporary cofferdams will need to be provided during construction. Temporary bridge structures will probably be needed to access the bents in the water.

The single span structures are likely to require temporary bents in the water to support portions of the structure during erection. Temporary bridge structures will probably be required to access and install the temporary support bents.

Duration of construction will be affected by the permitted in-water work window for the Clackamas River. It is likely that the construction will extend over two seasons to accomplish all of the in-water work, including removal of temporary structures. The single-span truss and tied arch alternatives have more complex members that will take longer to fabricate, but this is mitigated by avoiding construction of permanent piers in the water.

Maintenance requirements are likely to be minimal, such as periodic cleaning and minor repairs, and are similar for all of the alternatives. The steel structures will utilize weathering steel, so painting will not be necessary. Concrete deck and substructure will utilize high performance concrete for improved durability.

While not mandated by federal or state regulations, inspection of the bridge at regular intervals by a qualified bridge inspection professional is recommended. A 48-month inspection interval is probably sufficient as long as the bridge does not have significant deterioration or other conditions that warrant a more frequent inspection.

STRUCTURE CONSTRUCTION COST ESTIMATE

Concept-level cost estimates have been developed for each structure alternative. The approximate structure-only costs shown below are based on current 2019 dollar values and do not include allowances for mobilization, engineering and contingencies.

Structure Alternative	Estimated Cost/ Sq. Ft.	Estimated Structure Construction Cost
Alt. 1 - Single Span Steel Truss	$400	$2,628,000
Alt. 2 - 3-Span P/S Concrete Girder	$250	$1,643,000
Alt. 3 - 3-Span Steel Girder	$260	$1,709,000
Alt. 4 – Single Span Tied Steel Arch	$700	$4,600,000
Alt. 5 – 3-Span Steel Truss	$320	$2,102,000

TOTAL CONSTRUCTION COST ESTIMATE

A total concept-level construction cost estimate including non-structural work items as well as mobilization, construction engineering, administration and contingencies is included in Appendix D. Costs for engineering for final design and permitting, ROW acquisition and utility relocation are not included in this estimate. Due to design currently only being at a conceptual level, a contingency of 30% has been added in addition to 10% mobilization and 15% for construction engineering and administration. The estimated cost ranges from $2.8M for Alternative 2 to $7.4M for Alternative 4.

RECOMMENDATIONS

The table below summarizes the attributes of each structure type for certain key criteria.

Structure Alternative	Permitting	Aesthetics	Geometrics (Grade)	Right of Way Need	Cost
Alt. 1 - Single Span Steel Truss	Good	Good	Good	Lower	High
Alt. 2 - 3-Span P/S Concrete Girder	Average	Below Average	Below Average	Higher	Low
Alt. 3 - 3-Span Steel Girder	Average	Average	Average	Average	Low
Alt. 4 – Single Span Tied Steel Arch	Good	Excellent	Good	Lower	Very High
Alt. 5 – 3-Span Steel Truss	Average	Good	Good	Lower	Moderate

If funding is available, and a more historically appropriate bridge is desired, the 3-span truss alternatives would be a good choice with less cost than the single span truss. A signature bridge, such as the arch, makes a stronger visual statement but at a higher cost. If funding is limited, the 3-span steel girder alternative would be the preferred choice since its geometrics, aesthetic and right of way characteristics are better, while cost is just slightly more than the concrete girder alternative.

DAVID EVANS AND ASSOCIATES INC

Appendix A: Design Criteria Matrix

Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study
Clackamas County
Roadway Engineering Design Standard Summary
Date: April 17, 2019

County Project Number: 22265
Prepared by: Pegah Alavi
David Evans and Associates, Inc.
Length: 600 LF

Design Standards:	2011 Oregon Bicycle and Pedestrian Design Guide (OBPDG) 2012 AASHTO Guide for the Development of Bicycle Facilities 2009 Manual of Uniform Traffic Control Devices (MUTCD) AASHTO LRFD Bridge Design Specifications 8th Edition AASHTO Guide Specifications for Pedestrian Bridges 1st Edition ADA Accessibility Guildlines (ADAAG)
Highway Category:	N / A
Expressway	N / A
Terrain:	Generally Flat. Sloped to Bridge Abutments
Functional Class:	Multi-use Transportation Facility
NHS:	N / A
State Classification:	N / A
Work Type:	Feasibility Study (Shared-use bridge with potential for emergency vehicle access)
ADT (Two- Way)	N / A
% Trucks	N / A

DESIGN STANDARD SUMMARY

map	Standard	Comments
Design Speed	20 mph	AASHTO Bicycle Facilities Guide, Section 5.2.4
Lane Width	12' (OBPDG), 10-14' (AASHTO)	OBPDG, Page 7-7. AASHTO Bicycle Facilities Guide, Section 5.2.1. (11' is recommended for comfortable passing)
Shoulder Width (Right)	2'	OBPDG, Page 7-7 and 7-9, and AASHTO Bicycle Facilities Guide, Section 5.2.1 Width and Clearance, Figure 5-1
Shoulder Width (Left)	2'	OBPDG, Page 7-7 and 7-9, and AASHTO Bicycle Facilities Guide, Section 5.2.1 Width and Clearance, Figure 5-1
Bridge Railing	42 in. min, 48 in. recommended	OBPDG, Page 7-9, and AASHTO Bicycle Facilities Guide, Section 4.12.3
Bridge Width	16' Clear	OBPDG, Page 7-11
Horizontal Alignment	AASHTO Bicycle Facilities Guide, See Section 5.2.5	
• Degree of Curve (Min.)	74 ft	AASHTO Bicycle Facilities Guide, Section 5.2.5, Table 5-2. Lean Angle= 20-Degree. Cross slope can follow the direction of the existing terrain
• K crest (Min)	AASHTO Bicycle Facilities Guide, Section 5.2.8, Figure 5-8	
• K sag (Min)	N/A	No K sag requirements for bicycle facilities
• Grade (Max)	5%	OBPDG, Page 7-7
• Grade (ADA Max)	5%	OBPDG, Page 7-7, and ADAAG
Stopping Sight Distance (Min)	Dependent on grade	AASHTO Bicycle Facilities Guide, Section 5.2.8, Table 5-4
Pavement Cross Slope	2% (Max)	AASHTO Bicycle Facilities Guide, Section 5.2.6, and ADAAG
Superelevation (Max)	Not Needed	AASHTO Bicycle Facilities Guide, Section 5.2.6
Overhead (Vertical) Clearance	16 ft (Min)	ODOT Hwy Design Manual (Non-National Highway System routes), Section 4.5.1
Bridge Vertical Clearance Above River	3 ft above 100-year flood elevation	ODOT Hydraulic Manual (2014), Section 10.4.3
Design Vehicle	H-12 Truck	24,000 lb. City of Gladstone squad vehicle

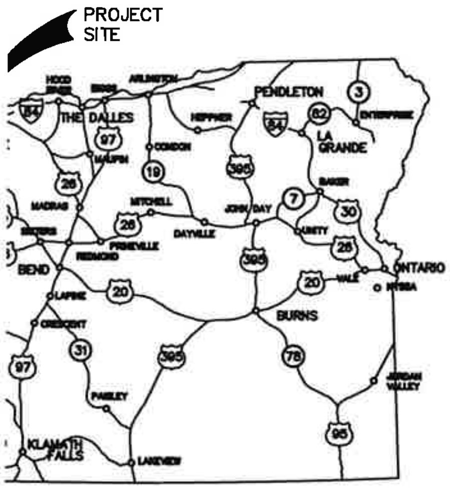
DAVID EVANS AND ASSOCIATES INC

Appendix B: Design Concept Alternative Plans

GLADSTONE TO OREGON CITY FEASIBILITY STUDY

CLACKAMAS COUNTY OREGON
PLANS FOR PROPOSED PROJECT

PROJECT SITE



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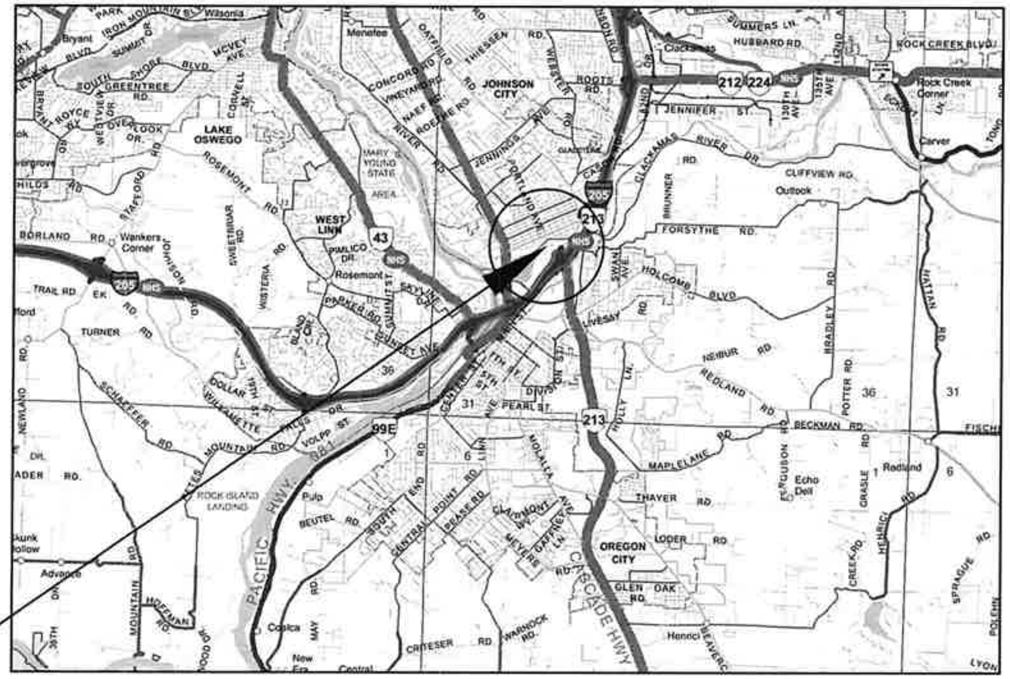


PROJECT SITE

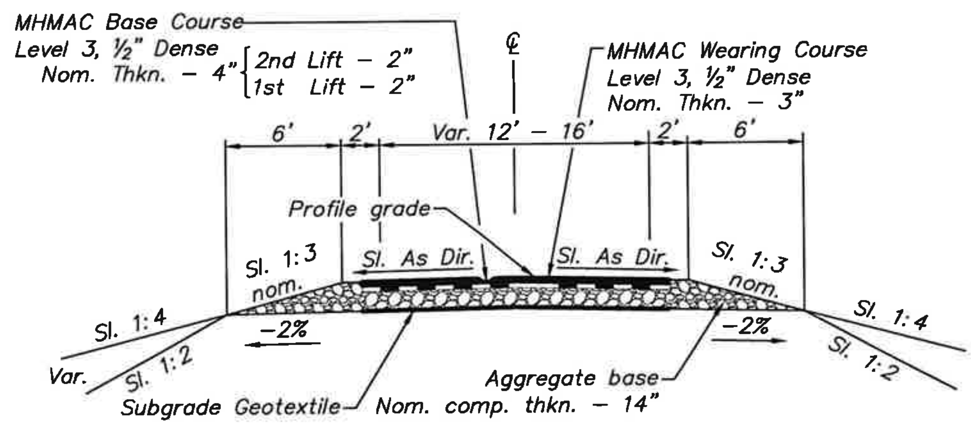
S. 36 T. 2 S, R. 2 E., W.M.

VICINITY MAP
NOT TO SCALE

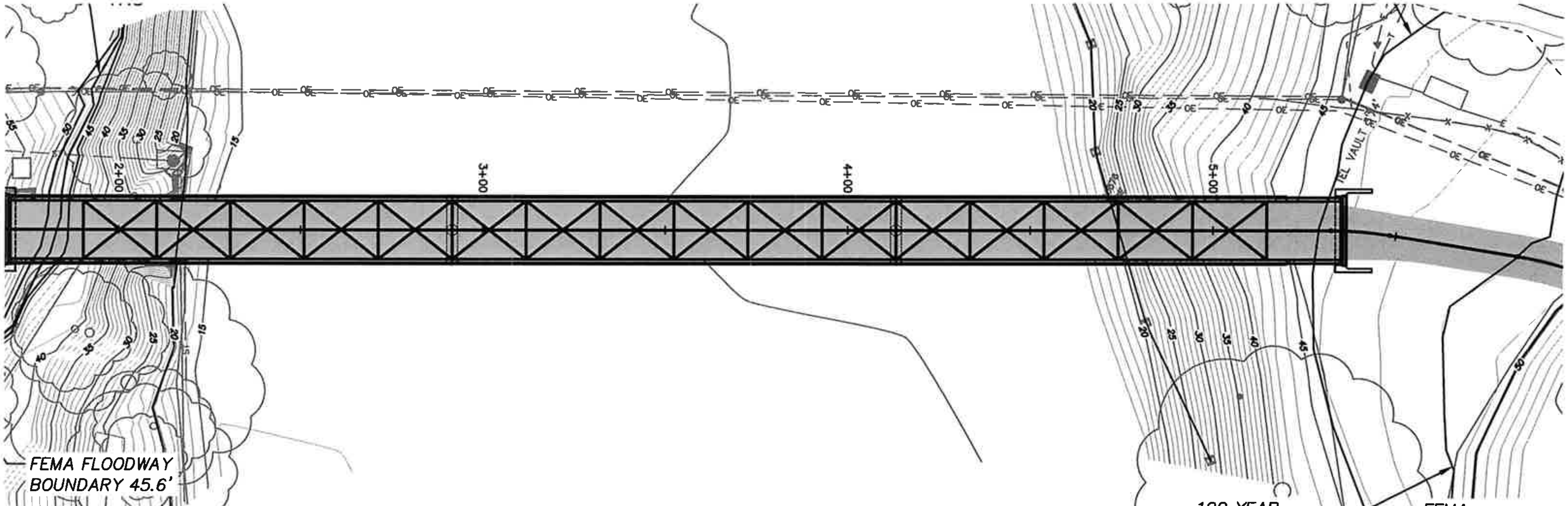
LEGEND

	EXISTING
MAJOR CONTOUR	
MINOR CONTOUR	
ORDINARY HIGH WATER (OHW) (PROJECTED)	
RIGHT OF WAY (ROW)	

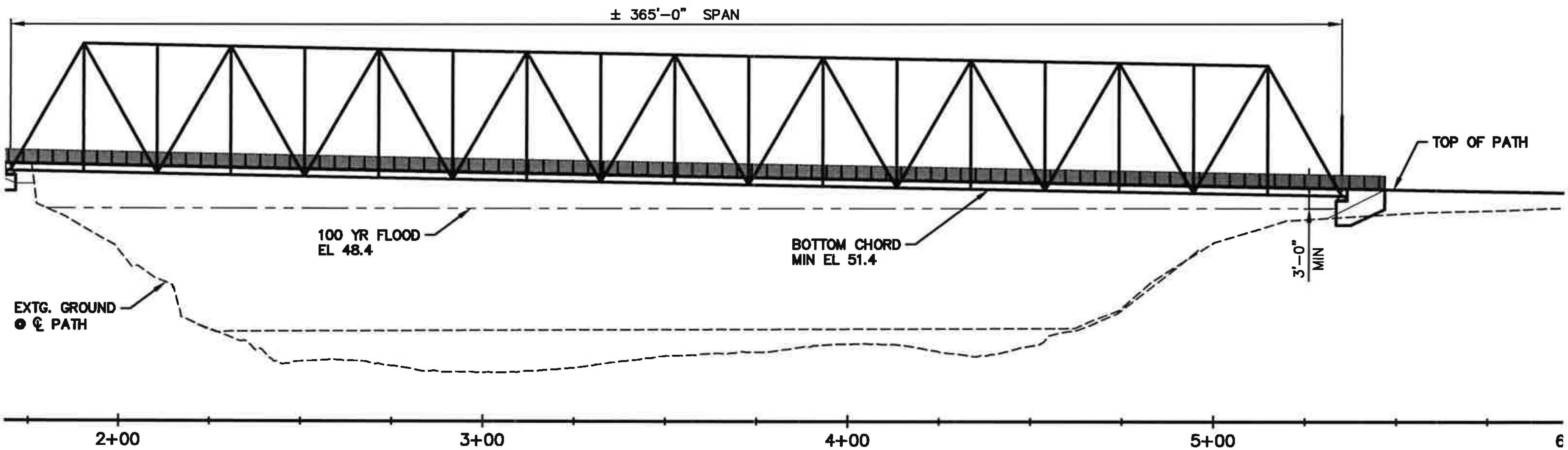
SHEET INDEX



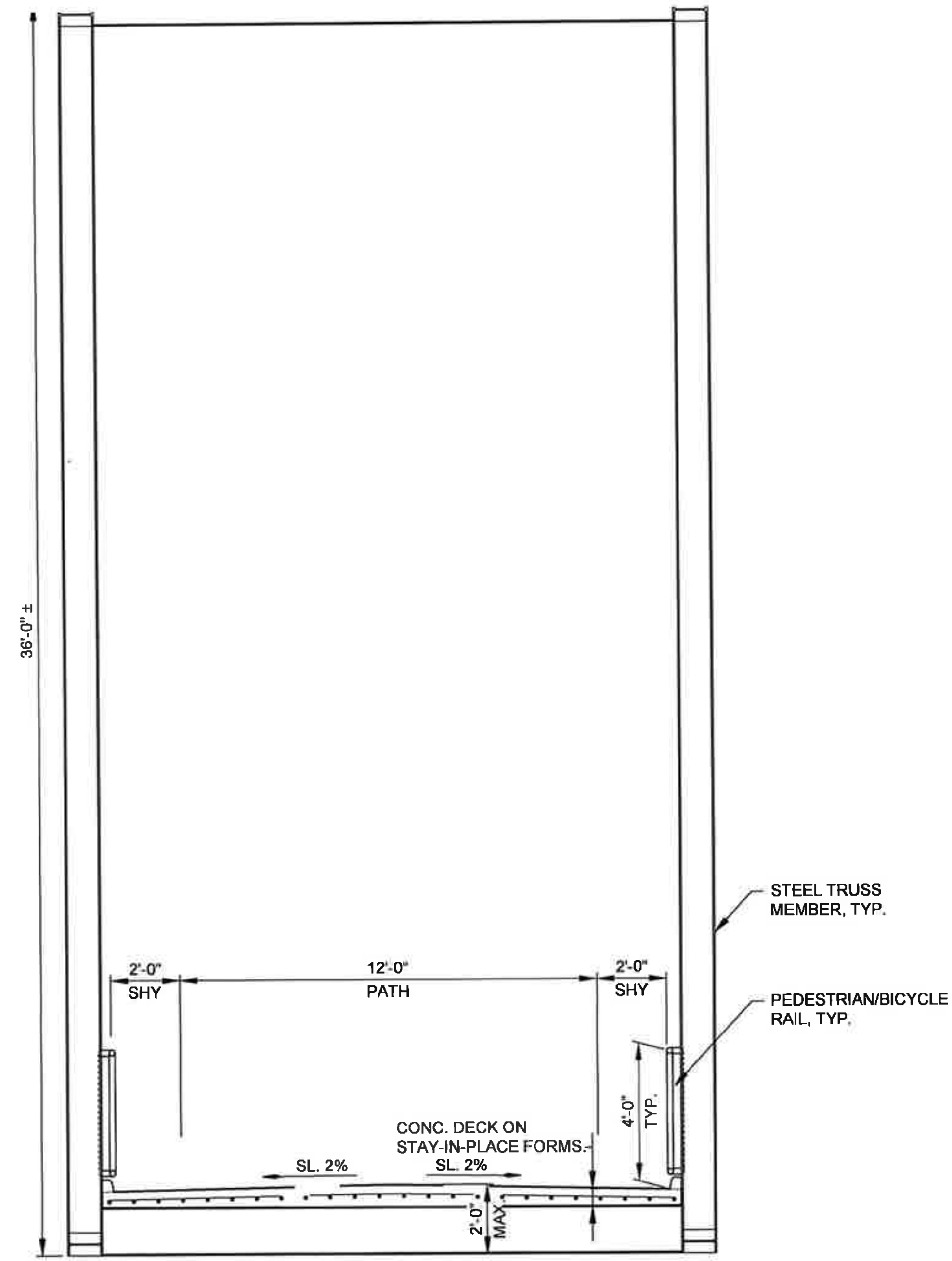
STA. 1+00 To STA. 1+69
1+69 To. 5+34 (Structure)
5+34 To. 6+58



PLAN
SCALE: 1"=20'-0"

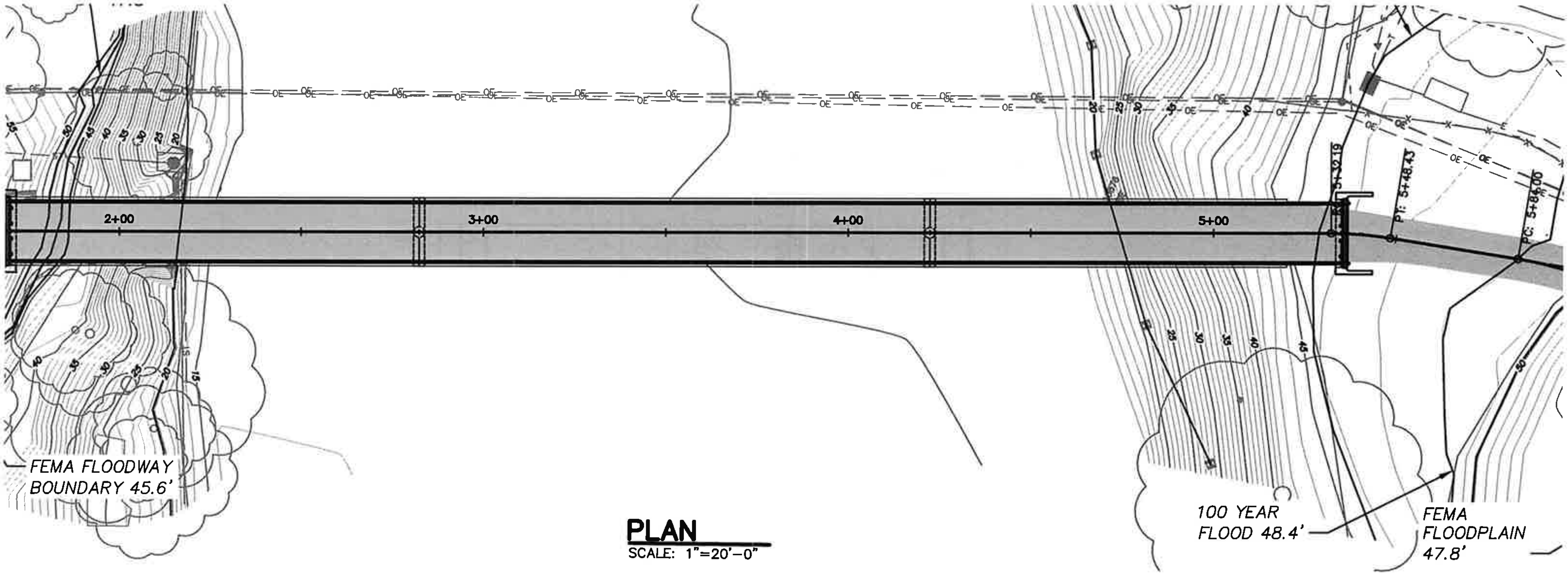


ELEVATION

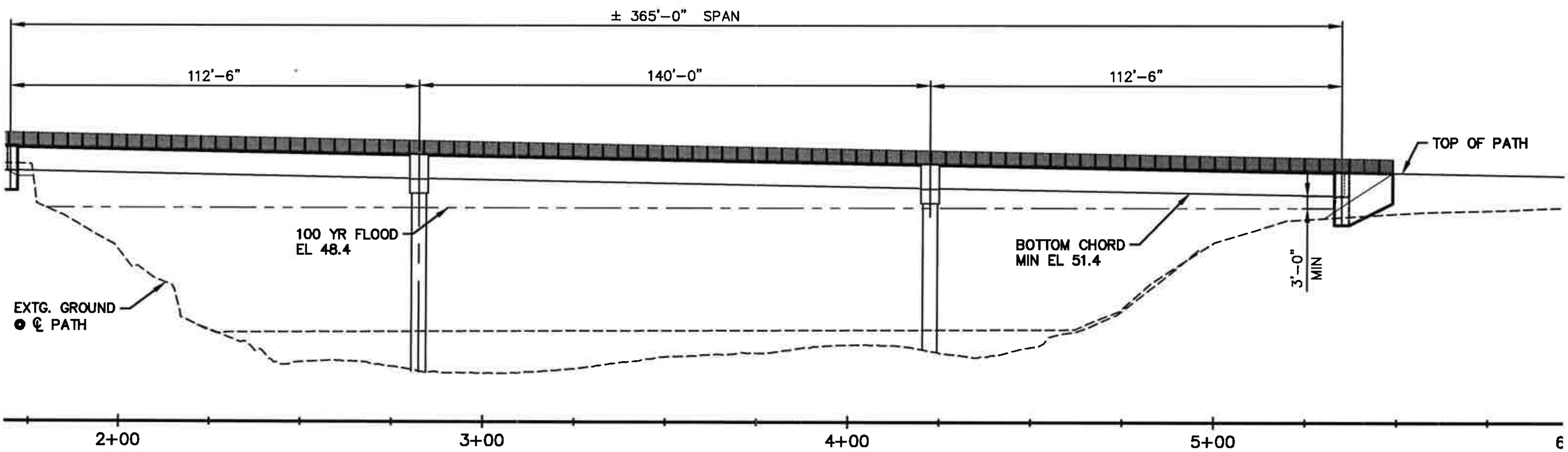


STEEL TRUSS TYPICAL SECTION (ALTERNATIVE 1)

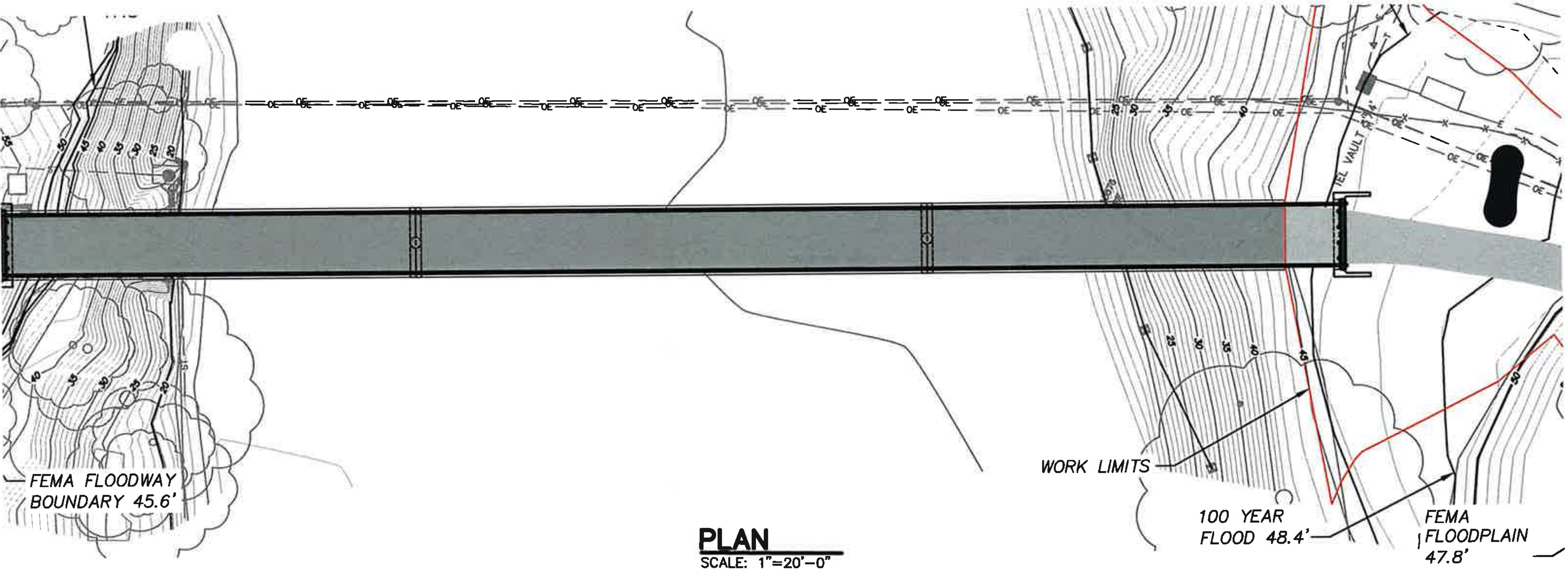
SCALE: 3/8"=1'-0"



PLAN
SCALE: 1"=20'-0"



ELEVATION



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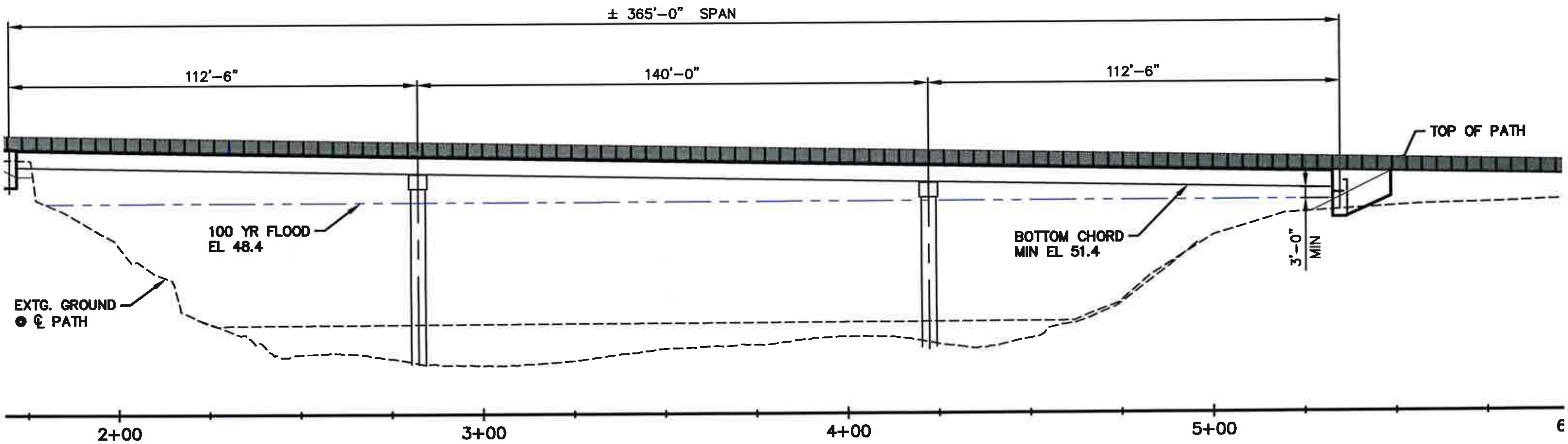
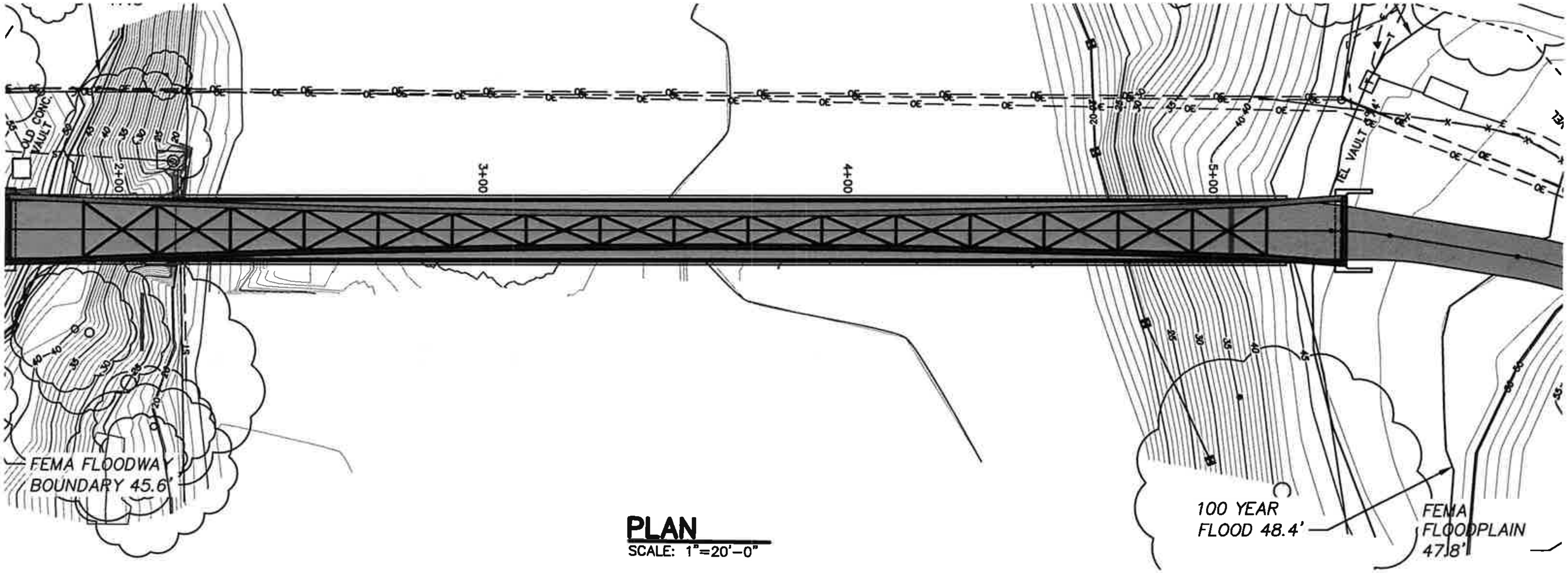
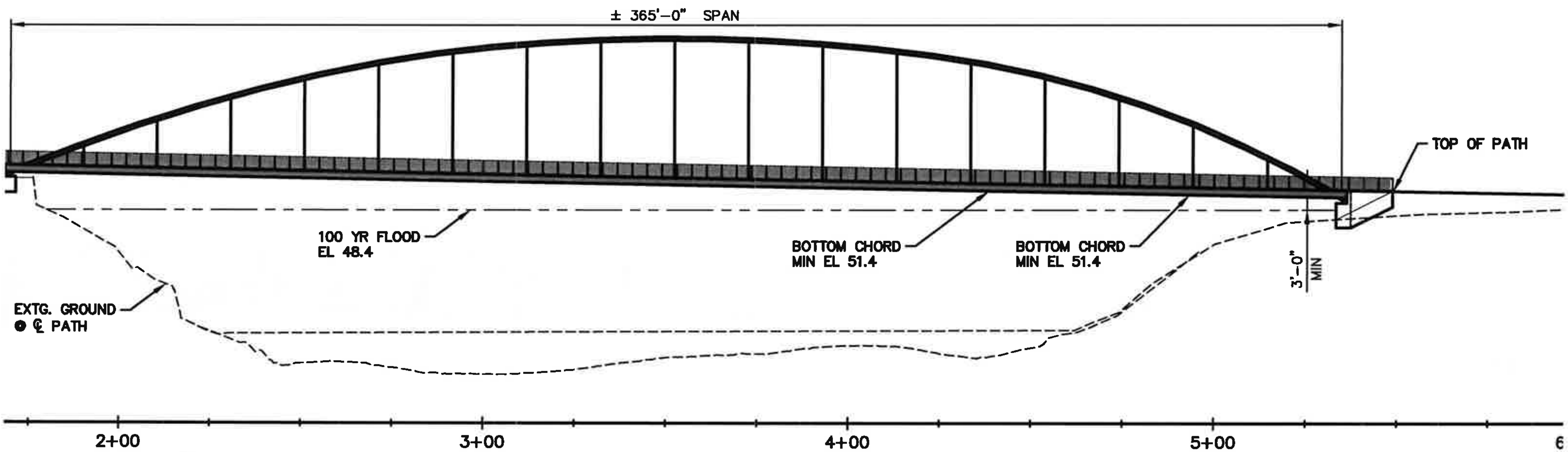
SCALE: 1"=20'-0"



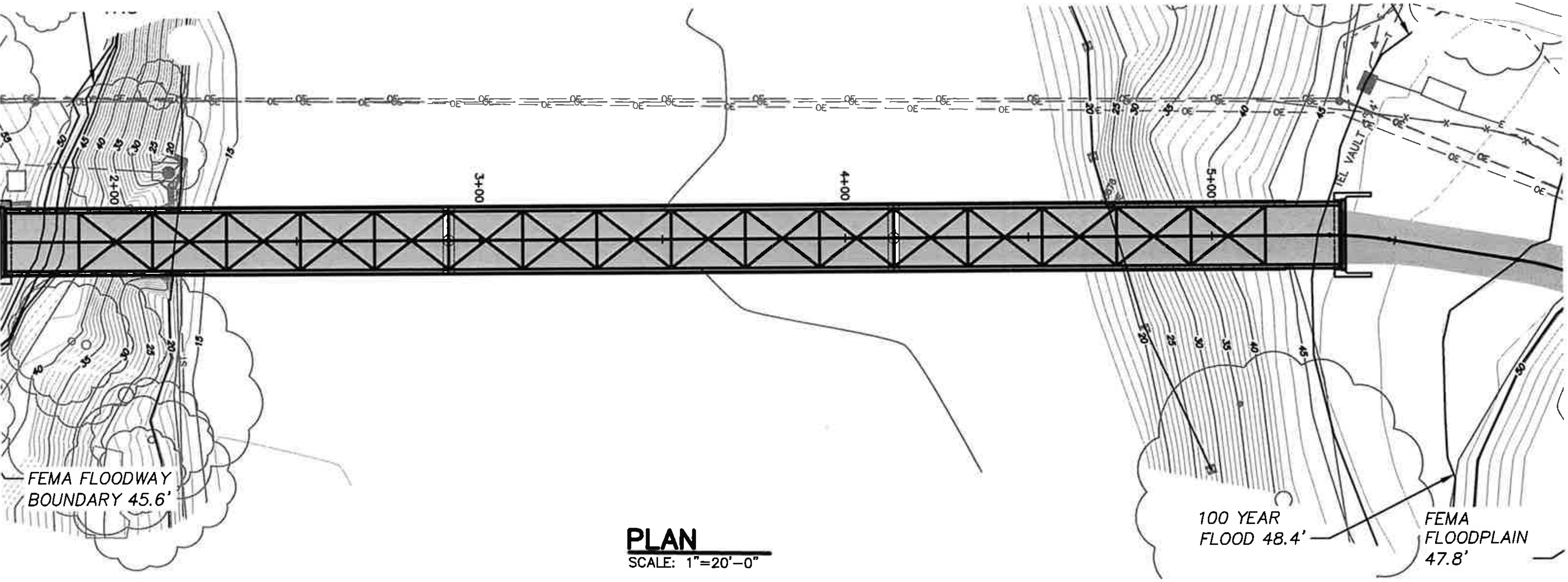
ELEVATION



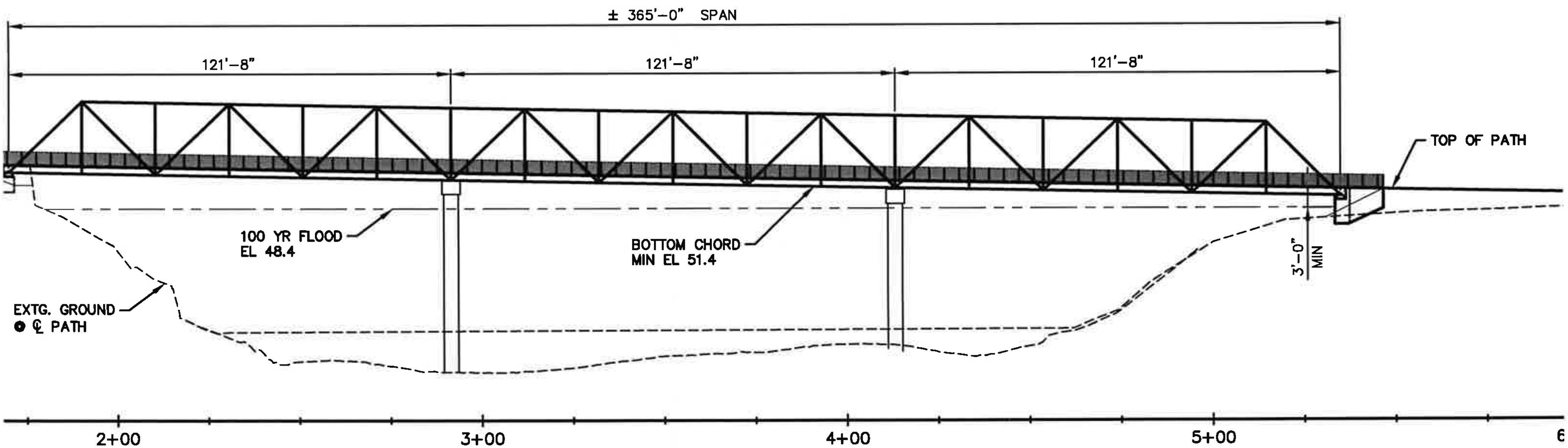
PLAN
SCALE: 1"=20'-0"



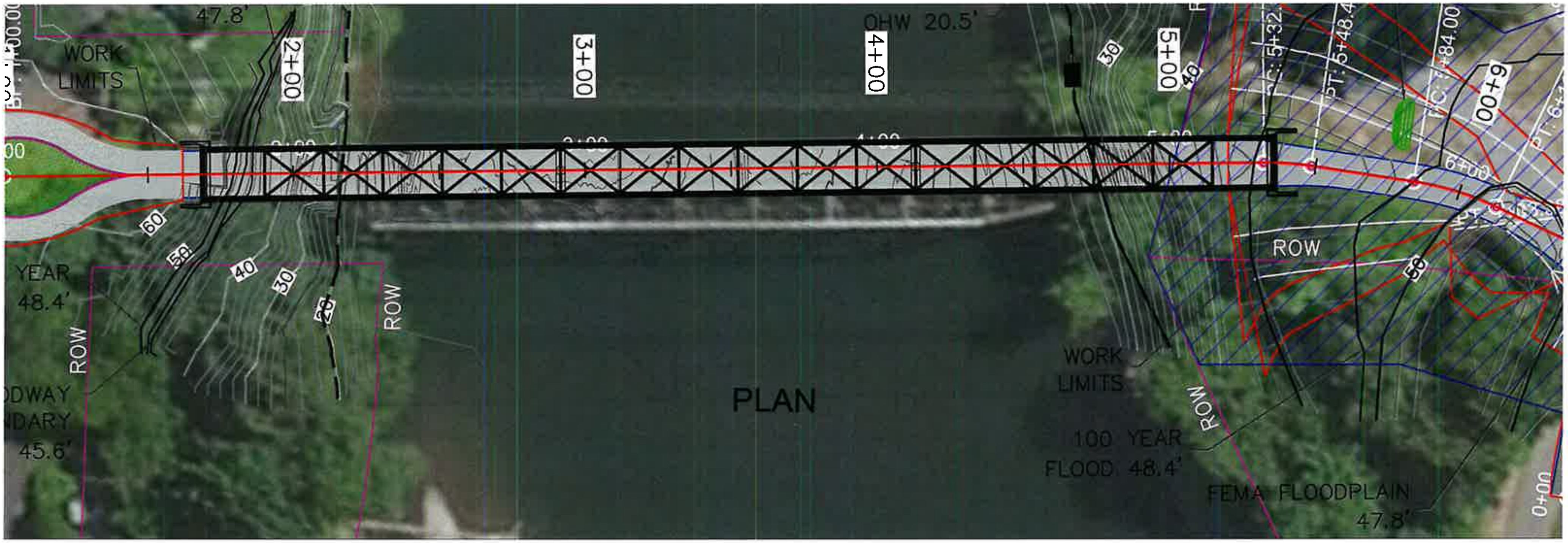
ELEVATION



PLAN
SCALE: 1"=20'-0"

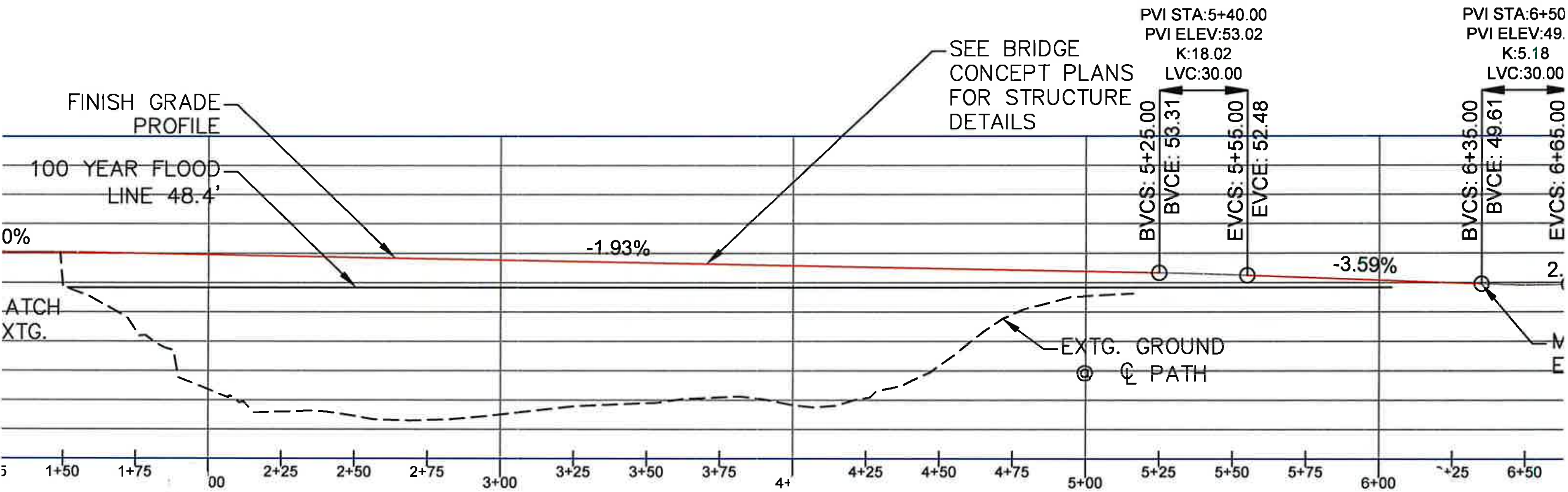


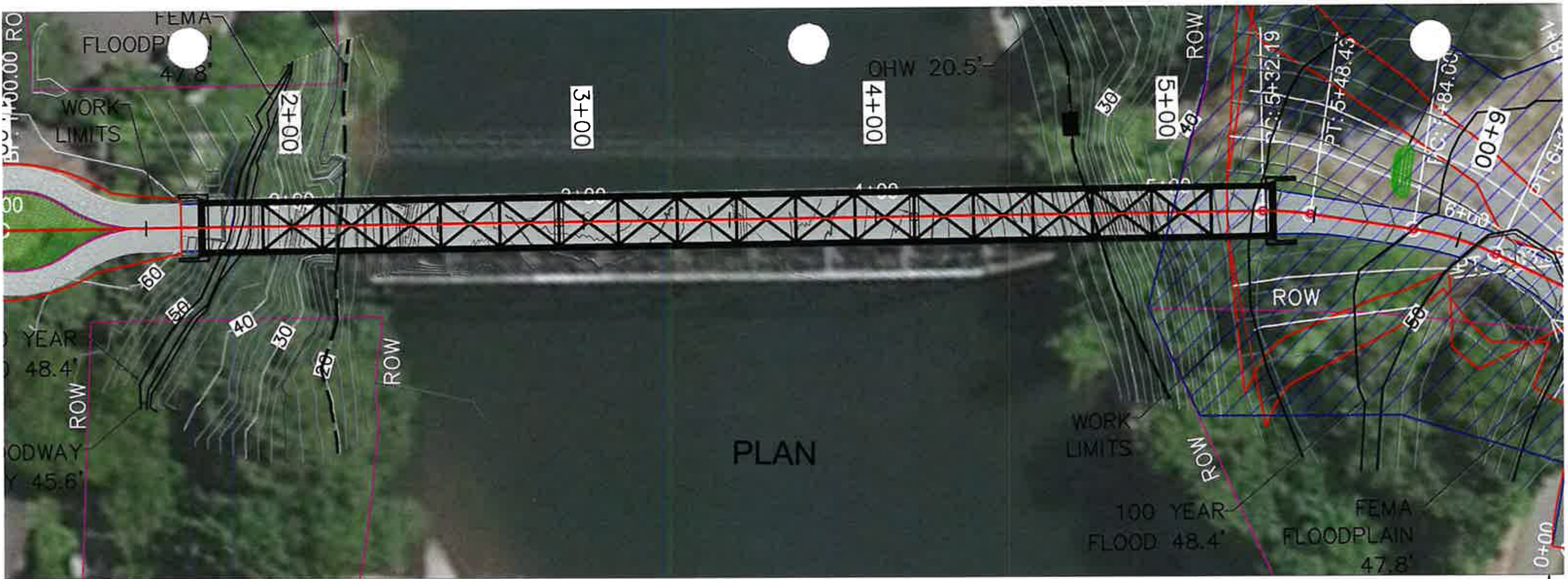
ELEVATION



Legend

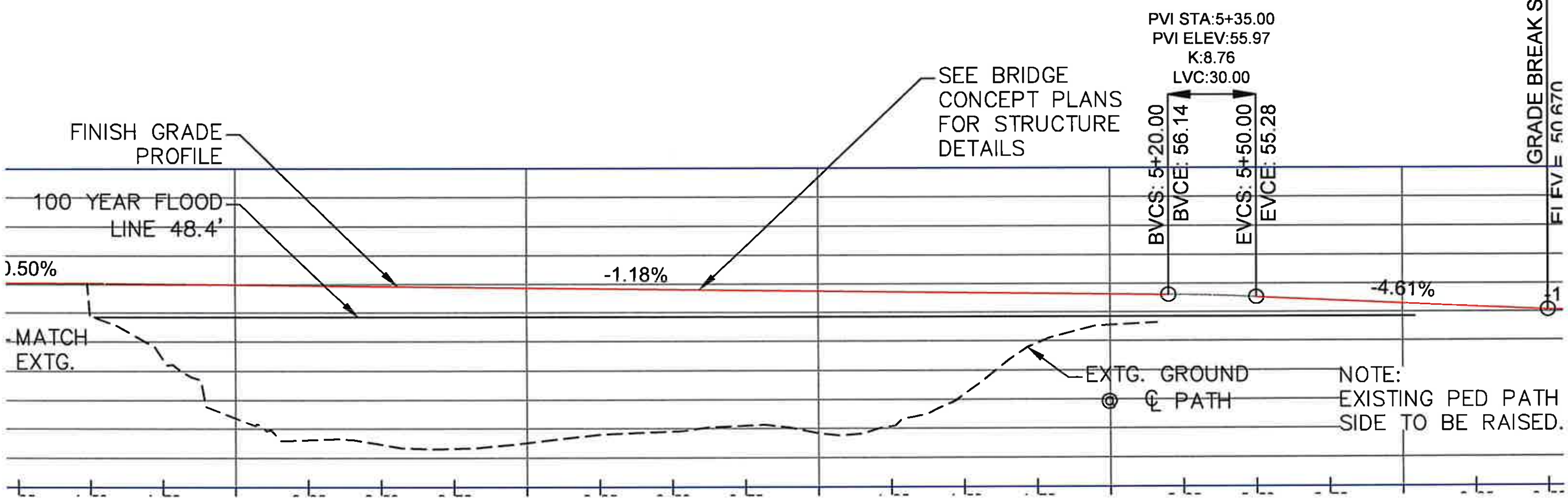
ROW Impacts

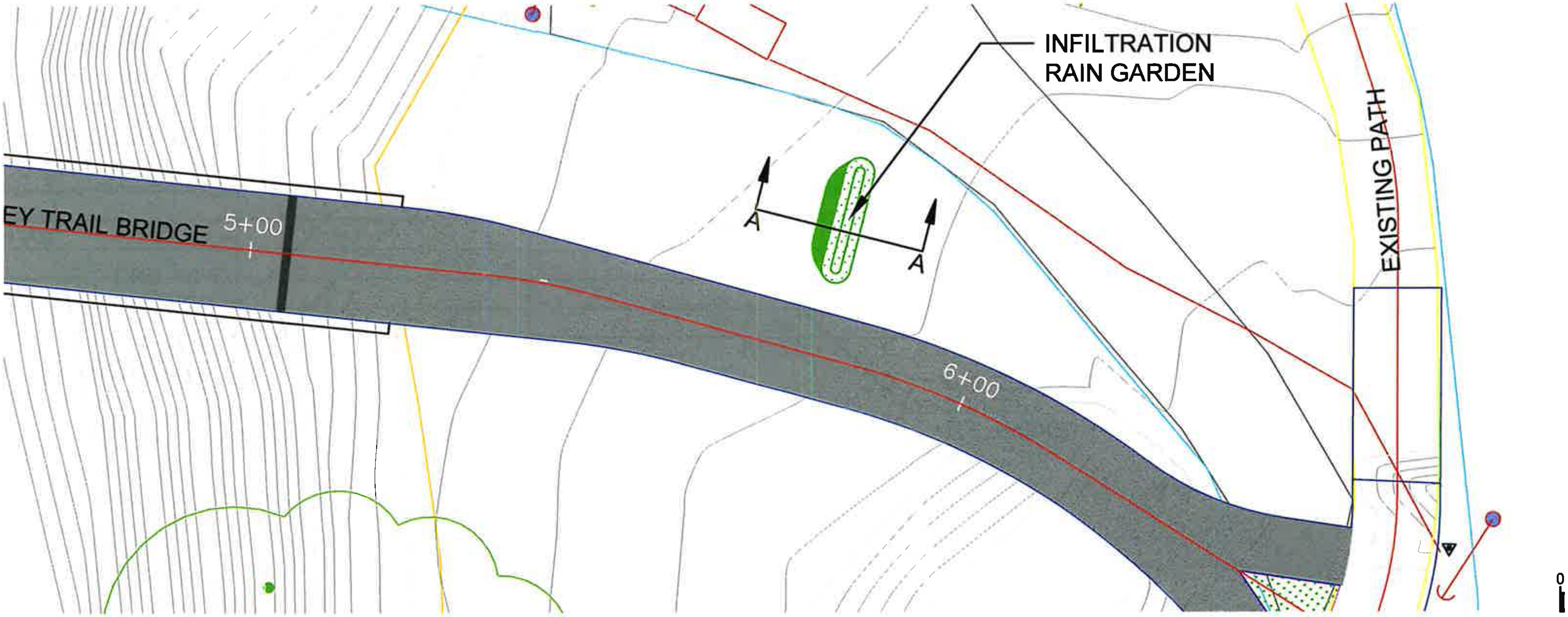




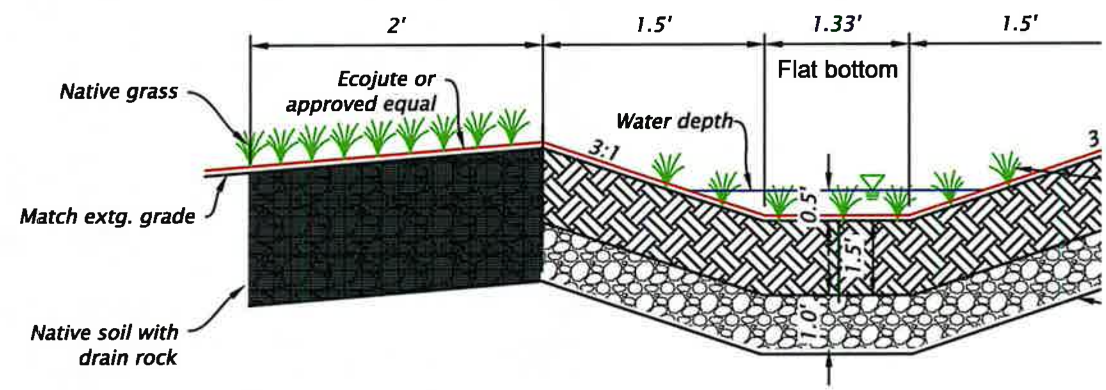
Legend

ROW Impacts





PLAN



INFILTRATION RAIN GARDEN SECTION A-A
N.T.S

DAVID EVANS AND ASSOCIATES INC

Appendix C: Land Use Permitting Memorandum

LAND USE PERMITTING

The Project would install a new bridge that would span the Clackamas River to carry the Trolley Trail from the City of Gladstone (Gladstone) south to the City of Oregon City (Oregon City). The Project is entirely within the Portland Metro UGB and crosses the Clackamas River floodplain. It crosses two local jurisdictions: Gladstone north of the Clackamas River and Oregon City south of the river. Land use permits from each of these two jurisdictions will be required for the Project. Zoning designations are Single-Family Residential (R-5) and Open Space (OS) in Gladstone; in Oregon City the zoning designations are Mixed Use Downtown (MUD) and General Industrial (GI).

1. Land Use Considerations

The Project area is located primarily within the floodplain of the Clackamas River and therefore, will require avoidance of and mitigation for the natural resources present. Per Title 44 of the Code of Federal Regulations, Section 60.3(d)(3), a local regulatory agency shall prohibit encroachments into the regulatory floodway (100-year floodplain) of a water body "unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the [100-year] flood discharge." Therefore, the Project should complete a no-rise statement supported by technical data and signed and stamped by a registered professional engineer.

Between the time of the preparation of this report and the submission of the land use permit and review applications, the cities could amend their codes and plans. Before submitting the applications, the project team will need to review updates to ensure compliance with any amendments.

Additional evaluation will be needed if the Trolley Trail Bridge needs to be substantially realigned or additional structures are needed.

2. Permit Timing

As listed in Table 1 and Table 2, land use permit reviews by each of the cities can extend up to 120 days, after a 30-day completeness review period. While most jurisdictions process land use permit applications in less time than the allowed 120 day window, it is reasonable to expect a 6-month land use permitting process when accounting for all review timelines, application preparation and response time. This timeline does not include the potential for appeals to the permit.

Land use permits and review approvals are valid only for two years to four years, with possible extensions. A building permit must be issued and substantial development must occur prior to the two-year (or extended) deadline. Therefore, the Project would not submit an application until the Project is close to construction.

3. Gladstone

Base Zoning

The majority of the Project within Gladstone would be within existing right-of-way of Portland Avenue and West Clackamas Boulevard. Adjacent parcels are zoned Single-Family Residential (R-5) and Open Space (OS).

Single-Family Residential (R-5)

A portion of the Project area that would be located within Gladstone is zoned Single-Family Residential (R-5). As stated in the Gladstone Municipal Code, "The purpose of an R-5 district is to implement the comprehensive plan and to provide land for families and individuals desiring to live in an environment of medium density, mixed single-family and multi-family dwellings."

Open Space (OS)

East of the existing alignment of SW Portland Avenue is the Charles Ames Memorial Park which is zoned Open Space (OS). As stated in the Gladstone Municipal Code, "The purpose of an OS district is to implement the comprehensive plan and to provide and preserve open space areas for use and enjoyment of the public."

Overlay Zoning

The Project alignment is within locally mapped State Planning Goal 5 resource sites: Riparian Wildlife Habitat Classes I and II. There is also a locally significant wetland located immediately east of the project alignment. The project is within the Federal Emergency Management Agency (FEMA)-mapped 100-year floodplain.

Habitat Conservation Area District

The Trolley Trail Bridge crosses a Gladstone Habitat Conservation Area District which covers the Clackamas River and its surrounding riparian area. Replacement structures are exempt from the requirement to obtain a Habitat Conservation Area Permit if the replacement has been lawfully commenced (e.g. applied for a land use or building permit) within one year of the date that the original structure was disassembled (Gladstone Municipal Code, Section 17.25.040(F)). Since more than one year has elapsed since the collapse of the original Trolley Trail Bridge in 2014, the Project would not be exempt from the requirement to obtain a Gladstone Habitat Conservation Area District Permit. Submittal requirements include a detailed construction management plan, Habitat Conservation Area Map Verification, and mitigation plan in accordance with Gladstone Municipal Code, Section 17.25.070.

Flood Management Area District

The project area is within the FEMA-mapped 100-year floodplain of the Clackamas River. Therefore, the Gladstone Flood Management Area District applies per Section 17.29.030 of the Gladstone Municipal Code. A Flood Management Area District Permit would be required to construct the project.

Water Quality Resource Area District

Water Quality Resource Area Districts include wetlands and streams, per Section 17.27.020 of the Gladstone Municipal Code. Since the project is over or adjacent to such areas, it is likely a Water Quality Resource Area District Permit would be required to construct the project.

Anticipated Land Use Approvals and Permits

Table 1 lists, for the City of Gladstone, the approval timeline, key standards and criteria, whether a public notice and/or public hearing is required, and the decision maker for each potential type of permit and review process.

Planning Commission Decision Making Procedure

The Planning Commission Decision Making Procedure begins with the applicant's submittal of a complete application on forms prescribed by Gladstone. After the application has been deemed compelte, notice will be sent to stakeholders. The proposal will be presented to the Planning

Commission at a hearing. The Planning Commission approves, approves with conditions, or denies the requested in writing based on the relevant approval criteria in the Gladstone Municipal Code.

Table 1: Gladstone Land Use Permit and Review Procedures

Potential Permits	Permit/Review Process	Approval Timeline[1]	Permit Standards and Criteria[2]	Public Notice and Hearings	Decision Maker	Expiration
Design Review Permit §17.80	Planning Commission Decision	120 calendar days	Per 17.80.021.3, compliance with standards that apply to base zone	Notice; public hearing	Planning Commission	Valid for maximum of two years with extension possible
Habitat Conservation Area District Development Permit §17.25	Planning Commission Decision	120 calendar days	Disturbance area limitations per 17.25.100	Notice; public hearing	Planning Commission	Valid for maximum of two years with extension possible
Flood Management District Development Permit §17.29	Planning Commission Decision	120 calendar days	Per 17.29.100, balance fill with cut within the floodplain	Notice; public hearing	Planning Commission	Valid for maximum of two years with extension possible
Water Quality Resource Area District Permit §17.27	Planning Commission Decision	120 calendar days	Per 17.27.045, no practicable alternatives	Notice; public hearing	Planning Commission	Valid for maximum of two years with extension possible

[1]After a 30-day completeness review.
[2]City of Gladstone 2019

4. Oregon City

Base Zoning

The Project area within Oregon City is zoned Mixed Use Downtown (MUD) and General Industrial (GI).

Mixed-Use Downtown (MUD)

A portion of the Project area that would be located within Oregon City is zoned Mixed Use Downtown (MUD). The following are intended land uses within the MUD zoning designation:

> *Land uses are characterized by high-volume establishments constructed at the human scale such as retail, service, office, multi-family residential, lodging or similar as defined by the community development director. A mix of high-density residential, office and retail uses are encouraged in this district, with retail and service uses on the ground floor and office and residential uses on the upper floors. The emphasis is on those uses that encourage pedestrian and transit use. (OCMC Section 17.34.010)*

Transportation facilities are a permitted use in the MUD per OCMC Subsection 17.34.020.Y.

General Industrial (GI)

A portion of the Project area that would be located within Oregon City is zoned General Industrial (GI). The purpose of the GI zoning district is "...to allow uses relating to manufacturing, processing, production, storage, fabrication and distribution of goods or similar as defined by the community development director." Transportation facilities are a permitted use per OCMC Subsection 17.36.020.N.

Overlay Zoning

The Project is within the Oregon City Flood Management Overlay District (FMOD) and the Natural Resource Overlay District (NROD). The FMOD applies to all areas of the mapped FEMA floodplain (100-year floodplain). Within the Project area, the NROD applies to roughly the same area as the 100-year floodplain.

Flood Management Overlay District

The Flood Management Overlay District applies to all areas of special flood hazard within the jurisdiction of the Oregon City, per OCMC Section 17.42.010. The purpose of the Flood Management Overlay District is:

> *1. To protect human life and health; To minimize expenditure of public money and costly flood control projects; To minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;*
>
> *2. To minimize prolonged business interruptions;*
>
> *3. To minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets and bridges located in areas of special flood hazard;*
>
> *4. To help maintain a stable tax base by providing for the sound use and development of areas of special flood hazard so as to minimize future flood blight areas;*
>
> *5. To ensure that potential buyers are notified that property is in an area of special flood hazard;*
>
> *6. To ensure that those who occupy the areas of special flood hazard assume responsibility for their actions; and*

7. To protect flood management areas, which provide the following functions:

a. Protect life and property from dangers associated with flooding;

b. Flood storage, reduction of flood velocities, reduction of flood peak;

c. Flows and reduction of wind and wave impacts;

d. Maintain water quality by reducing and sorting sediment loads;

e. Processing chemical and organic wastes and reducing nutrients, recharge, store and discharge groundwater; and

f. Provide plant and animal habitat, and support riparian ecosystems.

A development permit is required for construction within the Flood Management Overlay District. Application requirements include a delineation of the flood management areas on the development site (OCMC Section 17.42.080).

Natural Resource Overlay District (NROD)
The natural riparian area south of the Clackamas River is designated NROD in the Oregon City Comprehensive Plan per the Natural Resource Overlay District map.

Per OCMC Section 17.49.010, the purpose of the NROD is:

A. Protect and restore streams and riparian areas for their ecologic functions and as an open space amenity for the community.

B. Protect floodplains and wetlands, and restore them for improved hydrology, flood protection, aquifer recharge, and habitat functions.

C. Protect upland habitats, and enhance connections between upland and riparian habitat.

D. Maintain and enhance water quality and control erosion and sedimentation through the revegetation of disturbed sites and by placing limits on construction, impervious surfaces, and pollutant discharges.

E. Conserve scenic, recreational, and educational values of significant natural resources.

New trails and bridges are subject to a Type II review process per OCMC Subsections 17.49.100.E and F.

Comprehensive Plan Designations

The Project area is in an area that is designated Public/Quasi Public (QP) on the Oregon City Comprehensive Plan Map (adopted July 1, 2009). Public and Quasi-Public lands are, "publicly owned lands other than city parks, such as schools, cemeteries, undeveloped lands, open space, government buildings and public utility facilities, such as the sewage treatment plant and water reservoirs."

Surrounding Uses

In Oregon City, the surrounding properties to the south are zoned the same as the Project area, Mixed Use Downtown and General Industrial. Much of the surrounding land is undeveloped natural space. The

Tri-City Wastewater Treatment Plant is just southeast of the Project area, which serves Gladstone, Oregon City, and West Linn.

Anticipated Land Use Approvals and Permits

Table 2 lists the approval timeline, key standards and criteria, whether a public notice and/or public hearing is required, and the decision maker for each potential type of permit and review process.

Tree Preservation and Protection

Removal of trees should demonstrate conformance with Oregon City Municipal Code Chapter 17.41, Tree Protection, Preservation, Removal and Replanting Standards. A survey of all trees that are at least six inches in diameter at breast height and an arborist report for any trees that are dead, dying, diseased, or hazardous may be required. The tree replacement standards contained in Table 17.41.060-1 may apply. The Project should also comply with tree protection standards of Section 17.41.130 during construction.

Table 2: Oregon City Land Use Permit and Review Procedures

Potential Permits	Permit/Review Process	Approval Timeline[1]	Permit Standards and Criteria[2]	Public Notice and Hearings	Decision Maker	Expiration
Natural Resouces Overlay District Permit §17.49	Type II or III	120 calendar days	Standards of 17.49.100, 150, 170, 180, 190; or criteria of 17.49.200	Notice; Public Hearing for Type III	Type II: Planning Director; Type III: Planning Commission	3 years; no extensions allowed
Flood Management Area Development Permit §17.42	Type II or III	120 calendar days	Standards of 17.42.160; Criteria of 17.42.190		Planning Commission	3 years; no extensions allowed

[1]*After a 30-day completeness review.*
[2]*Oregon City, Oregon City Municipal Code.*

REFERENCES

City of Gladstone. 2019 (April 9, effective). City of Gladstone Municipal Code: Title 17, Zoning and Development.

_____. 2004 (January 1, effective). City of Gladstone Zoning (map).

City of Oregon City. 2019 (August 2, effective). City of Oregon City Municipal Code: Title 17, Zoning.

_____. 2019 (May 3, effective). City of Oregon City Zoning Map.

_____. 2019 (April 8, effective). City of Oregon City Comprehensive Plan Map.

_____. 2009 (July 1, effective). City of Oregon City Natural Resource Overlay District.

Appendix D: Concept Construction Cost Estimate

COST ESTIMATE - ALTERNATIVE 1
CLACKAMAS COUNTY

SECTION	Trolley Trail - Alt 1 Steel Truss Bridge			COUNTY Clackamas	
PROJECT # CLKX-0043	KIND OF WORK Grading, Structures, Paving	LENGTH	DATE 8.15.19	ROADWAY DESIGNER David Evans & Associates	
ITEM NUMBER	**ITEM DESCRIPTION**	**UNIT**	**AMOUNT**	**UNIT COST**	**TOTAL**
MOBILIZATION AND TRAFFIC CONTROL					
0210-0100000A	MOBILIZATION(10%)	LS	1	$270,000.00	$270,000
ROADWAY					
0305-0100000A	CONSTRUCTION SURVEY WORK	LS	1	$10,000.00	$10,000
0310-0106000A	REMOVAL OF STRUCTURES AND OBSTRUCTIONS (1%)	LS	1	$8,000.00	$8,000
0320-0100000R	CLEARING AND GRUBBING	LS	1.00	$10,000.00	$10,000
0330-0123000K	EMBANKMENT IN PLACE	CUYD	800	$25.00	$20,000
DRAINAGE					
					$0
STRUCTURES					
	SINGLE SPAN STEEL TRUSS BRIDGE	LS	1	$2,628,000.00	$2,628,000
BASES					
0641-0102000M	AGGREGATE BASE	TON	200	$30.00	$6,000
WEARING SURFACES					
0745-0202000M	LEVEL 2, 1/2 INCH ACP	TON	100	$120.00	$12,000
PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES					
					$0
					$0
RIGHT OF WAY DEVELOPMENT					
					$0
					$0
					$0
	CONSTRUCTION SUBTOTAL (without MOB/TPDT)				**$2,694,000**
	CONSTRUCTION SUBTOTAL (with MOB/TPDT)				**$2,964,000**
	ENGINEERING & CONTINGENCIES (15% CE & 30% Cont.)			45%	$1,334,000
CONSTRUCTION COST					**$4,298,000**

NOTES: **This estimate does not include final design, right-of-way, utility relocation, new utilities or hazmat costs**

COST ESTIMATE - ALTERNATIVE 2
CLACKAMAS COUNTY

SECTION				COUNTY	
Trolley Trail - Alt 2 Concrete Girder Bridge				Clackamas	
PROJECT # CLKX-0043	KIND OF WORK Grading, Structures, Paving	LENGTH	DATE 8.12.19	ROADWAY DESIGNER David Evans & Associates	
ITEM NUMBER	**ITEM DESCRIPTION**	**UNIT**	**AMOUNT**	**UNIT COST**	**TOTAL**
MOBILIZATION AND TRAFFIC CONTROL					
0210-0100000A	MOBILIZATION(10%)	LS	1	$175,000.00	$175,000
ROADWAY					
0305-0100000A	CONSTRUCTION SURVEY WORK	LS	1	$10,000.00	$10,000
0310-0106000A	REMOVAL OF STRUCTURES AND OBSTRUCTIONS (1%)	LS	1	$10,000.00	$10,000
0320-0100000R	CLEARING AND GRUBBING	LS	1.00	$14,000.00	$14,000
0330-0123000K	EMBANKMENT IN PLACE	CUYD	1,800	$25.00	$45,000
DRAINAGE					
					$0
STRUCTURES					
	3-SPAN P/S CONCRETE GIRDER BRIDGE	LS	1	$1,643,000.00	$1,643,000
BASES					
0641-0102000M	AGGREGATE BASE	TON	300	$30.00	$9,000
WEARING SURFACES					
0745-0202000M	LEVEL 2, 1/2 INCH ACP	TON	100	$120.00	$12,000
PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES					
					$0
					$0
RIGHT OF WAY DEVELOPMENT					
					$0
					$0
					$0
	CONSTRUCTION SUBTOTAL (without MOB/TPDT)				**$1,743,000**
	CONSTRUCTION SUBTOTAL (with MOB/TPDT)				**$1,918,000**
	ENGINEERING & CONTINGENCIES (15% CE & 30% Cont.)			45%	$864,000
CONSTRUCTION COST					**$2,782,000**

NOTES: This estimate does not include final design, right-of-way, utility relocation, new utilities or hazmat costs

COST ESTIMATE - ALTERNATIVE 3
CLACKAMAS COUNTY

SECTION				COUNTY	
Trolley Trail - Alt 3 - Steel Girder Bridge				Clackamas	
PROJECT # CLKX-0043	KIND OF WORK Grading, Structures, Paving	LENGTH	DATE 8.15.19	ROADWAY DESIGNER David Evans & Associates	
ITEM NUMBER	**ITEM DESCRIPTION**	**UNIT**	**AMOUNT**	**UNIT COST**	**TOTAL**
MOBILIZATION AND TRAFFIC CONTROL					
0210-0100000A	MOBILIZATION(10%)	LS	1	$180,000.00	$180,000
ROADWAY					
0305-0100000A	CONSTRUCTION SURVEY WORK	LS	1	$10,000.00	$10,000
0310-0106000A	REMOVAL OF STRUCTURES AND OBSTRUCTIONS (1%)	LS	1	$10,000.00	$10,000
0320-0100000R	CLEARING AND GRUBBING	LS	1.00	$12,000.00	$12,000
0330-0123000K	EMBANKMENT IN PLACE	CUYD	1,400	$25.00	$35,000
DRAINAGE					
					$0
STRUCTURES					
	3-SPAN STEEL GIRDER BRIDGE	LS	1	$1,709,000.00	$1,709,000
BASES					
0641-0102000M	AGGREGATE BASE	TON	300	$30.00	$9,000
WEARING SURFACES					
0745-0202000M	LEVEL 2, 1/2 INCH ACP	TON	100	$120.00	$12,000
PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES					
					$0
					$0
RIGHT OF WAY DEVELOPMENT					
					$0
					$0
	CONSTRUCTION SUBTOTAL (without MOB/TPDT)				**$1,797,000**
	CONSTRUCTION SUBTOTAL (with MOB/TPDT)				**$1,977,000**
	ENGINEERING & CONTINGENCIES (15% CE & 30% Cont.)			45%	$890,000
CONSTRUCTION COST					**$2,867,000**

NOTES: This estimate does not include final design, right-of-way, utility relocation, new utilities or hazmat costs.

COST ESTIMATE - ALTERNATIVE 4
CLACKAMAS COUNTY

SECTION				COUNTY	
Trolley Trail - Alt 4 Tied Steel Arch Bridge				Clackamas	
PROJECT # CLKX-0043	KIND OF WORK Grading, Structures, Paving	LENGTH	DATE 8.15.19	ROADWAY DESIGNER David Evans & Associates	
ITEM NUMBER	**ITEM DESCRIPTION**	**UNIT**	**AMOUNT**	**UNIT COST**	**TOTAL**
MOBILIZATION AND TRAFFIC CONTROL					
0210-0100000A	MOBILIZATION(10%)	LS	1	$467,000.00	$467,000
ROADWAY					
0305-0100000A	CONSTRUCTION SURVEY WORK	LS	1	$10,000.00	$10,000
0310-0106000A	REMOVAL OF STRUCTURES AND OBSTRUCTIONS (1%)	LS	1	$8,000.00	$8,000
0320-0100000R	CLEARING AND GRUBBING	LS	1.00	$10,000.00	$10,000
0330-0123000K	EMBANKMENT IN PLACE	CUYD	800	$25.00	$20,000
DRAINAGE					
					$0
STRUCTURES					
	SINGLE SPAN TIED STEEL ARCH BRIDGE	LS	1	$4,600,000.00	$4,600,000
BASES					
0641-0102000M	AGGREGATE BASE	TON	200	$30.00	$6,000
WEARING SURFACES					
0745-0202000M	LEVEL 2, 1/2 INCH ACP	TON	100	$120.00	$12,000
PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES					
					$0
					$0
RIGHT OF WAY DEVELOPMENT					
					$0
					$0
					$0
	CONSTRUCTION SUBTOTAL (without MOB/TPDT)				**$4,666,000**
	CONSTRUCTION SUBTOTAL (with MOB/TPDT)				**$5,133,000**
	ENGINEERING & CONTINGENCIES (15% CE & 30% Cont.)			45%	$2,310,000
CONSTRUCTION COST					**$7,443,000**

NOTES: This estimate does not include final design, right-of-way, utility relocation, new utilities or hazmat costs

COST ESTIMATE - ALTERNATIVE 5
CLACKAMAS COUNTY

SECTION				COUNTY	
	Trolley Trail - Alt 5 3-Span Steel Truss Bridge			Clackamas	
PROJECT # CLKX-0043	KIND OF WORK Grading, Structures, Paving	LENGTH	DATE 8.15.19	ROADWAY DESIGNER David Evans & Associates	
ITEM NUMBER	ITEM DESCRIPTION	UNIT	AMOUNT	UNIT COST	TOTAL
MOBILIZATION AND TRAFFIC CONTROL					
0210-0100000A	MOBILIZATION(10%)	LS	1	$217,000.00	$217,000
ROADWAY					
0305-0100000A	CONSTRUCTION SURVEY WORK	LS	1	$10,000.00	$10,000
0310-0106000A	REMOVAL OF STRUCTURES AND OBSTRUCTIONS (1%)	LS	1	$8,000.00	$8,000
0320-0100000R	CLEARING AND GRUBBING	LS	1.00	$10,000.00	$10,000
0330-0123000K	EMBANKMENT IN PLACE	CUYD	800	$25.00	$20,000
DRAINAGE					
					$0
STRUCTURES					
	THREE SPAN STEEL TRUSS BRIDGE	LS	1	$2,102,000.00	$2,102,000
BASES					
0641-0102000M	AGGREGATE BASE	TON	200	$30.00	$6,000
WEARING SURFACES					
0745-0202000M	LEVEL 2, 1/2 INCH ACP	TON	100	$120.00	$12,000
PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES					
					$0
					$0
RIGHT OF WAY DEVELOPMENT					
					$0
					$0
					$0
	CONSTRUCTION SUBTOTAL (without MOB/TPDT)				**$2,168,000**
	CONSTRUCTION SUBTOTAL (with MOB/TPDT)				**$2,385,000**
	ENGINEERING & CONTINGENCIES (15% CE & 30% Cont.)			45%	$1,074,000
CONSTRUCTION COST					**$3,459,000**

NOTES: This estimate does not include final design, right-of-way, utility relocation, new utilities or hazmat costs

DAVID EVANS AND ASSOCIATES INC

Appendix E: Geotechnical Report

SUBMITTED TO:
David Evans and Associates, Inc.
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Salem, Oregon 97301

BY:
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PRELIMINARY GEOTECHNICAL REPORT

Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study

CLACKAMAS COUNTY, OREGON

SHANNON & WILSON

January 2020
Shannon & Wilson No: 101474-005

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Submitted To: David Evans and Associates, Inc.
530 Center St NE, Suite 605
Salem, Oregon 97301
Attn: Mr. Doug Johnson, PE

Subject: PRELIMINARY GEOTECHNICAL REPORT, TROLLEY TRAIL BRIDGE: GLADSTONE TO OREGON CITY FEASIBILITY STUDY, CLACKAMAS COUNTY, OREGON

Shannon & Wilson, Inc. (Shannon & Wilson), prepared this report and participated in this project as a subconsultant to David Evans and Associates, Inc. (DEA). Our scope of services was specified in Clackamas County Contract #2018-63 and our Subconsultant Agreement with DEA dated April 23, 2019. This report presents the results of our existing information review, field explorations, laboratory testing, preliminary geotechnical analyses, and preliminary geotechnical design recommendations for the proposed project, and was prepared by the undersigned.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON, INC.

REGISTERED PROFESSIONAL ENGINEER
80491PE
OREGON
DEC. 12, 2012
ERIC C. PASLACK
EXPIRES: 12-31-2020

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MXH:ECP:RPP/wxp

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
A_s	Site-Adjusted Peak Ground Acceleration
bgs	below ground surface
bpf	blows per foot
CSZ	Cascadia Subduction Zone
CSZE	Cascadia Subduction Zone Earthquake
DEA	David Evans and Associates, Inc.
FHWA	Federal Highway Administration
F_{PGA}	Zero Period Site Factor
fps	feet per second
GDM	Geotechnical Design Manual
ksf	kips per square foot
LRFD	Load and Resistance Factor Design
m/sec	meters per second
M_w	Moment Magnitude
NAVD88	North American Vertical Datum of 1988
ODOT	Oregon Department of Transportation
OHW	ordinary high water
OSSC	Oregon Standard Specifications for Construction
PGA	Peak Ground Acceleration
psf	pounds per square foot
RQD	Rock Quality Designation
S&W	Shannon & Wilson, Inc.
SPT	Standard Penetration Test
USGS	United States Geological Survey
V_{s30}	average shear wave velocity in the upper 30 meters of the soil profile

1 INTRODUCTION

1.1 Project Overview

This report presents the results of our existing information review, field explorations, laboratory testing, preliminary geotechnical analyses, and preliminary geotechnical design recommendations for the proposed Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study project in Clackamas County, Oregon. The location of the project site is shown on the Vicinity Map, Figure 1.

Clackamas County (the County) is studying the feasibility of rebuilding an abandoned trolley bridge crossing the Clackamas River that collapsed in 2014 as an extension of the Trolley Trail, a shared-use path for bicycles and pedestrians. David Evans and Associates, Inc. (DEA) has been contracted by the County to provide engineering services for the planning phase of the proposed project. As a subconsultant to DEA, Shannon & Wilson Inc. (Shannon & Wilson), is providing geotechnical engineering services to support engineering design for the planning phase.

1.2 Scope of Services

Shannon & Wilson's services were conducted in accordance with the Statement of Work defined in Clackamas County Contract #2018-63 and our Subconsultant Agreement with DEA, dated April 23, 2019. The completed geotechnical services for the project consisted of the following tasks:

- Collect and review available existing information, including previous geology and geotechnical reports pertinent to the project and publicly available geologic maps;
- Visit the site to observe existing geologic conditions, explore the site for geologic hazards and related impacts to the proposed project, mark proposed exploration locations, and evaluate potential site constraints, environmental considerations, and construction staging issues;
- Develop a field exploration and testing work plan;
- Perform subsurface explorations consisting of one geotechnical boring, one in situ infiltration test, and collect of soil samples;
- Conduct laboratory testing on selected soil samples to characterize soils and develop engineering properties for evaluation;
- Perform preliminary geotechnical analyses and develop preliminary design recommendations for the bridge foundation design and other related structures, including the following:

  - Evaluate subsurface conditions;
  - Evaluate the site-specific seismic hazards, including ground motion, liquefaction potential, settlement, lateral spreading, seismic slope instability, and other seismic-related hazards;
  - Evaluate bridge foundation alternatives and provide design recommendations for the selected foundation type; and
  - Provide lateral earth pressures (both dynamic and static), bearing resistance, and wall geotechnical design parameters for bridge abutment and retaining wall design use.
- Prepare this Preliminary Geotechnical Report summarizing our existing information review, field explorations, laboratory testing, preliminary geotechnical analysis, and preliminary geotechnical design recommendations for the bridge foundations and retaining walls.

2 PROJECT UNDERSTANDING

2.1 Site Description

The project site spans over the Clackamas River between the cities of Gladstone and Oregon City in Clackamas County, Oregon. The proposed project bridge alignment is located along a narrow corridor that spans between the intersection of Portland Avenue and West Clackamas Boulevard on the north side of the river and the Clackamas River Trail to the south side of the river, as shown on the Site and Exploration Plan, Figure 2. The site is the former location of a trolley bridge that spanned the Clackamas River prior to the bridge's failure in 2014. The bridge remnants appear to have been mostly demolished and removed from the site following the 2014 failure. A rectangular concrete structure is present at the base of the northern riverbank slope (see Exhibit 2-1). This structure appears to be a remnant foundation element left in place after demolition of the former trolley bridge, but the structure also appears to contain piping for a storm drain outfall. Other structures are not visible on either bank of the river at the proposed bridge alignment, though the southern bank slope is marked by vegetation-covered rip-rap that may be related to the construction or demolition of the former bridge.

Exhibit 2-1: Concrete Structure at Northern Riverbank

The slope at the north riverbank is steep and ranges from approximately 0.75H:1V (horizontal:vertical) to 1.3H:1V. Surface conditions along the south bank consist of sand, rounded gravels, and cobbles as well as boulder-sized rip-rap penetrated by overgrown vegetation further upslope (see Exhibit 2-2).

Exhibit 2-2: Southern Riverbank

The River Intake Pump Station (RIPS), which pulls water from the Clackamas River for processing into drinking water, is located approximately 100 feet upstream of the site along the north bank of the river. The Tri-City Wastewater Treatment Plant is located southeast of the site beyond the Clackamas River Trail. The distance along the Clackamas River from the bridge site to the confluence with the Willamette River to the west is approximately 4,400 feet. The ground elevation on each side of the river ranges from approximately 50 to 60 feet above mean sea level (NAVD88), or roughly 30 to 40 feet above the ordinary high water (OHW) river level of 20.5 feet. The water level of the river at the bridge site has the potential to swell greatly during extreme weather events; preliminary design drawings provided by DEA show a 100-year flood elevation of 48.4 feet in the vicinity of the bridge.

2.2 Project Description

The proposed project centers on construction of a new shared-use bicycle and pedestrian bridge spanning the Clackamas River, between Gladstone and Oregon City, as shown on Figure 2. Based on a conceptual plan and elevation drawing prepared by DEA dated July

15, 2019, the proposed north abutment will be located approximately 50 feet south of the intersection of Portland Avenue and West Clackamas Boulevard at the top of the north riverbank of the Clackamas River. The south abutment will be located approximately 90 feet north of the Clackamas River Trail adjacent to the south riverbank. The number and locations of interior bents are not defined at this time however we understand all bridge alternatives currently under consideration are approximately 385 feet in length. The bridge alignment will be approximately parallel with Portland Avenue. Based on preliminary plans, the bridge will have a deck width on the order of 16 feet and an overall width of approximately 20 feet. We understand the bridge south approach will require placement of less than 10 feet of embankment fill and that no fill will be placed for the north approach.

DEA provided Clackamas River OHW and 100-year flood elevations of 20.5 feet and 48.4 feet, respectively. Scour depths have not been provided at the time of this report.

The project is currently at the feasibility study level, which includes an evaluation of structural alternatives including new bridge types, possible utility use (i.e., sewer main, storm water conveyance and outfall) or emergency access to create a lifeline and redundancy in crossing the Clackamas River, geotechnical evaluation of foundation alternatives, identification of environmental permitting requirements, evaluation of river hydraulics and scour potential, development of cost estimates, and trail concept planning for connections to Gladstone and Oregon City trails.

The preliminary geotechnical recommendations presented in this report are based on the available project information, provided existing information, and the subsurface conditions described in the report. If any of the noted information changes during the course of design, we should be informed so we may reconsider and amend, if necessary, the recommendations presented in this report.

3 REVIEW OF EXISTING INFORMATION

Shannon & Wilson reviewed the following publicly available geotechnical reports and information from our archive project files. The existing information is presented in Appendix A:

- Geotechnical Data Report, Lake Oswego Raw Water Pipeline, Clackamas County, Oregon, prepared by GeoDesign, Inc., dated March 18, 2011 (GeoDesign, 2011);
- Geotechnical Design Report, Tri-City Water Pollution Control Plant, Interim Expansion, Clackamas County, Oregon, prepared by Shannon & Wilson, Inc., dated September 2008 (Shannon & Wilson, 2008);

- Groundwater Monitoring Program Report, Tri-City Water Resource Recovery Facility, Solids Handling Improvement Project, Clackamas County, Oregon, prepared by Shannon & Wilson, Inc., dated October 26, 2016 (Shannon & Wilson, 2016); and
- Geotechnical Report, River Intake Pump Station (RIPS), Lake Oswego Tigard Water Partnership - Package 3, Gladstone, Oregon, prepared by GRI, dated March 16, 2012 (GRI, 2012);

Approximate locations of relevant geotechnical borings from the existing information are shown on Figure 2.

The proposed Trolley Trail Bridge alignment will generally conform to the alignment of a former steel-truss trolley bridge demolished in 2014. The demolished trolley bridge was constructed in 1908 to replace an earlier trolley bridge erected in 1892 (Street Railway Journal, 1908). A historical image of the 1892 bridge (Exhibit 3-1) depicts a 260-foot-long, timber and cable truss bridge supported by bents on each river bank and a central bent in the Clackamas River. The 1892 bridge was reportedly found structurally deficient in 1906, due to an increase in load demands since its construction. The support piers and foundations for the 1892 bridge were reportedly, "3-ft. 10-in. diameter steel tubes driven into hard gravel." The 1892 bridge piers and foundations on each river bank were reinforced, encased in concrete, and re-used for support of the 1908 bridge. A geotechnical boring performed in the center of the Clackamas River in 1908 reportedly encountered a gravel deposit at least 75 feet thick (Street Railway Journal, 1908).

Exhibit 3-1: Historical Image of 1892 Bridge

4 REGIONAL GEOLOGY AND SEISMIC SETTING

4.1 Regional Geology

The greater Portland metropolitan and Oregon City area lies within the topographical and structural depression of the Portland Basin (Beeson and others, 1991; Madin, 2009). The Portland Basin began forming as a syncline in the early Miocene (23 to 16 million years ago). Since the early Miocene as the basin developed, it has been inundated by the massive lava flows of the Columbia River Basalts, as well as millions of years of sediment deposition from alluvial, aeolian, and catastrophic processes.

Overlying the lava flows of the Miocene (23 to 5.3 million years ago) Columbia River Basalts in much of the Portland Basin area, is the Miocene to Pliocene (5.3 to 2.58 million years ago) Sandy River Mudstone and Troutdale Formation. These sediments were deposited as a broad alluvial plain by the ancestral Columbia River and rivers draining the Cascade Range into the Portland Basin as the basin was progressively subsiding (Madin, 2009). The Sandy River Mudstone consists of lakebeds composed of silt, siltstone, and claystone, and can contain small interbeds of gravel and conglomerate (Trimble, 1963). The Troutdale Formation consists of sandstones, siltstones, conglomerate, silt, sand, and gravels.

Stream cutting and erosion of the units was followed by deposition of Quaternary (2.6 million years ago to present) alluvium which continued in the vicinity to present day as the valley of the Clackamas River was formed.

The project area was mapped by Madin (1990) and shows the project site is underlain by Quaternary Alluvium consisting of silt, sand, and gravels at the surface. Other units mapped in the vicinity include Troutdale Formation, and Pleistocene Clackamas River Terrace Surface deposits.

4.2 Seismic Setting

The contemporary tectonics and seismicity of the region are the result of oblique, northeastward subduction at a rate of about 37 millimeters per year (mm/yr) (DeMets and others, 2010) of the Juan de Fuca oceanic plate beneath the North American continental plate (e.g., Wells and others, 1998; Wells and Simpson, 2001). This complex tectonic setting produces east-west compressive strain along the Cascadia Subduction Zone (CSZ), as well as northward translation and rotation of the mobile, crustal, Cascadia fore-arc blocks that span the leading edge of the North America plate (Wells and others, 1998; McCaffrey and others, 2007, 2013). Rotation of the Sierra-Nevada block and expansion of the Basin and Range drive the northward migration and clockwise rotation of the Cascadia fore-arc blocks (e.g., Pezzopane and Weldon, 1993; Wells and others, 1998; Wells and Simpson, 2001). As a result, the southern portion of the fore arc, the Oregon Coast block, is impinging on western Washington at a rate of about 8 to 12 mm/yr causing crustal shortening in northwest Oregon and western Washington (Wells and others, 1998; Wells and Simpson, 2001; Mazzotti and others, 2002).

The combined effect of margin-normal subduction and margin-parallel shortening produces complex and diverse deformation within the northern edge of the Cascadia fore arc and triggers large (greater than magnitude [M] 6), damaging earthquakes from three seismogenic source zones:

- The locked zone of the CSZ fault interface, which produces great mega-thrust earthquakes;
- The deep intraslab portion of the CSZ (i.e., the subducted portion of the Juan de Fuca Plate), the source off Wadati-Benioff zone earthquakes; and
- The overriding North American Plate, where shallow crustal faults rupture.

All three sources potentially produce earthquakes that impact the ground motion hazards at the project site. Offshore, elastic release of strain accumulated in the locked plate interface of the CSZ produces great megathrust earthquakes (greater than M 8.0) about every 500 years (Atwater and Hemphill-Haley, 1997; Clague, 1997; Goldfinger and others, 2003 and 2012); the most recent rupture occurred in A.D. 1700 (Satake and others, 1996; Atwater and Hemphill-Haley, 1997; Clague, 1997; Yamaguchi and others, 1997; Goldfinger and others, 2003 and 2012). Onshore, migration and rotation of tectonic blocks produce deformation along shallow faults within the upper part of the crust. At depth, rupture within the subducting slab, referred to as the intraslab, has produced some of the largest recorded earthquakes (M 6.5 to 7) to strike the Pacific Northwest, in the northern California Coast and Western Washington. However, over the past century, intraslab earthquakes have been markedly infrequent in Oregon. The following sections briefly describe the location, characteristics, and seismicity of each of the sources.

4.2.1 Cascadia Subduction Zone: Mega-Thrust Interface Source

CSZ mega-thrust earthquakes originate along the interface between the subducting oceanic plates and the North American plate. Because of the significant uncertainty of the landward extent of a potential rupture surface, estimates of the closest distance between the project site and potential rupture surface range between about 65 and 140 horizontal miles. Focal depths for mega-thrust earthquakes are commonly on the order of about 15 to 25 miles. Rupture of the interface could result in earthquakes with moment magnitudes on the order of 8.5 to over 9.0, with strong shaking that lasts for several minutes. No large earthquakes have occurred in this zone during historic times (the last 170 years). However, geologic evidence suggests that coastal estuaries have experienced rapid subsidence at various times within the last 2,000 years (e.g., Atwater, 1987; Atwater and Hemphill-Haley, 1997) as a result of tectonic movement associated with mega-thrust earthquakes on the CSZ. It appears that ruptures of this zone have occurred at irregular intervals that span from about 100 to more than 1,200 years, with an average recurrence interval of about 300 to 500 years (Atwater and Hemphill-Haley, 1997). Based on historical tsunami records in Japan (Satake and others, 1996) the most recent interplate event on the CSZ was a moment magnitude (M_w) 9 event on January 26, 1700.

4.2.2 Cascadia Subduction Zone: Intraslab Source

CSZ intraslab earthquakes originate from within the subducting oceanic plates as a result of down-dip tensional forces and bending caused by mineralogical and density changes in the plates at depth. These earthquakes typically occur 28 to 37 miles beneath the surface. The nearest seismogenic intraslab portion of the Juan de Fuca plate is approximately 30 to 60 miles below the Portland area. Ludwin and others (1991) estimate that the maximum M_w from this source zone would be about 7.5. Ground shaking produced by intraplate earthquakes would be less intense and less prolonged in the Portland area than ground motions generated by large subduction zone interface earthquake events. Historic seismicity from this source zone includes the 1949 M_w 6.7 Olympia earthquake, the 1965 M_w 6.7 earthquake between Tacoma and Seattle, and the 2001 M_w 6.8 Nisqually earthquake. While intraslab events have occurred frequently in the Puget Sound area, they are historically rare in Oregon.

4.2.3 Shallow Crustal Source

Shallow crustal earthquakes within the North American Plate have historically occurred in a diffuse pattern within Pacific Northwest, typically within the upper 4 to 19 miles of the continental crust. Mabey and others (1993) concluded from their analysis of local geologic features that a crustal earthquake of up to M_w 6.5 could occur virtually anywhere in the Portland area. Based on their fault model, Wong and others (2000) determined that an earthquake of up to M_w 6.8 is possible on the Portland Hills Fault, which is mapped within about one half-mile of the project site. The largest known crustal earthquake in the Pacific Northwest is the 1872 North Cascades earthquake at approximate M_w 6.5 to 7.0. Other examples include the 1993 M_w 5.6 Scotts Mill earthquake and the 1993 M_w 6.0 Klamath Falls earthquake.

Shallow crustal faults and folds throughout Oregon and Washington have been located and characterized by the United States Geological Survey (USGS). The USGS provides approximate fault locations and a detailed summary of available fault information in the USGS Quaternary Fault and Fold Database (USGS, 2017). The database defines four categories of faults, Class A through D, based on evidence of tectonic movement known or presumed to be associated with large earthquakes during Quaternary time (within the last 2.6 million years). For Class A faults, geologic evidence demonstrates that a tectonic fault exists and that it has likely been active within the Quaternary period. For Class B faults, there is equivocal geologic evidence of Quaternary tectonic deformation, or the fault may not extend deep enough to be considered a source of significant earthquakes. Class C and D faults lack convincing geologic evidence of Quaternary tectonic deformation or have been studied carefully enough to determine that they are not likely to generate significant earthquakes.

According to the USGS Quaternary Fault and Fold database (USGS, 2017), there are 12 Class A features within approximately 30 miles of the project site. Their names, general locations relative to the site, and the time since their most recent deformation are summarized in Exhibit 4-1. The CSZ itself is approximately 130 miles west of the project site, with an average slip rate of approximately 40 millimeters (1.5 inches) per year and the most recent deformation occurring about 300 years ago (Personius and Nelson, 2006).

Exhibit 4-1: USGS Class A Faults within Approximately 30-Mile Radius of the Project Site

Fault Name	USGS Fault Number	Approximate Length	Approximate Distance and Direction from Project Site[1]	Slip Rate Category[2]	Time Since Last Deformation[3]
Oatfield Fault	875	18.0 miles	0.6 miles SE	< 0.2 mm/yr	< 1.6 Ma
Portland Hills Fault	877	30.4 miles	1.3 miles NE	< 0.2 mm/yr	< 15 ka
Damascus-Tickle Creek Fault	879	9.9 miles	3.4 miles NE	< 0.2 mm/yr	< 750 ka
Canby-Molalla Fault	716	31.1 miles	5.5 miles SW	< 0.2 mm/yr	< 15 ka
Grant Butte Fault	878	6.2 miles	7.1 miles NE	< 0.2 mm/yr	< 750 ka
East Bank Fault	876	18.0 miles	9.5 miles NE	< 0.2 mm/yr	< 15 ka
Beaverton Fault Zone	715	9.3 miles	12.4 miles NW	< 0.2 mm/yr	< 750 ka
Lacamas Lake Fault	880	14.9 miles	17.3 miles NE	< 0.2 mm/yr	< 750 ka
Newberg Fault	717	3.1 miles	18.9 miles SW	< 0.2 mm/yr	< 1.6 Ma
Helvetia Fault	714	4.3 miles	19.6 miles NW	< 0.2 mm/yr	< 1.6 Ma
Mt. Angel Fault	873	18.6 miles	21.6 miles SW	< 0.2 mm/yr	< 15 ka
Gales Creek Fault Zone	718	45.4 miles	24.0 miles W	< 0.2 mm/yr	< 1.6 Ma

NOTES:

1 Approximate distance between project site and nearest extent of fault mapped at the ground surface.

2 mm = millimeters; yr = year.

3 Ma = "Mega-annum" or million years ago; ka = "Kilo-annum" or one thousand years ago.

5 FIELD EXPLORATIONS

5.1 Subsurface Explorations

Shannon & Wilson explored subsurface conditions at the project site with one geotechnical boring, designated B-1. The boring was drilled on July 26, 2019 to a depth of 71.5 feet below ground surface (bgs), using a CME-55 track mounted drilling rig provided and operated by Western States Soil Conservation, Inc., out of Hubbard, Oregon. The approximate boring location is shown on the Site and Exploration Plan, Figure 2. Shannon & Wilson engineering staff were on site throughout the exploration program to locate the boring, observe drilling, collect samples, and log the materials encountered. Details of the drilling program and logs of the materials encountered are presented in Appendix B, Field Explorations.

5.2 In Situ Infiltration Testing

One in situ infiltration test, designated I-1, was performed within approximately 10 feet of boring B-1. The test was performed in general accordance with the Encased Falling Head Test method in Appendix E of the Clackamas County Stormwater Standards. Infiltration test I-1 was performed with casing set at a depth of 4.7 feet bgs.

The raw (unfactored) infiltration rates ranged from 3.24 to 3.60 inches per hour at I-1. A factor of safety in accordance with the Clackamas County Stormwater Standards should be applied to the raw infiltration rate to determine the design infiltration rate. Detailed infiltration test procedures and results are presented in Appendix B.

6 LABORATORY TESTING

The samples we obtained during our subsurface explorations were transported to our laboratory for further examination. We then selected representative samples for a suite of laboratory tests. The testing program included moisture content tests, unit weight tests, Atterberg limits determinations, and particle-size analyses. In addition, West Consultants, Inc. provided a bulk sample of streambed material collected from the Clackamas River for particle-size analysis. Testing was performed by Shannon & Wilson. All test procedures were performed in accordance with applicable ASTM International standards. Results of the laboratory tests and brief descriptions of the test procedures are presented in Appendix C, Laboratory Test Results.

7 SUMMARY OF SUBSURFACE CONDITIONS

7.1 Geotechnical Soil Units

We grouped the subsurface materials at the site into five geotechnical units, as described below. Our interpretation of the subsurface conditions is based upon the explorations and regional geologic information from published sources. Subsurface data from boring CR-8 completed in 2011 by GeoDesign Inc. on the north side of the Clackamas River is included in this summary. The geotechnical units are as follows:

- **Fill**: includes pavement sections; medium stiff, Lean Clay (CL);
- **Sand Alluvium**: very loose to loose Silty Sand (SM) and very soft to very stiff Sandy Silt (ML); very loose to loose, Sand with some silt (SP-SM);
- **Gravel Alluvium**: medium dense to very dense, Gravel with varying amounts of sand and silt (GP/GP-GM); loose, Silty Sand (SM); very stiff, Sandy Silt (ML); cobbles were encountered in some samples;
- **Sandy River Mudstone**: very stiff Silty Clay (CL); hard, Sandy Silt (ML); very stiff to hard Clayey Silt (MH); and
- **Columbia River Basalt**: very soft to very hard (R1-R5), Basalt; very dense, Clayey Sand (SC).

These geotechnical units were grouped based on their engineering properties, geologic origins, and their distribution in the subsurface. The units and our interpretations of their inter-relationships in the subsurface is shown on the Interpretive Subsurface Profile A-A', Figure 3. The location of the profile is shown on Figure 2. The profile is interpretive, and variations in subsurface conditions may exist between the borings.

Contacts between the units may be more gradational than shown in the profile and in the drill logs in Appendix B. The Standard Penetration Test (SPT) blow counts shown on the drill logs, Figure 3, and discussed below, are in blows per foot (bpf) as counted in the field (uncorrected). The following sections describe the geotechnical unit characteristics in greater detail.

7.1.1 Fill

Fill was not identified in Boring B-1, performed near the proposed bridge abutment on the south side of the Clackamas River. Fill was encountered from the ground surface to approximately 4.5 feet in boring CR-8. Based on our review of available near-site geotechnical reports, up to approximately 5 feet of fill may be present at the site. Existing data show that fill composition is variable at the site, and may include medium stiff, brown Clay (CL).

7.1.2 Sand Alluvium

Alluvial sand and silt deposits were encountered in Boring B-1 from the ground surface to a depth of 23 feet bgs. This layer consisted of very loose to loose, dark brown, Silty Sand (SM) and Sand with some silt (SP-SM), as well as soft, dark brown, Sandy Silt (ML). The soil was typically moist. Fines were typically nonplastic. SPT blow counts (N-Values) in this layer ranged from 2 to 6 blows per foot (bpf) with an average N-value of 4 bpf.

7.1.3 Gravel Alluvium

Alluvial gravel was encountered in Boring B-1 at a depth of 23 feet bgs and extended to a depth of 52 feet bgs. The alluvial gravel layer consisted of dense to very dense, dark brown and dark gray, Gravel (GP) and Gravel with some sand and silt (GP-GM). Available near-site geotechnical reports describe cobbles and boulders up to 14 inches in diameter within the gravel layers north of the Clackamas River. The gravel was moist to wet and angular to subrounded with nonplastic fines. SPT N-values for two samples in this layer were 48 and 66 bpf and averaged 57 bpf. Four additional SPTs were attempted and met refusal with more than 50 blows over a 6-inch interval.

7.1.4 Sandy River Mudstone

Sandy River Mudstone was encountered below the Gravel Alluvium in Boring B-1 at 53 feet and the boring was terminated in the unit. This unit consisted of very stiff to hard, gray to blue-gray, Sandy SILT (ML), Silty CLAY with some sand (CL), and Clayey SILT with some sand (MH). The soil was typically wet and ranged from medium to high plasticity. The sand constituent was fine. Relict decomposed sand and gravel clasts were observed in some samples. SPT N-values in the unit ranged from 22 to 49 bpf with an average N-value of 32 bpf.

7.1.5 Columbia River Basalt

Columbia River Basalt was not encountered at Boring B-1 on the south side of the Clackamas River. Columbia River Basalt was encountered at approximately 50 to 65 feet bgs in boring CR-8. Based on our review of other borings and subsurface information available in geotechnical reports for projects performed near the site, Columbia River Basalt is expected to be present at approximately 50 to 55 feet bgs (Elevation 5 to 10 feet NAVD88) near the proposed bridge abutment on the north side of the Clackamas River. Existing core data shows Rock Quality Designations (RQD) along the river shoreline basalts ranging from 15 to 60 percent within the upper 20 feet, increasing with further depth. Further north from the shoreline, core data shows basalt with RQD ranging from 70 to 100 percent within the upper 20 feet. The basalt hardness typically ranges from very soft to hard (R2-R4), with occasional core runs described as very hard (R5). The unit is intensely weathered at initial contact, becoming slightly weathered to fresh with depth. Columbia River Basalt was not encountered in any borings south of the Clackamas River.

7.2 Groundwater

Groundwater was not measured at Boring B-1, due to the mud rotary drilling method used. Based on preliminary plans provided by DEA, we understand that the design Ordinary High Water (OHW) level of the Clackamas River at the site is elevation 20.5 feet NAVD88. Based on our review of readily available geotechnical reports, groundwater elevation measurements near the site on the south side of the Clackamas River typically range between elevation 13 and 21 feet NAVD88. Groundwater is expected to be perched above the Sandy River Mudstone on the north side of the river. Groundwater levels at the site may vary with changes in precipitation and river levels. Typically, groundwater highs occur at the end of the wet season in late spring or early summer, and groundwater lows occur toward the end of the dry season in the early to mid-fall.

8 SEISMIC DESIGN PARAMETERS AND HAZARD EVALUATION

8.1 General

The 2018 Oregon Department of Transportation (ODOT) Geotechnical Design Manual (GDM) (ODOT, 2018a) requires that all bridges be designed for 1,000-year return period ground motions under "Life Safety" criteria. Under this level of shaking, the bridge and approach structures, bridge foundations, and approach fills must be able to withstand the forces and displacements without collapse of any portion of the structure.

In addition to the 1,000-year "Life Safety" criteria, ODOT requires that all bridges be designed to remain "Operational" after a full rupture Cascadia Subduction Zone Earthquake (CSZE). Under this level of shaking, the bridge and approach fills are designed to remain in service shortly after the event to provide access for emergency vehicles.

8.2 Site Classification

The Seismic Site Class for the "Life Safety" seismic design criteria was developed based on the recommended procedure, using SPT N-values from the explorations, in the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications (AASHTO, 2017). Based on the subsurface conditions described in Section 7, subsurface conditions at the site are best characterized as Site Class D. Site Class D corresponds to soil profiles with a weighted average shear wave velocity between 600 and 1,200 feet per second (fps) or a weighted average SPT blow count between 15 and 50 bpf in the upper 100 feet of soil.

While the Site Class is used in deriving the "Life Safety" seismic design criteria, the average shear wave velocity in the upper 30 meters of the soil profile, V_{s30}, is required to derive the "Operational" criteria response spectra. A V_{s30} of 200 meters per second (m/sec) (650 fps) was estimated based the project borings.

8.3 Ground Motion Parameters

The ground motion seismic parameters for the "Life Safety" criteria were derived using the ODOT Bridge Section's Excel application, ODOT_ARS.v.2014.16, which uses the three-point curve method with data from the 2014 USGS probabilistic seismic hazard maps for the 1,000-year return period. This Excel application is available through ODOT's web portal (ODOT, 2017). The recommended site seismic parameters for the "Life Safety" criteria for Site Class D are presented in Exhibit 8-1.

Exhibit 8-1: Recommended "Life Safety" Criteria Seismic Parameters

Seismic Parameter	1,000-Year Return Period
Site Class (See Section 8.2)	D
Mapped Peak Ground Acceleration, PGA	0.256g
Mapped 0.2-Second (Short) Period Acceleration, Ss	0.561g
Mapped 1.0-Second (Long) Period Acceleration, S_1	0.203g
Zero-Period Site Factor, F_{pga}	1.34
0.2-Second Period Site Factor, F_a	1.35
1.0-Second Period Site Factor, F_v	2.19
Peak Ground Surface Acceleration, As	0.344g
0.2-Second Period Design Acceleration, S_{DS}	0.758g
1.0-Second Period Design Acceleration, S_{D1}	0.445g

NOTES:
1 Spectral values calculated assuming 5% structural damping.
2 g = gravity acceleration

The deterministic response spectrum for the CSZE considered in the "Operational" seismic design criteria was generated by using the web-based application developed by Portland State University and available on the ODOT Bridge Section website (ODOT, 2017). Using the ODOT web-based application, a V_{s30} of 200 m/sec was input to generate the Site Class D design response spectrum presented in Exhibit 8-2.

Exhibit 8-2: Recommended "Operational" Criteria Acceleration Response Spectra

Period, T (sec)	Spectral Acceleration, Sa (g)
0	0.1730
0.05	0.1671
0.1	0.2326
0.15	0.2940
0.2	0.3303
0.25	0.3602
0.3	0.3919
0.4	0.4238
0.5	0.4280
0.6	0.4115
0.7	0.4059
0.8	0.3959
1	0.3484
1.5	0.2478
2	0.1884
2.5	0.1522
3	0.1242

8.4 Seismic Hazards Evaluation

Seismic hazards considered in the evaluation include ground shaking, liquefaction and associated effects (e.g., flow failure, lateral spreading, and settlement), slope instability, fault rupture, tsunami, and seiche. The primary hazard at this site is ground shaking. However, as described below, liquefaction and associated effects may be a hazard near the riverbanks and within the river channel, especially at the south riverbank.

In our opinion, the potential for liquefaction and associated effects at the proposed bridge abutment locations is low, as the assumed groundwater elevation is below the very loose to loose, cohesionless, alluvial soil layer identified within the upper 23 feet of boring B-1. Liquefaction-susceptible soil layers may be present in areas closer to or within the river channel along the bridge alignment. We recommend that additional subsurface explorations be performed to assess liquefaction potential of soils at additional points along the bridge span, especially where interior support bents are proposed. Our recommendations for additional subsurface explorations to support final design are provided in Section 10.

The potential for fault rupture is low, given the large distance between the bridge site and the nearest potentially active fault. Seismically induced tsunami and seiche are non-hazards at this site, as the adjacent Clackamas River is not an enclosed body of water.

9 PRELIMINARY BRIDGE FOUNDATION AND RETAINING WALL DESIGN RECOMMENDATIONS

9.1 General

We understand that the proposed bridge is in conceptual design phase, and structural attributes including the bridge type, design loads, and exact locations of the proposed abutments and bents have not been determined. The layout of the proposed bridge will generally coincide with the alignment of the former Clackamas River rail bridge, which experienced partial collapse in 2014, reportedly due to scour-related foundation failure at the southern riverbank. Proposed bridge abutment and bent locations should be carefully selected to avoid construction complications related to encountering previous foundation remnants.

Our design recommendations for the proposed bridge replacement are based on the preliminary design information provided by DEA and our field explorations. Preliminary geotechnical design recommendations are provided for the proposed bridge foundations, abutments, and retaining walls. The geotechnical design recommendations are included in the following sections. If bridge foundation or retaining wall types or configurations change after this report, Shannon & Wilson should be contacted so that we may reevaluate our recommendations and provide updates if necessary.

9.2 Bridge Abutment Global Stability

We conducted preliminary global stability analyses at the proposed Trolley Trail Bridge abutments using the computer program SLIDE 2018 (Rocscience, 2018). This program employs limit equilibrium methods in accordance with the ODOT GDM (ODOT, 2018a). The Spencer slope stability analysis method was used for evaluating rotational surface failure mechanisms. The analyses were performed for static and seismic conditions. For seismic slope stability analyses, pseudo-static procedures described in the ODOT GDM Chapter 6 (ODOT, 2018a) were followed. Horizontal acceleration coefficients equal to one-half of the site-adjusted peak ground accelerations (0.5 x F_{pga} x PGA) were used. For our seismic slope stability analyses, we used horizontal seismic coefficients equal to 0.09 and 0.17 for the CSZE and 1,000-year ground motion levels, respectively.

The ODOT GDM requires that slopes supporting bridge foundations be designed with a maximum resistance factor for global stability of 0.65, equivalent to a FS of 1.5, for the static conditions. For seismic analyses a maximum resistance factor of 0.9, or an FS of 1.1, is required.

Generalized subsurface conditions and soil parameters were determined from the results of the field explorations and laboratory testing. We analyzed cross-sections drawn along the centerline of the proposed structure, perpendicular to each abutment (longitudinal direction).

Based on our analyses, factors of safety at the abutments under static and seismic conditions meet ODOT requirements. The results of our global stability analyses for the bridge abutments are presented in Appendix D, Global Stability Analysis Results.

9.3 Bridge Foundation Alternatives

The selection of an appropriate foundation system for the proposed Trolley Trail bridge is dependent upon several factors, including foundation capacities, tolerance to total and differential settlement resulting from static loads, subsurface conditions, and construction considerations. Based on available data regarding subsurface conditions, driven steel H-piles are the preferred foundation type to support the proposed abutments, and large diameter drilled shafts are the preferred foundation type to support the proposed interior bent(s). Preliminary recommendations for each of these foundation types are provided in the following sections.

9.4 Drilled Shaft Design Recommendations

9.4.1 General

The following sections provide our preliminary recommendations for axial and lateral resistance of 6- and 8-foot diameter drilled shafts for the proposed bridge replacement interior bent foundations. We have estimated preliminary shaft lengths and diameters assuming that proposed interior bents will be located at the edges of the river channel on each side of the Clackamas River. We recommend that supplemental exploratory borings be drilled at proposed interior bent locations to further investigate the depths and quality (hardness) of bedrock.

9.4.2 Drilled Shaft Axial Resistance

We performed preliminary axial resistance evaluation for drilled shafts in general accordance with the AASHTO LRFD Bridge Design Specifications, Section 10.8 (AASHTO, 2017). The analyses were based on the subsurface conditions encountered in Boring B-1, geotechnical data available in documents discussed in Section 3, and our experience with similar soils and project conditions in this area. We estimated unit side and tip resistance values based on the average SPT values (N-values) within each unit, laboratory tests, and our experience.

Estimated shaft lengths and tip elevations for interior bent foundations are summarized in Exhibit 9-1 and are based on our assumptions regarding subsurface conditions within the limits of the river channel. Relatively shallow basalt bedrock is expected to be encountered near the location of a potential interior bent at the north riverbank, while shafts supporting a potential interior bent at the south riverbank are assumed to be embedded within a thick stratum of Sandy River Mudstone. We assumed that drilled shafts extend a minimum of two shaft diameters (2B) into the Sandy River Mudstone or Basalt. The estimated foundation lengths and tip elevations do not consider lateral capacity requirements, such as the depth required to develop lateral shaft fixity.

Exhibit 9-1: Preliminary Estimated Drilled Shaft Length and Compressive Resistance

Interior Bent	[1]Estimated Top of Shaft Elevation (feet)	Foundation Type	[2]Estimated Shaft Length (feet)	Estimated Shaft Tip Elevation (feet)	Factored Axial Compressive Resistance (kips)		
					Strength Limit	Service Limit	Extreme Event Limit
North Riverbank	10	6-foot dia. Drilled Shaft	20	-10	2900	5200	5300
	10	8-foot dia, Drilled Shaft	20	-10	3900	6500	7000
South Riverbank	10	6-foot dia. Drilled Shaft	50	-40	1000	1500	2400
	10	8-foot dia. Drilled Shaft	50	-40	1600	2100	3800

NOTE:

1 Estimated top of shaft elevation based on existing ground surface elevation at proposed bent location.

2 Estimated shaft length, taken as the distance between estimated top of shaft and estimated shaft tip elevation, is assumed to be +/-5 feet of the table value.

3 dia. = diameter

The estimated nominal axial resistance assumes the shafts are oriented in a single row and spaced at least three shaft diameters apart (3B), measured center-to-center. Based on this assumption, the shaft group effects are not considered. If the shafts are in a single row and spacing is less than 3B, a shaft efficiency factor must be applied, as recommended by the AASHTO LRFD (AASHTO, 2017).

9.4.3 Drilled Shaft Lateral Resistance

We understand that the drilled shaft foundations will be subjected to lateral loads resulting from live loading and seismic loading. We understand that the laterally loaded shaft analyses will be performed with the aid of the LPILE computer program.

Table 1 (attached at the end of this report) presents the recommended static/seismic LPILE geotechnical input parameters for the drilled shafts.

The estimated lateral resistance parameters presented in Table 1 are recommended for drilled shafts with center-to-center spacing greater than five shaft diameters (5B) and in a single row. Based on this assumption, the shaft group effects are not considered. If the shaft spacing is less than 5B, or multiple rows of shafts are required, the appropriate P-Multiplier must be established and applied, as recommended by the AASHTO LRFD Bridge Design Specifications, Section 10.7.2.4 (AASHTO, 2017).

9.5 Driven Pile Design Recommendations

9.5.1 General

The following sections provide our preliminary recommendations for axial and lateral resistance of driven piles at the proposed abutments. We recommend driven steel H-piles for support of the abutment foundations on each side of the bridge and have based our preliminary recommendations assuming use of HP14x89 piles. The number and spacing of piles at each abutment are unknown at this time, as design loads are currently undetermined.

Piles may occasionally encounter driving refusal at variable, unpredictable depths, where piles are driven through dense gravel, cobbles, and boulders. We recommend that the pile driving contractor drive piles with sufficient length to account for driving refusal variability or be prepared to weld additional material to the butt to achieve design driving criteria. The pile driving contractor should also plan to cut off excess material from the ends of the piles after installation, in order to achieve pile cap embedment required by the structural engineer.

9.5.2 Driven Pile Axial Resistance

We performed preliminary axial resistance evaluation for driven HP14x89 piles in general accordance with the AASHTO LRFD Bridge Design Specifications, Section 10.7 (AASHTO, 2017). The analyses were based on the subsurface conditions encountered in Boring B-1, geotechnical data available in documents discussed in Section 3, and our experience with similar soils and project conditions in this area. We estimated unit side and tip resistance values based on the average SPT values (N-values) within each unit, laboratory tests, and our experience.

We recommend that the steel piles conform to the requirements of ASTM A572, Grade 50. Mill certification of the steel should be provided by the supplier. All portions of pile design and construction should meet the requirements of the 2018 ODOT Oregon Standard Specifications for Construction (OSSC) Section 00520 (ODOT, 2018b) and its project special provisions. Exhibit 9-2 presents the typical pile section design properties.

Exhibit 9-2: Pile Section Properties

Pile Type	Steel Grade (kips/inch^2)	Section Area (inch^2)	Nominal Structural Capacity (kips)
HP 14x89	A572 Grade 50	26.1	1305

The estimated nominal and factored compressive resistance of the piles is established using a resistance factor of 0.4, assuming the Federal Highway Administration (FHWA) Gates Equation will be used to establish the pile driving criteria.

The estimated driven pile lengths, tip elevations, and the nominal and factored axial compressive resistances are presented in Exhibit 9-3. The estimated driven pile lengths and tip elevations provided are based on axial capacity requirements only and do not consider lateral capacity requirements, such as the depth required to develop lateral pile fixity. The resistances presented in Exhibit 9-3 are based on a single pile and do not consider axial group effects due to our understanding that the piles will be spaced at least 2.5 pile diameters (2.5D) apart (center-to-center).

Exhibit 9-3: Preliminary Estimated Driven HP14x89 Pile Length and Compressive Resistance

Abutment	[1]Estimated Bottom of Pile Cap Elevation (feet)	[2]Estimated Driven Length (feet)	Estimated Pile Tip Elevation (feet)	Nominal Axial Compressive Resistance (kips)	Factored Axial Compressive Resistance (kips)		
					Strength Limit	Service Limit	Extreme Event Limit
North	55	45	10	500	200	500	500
South	50	65	-15	550	220	500	500

NOTES:

1 Estimated bottom of pile cap elevation based on existing ground surface elevation at proposed bent location.

2 Estimated driven pile length, taken as the distance between estimated bottom of pile cap and estimated pile tip elevation, is assumed to be +/-5 feet of the table value.

9.5.3 Driven Pile Lateral Resistance

We understand that the driven pile foundations will be subjected to lateral loads resulting from live loading and seismic loading. We understand that the laterally loaded pile analyses will be performed with the aid of the LPILE computer program.

Table 1 (attached at the end of this report) presents the recommended static/seismic LPILE geotechnical input parameters for the driven piles.

The estimated lateral resistance parameters presented in Table 1 are recommended for driven piles with center-to-center spacing greater than five pile widths or diameters (5B) and in a single row. Based on this assumption, pile group effects are not considered. If the pile spacing is less than 5B, or multiple rows of piles are required, the appropriate P-Multiplier must be established and applied, as recommended by the AASHTO LRFD Bridge Design Specifications, Section 10.7.2.4 (AASHTO, 2017).

9.6 Bridge Abutment and Wing Wall Design Recommendations

9.6.1 General

We understand bridge abutment walls will be required at the south abutment and may be required at the north abutment. Wing walls may also be required at the abutments. Abutment wall dimensions have not been determined at the time of this report. For design purposes, we have assumed that subdrainage systems will be installed to prevent hydrostatic pressures from developing behind both abutments. Also, we have assumed that the backfill behind the abutments will be flat and comprised of standard ODOT Granular Wall Backfill material.

Additional loads will be imposed on the foundations supporting the bridge if wing walls are cantilevered from the bridge abutments beneath the bridge deck. If the wing walls are not cantilevered from the bridge abutments and retaining walls are required, we will provide geotechnical design recommendations once the wall type and configurations are determined by the design team.

9.6.2 Lateral Earth Pressures

The lateral earth pressures on the abutment and wing walls depend on the type of wall (i.e., yielding or non-yielding), the type and method of placement of backfill against the wall, the magnitude of surcharge weight on the ground surface adjacent to the wall, the slope of the backfill, and the design criteria. We recommend that at-rest (non-yielding wall) earth pressures be considered at the wing wall/abutment connection. At the ends of the wing walls, active (yielding wall) earth pressures may be used if the length is sufficient to allow yielding of the wall. The earth pressure loads can be linearly interpolated along the length of the wing wall between these values. The abutment wall should be designed as a non-yielding wall.

Based on the structural design information and the above assumptions, the lateral earth pressures on the walls were developed according to the ODOT GDM (ODOT, 2018a) and AASHTO LRFD Bridge Design Specifications (AASHTO, 2017). The static lateral earth pressure acting on walls consists of two components: static earth pressure and static surcharge pressure. The seismic lateral earth pressure on walls consists of three components: static earth pressure, static surcharge pressure, and seismic earth pressure. A horizontal acceleration coefficient, k_h, equal to the site peak ground acceleration (F_{pga} x PGA), A_s, was used to determine the seismic earth pressure for non-yielding walls. A k_h equal to 1/2 of A_s was used to determine the seismic earth pressure for yielding walls, where 1 to 2 inches of lateral deformation is acceptable. The distributions of these lateral pressures are shown on Figure 4, Preliminary Lateral Earth Pressure Distribution on Abutment and Wing Walls.

9.6.3 Subdrainage

Suitable drainage for walls can be provided by granular backfill material and a wall base subdrain system consisting of a 6-inch-diameter perforated or slotted drain pipe. The perforated or slotted drain pipe should be wrapped in an envelope of filter material at least 12 inches thick and confined by a separation geotextile. The filter material is specified in Section 02610.10(a) of the OSSC (ODOT, 2018b). The subdrain should be above the typical groundwater level, convey any collected seepage to the end of the wall, and daylight at low spots below the wall elevation or connect to subsurface roadway or other appropriate drain pipe.

9.6.4 Backfill Material and Compaction

The wall backfill material should be in accordance with standard ODOT Granular Wall Backfill (Section 00510.12 of the OSSC). Heavy compaction equipment should not be allowed closer than 3 feet to the retaining wall to prevent high lateral earth pressures and/or wall yielding and/or damage. Required compaction of wall backfill within 3 feet of the walls shall be obtained using hand-operated compaction equipment, such as a vibrating plate compactor.

9.6.5 Lateral Resistance

We assume the static and seismic lateral resistance of the abutment walls can be provided by the deep foundations and the lateral resistance for the wing walls will be generated through the structural connection with the foundation element. If it is determined that bridge foundations cannot adequately support the retaining/wing wall loads, specific foundation design recommendations will be provided upon request.

10 ADDITIONAL RECOMMENDED SUBSURFACE EXPLORATIONS FOR FINAL DESIGN

Additional subsurface explorations will be required to develop the final design recommendations for the proposed bridge as shown in Exhibit 10-1 below.

Exhibit 10-1: Recommended Additional Subsurface Explorations for Final Design

Boring Location	Purpose	Type of Exploration	Proposed Depth (feet)
Proposed north abutment	Bridge Abutment Foundation	Land boring (truck rig)	60 to 70
Near north riverbank	Interior Bent Foundation	In-water boring (barge drilling)	50 to 60
Near south riverbank	Interior Bent Foundation	In-water boring (barge drilling)	70 to 80

11 LIMITATIONS

The analyses, conclusions, and recommendations contained in this report are based on site conditions as they presently exist, and further assume that the explorations are representative of the subsurface conditions throughout the site; that is, the subsurface conditions everywhere are not significantly different from those disclosed by the explorations. If subsurface conditions different from those encountered in the explorations are encountered or appear to be present during construction, we should be advised at once so that we can review these conditions and reconsider our recommendations, where necessary. If there is a substantial lapse of time between the submission of this report and the start of construction at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that we review our report to determine the applicability of the conclusions and recommendations.

Our evaluations were performed for preliminary design purposes and should not be relied upon for final design or construction. Additional explorations are required to develop final design recommendations for this project.

Within the limitations of scope, 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 other warranty, either express or implied.

These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as observed at the time of our explorations.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by merely taking soil samples from test borings. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

This report was prepared for the exclusive use of DEA and Clackamas County in the design of the Trolley Trail Bridge: Gladstone to Oregon City Feasibility Study project. Our report, conclusions, and interpretations should not be construed as a warranty of subsurface conditions included in this report.

The scope of our present work did not include environmental assessments or evaluations regarding the presence or absence of wetlands, or hazardous or toxic substances in the soil, surface water, groundwater, or air, on or below or around this site, or for the evaluation or disposal of contaminated soils or groundwater should any be encountered.

Please read the Important Information Section at the back of this report to reduce your project risks.

12 REFERENCES

American Association of State Highway and Transportation Officials, 2017, AASHTO LRFD 8th Edition, Washington, DC.

Atwater, B.F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, p. 942-944.

Atwater, B.F., and Hemphill-Haley, E., 1997, Recurrence intervals for great earthquakes of the past 3500 years at Northeastern Willapa Bay, Washington: U.S. Geological Survey Professional Paper 1576.

Beeson, M.H., Tolan, T.L., and Madin, I.P., 1991, Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington: Oregon Department of Geology and Mineral Industries, Geological Map Series GMS-75, scale 1:24,000.

Clague, J.J., 1997, Evidence for Large Earthquakes at the Cascadia Subduction Zone: Reviews of Geophysics, v. 35, no. 4, p. 439-460.

DeMets, C., Gordon, R.G. and Argus, D.F., 2010, Geologically Current Plate Motions: Geophysical Journal International, v. 181, no. 1, p. 1–80.

Goldfinger, C., Nelson, C.H., and Johnson, J.E., 2003, Deep-Water Turbidites as Holocene Earthquake Proxies: The Cascadia Subduction Zone and Northern San Andreas Fault Systems: Annali Geofisica, v. 46, p. 1169-1194.

Goldfinger, C., Nelson, C.H., Morey, A., Johnson, J.E., Gutierrez-Pastor, J., Eriksson, A.T., Karabanov, E., Patton, J., Gracia, E., Enkin, R., Dallimore, A., Dunhill, G., and Vallier, T., 2012, Turbidite Event History: Methods and Implications for Holocene Paleoseismicity of the Cascadia Subduction Zone: USGS Professional Paper 1661-F, 184 p, 64 Figures.

Ludwin, R.S., Weaver, C.S., and Crosson, R.S., 1991, Seismicity of Washington and Oregon in Slemmons, D.B., E.R. Engdahl, M.D. Zoback, and D.D. Blackwell (eds.), Neotectonics of North America, p. 77-98.

Mabey, M.A., Madin,I.P., Youd, T.L., and Jones, C.F., 1993, Earthquake hazard maps of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-79.

Madin, I.P., 1990, Earthquake-Hazard Geology Maps of the Portland Metropolitan Area, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-90-2, scale 1:24,000, 21 p.

Madin, I.P., 2009, Geologic Map of the Oregon City 7.5' Quadrangle, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-119, scale 1:24,000.

Mazzotti, S., Dragert, H., Hyndman, R.D., Miller, M.M., and Henton, J.A., 2002, GPS Deformation in a Region of High Crustal Seismicity, North Cascadia Forearc: Earth and Planetary Science Letters, v. 198, p. 41-48.

McCaffrey, R., King, R.W., Payne, S.J., and Lancaster, M., 2013, Active Tectonics of Northwestern U.S. Inferred from GPS-derived Surface Velocities: Journal of Geophysical Research, Solid Earth, v. 118, no. 2, p. 709–723.

McCaffrey, R., Qamar, A.I., King, R.W., Wells, R., Khazaradze, G., Williams, C.A., Stevens, C. W., Vollick, J.J., and Zwick, P. C., 2007, Fault Locking, Block Rotation and Crustal Deformation in the Pacific Northwest: Geophysical Journal International, v. 169, no. 3, p. 1315–1340.

Oregon Department of Transportation, 2017, ODOT Design Response Spectrum Program ODOT_ARS.v.2014.16.xlsx: ODOT website: https://www.oregon.gov/ODOT/HWY/BRIDGE/Pages/seismic.aspx, accessed 1/5/2019 12:01 PM.

Oregon Department of Transportation (ODOT), 2018a, Geotechnical Design Manual, Version 2.0, ODOT Website: https://www.oregon.gov/ODOT/GeoEnvironmental/Pages/Geotech-Manual.aspx

Oregon Department of Transportation (ODOT), 2018b, Oregon Standard Specifications for Construction, Salem, Oregon.

Personius, S.F., compiler, 2002, Fault number 714, Helvetia fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 10:06 AM.

Personius, S.F., compiler, 2002, Fault number 715, Beaverton fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:46 AM.

Personius, S.F., compiler, 2002, Fault number 716, Canby-Molalla fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:44 AM.

Personius, S.F., compiler, 2002, Fault number 717, Newberg fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:50 AM.

Personius, S.F., compiler, 2002, Fault number 718, Gales Creek fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 10:02 AM.

Personius, S.F., compiler, 2012, Fault number 873, Mount Angel fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 10:11 AM.

Personius, S.F., compiler, 2002, Fault number 875, Oatfield fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:49 AM.

Personius, S.F., compiler, 2002, Fault number 876, East Bank fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:59 AM.

Personius, S.F., compiler, 2012, Fault number 877, Portland Hills fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:54 AM.

Personius, S.F., compiler, 2002, Fault number 878, Grant Butte fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 10:08 AM.

Personius, S.F., compiler, 2002, Fault number 879, Damascus-Tickle Creek fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 09:56 AM.

Personius, S.F., compiler, 2002, Fault number 880, Lacamas Lake fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 10:14 AM.

Personius, S.F., and Nelson, A.R., compilers, 2006, Fault number 781, Cascadia subduction zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 06/27/2019 11:46 AM.

Pezzopane, S.K. and Weldon II, R.J., 1993, Tectonic Role of Active Faulting in Central Oregon: Tectonics, v. 12, no. 5, p. 1140–1169.

Rocscience Inc. 2018, Slide 2018 – 2D Limit Equilibrium Analysis of Slope Stability. www.rocscience.com, Toronto, Ontario, Canada.

Satake, K., Shimazaki, K., Tsuji, Y., and Ueda, K., 1996, Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700, Nature, 379, p. 246-249.

Street Railway Journal, 1908, Electric Railway Bridge Over the Clackamas River Near Portland, Ore., Volume XXXI, No. 19, Page 790.

Trimble, D.E., 1963, Geology of Portland, Oregon and Adjacent Areas: United States Geological Survey Bulletin, no. 1119, p. 119.

United States Geological Survey, 2017, Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquake.usgs.gov/hazards/qfaults/map/#qfaults, accessed 10/11/2019.

Wells, R.E., and Simpson, R.W., 2001, Northward Migration of the Cascadia Forearc in the Northwestern U.S. and Implications for Subduction Deformation: Earth, Planets and Space, v. 53, no. 4, p. 275-283.

Wells, R.E., Weaver, C.S., and Blakeley, R.J., 1998, Fore-arc migration in Cascadia and its neotectonic significance: Geology, v. 26, p. 759-762.

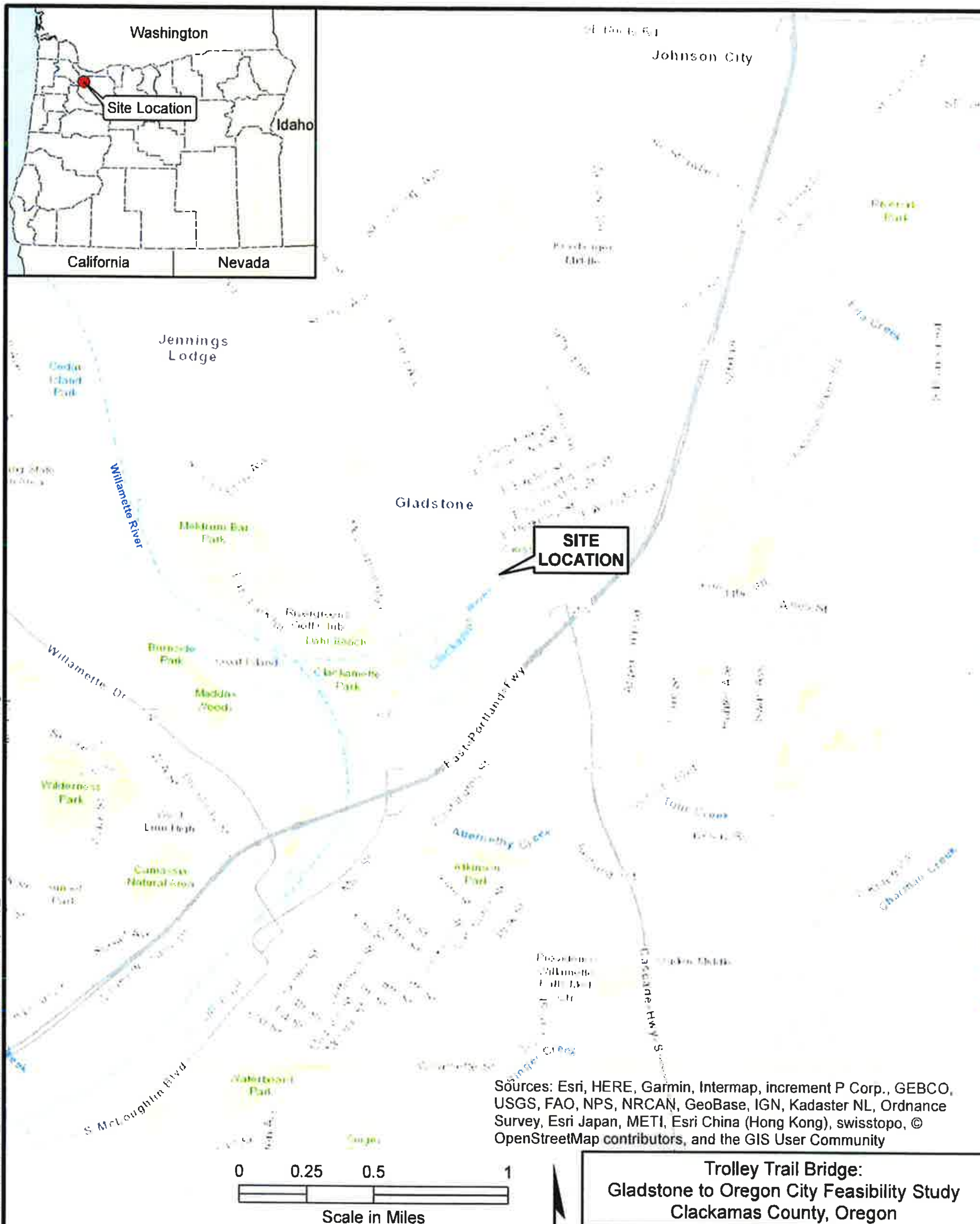
Wong, I., Silva, W., Bott, J., Wright, D., Thomas, P., Gregor, N., Li, S., Mabey, M., Sojourner, A., and Wang, Y., 2000, Earthquake scenario and probabilistic ground shaking maps for the Portland, Oregon, metropolitan area: Oregon Department of Geology and Mineral Industries Interpretive Map Series IMS-16.

Yamaguchi, D.K., Atwater, B.F., Bunker, D.E., Benson, B.E., Reid, M.S., 1997, Tree-ring Dating the 1700 Cascadia Earthquake: Nature, v.389, p. 922-923.

Table 1 - Preliminary Recommended Static/Seismic LPILE Geotechnical Input Parameters for Bridge Foundations

Location	[1]Approximate Elevation (feet) Upper Bound	Lower Bound	Generalized Soil Unit	*p-y* model	Soil Effective Unit Weight (pcf)	Friction Angle (deg)	*p-y* modulus k (pci)	Strain Factor ε_{50}	Undrained Cohesion (psf)	Unconfined Compressive Strength (psi)
North Abutment	60	50	Medium Stiff Clay (Fill)	Stiff Clay w/o Free Water	100	--	--	0.01	500	--
	50	38	Dense Gravel (Alluvium)	Sand (Reese)	130	45	225	--	--	--
	38	28	Medium Dense Sand and Gravel (Alluvium)	Sand (Reese)	120	32	90	--	--	--
	28	20.5	Very Stiff Silt (Sandy River Mudstone)	Stiff Clay w/o Free Water	130	--	--	0.004	4,000	--
	20.5	10	Very Stiff Silt (Sandy River Mudstone)	Stiff Clay w/o Free Water	65	--	--	0.004	4,000	--
North Bent	10	5	Decomposed Basalt	Sand (Reese)	65	45	225	--	--	--
	5	Base	Basalt	Strong Rock (Vuggy Limestone)	65	--	--	--	--	3,000
South Bent	10	Base	Siltstone and Claystone (Sandy River Mudstone)	Stiff Clay w/o Free Water	55	--	--	0.005	3,000	--
South Abutment	50	20.5	Loose Silty Sand (Alluvium)	Sand (Reese)	100	27	25	--	--	--
	20.5	-5	Dense Gravel (Alluvium)	Sand (Reese)	65	45	125	--	--	--
	-5	Base	Siltstone and Claystone (Sandy River Mudstone)	Stiff Clay w/o Free Water	55	--	--	0.005	3,000	--

NOTES:
1 Elevation estimated from existing ground surface (NAVD 88)
deg = degrees; pcf = pounds per cubic foot; pci = pounds per cubic inch; psf = pounds per square foot.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Trolley Trail Bridge:
Gladstone to Oregon City Feasibility Study
Clackamas County, Oregon

VICINITY MAP

January 2020 | 101474

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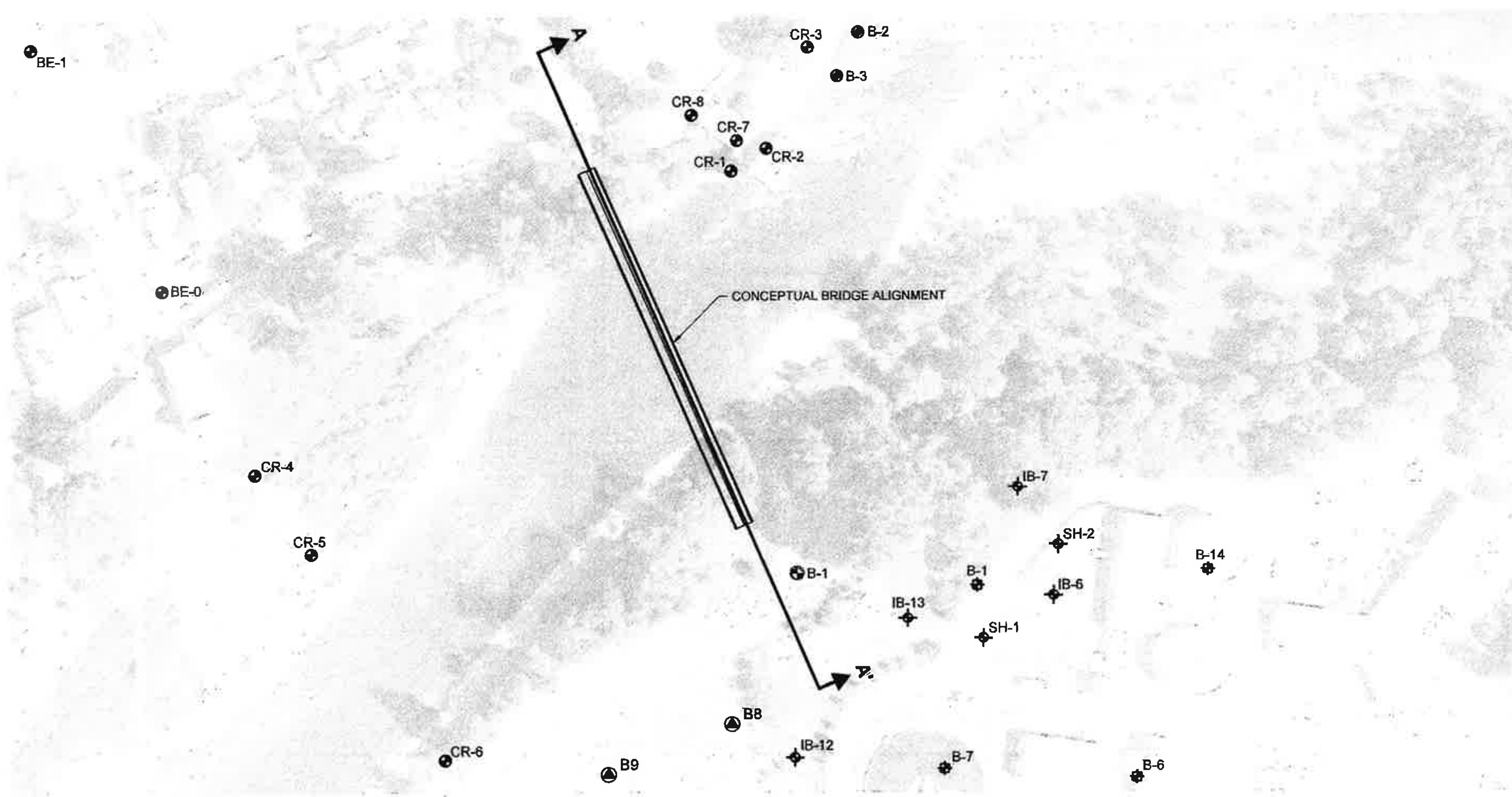
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

Filename: T:\Projects\PDX\101000s\101474_Clackamas County\Avmxd\VicinityMap_10.6.mxd Date: 10/3/2019 Login: AEH



LEGEND

B-1	Designation and Approximate Location of Boring (Shannon & Wilson, 2019)
IB-13 SH-2	Designation and Approximate Location of Boring (Shannon & Wilson, 2007, 2008, 2016)
B-2	Designation and Approximate Location of Boring (GRI, 2011)
CR-1 BE-02	Designation and Approximate Location of Boring (GeoDesign, Inc., 2010)
B8	Designation and Approximate Location of Boring URS, 2001)
B-1	Designation and Approximate Location of Boring (CH2M Hill, 1981)
A A'	Location and Designation of Interpretive Subsurface Profile

NOTES

1. See Appendix A for site plans of logs of historic borings.

Trolley Trail Bridge:
Gladstone to Oregon City Feasibility Study
Clackamas County, Oregon

SITE AND EXPLORATION PLAN

January 2020 101474

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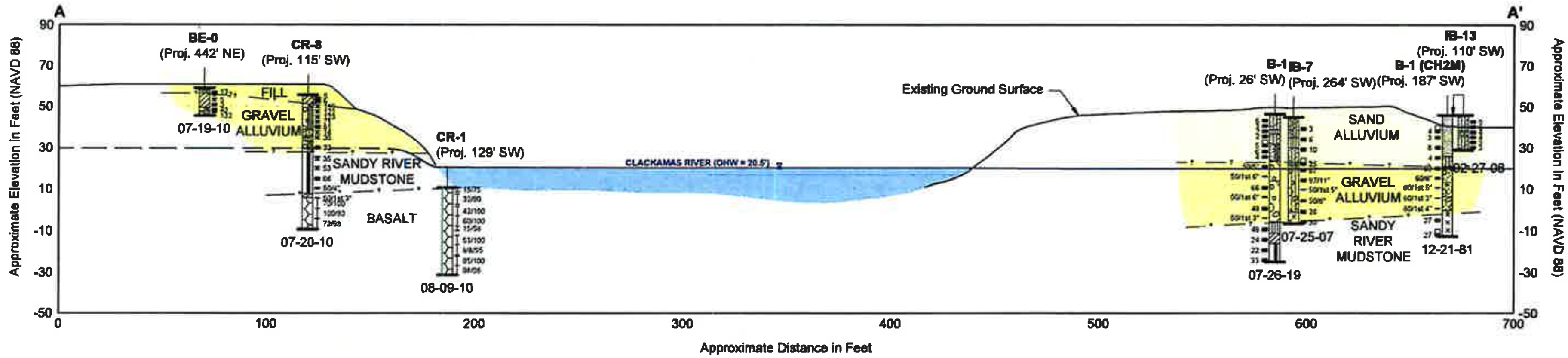
FIG. 2

File: I:\EF\PDX\101000s\101474 Clackamas Count\DRAFTING\101474_Fig2_WorkPlan.dwg Date: 10-15-2019 Author: MXH

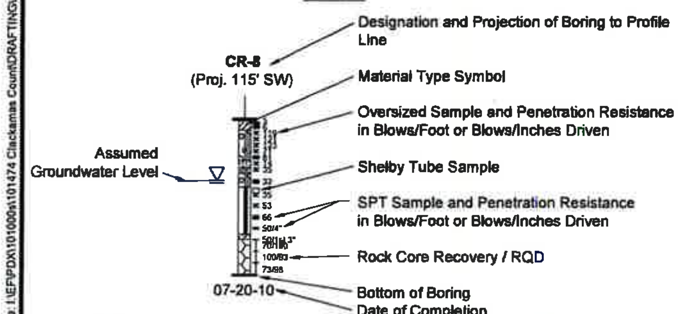


0 50 100

Scale in Feet

No Vertical Exaggeration

LEGEND



NOTES

1. The ground surface was derived from 2014 LiDAR data and may not reflect current existing grade at all locations.
2. Boring locations and elevations are approximate.
3. See Figure 2 for profile location.
4. Profile generalized from materials observed in borings and reported in boring logs by others. Variations may exist between profile and actual conditions. See Appendices A and B for complete boring logs.

Trolley Trail Bridge:
Gladstone to Oregon City Feasibility Study
Clackamas County, Oregon

INTERPRETIVE SUBSURFACE PROFILE A-A'

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FIG. 3

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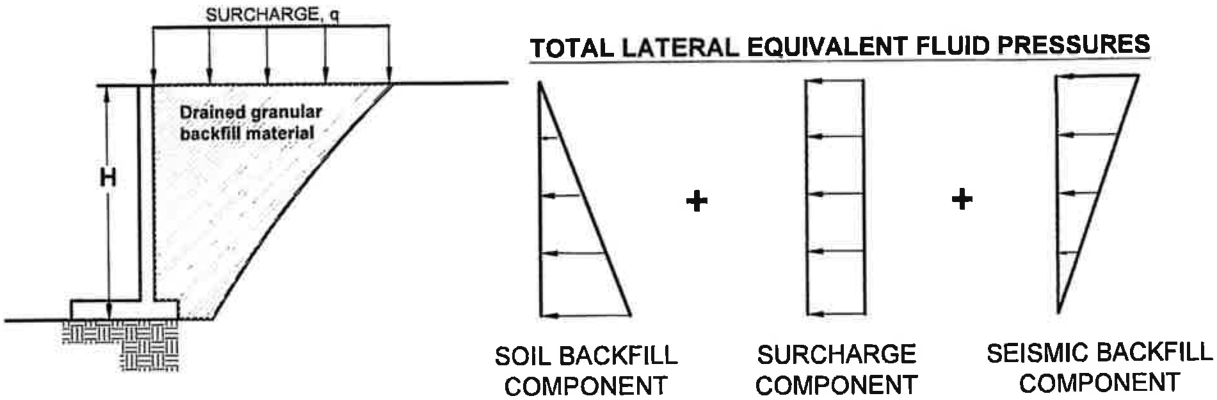
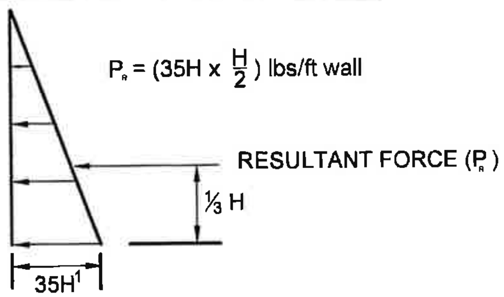


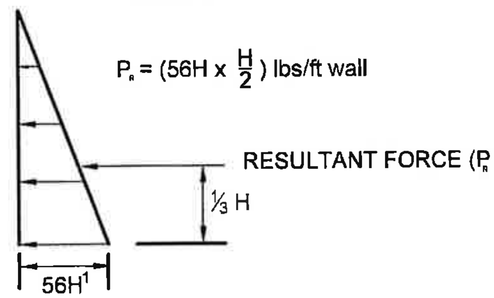
YIELDING WALL SOIL COMPONENT

$P_R = (35H \times \frac{H}{2})$ lbs/ft wall



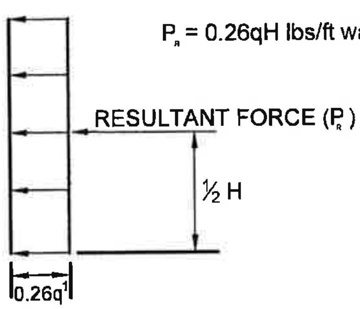
NON-YIELDING WALL SOIL COMPONENT

$P_R = (56H \times \frac{H}{2})$ lbs/ft wall



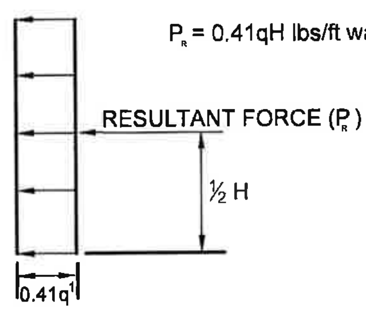
YIELDING WALL SURCHARGE COMPONENT

$P_R = 0.26qH$ lbs/ft wall



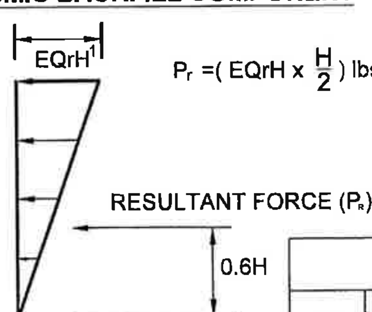
NON-YIELDING WALL SURCHARGE COMPONENT

$P_R = 0.41qH$ lbs/ft wall



SEISMIC BACKFILL COMPONENT

$P_r = (EQrH \times \frac{H}{2})$ lbs/ft wall



AT-REST SEISMIC BACKFILL COMPONENT

$P_r = (EQrH \times \frac{H}{2})$ lbs/ft wall

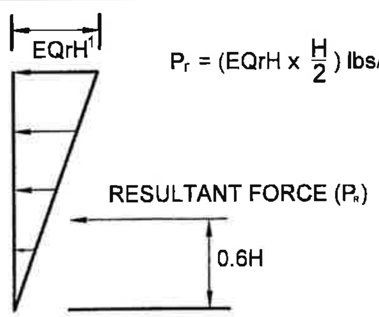


TABLE 1

EQ LEVEL	EQr (pcf)	
	YIELDING	NON-YIELDING
CSZE	7	17
1000	14	35

NOTES
1. Units are pounds per square foot (psf).
2. Backfill unit weight of 135 pcf.
3. Backfill friction angle is 36 deg.
4. Wall backfill is assumed to be drained granular backfill material.
5. Seismic pressures provided for peak ground accelerations associated with the CSZE and 1,000-year earthquakes (see Fig. 4 Table 1 for values)

Trolley Trail Bridge
Gladstone to Oregon City Feasibility Study
Clackamas County, Oregon

PRELIMINARY LATERAL EARTH PRESSURE DISTRIBUTION ON ABUTMENT AND WING WALLS

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FIG. 4

File: I:\EFPDX\101000s\101474 Clackamas Count\DRAFTING\101474 Lateral Earth Pressures.dwg Date: 10-08-2019 Author: MXH

APPENDIX A: PROVIDED EXISTING INFORMATION

Appendix A

Provided Existing Information

CONTENTS

- Geotechnical Data Report, Lake Oswego Raw Water Pipeline, Clackamas County, Oregon, prepared by GeoDesign, Inc., dated March 18, 2011 (GeoDesign, 2011);
- Geotechnical Design Report, Tri-City Water Pollution Control Plant, Interim Expansion, Clackamas County, Oregon, prepared by Shannon & Wilson, Inc., dated September 2008 (Shannon & Wilson, 2008);
- Groundwater Monitoring Program Report, Tri-City Water Resource Recovery Facility, Solids Handling Improvement Project, Clackamas County, Oregon, prepared by Shannon & Wilson, Inc., dated October 26, 2016 (Shannon & Wilson, 2016); and
- Geotechnical Report, River Intake Pump Station (RIPS), Lake Oswego Tigard Water Partnership - Package 3, Gladstone, Oregon, prepared by GRI, dated March 16, 2012 (GRI, 2012);
- Site Map, Boring Location Map, and Boring Logs, Tri-City Service District, Clackamas County, Project No. 52-00082010.09, prepared by URS, dated July 2001 (URS, 2001).

GEODESIGN INC

GEOTECHNICAL DATA REPORT

Lake Oswego Raw Water Pipeline

Clackamas County, Oregon

For

Brown and Caldwell

March 18, 2011

GeoDesign Project: BrownCald-49-05-01

Engineers | Geologists | Environmental Consultants

GEODESIGN INC

March 18, 2011

Brown and Caldwell
6500 SW Macadam Avenue, Suite 200
Portland, OR 97239

Attention: Mr. Brett Teel

Report of Geotechnical Engineering Services
Lake Oswego Raw Water Pipeline
Clackamas County, Oregon
GeoDesign Project: BrownCald-49-05-01

GeoDesign, Inc. is pleased to submit our geotechnical data report for the proposed raw water pipeline alignment located in Clackamas County, Oregon. Our services for this project were conducted in accordance with our proposal dated July 14, 2010. Additional services for explorations completed for the crossing at Highway 99E were conducted in accordance with our proposal dated June 23, 2010. This report presents the results of our surface reconnaissance, subsurface exploration, and laboratory analyses.

We appreciate the opportunity to be of continued service to you. Please call if you have questions regarding this report.

Sincerely,

GeoDesign, Inc.

Brett A. Shipton, P.E., G.E.
Principal Engineer

cc: Mr. Bob Jossis, Brown and Caldwell (via email only)
Ms. Corianne Hart, Brown and Caldwell (via email only)
Mr. Nick Wobbrock, Brown and Caldwell (via email only)
Ms. Deborah Rose, Brown and Caldwell (via email only)

EMH:BAS:kt
Attachments
Seven copies submitted
Document ID: BrownCald-49-05-01-031811-geor.doc

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1.0 INTRODUCTION

GeoDesign, Inc. is pleased to submit this geotechnical data report for the proposed raw water pipeline alignment in Clackamas County, Oregon. Data collected for the Willamette River Crossing portion of the raw water pipeline is included in a separate report. We understand that the proposed raw water pipeline alignment begins at the Clackamas RIPS and will follow surface streets within residential areas in Gladstone, Oregon. The proposed pipeline alignment crosses beneath Highway 99E and continues through Meldrum Bar Park where it crosses the Willamette River. The alignment continues on the west side of the Willamette River, where it passes through Mary S. Young State Park and residential streets in West Linn, Oregon. The proposed raw water pipeline alignment ends at the existing Lake Oswego WTP in West Linn, Oregon. The site location relative to surrounding physical features is shown on Figure 1. For your reference, definitions of all acronyms used in this report are attached at the end of this document.

2.0 PURPOSE AND SCOPE

The purpose of our services was to explore subsurface conditions at the site and provide geotechnical engineering data for use in future design and construction. Specifically, we performed the following tasks:

- Reviewed geologic and geotechnical data relevant to the site.
- Obtained permits for the required drilling from the appropriate jurisdictions.
- Coordinated and managed the field investigation, including scheduling drillers, traffic control personnel, utility locators, and GeoDesign's staff.
- Drilled a total of 32 borings along the proposed alignment to depths ranging between 6.5 and 27.0 feet BGS. Specifically, we completed the following:
  - Four borings to depths ranging between 21.5 and 27.0 feet BGS east and west of Highway 99E
  - Twenty-six borings to depths ranging between 11.8 and 26.5 feet BGS along the proposed alignment
  - Two borings to a depth of 6.5 feet BGS, which were terminated due to refusal on boulders or encountered trench fill and were re-drilled within 3 to 5 feet of the original location
- Recorded pavement and base rock thicknesses in borings that were drilled through the pavement.
- Obtained relatively undisturbed and disturbed soil samples for laboratory testing and maintained a log of subsurface conditions observed in the exploratory borings.
- Completed a laboratory testing program on selected soil samples collected from the explorations. Specifically, the following were completed:
  - Moisture content determination on all soil samples in general accordance with ASTM D 2216
  - Density determination on all relatively undisturbed and ring samples in general accordance with ASTM D 2937
  - Eighteen fines determinations in general accordance with ASTM D 1140
  - Seventeen gradations in general accordance with ASTM C 117 and ASTM C 136

- Eighteen Atterberg limits determinations in general accordance with ASTM D 4318
- Three direct shear tests in general accordance with ASTM D 3080

- Provided this data report detailing our findings and recommendations regarding trench stabilization, dewatering, shoring, and rock excavatability.

3.0 SITE CONDITIONS

3.1 SURFACE CONDITIONS

The majority of the alignment runs through residential areas on paved streets. The raw water pipeline alignment begins near the intersection of Clackamas Boulevard and Portland Avenue in Gladstone, Oregon. The alignment continues to the west along Clackamas Boulevard to the intersection with Bellevue Avenue, where it continues to the north. The proposed alignment turns to the west and continues down Exeter Street, crossing beneath Highway 99E. West of Highway 99E, the alignment runs down a paved multi-use path called Jensen Road. At the approximate midpoint of the paved path, the alignment continues to the north through a grassy area to Meldrum Bar Park Road, where the alignment turns to the west and continues down the road to the Willamette River. On the west side of the Willamette River, the alignment passes through Mary S. Young State Park to the northern entrance of the park on Mapleton Drive. The proposed alignment follows Mapleton Drive to the existing Lake Oswego WTP, where the raw water pipeline ends. The proposed alignment is shown on Figures 2 and 3.

3.2 REGIONAL GEOLOGY

The complete proposed waterline alignment is located at the southwestern margin of the Portland Basin physiographic province and crosses into the southeastern portion of the Tualatin Basin physiographic province. The Portland Basin is bound by the Tualatin Mountains to the west and south and the Cascade Range to the east and north. The Portland Basin is described as a fault-bounded, pull-apart basin that was formed by two northwest trending fault zones (Pratt, et al., 2001). The Portland Hills Fault Zone trends along the west side of the basin and the Frontal Fault Zone trends along the east side of the basin near Lacamas Lake, east of Vancouver, Washington. The Portland Basin is underlain by volcanic bedrock and contains a thick sequence of sedimentary deposits that lap onto the uplifted bedrock highlands at the basin margins.

The Tualatin Basin is a northwest- to southeast-trending structural basin bound by the Portland Hills and Tualatin Mountains to the north and east and the Chehalem Mountains and Coast Range to the south and west, respectively (Wilson, 1998). The Tualatin Basin is underlain by volcanic bedrock and contains a thick sequence of sedimentary deposits that lap onto the uplifted bedrock found at the basin margins.

The complete proposed waterline alignment follows a topographic depression locally known as the Oswego Gap that is controlled by bedrock structure. The Oswego Gap cuts through the Tualatin Mountains between the Portland Basin to the east and the Tualatin Basin to the west. The eastern end of the gap is now occupied by Oswego Lake. The Oswego Gap was likely formed by Miocene to Pleistocene age (20 million to 2 million years before present) uplift of the Tualatin Mountains and displacement on the Lake Oswego Fault, which trends southwest to northeast along the axis of the gap. The ancient Tualatin River likely eroded the bedrock weakened by the fault and initially formed the gap. The Oswego Gap was subsequently scoured and enlarged by late Pleistocene age (15,500 to 13,000 years before present) glacial outburst floods referred to as the Missoula Floods.

The complete proposed waterline alignment traverses a large area of the southwestern portion of the Portland Basin and spans a number of geologic units. The bedrock unit underlying the project area is a sequence of basalt flows belonging to the Miocene age (20 million to 10 million years before present) CRBG. The CRBG is a widespread series of flood basalt flows that originated from southeastern Washington and northeastern Oregon and flowed westward down the ancient Columbia River Valley. The basalt flows generally followed and filled pre-existing topographic lowlands in western Oregon. Basalt thicknesses can range from tens of feet to several hundred feet. The CRBG underlies the Portland and Tualatin basins and forms the upland topography of the Tualatin Mountains. The CRBG was subsequently covered by volcanic, fluvial, and lacustrine sediments derived from erosion of the adjacent highlands.

Faulting and folding were contemporaneous with deposition of the CRBG flows, and this structural deformation continued into the Quaternary (2.6 million years to present). The CRBG mapped along the southern boundary of the Tualatin and Portland basins and in the Oswego Gap area shows an extensive history of faulting and tectonic displacement (Burns, et. al., 1997; Ma, et. al., 2009). The general trend of faulting is southwest to northeast and southeast to northwest with widely variable fault displacements and ages of activity. Faulting in the vicinity of the raw water pipeline generally trends southeast to northwest paralleling the Tualatin Mountains and the Willamette River. These faults form an enechelon pattern with offsets that step-down to the northeast. Vertical offset of the top of the weathered basalt surface was encountered along the trend of borings HDD-1 to HDD-5. This offset may be evidence of previously undocumented faulting of the CRBG associated with faults trending parallel to the Willamette River. A more thorough discussion of offset in the top of basalt at the Willamette River Crossing and its possible relation to faulting is provided in the Willamette River Crossing report (GeoDesign, 2011). A majority of the mapped faults in the project area show no documented evidence of displacement during the Quaternary and are considered to be inactive (Burns, et. al., 1997; Personius, S.F., 2002).

However, several of the faults in the area have evidence of displacement during the Pliocene to Pleistocene (5.3 million years to 10,000 years), and down-drop along these faults created lowlands now identified as the Portland and Tualatin basins. As the floor of these basins down-dropped, they were filled with a thick sequence of alluvial and fluvial sediments. The Portland and Tualatin basins were initially in-filled with a fine-grained facies of the Troutdale Formation, termed the Sandy River Mudstone. This unit consists of interbedded lacustrine sand, silt, and clay and is the oldest sedimentary rock overlying the CRBG in the Portland and Tualatin basins. Following deposition of the Sandy River Mudstone, a coarse-grained facies of the Troutdale Formation consisting of a sequence of alluvial gravel, sand, and silt was deposited in the central part of the Portland Basin. A significant portion of the sand and gravel component of this coarse-grained facies was derived from sediment sources located in eastern Washington and Idaho and transported to the Portland Basin by the proto-Columbia River.

The Springwater Formation is a sequence of Pliocene to Pleistocene alluvial gravel, sand, and silt deposited in the eastern part of the Portland Basin. The Springwater Formation was deposited in major river drainages that originated in the Cascade Mountains and foothills. Consequently, a significant portion of the sand and gravel component of this formation contains volcanic rock of the Cascade Mountains, which distinguishes it from the Troutdale Formation.

During the late Pleistocene (15,500 to 13,000 years before present), a sequence of catastrophic floods inundated the Portland and Tualatin basins. These floods originated from repeated collapses of a glacially dammed lake in western Montana, and water from these outbursts flowed down the Columbia River into the Portland and Tualatin basins. These series of outburst floods are termed the Missoula Floods, and the upper water surface during these events reached as high as 400 feet, inundating much of the Portland and Tualatin basins.

The Missoula Floods selectively eroded the pre-existing topography in the Portland and Tualatin basins and subsequently deposited sediments as the flood waters receded. A variety of individual sedimentary facies are associated with the Missoula Floods, including coarse-grained deposits of gravel and sand associated with floodways and tributary channels and a fine-grained facies composed of silt and clay deposited in slack-water lakes.

The basalt bedrock and older sedimentary deposits in the project area have subsequently been modified by Holocene, or recent, (10,000 years to present) river and stream erosion and deposition. A discussion of the geologic units in the raw water portion of the pipeline alignment is provided in the following sections.

3.3 RAW WATER PIPELINE GEOLOGY

3.3.1 Clackamas RIPS to Willamette River

The raw water pipeline extends west from the Clackamas RIPS across a broad, gently sloping older alluvial terrace located between the Clackamas and Willamette rivers. The geologic profile located along the Gladstone waterline alignment consists of basalt flows of the Miocene age (20 million to 10 million years before present) CRBG overlain by laminated, sandy silt and clay of the Pliocene to Pleistocene age (5 million to 1.5 million years before present) lower Troutdale Formation (Madin, 1990; Ma, et. al., 2009). The Troutdale Formation is overlain by interbedded sand and gravel layers of the late Pleistocene (15,500 to 13,000 years before present) channel facies of the Missoula Flood deposits. Based on the results of our subsurface explorations, the flood deposits extend to depths of approximately 25 feet BGS.

The eastern pipeline approach to the Willamette River crosses Meldrum Bar Park, which consists of a low, broad, flat alluvial terrace. The terrace is mapped as Quaternary alluvium, which generally consists of unconsolidated silt, sand, and gravel deposits that extend below our deepest exploration of 27 feet BGS (Madin, 1990; Ma, et. al., 2009). The alluvium is likely a mixture of recent river-deposited sand and gravel and Missoula Flood deposits.

3.3.2 Willamette River to Lake Oswego WTP

The raw water pipeline crosses the Willamette River from Meldrum Bar Park and runs north along the west riverbank through Mary S. Young State Park and terminates at the Lake Oswego WTP. The river bottom consists of recent alluvium that ranges in thickness from approximately 23 to

57 feet BGS based on subsurface explorations. The river alluvium is underlain by basalt bedrock that is interpreted to belong to the CRBG. The CRBG is mapped along both sides of the river above the pipeline crossing (Madin, 1990; Ma, et. al., 2009).

The Willamette River is flanked by several river terraces consisting of Quaternary alluvium, Springwater Formation gravel, and basalt bedrock belonging to the CRBG (Madin, 1990; Ma, et. al., 2009). The west riverbank is located on the eastern portion of Mary S. Young State Park and consists of a series of river-cut bedrock terraces. This offset may also be evidence of previously undocumented faulting of the CRBG associated with faults trending parallel to the Willamette River. A more thorough discussion of offset in the top of basalt at the Willamette River Crossing and its possible relation to faulting is provided in the Willamette River Crossing report (GeoDesign, 2011). Shallow basalt bedrock mapped as CRBG outcrops along portions of the lower river terrace in the vicinity of the proposed raw water pipeline alignment (Madin, 1990; Ma, et. al., 2009). Basalt bedrock outcrops were observed north of the existing pipeline at the edge of the river. Shallow basalt bedrock was encountered at a depth of 6 feet BGS in boring HDD-5 drilled for GeoDesign's Willamette River Crossing study. The log of this study can be found in GeoDesign's Willamette River Crossing Report (Geodesign, 2011). Quaternary alluvium is mapped on most of the terraces next to the river and generally consists of unconsolidated silt, sand, and gravel deposits. Silt and fine sand deposits may correspond to fine-grained Missoula Flood deposits that mantle the upper river terrace and lower slopes of West Linn. The Quaternary alluvium generally consists of unconsolidated silt, sand, and gravel deposits that extend below our deepest exploration of 40 feet BGS.

Springwater Formation silt, sand, and gravel deposits are mapped (Madin, 1990; Ma, et. al., 2009) along portions of the middle river terrace in the vicinity of the proposed water pipeline alignment and were likely encountered in borings MSY-1 and MSY-3. The Springwater Formation generally consists of poorly to moderately consolidated, semi-cemented silt and subrounded to rounded sand and gravel. The Springwater Formation is similar to the more common Troutdale Formation in age and geologic history. However, the Springwater Formation originates from alluvial deposits from the Cascade Mountains; whereas the Troutdale Formation sediments have their origins in the Columbia Basin. The Springwater Formation underlying the alluvium was likely scoured by Missoula Flood waters and subsequently covered by slack-water flood silt and recent river alluvium.

3.4 SUBSURFACE CONDITIONS

We explored subsurface conditions at the site by drilling 32 borings (99-1 through 99-4, BE-0 through BE-2, DA-1, EX-1 through EX-3, JE-1 through JE-3, MA-1 through MA-5A, ME-2 through ME-5, MP-1, and MSY-1 through MSY-5) to depths ranging between 6.5 and 27.0 feet BGS. The approximate locations of the borings completed on the east side of the Willamette River are shown on Figure 2. The approximate locations of the borings completed on the west side of the Willamette River are shown on Figure 3. Descriptions of the field explorations, laboratory procedures, and logs of the explorations are provided in the Appendix.

The subsurface conditions encountered to the east of the Willamette River along the raw water pipeline alignment generally consist of alluvial soils consisting of alternating layers of soft to very stiff silt and clay, dense to very dense gravel, and very loose to medium dense sand with varying amounts of silt and clay. To the west of the Willamette River, subsurface conditions generally consist of alluvial soils similar to that encountered on the east side of the river, overlying decomposed to moderately weathered basalt. In borings MA-1 and MA-2, alluvial materials were not encountered beneath the AC and aggregate base material. Residual soil consisting of silt and clay were encountered at these locations. The subsurface conditions are summarized on cross sections A-A', B-B', C-C', D-D', E-E', F-F', G-G', and H-H' as shown on Figures 4 through 11, respectively.

3.4.1 AC and Aggregate Base

The majority of the explorations drilled for the on-land portion of the raw water pipeline alignment were completed on surface streets or on a paved pathway. Borings that were not drilled through pavements include MP-1 and MSY-1 through MSY-5. The thickness of the AC and aggregate base observed at the boring locations is summarized in Table 1. For clarity, AC and aggregate base thicknesses are not shown on the cross sections on Figures 4 through 11.

Table 1. AC and Aggregate Base Thicknesses

Boring	AC Thickness (inches)	Aggregate Base Thickness (inches)
99-1	6.0	18.0
99-2	7.0	12.0
99-3	3.0	15.0
99-4	6.0	12.0
BE-0	3.0	9.0
BE-1	2.5	1.5
BE-2	1.5	2.5
DA-1	4.5	5.5
EX-1	3.0	3.0
EX-2	4.0	2.0
EX-2A	4.0	2.0
EX-3	4.0	6.0
JE-1	3.0	21.0
JE-1A	1.5	10.5
JE-2	1.5	22.5
JE-3	0.75[1]	29.25
ME-2	2.0	4.0
ME-3	2.0	10.0
ME-4	2.0	10.0
ME-5	2.0	10.0
MA-1	3.5	8.5
MA-2	4.0	8.0

Table 1. AC and Aggregate Base Thicknesses (continued)

Boring	AC Thickness (inches)	Aggregate Base Thickness (inches)
MA-3	2.5	13.0
MA-4	4.0	6.0
MA-5	6.0	NE
MA-5A	5.0	5.0
MP-1	Not encountered	Not encountered
MSY-1	Not encountered	Not encountered
MSY-2	Not encountered	Not encountered
MSY-3	Not encountered	Not encountered
MSY-4	Not encountered	Not encountered
MSY-5	Not encountered	Not encountered

1. Chip seal was encountered at the surface in boring JE-3.

3.4.2 Undocumented Fill

Undocumented fill was encountered in a total of seven borings (99-2, BE-0, JE-3, ME-3, ME-4, MA-5, MA-5A, and MP-1) and ranges in thickness from 1.5 to 11.4 feet. In general, fill soils consist of loose to medium dense gravel with varying amounts of silt and sand. Soft to medium stiff silt was encountered in MP-1 and 99-2.

3.4.3 Alluvium

Alluvium was encountered in all of the borings with the exception of MA-1 and MA-2, which encountered residual soil near the surface. The alluvial soils observed in the borings consist of soft to very stiff silts and clays with varying amounts of sand and gravel; very loose to very dense sand with varying amounts of silt, clay, and gravel; and loose to very dense gravel with varying amounts of sand and silt are also present. Zones of silt, clay, sand, and gravel are present in alternating layers. Difficult drilling and possible cobbles and boulders were encountered in borings DA-1, EX-1, EX-2, EX-2A, JE-1, JE-1A, JE-2, MA-3, MP-1, and MSY-3.

3.4.4 Residual Soil and Weathered Bedrock

Residual soil was encountered near the surface in borings MA-1 and MA-2. In addition, residual soil was encountered in boring JE-1 at a depth of 22.0 feet BGS, beneath the alluvial soils. Residual soils consist of soft to hard silts and clays with varying amounts of sand and gravel. Decomposed to moderately weathered bedrock was encountered beneath the alluvial soils in borings MA-3, MSY-1, and MSY-2. The material consists of hard silt and very dense, silty sand. These units are derived from basaltic origins.

3.4.5 Groundwater

Where possible, borings were drilled using hollow-stem auger drilling techniques in order to measure the depth to groundwater during drilling. In boring 99-1, mud-rotary drilling techniques were used, and the hole was flushed and allowed to equilibrate for approximately 3.25 hours prior to measurement. Measurements taken during drilling likely represent seasonally low values. Groundwater levels may fluctuate due to periods of heavy rainfall as well as the rise and fall of the nearby Willamette River. Table 2 presents the groundwater levels measured at each location at the time of drilling.

Table 2. Groundwater Depths

Boring	Depth to Groundwater (feet)
99-1	2.9[1]
99-2	13.0
99-3	6.0
99-4	14.6
BE-0	Not encountered
BE-1	Not encountered
BE-2	Not encountered
DA-1	9.8
EX-1	9.8
EX-2	Not encountered
EX-2A	12.0
EX-3	12.4
JE-1	6.5
JE-1A	10.0
JE-2	9.5
JE-3	Not encountered
MA-1	Not encountered
MA-2	Not encountered
MA-3	6.8
MA-4	Not encountered
MA-5	Not encountered
MA-5A	Not encountered
ME-2	6.5
ME-3	15.0
ME-4	Not encountered
ME-5	Not encountered
MP-1	11.5
MSY-1	Not encountered
MSY-2	Not encountered
MSY-3	Not encountered
MSY-4	Not encountered
MSY-5	Not encountered

1. Mud-rotary drilling techniques used. Water level allowed to equilibrate for 3.25 hours prior to measurement.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

Subsurface conditions encountered in the explorations and our recommendations for feasible construction methods for the trench along the raw water pipeline alignment are provided in the following sections. Based on our geotechnical investigation, the following factors are likely to have an impact on design and construction:

- Cobbles and boulders are present in the alluvial soils encountered at the site. Utility excavations will likely require removal of some cobbles and boulders. Where encountered, removal of cobbles and boulders will be difficult, may require special equipment, and may result in larger backfill volumes. Excavation estimates and the project budget should account for enlarged trenches and slowed excavations.
- Shallow groundwater was encountered in several locations along the alignment. Due to the discontinuity of the groundwater measurements, water encountered is likely perched rather than representative of the regional groundwater table. Dewatering will be required, particularly during the winter months.
- Isolated areas of weathered bedrock were encountered near the base of the borings. If the trench extends into these isolated areas of weathered rock, excavation may be difficult and require special equipment and excavating techniques. This includes breaking the rock with an excavator-mounted hydraulic jackhammer, ripping, or the use of non-explosive chemical agents.

4.2 EXCAVATION

We anticipate that perched groundwater will be encountered throughout the year in portions of the excavation, particularly during or after periods of significant precipitation. The contractor should be prepared to dewater excavations. The dewatering methods used should be chosen by the contractor. Cobbles and boulders may be encountered in the overburden soils during excavation. Where encountered, cobbles and boulders will result in difficult trench excavations and may require special equipment and procedures for removal. This indicates the use of excavation equipment capable of lifting large boulders and breaking up of boulders. Where cobbles and boulders are encountered, trenches may be wider than anticipated, increasing the amount of backfill material required.

If excavations extend into the weathered bedrock, specialized excavation techniques may be required. This includes breaking the rock with an excavator-mounted hydraulic jackhammer. Non-explosive chemical agents are an alternative to blasting. When chemical agents are used, holes are drilled in the bedrock. The slurry agent is poured in the holes and expands, typically for a period of a few hours, and breaks up the rock in a similar fashion to blasting.

4.2.1 Excavation Support

In our opinion, a trench box or other inactive shoring system is appropriate for excavations up to 8 feet deep, provided that there are no sensitive nearby improvements; an active shoring system should be considered to protect nearby improvements. Selection of the type of shoring system should be the responsibility of the contractor and should be designed by a licensed engineer.

Shoring design should be made in accordance with applicable Occupational Safety and Health Administration and state regulations and should consider groundwater, soil type, and protection of nearby improvements.

Oversize materials will likely be encountered in the excavation, particularly in the deeper segments. Removal of boulders may require specialized shoring equipment and limited unshored segments of open trench.

5.0 LIMITATIONS

We have prepared this data report for use by Brown and Caldwell, the City of Lake Oswego, and members of their design and construction teams for the proposed project. The data and report can be used for bidding or estimating purposes, but our report, conclusions, and interpretations should not be construed as warranty of the subsurface conditions and are not applicable to other sites.

Exploration observations indicate soil conditions only at specific locations and only to the depths penetrated. They do not necessarily reflect soil strata or water level variations that may exist between exploration locations. If subsurface conditions differing from those described are noted during the course of excavation and construction, re-evaluation will be necessary. The scope of our services does not include services related to construction safety precautions, and our recommendations are not intended to direct the contractor's methods, techniques, sequences, or procedures.

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

◆ ◆ ◆

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,

GeoDesign, Inc.

Erica M. Hann, P.E.
Project Engineer

Brett A. Shipton, P.E., G.E.
Principal Engineer

REGISTERED PROFESSIONAL ENGINEER
56207
OREGON
JULY 11, 2000
BRETT A SHIPTON

EXPIRES: 6-30-2012

REFERENCES

Burns, Scott, Growney, Lawrence, Brodersen, Brett, Yeats, Robert S., Popowski, Thomas A., 1997, Map showing faults, bedrock geology, and sediment thickness of the western half of the Oregon City 1:100,000 quadrangle, Washington, Multnomah, Clackamas, and Marion Counties, Oregon, Oregon Department of Geology and Mineral Industries, IMS-75, scale 1:100,000.

GeoDesign, 2011. *Geotechnical Data Report, Lake Oswego Raw Water Pipeline, Willamette River Crossing, Clackamas County Oregon,* dated March 3, 2011. GeoDesign Project: BrownCald-49-02-03.

Ma, Lina, Madin, Ian P., Olson, Keith V., Watzig, Rudie J., compilers, 2009, Oregon Geologic Data Compilation, Version 5, Oregon Department of Geology and Mineral Industries, ODGC-5, GIS digital data.

Madin, I.P., 1990. Earthquake Hazard Geology Maps of the Portland Metropolitan Area, Oregon: Test and Map Explanation, DOGAMI Open File Report 0-90-2.

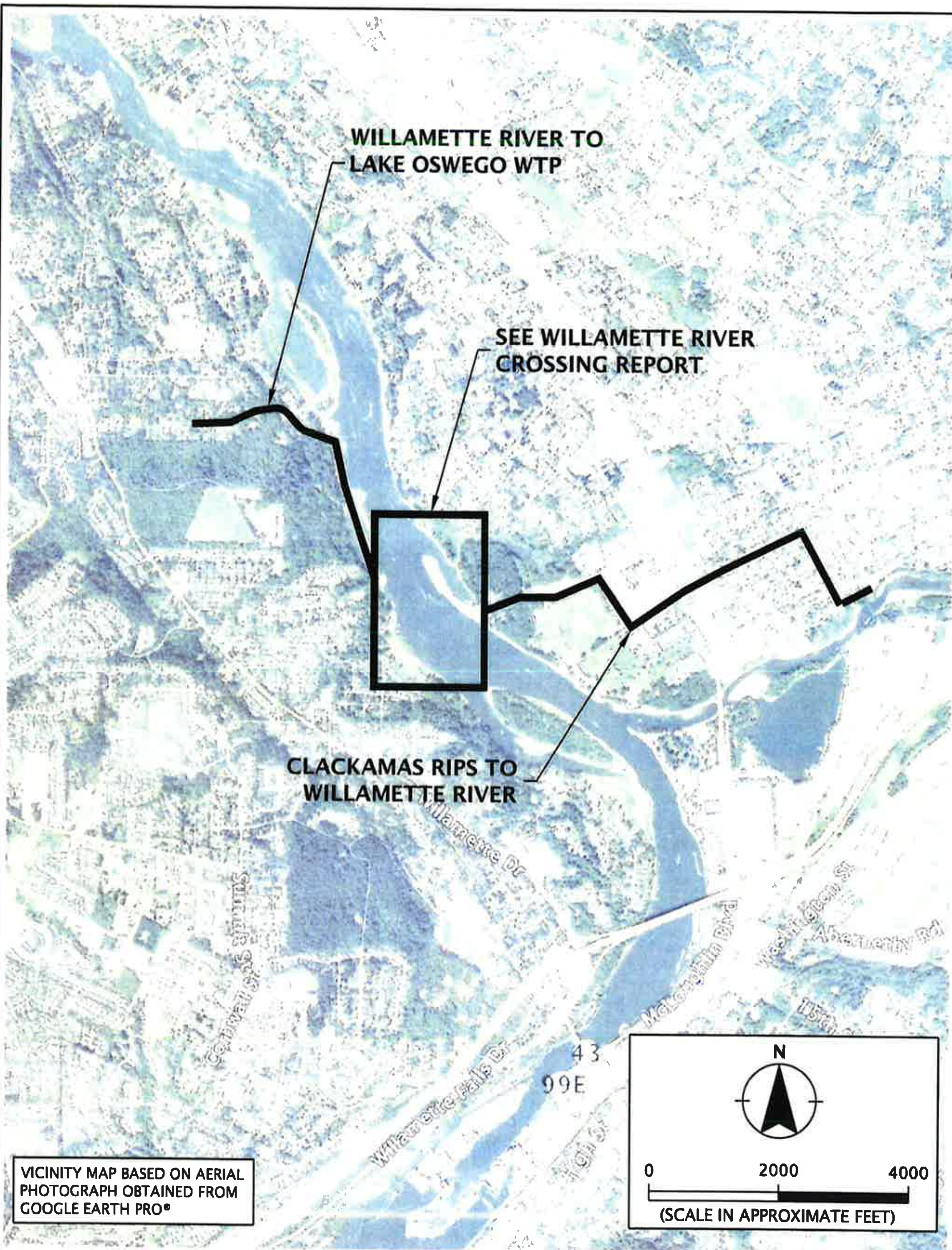
Orr, E.L. and Orr, W.N., 1999, Geology of Oregon. Kendall/Hunt Publishing, Iowa: 254 p.

Personius, S.F., compiler, 2002, Quaternary fault and fold database of the United States, ver. 1.0: U.S. Geological Survey Open-File Report 03-417, http://qfaults.cr.usgs.gov.

Pratt, T.L., Odum, J., Stephenson, W., Williams, R., Dadisman, S., Holmes, M., and Haug, B., 2001, Late Pleistocene and Holocene Tectonics of the Portland Basin, Oregon and Washington, from High-Resolution Seismic Profiling, Bulletin of the Seismological Society of America, 91, pp. 637-650.

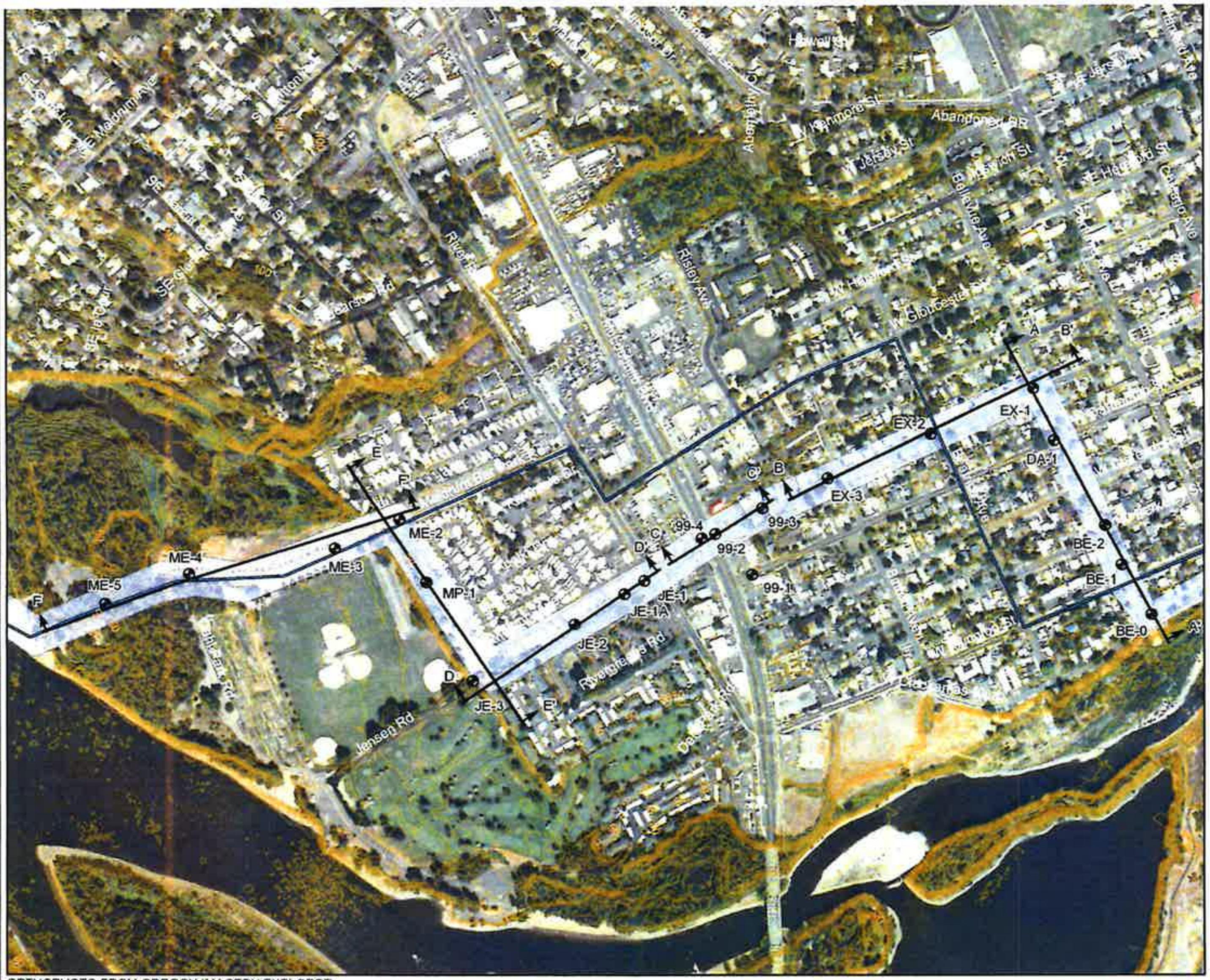
Wilson, Doyle C., 1998, Post-middle Miocene Geologic Evolution of the Tualatin Basin, Oregon, Oregon Geology, vol. 60, no. 5., p. 99-116.

FIGURES



GEODESIGN INC 15575 SW Sequoia Parkway - Suite 100 Portland OR 97224 Off 503.968.8787 Fax 503.968.3068	BROWNCALD-49-05-01	**VICINITY MAP**
	FEBRUARY 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR — **FIGURE 1**

Printed By: aday | Print Date: 3/18/2011 9:49:32 AM
File Name: J:\A-D\BrownCald\BrownCald-49\BrownCald-49-05\BrownCald-49-05-01\Figures\CAD\BrownCald-49-05-01-VM01.dwg | Layout: FIGURE 1



LEGEND

BE-0 ⊕ BORING

EXISTING RAW WATER PIPELINE

PREFERRED ALIGNMENT

2-FOOT LIDAR CONTOUR

A A' CROSS SECTION LINE

N

0 250 500 1,000

(SCALE IN FEET)

ORTHOPHOTO FROM OREGON IMAGERY EXPLORER
TOPOGRAPHY DERIVED FROM 2007 OREGON LIDAR CONSORTIUM
BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OREGON

Printed By: aday | Print Date: 2/18/2011 8:55:00 AM
File Name: J:\A-D\BrownCald\BrownCald-49\BrownCald-49-05\BrownCald-49-05-01\Figures\CAD\BrownCald-49-05-01-SP01.dwg | Layout: FIGURE 2

SITE PLAN - CLACKAMAS RIPS TO WILLAMETTE RIVER CROSSING

FIGURE 2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

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MARCH 2011

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LEGEND

MA-1 ⊕ BORING

PREFERRED ALIGNMENT

EXISTING RAW WATER PIPELINE

2-FOOT LIDAR CONTOUR

G G' CROSS SECTION LINE

N

0 250 500 1,000

(SCALE IN FEET)

ORTHOPHOTO FROM OREGON IMAGERY EXPLORER. TOPOGRAPHY DERIVED FROM 2007 OREGON LIDAR CONSORTIUM. BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OREGON

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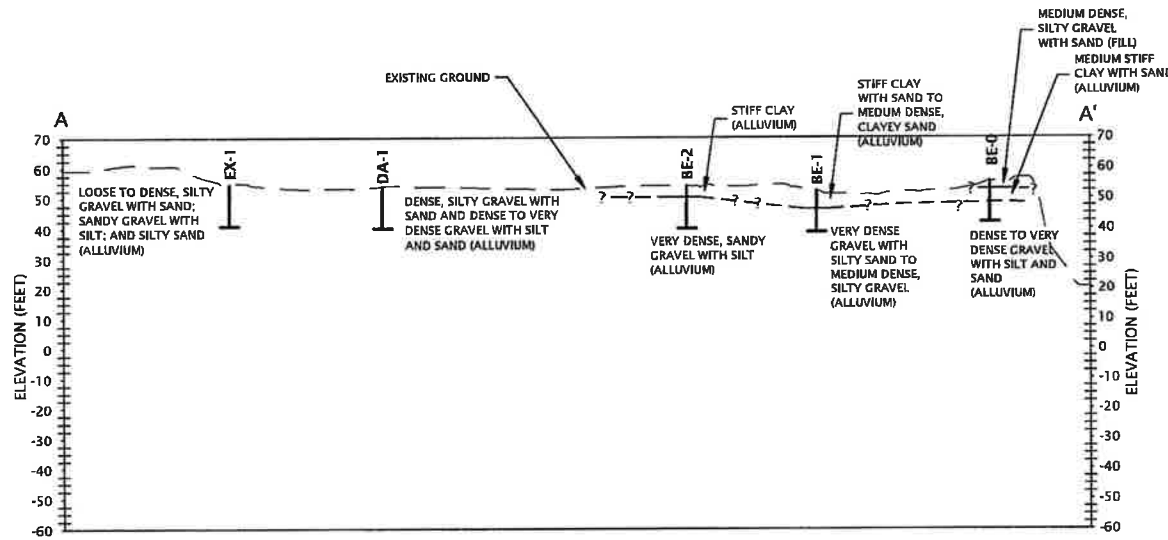
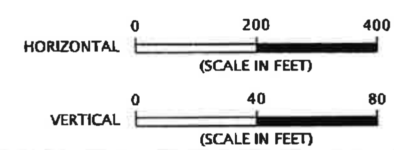
GEODESIGN INC 15575 SW Sequoia Parkway - Suite 100 Portland OR 97224 Off 503.968.8787 Fax 503.968.3068	BROWNCALD-49-05-01	SITE PLAN WILLAMETTE RIVER CROSSING TO LAKE OSWEGO WTP
	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR — FIGURE 3



NOTE:

1. PROFILE SURFACE LINE OBTAINED FROM WESTLAKE CONSULTANTS; BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OR



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CROSS SECTION A-A'

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE 4

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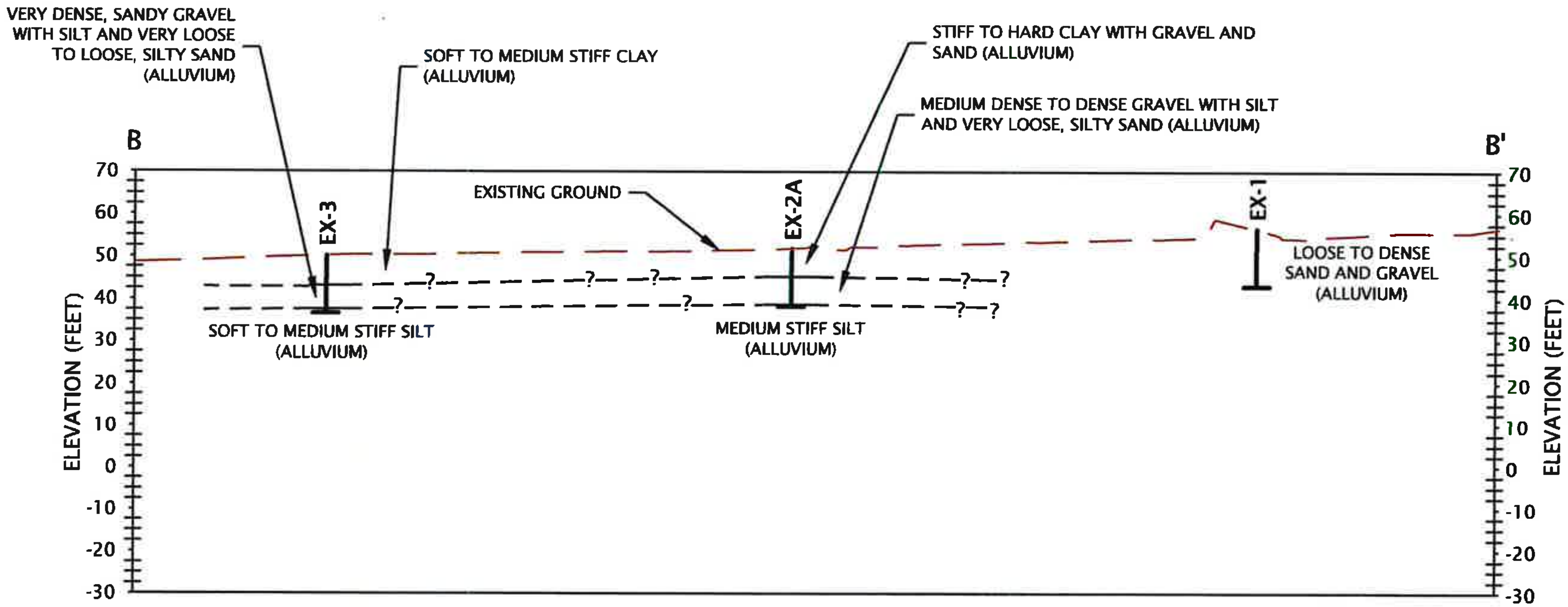

NOTE:

1. PROFILE SURFACE LINE OBTAINED FROM WESTLAKE CONSULTANTS; BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OR

HORIZONTAL 0 200 400 (SCALE IN FEET)

VERTICAL 0 40 80 (SCALE IN FEET)

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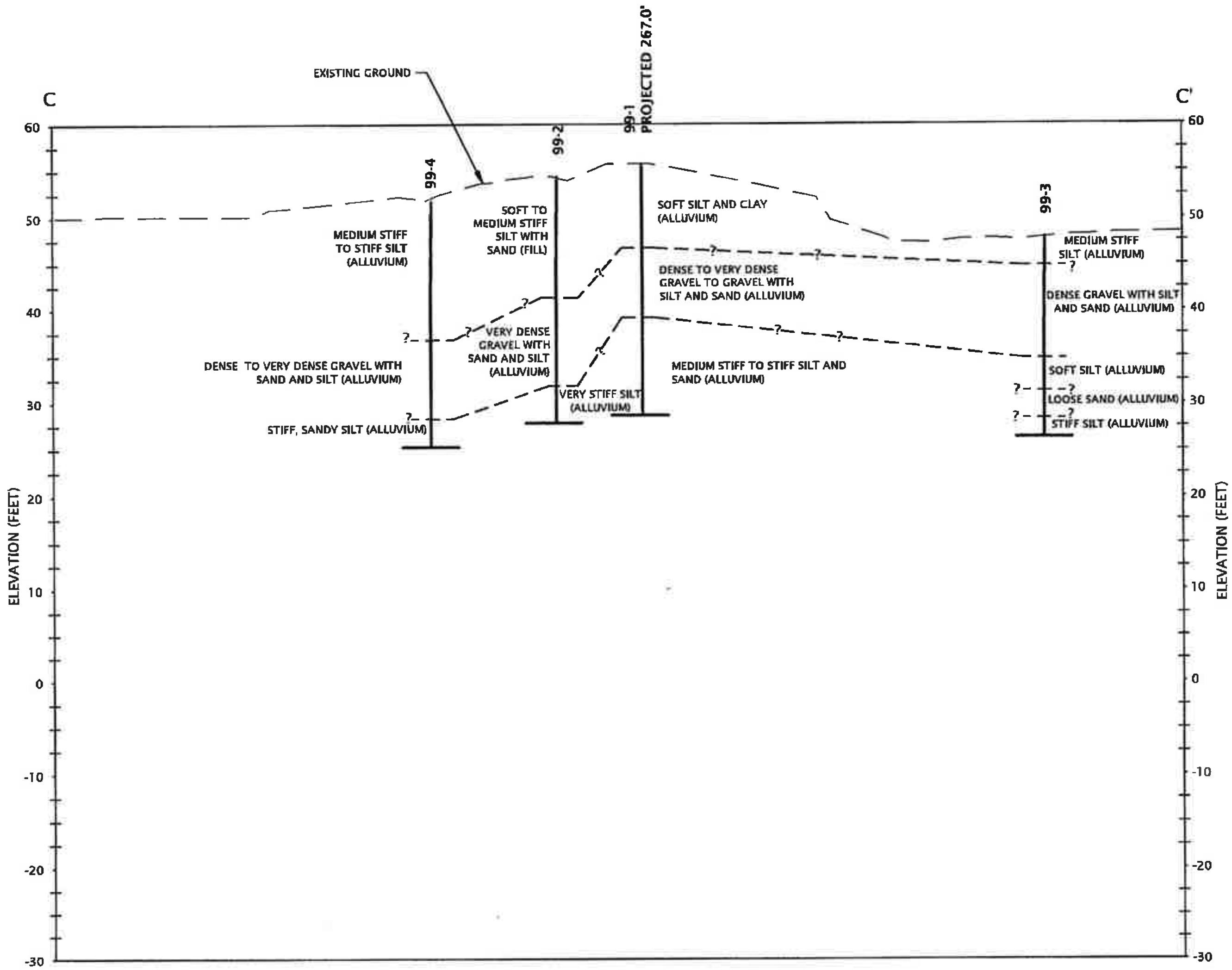
CROSS SECTION B-B'

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE 5



NOTE:
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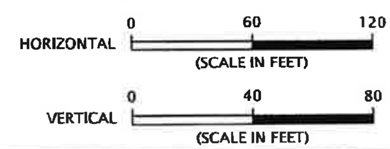

GEODESIGN INC 15575 SW Sequoia Parkway - Suite 100 Portland OR 97224 Off 503.968.8787 Fax 503.968.3068	BROWNCALD-49-05-01	CROSS SECTION C-C'
	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR
		FIGURE 6

Printed By: aday | Print Date: 3/18/2011 9:46:42 AM
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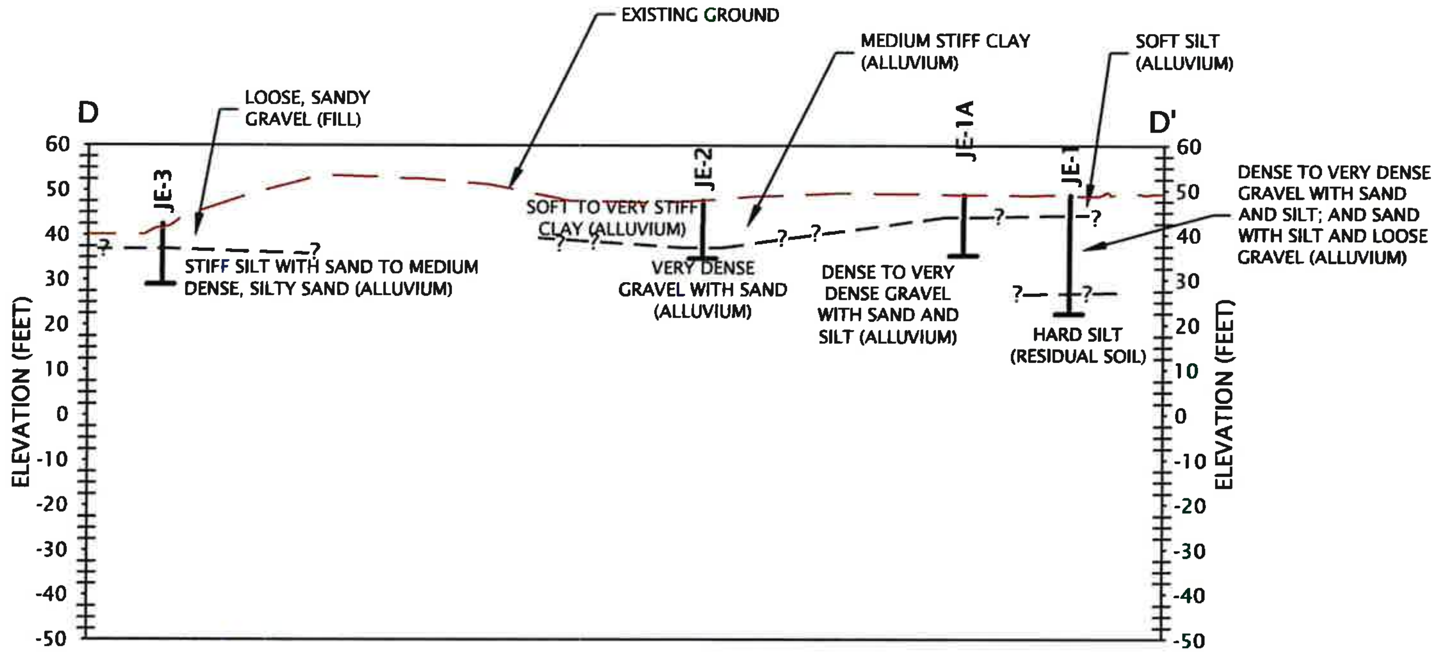

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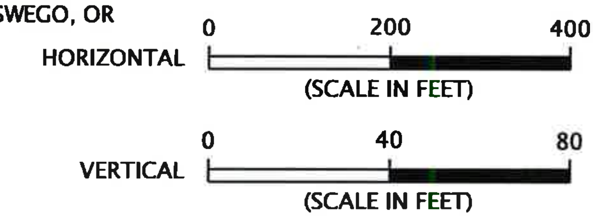

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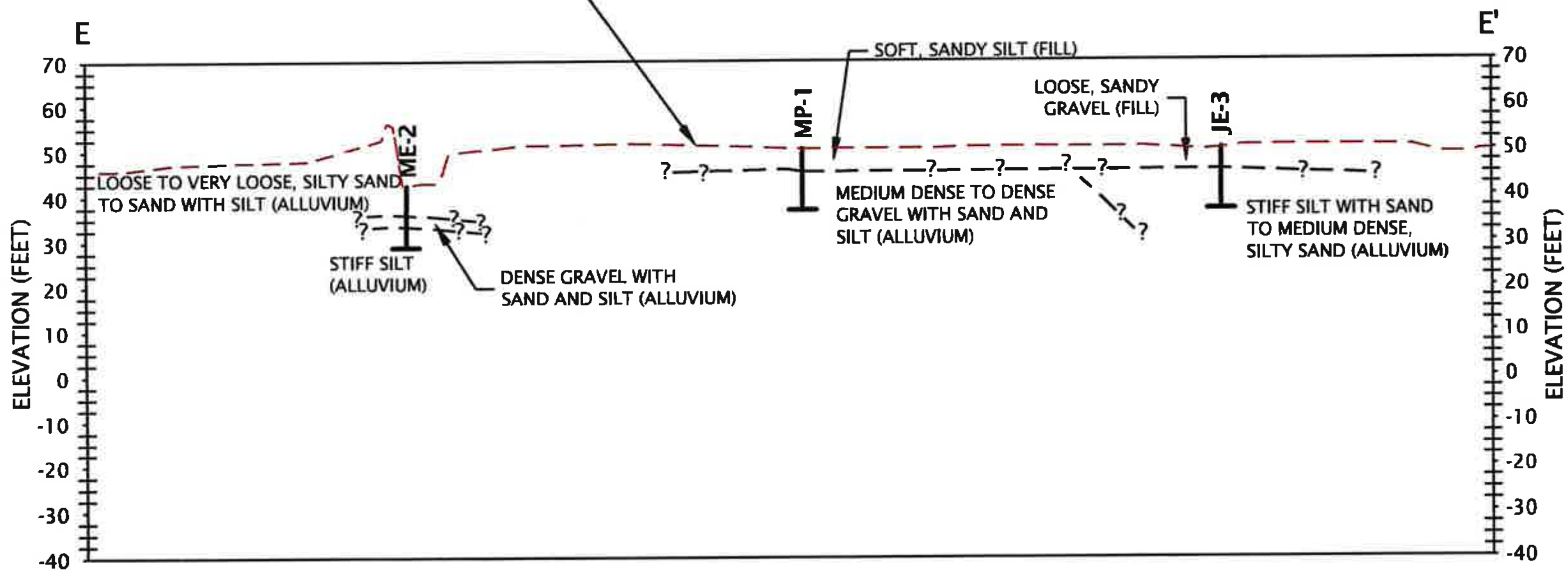
BROWNCALD-49-05-01	CROSS SECTION D-D'
MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR

FIGURE 7



NOTE:

1. PROFILE SURFACE LINE OBTAINED FROM WESTLAKE CONSULTANTS; BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OR

HORIZONTAL 0 200 400 (SCALE IN FEET)

VERTICAL 0 40 80 (SCALE IN FEET)

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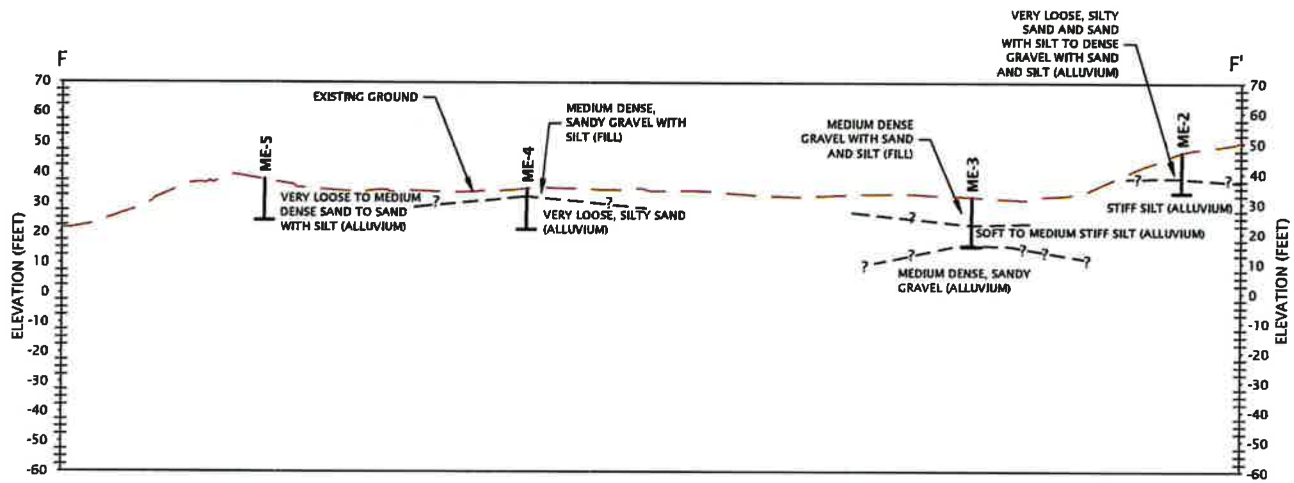
CROSS SECTION E-E'

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE 8



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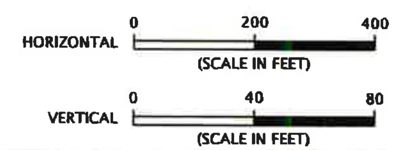

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MARCH 2011

CROSS SECTION F-F'

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE 9

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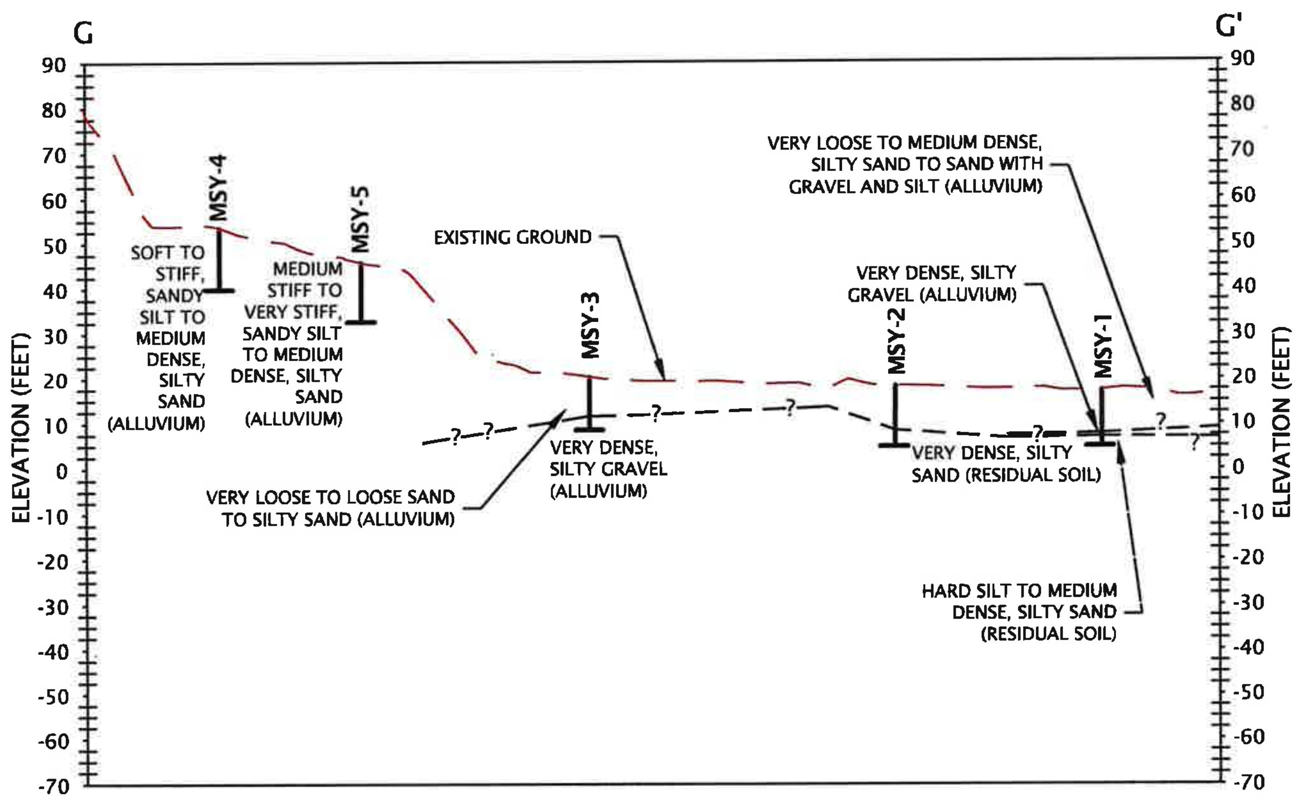

NOTE:
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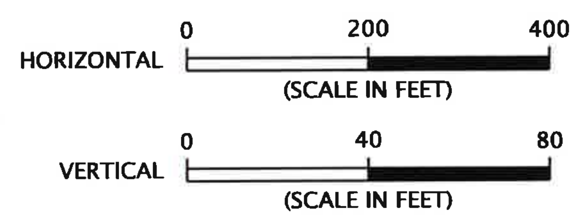
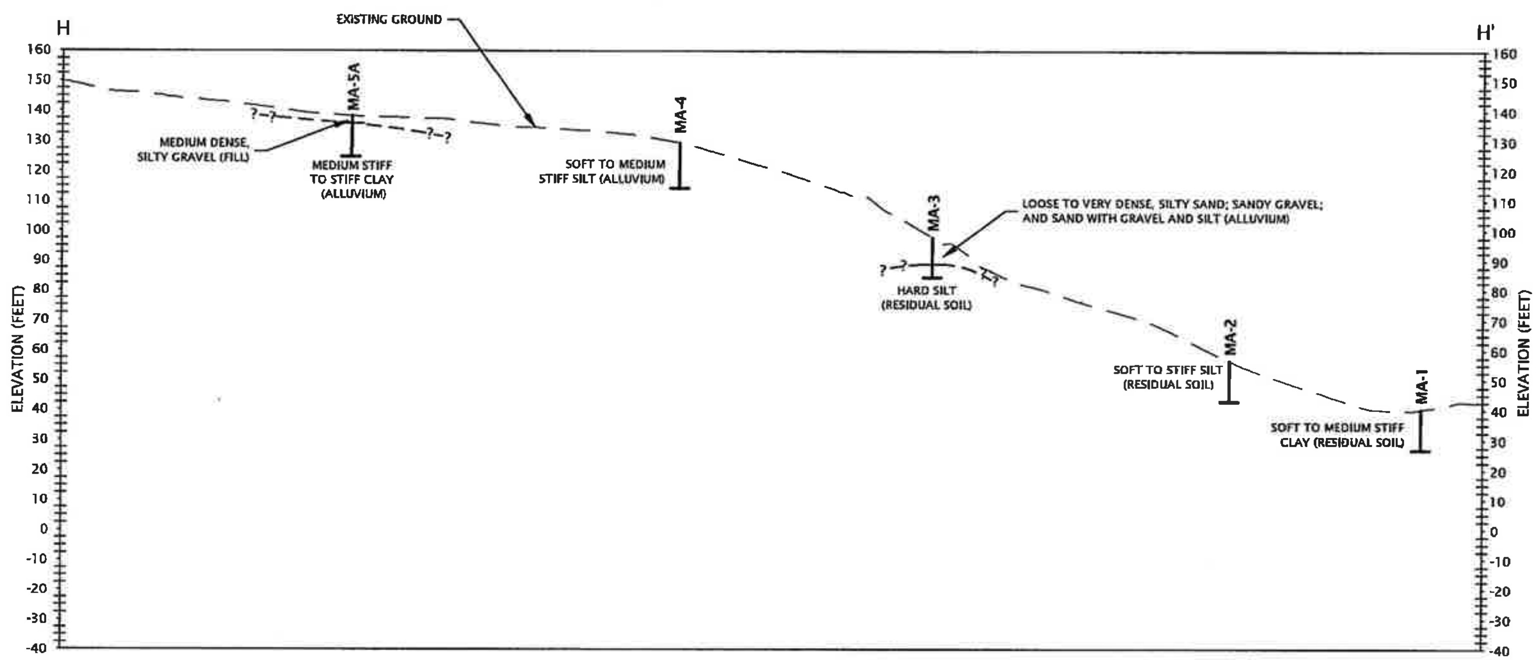
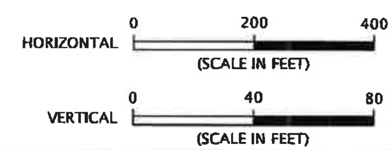


GEODESIGN INC 15575 SW Sequoia Parkway - Suite 100 Portland OR 97224 Off 503.968.8787 Fax 503.968.3068	BROWNCALD-49-05-01	**CROSS SECTION G-G'**
	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR — **FIGURE 10**



NOTE:

1. PROFILE SURFACE LINE OBTAINED FROM WESTLAKE CONSULTANTS; BORING LOCATIONS SURVEYED BY WESTLAKE CONSULTANTS OF LAKE OSWEGO, OR



GEODESIGN INC, 15575 SW Sequoia Parkway - Suite 100, Portland OR 97224, Off 503.968.8787 Fax 503.968.3068	BROWNCALD-49-05-01	CROSS SECTION H-H'
	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE, CLACKAMAS COUNTY, OR
		FIGURE 11

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File Name: C:\DOCUME~1\aday\LOCALS~1\Temp\AcPublish_5088\BrownCald-49-05-01-CS01.dwg | Layout: FIGURE 11

APPENDIX

APPENDIX

FIELD EXPLORATIONS

GENERAL

We explored subsurface conditions at the site by completing a total of 32 borings (99-1 through 99-4, BE-0 through BE-2, DA-1, EX-1 through EX-3, JE-1 through JE-3, MA-1 through MA-5A, ME-2 through ME-5, MP-1, and MSY-1 through MSY-5). The borings were drilled to depths varying between 6.5 and 27.0 feet BGS and were completed between June 25 and August 26, 2010. The locations of our exploration are shown on Figures 2 and 3. The locations of the explorations are approximate based on the proposed locations provided to us by Brown and Caldwell.

Drilling services were completed by Western States Soil Conservation of Aurora, Oregon.

SOIL SAMPLING

A member of our geological staff observed the explorations. We obtained disturbed soil samples from the explorations for geotechnical laboratory testing. Classifications and sampling intervals are shown in the exploration logs included in this appendix.

Soil samples were obtained from the borings using one of the following methods:

- SPTs were performed in sandy soils in general conformance with ASTM D 1586. The sampler was driven with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler 1 foot, or as otherwise indicated, into the soils is shown adjacent to the sample symbols on the exploration logs. Disturbed sand samples were obtained from the split barrel for subsequent classification and index testing.
- A 3-inch-diameter, split-spoon sampler was also used to collect samples. The sampler was driven using a 140-pound hammer free-falling 30 inches, just as with the SPT samples, and the penetration resistance was recorded for general correlation with previous subsurface information.
- A Dames & Moore type U sampler was also used to collect samples. The sampler was driven using a 140-pound hammer free-falling 30 inches, just as with the SPT samples, and the penetration resistance was recorded for general correlation with previous subsurface information. Samples retained from the split barrel consist of up to six 1-inch-high by 2.48-inch-diameter brass rings.
- Relatively undisturbed samples were obtained at selected intervals by pushing a Shelby tube sampler 24 inches ahead of the boring front or as noted on the exploration logs in general accordance with ASTM D 1587.

An automatic trip hammer was used to drive the samples in all of the borings.

SOIL CLASSIFICATION

The soil samples were classified in the field in accordance with the "Exploration Key" (Table A-1) and "Soil Classification System" (Table A-2), which are included in this appendix. The exploration logs indicate the depths at which the soil characteristics change, although the change actually could be gradual. If the change occurred between sample locations, the depth was interpreted. Classifications and sampling intervals are presented on the exploration logs included in this appendix.

LABORATORY TESTING

CLASSIFICATION

The soil samples were classified in the laboratory to confirm field classifications. The laboratory classifications are presented on the exploration logs if those classifications differed from the field classifications.

MOISTURE CONTENT

We determined the natural moisture content of all soil samples in general accordance with ASTM D 2216. The natural moisture content is a ratio of the weight of the water to soil in a test sample and is expressed as a percentage. The moisture contents are presented on the exploration logs included in this appendix.

DRY DENSITY

We determined the dry density on selected in general accordance with ASTM D 2937. The test results are presented on the exploration logs and Figure A-36 in this appendix. The dry density is the dry unit weight of a soil sample in pound per cubic foot.

ATTERBERG LIMITS

Atterberg limits tests were performed on selected samples in general accordance with ASTM D 4318. Atterberg limits include the liquid limit, plastic limit, and the plasticity index of soils. These index properties are used to classify soils and for correlation with other engineering properties of soils. The test results are presented on Figure A-33.

DIRECT SHEAR TESTING

Direct shear testing was performed on selected samples in general accordance with ASTM D 3080. This test determines the consolidated drained shear strength of a soil sample in direct shear. The test is performed by deforming a sample at a controlled strain rate on or near a single shear plane. Generally, three or more samples are tested, each under a different normal load, to determine the Mohr strength envelope. Settlement under each applied normal load was monitored to confirm that consolidation was essentially complete before the specimen was sheared. The test results are presented on Figure A-34.

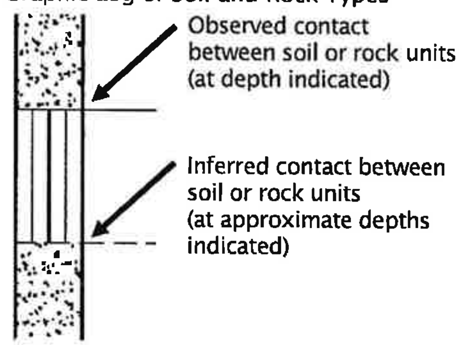
PARTICLE SIZE ANALYSIS

Particle size analyses were performed on selected samples in general accordance with ASTM C 136. These tests are a quantitative determination of the soil particle size distribution expressed as a percentage of soil weight. The test results are presented on Figure A-35.

The fines content of selected samples was determined in general accordance with ASTM C 117. The test is a quantitative determination of the percent of soil passing the U.S. Standard No. 200 Sieve as a percentage of soil weight. The results are presented on Figure A-36 of this appendix.

SYMBOL	SAMPLING DESCRIPTION
	Location of sample obtained in general accordance with ASTM D 1586 Standard Penetration Test with recovery
	Location of sample obtained using thin-wall Shelby tube or Geoprobe® sampler in general accordance with ASTM D 1587 with recovery
	Location of sample obtained using Dames & Moore sampler and 300-pound hammer or pushed with recovery
	Location of sample obtained using Dames & Moore or 3-inch-O.D. split-spoon sampler and 140-pound hammer or pushed with recovery
	Location of grab sample
	Rock coring interval
▽	Water level during drilling
▼	Water level taken on date shown

Graphic Log of Soil and Rock Types



GEOTECHNICAL TESTING EXPLANATIONS

ATT	Atterberg Limits	P	Pushed Sample
CBR	California Bearing Ratio	PP	Pocket Penetrometer
CON	Consolidation	P200	Percent Passing U.S. Standard No. 200 Sieve
DD	Dry Density	RES	Resilient Modulus
DS	Direct Shear	SIEV	Sieve Gradation
HYD	Hydrometer Gradation	TOR	Torvane
MC	Moisture Content	UC	Unconfined Compressive Strength
MD	Moisture-Density Relationship	VS	Vane Shear
OC	Organic Content	kPa	Kilopascal

ENVIRONMENTAL TESTING EXPLANATIONS

CA	Sample Submitted for Chemical Analysis	ND	Not Detected
P	Pushed Sample	NS	No Visible Sheen
PID	Photoionization Detector Headspace Analysis	SS	Slight Sheen
ppm	Parts per Million	MS	Moderate Sheen
		HS	Heavy Sheen

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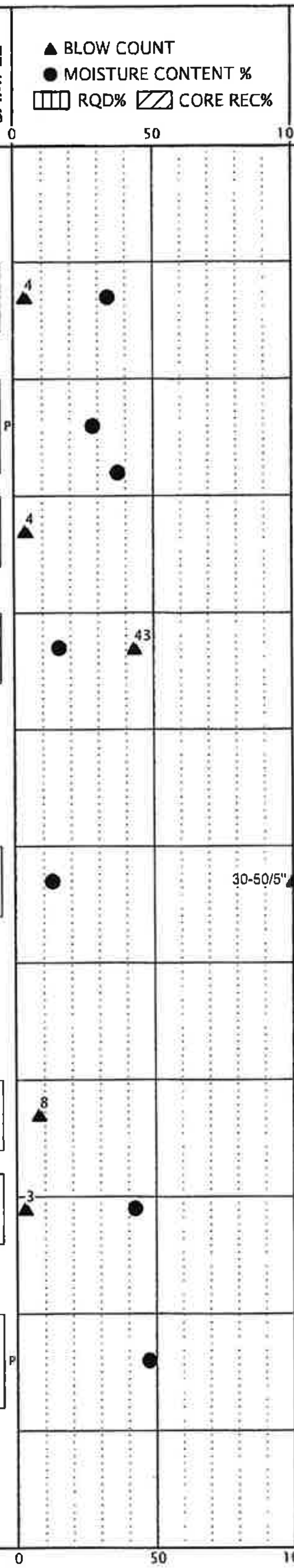
EXPLORATION KEY

TABLE A-1

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	INSTALLATION AND COMMENTS
0.0		50.6		
	ASPHALT CONCRETE (6 inches).	50.1 / 0.5		
	GRAVEL subgrade.	48.6 / 2.0		
2.5	Soft, brown SILT (ML), minor gravel; moist, low plasticity (alluvium). becomes without gravel at 3.0 feet			2.85 feet, after drilling
5.0	becomes soft to medium stiff at 5.0 feet		DD DS	DD = 93 pcf
7.5	Soft, brown CLAY (CH); moist, medium plasticity (alluvium).	43.6 / 7.0	ATT	LL = 51% PL = 28%
10.0	Dense, gray to brown, fine to medium GRAVEL with silt and sand (GP-GM); moist to wet, subangular to subrounded (alluvium).	41.6 / 9.0	SIEV	Drilling becomes hard at 9.0 feet.
12.5				
15.0	Very dense, gray, medium GRAVEL (GP); moist to wet, subrounded to subangular (alluvium).	35.6 / 15.0		SPT stopped at 12 inches by driller (sampler bent)
17.5	Medium stiff to stiff, gray SILT (ML); moist to wet, low plasticity (alluvium).	34.1 / 16.5		Drilling eases at 16.5 feet. Driller Comment: possible sand at 16.5 feet
20.0				
22.5	becomes soft at 22.0 feet			3-inch-O.D. split-spoon sampler used
25.0			DD	DD = 74 pcf
27.5	Exploration completed at a depth of 27.0 feet.	23.6 / 27.0		
30.0				



DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: ASB COMPLETED: 06/25/10

BORING METHOD: mud rotary (see report text) BORING BIT DIAMETER: 3 7/8-inch

GEODESIGN INC	BROWNCALD-49-05-01	**BORING 99-1**
15575 SW Sequoia Parkway - Suite 100 Portland OR 97224 Off 503.968.8787 Fax 503.968.3068	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR — **FIGURE A-1**

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (7 inches).	54.3			
	AGGREGATE BASE (12 inches).	53.7 / 0.6			
	Soft, brown SILT with sand (ML); moist, low plasticity, disturbed structure - FILL.	52.7 / 1.6			
2.5			P200	3	P200 = 69%
5.0				3	
7.5	becomes medium stiff, dark brown, without sand at 7.5 feet			7	
10.0	becomes with red-brown mottles at 10.0 feet			4	
12.5	Very dense, dark gray and brown, fine to coarse GRAVEL with sand and silt (GP-GM); wet, subrounded, mixed lithology (alluvium).	41.3 / 13.0			Drill chatter at 13.0 feet; ⊻ 13.0 feet, during drilling
15.0				47-50/5.5"	
17.5					Auger refusal at 17.0 feet, switch to mud rotary 3 7/8-inch
20.0				67	Lose drill fluid circulation in gravels
22.5	Very stiff, light gray mottled red-brown SILT (MH); moist to wet, high plasticity (alluvium).	31.8 / 22.5			Driller Comment: smoother drilling at 22.5 feet
25.0			ATT	29	LL = 84% PL = 44%
	Exploration completed at a depth of 26.5 feet.	27.8 / 26.5			
27.5					
30.0					

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: CMC COMPLETED: 06/29/10

BORING METHOD: hollow-stem auger and mud rotary (see report text) BORING BIT DIAMETER: 3 7/8-inch

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BORING 99-2

MARCH 2011

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-2

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0		48.0			
	ASPHALT CONCRETE (3 inches).	47.7 / 0.3			
	GRAVEL subgrade.	46.5 / 1.5			
	Medium stiff, brown, sandy SILT (ML); moist, low plasticity (alluvium).	45.0 / 3.0			
2.5	Dense, gray to brown, fine to coarse GRAVEL with silt and sand (GP-GM); dry to moist, subrounded to subangular (alluvium).			44	Very hard drilling at 3.0 feet.
5.0	becomes very dense, trace to some sand, trace silt at 5.0 feet			67	∇ 6.0 feet, after drilling
7.5	becomes moist to wet at 7.5 feet			68	∇ 9.0 feet, pre-auger removal
10.0	wet at 10.0 feet	35.0 / 13.0	SIEV	66	
12.5	Soft, gray SILT (ML); moist to wet, low plasticity (alluvium).	31.5 / 16.5			Drilling becomes easy at 13.0 feet.
15.0				4	
17.5	Loose, gray, fine SAND (SP), trace silt; wet (alluvium).	28.5 / 19.5			Two inches of sand in shoe of SPT at 16.5 feet.
20.0	Stiff, red-brown, sandy SILT (MH); moist (alluvium).	26.5 / 21.5	ATT	52	Driller Comment: soil changed at 19.5 feet LL = 57% PL = 37%
22.5	Exploration completed at a depth of 21.5 feet.				
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: ASB COMPLETED: 06/25/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 3 7/8-inch

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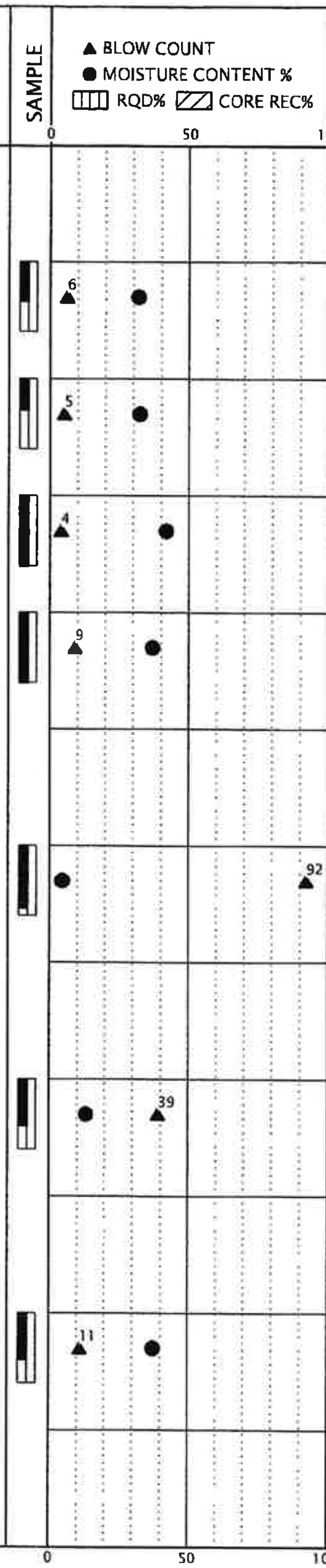
BORING 99-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-3

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (6 inches).	52.0	
	AGGREGATE BASE (12 inches).	51.5 / 0.5	
	Medium stiff, brown SILT (ML); moist, low plasticity (alluvium).	50.5 / 1.5	
5.0	becomes with red-brown mottles at 5.0 feet		
10.0	becomes stiff, brown with dark gray mottles; non-organic odor at 10.0 feet		SS PID = 310 ppm
15.0	Very dense, dark gray and brown, fine to coarse GRAVEL with sand and silt (GP-GM); moist, subrounded, non-organic odor (alluvium).	37.0 / 15.0	SS PID = 31 ppm
20.0	becomes dense; wet, no odor at 20.0 feet		NS PID = 6.5 ppm
	Stiff, gray, sandy SILT (ML); wet, nonplastic, interbedded with fine sand (alluvium).	28.5 / 23.5	Driller Comment: smooth drilling at 23.5 feet
25.0			NS No odor PID = 5.3 ppm LL = NP PL = NP
	Exploration completed at a depth of 26.5 feet.	25.5 / 26.5	



▽ 14.6 feet, during drilling

DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: CMC
COMPLETED: 06/30/10

BORING METHOD: hollow-stem auger (see report text)
BORING BIT DIAMETER: 8-inch

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BORING 99-4

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-4

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (3 inches).	55.6 / 55.3 / 0.3			
	AGGREGATE BASE (9 inches).	54.6 / 1.0			
	Medium dense, brown-gray, silty GRAVEL with sand (GM); moist, subrounded to subangular - **FILL**.			13	
2.5	Medium stiff, brown CLAY with sand (CL), trace gravel; moist (alluvium).	53.1 / 2.5		7	3-inch-O.D. split-spoon sampler used
5.0	becomes soft, without gravel at 5.0 feet		DD	5	Dames & Moore sampler used DD = 79 pcf
7.5	becomes minor sand at 7.5 feet		ATT	3	LL = 46% PL = 25%
10.0	Dense, gray-brown, fine to coarse GRAVEL with silt and sand (GP-GM), trace silt; moist, subrounded to subangular (alluvium).	46.1 / 9.5		43	Driller Comment: gravel at 9.5 feet Softer drilling at 10.0 feet.
12.5	becomes very dense at 12.0 feet		SIEV	132	Driller Comment: harder drilling at 11.5 feet 3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 13.5 feet.	42.1 / 13.5			

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/19/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING BE-0

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-5

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (2.5 inches).	51.8 / 51.6 0.2			
	AGGREGATE BASE (1.5 inches).	51.5 0.3			
	Stiff, brown CLAY with sand (CH), trace gravel; moist, medium to high plasticity (alluvium).			9	
2.5	becomes sandy, without gravel at 2.5 feet		ATT	12	LL = 52% PL = 25%
5.0	Medium dense, brown, clayey SAND (SC), trace gravel; moist (alluvium). grades to dense at 5.5 feet	46.8 5.0	P200 DD		Dames & Moore sampler used P200 = 35% DD = 79 pcf Driller Comment: gravel, drilling chatter, slow and hard drilling at 6.0 feet
7.5	Very dense, gray-brown, fine to coarse GRAVEL with silt and sand (GP-GM); moist, subangular to angular (alluvium).	45.8 6.0		74	
10.0	becomes dense at 10.0 feet			37	
12.5	Medium dense, brown-gray, fine to coarse, silty GRAVEL with sand (GM); moist, subangular to subrounded (alluvium).	40.3 11.5		56	3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 13.5 feet.	38.3 13.5			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/22/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING BE-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-6

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	BLOW COUNT / MOISTURE CONTENT %	INSTALLATION AND COMMENTS
0.0		53.7			
	ASPHALT CONCRETE (1.5 inches).	53.6 0.1			
	AGGREGATE BASE, rounded gravel (2.5 inches).	53.4 0.3			
	Stiff, brown CLAY (CL), minor sand; moist, low to medium plasticity (alluvium).			10	
2.5	becomes sandy at 2.5 feet			48	
	with gravel at 3.5 feet	50.2 3.5			Gravel at 3.5 feet; hard, slow, drilling chatter, one of the auger teeth broke
5.0	Very dense, brown-gray, fine to coarse, sandy GRAVEL with silt (GP-GM); moist, subrounded to subangular (alluvium).			44-100/5"	3-inch-O.D. split-spoon sampler used
7.5			SIEV	38-73-100/4"	3-inch-O.D. split-spoon sampler used
10.0	becomes moist to wet at 10.5 feet			35-100/6"	3-inch-O.D. split-spoon sampler used
	with cobbles at 11.5 feet			50/2"	Refusal to drilling at 11.5 feet; possible cobble/boulder, could not advance with hollow-stem auger, switched to mud rotary at 11.5 feet
12.5	with orange mottles at 12.5 feet			17-82-100/3"	Driller Comment: 9-inch-diameter cobble at 11.5 feet; heaving, drilling chatter 3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 13.8 feet.	39.9 13.8			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

0 50 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/22/10

BORING METHOD: hollow-stem auger and mud rotary (see report text) BORING BIT DIAMETER: 8-inch/3 7/8-inch

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

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MARCH 2011

BORING BE-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-7

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT / MOISTURE CONTENT %	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (4.5 inches).	53.5 53.1 / 0.4			
	AGGREGATE BASE (5.5 inches).	53.0 / 0.5			
	Dense, gray-brown, fine to coarse, silty GRAVEL with sand (GM); moist, subrounded to subangular (alluvium).	52.0 / 1.5	SIEV	39	
2.5	Dense, gray-brown, fine to coarse GRAVEL with silt and sand (GP-GM); moist, subrounded to subangular (alluvium).			84	3-inch-O.D. split-spoon sampler used
5.0	becomes subangular to angular at 4.5 feet			38	Slow drilling at 5.0 feet.
7.5	becomes very dense at 7.5 feet			133	Possible cobbles at 7.5 feet, broken gravel greater than 3 inches in diameter 3-inch-O.D. split-spoon sampler used
10.0	becomes wet; subrounded to subangular gravel at 10.0 feet			62	9.75 feet, during drilling
12.5		40.0 / 13.5		74	
	Exploration completed at a depth of 13.5 feet.				
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

0 50 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/19/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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MARCH 2011

BORING DA-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-8

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT / MOISTURE CONTENT %	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (3 inches).	54.6 / 54.3 0.3			
	AGGREGATE BASE (3 inches).	54.1 0.5			
	Medium dense, brown, fine to coarse, silty SAND (SM), minor gravel; moist (alluvium).			11	
2.5	Medium dense, brown, fine to coarse, silty GRAVEL with sand (GM); moist, subrounded to subangular (alluvium). with cobbles at 4.0 feet	52.1 2.5	SIEV	16	Driller Comment: cobble at 4.0 feet, slow drilling
5.0	becomes very dense, sandy at 5.0 feet			47-74/3"	3-inch-O.D. split-spoon sampler used
7.5	Dense, brown-gray, fine to coarse, sandy GRAVEL with silt (GP-GM); moist, subrounded to subangular (alluvium). becomes moist to wet at 8.8 feet	48.1 6.5		119	3-inch-O.D. split-spoon sampler used; 9.8 feet, during drilling
10.0	Medium dense, brown, fine to medium, silty SAND (SM); wet (alluvium). becomes gravelly at 11.0 feet	45.1 9.5		36	3-inch-O.D. split-spoon sampler used
12.5	Loose, brown, fine to coarse, silty, sandy GRAVEL (GM); wet, subrounded (alluvium).	43.1 11.5		21	3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 13.5 feet.	41.1 13.5			

DRILLED BY: Western States Soil Conservation, Inc.

LOGGED BY: NAK

COMPLETED: 07/16/10

BORING METHOD: hollow-stem auger (see report text)

BORING BIT DIAMETER: 8-inch

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BORING EX-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-9

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 – 50 – 100)	INSTALLATION AND COMMENTS
0.0		ASPHALT CONCRETE (4 inches).	52.2 / 51.9 / 0.3				
		AGGREGATE BASE (2 inches).	51.7 / 0.5				
		Stiff, brown CLAY with gravel and sand (CL); moist, low plasticity (alluvium).				14	
2.5		becomes minor sand and gravel at 3.5 feet				11	
5.0		becomes hard, sandy, with gravel at 5.0 feet				9-50/3"	Drill chatter at 5.5 feet, hard drilling Observed severe wearing of auger bit? Auger bit had considerable wearing, pulled out of hole. Note: moved 3 feet north and drilled EX-2A
		Exploration terminated due to refusal on possible metal or hard rock at a depth of 6.5 feet.	45.7 / 6.5				
7.5							
10.0							
12.5							
15.0							
17.5							
20.0							
22.5							
25.0							
27.5							
30.0						0 – 50 – 100	

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/16/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING EX-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-10

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 50 100)	INSTALLATION AND COMMENTS
0.0		ASPHALT CONCRETE (4 inches).	52.2 / 51.9 0.3				
		AGGREGATE BASE (2 inches).	51.7 0.5	SIEV			
		Stiff, brown CLAY with gravel and sand (CL); moist, low plasticity (alluvium).					
2.5							
		becomes minor sand and gravel at 3.5 feet					
5.0		becomes hard, sandy, with gravel at 5.0 feet					Drill chatter at 5.5 feet, hard drilling
		Dense, gray-brown, fine to coarse GRAVEL with sand and silt (GP-GM); moist, subrounded to subangular (alluvium).	45.7 6.5				Hard drilling at 6.5 feet.
7.5						113	3-inch-O.D. split-spoon sampler used
10.0		becomes medium dense at 10.0 feet				30	3-inch-O.D. split-spoon sampler used
		becomes moist to wet at 11.3 feet					▽ 12.0 feet, after drilling
		Very loose, brown-gray, fine to medium, silty SAND with gravel (SM); wet (alluvium).	40.2 12.0				
12.5			39.2 13.0	ATT		2	LL = 51% PL = 36%
		Medium stiff, light brown-gray SILT (MH); moist, medium plasticity (alluvium).	38.7 13.5				
15.0		Exploration completed at a depth of 13.5 feet.					
17.5							
20.0							
22.5							
25.0							
27.5							
30.0							

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/16/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING EX-2A

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-11

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (4 inches).	49.8 / 49.5 / 0.3		
	AGGREGATE BASE (6 inches).	49.0 / 0.8		
	Medium stiff, brown CLAY (CH), minor sand, trace gravel; moist (alluvium).			
	becomes soft, some silt at 3.5 feet		ATT	LL = 53% PL = 27%
			DD	DD = 74 pcf
7.0	Very dense, gray-brown, fine to coarse, sandy GRAVEL with silt (GP-GM); moist, subrounded to subangular (alluvium).	42.8 / 7.0		Sandy clay at Shelby tip at 6.5 feet Hard drilling at 7.0 feet.
	becomes dense at 10.0 feet			3-inch-O.D. split-spoon sampler used
11.5	Very loose to loose, brown, fine to medium, silty SAND (SM); wet (alluvium).	38.3 / 11.5		
12.5	Soft to medium stiff, orange mottled light brown SILT (ML), moist, low plasticity, slow dilatancy (alluvium). becomes gray at 13.3 feet	37.3 / 12.5 36.3 / 13.5	P200	P200 = 19%
	Exploration completed at a depth of 13.5 feet.			

12.4 feet, during drilling

Blow count / moisture content chart (legend: ▲ BLOW COUNT; ● MOISTURE CONTENT %; RQD%; CORE REC%; scale 0–50–100). Blow counts: 6, 3, 65, 95, 4.

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/16/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING EX-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-12

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (3 inches).	49.0 / 0.0; 48.7 / 0.3			
0.3	Brown, silty GRAVEL (GM) with sand; dry to moist (aggregate base).	47.0 / 2.0			Hard drilling at 0.5 foot.
2.0	Soft, brown SILT (ML), trace sand and gravel; moist (alluvium).	44.5 / 4.5		4	Easy drilling at 2.0 feet.
4.5	Dense, gray to brown, fine to coarse GRAVEL (GP), trace to some sand, trace silt; moist to wet (alluvium).	38.0 / 11.0	SIEV	46; 73	Hard drilling at 4.5 feet. ▽ 6.5 feet, after drilling. Petroleum-like odor observed among sampled soil and cuttings. Drilling rods swelled strongly upon attempting a depth of 10.0 feet. Slight sheen observed among clean water at 10.0 feet. Driller indicated he needs a clean trailer to continue boring.
11.0	Very dense, gray-brown, fine to coarse GRAVEL with sand and silt (GP-GM); wet, subrounded (alluvium).	32.0 / 17.0		14-50/4"	SS. Slight non-organic odor PID = 43 ppm. Extremely hard drilling at 16.5 feet.
17.0	Loose, dark gray SAND with silt and gravel (SP-SM); wet (alluvium).	27.0 / 22.0	SIEV	7	Smoother drilling at 17.0 feet. NS. Heaving sand, slight odor at 20.0 feet PID = 3.7 ppm
22.0	Hard, light gray mottled red-brown SILT (MH); moist, high plasticity (residual soil). becomes light gray at 26.0 feet	22.5 / 26.5	ATT	34	Stiff drilling at 22.0 feet. NS. No odor PID = 3.2 ppm LL = 107% PL = 49%
26.5	Exploration completed at a depth of 26.5 feet.				Two drums of soil cuttings. Drum cuttings sample: PID = 52 ppm

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: ASB/CMC COMPLETED: 06/30/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING JE-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-13

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (1.5 inches).	49.0 48.9 0.1			
	AGGREGATE BASE (10.5 inches).	48.0 1.0			
	Medium stiff, dark brown to brown-red CLAY (CL), trace gravel and carbonized organics, minor sand; moist, no odor (alluvium).			7	
2.5	becomes brown, without organics (no odor) at 3.5 feet		ATT	6	LL = 42% PL = 26%
5.0	Very dense, brown-yellow GRAVEL with sand and silt (GP-GW); moist, angular, no odor (alluvium).	44.0 5.0	SIEV	50/5"	Hard drilling at 5.0 feet.
	becomes brown-gray, fine to coarse; moist to wet, subrounded to subangular at 6.5 feet				
7.5				29-100/4"	3-inch-O.D. split-spoon sampler used
10.0	becomes dense, gray-brown; wet, petroleum-like odor at 10.0 feet			91	3-inch-O.D. split-spoon sampler used SS PID = 3.9 ppm
12.5				41	SS PID = 5.7 ppm
	Exploration completed at a depth of 13.5 feet.	35.5 13.5			

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

0 50 100

∇ 10.0 feet, during drilling

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/14/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING JE-1A

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-14

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT / MOISTURE CONTENT %	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (1.5 inches).	47.8 / 47.7 / 0.1			
	AGGREGATE BASE (22.5 inches).			33	
	Very stiff, brown-gray CLAY (CH), minor sand, trace organics; moist (alluvium).	45.9 / 1.9			
2.5					No odor at 2.5 feet
	becomes soft to medium stiff, brown, sandy at 3.5 feet			4	No odor at 4.0 feet
5.0			ATT	4	LL = 52% PL = 28%
	with orange mottles at 6.2 feet				No odor at 6.0 feet
7.5			DD	P	12-Inch grab sample at Shelby tip, possibly disturbe Shelby DD = 81 pcf
					No odor at 9.0 feet
	becomes soft; wet at 9.5 feet			23	∇ 9.5 feet, during drilling
10.0	Very dense, gray-brown, fine to coarse, clayey GRAVEL with sand (GC); wet, subrounded to subangular (alluvium).	37.3 / 10.5			Coarse gravel at SPT tip at 10.5 feet, hard drilling
12.5			SIEV	38-50/4"	
	Exploration completed at a depth of 12.9 feet.	34.9 / 12.9			No odor at 12.9 feet
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc.   LOGGED BY: NAK   COMPLETED: 07/14/10

BORING METHOD: hollow-stem auger (see report text)   BORING BIT DIAMETER: 8-inch

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BORING JE-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-15

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	▲ BLOW COUNT	INSTALLATION AND COMMENTS
0.0	CHIP SEAL (0.75 inch).	42.0 / 41.9 / 0.1			
	AGGREGATE BASE (29.25 inches).				
2.5	Loose, brown-gray, fine to coarse, silty, sandy GRAVEL (GM); moist, subrounded to subangular - FILL.	39.6 / 2.4	SIEV	20	3-inch-O.D. split-spoon sampler used
5.0	Stiff, orange mottled light brown SILT with sand (ML), trace organics (rootlets); moist, low plasticity (alluvium).	36.5 / 5.5		13	3-inch-O.D. split-spoon sampler used
7.5	with interbeds of silty sand at 8.5 feet		DD	35	Dames & Moore sampler used DD = 96 pcf
	Medium dense, brown-orange, fine to medium, silty SAND (SM); moist (alluvium).	33.5 / 8.5			
10.0			P200	27	P200 = 19%
12.5	becomes brown-gray; with interbeds of silt at 12.0 feet			20	
	Exploration completed at a depth of 13.5 feet.	28.5 / 13.5			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

GRAPHIC LOG · SAMPLE · ● MOISTURE CONTENT % · RQD% · CORE REC% · 0 · 50 · 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/14/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING JE-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-16

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0		40.3			
	ASPHALT CONCRETE (3.5 inches).	40.0 / 0.3			
	AGGREGATE BASE (8.5 inches).	39.3 / 1.0			
	Medium stiff, black striked brown-red CLAY (CH), trace sand; moist, medium to high plasticity (residual soil).			7	
2.5	becomes stiff, trace subrounded gravel at 2.5 feet		DD	15	Dames & Moore sampler used DD = 88 pcf
5.0	becomes soft to medium stiff, with red and black mottles, without gravel; high plasticity at 5.0 feet		ATT	4	LL = 61% PL = 31%
7.5	becomes minor sand; medium plasticity at 7.5 feet		DD	P	DD = 76 pcf
	Soft, brown-red, sandy CLAY (CL); moist to wet (residual soil).	30.8 / 9.5			
10.0			P200	3	P200 = 56%
12.5	grades to medium stiff, brown-yellow and gray; moist, decomposed rock fragments at 12.0 feet		DD	11	DD = 71 pcf Dames & Moore sampler used
	Exploration completed at a depth of 13.5 feet.	26.8 / 13.5			

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

GRAPHIC LOG — SAMPLE

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/21/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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	MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR — FIGURE A-17

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	BLOW COUNT	MOISTURE CONTENT %	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (4 inches).	53.5 / 53.2 0.3				
	AGGREGATE BASE (8 inches).	52.5 1.0				
	Medium stiff, brown-red SILT (MH), trace sand and gravel; moist, medium to high plasticity (residual soil).			6		
2.5	becomes soft to medium stiff, brown and gray with yellow mottles, without gravel at 2.5 feet		ATT	4		LL = 66% PL = 45%
5.0	becomes stiff, brown at 5.0 feet		DD DS	23		Dames & Moore sampler used DD = 69 pcf
7.5	becomes brown-yellow at 7.5 feet			10		
10.0	becomes minor sand, decomposed rock fragments at 10.0 feet			14		
12.5				8		
	Exploration completed at a depth of 13.5 feet.	40.0 13.5				

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

Chart scale: 0, 50, 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/21/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MA-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-18

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0		87.6			
	ASPHALT CONCRETE (2.5 inches).	87.4 / 0.2			
	AGGREGATE BASE (13 inches), petroleum-like odor.	86.3 / 1.3			NS PID = 75 ppm
2.5	Loose, light brown-gray, fine, silty SAND (SM); moist, no odor (alluvium).			9	
5.0					
	Dense, orange mottled brown-gray, fine to coarse, silty, sandy GRAVEL (GM); moist, angular (alluvium). becomes wet at 6.4 feet	82.1 / 5.5		32	Hard, drilling chatter at 5.5 feet NS PID = 0.5 ppm 6.8 feet, during drilling
7.5	Very dense, brown-orange and gray, fine to coarse SAND with gravel and silt (SW-SM); wet (alluvium).	80.1 / 7.5	SIEV	27-50/5"	
	Hard, red SILT (MH), trace sand; moist, high plasticity (residual soil).	78.6 / 9.0			
10.0			ATT	25-63-100/4"	3-inch-O.D. split-spoon sampler used LL = 58% PL = 37%
12.5	becomes minor sand at 12.0 feet			48	
	Exploration completed at a depth of 13.5 feet.	74.1 / 13.5			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT
● MOISTURE CONTENT %
RQD% CORE REC%
0 50 100

DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: NAK
COMPLETED: 07/29/10

BORING METHOD: hollow-stem auger (see report text)
BORING BIT DIAMETER: 8-inch

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BORING MA-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-19

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (4 inches).	128.8 / 128.5 / 0.3			
	AGGREGATE BASE (6 inches).	128.0 / 0.8			
	Soft to medium stiff, gray-brown SILT (ML), trace sand; moist low plasticity (alluvium).			4	
2.5	becomes medium stiff, with sand at 2.5 feet			6	
5.0	becomes with sand to sandy at 5.0 feet			5	
7.5	becomes minor sand, trace clay at 7.5 feet		DD	10	Dames & Moore sampler used DD = 85 pcf
10.0	becomes soft to medium stiff, with sand at 10.0 feet		ATT	4	LL = 39% PL = 29%
	becomes brown, fine, sandy at 11.5 feet				
12.5			P200	4	P200 = 67%
	Exploration completed at a depth of 13.5 feet.	115.3 / 13.5			

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

Scale: 0 50 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/21/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MA-4

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-20

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 – 50 – 100)	INSTALLATION AND COMMENTS
0.0		ASPHALT CONCRETE (6 inches).	137.7				
		Medium dense, brown-gray, fine to coarse, sandy GRAVEL (GW), trace silt; moist, angular (crushed rock) - **FILL**.	137.2 / 0.5			25	
2.5		grades to sandy GRAVEL (GW) to gravelly SAND (SW) at 2.5 feet				11	
5.0		becomes loose at 5.0 feet				8	
		Exploration terminated due to potential trench at a depth of 6.5 feet.	131.2 / 6.5				Moved 5 feet east and drilled MA-5A.
7.5							
10.0							
12.5							
15.0							
17.5							
20.0							
22.5							
25.0							
27.5							
30.0							

0 50 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/30/10

BORING METHOD: hand-auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MA-5

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-21

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (5 inches).	137.6			
	AGGREGATE BASE (5 inches).	137.2 / 0.4			
	Medium dense, brown, silty, sandy GRAVEL (GM); moist, subrounded - FILL.	136.8 / 0.8			
2.5	Medium stiff, orange and black mottled brown CLAY (CH), trace sand; moist (alluvium).	135.1 / 2.5		6	
5.0	becomes gray, with sand at 5.0 feet becomes brown with orange mottles, minor sand at 5.5 feet		ATT	6	LL = 55% PL = 29%
7.5	becomes stiff, trace to minor sand at 7.5 feet		DD	15	Dames & Moore sampler used DD = 84 pcf
10.0	becomes medium stiff; lenses of sand at 10.0 feet			5	
12.5	becomes soft, with sand at 12.0 feet			3	
	Exploration completed at a depth of 13.5 feet.	124.1 / 13.5			

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC%

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

Chart scale: 0, 50, 100

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/30/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MA-5A

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-22

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (2 inches).	47.0 / 46.8 / 0.2			
	AGGREGATE BASE (4 inches).	46.5 / 0.5			
	Very loose, brown, fine to medium, silty SAND (SM); moist (alluvium).			3	
2.5	becomes moist to wet at 3.5 feet			9	Dames & Moore sampler used
5.0	Loose, gray-brown, fine to medium SAND with silt (SP-SM), trace gravel; wet (alluvium).	42.0 / 5.0	SIEV	7	▽ 6.5 feet, during drilling
	Dense, gray-brown, fine to coarse GRAVEL with sand and silt (GP-GM); moist to wet, subrounded to subangular (alluvium).	40.5 / 6.5			Driller Comment: gravel at 6.5 feet, scatter drilling
7.5				45	
	Stiff, white mottled brown-gray SILT (MH), trace sand; moist, medium to high plasticity (alluvium).	38.0 / 9.0			Driller Comment: smooth drilling at 9.0 feet
10.0			ATT	10	LL = 53% PL = 37%
	becomes stiff to very stiff at 11.5 feet brown-green and gray at 12.0 feet				
12.5				25	3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 13.5 feet.	33.5 / 13.5			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

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BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING ME-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-23

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (2 inches).	31.6 / 31.4 / 0.2			
	AGGREGATE BASE (10 inches).	30.6 / 1.0			
	Medium dense, brown-gray, fine to coarse GRAVEL with sand and silt (GP-GM); moist, subrounded to subangular - **FILL**.			14	
2.5					
	Soft to medium stiff, brown SILT (MH), trace sand; moist (alluvium).	28.1 / 3.5		4	Easy drilling from 3.5 to 15.0 feet.
5.0	becomes medium stiff, sandy, trace carbonized organics at 5.0 feet		DD	7	Dames & Moore sampler used DD = 72 pcf
7.5	becomes soft, trace sand, without organics at 7.5 feet		ATT	2	LL = 65% PL = 36%
10.0			DD	P	DD = 75 pcf
12.5	grades to sandy at 12.0 feet				SM to ML at Shelby tip
	grades to minor sand at 13.0 feet		P200	2	P200 = 84%
15.0	grades to sandy SILT to silty SAND; wet at 15.0 feet	15.6 / 16.0		19	∇ 15.0 feet, during drilling
	Medium dense, gray-brown, fine to coarse, sandy GRAVEL (GP), trace silt; moist to wet, subrounded to subangular (alluvium).	15.1 / 16.5			
17.5	Exploration completed at a depth of 16.5 feet.				
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 50 100)

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BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING ME-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-24

BORING ME-4

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (2 inches).	35.8 / 35.6 0.2			
	AGGREGATE BASE (10 inches).	34.8 / 1.0			
	Medium dense, brown-gray, fine to coarse, sandy GRAVEL with silt (GP-GM); moist, subrounded - **FILL.**	33.3 / 2.5			
2.5	Very loose, brown, fine, silty SAND (SM), trace carbonized organics; moist (alluvium).			2	
5.0	becomes without organics at 5.0 feet		DD	5	Dames & Moore sampler used DD = 77 pcf
7.5				2	
10.0	becomes brown-gray at 9.5 feet		P200	3	P200 = 12%
12.5				6	Dames & Moore sampler used
	Exploration completed at a depth of 13.5 feet.	22.3 / 13.5			
15.0					
17.5					
20.0					
22.5					
25.0					
27.5					
30.0					

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 – 50 – 100)

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BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-25

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	ASPHALT CONCRETE (2 inches).	37.3 / 37.1 / 0.2			
	AGGREGATE BASE (10 inches).	36.3 / 1.0			
	Medium dense, gray-brown, fine to medium SAND (SP), trace silt; dry to moist (alluvium).			11	
2.5	becomes loose; moist at 2.5 feet		DD	17	Dames & Moore sampler used DD = 85 pcf
5.0	Loose, brown, fine SAND with silt (SP-SM); moist (alluvium).	32.3 / 5.0		6	
7.5	Very loose to loose, brown-gray, fine, silty SAND (SP); moist (alluvium).	29.8 / 7.5		4	
10.0	becomes very loose at 10.0 feet		DD DS	7	Dames & Moore sampler used DD = 75 pcf
12.5	becomes loose, brown at 12.0 feet		P200	5	P200 = 30%
	Exploration completed at a depth of 13.5 feet.	23.8 / 13.5			

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

DRILLED BY: Western States Soil Conservation, Inc. LOGGED BY: NAK COMPLETED: 07/15/10

BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING ME-5

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-26

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 50 100)	INSTALLATION AND COMMENTS
0.0		Soft, dark brown/black, sandy SILT (ML), some organics, minor gravel; organic odor (3-inch-thick root zone) - **FILL.**	51.2	SIEV		3	
2.5		becomes medium stiff at 2.5 feet				6	
5.0		Medium dense, orange mottled brown-gray, fine to coarse GRAVEL with sand and silt (GP-GM); moist, subrounded to subangular (alluvium).	46.2 5.0			34	Dames & Moore sampler used Collected disturbed sample at 5.0 feet.
7.5		becomes dense at 7.5 feet				43	Hard drilling from 8.0 to 13.5 feet.
10.0				SIEV		46	
		becomes wet at 11.5 feet becomes very dense at 12.0 feet					∇ 11.5 feet, during drilling
12.5						81	
		Exploration completed at a depth of 13.5 feet.	37.7 13.5				
15.0							
17.5							
20.0							
22.5							
25.0							
27.5							
30.0							

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BORING MP-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-27

BORING LOG BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/16/11:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	GRASS/TOPSOIL (1 inch).	137.6 / 137.5 / 0.1			
	Very loose, brown, silty SAND (SM), trace rootlets; moist (alluvium).			3	Driller Comment: gravelly to 7.0 feet
2.5	becomes loose, brown with gray and orange mottles at 2.5 feet		P200	5	P200 = 12%
5.0	Loose, gray and orange mottled brown SAND with gravel and silt (SP-SM); moist, gravel is fine to coarse and subangular (alluvium).	131.9 / 5.8	DD	23	Dames & Moore sampler used DD = 81 pcf
7.5	Medium dense, gray, silty SAND with gravel (SM); moist to wet (alluvium).	130.1 / 7.5		12	Driller Comment: out of gravel at 7.0 feet
10.0	Very dense, gray, silty GRAVEL with sand (GM); wet (alluvium).	128.1 / 9.5			
	Hard, black, orange mottled blue-green SILT (ML); moist to wet (residual soil).	127.4 / 10.3		136	3-inch-O.D. split-spoon sampler used
12.5	Very dense, black and blue-green mottled gray, silty SAND (SM); moist to wet (residual soil).	125.6 / 12.0		113/5"	3-inch-O.D. split-spoon sampler used
	Exploration completed at a depth of 12.4 feet.	125.2 / 12.4			

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

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BORING METHOD: hollow-stem auger (see report text)   BORING BIT DIAMETER: 8-inch

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BORING MSY-1

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-28

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	GRASS/TOPSOIL (1 inch).	18.3 / 18.2 / 0.1			
	Very loose, brown, silty SAND (SM); moist (alluvium).	17.9 / 0.4		3	
	Very loose, brown, fine to medium SAND (SP), trace silt; moist (alluvium).				
2.5	trace rootlets at 2.5 feet			9	Dames & Moore sampler used
5.0	seams to layers of silty SAND (SM) at 5.0 feet			3	
7.5	loose, brown with orange and red specks (grains) at 7.5 feet	10.6 / 7.8	P200	9	P200 = 40% Driller Comment: harder drilling from 8.0 to 9.0 feet
	gray at 7.52 feet				
	Loose, gray, fine to medium, silty SAND (SM); wet (alluvium).				
10.0	minor gravel at 9.8 feet				
	Very dense, gray with blue-gray and light gray vertical striations, silty SAND with gravel (SM); moist to wet, vertical layers of black, gray, and orange-brown vertical layers (residual soil).	7.6 / 10.7	P200	75	P200 = 34%
12.5	vertical layers of gray, orange, and black at 12.0 feet	4.8 / 13.5		85	
15.0	Exploration completed at a depth of 13.5 feet.				

▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (0 – 50 – 100)

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BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MSY-2

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-29

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	TOPSOIL and ROOTS (up to 1/2-inch diameter) (1 inch).	19.8 / 19.7 / 0.1	P200	6	P200 = 38%
	Loose, brown, fine to medium, silty SAND (SM); moist (alluvium).				
2.5	rootlets at 2.5 feet			5	
5.0	becomes very loose, gray; wet at 5.8 feet		P200	1	P200 = 34%
7.5					
	Very dense, gray, fine to coarse, silty GRAVEL with fine to medium sand (GM); wet (alluvium).	11.0 / 8.8		50/5.5"	Lost Shelby tube sample
10.0	with cobbles/boulders at 11.5 feet	8.0 / 11.8		110/3"	Driller encountered cobble or boulder at ~10.5 feet that has skewed the auger. At 11.5 feet, the auger is so skewed, it will probably break something if continue. Sample at 11.5 feet. 3-inch-O.D. split spoon sampler used
12.5	Exploration terminated due to refusal on cobble/boulder at a depth of 11.8 feet.				

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

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BORING METHOD: hollow-stem auger (see report text) BORING BIT DIAMETER: 8-inch

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BORING MSY-3

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-30

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	BLOW COUNT	INSTALLATION AND COMMENTS
0.0	BARK DUST and TOPSOIL (1 inch).	53.4 / 53.3 / 0.1		18	
	Medium dense, gray, red, and yellow mottled brown, silty SAND (SM); moist (alluvium).				
2.5	Stiff, red, black, and gray speckled brown, sandy SILT (ML), trace gravel and roots (1 mm diameter); moist (alluvium).	50.9 / 2.5	P200	13	P200 = 54%
5.0	Medium dense, red-orange and gray mottled red-orange brown, fine to medium, silty SAND with gravel (SM), trace gravel and organics; moist (alluvium).	48.4 / 5.0		17	
7.5	very loose to loose, without organics at 7.5 feet		SIEV	4	Driller Comment: softer drilling at 7.0 feet
10.0	becomes loose, red-brown with gray and orange mottles, fine to coarse, minor fine to coarse subangular to angular gravel at 10.0 feet			8	
12.5	Soft to medium stiff/loose, red, gray, black and orange mottled red-brown, sandy SILT/silty SAND (ML/SM); moist to wet (alluvium).	41.4 / 12.0	P200	4	P200 = 39%
	Exploration completed at a depth of 13.5 feet.	39.9 / 13.5			

Legend: ▲ BLOW COUNT ● MOISTURE CONTENT % RQD% CORE REC% (scale 0 – 50 – 100)

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

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BORING METHOD: hollow-stem auger (see report text)

BORING BIT DIAMETER: 8-inch

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BORING MSY-4

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

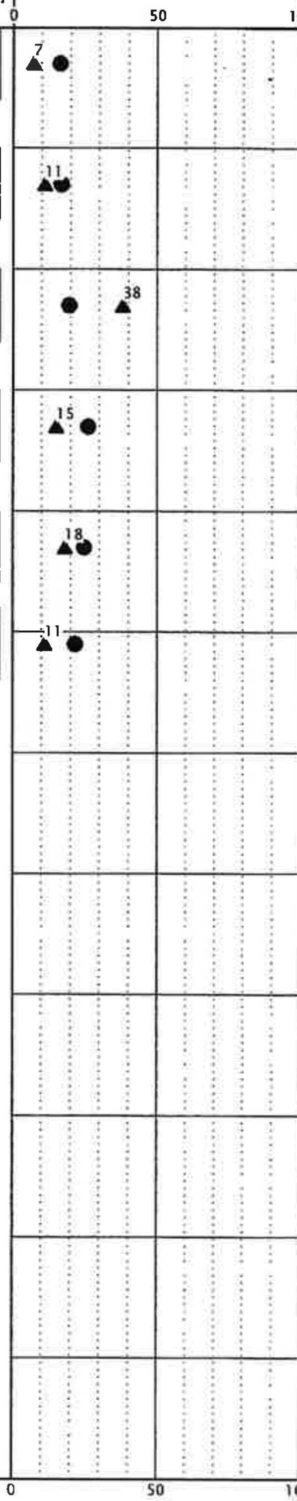
FIGURE A-31

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING	INSTALLATION AND COMMENTS
0.0	Medium stiff, brown, sandy SILT (ML), minor rootlets; dry.	44.7 / 44.5 / 0.2		
	Medium stiff, black and orange mottled brown, sandy SILT (ML); moist, sand is fine to medium (alluvium).			
2.5	stiff, trace rootlets (1 mm diameter); dry to moist at 2.5 feet			
5.0	trace branchy root (1/2-inch diameter) at 5.0 feet			Dames & Moore sampler used
7.5	becomes stiff to very stiff; branches up to 1/2- to 3/4-inch diameter at 7.5 feet		P200	P200 = 71%
10.0	trace black burnt wood debris; moist at 10.0 feet			
12.5	Medium dense, brown, fine to medium, silty SAND (SM); moist (alluvium).	32.7 / 12.0	P200	P200 = 40%
	Exploration completed at a depth of 13.1 feet.	31.6 / 13.1		

DEPTH FEET: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0

GRAPHIC LOG | SAMPLE

▲ BLOW COUNT
● MOISTURE CONTENT %
RQD% CORE REC%



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BORING METHOD: hollow-stem auger (see report text)

BORING BIT DIAMETER: 8-inch

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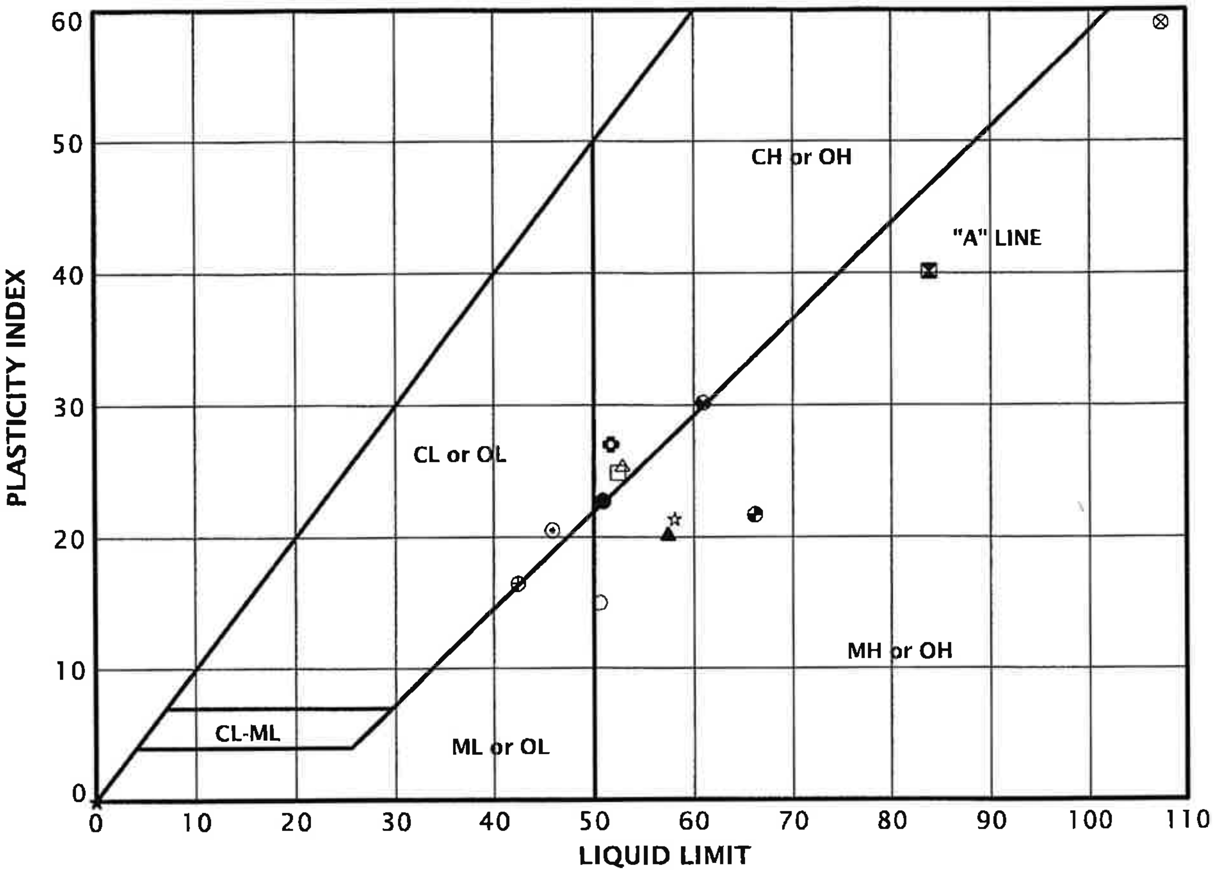
BORING MSY-5

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-32



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
●	99-1	7.0	37	51	28	23
⊠	99-2	25.0	58	84	44	40
▲	99-3	20.0	42	57	37	20
★	99-4	25.0	37	NP	NP	NP
⊙	BE-0	7.5	28	46	25	21
✤	BE-1	2.5	19	52	25	27
○	EX-2A	13.0	49	51	36	15
△	EX-3	3.5	28	53	27	26
⊗	JE-1	25.0	53	107	49	58
⊕	JE-1A	3.5	28	42	26	16
□	JE-2	5.0	35	52	28	24
●	MA-1	5.0	33	61	31	30
●	MA-2	2.5	51	66	45	21
☆	MA-3	10.0	42	58	37	21

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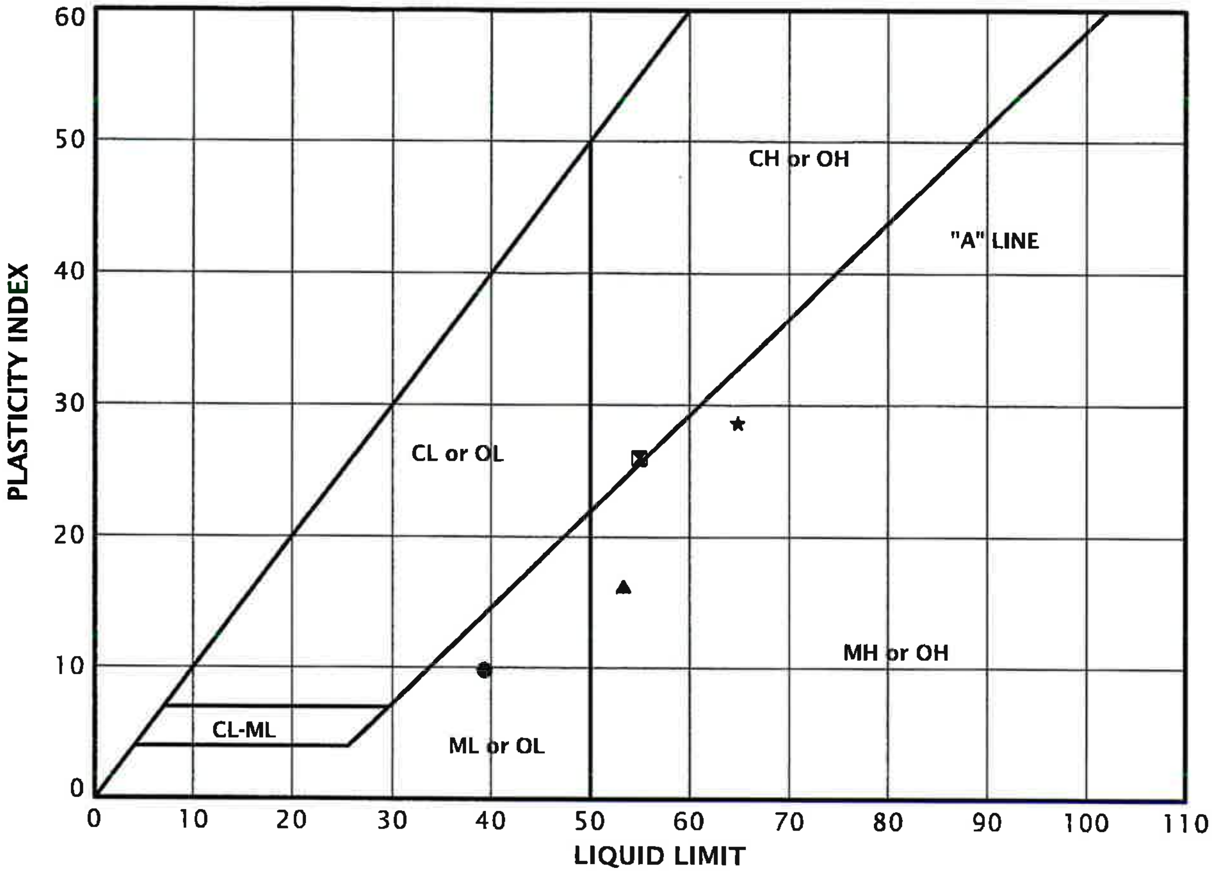
ATTERBERG LIMITS TEST RESULTS

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-33



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
●	MA-4	10.0	37	39	29	10
⊠	MA-5A	5.0	33	55	29	26
▲	ME-2	10.0	46	53	37	16
★	ME-3	7.5	47	65	36	29

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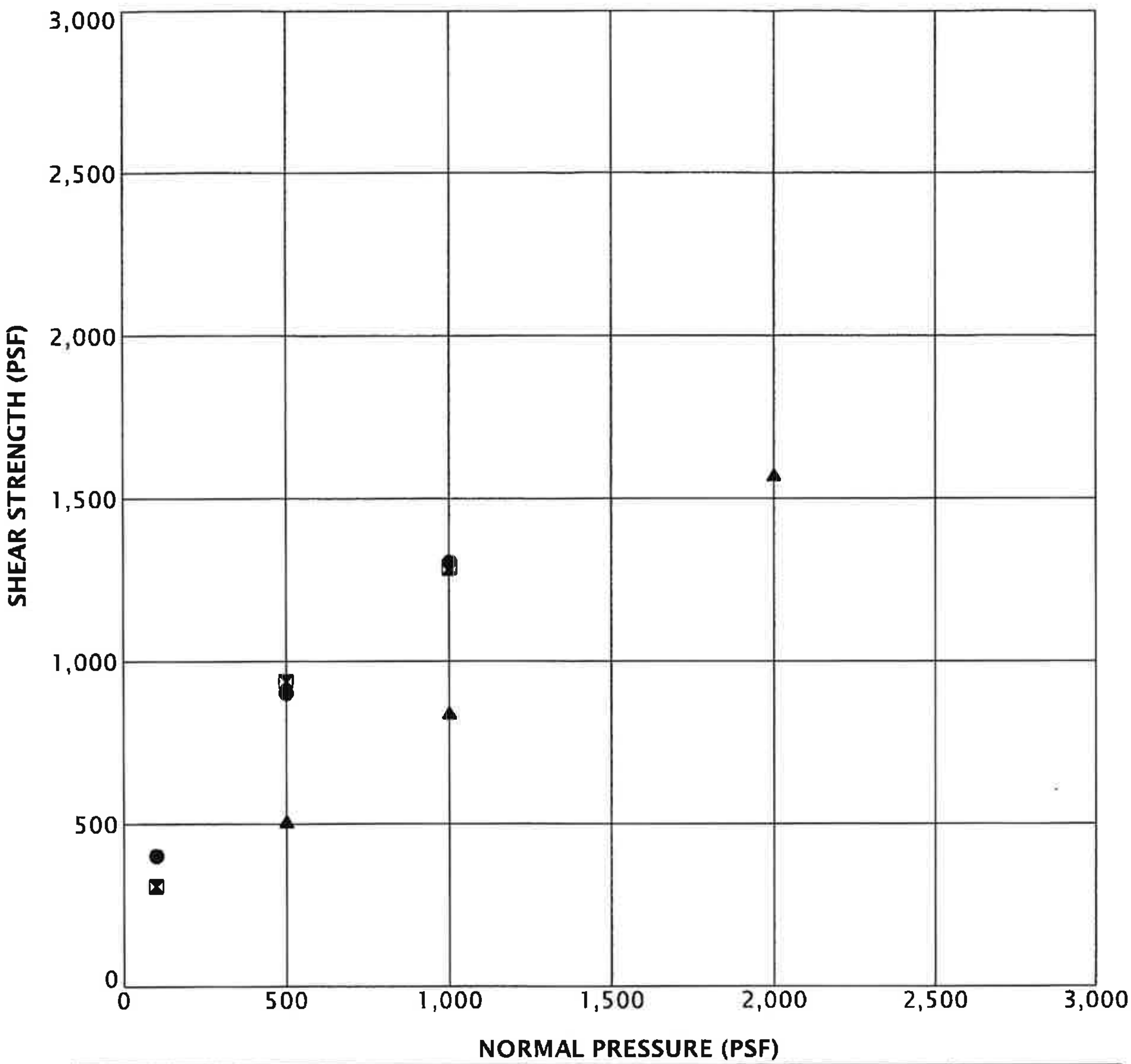
BROWNCALD-49-05-01	ATTERBERG LIMITS TEST RESULTS (continued)	
MARCH 2011	LAKE OSWEGO RAW WATER PIPELINE CLACKAMAS COUNTY, OR	FIGURE A-33



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SOAKED
●	99-1	5.0	29	91	YES
⊠	MA-2	5.0	51	71	YES
▲	ME-5	10.0	11	76	YES

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DIRECT SHEAR TEST RESULTS

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-34

RELATIVE DENSITY - COARSE-GRAINED SOILS			
Relative Density	**Standard Penetration Resistance**	**Dames & Moore Sampler (140-pound hammer)**	**Dames & Moore Sampler (300-pound hammer)**
Very Loose	0 - 4	0 - 11	0 - 4
Loose	4 - 10	11 - 26	4 - 10
Medium Dense	10 - 30	26 - 74	10 - 30
Dense	30 - 50	74 - 120	30 - 47
Very Dense	More than 50	More than 120	More than 47

CONSISTENCY - FINE-GRAINED SOILS				
Consistency	**Standard Penetration Resistance**	**Dames & Moore Sampler (140-pound hammer)**	**Dames & Moore Sampler (300-pound hammer)**	**Unconfined Compressive Strength (tsf)**
Very Soft	Less than 2	Less than 3	Less than 2	Less than 0.25
Soft	2 - 4	3 - 6	2 - 5	0.25 - 0.50
Medium Stiff	4 - 8	6 - 12	5 - 9	0.50 - 1.0
Stiff	8 - 15	12 - 25	9 - 19	1.0 - 2.0
Very Stiff	15 - 30	25 - 65	19 - 31	2.0 - 4.0
Hard	More than 30	More than 65	More than 31	More than 4.0

PRIMARY SOIL DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS (more than 50% retained on No. 200 sieve)	GRAVEL (more than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVELS (< 5% fines)	GW or GP	GRAVEL
		GRAVEL WITH FINES (≥ 5% and ≤ 12% fines)	GW-GM or GP-GM	GRAVEL with silt
			GW-GC or GP-GC	GRAVEL with clay
		GRAVELS WITH FINES (> 12% fines)	GM	silty GRAVEL
			GC	clayey GRAVEL
			GC-GM	silty, clayey GRAVEL
	SAND (50% or more of coarse fraction passing No. 4 sieve)	CLEAN SANDS (<5% fines)	SW or SP	SAND
		SANDS WITH FINES (≥ 5% and ≤ 12% fines)	SW-SM or SP-SM	SAND with silt
			SW-SC or SP-SC	SAND with clay
		SANDS WITH FINES (> 12% fines)	SM	silty SAND
			SC	clayey SAND
			SC-SM	silty, clayey SAND
FINE-GRAINED SOILS (50% or more passing No. 200 sieve)	SILT AND CLAY	Liquid limit less than 50	ML	SILT
			CL	CLAY
			CL-ML	silty CLAY
			OL	ORGANIC SILT or ORGANIC CLAY
		Liquid limit 50 or greater	MH	SILT
			CH	CLAY
			OH	ORGANIC SILT or ORGANIC CLAY
HIGHLY ORGANIC SOILS			PT	PEAT

MOISTURE CLASSIFICATION	
Term	**Field Test**
dry	very low moisture, dry to touch
moist	damp, without visible moisture
wet	visible free water, usually saturated

ADDITIONAL CONSTITUENTS					
Secondary granular components or other materials such as organics, man-made debris, etc.					
Percent	**Silt and Clay In: Fine-Grained Soils**	**Silt and Clay In: Coarse-Grained Soils**	**Percent**	**Sand and Gravel In: Fine-Grained Soils**	**Sand and Gravel In: Coarse-Grained Soils**
< 5	trace	trace	< 5	trace	trace
5 - 12	minor	with	5 - 15	minor	minor
> 12	some	silty/clayey	15 - 30	with	with
			> 30	sandy/gravelly	sandy/gravelly

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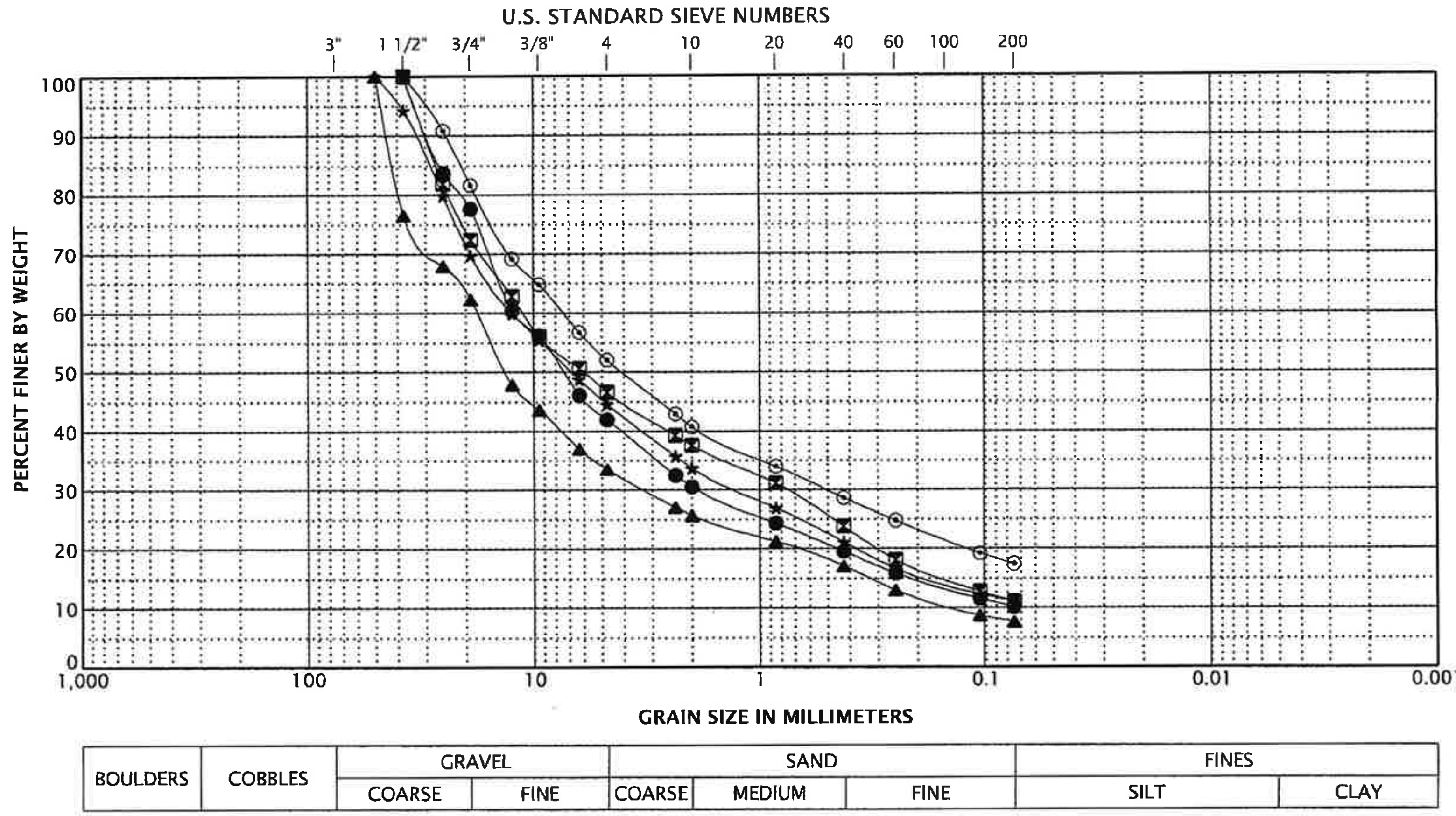
SOIL CLASSIFICATION SYSTEM

TABLE A-2

GRAIN SIZE NO P200 BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/1/11:KT



KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	D60	D50	D30	D10	D5	GRAVEL (PERCENT)	SAND (PERCENT)	SILT (PERCENT)	CLAY (PERCENT)
●	99-1	10.0	16	12.19	7.38	1.86			58	32	10	
⊠	99-3	10.0	12	11.14	6.01	0.76			53	36	11	
▲	BE-0	12.0	5	17.75	13.29	3.25	0.14		66	26	8	
★	BE-2	7.5	6	12.51	6.78	1.25			55	34	11	
⊙	DA-1	1.0	9	7.43	4.05	0.51			48	35	17	

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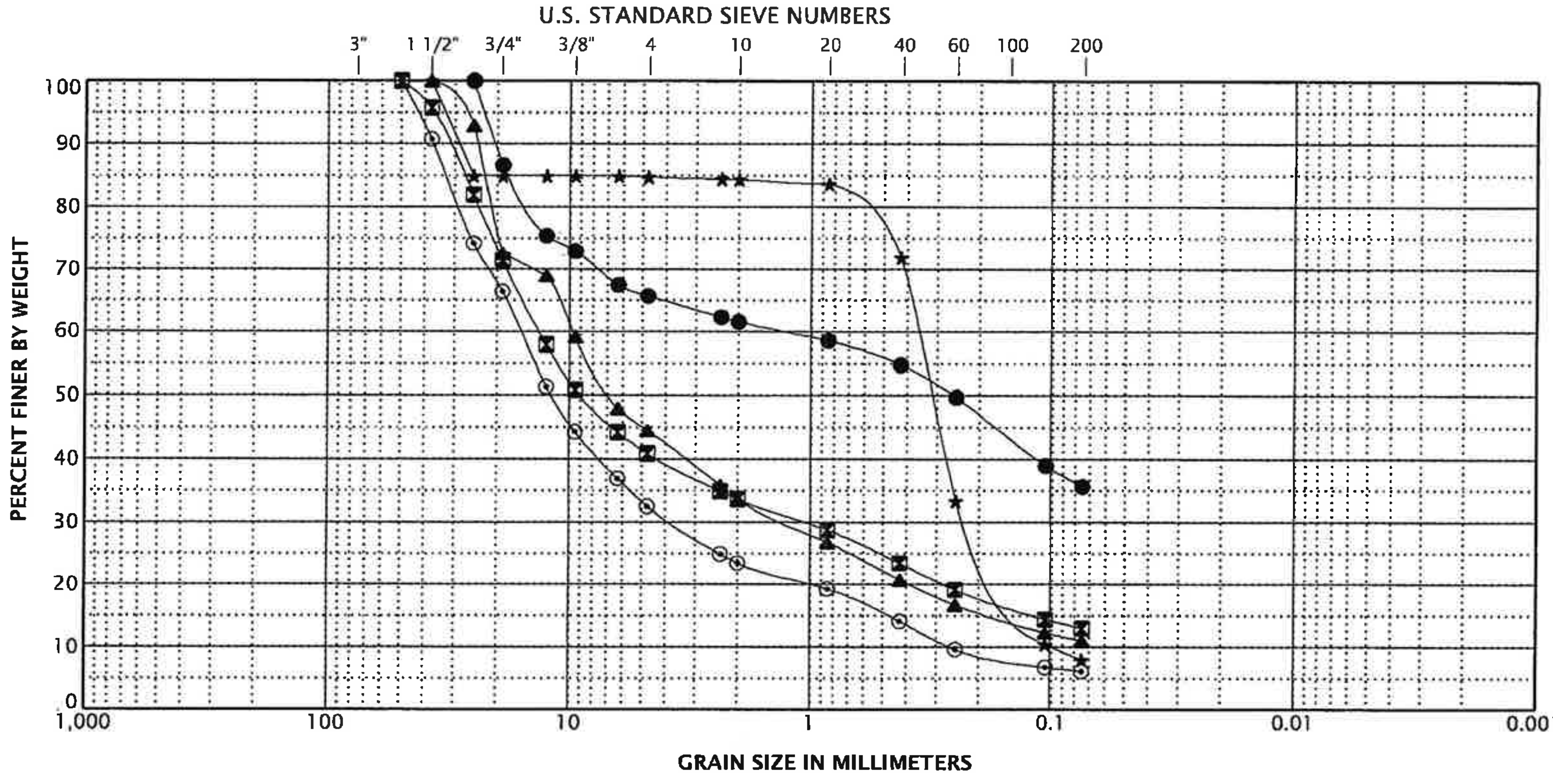
GRAIN-SIZE TEST RESULTS

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-35



BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY

KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	D60	D50	D30	D10	D5	GRAVEL (PERCENT)	SAND (PERCENT)	SILT (PERCENT)	CLAY (PERCENT)
●	EX-1	3.5	12	1.28	0.26				34	30	36	
⊠	EX-2A	1.0	7	13.33	9.02	1.06			59	28	13	
▲	JE-1	5.0	6	9.72	6.79	1.27			56	34	11	
★	JE-1	20.0	36	0.36	0.31	0.22	0.10		15	77	8	
⊙	JE-1A	5.0	12	15.90	11.87	3.77	0.26		67	26	6	

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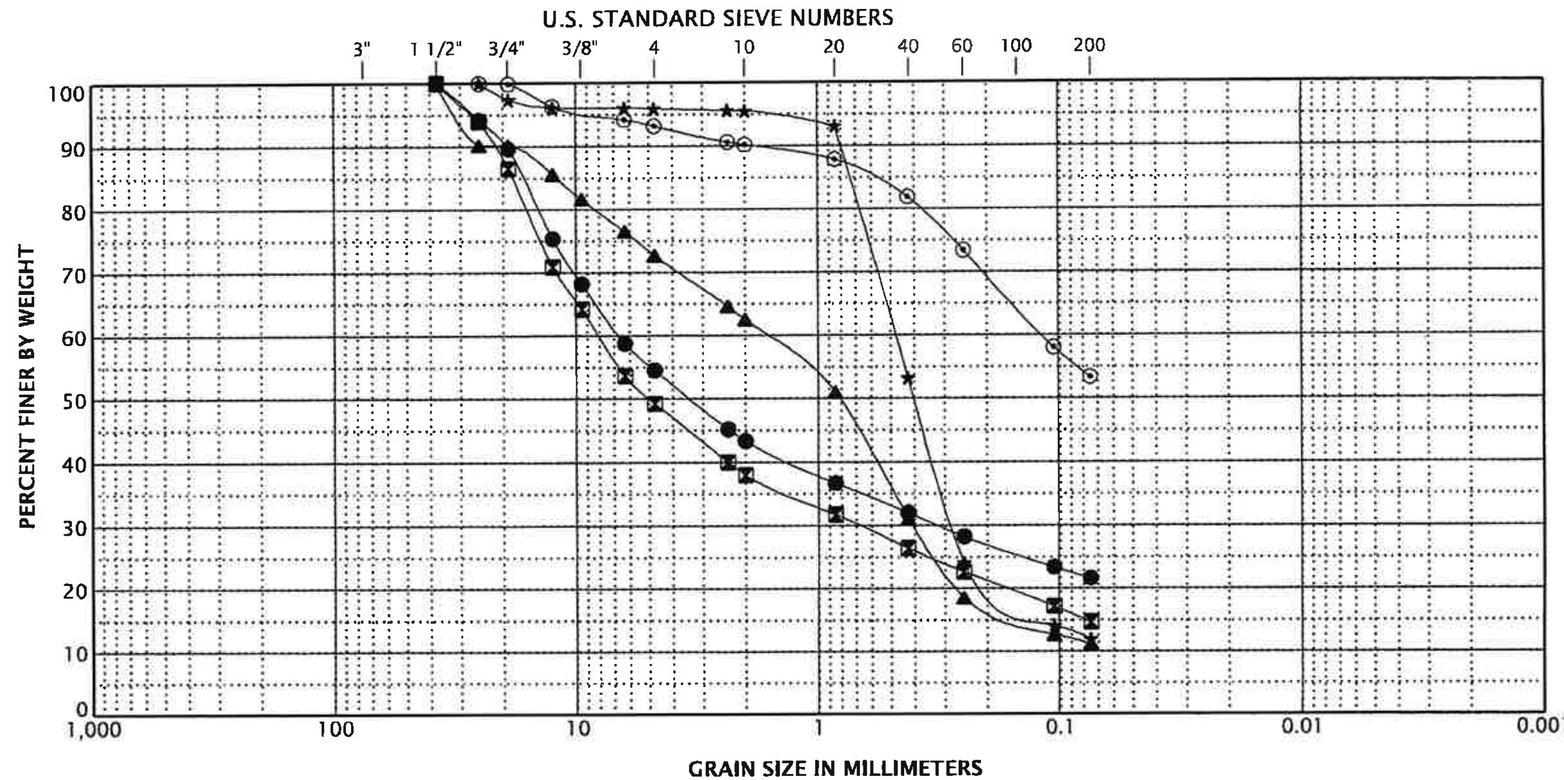
GRAIN-SIZE TEST RESULTS
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-35

GRAIN SIZE NO P200 BROWNCALD-49-05-01-MASTER.GPJ GEODESIGN.GDT PRINT DATE: 3/1/11:KT



BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY

KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	D60	D50	D30	D10	D5	GRAVEL (PERCENT)	SAND (PERCENT)	SILT (PERCENT)	CLAY (PERCENT)
●	JE-2	12.0	16	6.64	3.38	0.32			45	33	22	
⊠	JE-3	2.5	7	8.06	4.98	0.68			51	35	15	
▲	MA-3	7.5	16	1.66	0.82	0.41			27	61	11	
★	ME-2	5.0	32	0.48	0.40	0.28			4	84	12	
⊙	MP-1	1.0	32	0.12					7	40	53	

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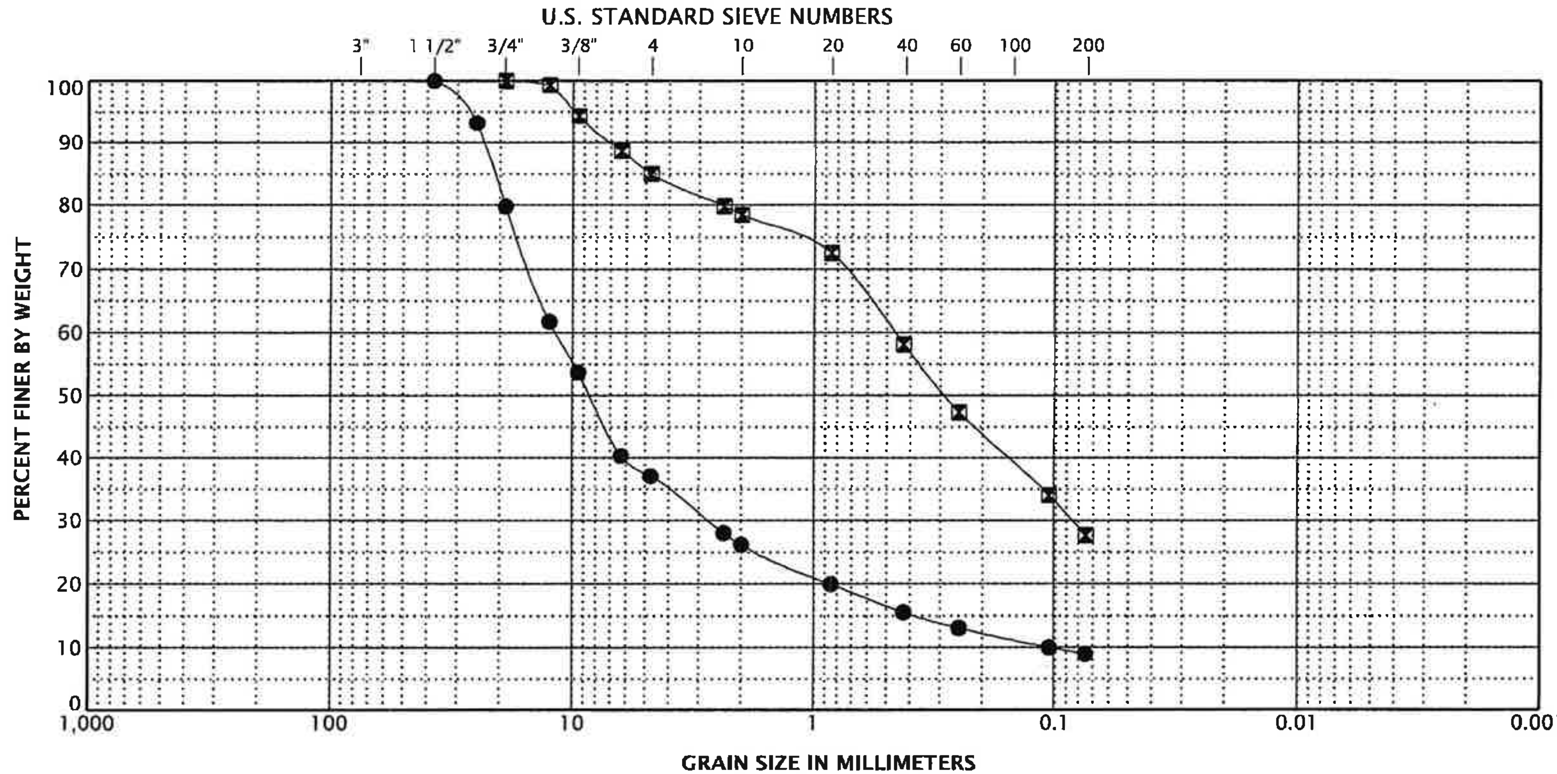
GRAIN-SIZE TEST RESULTS
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-35



BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY

KEY	EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	MOISTURE CONTENT (PERCENT)	D60	D50	D30	D10	D5	GRAVEL (PERCENT)	SAND (PERCENT)	SILT (PERCENT)	CLAY (PERCENT)
●	MP-1	10.0	7	11.78	8.48	2.75	0.11		63	28	9	
⊠	MSY-4	7.5	25	0.47	0.28	0.09			15	57	28	

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GRAIN-SIZE TEST RESULTS
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-35

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
99-1	2.5		34							
99-1	5.0		28	93						
99-1	7.0		37					51	28	23
99-1	10.0		16		58	32	10			
99-1	15.0		13							
99-1	22.0		42							
99-1	25.0		47	74						
99-2	2.5		31				69			
99-2	5.0		35							
99-2	7.5		34							
99-2	10.0		39							
99-2	15.0		11							
99-2	20.0		15							
99-2	25.0		58					84	44	40
99-3	2.5		23							
99-3	5.0		4							
99-3	7.5		8							
99-3	10.0		12		53	36	11			
99-3	15.0		17							
99-3	20.0		42					57	37	20
99-4	2.5		32							
99-4	5.0		32							
99-4	7.5		42							
99-4	10.0		37							
99-4	15.0		5							
99-4	20.0		13							
99-4	25.0		37					NP	NP	NP

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SUMMARY OF LABORATORY DATA

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
BE-0	1.0		9							
BE-0	2.5		25							
BE-0	5.0		28	79						
BE-0	7.5		28					46	25	21
BE-0	10.0		5							
BE-0	12.0		5		66	26	8			
BE-1	1.0		18							
BE-1	2.5		19					52	25	27
BE-1	5.0		21	79			35			
BE-1	7.5		6							
BE-1	10.0		5							
BE-1	12.0		6							
BE-2	1.0		16							
BE-2	2.5		18							
BE-2	5.0		4							
BE-2	7.5		6		55	34	11			
BE-2	10.0		8							
BE-2	11.5		5							
BE-2	12.5		10							
DA-1	1.0		9		48	35	17			
DA-1	2.5		6							
DA-1	5.0		6							
DA-1	7.5		5							
DA-1	10.0		12							
DA-1	12.0		14							
EX-1	1.0		13							
EX-1	3.5		12		34	30	36			

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SUMMARY OF LABORATORY DATA
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
EX-1	5.0		6							
EX-1	10.0		28							
EX-1	12.0		23							
EX-2	1.0		13							
EX-2	3.5		16							
EX-2	5.0		14							
EX-2A	1.0		7		59	28	13			
EX-2A	10.0		8							
EX-2A	12.0		24							
EX-2A	13.0		49					51	36	15
EX-3	1.0		26							
EX-3	3.5		28					53	27	26
EX-3	5.0		43	74						
EX-3	7.0		8							
EX-3	10.0		5							
EX-3	12.0		28				19			
EX-3	12.5		49							
JE-1	2.5		24							
JE-1	5.0		6		56	34	11			
JE-1	15.0		17							
JE-1	20.0		36		15	77	8			
JE-1	25.0		53					107	49	58
JE-1A	1.0		25							
JE-1A	3.5		28					42	26	16
JE-1A	5.0		8		67	26	6			
JE-1A	7.5		9							
JE-1A	10.0		12							

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SUMMARY OF LABORATORY DATA
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
JE-1A	12.0		14							
JE-2	1.0		26							
JE-2	3.5		27							
JE-2	5.0		35					52	28	24
JE-2	7.5		35	81						
JE-2	9.5		46							
JE-2	12.0		16		45	33	22			
JE-3	2.5		7		51	35	15			
JE-3	5.0		33							
JE-3	7.5		17	96						
JE-3	10.0		22				19			
JE-3	12.0		26							
MA-1	1.0		20							
MA-1	2.5		28	88						
MA-1	5.0		33					61	31	30
MA-1	7.5		40	76						
MA-1	9.5		38				56			
MA-1	12.0		54	71						
MA-2	1.0		42							
MA-2	2.5		51					66	45	21
MA-2	5.0		51	69						
MA-2	7.5		50							
MA-2	10.0		50							
MA-2	12.0		45							
MA-3	2.5		23							
MA-3	5.0		18							
MA-3	7.5		16		27	61	11			

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SUMMARY OF LABORATORY DATA
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
MA-3	10.0		42					58	37	21
MA-3	12.0		46							
MA-4	1.0		24							
MA-4	2.5		35							
MA-4	5.0		37							
MA-4	7.5		36	85						
MA-4	10.0		37					39	29	10
MA-4	12.0		27				67			
MA-5	1.0		4							
MA-5	2.5		4							
MA-5	5.0		4							
MA-5A	2.5		28							
MA-5A	5.0		33					55	29	26
MA-5A	7.5		35	84						
MA-5A	10.0		38							
MA-5A	12.0		36							
ME-2	1.0		26							
ME-2	3.5		32							
ME-2	5.0		32		4	84	12			
ME-2	7.5		7							
ME-2	10.0		46					53	37	16
ME-2	12.0		43							
ME-3	1.5		5							
ME-3	3.0		35							
ME-3	5.0		39	72						
ME-3	7.5		47					65	36	29
ME-3	10.0		41	75						

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
ME-3	12.0		42				84			
ME-3	15.0		40							
ME-3	16.0		9							
ME-4	2.5		33							
ME-4	5.0		15	77						
ME-4	7.5		24							
ME-4	10.0		17				12			
ME-4	12.0		23							
ME-5	1.0		8							
ME-5	2.5		8	85						
ME-5	5.0		14							
ME-5	7.5		8							
ME-5	10.0		11	75						
ME-5	12.0		13				30			
MP-1	1.0		32		7	40	53			
MP-1	2.5		22							
MP-1	5.0		16							
MP-1	7.5		6							
MP-1	10.0		7		63	28	9			
MP-1	12.0		11							
MSY-1	0.0		21							
MSY-1	2.5		10				12			
MSY-1	5.0		27	81						
MSY-1	7.5		33							
MSY-1	10.0		28							
MSY-1	12.0		16							
MSY-2	0.0		16							

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SUMMARY OF LABORATORY DATA
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LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

SAMPLE INFORMATION			MOISTURE CONTENT (PERCENT)	DRY DENSITY (PCF)	SIEVE			ATTERBERG LIMITS		
EXPLORATION NUMBER	SAMPLE DEPTH (FEET)	ELEVATION (FEET)			GRAVEL (PERCENT)	SAND (PERCENT)	P200 (PERCENT)	LIQUID LIMIT (PERCENT)	PLASTIC LIMIT (PERCENT)	PLASTICITY INDEX (PERCENT)
MSY-2	2.5		17							
MSY-2	5.0		29							
MSY-2	7.5		38				40			
MSY-2	10.0		29				34			
MSY-2	12.0		32							
MSY-3	0.0		19				38			
MSY-3	2.5		22							
MSY-3	5.0		34				34			
MSY-3	8.8		20							
MSY-3	12.0		12							
MSY-4	0.0		17							
MSY-4	2.5		17				54			
MSY-4	5.0		22							
MSY-4	7.5		25		15	57	28			
MSY-4	10.0		23							
MSY-4	12.0		27				39			
MSY-5	0.0		16							
MSY-5	2.5		17							
MSY-5	5.0		19							
MSY-5	7.5		26				71			
MSY-5	10.0		25							
MSY-5	12.0		21				40			

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SUMMARY OF LABORATORY DATA
(continued)

LAKE OSWEGO RAW WATER PIPELINE
CLACKAMAS COUNTY, OR

FIGURE A-36

ACRONYMS

ACRONYMS

AC	asphalt concrete
ASTM	American Society for Testing and Materials
BGS	below ground surface
CRBG	Columbia River Basalt Group
LiDAR	light detection and ranging
RIPS	River Intake Pump Station
SPT	standard penetration test
WTP	water treatment plan

Geotechnical Design Report
Tri-City Water Pollution Control Plant
Interim Expansion
Clackamas County, Oregon

September, 2008

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Geotechnical Design Report
Tri-City Water Pollution Control Plant
Interim Expansion
Clackamas County, Oregon

September, 2008

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Lake Oswego, Oregon 97035

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GEOTECHNICAL DESIGN REPORT
INTERIM EXPANSION
TRI-CITY WATER POLLUTION CONTROL PLANT
CLACKAMAS COUNTY, OREGON

1.0 INTRODUCTION

Water Environment Services (WES), a department of Clackamas County, is in the process of upgrading its wastewater treatment capacity. A significant portion of this upgrade includes a phased expansion of the Tri-City Water Pollution Control Plant (WPCP). The Interim Expansion Phase encompasses new facilities for a Membrane Bioreactor treatment process as well as interaction with the future Post-Interim facilities. Additionally, this project includes site work on the existing plant work to reduce the environmental impacts of the plant. This expansion will provide capacity to handle growth from both the Tri-City Service District (TCSD) and Clackamas Service District No. 1 (CCSD#1). WES has contracted the MWH team to provide engineering services for the design of the Interim Expansion. This document presents Shannon & Wilson's geotechnical design recommendations and conceptual construction considerations. The information in the report is intended to support MWH during the design phase.

1.1 Site Location

The WPCP is located at 15951 S. Agnes Ave in Clackamas County near the confluence of the Clackamas and the Willamette Rivers. The legal location description is the SE Quarter of the SW Quarter of Section 20 in Township 2 South and Range 2 East. Figure 1, Vicinity Map displays the project location in relation to nearby landmarks. The proposed plant expansion area will be immediately to the south of the existing plant. Locations of each of the interim expansion facilities in relation to the existing plant are shown on Figure 2.

1.2 Objectives

The objective of this report is to provide the design team with recommendations regarding geotechnical issues. In particular, we want to document the current foundation recommendations for each major facility and develop conceptual construction considerations which may impact future design decisions. We provided a general description about site geology and seismic considerations as a backdrop to the discussion of individual facilities. In general, for each facility we covered foundation recommendation (foundation type and static performance), seismic performance (liquefaction and ground deformation) and construction considerations (excavation and dewatering). Our primary goal is to reiterate existing predesign geotechnical recommendations in a consistent document and highlight areas that require continued effort.

2.0 SCOPE OF WORK

The scope of this document includes discussions of local geology and subsurface conditions based on Shannon & Wilson's explorations and literature reviews, seismic site response based on a probabilistic site hazard assessment and recommendations for site preparation, foundations backfill for the interim facilities. Our evaluation will be based on the current facility layout, shown on Figure 2, and our understanding of proposed facilities at the time of this document, using existing and new geotechnical information obtained at the plant site. It should be noted that a Geotechnical Data Report (Dated May 2008) containing data only related to the Interim Expansion has been prepared as a separate document.

3.0 REVIEW OF EXISTING INFORMATION

Portions of the evaluation provided in this report are based on existing subsurface information. Specifically, Shannon & Wilson collected and reviewed geotechnical information from the following documents.

"Geotechnical Design Recommendations, Tri-City WPCP Liquids Expansion" by CH2M Hill, Inc, 2002, prepared for the Tri-City Service District.

"Geotechnical Data Report, Tri-City WPCP Liquids Expansion" by CH2M Hill, Inc, 2002, prepared for the Tri-City Service District.

"Soils Report, Tri-City Sewerage Treatment Plant" by CH2M Hill, Inc, 1982, prepared for the Tri-City Service District.

"Seismic Vulnerability Assessment, Tri-City Wastewater Treatment Plant" by URS Corporation, 2002, prepared for Water Environment Services.

"Phase I and Phase II Environmental Site Assessment, Tax Lot 502" by URS Corporation, 2001, prepared for Tri-City Service District.

"Remedial Action Work Plan, Unpermitted Rossman Landfill" by URS Corporation, 2000, prepared for Tri-City Service District.

4.0 GEOLOGY, SUBSURFACE CONDITIONS AND LABORATORY TESTING

4.1 Site Topography

The WPCP is located approximately 4500 feet to east / northeast of the confluence of the Willamette and Clackamas River, as shown on Figue 1. The project site is bordered on the north and east by the Clackamas River and by Clackamette Cove to the west and south, both of which are at approximately elevation 15 ft above mean sea level. To the north and west of the site the ground is relatively flat for approximately 2000 feet before giving rise to steep terrace formations. On-site, the ground surface near the planned facilities is generally flat but varies from elevation 44 to 46 feet.

4.2 Geologic Setting

The project site is underlain by three significant geologic units. The youngest unit is found at the ground surface and is composed of catastrophic flood deposits laid down during the outwashing of glacial Lake Missoula some 15,000 years ago. Soils found in the flood deposits are generally silts with sand interbeds with underlying layers of gravel. The gravel alluvium consists of very dense sandy gravel and cobbles. A geologic unit named Sandy River Mudstone is found below the alluvial gravels and locally observed along the banks of the Clackamas River. The Sandy River Mudstone Unit is generally composed of Pliocene-aged sedimentary rock beds. When encountered during our explorations the Sandy river mudstone was identified as very soft siltstone/very hard clayey silt.

4.3 Subsurface Conditions

Shannon & Wilson has developed a model of subsurface conditions based on our knowledge from both on-site exploration and review of existing on-site and nearby geotechnical evaluations. Shannon & Wilson drilled seven exploratory mud rotary borings to depths ranging from 30 to 50 feet below the ground surface. In addition to borings the subsurface was explored using an electric cone penetrometer (CPT). We advanced four CPT holes to depths between 20 and 35 feet. The CPT probes were stopped where they reached a refusal pushing force on the Troutdale gravels. Logs of the exploration program are contained in Appendix A. For reference, boring logs from previous reports in the plant area are contained in Appendix D. More details of the recent exploration program is contained in the Geotechnical Data Report.

After the explorations were completed, we performed a number of index and analytical laboratory tests to further refine our understanding of the soils that were collected, during the boring phase of the exploration program. Once available data was collected we developed our subsurface model which is represented by our boring logs (see Appendix A) and the Geologic Cross Sections (see Figures 3 and 4). The following list is a summary of the soil groups that have been identified in the subsurface model.

4.3.1 Soil Unit Descriptions

The subsurface is described using the following units:

- **Site Fill**: This material ranges in thickness from 4 to 7 feet. This fill was part of the original plant construction; therefore, it is likely made up of excess select fine-grained native soil fill and remnants of the coarse-grained preload fill soils. The fine-grained fill was non- to low plasticity medium stiff silt with scatted organics. Thickness of the fine-grained soils was typically between 2 to 3 feet. Below the fine-grained fill, the coarse-grained soils were very dense and consisted of a combination of silt, gravel and cobbles. The coarse-grained soils were typically between 3 to 4 feet thick.
- **Alluvial silt, sandy silt, silty sand**: This layer is quite variable across the site in both composition and relative thickness. This layer is largely made up of silts and silty sands. In some areas, primarily closer to the river, the soil is more sandy. These materials are flood-deposited and fine-grained with low to non-plastic characteristics. Thickness of the deposit ranges from 22 to 37 feet, on average the upper 20 feet of the unit is soft to stiff silt below which is a 2 to 4 feet thick bed of loose silty sand. During large earthquake events, these materials are susceptible to loss of strength and liquefaction when saturated under the groundwater table. The thickness range of this layer in the vicinity of the planned interim structures is 25 to 30 feet. More sandy soils result in less consolidation under static loading, but more susceptible to loss of strength during large seismic events.
- **Alluvial gravelly sand, sandy gravel:** This material is flood deposited and primarily coarse-grained material with fines in the matrices between gravel particles. This material is non-plastic, but is dense to very dense and is not susceptible to loss of strength and liquefaction under the groundwater table. This unit is encountered fairly regularly across the site at an elevation of approximately 20 ft msl with the exception being the area beneath the proposed fine-screening building where the top of the gravel was significantly lower and was encountered at an elevation of 7 ft msl.

- **Siltstone (Sandy River Mudstone):** Below the gravel unit is a weathered siltstone layer that appears to be quite uniform in depth below the ground surface. Based on the borings that encountered the siltstone unit, we estimate the top of the unit is at a depth of 40 ft bgs(EL 5 ft msl). The siltstone is a very weak rock that remolds to a non-plastic silt or medium plasticity clayey silt depending on the degree of weathering.

4.3.2 Groundwater

Ground water levels at the site appear to fluctuate by up to about 10 feet. During maximum seasonal high ground water levels, the depth to ground water could reach 25 feet below the existing ground surface, elevation 20 feet, or possibly higher. We estimate the average seasonal high ground water level is elevation 18 feet. During the dry seasons, the depth to ground water is about 30 to 35 feet.

4.4 Laboratory Testing

Shannon & Wilson completed a laboratory testing program composed of standard index testing. The laboratory testing is intended to compliment and confirm the field classification performed during the subsurface exploration program. In our geotechnical evaluation, we also used laboratory testing completed for previous on-site explorations; these results, as well as, the results of the laboratory are presented in Appendix B. A complete discussion of the lab testing program and results is presented in the Geotechnical Data Report.

5.0 GENERAL SEISMIC CONSIDERATIONS

5.1 Seismic Setting

Within the present understanding of the regional tectonic framework and historical seismicity, three broad seismogenic sources have been identified:

- A mega-thrust source at in interface between the North American and Juan de Fuca plates in the Cascadia Subduction Zone (CSZ).
- A deep subcrustal zone (intra-slab) in the subducted Juan de Fuca Plate and Gorda plates in the CSZ.
- A shallow crustal zone within the forearc of North American Plate.

For the general area of the WPCP, the seismogenic sources that contribute significantly to the ground motion hazard include both megathrust earthquakes on the CSZ (located about 95 miles west of the site) and shallow crustal earthquakes on nearby faults. The nearest mapped shallow crustal faults are the Portland Hills Fault and the Oatfield Fault. According to the USGS Quaternary Fault Database, the Oatfield fault has been traced to within less than a mile of the WPCP site. The Portland hills fault has been traced to within 2 miles of the WPCP site.

Table 1 illustrates the different properties or parameters for the earthquakes that contribute to the ground motion hazard levels. We used these earthquake parameters in evaluating the seismic hazards at the Tri-City WPCP site. The magnitudes and distances of earthquakes were obtained from the USGS web site, Probabilistic Seismic Hazard Deaggregation, based upon the project site location (Longitude = -122.590, and Latitude = 45.375). Peak ground accelerations (PGA) shown on Table 1 were obtained from the 2002 USGS Seismic Hazard Maps (Frankel et al., 2002) and USGS Ground Motion Parameter Tool (Version 5.0.7) for the Pacific Northwest Region. The relative contribution of seismogenic sources to the ground motion hazard levels were calculated from the USGS PSHA. As shown on this table shallow crustal and CSZ megathrust earthquakes contribute the most to the seismic hazard at the WPCP site.

TABLE 1 - Earthquake Characterization by Seismogenic Source

Exceedance Probability	Bedrock PGA (g)	Seismogenic Source	Contribution to Seismic Hazard	Modal Distance from Site (km)	Modal Magnitude (M_w)
2 % in 50 yr	0.389	Shallow Crustal	80 %	10	6.0
		CSZ Intra-slab	N/A	N/A	N/A
		CSZ Megathrust	20 %	95	8.5

5.1.1 Earthquake Ground Motions

Design ground motions were calculated using the IBC 2006 design guidelines which are based on the "Maximum Considered Earthquake" (MCE) ground motions. As defined in the IBC 2006, a MCE corresponds to ground motions with a 2 percent probability of exceedance in 50 years and determined from the USGS national probabilistic seismic hazard analysis. These ground motions are then transformed, either amplified or damped, by the soil column below a point of interest. How soil conditions affect the ground motions is determined by the assignment of a seismic soil profile. We evaluated each structure separately, and depending on the soils and the depth of the foundation, designated a seismic site class and design ground motion for each. A description of the seismic site class and estimated seismic performance of each structure is discussed in Section 7, Geotechnical Design Recommendations. The following sections detail the inputs used to develop the site response for each of the structures.

5.1.1.1 S_s and S_1

The seismological inputs used to construct a response spectrum using the IBC 2006 procedure are short period spectral acceleration, S_S, and spectral acceleration at the 1 second period, S_1, shown on Figure 1615 in the code. As defined in the IBC 2006, S_S and S_1 are for a MCE. For the design earthquake at the site the acceleration values are shown on Figure 5.

5.1.1.2 Site Class

The site soil response factors are based on determination of the Site Class. Determination of the seismic Site Class was based on the procedure described in the IBC-2006 and Oregon Structural Specialty Code 2007 for seismic site classification using standard penetration resistance values. Based on the subsurface explorations at the site, it is our opinion that the site depending on the structure in question, may be best classified as a site class C, D or E. The liquefaction hazard calculations, discussed in later sections of this report, indicate that the fine-grained soil directly overlying the dense gravel below the ground water level is liquefiable during design ground motions. Subsurface conditions with potentially liquefiable soils correspond to Site Class F. For F sites, the code requires a site-specific ground response evaluation for structures with periods greater than 0.5 seconds. For structures with periods less than 0.5 seconds, the code allows for seismic design based on a site class determined directly from information in the codes and supplementary references without regard to liquefaction. A number of the structures may qualify for this exception and although they will experience some liquefaction they may be classified as a Site Class E.

The Site Class, ground surface peak ground acceleration (PGA) and liquefaction hazards are shown in Table 2. We did not account for liquefaction mitigation that may occur during construction. Our recommendations regarding liquefaction mitigation and seismic performance will be covered in the following sections within the discussion of each structure.

TABLE 2 - Seismic Profile and Liquefaction Hazard

Site Class	Ground Surface PGA, g	Potential Liquefaction	Sand Boiling	Loss of Bearing Capacity in Liquefiable Layer	Settlement, in
E	0.244	Y	N	Y	0 to 1
D	0.277	Y	N	Y	0 to 7
C	0.253	Y	Y	Y	N/A
C	0.253	N	N/A	N/A	N/A

5.1.1.3 Response Spectra

The response spectra for the probable Site Classes on site are presented on Figure 5. Peak bedrock ground accelerations, S_S, and S_1 were determined using the USGS Earthquake Ground Motion Parameters software, version 5.0.7 (June 18, 2007). The response spectra were constructed using the IBC 2006 procedure.

5.1.2 Earthquake-Induced Geologic Hazards

Earthquake-induced geologic hazards that may affect a given site include landsliding, fault rupture, settlement, liquefaction of fine-grained, alluvial soils below the ground water level and associated effects (loss of shear strength, bearing capacity failures, loss of lateral support, ground oscillation, lateral spreading toward the open slope of the Clackamas River, etc.), and flooding (i.e., seiche and tsunami). Liquefaction and related effects appear to pose the most likely and significant earthquake-induced geologic hazard at the site.

5.1.2.1 Liquefaction

Liquefaction potential was evaluated for the Interim Structures not founded in or on the dense gravel. Soils that are typically highly susceptible to liquefaction are loose, saturated cohesionless sandy or silty soils. Soil particles in a loose soil will tend to arrange themselves in a more compact configuration (i.e., densify) when shaken with sufficient intensity. If there is water between the soils particles (i.e., the soil is saturated), the tendency of the soil to densify decreases the pore space between the soil particles and increases the pore water pressure. Liquefaction results as pore water pressure in the soil approaches the effective confining stress, causing the soil to effectively loose most of its shear strength. The effects of liquefaction may include loss of bearing capacity for shallow foundations, reduction in lateral and vertical capacities of deep foundations, buoyant rise of buried structures, ground surface settlements, lateral spreading and embankment instability or slumping.

The most widely used method is an empirical procedure, termed "Seed's Simplified Procedure." This method was proposed by Seed and his colleagues (1971 and 1983) and updated by Youd et al. (2001) and is based on correlations between standard penetration resistance (SPT N-value), soil peak ground acceleration (PGA), and earthquake magnitude. Based upon the geologic profiles presented in Figures 3 and 4 , we selected two representative soil profiles to evaluate the liquefaction potential using the above procedure.

5.1.2.2 Liquefaction Induced Settlement

The liquefaction-induced settlement was evaluated using Ishishara and Yoshimine (1992). The estimated range of liquefaction-induced settlement (without mitigation) for the various foundation types are discussed in the next section under the individual structures. For these evaluations, it was assumed that liquefaction settlement needs to be mitigated for all the structures.

5.1.2.3 Lateral Spreading

Liquefaction induced by reduction in soil shear strength can result in deep seated shear and lateral displacement (lateral spreading). As a result, the subsoils beneath the project site sufficiently close to the slopes of the Clackamas River may move laterally towards Clackamas River. We estimated the magnitude of the potential lateral spreading of the subsoils underneath the facilities using the simplified approach presented by T. Leslie Youd (1998). We estimate that lateral ground spreading toward the river at the Standby Power building location will be less than 12-inches following the CSZ megathrust design earthquake and less than 1-inch following a shallow crustal design earthquake. Based on our previous evaluation, lateral spreading for Interim structures east of the Standby Power building is not considered a hazard.

5.1.2.4 Liquefaction-Related Reduced Foundation Capacities

The effects of liquefaction on the foundation capacities of specific structures or of uplift forces are a potential risk at the site. We believe that reduction in foundation capacities, both lateral and vertical, and uplift forces will occur for unmitigated structures. All the interim main structures have been mitigated for liquefaction potential by either placing the structures on piles or overexcavating the liquefiable soil and replacing with non-liquefiable imported crushed rock.

5.1.2.5 Other Earthquake-Induced Geologic Hazards

The risk posed by other earthquake-induced geologic hazards to the WPCP is relatively low in our opinion. A brief discussion of other earthquake-induced geologic hazards is provided in this section of the report. The risk posed by landsliding is relatively low, in our opinion. We base this opinion on the flat topography at the site and the large distances to significant slopes.

The potential for fault rupture is also relatively low. The nearest mapped fault is the Oatfield Fault Zone, located approximately 1 mile north of the site. This zone consists of a northwest trending fault. While this fault is considered potentially active by the USGS, the potential for fault rupture at the site is relatively low because of the distance and orientation between the site and the fault.

The potential for flooding due to seismic waves (tsunami or seiches) is not applicable because the site is located several tens of miles inland from the coast and any potential tsunami wave, and the elevation difference between the site and Clakamette Cove result in a low risk that a free-standing oscillating wave (seiche) could develop and affect the site.

6.0 GENERAL CONSTRUCTION CONSIDERATIONS

6.1 Construction Sequencing

Our understanding of the construction of the Interim Expansion is as follows. The open cut excavation for the main portion of the facility will be completed as a single site excavation down to varying subgrade elevations, as determined by footing elevations and constructability needs. The main excavation will encompass the footprints for the Membrane building, Aeration Basin, Fine Screenings building, Ultra Violet Disinfection and Chemical Handling building and the three interconnecting galleries. Under a portion of the Aeration Basin, overexcavation will occur to remove fine-grained soils above the gravel, and replaced with working pad material. A working pad will be placed following completion of the excavation. Once the working pad is in place, the auger-cast pile foundation system will be constructed for the structures within the excavation. Depending of the final excavation plan, the top elevation of a number of the auger-cast piles will have to be extended, with columns, to design building slab elevation, e.g. chemical handling building. After, and in some cases before, installation of auger-cast piles, yard piping below the structures will be installed. We assume that excavation and replacement of the existing fill with lightweight fill next to the existing Aeration Basin will be completed during yard pipe installation. Following yard pipe installation, structure construction will begin, including the installation of the subdrain (underdrain) system beneath the Aeration Basin. We anticipate that backfill will be placed concurrently as structures are built up. Once the excavation has been backfilled to design elevation along the north wall of the proposed aeration basin, additional auger-cast piles will be installed to support the Membrane Electric and Blower building. With regard to geotechnical considerations, the Standby Power Generation building is independent of this construction sequence.

6.2 General Earthwork

6.2.1 Site Preparation

All areas that will receive structural fill, pavement or support structures should be stripped to a depth is sufficient to remove topsoil, significant roots, asphalt, concrete curbs and any other deleterious material. We estimate that it will be necessary to strip approximately 8 to 12 inches of top soil. Localized stripping to greater depths may be required.

6.2.2 Segregation and Stockpiling Materials

In the proposed open cut areas, the excavated materials will include organic surface soils and vegetation; silty gravel; sands, silty sands and sandy silts and silts. We recommend segregating and appropriately stockpiling the organic soils, the silty gravels, sand and silty sand for future use as topsoil and "select native" backfill or fill, respectively. Sandy silts and silts that are not suitable for backfill or other engineering purposes, should be hauled to an offsite disposal area or used in landscape berms. Stripped asphalt pavement and concrete curbs and other debris are not suitable for structural fill and should be removed from the site.

6.2.3 Temporary Cut and Fill Slopes

We understand that proposed construction method is an unshored open cut excavation with slopes sides. The excavation will be open cut in the range of 14 to 32 feet deep. The excavation will be in various materials including site fill, dense alluvial gravel, but mainly very soft/very loose alluvial silts and sands, and for this material we recommend that temporary slopes not be steeper than 1.5H:1V and covered with erosion control measures such as a plastic membrane. Temporary cut slopes are typically the responsibility of the contractor and should comply with applicable local, state and federal safety regulations, including the current OSHA Excavation and Trench Safety Standards.

6.2.4 Backfill

We understand that large number of different backfill materials will be utilized for the construction of this project. S&W anticipates that all backfill materials and their specific locations and placement criteria will be fully described in the construction plan and specifications. Generally, backfill recommendations include subgrade preparation, material type/gradation, compactive effort, maximum lift thickness and testing criteria. The following sections described general backfill criteria that are subject to modification under specific design recommendations and the construction plans and specifications.

6.2.4.1 Subgrade Preparation

The subgrade should be prepared by scarifying and recompacting the subgrade soil to a depth of 12-inches. The prepared subgrade should than be observed for suitability by an appropriate design professional. The subgrade suitability should be determined by a hand probing and proof rolling and/or density testing with a nuclear densometer. Proof rolling should be performed with a fully loaded 10 yard dump truck or other suitable rubber tired construction vehicle. Areas of the subgrade that pump or weave or appear soft or excessively wet should be rescarified, dried and recompacted to obtain acceptable performance or else removed and replaced with suitable compacted granular fill.

6.2.4.1 Backfill Material

Backfill material should be provided in accordance with the final construction plans and specifications. Generally, we recommend that compacted crushed rock be used beneath any structure, pipeline and pavement or behind buried walls that were designed with drained backfill, with the gradation varying depending on function. Select native soils may be used a backfill in areas where there are no structures and behind walls that were designed to withstand undrained lateral loading. Moisture conditioning may be required before the on-site soils are suitable for placement as select native fill. Other specialized backfill materials such a controlled density, low strength concrete fill and light weight fill materials may be required where specifically noted.

6.2.4.1 Backfill Placement

Backfill material should be placed in accordance with the final construction plans and specifications. Generally, we recommend that crushed rock fill be placed in 8-inch maximum loose lift thickness and compacted to 92 percent of the maximum dry density based on a modified proctor value (ASTM International D 1557). Over pipelines and other buried structures we recommend the granular fill be compacted to 90 percent of the modified proctor value to a maximum thickness of with five feet above the structure or within 2 feet of the finish grade, whichever is smaller. Compaction of crushed rock fill is generally accomplished by the use of a smooth drum vibratory roller or hand methods adjacent to walls. Select native fill material should be placed in maximum 8-inch loose lift thickness and be compacted to a minimum of 92 percent modified proctor value. Compaction of select native fill is generally accomplished by the use of a kneading roller or smooth drum vibratory roller, depending on the material type being placed.

6.3 Wet Weather Construction

The silts and sands that may be exposed as subgrade material are sensitive to moisture. Because of the duration of the project and assuming that excavation cannot be fully completed during the "dry" season, we recommend that 18-inch crushed rock working pad be placed of the exposed soil subgrade to protect it from degradation due rutting or pumping and to provide a suitable working surface. Below the working pad we recommend placing a non-woven geotextile to act as a separation layer. Before the working pad is buried by backfill materials, damaged or failed locations, as determined by proof rolling, should be excavated and replaced with suitable material. Additional geotextile may be required depending on the situation.

6.4 Temporary Shoring for Pipeline Trenches

Based on the site conditions and the evaluation of various construction methods, the approach of the design team is to assume the pipelines will be constructed using cut and cover methods using typical trench shields or trench boxes. We understand that means and methods for temporary trench support will be the responsibility of the contractor.

6.5 Control of Water (Construction Dewatering)

From the explorations and based on groundwater level measurements, control of groundwater will be needed for all the excavations below an elevation of 18 feet, msl during the wet times of the year. Perched water zones may be encountered at any time. Control of ground water will be needed for the aeration basin, fine screening building, effluent box, and some of the deep yard piping. We anticipate other portions of the excavation will be above the ground water and only perched water or incidental water would need to be controlled.

The type of dewatering system and the amount of ground water flow is largely dependent on the depth of the excavation and time of year for the construction. Our opinion is that a significant portion of construction dewatering, both above and below the water table, may be achieved with the use of a sump system. We understand that disposal of the construction water will be in the proposed retention basin.

7.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

This Section describes Shannon & Wilson's current understanding of the Interim Expansion Project and documents our geotechnical recommendations on a structure by structure basis in sections 7.1 through 7.9. Sections 7.10 and 7.11 discuss our geotechnical recommendations for facility wide project elements.

7.1 Fine Screenings Building

The Fine Screenings building is located at the north east corner of the proposed expansion. The proposed top of slab elevation is approximately EL 26 ft. We understand that the footprint dimension of the Fine Screenings building will be approximately 110 feet by 60 feet. We understand that the building will be adjacent, and likely structurally attached, to the primary gallery along a portion of the western wall of the building. We understand that on the east side of the building there will be a solids discharge structure founded at final grade. The current configuration of the building shows that there will be a number of relatively large diameter pipes beneath the slab of the building. Our subsurface exploration program indicated that the fine-grained soil unit is significantly deeper and softer under the Fine Screenings building than other explored locations on-site. The subsurface conditions and performance criteria suggest that a deep foundation alternative is a practical choice to support this facility.

7.1.1 Foundation System

In our opinion, the Fine Screenings building should be supported on auger-cast piles in conjunction with a structural slab. Our foundation evaluation indicates that a shallow foundation will experience significant static settlement on the order of 2" to 3" of total settlement and ½" to 1" of differential settlement. A pile supported structure will experience only small amount of static primarily elastic settlements and should perform adequately during the design seismic event.

We recommend that the auger-cast piles achieve the required capacity from an embedment into the siltstone unit, the top of which was encountered at an approximate elevation of 5 feet, msl. In our opinion the piles should have a nominal diameter of 18 inches. Required axial pile capacity is a function of pile length which should be determined during the final design phase from the capacity curves provided in Figures 6 and 7. Based on our exploration of the subsurface beneath the Fine Screenings building we anticipate that two different pile lengths should be used for the north one third and the south two-thirds of the Fine Screenings building, Figures 6 and 7, respectively. The figures provide ultimate axial capacities of the piles in both uplift and compression, maximum allowable capacity at 0.5 and 1 inch of pile head settlement and ultimate axial capacity under the post-earthquake, downdrag loading. The figures also indicate the recommended factor of safety that should be applied to the axial capacity under each scenario.

Figures 8 and 9 provide estimated auger-cast pile reaction under lateral loading for the north one third and the south two-thirds of the Fine Screenings building, respectively. The figures include pile head deflection of a partially fixed-head pile as a function of a lateral point load applied at the pile head, bending moment within the pile and pile deflection as a function of pile depth for a number of different applied loads. Design curve figures, both axial and lateral, have been developed for each of the structures for which we have recommended pile support. The figure numbers will be noted in the text where they apply.

Minimum center to center pile spacing needed to avoid group effect capacity reductions is three times the nominal pile diameter. Tolerance of pile spacing is typically 3 inch derivation between actual installation and design drawings. We recommend that the maximum vertical derivation is limited to less than 4 inches in 10 feet. Additionally, we recommend that the auger-cast pile construction specifications and construction procedures follow the most recent addition of the "Augered Cast-in-Place Piles Manual" Published by the Deep Foundations Institute's, Augered Cast-in-place Pile Committee.

7.1.2 Seismic Performance

Our subsurface model indicates that the seismic site class for the Fine Screenings building is a Site Class E. Following a seismic event we anticipate that there will be some maintenance required on the building associated with seismically related ground deformations, but in our opinion the structural capacity of the foundation system will not be compromised. Two key issues that will likely require some maintenance are cracking of concrete slabs and/or wall and the creation of a void space between the building foundation slab and soil subgrade due to liquefaction induced settlement. Our estimates indicate that the void under the foundation may be on the order of 2 to 7 inches.

7.1.3 Construction Considerations

Our recommendation regarding the use of auger-cast piles will likely result in the need for a specialty subcontractor by the general contractor during construction. Currently we are recommending the use of auger-cast piles for other structures on-site and the following discussion regarding their construction applies to the other structures unless otherwise noted.

Auger-cast piles are constructed by drilling to a prescribed bearing stratum with a hollow stem, continuous flight auger. The auger is left in place to support the walls of the borehole and a grout mix is pumped under pressure into the stem while the auger slowly withdrawn from the hole. As the auger is withdrawn, a sufficient head of the grout mix is maintained within the auger stem to prevent any caving or necking of the surrounding soil which would result in a reduction in cross sectional area of the pile. Steel reinforcement is than inserted into the grout mix before it hardens. The details of the steel reinforcement will be developed by the project structural engineer. Auger-cast pile construction requires an experienced foundation contractor in addition to careful QA/QC observation and documentation provided by a knowledgeable geotechnical engineer to assure satisfactory installation and long term performance.

Based on our understanding of the construction sequence we suggest that the yard piping be constructed after to the placement of the pile system.

7.2 Aeration Basin

We understand that the Aeration Basin is a reinforced concrete structure with a top of slab elevation at approximately EL 23 ft msl. We understand that the footprint dimension of the Fine Screenings building will be approximately 150 feet by 50 feet. The basin will have common wall structures on all four sides; primary gallery to the east, blower and electrical buildings to the north, membrane building gallery to the west and a gallery to the south that connects the primary and membrane galleries.

7.2.1 Foundation System

In our opinion, the Aeration Basin may be founded on a slab foundation, provided the foundation is on the gravel unit or crushed rock backfill placed on the native gravel. The top of the gravel layer that was identified during the explorations at approximately El 18 to 20 ft msl. We anticipate that the majority of the foundation excavation will encounter the gravel layer with the exception of the eastern ¼ of the excavation, which based on our explorations, falls in elevation towards the east. Under the eastern ¼ of the Aeration Basin foundation we recommend that the any fine-grained material be removed to the gravel unit and replaced with a crushed rock backfill material. The best estimate we can make for maximum over excavation is depth is approximately 5 feet under the east wall of the basin. We recommend any crushed rock backfill extend a minimum 3 feet beyond the edge of the foundation. Also, we recommend the crushed rock backfill zone extend downward at the edges on a slope of 0.5 horizontal: 1 vertical or flatter.

For a mat foundation resting on an adequately prepared native gravel subgrade we recommend a maximum allowable bearing resistance of 7000 psf be used to support design live and dead loads. A 30% increase in bearing resistance may be used during transient loading such as wind and earthquake. For mat design, we recommend a maximum modulus of subgrade reaction of 225 pci for a mat with 12-inch thick base rock layer or 275 pci for an 18-inch thick base rock layer. Settlement estimates for the basin are less than 1-inch for total static settlement and less than ½ for differential settlement.

7.2.2 Underdrain System

We understand that the Aeration Basin will have an underdrain system to protect from uplift forces during periods of high ground water or flooding. We recommend that the under drain system be composed of 18-inches of clean crushed rock with a 6-inch-diameter perforated pipe located at the mid-height of the drainage layer and placed on an interval of 20 feet laterally. We understand the under drain system will be connected to pressure relief valves (flap valves) in the walls of the structure. The working pad may be used for the underdrain system if it meets the gradation required in the construction documents and is not contaminated by construction activities. Partial replacement of the working pad material may be adequate depending of the degree of contamination.

7.2.3 Seismic Performance

We do not anticipate any seismic issues related to liquefaction or bearing soil strength loss for this structure. The seismic site class for the Aeration Basin is Site Class C.

7.2.4 Construction Considerations

We anticipate that the excavation for the Aeration Basin will be on the order of 25 to 30 feet deep. We understand that currently the preferred method of excavation is open cut with sloped sides. The sides slopes of the excavation should be less than or equal to 1.5 horizontal to 1 vertical. Groundwater control may be necessary during wet seasons of the year and for portions of the excavation below elevation 18 ft msl. We also anticipate that there will be some incidental groundwater flow into the excavation due to surface runoff, and limited perched water within the bedded sands. In our opinion the ground water may be controlled by a contractor designed and operated drainage collection and sump system.

We recommend that the entirety of the mat be underlain by a least 12" of angular crushed rock that will function as a working pad, drainage collection layer and a leveling course. The working mat gravel may be part of or in addition to material used for a permanent underdrain system. The material should be free draining and placed in lifts and compacted (92% of ASTM D1557).

7.3 Blower / Electrical Building

We understand that the Blower / Electrical (B/E) building will be common wall with the Aeration basin on the south. The proposed top of slab elevation is approximately EL 50 ft msl. The footprint dimensions of the structure is about 135 ft by 50 ft.

7.3.1 Foundation System

We recommend that the interior slab of the B/E building be founded on a mat and the walls be detached from the interior slab and be supported on auger-cast piles due to connection with adjacent structures. We further recommend that the foundations for the blowers also be detached from the interior slab. Based on our understanding of the excavation plan the footprint of the B/E building will span between fully excavated and backfilled material (approximately 30 feet), on the south side of the building adjacent to the aeration basin, to existing soil with approximately five feet of fill, along the north side of the building. Due to the significant variation in subsurface conditions, and the fact that the south, east and west wall will be rigidly attached to adjacent structures we recommend that the interior slabs be independent of the walls.

The auger-cast pile design capacity curves are presented in Figures 10 and 11 for axial and lateral pile capacities, respectively. Refer to recommendations described for Fine Screenings building (Sections 7.1.2) with regard to pile spacing and pile design guidelines.

A mat constructed without overexcavation would experience total static settlements on the order of 3 inches. A mat foundation placed on a fully excavated and replaced subgrade would experience static settlements of less than 1 inch and differential settlements of less than ½ inch. For a mat foundation resting on crushed rock backfill we recommend a maximum allowable bearing resistance of 3000 psf be used to support design live and dead loads. A 30% increase in bearing resistance may be used during transient loading such as wind and earthquake. For crushed rock backfill we recommend a maximum modulus of subgrade reaction of 275 pci.

7.3.2 Seismic Performance

We do not anticipate any seismic issues related to liquefaction or bearing soil strength loss for this structure. The seismic site class for this structure is Site Class C.

7.3.3 Construction Considerations

We anticipate that the excavation for this structure will be part of the excavation for the Aeration Basin and therefore excavations recommendations are the same. In addition, the backfill for the overexcavation should be replaced in lifts and compacted to a specified density. We recommend that the backfill placement be monitored and documented to assure satisfactory installation. We anticipate construction of auger-cast piles similar to the Fine Screenings building (see Section 7.1.3).

7.4 Membrane Building

The Membrane Building(MBR) will be the largest of the Interim Expansion structures with a footprint footprint of approximately 95 ft x 115 ft. The estimated top of slab elevation for the MBR is El 35 ft msl. MBR will be common wall with the membrane building gallery along the full length of the east wall. We understand that in the future there will likely be buildings immediately to the south and west. We understand that the MBR is very sensitive to excessive differential settlement.

7.4.1 Foundation System

Based on the MBR's sensitivity to differential settlement, the risk associated with seismic hazards, we recommend that the MBR be founded on an auger-cast pile system. Our foundation evaluation indicates that a mat foundation will experience static settlement on the order of 1.5 to 2 inches of total settlement and 0.5 to 1 inch of differential settlement. A pile supported structure will experience only small amount of static elastic settlements and should perform well during the design seismic event.

We recommend supporting the MBR on auger-cast piles. The auger-cast pile design capacity curves are presented in Figures 12 and 13 for axial and lateral pile capacities, respectively. Use recommendations described for Fine Screenings building (Sections 7.1.1) with regard to pile spacing and pile design guidelines.

7.4.2 Seismic Performance

The soil beneath the membrane building is classified as a Site Class D. We anticipate seismic performance similar to the Fine Screenings building (see Section 7.1.2).

7.4.3 Construction Considerations

We anticipate construction of auger-cast piles similar to the Fine Screenings building (see Section 7.1.3). We currently understand that there will not be any yard piping under the MBR.

7.5 Standby Power Generation Building

Shannon & Wilson has not developed significant engineering recommendations for the Standby Power (STP) building at this time. We do understand that the structure will likely be at the proposed finish grade of the site. The structure will be located just to the south of the existing secondary clarifiers. The footprint dimensions of the structure is about 85 ft x 50 ft.

7.5.1 Foundation System

Currently it is anticipated that auger-cast piles will be required to support the STP building. The auger-cast pile design capacity curves are presented in Figures 10 and 11 for axial and lateral pile capacities, respectively. Use recommendations described for Fine Screenings building (Sections 7.1.1) with regard to pile spacing and pile design guidelines.

7.5.2 Seismic Performance

We anticipate foundation performance similar to the Fine Screenings building (See section 7.1.2). We estimate that lateral ground spreading toward the river at the STP location will be less than 12-inches following the CSZ megathrust earthquake. In our opinion, a pile supported structure will experience less movement than the ground around the building. Seismic Site class is E.

7.5.3 Construction Considerations

We anticipate construction of auger-cast piles similar to the Fine Screenings building (see Section 7.1.3).

7.6 Ultra Violet Disinfection / Chemical Handling and Storage Buildings

The Ultra Violet Disinfection (UV) and Chemical Handling (CH) and Storage Buildings will be located at the southeast corner of the interim expansion site. We understand that the buildings are structurally connected. The UV building is approximately 40 ft x 60 ft while the Chemical Handling and Storage is 25 x 35 ft. Top of slab is for the UV building is El 27 ft msl. The UV Building will be serviced by a utilidor extending form the end of the primary gallery, and will in the future, be attached to the primary gallery during a later expansion phase. Top of slab for the Chemical Handling building will match the proposed finish grade (~El 50 ft).

7.6.1 Foundation System

The UV/CH building will be founded on auger-cast piles to minimize differential settlement between the two different slab elevations. We understand that the UV portion of the structure will be sensitive to differential settlements and auger cast piles will reduce both static and seismic differential settlements. The auger-cast pile design capacity curves are presented in Figures 14 and 15 for axial capacities of UV and CH portions, respectively and in Figures 16 and 17 for lateral pile reaction for UV and CH portions, respectively. Use recommendations described for Fine Screenings building (Sections 7.1.1) with regard to pile spacing and pile design guidelines.

7.6.2 Seismic Performance

The soil beneath the UV/CH building is classified as a Site Class D. We anticipate seismic performance similar to the Fine Screenings building (see Section 7.1.2).

7.6.3 Construction Considerations

We anticipate auger-cast pile construction for the UV portion of the building similar to the Fine Screenings building (see Section 7.1.3). We anticipate that the entire footprint of the UV/CH building will be excavated to subgrade elevation of the UV (deeper) portion of the building. All of the auger-cast piles for the structure will be installed at that elevation. At an appropriate time during construction, the piles for the CH portion of the building will be extended upwards by using cast-in-place columns. We recommend that the backfill around the columns be placed and compacted as required for backfill beneath other structures. Smaller compaction equipment may be required in order to maneuver between the columns.

7.7 Lateral Earth Pressures

Three lateral earth pressure cases were investigated, drained static, drained seismic and static flood condition. We developed the lateral earth pressures in terms of equivalent fluid pressures for both yielding (flexible) and non-yielding (restrained) walls. The three lateral earth pressure cases are presented in Figures 18, 19 and 20.

7.8 Existing Aeration Basin

The proposed Interim Expansion design calls for an additional 5 feet of site fill to be placed adjacent to the south wall of the existing Aeration Basin. We understand that based on an analysis performed by the structural engineer that the lateral loads cannot be increased on the existing structure. Therefore, we recommend the following course of action to reduce lateral earth pressures on the existing wall.

7.8.1 Light Weight Backfill

Shannon & Wilson recommends that the soil along the south wall of the basin be removed to the top of the existing subdrain system (~ El 27 ft) and replaced with a combination of expanded polystyrene geofoam and crushed rock backfill. The backfill profile should be approximately 10 ft of geofoam covered by 13 ft of granular material/pavement section. Design guidelines indicate that geofoam does not apply lateral earth pressure to a wall. We recommend using EPS geofoam type IX (1.80 pcf unit weight). A drainage layer, most likely a geosynthetic wall drain, should be placed between the geofoam block and the basin wall. In order to avoid using tiedowns to mitigate buoyant forces acting on the foam, the ratio of geofoam to soil overburden is 1 to 1.

A lateral earth pressure diagram showing the configuration of forces acting on the existing aeration basin wall is shown in Figure 21.

7.8.2 Construction Considerations

We understand that geofoam is typically manufactured and delivered in block form (approximately 2'x2'x6') and then placed by hand into the excavation. The excavation may need to be performed in segments to avoid removing lateral support from the basin wall. Excavation side slopes should be no steeper than 1.5 horizontal to 1 vertical. Before placing geofoam blocks, a 6 inch thick bed of clean sand used as a level course needs to be placed. The foam is typically placed in a pattern where each layer is placed at 90 degree angles to the layers above and below.

When filling above the blocks, the first 12-inches of granular material should be pushed out in front of a small bulldozer so that equipment does not operate directly on the geofoam. The energy of compaction equipment should be limited to a maximum applied stress less than that of the elastic limit stress of the foam material. The compaction method may need to be determined experimentally in the field by compacting a test strip. Additionally, a nuclear densometer may not provide accurate compaction measurements due to the chemical makeup of the foam. We recommend that the density measurements be checked with a traditional soil compaction method such as a sand cone test.

7.9 Galleries

We understand that there will be three main underground galleries constructed during the interim expansion. Two galleries, Primary and Membrane Building, will be oriented in the north-south direction and will connect to existing plant galleries. A third gallery will connect the Primary and Membrane galleries by traversing in an east-west orientation adjacent to the south wall of the aeration basin.

7.9.1 Primary Gallery

We understand that the Primary Gallery will be connected to the existing gallery on the north end and be common wall with the Aeration Basin and Fine Screenings building. In the future the Primary Gallery will extend out to service the UV building, the current proposal is to terminate it where it intersects the transverse Membrane building access gallery. We understand that the proposed top of slab is El 27 ft msl. Because the gallery will be attached to the adjacent buildings, which will experience a small amount of static and seismically related settlement, we recommend that the gallery be founded on auger-cast piles between the from the south termination point and the location associated with the north end of the Fine Screenings building.

7.9.2 Membrane Building Gallery

We understand that the Membrane Building Gallery will be connected to an existing gallery on the north end and be common wall with the Aeration Basin and Membrane building. In the future the Primary Gallery will extend out to service future Aeration basins and MBR basins, the current proposal is to terminate it where it intersects the transverse Membrane building access gallery. We understand that the proposed top of slab is El 27 ft msl. Because the gallery will be attached to the adjacent buildings, which will experience a small amount of static and seismically related settlement, we recommend that the gallery be founded on auger-cast piles between the from the south termination point and the location associated with the north end of the MBR basin.

7.9.3 Aeration Basin Gallery

We understand that the transverse gallery will connect the Primary gallery to the north and the Membrane building on the south. The transverse gallery will be common wall to the aeration basin to the north. In our opinion, the gallery should be supported by over excavating to the native gravel unit and replacement with engineered crushed rock backfill as described in previous sections.

7.10 Pervious Pavement

New pavement and a portion of the existing pavement will be designed and constructed as pervious pavements. The goal of the pavement is to capture precipitation, store it in a reservoir layer and infiltrate the water into the subgrade. Based on the soil classifications, we developed conceptual permeability constants for sections of pavement subgrade soils. We understand that the final pavement design will be completed by others.

7.10.1 Subgrade Permeability

See Appendix C for the figure describing the estimated subgrade permeability zones.

7.10.2 Construction Considerations

To maintain the highest in-situ soil permeability, compaction of pavement subgrade should be kept to the lowest practical effort.

7.11 Yard Piping

It appears that a large portion of the yard piping will be independent of the structural foundations. Based on the current invert and location of yard piping we do not foresee any special foundation considerations being required. We understand that all of the piping beneath structures will be fully encased in concrete. We recommend that the full encasement be extended past the footprint of buildings a distance of two times the distance between the bottom of the slab and invert of the pipe.

8.0 LIMITATIONS

The observations, analyses, conclusions, and recommendations contained in this report are based upon site conditions as they presently exist and further assume that the borings are representative of subsurface conditions throughout the site, i.e., the subsurface conditions everywhere are not significantly different from those disclosed by the field explorations.

If, during construction or future explorations, subsurface conditions different from those encountered in the field explorations are observed, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time since the submission of this report or if conditions have changed due to natural causes or construction operations at or adjacent to the site, it is recommended that this report be reviewed to determine the applicability of these conclusions and recommendations, considering the changed conditions and the elapsed time.

This report is prepared for the exclusive use of the Water Environment Services and MWH. It should be made available to prospective contractors for information on factual data only, and not as a warranty of subsurface conditions described in this report. Shannon & Wilson has prepared the attached, "Important Information About Your Geotechnical Engineering Report," to assist you and others in understanding the use and limitations of our reports. This attachment is presented in Appendix E of this report.

Please note that the scope of our services did not include any environmental assessment or evaluation regarding the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below or around the WPCP site.

Sincerely,

SHANNON & WILSON, INC.

Derrick Hayes
Engineering Staff

Jerry L. Jacksha, PE
Senior Associate

DRH/JLJ/drh

9.0 REFRENCES

2006 International Building Code, January 2006, International Code Council, Inc, Section 1615

2007 Oregon Structural Specialty Code, January 2007, International Code Council, Inc, Section 1613, pp 407-414.

"Geotechnical Design Recommendations, Tri-City WPCP Liquids Expansion" by CH2M Hill, Inc, 2002, prepared for the Tri-City Service District.

"Geotechnical Data Report, Tri-City WPCP Liquids Expansion" by CH2M Hill, Inc, 2002, prepared for the Tri-City Service District.

"Soils Report, Tri-City Sewerage Treatment Plant" by CH2M Hill, Inc, 1982, prepared for the Tri-City Service District.

"Seismic Vulnerability Assessment, Tri-City Wastewater Treatment Plant" by URS Corporation, 2002, prepared for Water Environment Services.

"Phase I and Phase II Environmental Site Assessment, Tax Lot 502" by URS Corporation, 2001, prepared for Tri-City Service District.

"Remedial Action Work Plan, Unpermitted Rossman Landfill" by URS Corporation, 2000, prepared for Tri-City Service District.

Frankel, A., Petersen, M., Mueller, C., Haller, K., Wheeler, R., Leyendecker, E., Wesson, R., Harmsen, S., Cramer, C., Perkins, D., and Rukstales, K., 2002, Documentation for the 2002 update of the national seismic hazard maps: U.S. Geological Survey Open-File Report 02-420, 39 p

Kramer, Steven L. (1995), "Geotechnical Earthquake Engineering," pp 487-496.

Oregon Department of Forestry, Oregon Latitude Longitude Locator, accessed 12, October 2007, from ODF GIS website: http://salemgis.odf.state.or.us/scripts/esrimap.dll?name=locate&cmd=start

http://earthquakes.usgs.gov/regional/qfaults, accessed 12/04/2007 02:22 PM.

Seed, H.B., and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential in Journal of the Soil Mechanics and Foundations Division, New York, American Society of Civil Engineers, vol. 97, no. SM9, p. 1249-1273.

Seed, H.B., Idriss, I., and Arango, I., 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, New York, American Society of Civil Engineers, vol. 109, no. 3, p. 458-482.

Seed, R.B. and Harder, L.F., Jr. (1990), "SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength," H.B. Seed Memorial Symposium, J.M. Duncan, Editor, Tech Publishers Ltd., Vancouver, Canada, Vol. 2, pp. 351-376.

Tokimatsu, K. and Seed, H.B., (1987), "Evaluation of Settlements in Sands Due to Earthquake Shaking", JGED, ASCE, Vol. 113, No. 8, pp. 861-878.

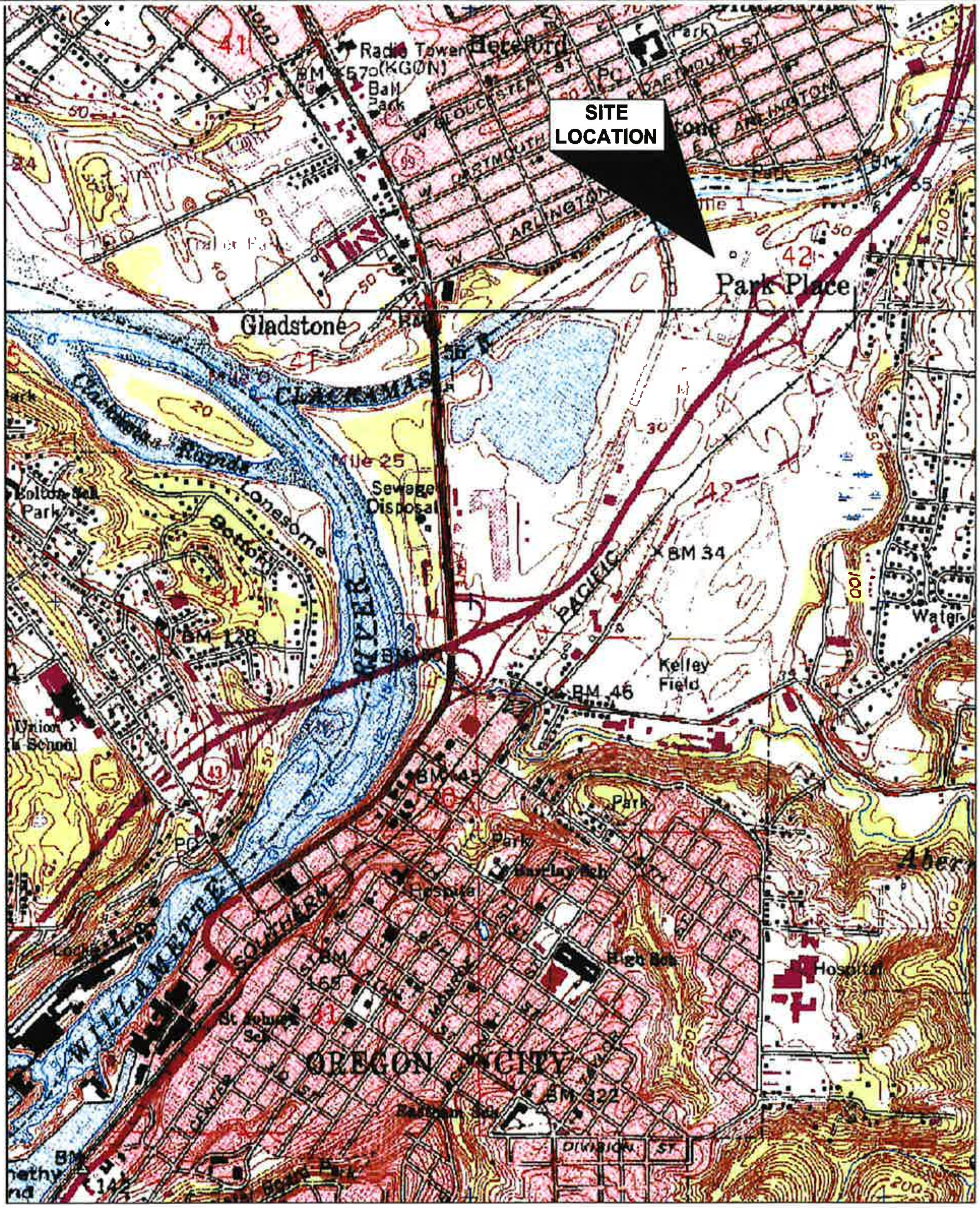
United States Geological Survey, 2002, Interactive deaggregation, accessed 22, October 2007, from USGS Custom Mapping and Analysis Tools Website: http://earthquake.usgs.gov/research/hazmaps/interactive/index.php

United States Geological Survey, 2006, Quaternary fault and fold database for the United States, Accessed 25 October 2007, from USGS web site: http//earthquakes.usgs.gov/regional/qfaults/.

United States Geological Survey Earthquake Ground Motion Tool, version 5.0.7, June 18, 2007.

Youd, L.T., I. M. Idriss, Ronald D. Andrus, Ignacio Arango, Gonzalo Castro, John T. Christian, Richardo Dobry, W. D. Liam Finn, Leslie F. Harder Jr., Mary Ellen Hynes, Kenji Ishihara, Joseph P. Koester, Sam S. C. Liao, William F. Marcuson III, Geoffrey R. Martin, James K. Mitchell, Yoshiharu Moriwaki, Maurice S. Power, Peter K. Robertson, Raymond B. Seed, and Kenneth H. Stokoe II, 2001, Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on Evaluation of Liquefaction Resistance of Soils *in* Journal of Geotechnical and Environmental Engineering, New York, American Society of Civil Engineers, vol. 127, no. 10, p. 817-833, October..

Youd, L.T., Hansen, C. M., and Bartlett, S.F., 2002, Revised MLR equations for prediction of lateral spread displacement, Journal of Geotechnical and Geoenvironmental Engineering, American Society of Civil Engineers, vol. 128, no. 12, December, p. 1007-1017.



0 1500 3000

Scale in Feet

N

NOTE: Map from Delorme 3-D TopoQuads software.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

VICINITY MAP

February 2008 24-1-03420-001

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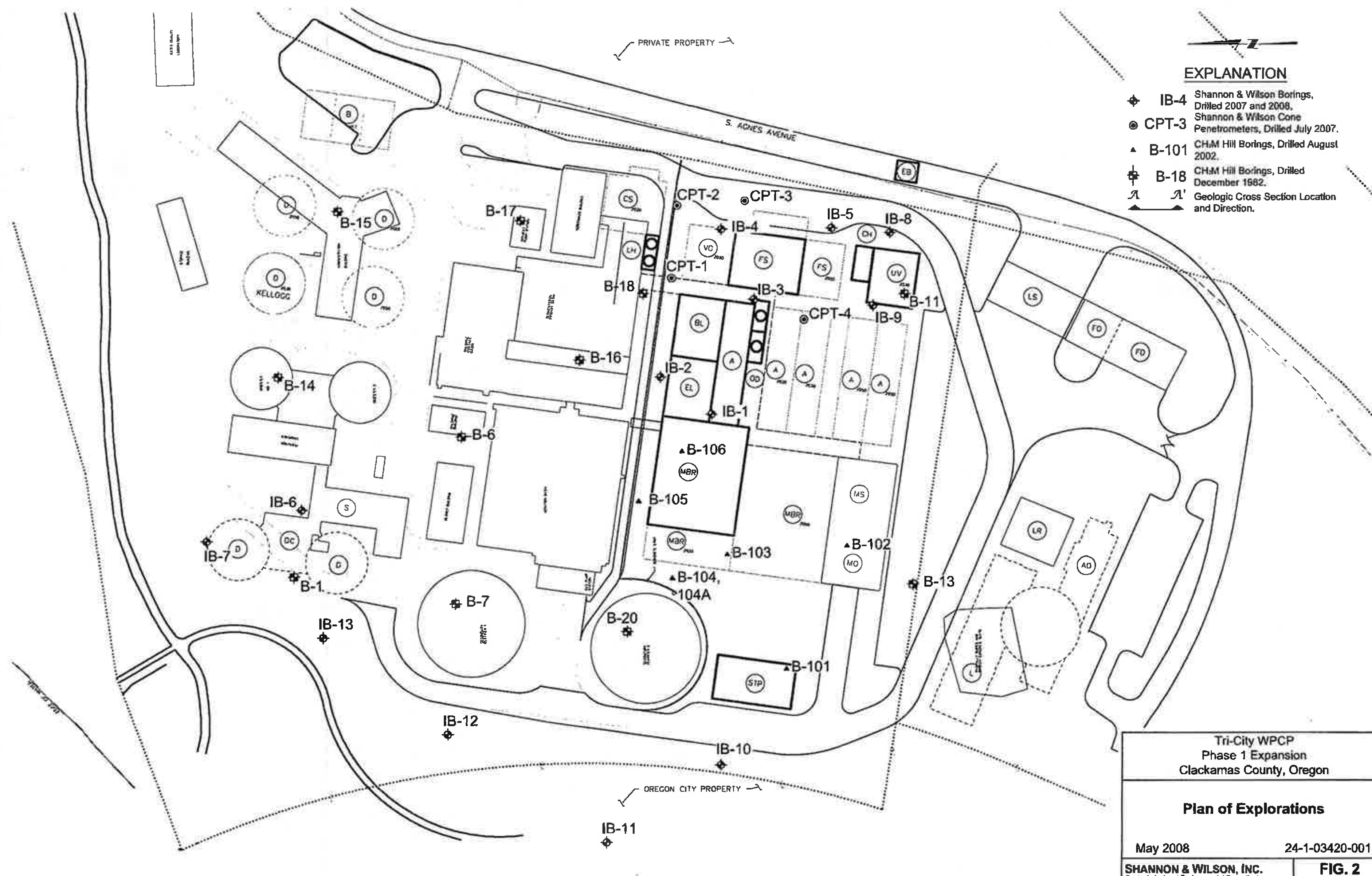
FIG. 1



Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

Plan of Explorations

May 2008 24-1-03420-001

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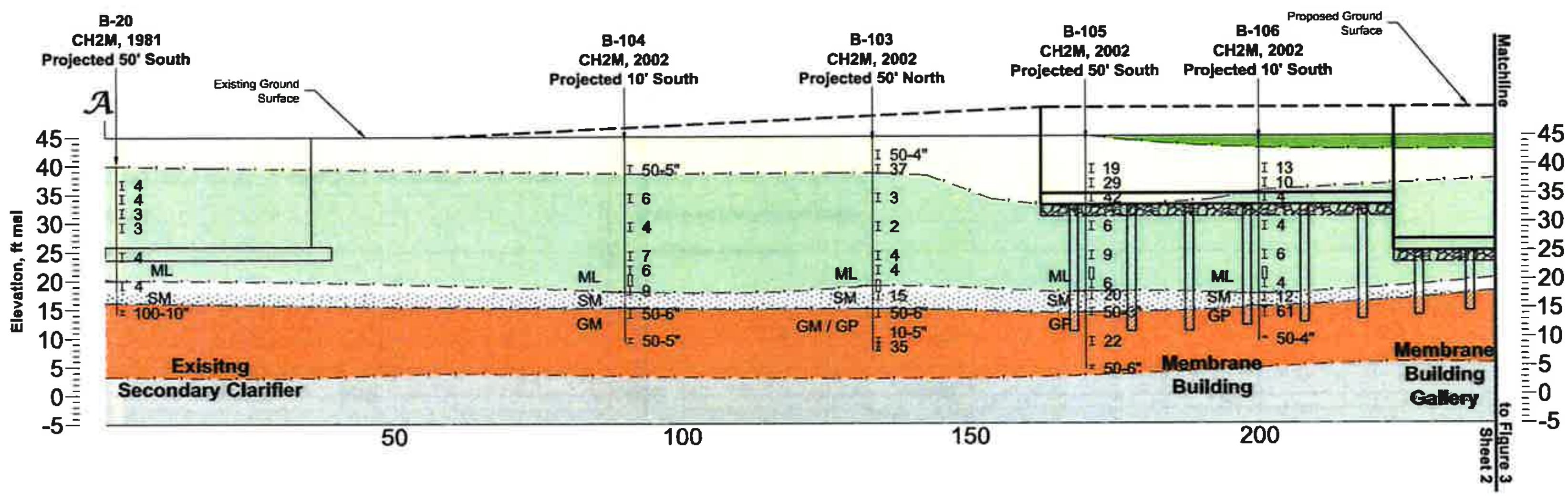
FIG. 2



EXPLANATION

- FILL- Organic SILT
- FILL - Gravelly SILT
- Very loose or very soft to sitff SILT to sandy SILT; low plasticity to non-plastic
- Very loose to medium dense Silty SAND
- Medium dense to very dense Sandy GRAVEL
- Low strength SILTSTONE
- Potetnially liquefiable soils
- Foundation Base Rock
- Auger Cast Pile Representation
- SM USCS Soil Classification Symbol
- Interpreted soil boundary
- I 1 Split spoon sampler (SPT) and field blow counts (Nvalue)
- Thin walled sampler
- 35 Dames and Moore spoon sampler and field blow counts (Nvalues)

Scale: 1" = 20 ft

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

GEOLOGIC PROFILE A-A'

February 2008 24-1-03420-001

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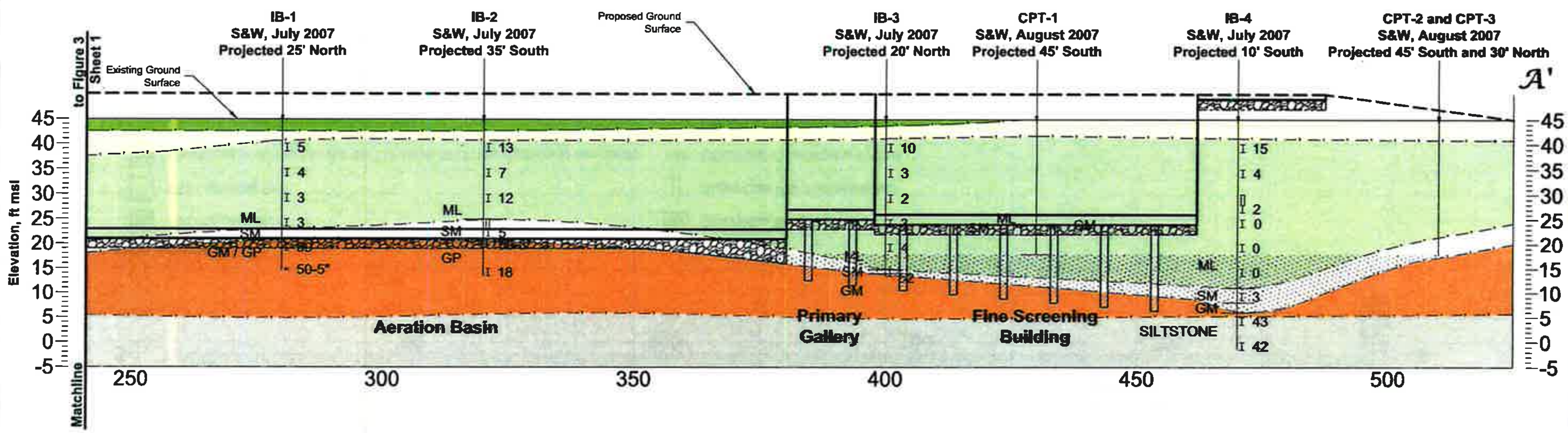
FIG. 3
Sheet 1 of 2



EXPLANATION

- FILL- Organic SILT
- FILL - Gravelly SILT
- Very loose or very soft to sitff SILT to sandy SILT; low plasticity to non-plastic
- Very loose to medium dense Silty SAND
- Medium dense to very dense Sandy GRAVEL
- Low strength SILTSTONE
- Potetnially liquefiable soils
- Foundation Base Rock
- Auger Cast Pile Representation
- SM USCS Soil Classification Symbol
- Interpreted soil boundary
- I 1 Split spoon sampler (SPT) and field blow counts (Nvalue)
- Thin walled sampler
- I 35 Dames and Moore spoon sampler and field blow counts (Nvalues)

Scale: 1" = 20 ft

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

GEOLOGIC PROFILE A-A'

February 2008 24-1-03420-001

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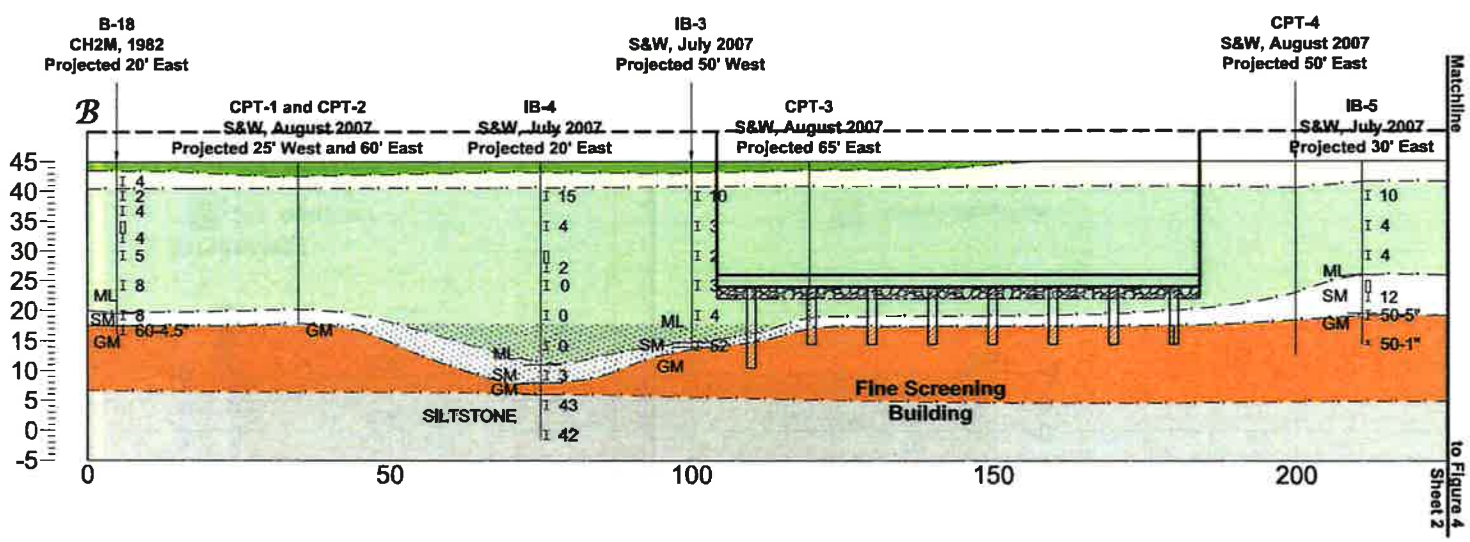
FIG. 3
Sheet 2 of 2



EXPLANATION

- FILL- Organic SILT
- FILL - Gravelly SILT
- Very loose or very soft to stiff SILT to sandy SILT; low plasticity to non-plastic
- Very loose to medium dense Silty SAND
- Medium dense to very dense Sandy GRAVEL
- Low strength SILTSTONE
- Potetnially liquefiable soils
- Foundation Base Rock
- Auger Cast Pile Representation
- SM USCS Soil Classification Symbol
- Interpreted soil boundary
- I 1 Split spoon sampler (SPT) and field blow counts (Nvalue)
- Thin walled sampler
- I 35 Dames and Moore spoon sampler and field blow counts (Nvalues)

Scale: 1" = 20 ft

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

GEOLOGIC PROFILE B-B'

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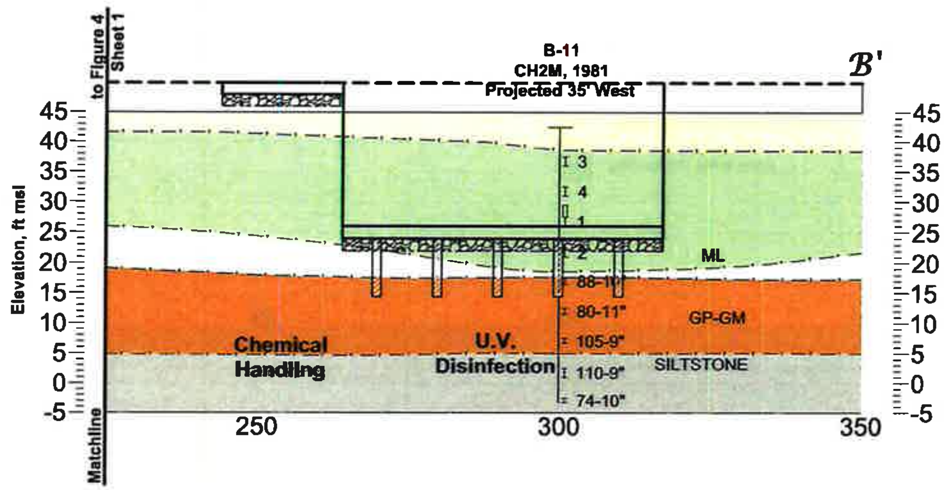
FIG. 4
Sheet 1 of 2



EXPLANATION

FILL- Organic SILT	Foundation Base Rock
FILL - Gravelly SILT	Auger Cast Pile Representation
Very loose or very soft to sitff SILT to sandy SILT; low plasticity to non-plastic	SM USCS Soil Classification Symbol
Very loose to medium dense Silty SAND	Interpreted soil boundary
Medium dense to very dense Sandy GRAVEL	1 Split spoon sampler (SPT) and field blow counts (Nvalue)
Low strength SILTSTONE	Thin walled sampler
Poteinially liquefiable soils	35 Dames and Moore spoon sampler and field blow counts (Nvalues)

Scale: 1" = 20 ft

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

GEOLOGIC PROFILE B-B'

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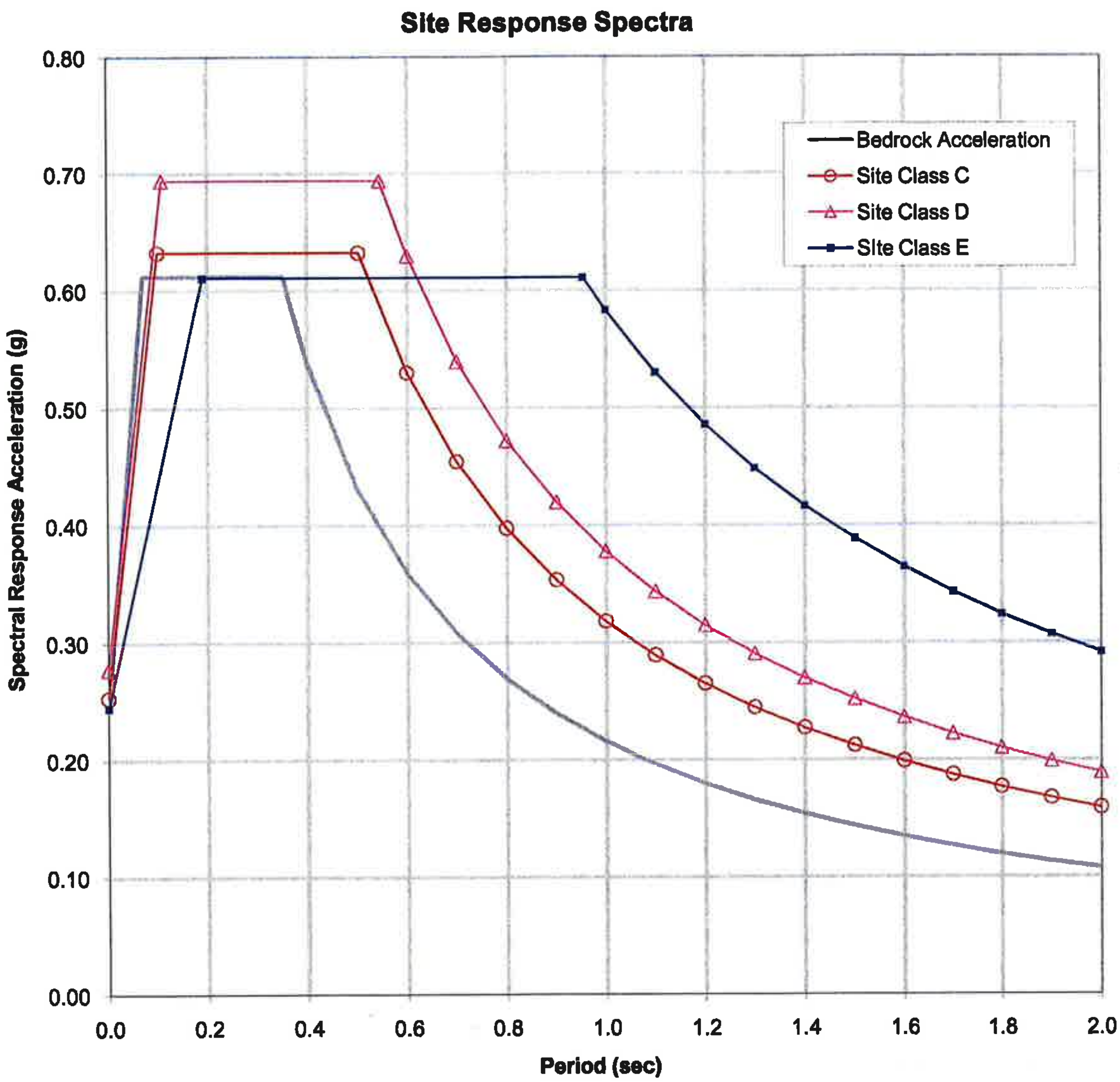
FIG. 4
Sheet 2 of 2



Seismic Design Parameters

Site Classification	B	C	D	E
Return Period, yr	IBC Design Values			
PGA, g	0.245	0.253	0.277	0.244
F_a	1.00	1.03	1.13	0.998
F_v	1.00	1.48	1.75	2.71
S_{DS}	0.61	0.63	0.69	0.61
S_{D1}	0.22	0.32	0.38	0.58

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

CODE BASED RESPONSE SPECTRA

February 2008 24-1-03420-002

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FIG. 5

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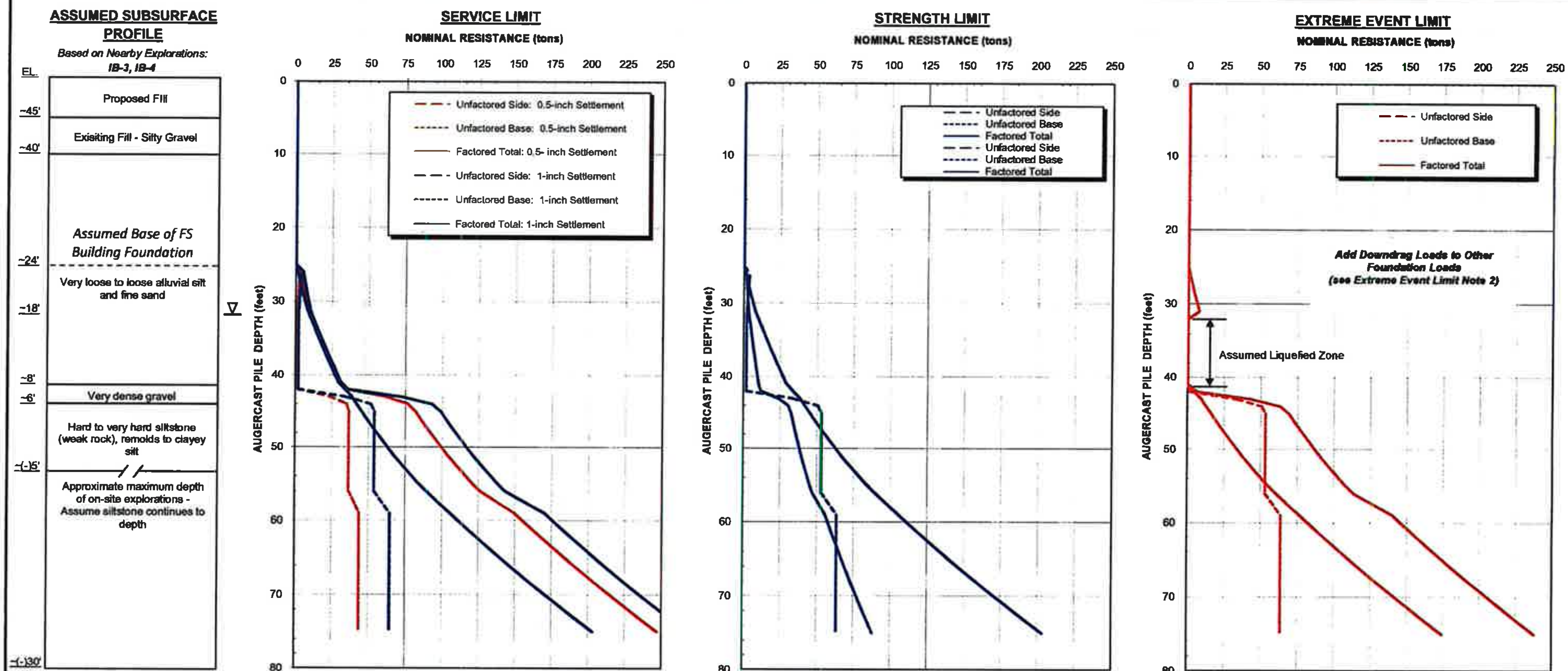
mfc/hjs



SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistance for both service levels are equal.

STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.

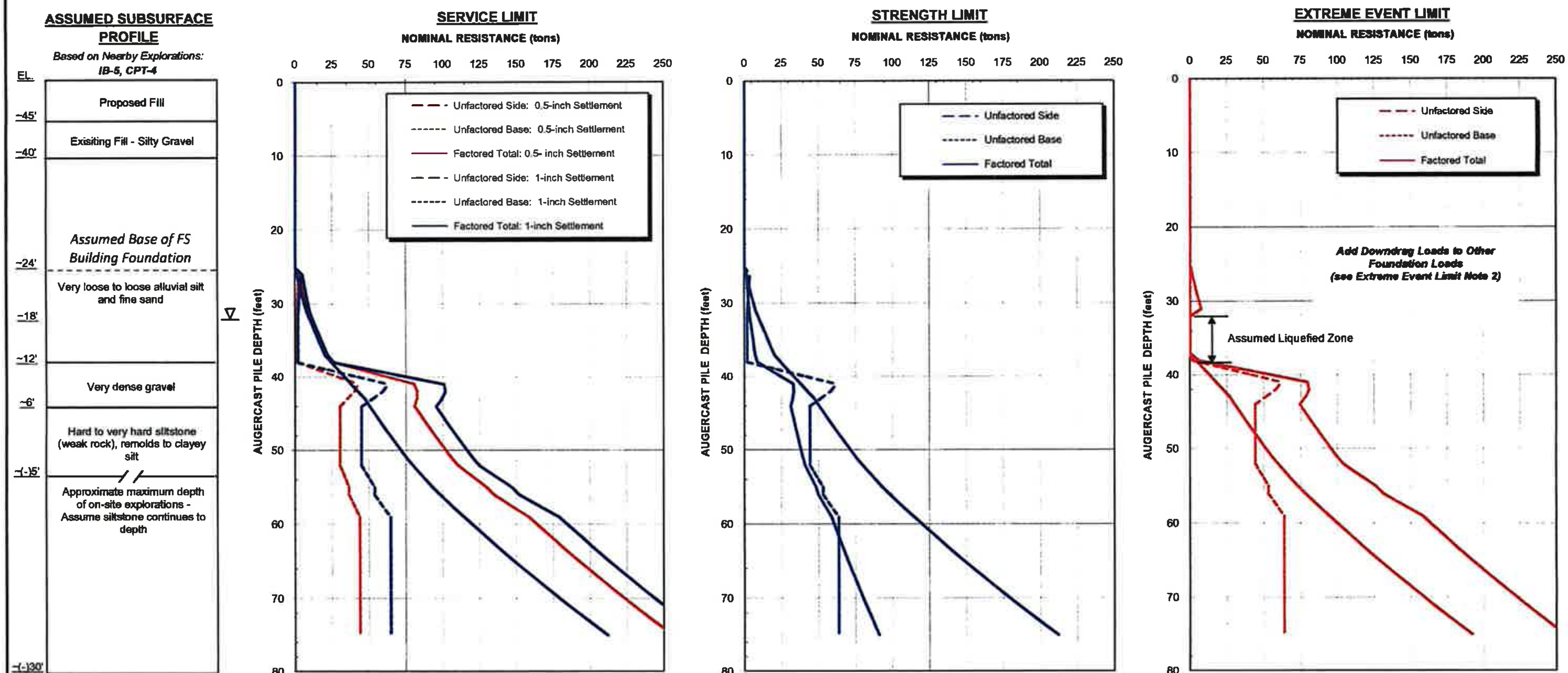
EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 10 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP Interim Expansion Clackamas County, Oregon	
ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE NORTH 1/3 FINE SCREENING BUILDING	
July 2008	24-1-3420-002
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 6**



SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistence for both service levels are equal.

STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.

EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 8 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE SOUTH 2/3 FINE SCREENING BUILDING

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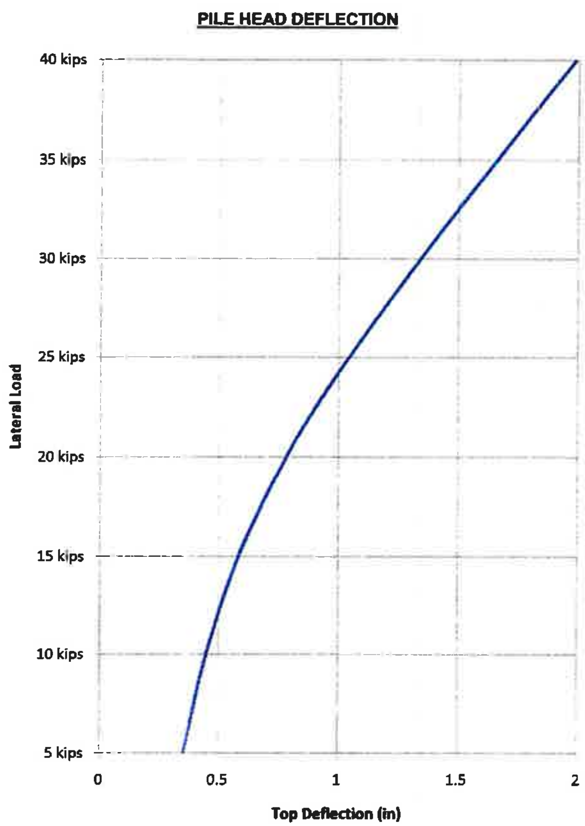
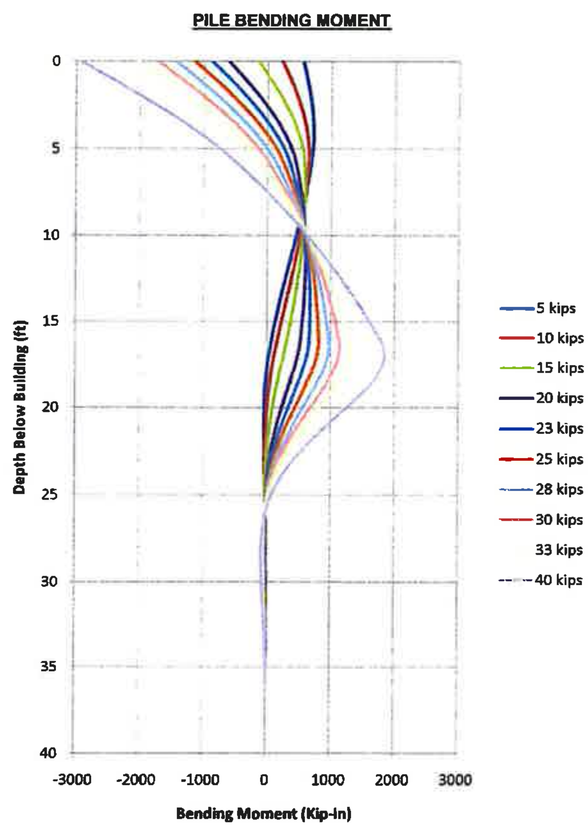
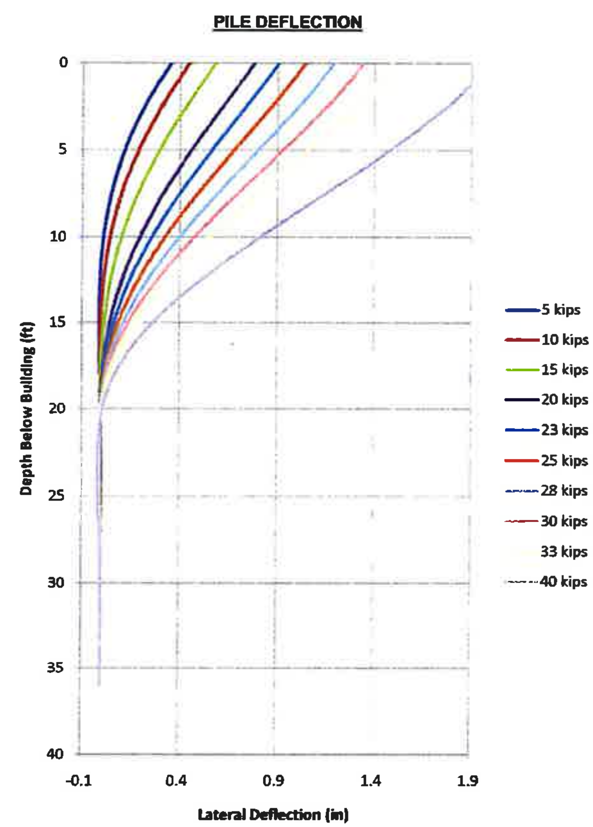
FIG. 7







Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA AUGER-CAST PILE REACTION TO LATERAL LOADING -FS BUILDING NORTH 1/3

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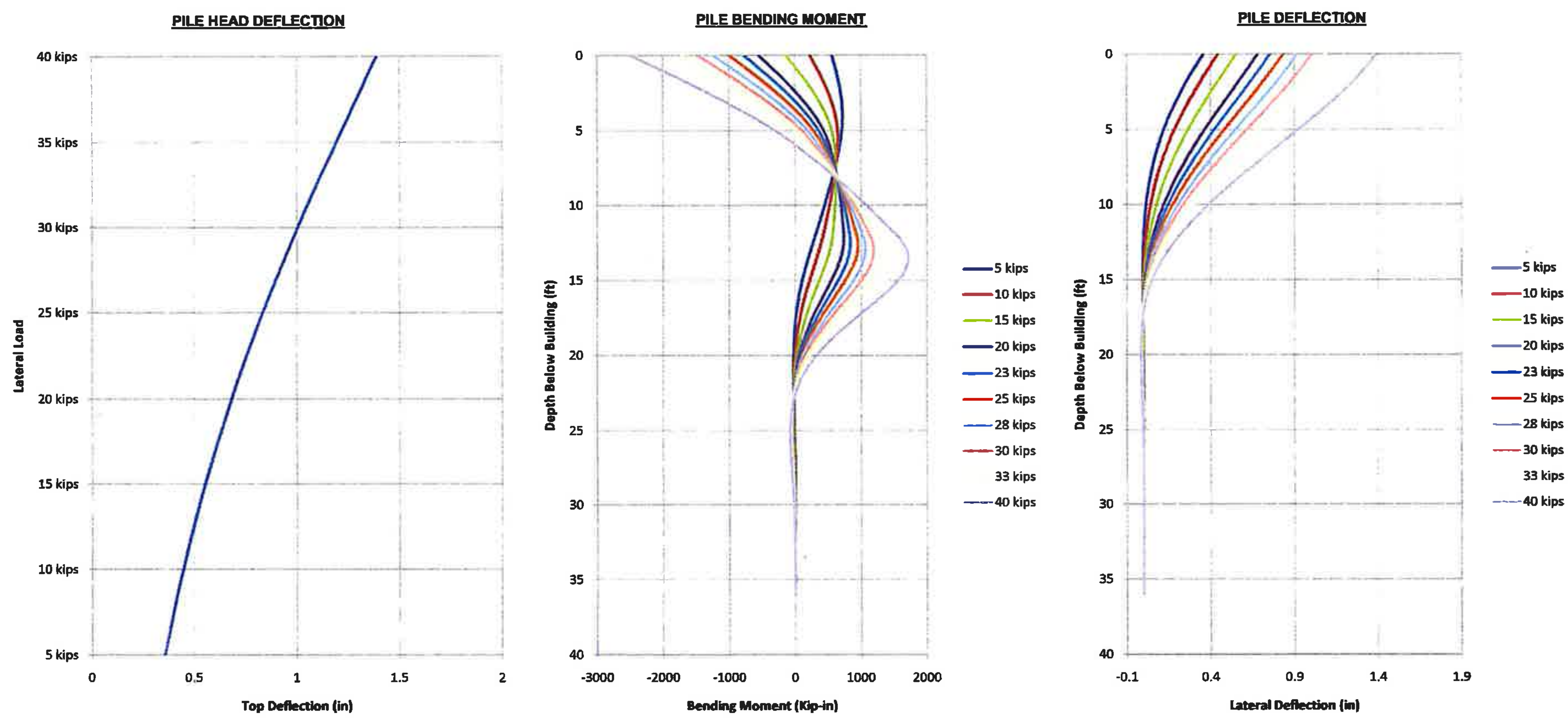
FIG. 8



Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA-AUGER-CAST-PILE REACTION TO LATERAL LOADING -FS BUILDING SOUTH 2/3

July 2008 | 24-1-3420-002

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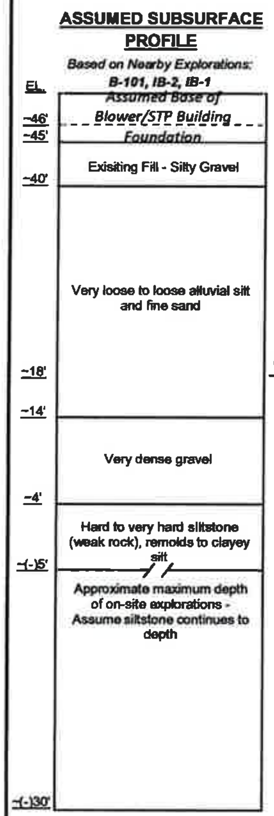
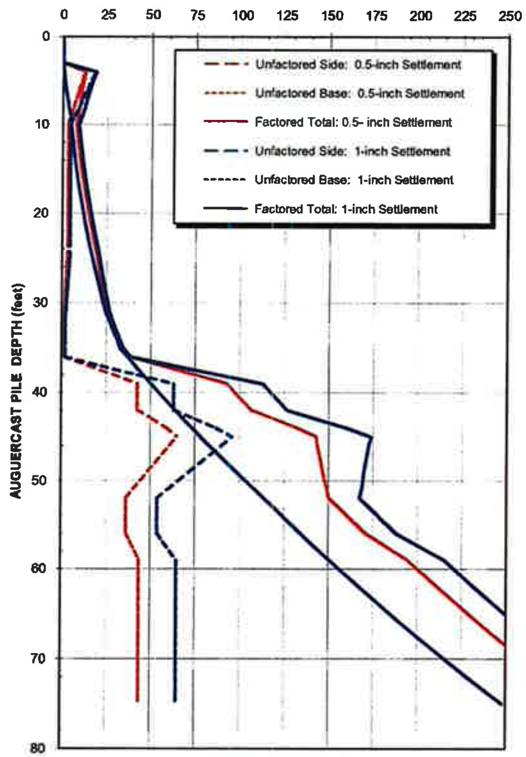
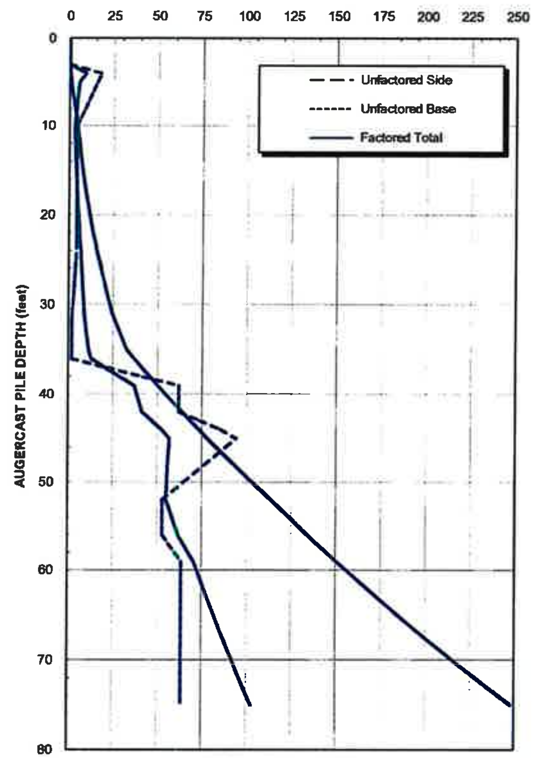
FIG. 9





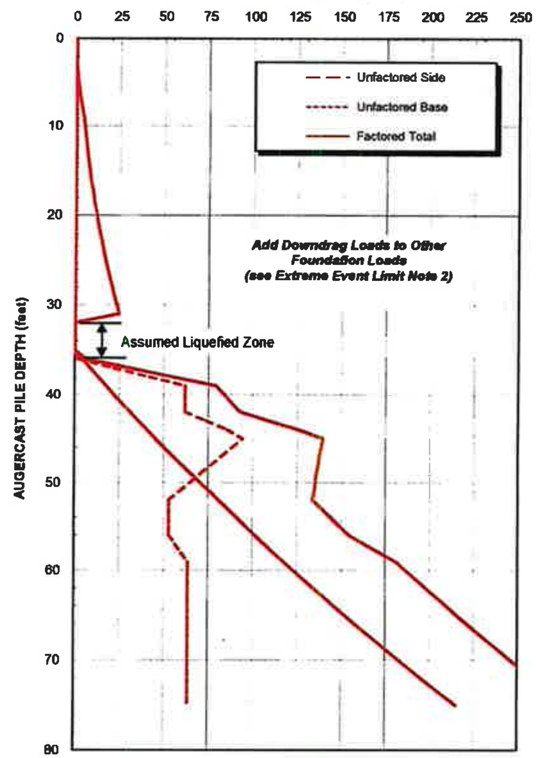
SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistance for both service levels are equal.



STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.



EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 35 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE BLOWER/STP BUILDING

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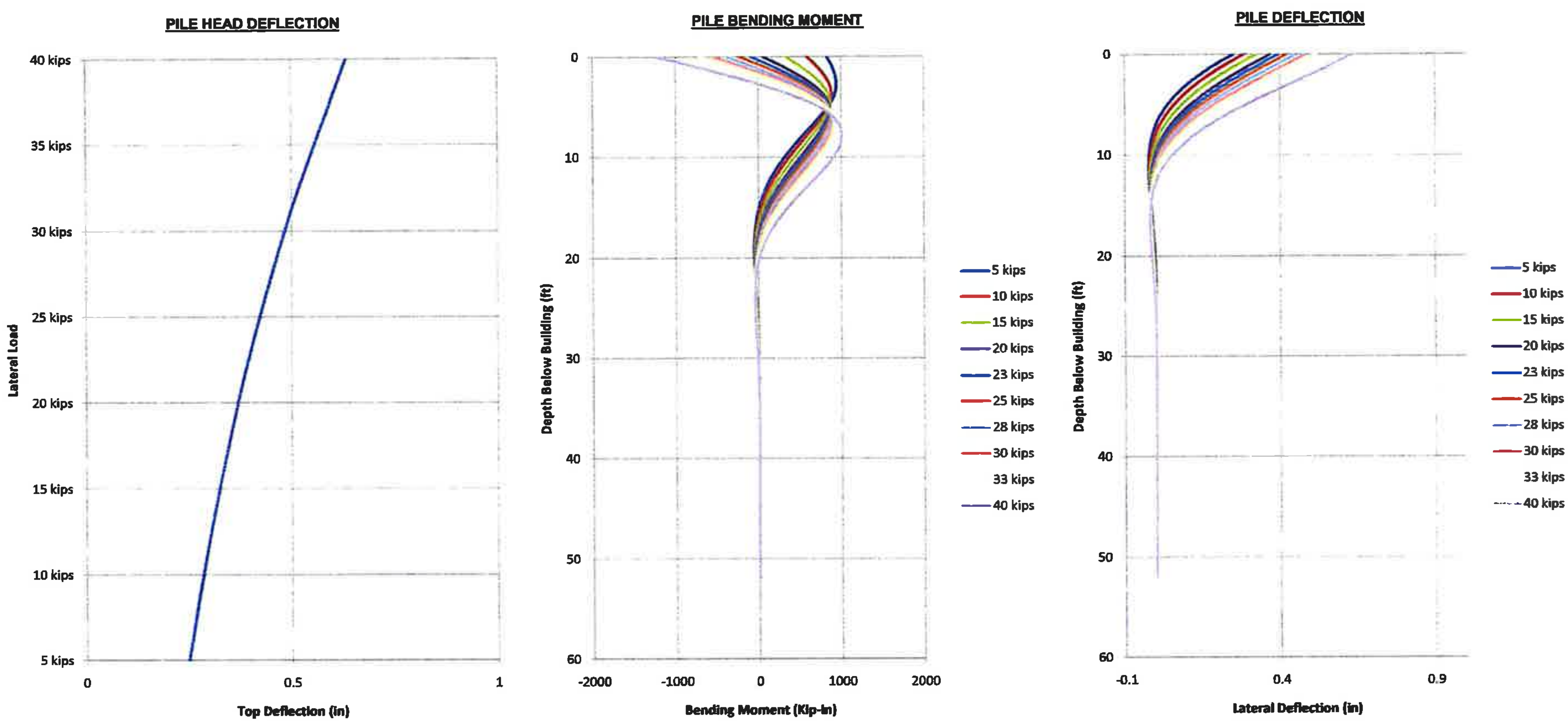
FIG. 10



Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA. PILE REACTION TO LATERAL LOADING -STANDBY POWER / BLOWER BUILDINGS

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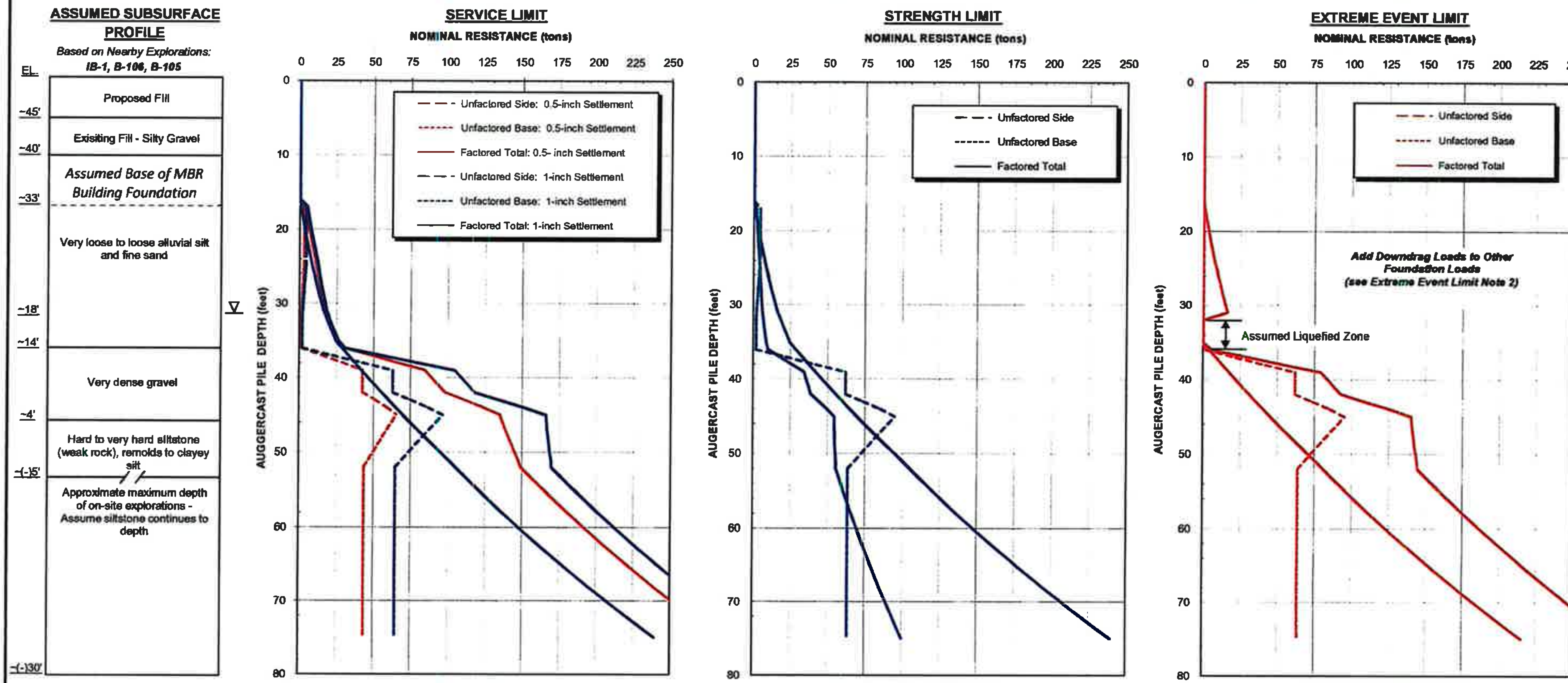
FIG. 11

7/29/2008-Fig A2_18in_MBR.xls

mfc/hjs



SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistance for both service levels are equal.

STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.

EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 20 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE MBR BUILDING

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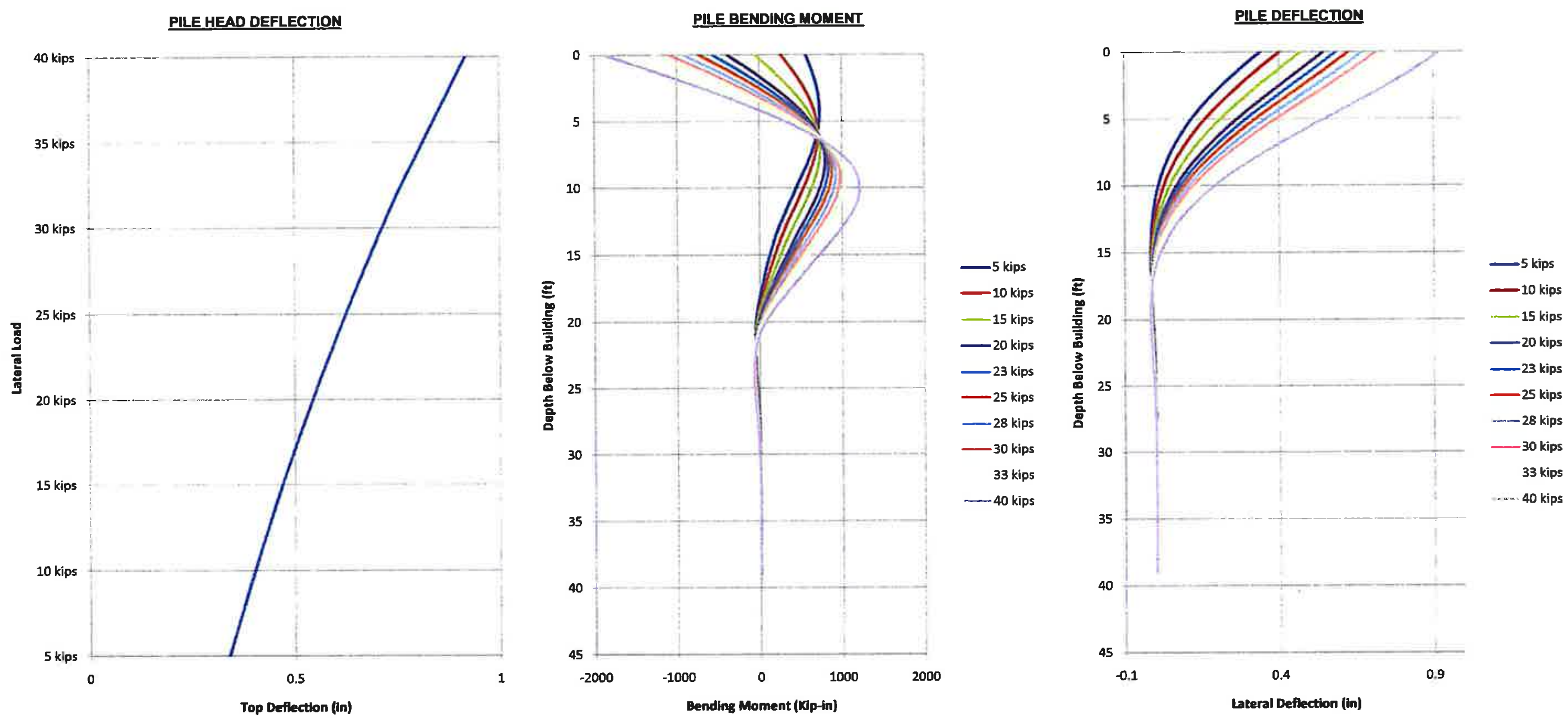
FIG. 12



Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA AUGER-CAST PILE REACTION TO LATERAL LOADING -MBR BUILDING

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FIG. 13

7/29/2008-Fig E_18in_UV.xlsx

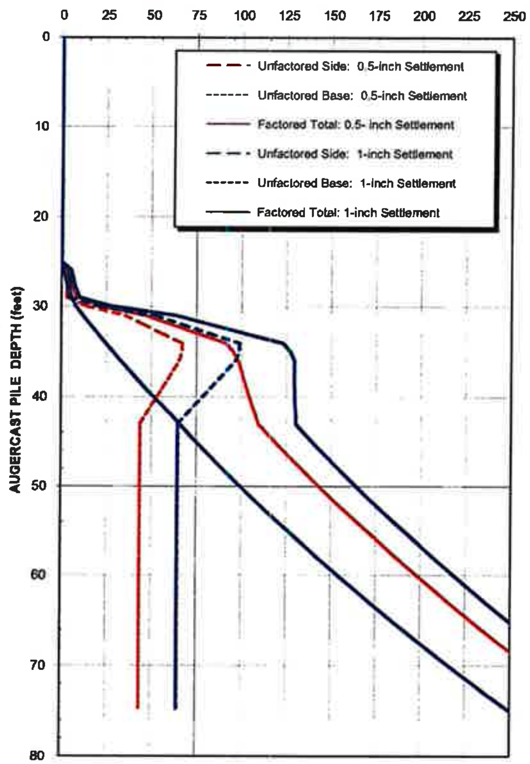
mfc/hjs

ASSUMED SUBSURFACE PROFILE

Based on Nearby Explorations: IB-8, B-11

EL	
	Proposed Fill
~45'	Existing Fill - Silty Gravel
~40'	*Assumed Base of UV Building Foundation*
~24'	Very loose to loose alluvial silt and fine sand
	Medium dense clean sand
~18'	Very dense gravel
~12'	
~6'	Hard to very hard siltstone (weak rock), remolds to clayey silt
~(-)5'	Approximate maximum depth of on-site explorations - Assume siltstone continues to depth
~(-)30'	

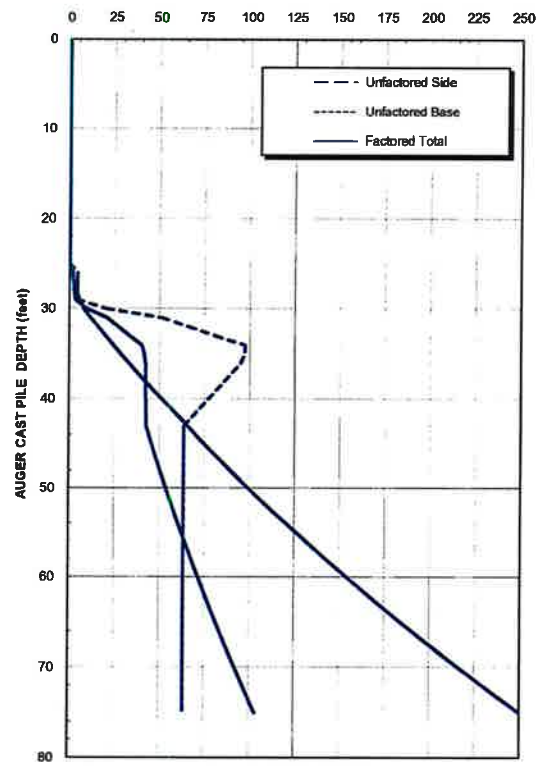
SERVICE LIMIT



SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistance for both service levels are equal.

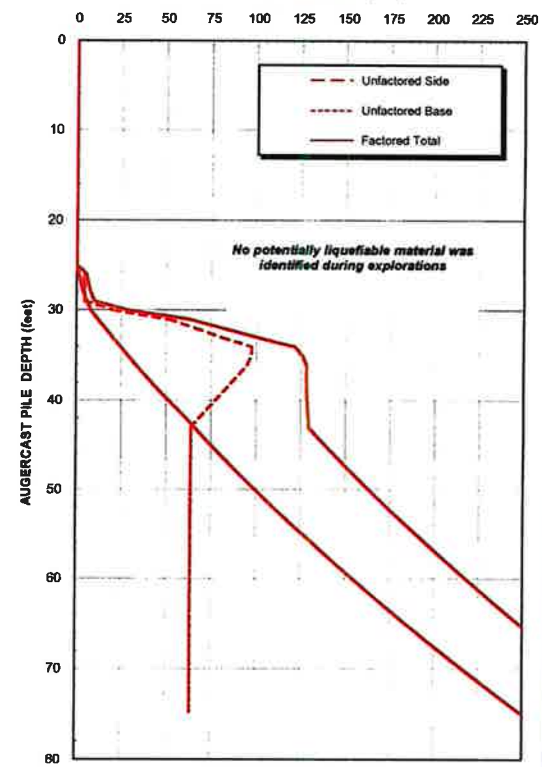
STRENGTH LIMIT



STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.

EXTREME EVENT LIMIT



EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 0 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE UV BUILDING

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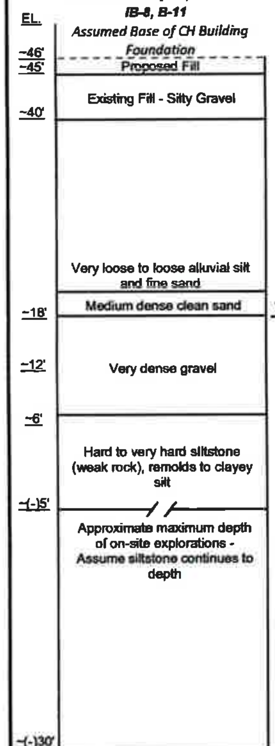
FIG. 14

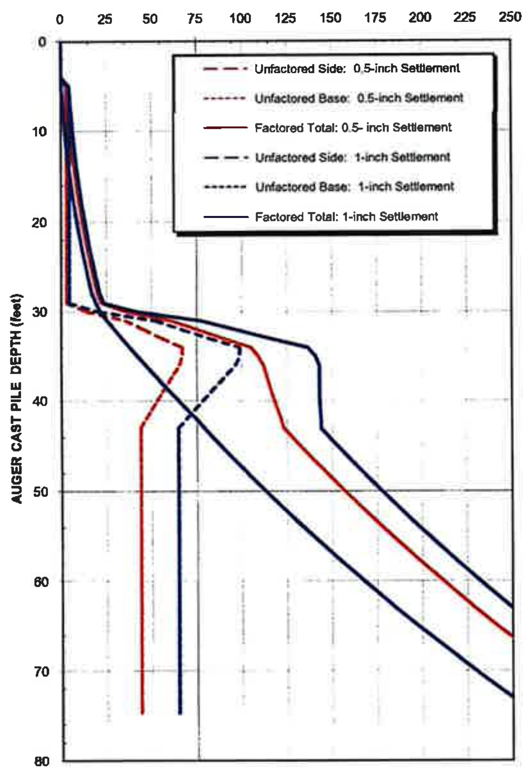
ASSUMED SUBSURFACE PROFILE

Based on Nearby Explorations:
IB-8, B-11



SERVICE LIMIT

NOMINAL RESISTANCE (tons)

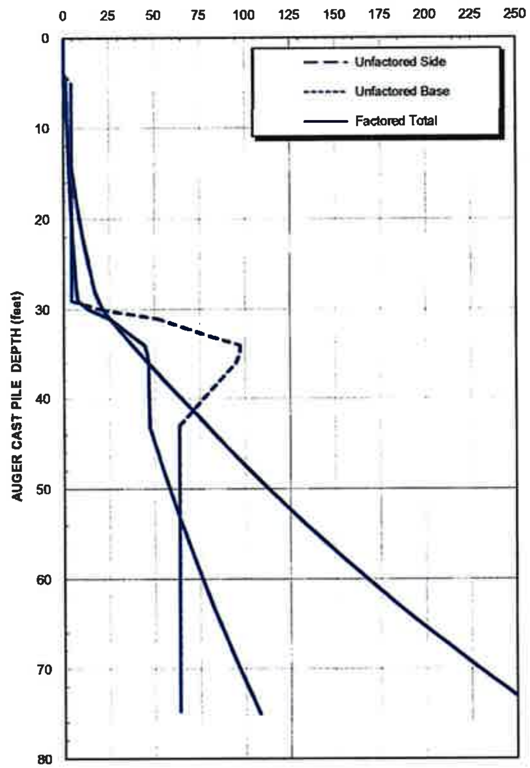


SERVICE LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Settlement is based on a single shaft. No group action is considered.
3. Side Resistance for both service levels are equal.

STRENGTH LIMIT

NOMINAL RESISTANCE (tons)

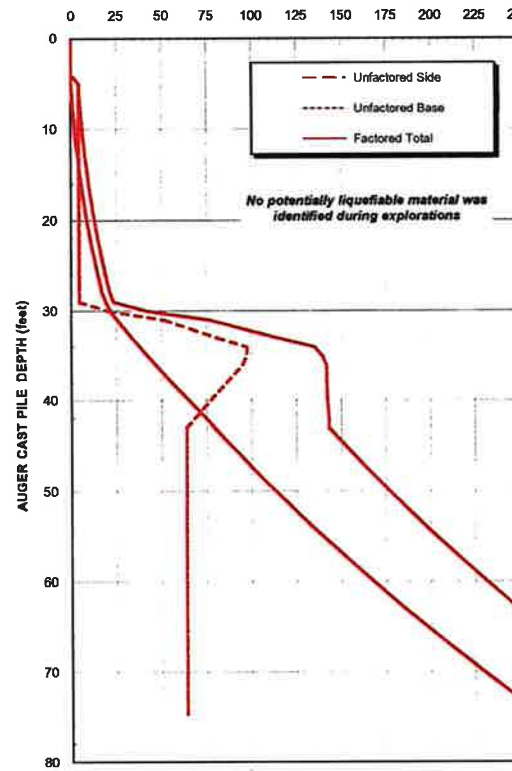


STRENGTH LIMIT NOTES:

1. Recommended factor of safety is 3.0 for side and base resistance.
2. Shaft uplift capacity can be estimated by using the unfactored side resistance shown above and a recommended factor of safety of 1.5.

EXTREME EVENT LIMIT

NOMINAL RESISTANCE (tons)



EXTREME EVENT LIMIT NOTES:

1. Recommended factor of safety is 1.0 for both side and base resistance.
2. Unfactored downdrag force is estimated to be 0 tons. A load factor of 1.25 is recommended to determine downdrag force. Downdrag force is recommended to be applied with post-earthquake loading.

GENERAL NOTES

1. Calculations assume static loading conditions.
2. Factored total shaft resistance shown on plots is determined by adding its unfactored side and based resistances multiplied by the appropriate factors of safety as noted above.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED AXIAL CAPACITY FOR 18-IN-DIA. AUGER-CAST PILE CHEMICAL BUILDING

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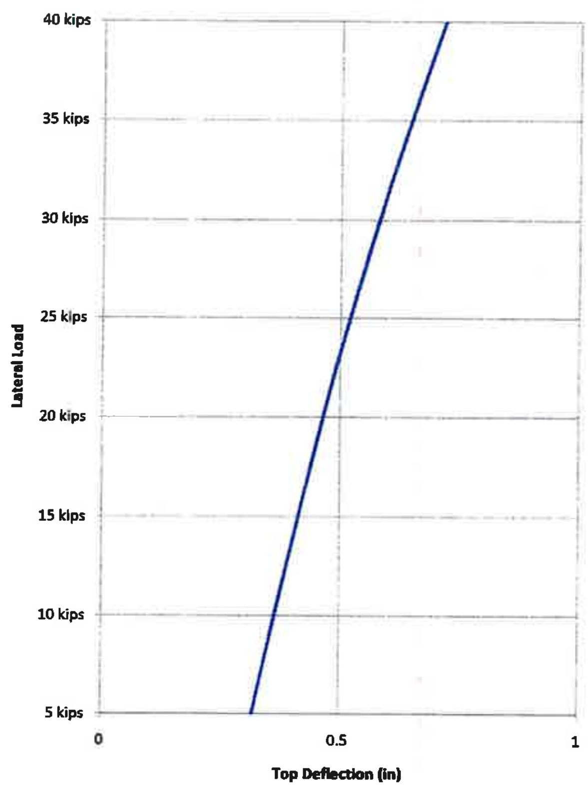
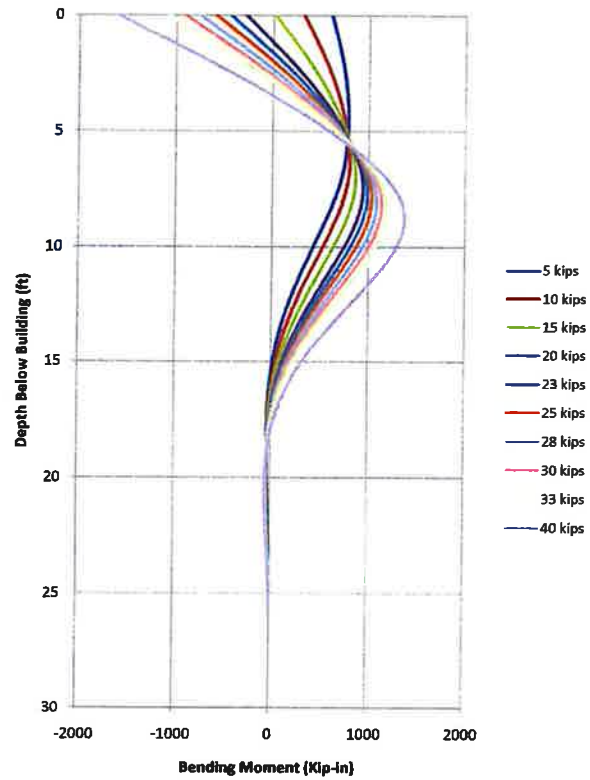
FIG. 15

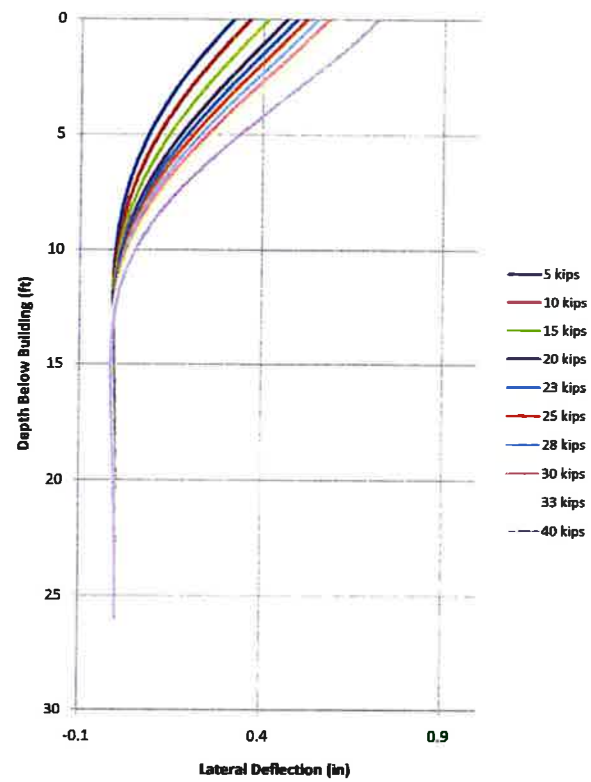
PILE HEAD DEFLECTION



PILE BENDING MOMENT



PILE DEFLECTION



Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA-AUGER-CAST PILE REACTION TO LATERAL LOADING -UV BUILDING

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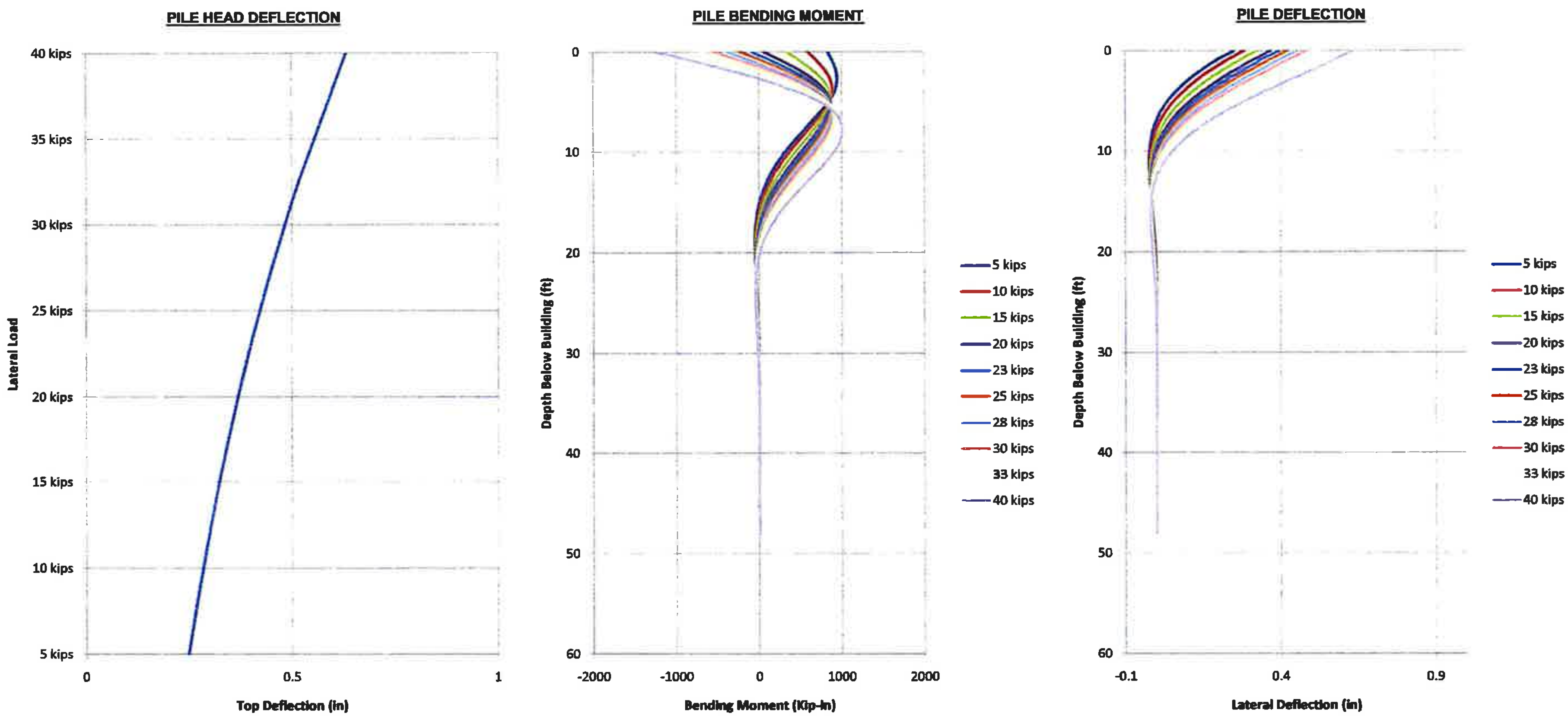
FIG. 16



Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

ESTIMATED 18-IN-DIA-AUGER-CAST PILE REACTION TO LATERAL LOADING - CHEMICAL BUILDING

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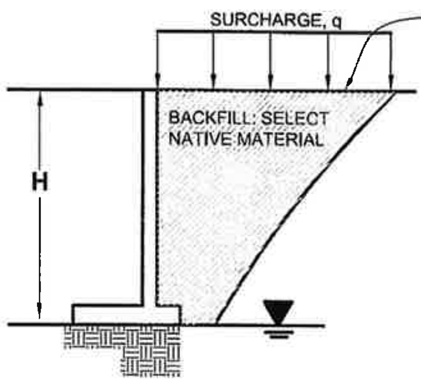
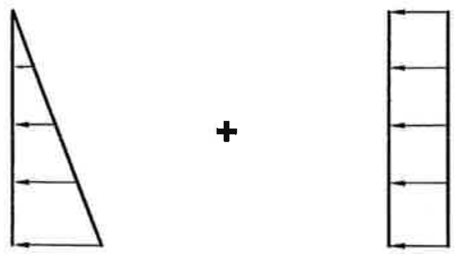
FIG. 17

TOTAL STATIC LATERAL PRESSURES (WALL DRAINED OR G.W.T. BELOW WALL)



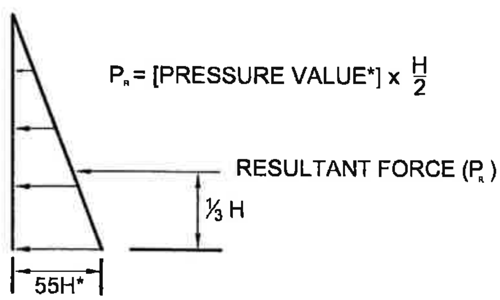
TOTAL LATERAL EQUIVALENT FLUID PRESSURES



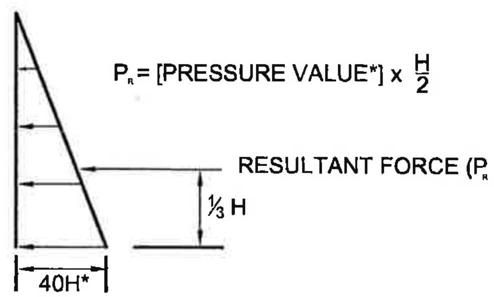
SOIL AND WATER BACKFILL COMPONENT

SURCHARGE COMPONENT

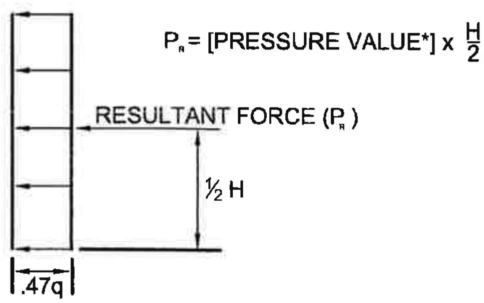
NON-YIELDING SOIL AND WATER COMPONENT



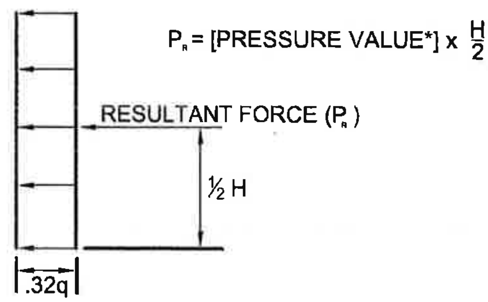
YIELDING SOIL AND WATER COMPONENT



NON-YIELDING SURCHARGE COMPONENT



YIELDING SURCHARGE COMPONENT



Note:

1. Values are for Equivalent Fluid Pressures.
2. No groundwater influence was incorporated into the soil backfill components.
3. Assume groundwater is below the wall or is drained into basins by PRV's or collected in an underdrain system and pumped to a storm drain or a "daylight" location above the 100 yr flood level.

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

STATIC DRAINED LATERAL PRESSURE DISTRIBUTION ON WALLS

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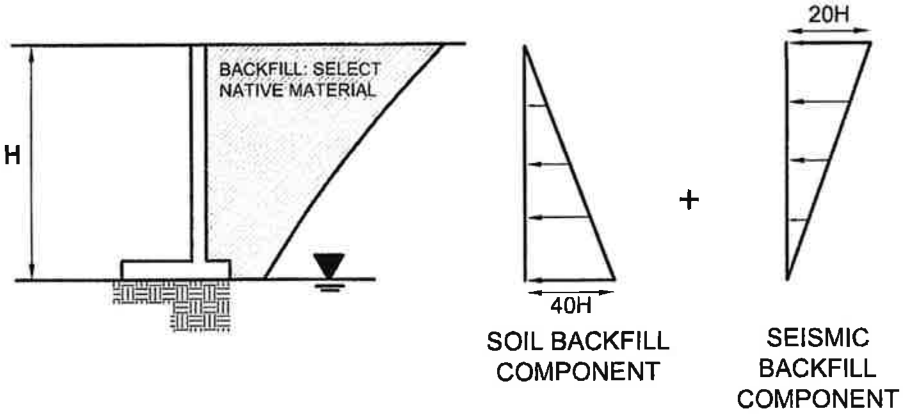
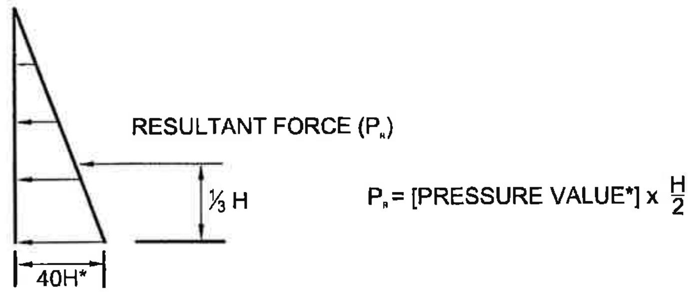
FIG. 18

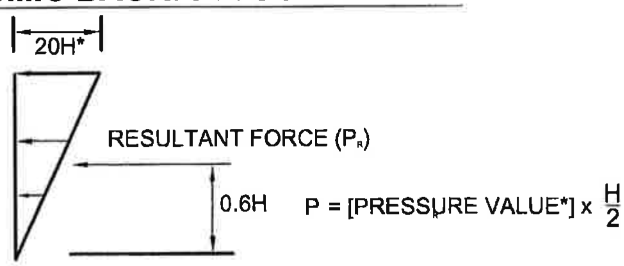
TOTAL SEISMIC LATERAL PRESSURE



YIELDING SOIL AND WATER COMPONENT



SEISMIC BACKFILL COMPONENT



Note:

1. Values are for Equivalent Fluid Pressures.
2. Groundwater influence was incorporated into the soil backfill components.
3. Assume groundwater is at annual high during earthquake event (elevation 18).

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

SEISMIC LATERAL PRESSURE DISTRIBUTION ON WALLS

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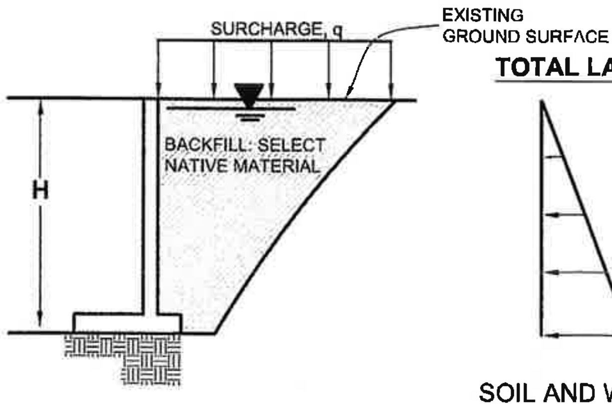
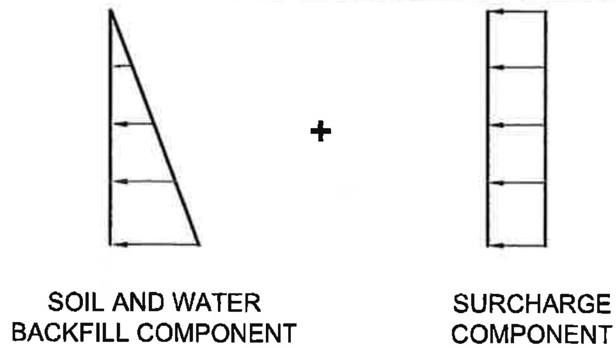
FIG. 19

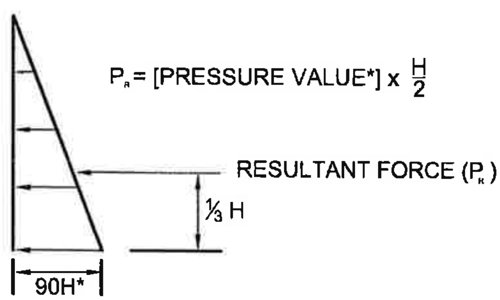
TOTAL STATIC LATERAL PRESSURES (100 YR FLOOD)



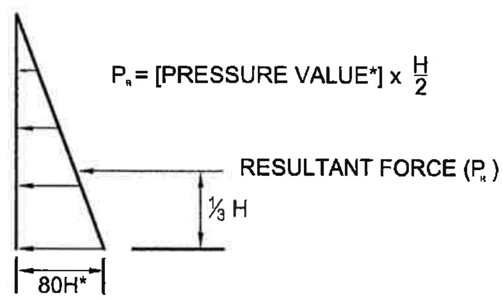
TOTAL LATERAL EQUIVALENT FLUID PRESSURES



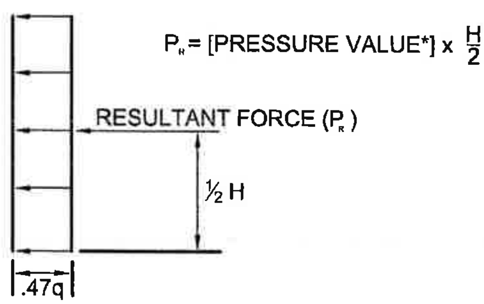
NON-YIELDING SOIL AND WATER COMPONENT



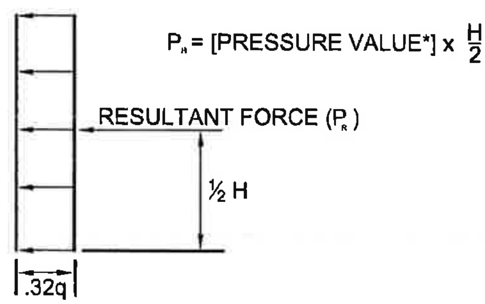
YIELDING SOIL AND WATER COMPONENT



NON-YIELDING SURCHARGE COMPONENT



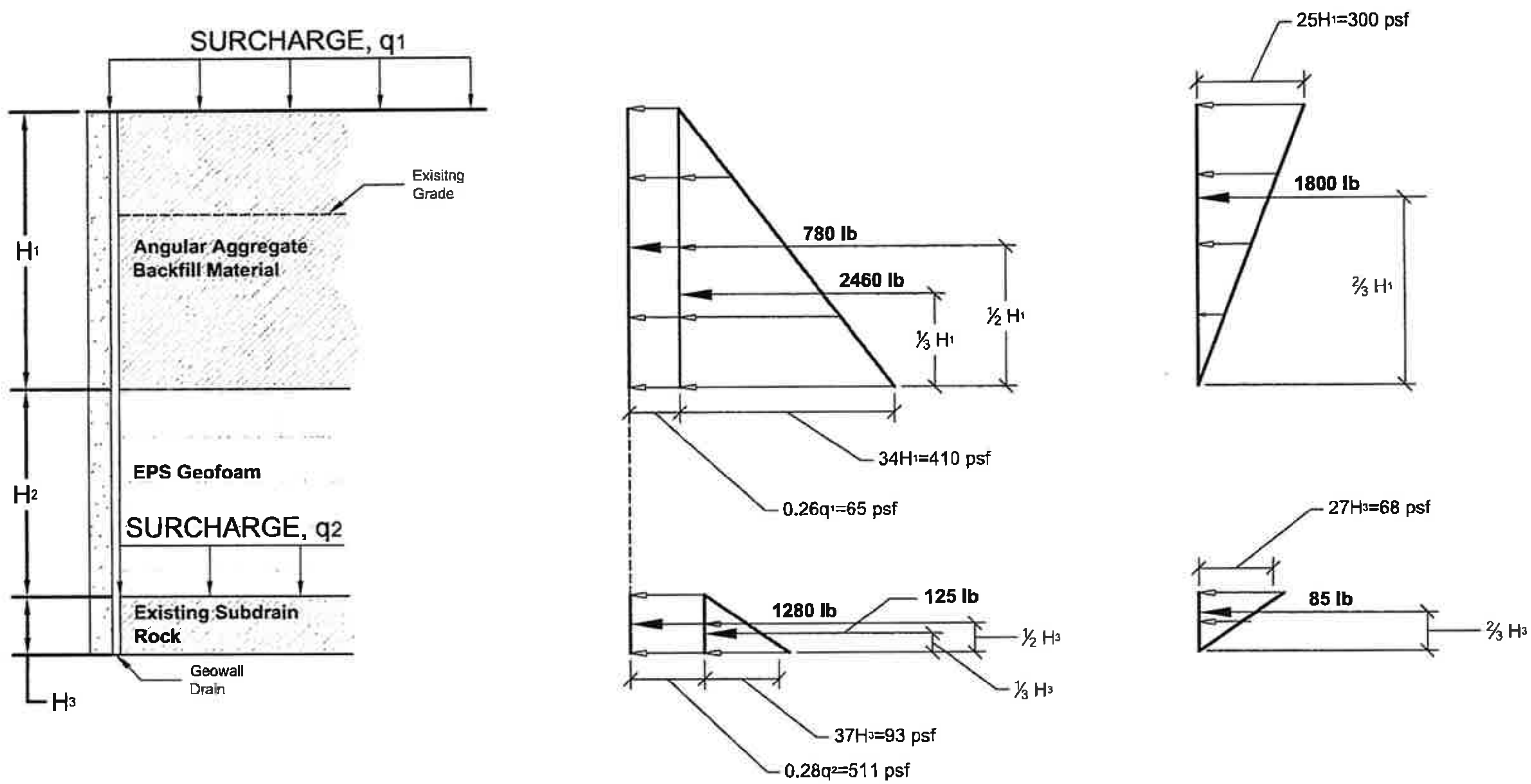
YIELDING SURCHARGE COMPONENT



Note:

1. Values are for Equivalent Fluid Pressures.
2. Groundwater influence was incorporated into the soil backfill components.
3. Assume groundwater is at 100 yr flood elevation for static design (elevation 46.5 ft).

Tri-City WPCP Interim Expansion Clackamas County, Oregon	
STATIC (100YR FLOOD) LATERAL PRESSURE DISTRIBUTION ON WALLS	
February 2008	24-1-03420-002
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 20**



Note:
1. Aggregate backfill unit weight of 130 pcf.
2. Aggregate backfill friction angle is 36 deg.
3. H_1 is depth to EPS Geofoam, assumed 12 ft.
4. Unit weight of EPS Geofoam ~2 pcf.
5. Assume Seismic site class E, pga = 0.277g
6. Lateral earth pressure behind EPS Geofoam block resisted by base friction on the bottom of foam block.

FIG. 21

Tri-City WPCP
Interim Expansion
Clackamas County, Oregon

STATIC AND DYNAMIC - LATERAL EARTH PRESSURE DISTRIBUTION ON EXISITNG AERATION BASIN WALLS

February 2008 — 24-1-03420-002

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FIG. 21

APPENDIX A
S&W FIELD EXPLORATIONS

APPENDIX A

S&W FIELD EXPLORATIONS

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APPENDIX A

S&W FIELD EXPLORATIONS

A.1 GENERAL

Shannon & Wilson planned and executed a subsurface exploration program to characterize the subsurface conditions at the WPCP project site. The program consisted of three individual exploration Stages. Stage One efforts focused on developing a general subsurface model across the project site. Stage Two explorations were specifically directed at refining a subsurface anomaly that was detected during the Stage One explorations. Stage Three explorations focused on gathering specific subsurface data that is required for the facility design. The locations of S&W's explorations, in addition to locations of pertinent previous subsurface explorations, are illustrated on Figure 2. The relative locations of S&W explorations were established by the use of field methods, including hand taping and laser range finding to known on-site features. The locations of S&W's explorations should be considered approximate. Table 2, below, describes the drilling method and depth below ground surface for all stages of S&W's subsurface explorations.

TABLE A1

Exploration Hole Details

Boring Label	Boring Type	Nearest Structure to Boring Location	Bottom	
			Depth, ft	Approximate Elevation, ft MSL
IB-1	Mud Rotary	Aeration Basin	31.5	13
IB-2	Mud Rotary	Blower/electrical	31.5	13
IB-3	Mud Rotary	Primary Gallery	31.5	13
IB-4	Mud Rotary	Fine Screening	46.5	-1
IB-5	Mud Rotary	Fine Screening/UV	30.6	14
IB-6	Mud Rotary	Future Digester	51.5	-6
IB-7	Mud Rotary	Future Digester	51.5	-6
IB-8	Mud Rotary	UV Building	26.5	18
IB-9	Mud Rotary	UV Building	34.2	11
IB-10	Mud Rotary	West of Plant	40.2	10
IB-11	Hollow Stem Auger	West of Plant	46.5	-6
IB-12	Hollow Stem Auger	Retention Basin	31.5	16
IB-13	Hollow Stem Auger	Retention Basin	17	29

CPT-1	Electric Cone Penetrometer	Primary Gallery	27.72	17
CPT-2	Electric Cone Penetrometer	Fine Screening	29.04	16
CPT-3	Electric Cone Penetrometer	Fine Screening	19.69	25
CPT-4	Electric Cone Penetrometer	Primary Gallery	33.14	12

Stage one and stage three subsurface explorations were performed by a drilling subcontractor hired by Shannon and Wilson. The subcontractor was Hardcore Drilling, Inc., of Dundee Oregon. Each of the borings were advanced using a truck-mounted CME-75 drill rig utilizing mud rotary drilling or hollow stem auger techniques. The drilling operations were directed by a representative from Shannon & Wilson who also logged the subsurface conditions during drilling and the logged and classified the soil samples that were collected during the operation. Soil sampling was performed using a standard split spoon sampler, Dames and Moore split spoon sampler and thin-walled Shelby tube sampler. Samples were sealed in containers and returned to our laboratory for further classification and index testing.

Stage One explorations, completed on the dates July 23rd through July 26th, 2007, consisted of seven mud rotary borings to depths ranging from 30 to 51.5 feet below the ground surface. Five borings, labeled IB-1 through IB-5, were located near of the Phase One Plant Expansion on the south side of the existing WPCP. Two borings, label IB-6 and IB-7, were located near the proposed digesters on the northwest corner of the WPCP site. A standpipe piezometer was installed in IB-6

Stage two explorations consisted of pushing four (CPT-1 through CPT-4) electric cone penetrometer test (CPT) holes on the August 14th, 2007. The work was performed by Vandehey Exploration, Inc. of Banks Oregon, who was a subcontractor to S&W. The CPT test holes were pushed to depths between 20 and 33 feet. The CPT probes were advanced to locate the top of the gravel layer near the Fine Screening Building. The CPT probes were stopped where they reached a refusal pushing force. No samples are collected during CPT exploration. The CPT logs provide a continuous record of soil resistance which includes tip resistance and side friction. Estimates of soil properties/classification can be made based on published correlations between tip and skin resistance. The estimated soil properties are based on analyses performed using published correlations and equations. The method used for estimating the properties listed above are:

a. Uncorrected N-Value (N_{60}) based on Robertson & Campanella. This Correlation of CPT data to ASTM International 1586 N-Value is interpretive and should not be considered factual or used as data on this project.
b. Soil Behavior Type based on University of British Columbia-1983. This correlation is interpretive, and should not be considered the actual soil type according to ASTM D2488.

Some of the logs have no data in the upper five feet of soil because the holes had to be predrilled to advance the CPT through the gravelly fill material.

Stage Three explorations consisted of six borings (IB-8 through IB-13), ranging in depth form 17 to 46.5 feet, and completed during the dates February 25th through February 27th 2008. Boring IB-8 and IB-9 were drilled near the proposed UV disinfection building and advanced to the top of the dense gravel layer. Borings IB-10 and IB-11 were drilled on the west side of the aid in the characterization of subsurface materials between the plant and the river. Borings IB-12 and IB-13 were drilled near the footprint of the proposed storm water retention basin. Standpipe piezometers were installed in borings IB-12 and IB-13. In-situ infiltration (permeability) tests were performed on boring IB-12 and IB-13, see Appendix C for detailed description of the in-situ testing.

Logs of the current exploration program are contained in this Appendix. For reference, boring logs from previous reports in the plant area are contained in Appendix D.

Shannon & Wilson, Inc. (S&W), uses a soil classification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following page. Soil descriptions are based on visual-manual procedures (ASTM D 2488-93) unless otherwise noted.

S&W CLASSIFICATION OF SOIL CONSTITUENTS

MAJOR constituents compose more than 50 percent, by weight, of the soil. Major consituents are capitalized (i.e., SAND).

Modifying (secondary) constituents compose 30 to 45 percent of the soil (i.e. sandy, silty, etc).

Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).

Trace constituents compose 5 percent of the soil (i.e., slightly silty SAND, trace of gravel).

Dual symbols apply to coarse grained soils with 10 percent fines.

MOISTURE CONTENT DEFINITIONS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

ABBREVIATIONS

ATD	At Time of Drilling
Elev.	Elevation
ft	feet
FeO	Iron Oxide
MgO	Magnesium Oxide
HSA	Hollow Stem Auger
ID	Inside Diameter
in	inches
lbs	pounds
Mon.	Monument cover
N	Blows for last two 6-inch increments
NA	Not applicable or not available
NP	Non plastic
OD	Outside diameter
OVA	Organic vapor analyzer
PID	Photo-ionization detector
ppm	parts per million
PVC	Polyvinyl Chloride
SS	Split spoon sampler
SPT	Standard penetration test
USC	Unified soil classification
WLI	Water level indicator

GRAIN SIZE DEFINITION

DESCRIPTION	SIEVE NUMBER AND/OR SIZE
FINES	< #200 (0.08 mm)
SAND*	
- Fine	#200 to #40 (0.08 to 0.4 mm)
- Medium	#40 to #10 (0.4 to 2 mm)
- Coarse	#10 to #4 (2 to 5 mm)
GRAVEL*	
- Fine	#4 to 3/4 inch (5 to 19 mm)
- Coarse	3/4 to 3 inches (19 to 76 mm)
COBBLES	3 to 12 inches (76 to 305 mm)
BOULDERS	> 12 inches (305 mm)

* Unless otherwise noted, sand and gravel, when present, range from fine to coarse in grain size.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	Under 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

WELL AND OTHER SYMBOLS

Bent. Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Bedrock
PVC Screen	Fill
Vibrating Wire	

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

SOIL CLASSIFICATION AND LOG KEY

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A1
Sheet 1 of 2

BORING CLASS1 TRI-CITY WWTP.GPJ SWNEW.GDT 8/7/08

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(From ASTM D 2487-98 & 2488-93)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOIL *(more than 50% retained on No. 200 sieve)*	Gravel *(more than 50% of coarse fraction retained on No. 4 sieve)*	Clean Gravel *(less than 5% fines)*	GW	Well-graded gravel, gravel, gravel/sand mixtures, little or no fines.
			GP	Poorly graded gravel, gravel-sand mixtures, little or no fines
		Gravel with Fines *(more than 12% fines)*	GM	Silty gravel, gravel-sand-silt mixtures
			GC	Clayey gravel, gravel-sand-clay mixtures
	Sand *(50% or more of coarse fraction passes the No. 4 sieve)*	Clean Sand *(less than 5% fines)*	SW	Well-graded sand, gravelly sand, little or no fines
			SP	Poorly graded sand, gravelly sand, little or no fines
		Sand with Fines *(more than 12% fines)*	SM	Silty sand, sand-silt mixtures
			SC	Clayey sand, sand-clay mixtures
FINE-GRAINED SOIL *(50% or more passes the No. 200 sieve)*	Silt and Clay *(liquid limit less than 50)*	Inorganic	ML	Inorganic silt of low to medium plasticity, rock flour, sandy silt, gravelly silt, or clayey silt with slight plasticity
			CL	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay, silty clay
		Organic	OL	Organic silt and organic silty clay of low plasticity
	Silt and Clay *(liquid limit 50 or more)*	Inorganic	MH	Inorganic silt, micaceous or diatomaceous fine sand or silty soils, elastic silt
			CH	Inorganic clay or medium to high plasticity
		Organic	OH	Organic clay of medium to high plasticity, organic silt
HIGHLY-ORGANIC SOIL	Primarily organic matter, dark in color, and organic odor		PT	Peat, humus, swamp soils with high organic content (see ASTM D 4427)

NOTE: No. 4 size = 5 mm; No. 200 size = 0.075 mm

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND)* are used for soils with between 5% and 10% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND)* indicate that the soil may fall into one of two possible basic groups.

Tri-City WPCP
Phase 1 Expansion
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SOIL CLASSIFICATION AND LOG KEY

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FIG. A1
Sheet 2 of 2

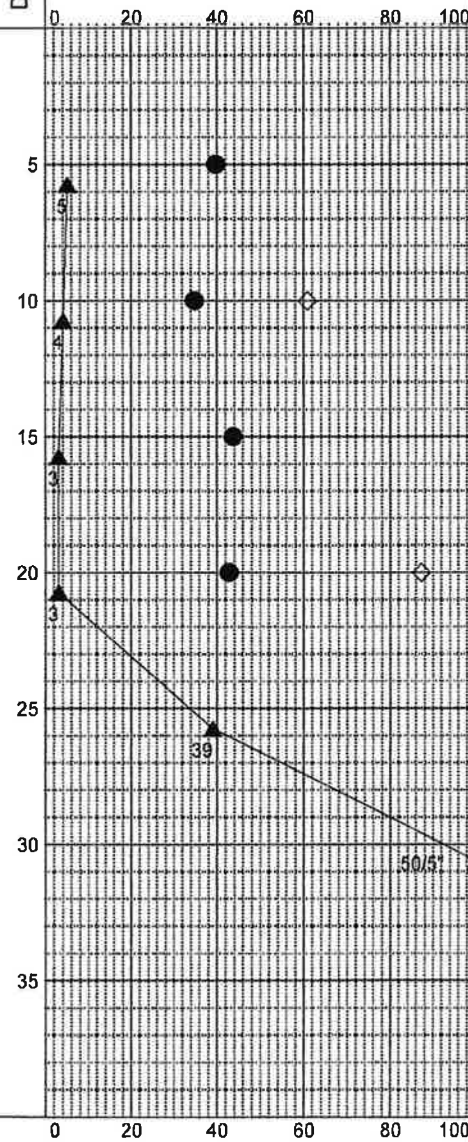
BORING_CLASS2 TRI-CITY WWTP.GPJ SWNEW.GDT 8/7/08

Total Depth:	31.5 ft.	Northing:	~	Drilling Method:	Mud Rotary
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75
Horiz. Datum:		Offset:	~	Other Comments:	

Hole Diam.: 5 in.
Rod Type: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Samples	Ground Water
SILT; with organics. (ML) **FILL**	43 2.0		
Gravelly SILT with cobbles (ML)	40 5.0		
Soft to medium stiff brown SILT to SILT with sand; moist, non- to low plasticity, fine sand, micaceous. (ML)		S-1	
Grades to sandy SILT, moist, non-plastic at 10 ft. **ALLUVIUM**		S-2	
Grades to SILT with sand, moist, non-plastic at 15 ft.		S-3	
Grades to wet, low plasticity at 20 ft.	23 22.0	S-4	During Drilling ∇
Brown silty SAND. (SM)	21 24.0		
Dense to very dense dark grey sandy GRAVEL with silt; moist, non-plastic, fine to coarse sand and gravel, rounded gravel. (GP-GM) **ALLUVIUM**		S-5 S-6	
Bottom of Boring - 24 July 2007	13.5 31.5		

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered
⌶ 2.5" OD Split Spoon Sample
∇ Ground Water Level

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
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LOG OF BORING IB-1

May 2008 | 24-1-03420-001

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FIG. A2

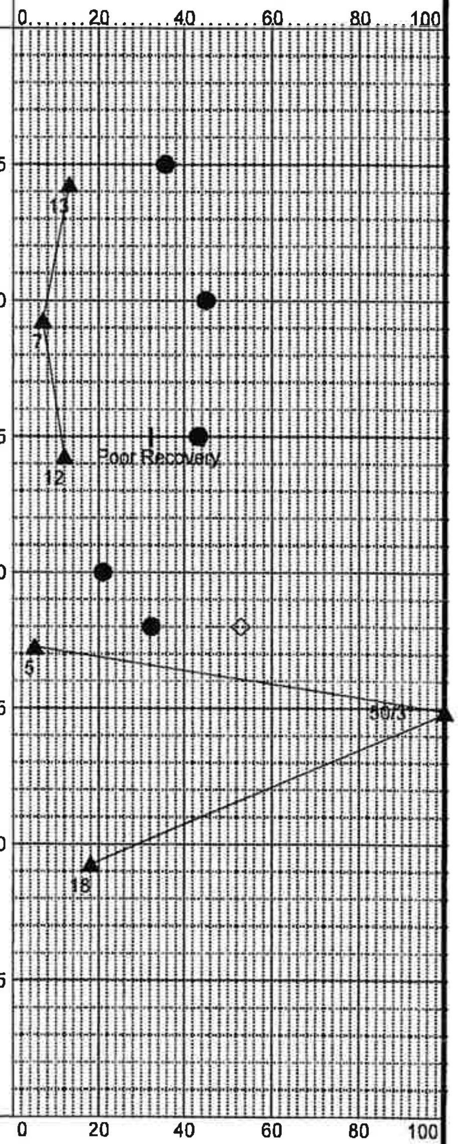
MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: AAH Rev: DRH Typ: ECP

Total Depth:	31.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Samples	Ground Water
SILT; with organics. (ML) **FILL**	43 / 2.0		
Gravelly SILT with cobbles. (ML)	40 / 5.0		
Medium stiff to stiff brown SILT; moist, non- to low plasticity, micaceous, scattered iron staining at 5 ft. (ML) Grades to trace coarse sand. **ALLUVIUM** Grades to trace fine sand, medium plasticity.	25 / 20.0	S-1, S-2, S-3	
Loose brown sandy SILT to silty SAND; moist to wet, non-plastic, fine sand, micaceous. (ML/SM)	20.5 / 24.5	S-4, S-5	During Drilling
Medium dense to very dense dark grey sandy GRAVEL. (GP) **ALLUVIUM**	13.5 / 31.5	S-6, S-7	
Bottom of Boring - 23 July 2007			

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

- * Sample Not Recovered
- 2.5" OD Split Spoon Sample
- 3.25" O.D. Split Spoon Sample
- 3.0" O.D. Osterberg Sample
- Ground Water Level

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
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LOG OF BORING IB-2

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FIG. A3

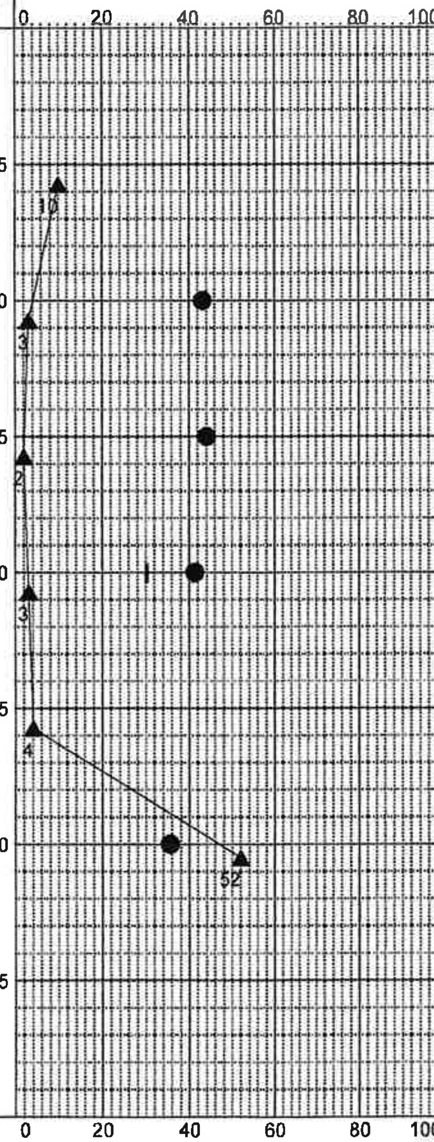
MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: AAH Rev: DRH Typ: ECP

Total Depth:	31.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Dark brown SILT; moist, with organics. (ML) FILL	43.5 1.5				
Gravelly SILT with cobbles. (ML)	42 3.0				
Stiff brown SILT; moist, medium plasticity, micaceous, scattered iron oxide stains at 5 ft. (ML)			S-1		5
Grades to soft at 10 ft.			S-2		10
ALLUVIUM					
Grades to very soft to soft at 15 ft.			S-3		15
			S-4		20
Grades to soft to medium stiff at 25 ft.			S-5*		25
Grades to with sand at 28 ft.				During Drilling ∇	
Very loose brown silty SAND; wet, non-plastic, fine sand. (SM)	14.8 30.2		S-6A		30
Very dense dark grey sandy GRAVEL with silt; wet, non-plastic, fine to coarse sand and gravel. (GP-GM) ALLUVIUM	14 31.0 13.5 31.5		S-6B		
Bottom of Boring - 24 July 2007					35

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered

⌶ 2.5" OD Split Spoon Sample

∇ Ground Water Level

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
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LOG OF BORING IB-3

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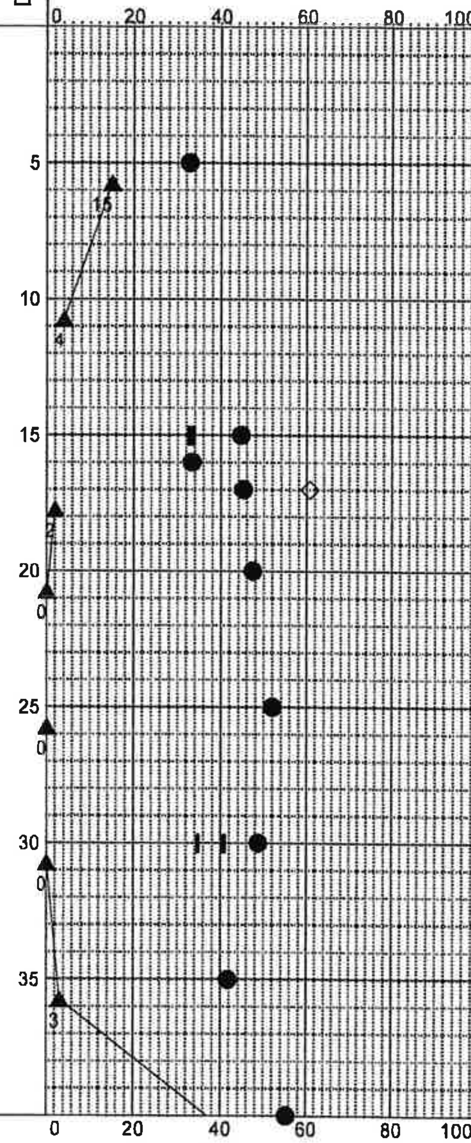
FIG. A4

MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: AAH Rev: DRH Typ: ECP

Total Depth:	46.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	*Elev.* Depth (ft.)	Symbol	Samples	Ground Water
Gravelly SILT to silty GRAVEL. (ML/GM) **FILL**				
Stiff to very stiff dark grey SILT; trace gravel, moist, low plasticity. (ML)	*40* 5.0		S-1	
Medium stiff brown stratified SILT with sand to sandy SILT; moist, non- to low plasticity, fine sand, micaceous. (ML)	*38.5* 6.5		S-2	
Grades to very soft at 15 ft.			S-3 S-4	
ALLUVIUM			S-5	During Drilling ⊻
			S-6	
Grades to trace sand at 30 ft.			S-7	
Very loose grey and brown silty SAND; wet, non-plastic, fine sand. (SM)	*11* 34.0		S-8	
Sandy silty GRAVEL. (GM) **ALLUVIUM**	*8* 37.0			
CONTINUED NEXT SHEET	*6* 39.0			

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: *lbs / inches*
140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ⊢—●—⊣ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
⌶ 2.5" OD Split Spoon Sample
Ⓘ 3.0" O.D. Osterberg Sample
⊻ Ground Water Level

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
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LOG OF BORING IB-4

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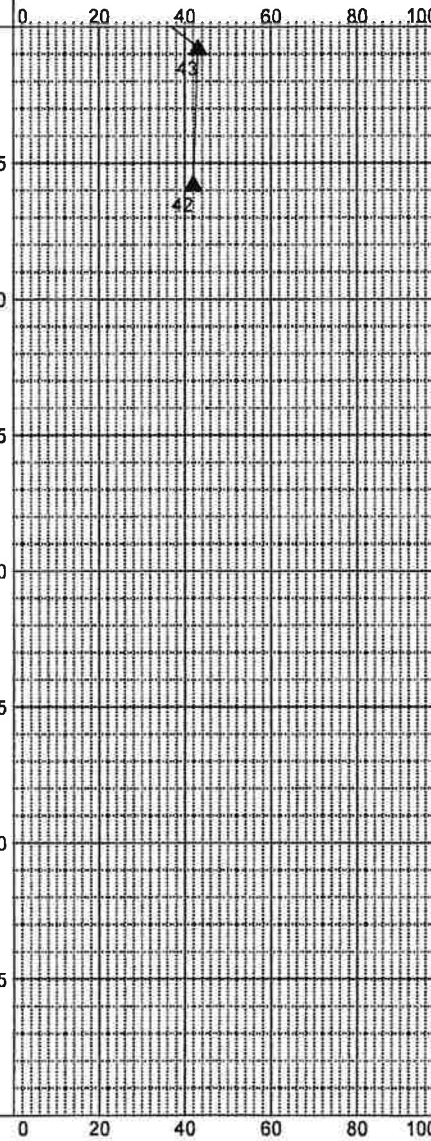
FIG. A5
Sheet 1 of 2

MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: AAH Rev: DRH Typ: ECP

Total Depth:	46.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
SILTSTONE; very low strength, grey, fresh, massive. **SILTSTONE**	-1.5 46.5		S-9 S-10		45 50 55 60 65 70 75
Bottom of Boring - 24 July 2007					

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: lbs / inches
140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2.5" OD Split Spoon Sample
- 3.0" O.D. Osterberg Sample
- ⊻ Ground Water Level

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-4

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FIG. A5
Sheet 2 of 2

MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: AAH Rev: DRH Typ: ECP

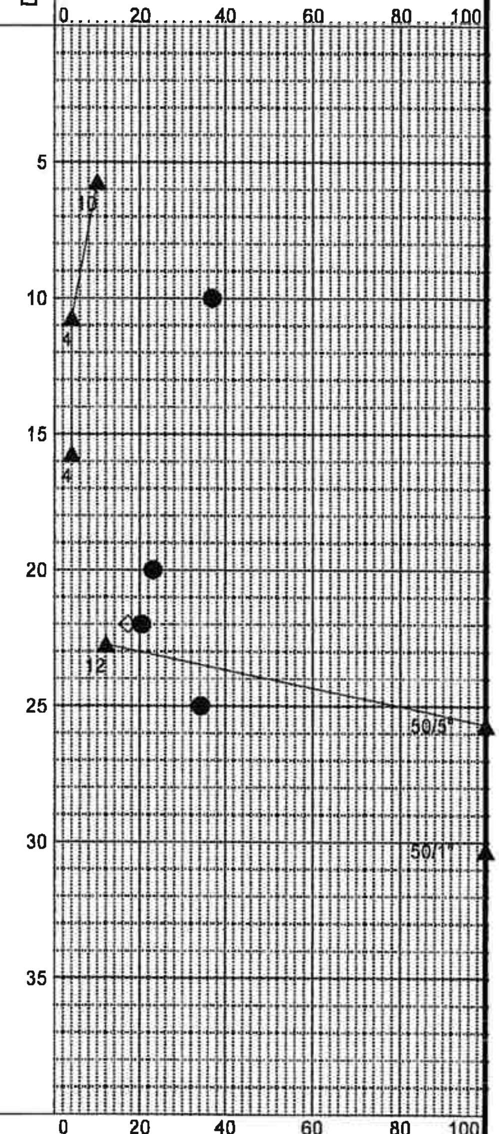
Total Depth:	30.6 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Samples
Silty GRAVEL to gravelly SILT. (ML/GM) **FILL**	41 4.0	
Stiff brown SILT; moist, non- to low plasticity, micaceous. (ML) Grades to soft to medium stiff at 10 ft. **ALLUVIUM**	26 19.0	S-1 S-2 S-3 *
Medium dense brown SAND with silt to silty SAND; moist, non-plastic, fine to medium angular to subangular sand. (SP-SM/SM)	19.5 25.5	S-4 S-5
Very dense dark grey sandy silty GRAVEL; wet, non-plastic, fine to coarse subrounded to rounded gravel, fine to coarse sand. (GM) **ALLUVIUM**	14.4 30.6	S-6 S-7
Bottom of Boring - 25 July 2007		

Symbol | Ground Water | Depth, ft.

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

LEGEND

* Sample Not Recovered

I 2.5" OD Split Spoon Sample

Shelby Tube Sample Portland Test Pit Log

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
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LOG OF BORING IB-5

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FIG. A6

Total Depth:	*51.5 ft.*	Northing:	~	Drilling Method:	*Mud Rotary*
Top Elevation:	*45 ft.*	Easting:	~	Drilling Company:	*Hardcore Drilling*
Vert. Datum:		Station:	~	Drill Rig Equipment:	*CME-75*
Horiz. Datum:		Offset:	~	Other Comments:	

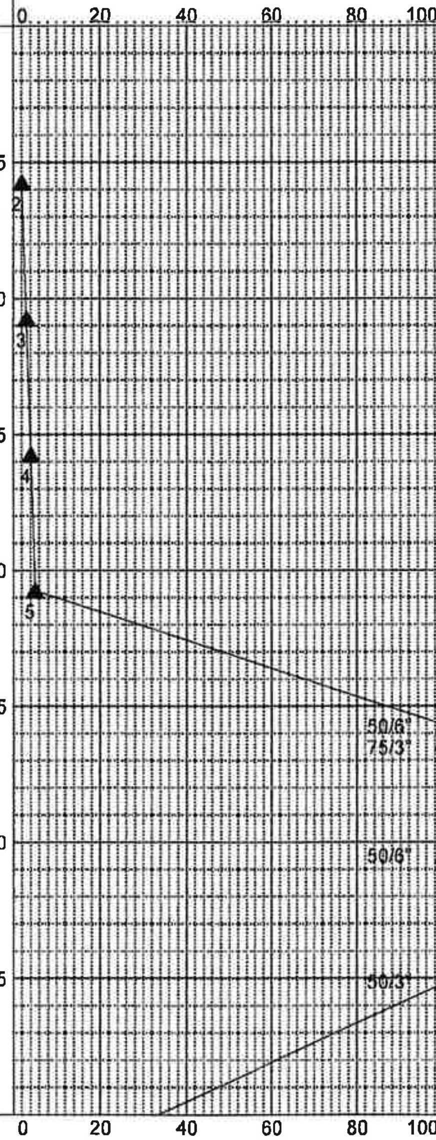
Hole Diam.:	*6 in.*
Rod Type:	*NWJ*
Hammer Type:	*Automatic*

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Soft to medium stiff brown SILT to sandy SILT; non- to low plasticity, moist to wet. (ML) **ALLUVIUM**			S-1, S-2, S-3, S-4		5, 10, 15, 20
Loose dark brown SAND; trace silt. (SP)	24.1 20.9			During Drilling ∇	
Very dense GRAVEL with cobbles and possible boulders; trace sand and silt. (GP) **ALLUVIUM** Grades to medium dense, caving at 29 ft. Grades to very dense at 30.5 ft.	22.5 22.5		S-5, S-6, S-7, S-8		25, 30, 35
Sandy GRAVEL. (GP)	6.5 38.5				

CONTINUED NEXT SHEET

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



LEGEND

* Sample Not Recovered

⌶ 2.5" OD Split Spoon Sample

⏀ 3.25" O.D. Split Spoon Sample

∇ Ground Water Level

Plastic Limit ⊢●⊣ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
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LOG OF BORING IB-6

May 2008 24-1-03420-001

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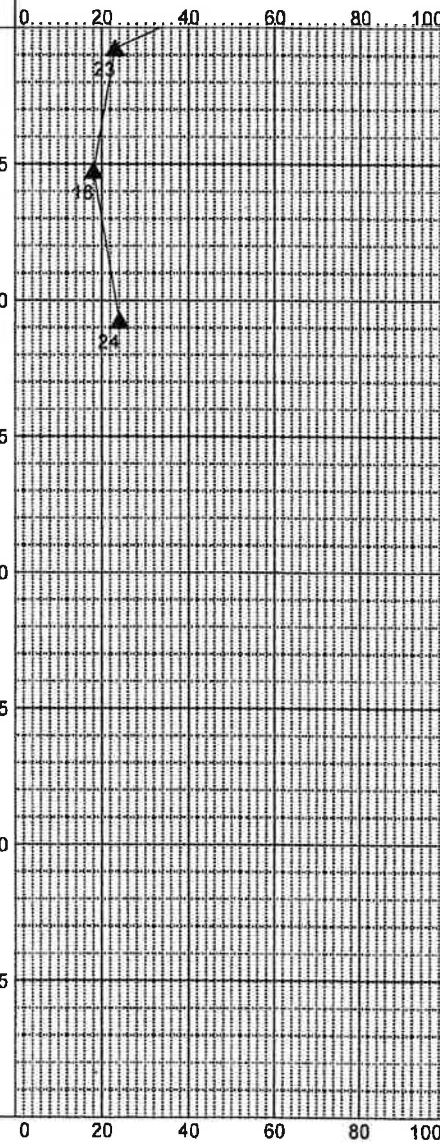
FIG. A7
Sheet 1 of 2

Total Depth:	51.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	6 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Continued: Sandy GRAVEL. (GP)	0.5 44.5		S-9		
Hard blue grey SILTSTONE; moist, medium plasticity, red brown mottling, remolds to very stiff clayey silt. (MH) **SILTSTONE**	-6.5 51.5		S-10 S-11		45 50
Bottom of Boring - 26 July 2007					55 60 65 70 75

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
⌶ 2.5" OD Split Spoon Sample
⌶ 3.25" O.D. Split Spoon Sample
⊻ Ground Water Level

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-6

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

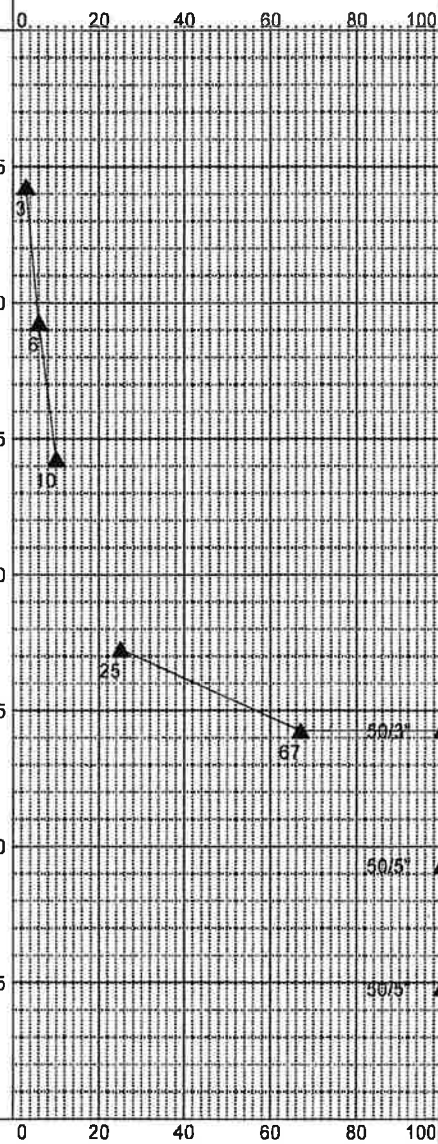
FIG. A7
Sheet 2 of 2

Total Depth:	51.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Very loose brown silty SAND to sandy SILT; moist, non-plastic, fine sand, micaceous. (SM/ML) **ALLUVIUM**			S-1		5
Medium stiff brown SILT with sand; moist, fine sand, micaceous. (ML)	35 10.0		S-2		10
Loose to medium dense brown silty SAND; moist, non-plastic, fine sand. (SM)	30 15.0		S-3 S-4 S-5		15 20
Very dense grey to brown sandy silty GRAVEL with scattered cobbles and boulders; moist, non-plastic, fine to coarse sand and gravel. (GM) **ALLUVIUM**	21.5 23.5		S-6 S-7 S-8 S-9		25 30 35

CONTINUED NEXT SHEET

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
2.5" OD Split Spoon Sample
Shelby Tube Sample Portland Test Pit Log
3.25" O.D. Split Spoon Sample

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-7

May 2008 24-1-03420-001

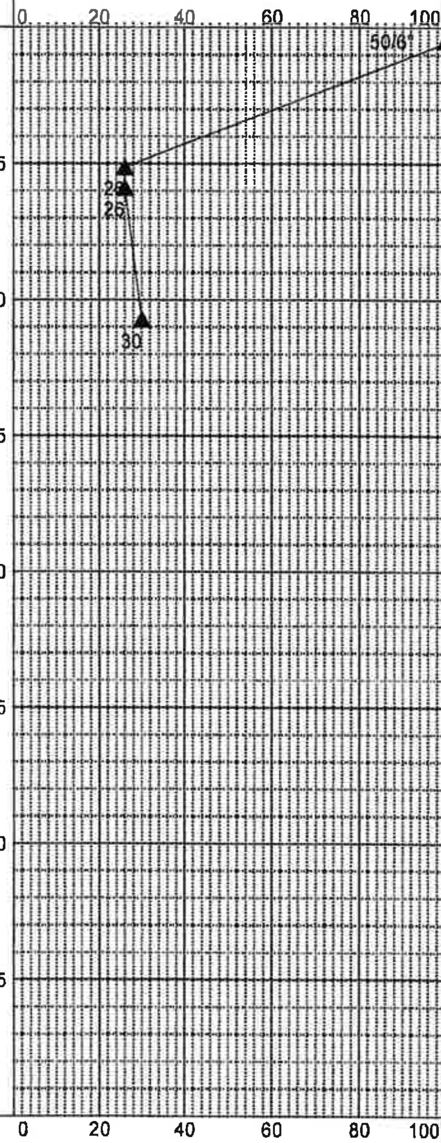
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A8
Sheet 1 of 2

Total Depth:	51.5 ft.	Northing:	~	Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Continued: Very dense grey to brown sandy silty GRAVEL with scattered cobbles and boulders; moist, non-plastic, fine to coarse sand and gravel. (GM)	-1 46.0		S-10 S-11A S-11B		45
Very stiff dark grey SILTSTONE; weathered, moist, low to medium plasticity, red orange staining. **SILTSTONE**	-6.5 51.5		S-12		50
Bottom of Boring - 25 July 2007					55 60 65 70 75

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND
- * Sample Not Recovered
- 2.5" OD Split Spoon Sample
- Shelby Tube Sample Portland Test Pit Log
- 3.25" O.D. Split Spoon Sample

Plastic Limit — Liquid Limit
Natural Water Content

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-7

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A8
Sheet 2 of 2

Total Depth:	26.5 ft.	Northing:	~	Drilling Method:	Mud Rotary
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75
Horiz. Datum:		Offset:	~	Other Comments:	

Hole Diam.: 5 in.
Rod Type: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

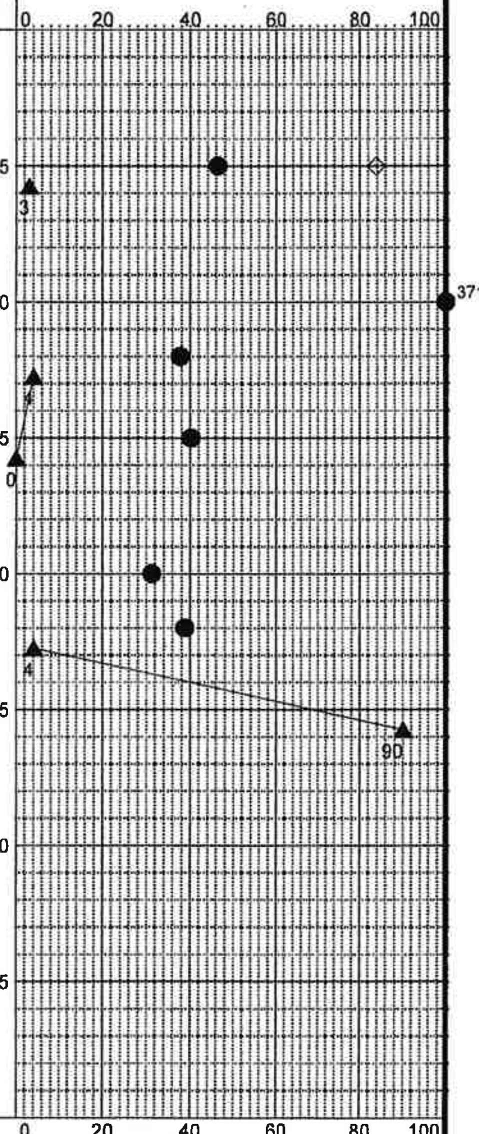
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.

Soil Description	Elev. / Depth (ft.)	Samples
Loose dark brown SILT, moist, numerous roots (Based on drill cuttings). (ML) **TOPSOIL**	44 / 1.0	
Brown silty GRAVEL, moist, rounded to subangular gravel (Based on drill cuttings). (GM) **FILL**	40.5 / 4.5	S-1
Very loose brown silty SAND, moist, fine to medium sand, micaceous, no to low plasticity silt. (SM)		S-2, S-3
Very soft brown sandy SILT, moist, no plasticity, fine sand. (ML) **ALLUVIUM**	30 / 15.0	S-4
Very loose brown silty SAND, moist, fine to medium sand, micaceous, occasional seams of sandy GRAVEL with traceof silt. (SM)	25 / 20.0	S-5, S-6
Dense SAND layer approximately 12 inches thick of unknown silt content (According to driller). (SW/SM)	21 / 24.0	
Very dense gray and brown sandy GRAVELwith silt, moist, rounded to subrounded gravel, slight Fe-oxidation, granitic, quartzitic and basaltic clasts in a sand with silt matrix. (GW-GM) **ALLUVIUM**	20 / 25.0	S-7
Bottom of Boring Completed 2/25/2008.	18.5 / 26.5	

Symbol | Samples | Ground Water | Depth, ft.

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- Ⅰ Standard Penetration Test
- Ⅱ 3" O.D. Shelby Tube

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-8

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A9

MASTER LOG E TRI-CITY WWTP.GPJ SHAN WIL.GDT 8/7/08 Log: CKS Rev: Typ: CKS

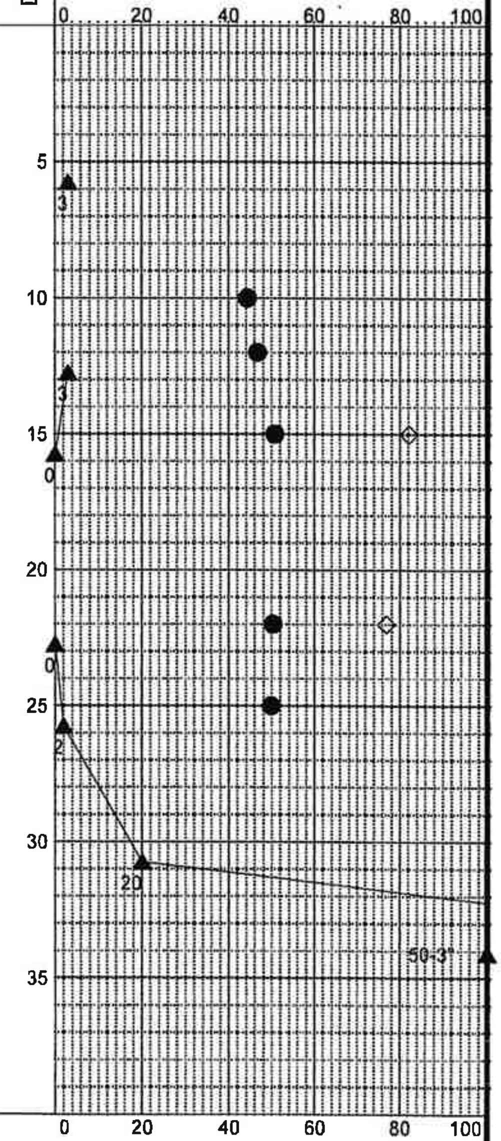
Total Depth:	34.2 ft.	Northing:	~	Drilling Method:	Mud Roatary	Hole Diam.:	5 in.
Top Elevation:	45 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.

Soil Description	Elev. Depth (ft.)	Samples	Ground Water
Loose dark brown SILT, moist, scattered roots and organics (Based on drill cuttings). (ML) **TOPSOIL**	43 / 2.0		
	41.5 / 3.5		
Brown silty GRAVEL, moist, rounded to subangular gravel (Based on drill cuttings and driller). (GM) **FILL**	38.5 / 6.5	S-1	
Soft Red-brown and gray mottled SILT trace of fine sand, moist, scattered wood debris, non to low plasticity silt. (ML)		S-2, S-3	
Very loose brown silty SAND, moist to wet, fine to medium sand, non to low plasticity silt, micaceous, faintly stratified. (SM) **ALLUVIUM**	14 / 31.0	S-4, S-5, S-6, S-7, S-8	During Drilling ⊽
Medium dense in upper to very dense lower gray to gray-brown sandy GRAVEL with silt, moist to wet, fine to coarse sand, rounded to subrounded gravel, scattered cobbly zones, driller losing circulation. (GW-GM) **ALLUVIUM**	10.8 / 34.2	S-8	
Bottom of Boring Completed 2/25/2008			

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- Ɪ Standard Penetration Test
- ǁ 3" O.D. Shelby Tube
- ⊽ Ground Water Level

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-9

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A10

Total Depth:	40.2 ft.	Northing:	~	Drilling Method:	Mud Roatary
Top Elevation:	50 ft.	Easting:	~	Drilling Company:	Hardcore Drilling
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75
Horiz. Datum:		Offset:	~	Other Comments:	

Hole Diam.: 5 in.
Rod Type: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

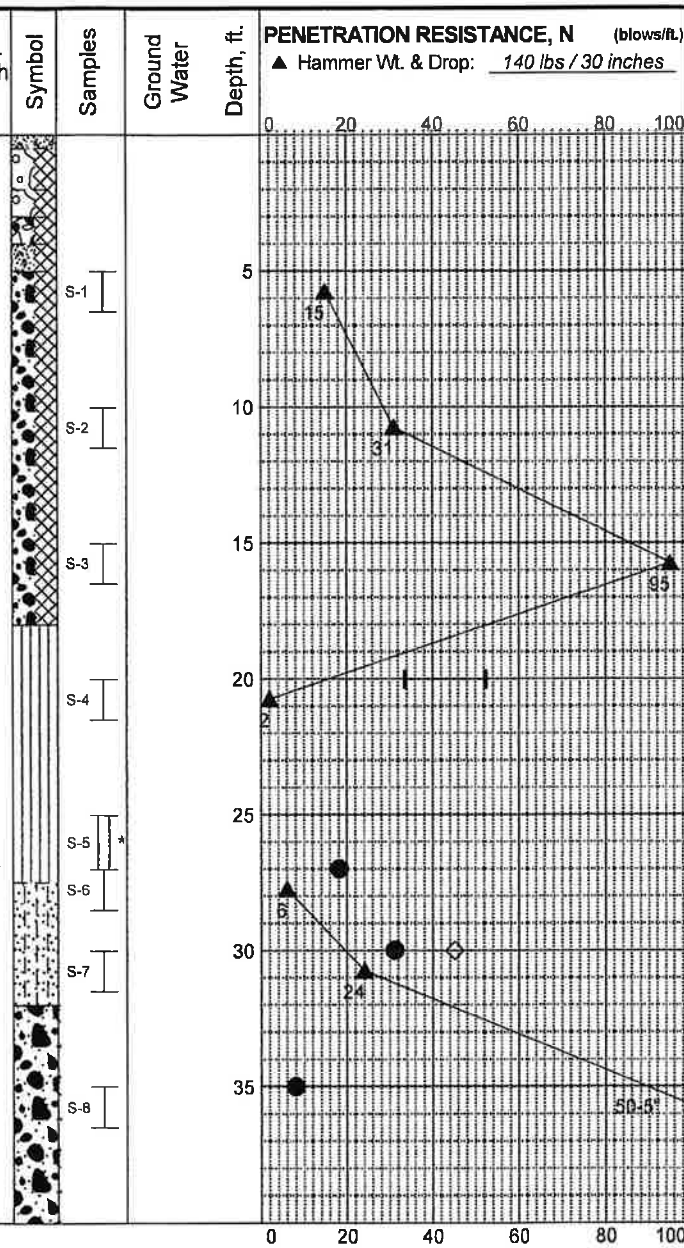
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.

Soil Description	Elev. / Depth (ft.)	Samples
Concrete- old building pad.	49.5 / 0.5	
Cobbles and gravel/ Railroad Ballast Fill (According to driller).	48 / 2.0	
Silty sandy GRAVEL (According to driller).	47 / 3.0	
6 to 8-inch diameter cobble encountered (According to driller).	46 / 4.0	
Concrete chunks encountered (According to driller and observed in drill cuttings).	45 / 5.0	S-1
Medium dense to very dense light gray and gray-brown to pinkish-gray sandy GRAVEL with silt, moist, rounded to angular fine to medium gravel up to 1.5-inch diameter, numerous lenses and pockets of bentonite or ash. (GW-GM) **FILL**		S-2, S-3
Wood debris encountered.	32 / 18.0	
Very soft to soft gray SILT trace of sand, trace of clay, moist, low to medium plasticity, fine sand, micaceous, occasional to scattered organics. (ML) **ALLUVIUM**	22.5 / 27.5	S-4, S-5*
Loose to medium dense gray-brown and brown interbedded silty SAND and SAND trace of silt, moist, silty SAND typically fine sand with low plasticity silt, SAND with trace of silt typically medium to coarse sand, trace of micas, rounded to subrounded medium gravels at 31.0 feet. (SW/SM)	18 / 32.0	S-6, S-7
Very dense gray-brown sandy GRAVEL with silt, moist, rounded to subangular gravel, occasional cobbles, slight Fe-oxidation. (GW-GM)		S-8

CONTINUED NEXT SHEET

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND
- * Sample Not Recovered
- Ɪ Standard Penetration Test
- Ⅱ 3" O.D. Shelby Tube

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-10

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A11
Sheet 1 of 2

Total Depth:	40.2 ft.	Northing:	~	Drilling Method:	Mud Roatary	Hole Diam.:	5 in.
Top Elevation:	50 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.	PENETRATION RESISTANCE, N (blows/ft.) ▲ Hammer Wt. & Drop: 140 lbs / 30 inches
ALLUVIUM	9.8		S-9			50/4" ▲
Bottom of Boring Completed 2/26/2008.	40.2					
					45	
					50	
					55	
					60	
					65	
					70	
					75	

0 20 40 60 80 100

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND
* Sample Not Recovered
Ⅰ Standard Penetration Test
Ⅱ 3" O.D. Shelby Tube

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-10

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A11
Sheet 2 of 2

Total Depth:	46.5 ft.	Northing:	~	Drilling Method:	Hollow Stem Auger	Hole Diam.:	8 in.
Top Elevation:	40 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.

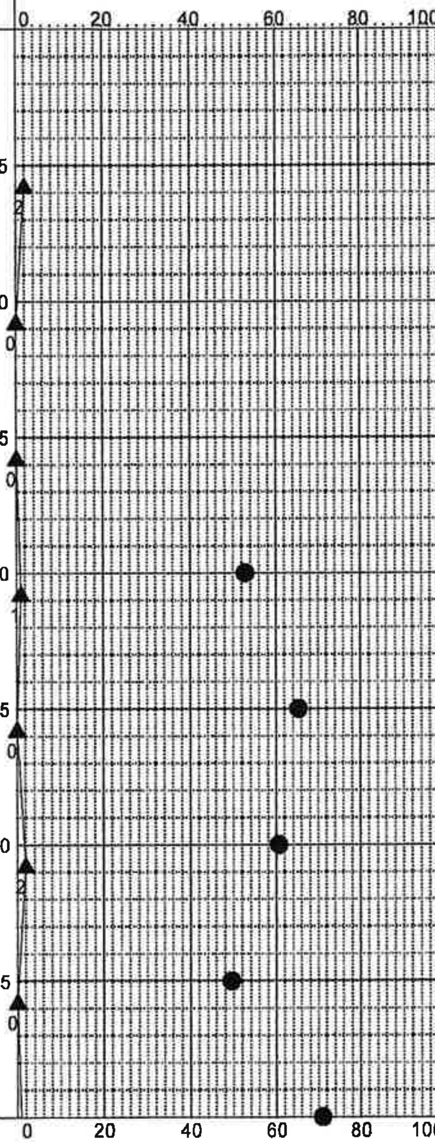
Soil Description	Elev. / Depth (ft.)	Samples	Depth, ft.
Dark brown SILT numerous roots and organics. (ML) **TOPSOIL**	39.5 / 0.5		
Very soft to soft red-brown SILT trace of sand and gravel, moist, fine subrounded to subangular gravel, slight Fe-oxidation. (ML) **FILL**		S-1	5
Very soft dark gray-brown SILT trace of fine sand, wet, no plasticity silt, occasional to scattered seams to layers of fine sand with numerous organics and wood debris, trace of micas. (ML) **GRAVEL PIT WASH DEPOSITS**	30 / 10.0	S-2, S-3, S-4	10, 15, 20
Very soft dark gray-brown interbedded to laminated fine sandy SILT and silty fine to medium SAND with scattered organics, wet, trace of micas, no to low plasticity, occasional organic odor. (ML/SM) **GRAVEL PIT WASH DEPOSITS**	15 / 25.0	S-5, S-6, S-7	25, 30, 35

Ground Water: During Drilling ⊻ (at approx. 36 ft.)

CONTINUED NEXT SHEET

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered

⌶ Standard Penetration Test

⊻ Ground Water Level

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-11

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
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FIG. A12
Sheet 1 of 2

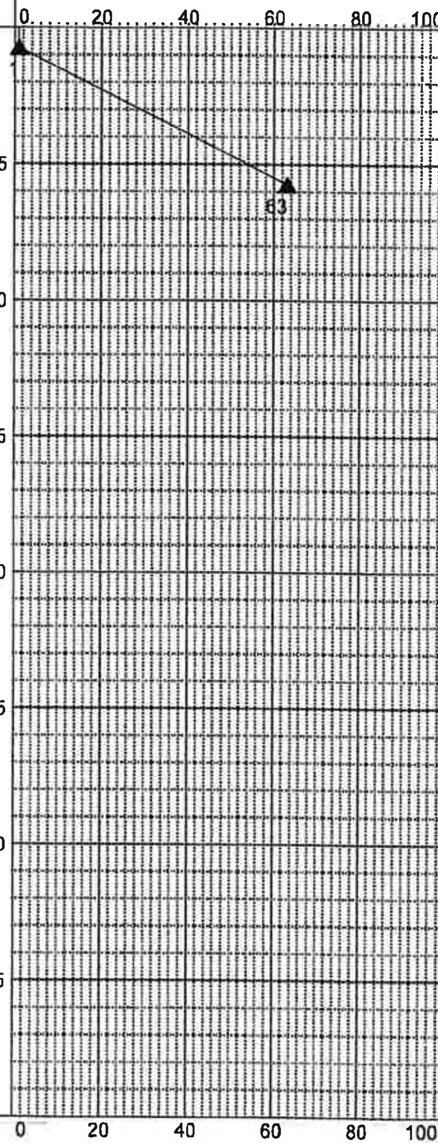
MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: CKS Rev: Typ: CKS

Total Depth:	46.5 ft.	Northing:	~	Drilling Method:	Hollow Stem Auger	Hole Diam.:	8 in.
Top Elevation:	40 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
continued, Very soft dark gray-brown interbedded to laminated fine sandy SILT and silty fine to medium SAND with scattered organics, wet, trace of micas, no to low plasticity, occasional organic odor. (ML/SM) **GRAVEL PIT WASH DEPOSITS**	-3.5 43.5		S-8		
Very dense gray to reddish-brown sandy GRAVEL with silt, moist, ronded to subrounded gravel. (GM-GW) **ALLUVIUM**	-6 46.0		S-9		45
Very hard clayey SILT trace of sand, moist, moderate Fe-oxidation, relic conglomerate structure or relic siltstone, severely weathered gravel. (MH) **SILTSTONE**	-6.5 46.5				
Bottom of Boring Completed 2/26/2008.					

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered

Ground Water Level

Standard Penetration Test

Plastic Limit ├──●──┤ Liquid Limit

Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-11

May 2008 | 24-1-03420-001

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FIG. A12
Sheet 2 of 2

Total Depth:	*31.5 ft.*	Northing:	~	Drilling Method:	*Hollow Stem Auger*	Hole Diam.:	*8 in.*
Top Elevation:	*48 ft.*	Easting:	~	Drilling Company:	*Hardcore Drilling*	Rod Type:	*NWJ*
Vert. Datum:		Station:	~	Drill Rig Equipment:	*CME-75*	Hammer Type:	*Automatic*
Horiz. Datum:		Offset:	~	Other Comments:			

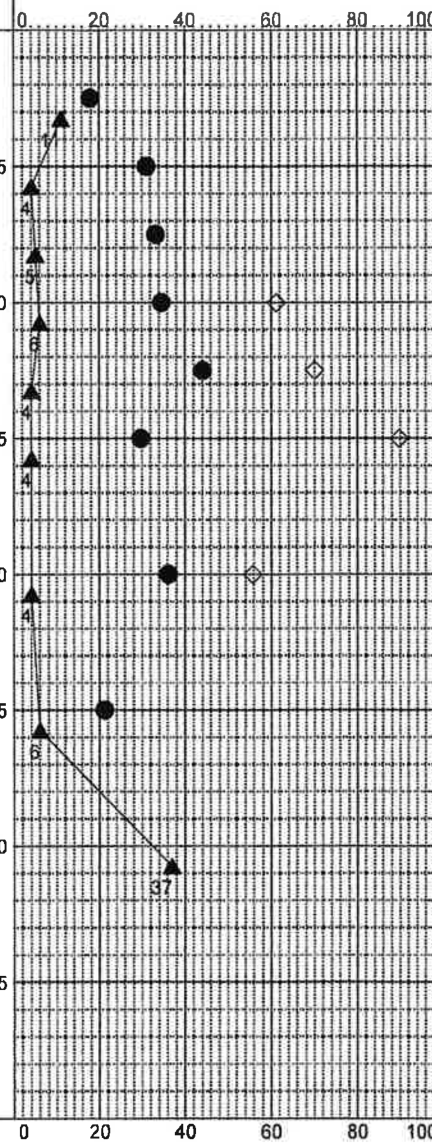
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.

SOIL DESCRIPTION	Elev. Depth (ft.)	Samples
Sandy GRAVEL with cobbles, moist, angular to subangular gravels and cobbles. (GM) **RAILROAD BALLAST FILL**	*46* 2.0	
Very loose to loose brown silty SAND, moist, fine to medium sand, no to low plasticity silt, occasional pockets of dark brown silt with scattered organic debris. (SM) **ALLUVIUM**	*33* 15.0	S-1, S-2, S-3, S-4, S-5
Soft brown sandy SILT, moist, fine to medium sand, no to low plasticity silt, occasional organic debris. (ML)	*28* 20.0	S-6
Very loose to loose brown silty SAND, moist, fine to medium sand, no to low plasticity silt, micaceous. (SM)	*18.5* 29.5	S-7, S-8
Dense brown-gray sandy GRAVEL trace of silt, dry to moist, rounded to subangular gravel, fine to medium gravel up to 1.5-inch diameter. (GW) **ALLUVIUM**	*16.5* 31.5	S-9
Bottom of Boring Completed 2/27/2008.		

PENETRATION RESISTANCE, N (blows/ft.)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
I Standard Penetration Test

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-12

May 2008 24-1-03420-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

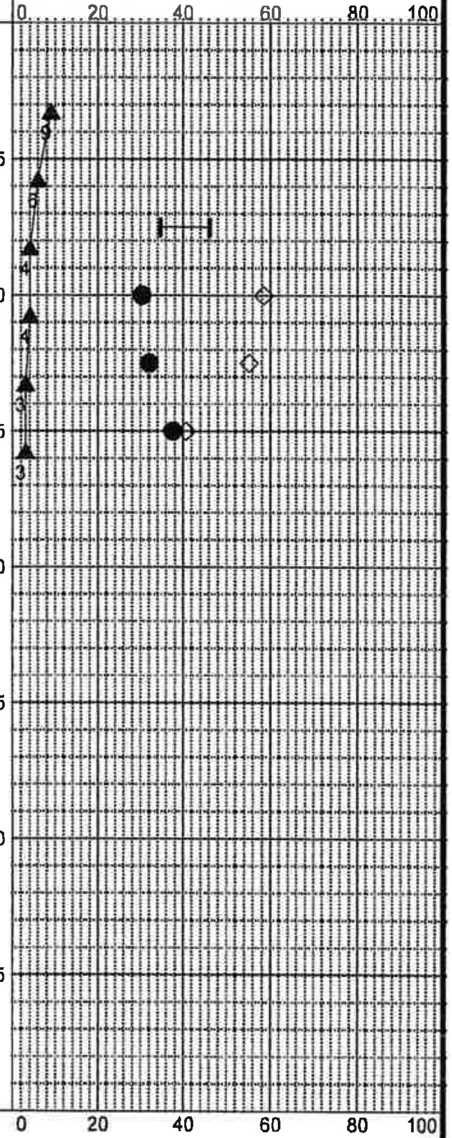
FIG. A13

MASTER_LOG_E TRI-CITY WWTP.GPJ SHAN_WIL.GDT 8/7/08 Log: CKS Rev: Typ: CKS

Total Depth:	17 ft.	Northing:	~	Drilling Method:	Hollow Stem Auger	Hole Diam.:	8 in.
Top Elevation:	46 ft.	Easting:	~	Drilling Company:	Hardcore Drilling	Rod Type:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME-75	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*	Elev. Depth (ft.)	Symbol	Samples	Ground Water	Depth, ft.
Loose brown silty SAND, moist, fine to medium sand, low plasticity silt, occasional to scattered roots and organic debris, trace of subrounded gravels in upper 4.0 feet. (SM) **FILL**	*38.5* 7.5		S-1, S-2		5
Soft brown sandy SILT, moist, fine sand, low plasticity silt, occasional roots and organic debris. (ML)	36 10.0		S-3		10
Very loose brown silty SAND, moist, fine to medium sand, low plasticity silt, occasional roots and organic debris. (SM) **ALLUVIUM**	29 17.0		S-4, S-5, S-6		15
Bottom of Boring Completed 2/27/2008.					20, 25, 30, 35

PENETRATION RESISTANCE, N (blows/ft.)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND
* Sample Not Recovered
I Standard Penetration Test

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

LOG OF BORING IB-13

May 2008 24-1-03420-001

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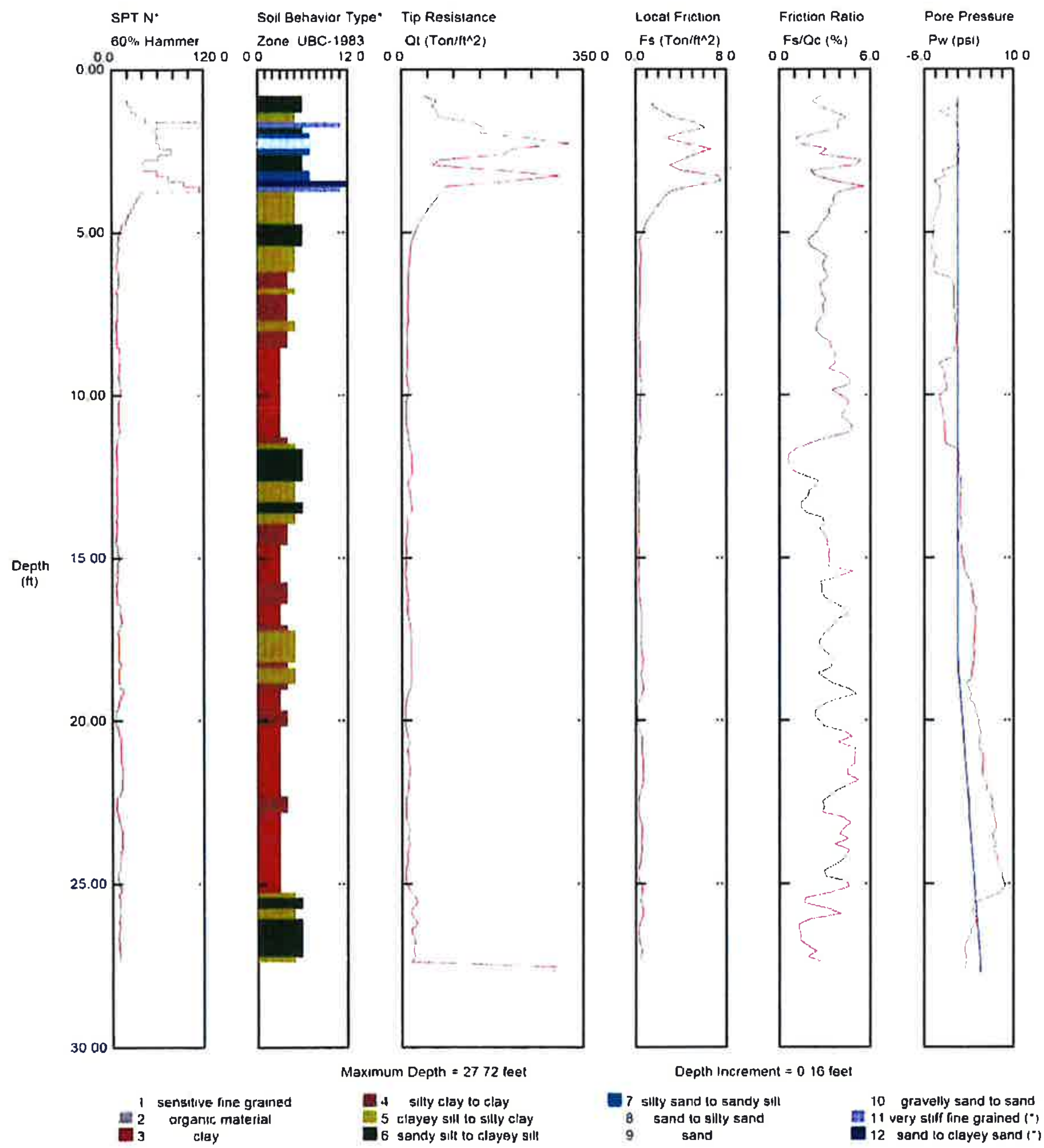
FIG. A14

*Soil behavior type and SPT based on data from UBC-1983

CPT-1

Operator JSP/SVAN/VAN EXP
Sounding FILO04
Cone Used 4CH

CPT Date/Time 08-14-07 08 49
Location CP1 AGNESWWTP OC
Job Number S&W/24-1-03420-1



NOTES:
1. A Log of probe is based on piezocone probe data provided by Vandehey Explorations.
2. The pore pressure was measured behind the tip of the penetrometer. Hydrostatic pore pressure based on an estimated groundwater depth.
3. The estimated soil properties are based on analyses performed using published correlations and equations. The method used for estimating the properties listed above are:
a. Uncorrected N-Value (N60) based on Robertson & Campanella.
b. Soil Behavior Type based on UBC-1983.

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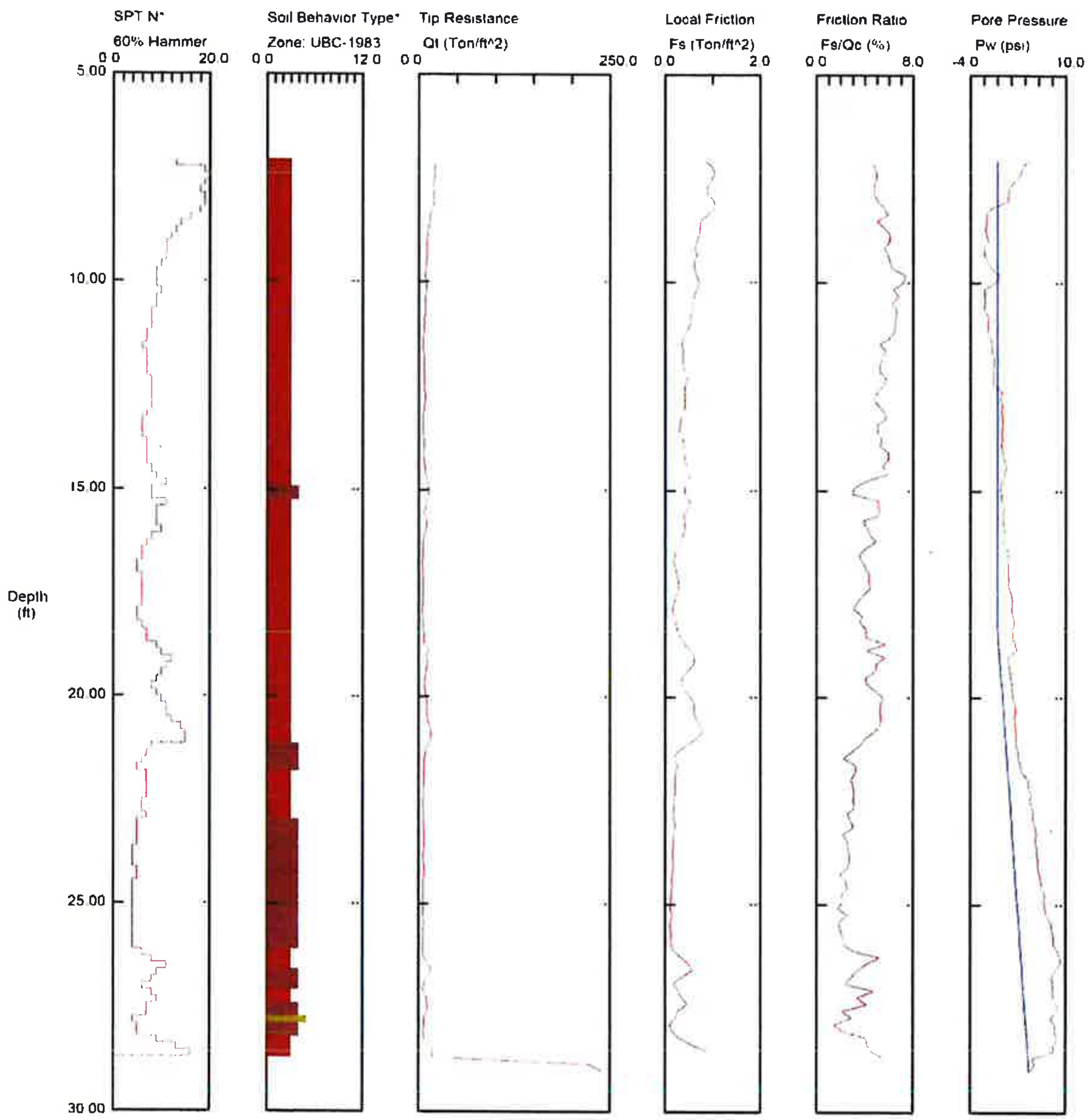
FIG. A15

*Soil behavior type and SPT based on data from UBC-1983

CPT-2

Operator JSP/SVAN/VAN EXP
Sounding FIL005
Cone Used 4CH

CPT Date/Time 08-14-07 11 04
Location: CP2 AGNESWWTP OC
Job Number S&W/24-1-03420-1



Maximum Depth = 29.04 feet

Depth Increment = 0.16 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

NOTES:
1. A Log of probe is based on piezocone probe data provided by Vandehey Explorations.
2. The pore pressure was measured behind the tip of the penetrometer. Hydrostatic pore pressure based on an estimated groundwater depth.
3. The estimated soil properties are based on analyses performed using published correlations and equations. The method used for estimating the properties listed above are:
a. Uncorrected N-Value (N60) based on Robertson & Campanella.
b. Soil Behavior Type based on UBC-1983.

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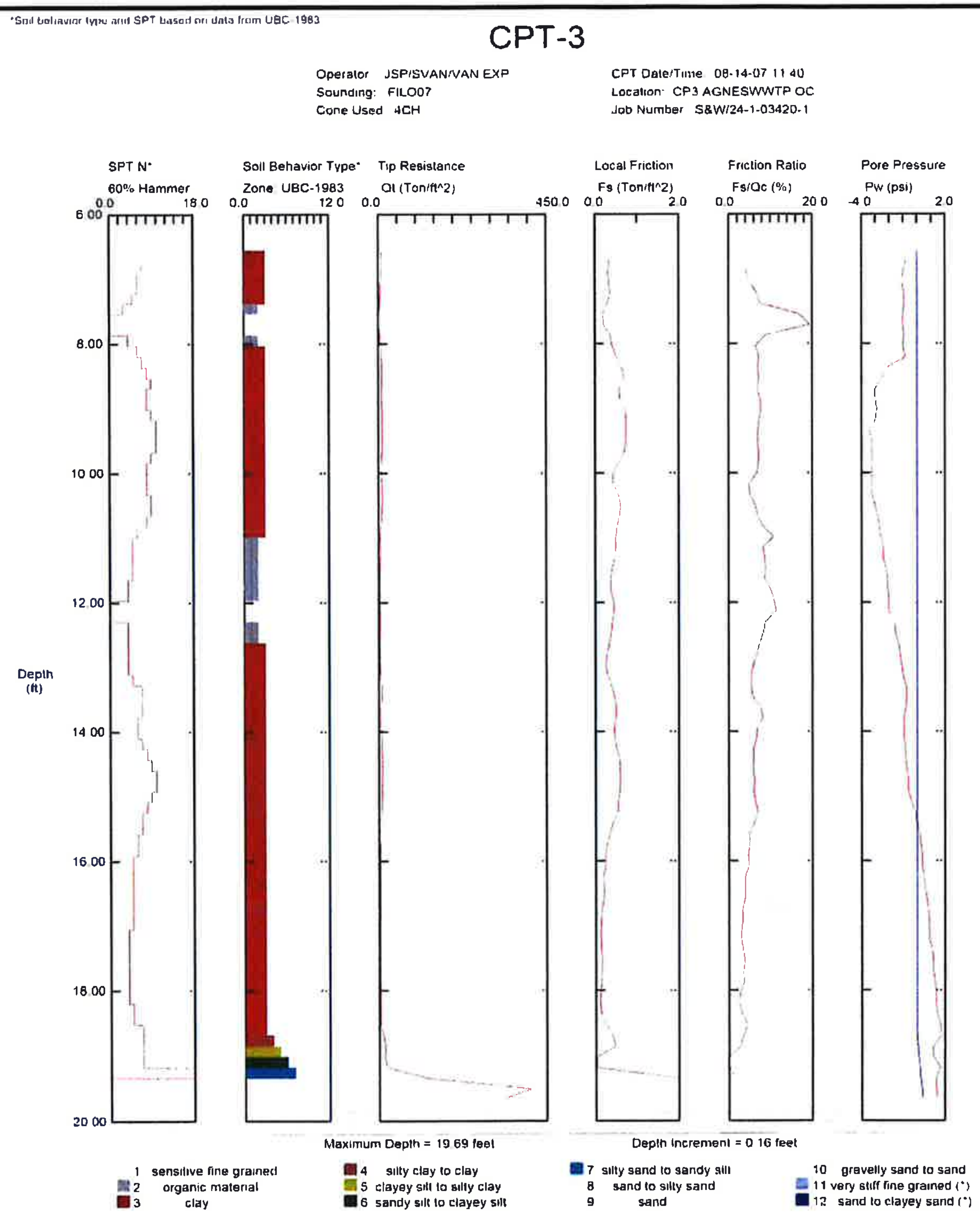
FIG. A16



NOTES:

1. A Log of probe is based on piezocone probe data provided by Vandehey Explorations.
2. The pore pressure was measured behind the tip of the penetrometer. Hydrostatic pore pressure based on an estimated groundwater depth.
3. The estimated soil properties are based on analyses performed using published correlations and equations. The method used for estimating the properties listed above are:
a. Uncorrected N-Value (N60) based on Robertson & Campanella.
b. Soil Behavior Type based on UBC-1983.

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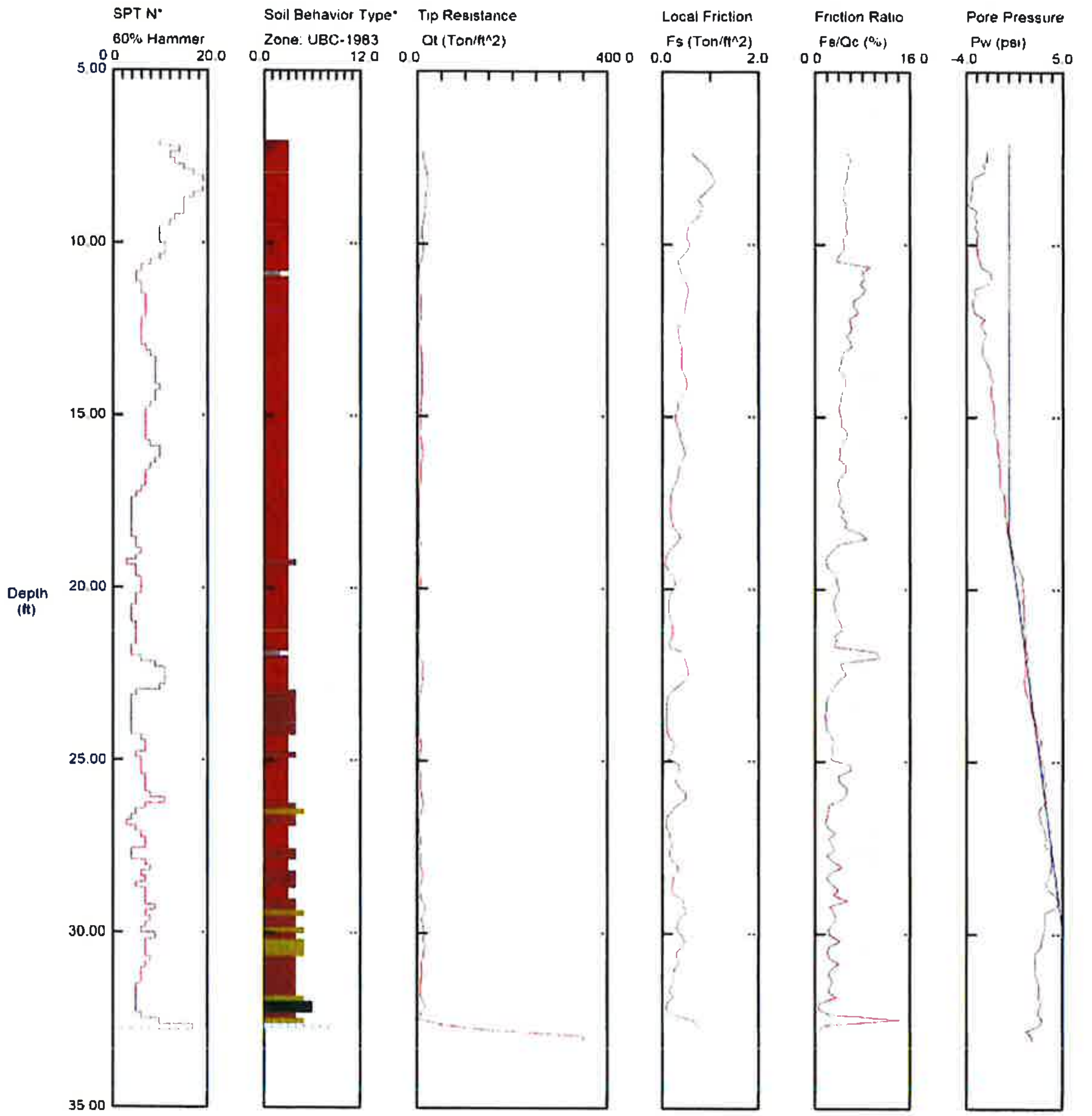
FIG. A17

*Soil behavior type and SPT based on data from UBC 1983

CPT-4

Operator JSP/SVAN/VAN EXP
Sounding: FILO08
Cone Used 4CH

CPT Date/Time 08-14-07 13:00
Location CP4 AGNESWWTP OC
Job Number S&W/24-1-03420-1



Maximum Depth = 33.14 feet

Depth Increment = 0.16 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

NOTES:
1. A Log of probe is based on piezocone probe data provided by Vandehey Explorations.
2. The pore pressure was measured behind the tip of the penetrometer. Hydrostatic pore pressure based on an estimated groundwater depth.
3. The estimated soil properties are based on analyses performed using published correlations and equations. The method used for estimating the properties listed above are:
a. Uncorrected N-Value (N60) based on Robertson & Campanella.
b. Soil Behavior Type based on UBC-1983.

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FIG. A18

APPENDIX B
S&W LABORATORY TESTING

APPENDIX B

S&W LABORATORY TESTING

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APPENDIX B

S&W LABORATORY TESTING

B.1 GENERAL

A laboratory testing program was developed and implemented in order to evaluate physical and engineering characteristics of the subsurface soils. Laboratory tests on selected soil samples included standard classification tests, which consisted of visual examination, moisture/density tests, Atterberg limits, grain-size analysis, hydrometers, and grain-size wash analysis, i.e., percent finer than the No. 200 sieve. In addition, in-place density tests, in-situ shear strength and unconfined compressive strength tests were conducted on selected undisturbed thin-walled samples. This Appendix contains the full lab results from S&W laboratory testing program, in addition to Figure B1, which summarizes all laboratory testing performed on samples collected on site (this includes the laboratory results from previous work done on-site by others). We cannot assure the completeness or accuracy of the data from other sources, but the information was used by Shannon & Wilson to supplement our interpretation of subsurface conditions and soil properties. The last column of Figure B1 indicates from which previous report the laboratory data was assembled.

B.1.1 Moisture (Natural Water) Content

Selected soil samples were evaluated to determine their in-situ water content. The moisture content is defined as the ratio of the weight of water to the dry weight of soil, expressed as a percentage. The results from our moisture testing are shown on Figure B-1. Additionally, the results of the moisture content determinations are presented on the logs of the borings in Appendix A.

B.1.2 Atterberg Limits

Atterberg Limits were determined on selected samples of fine-grained soils (that is, silts, clays and clayey silts) for the purpose of classifying fine-grained soils into groups based on plastic properties of the soil. Plastic properties of soils are used in a number of soil property correlations. Table 1 below shows the results of the Atterberg Limits tests that were performed by Shannon & Wilson. The results of the Atterberg Limits test are plotted on the plasticity chart on Figure B2 in this appendix.

TABLE 1
Atterberg Limits

Boring	Depth, ft	Liquid Limit	Plastic Limit	Plasticity Index	Classification
IB-2	15	44	32	12	ML
IB-3	20	41	30	11	ML
IB-4	15	34	33	1	ML
IB-4	30	41	35	6	ML
IB-9	20	NP	NP	NP	ML
IB-10	20	52	34	18	MH
IB-13	7.5	45	35	11	ML

B.1.3 Grain-Size Analyses

Grain-size analyses were conducted on selected soil samples to determine their particle size distribution. For most samples, a wet sieve analyses was performed to determine a percentage (by weight) of the sample passing the No. 200 (0.75 mm) sieve. For selected samples, a full grain size distribution curve was developed by testing the minus No. 10 material using a hydrometer, washing the full sample over a No. 200 sieve, and sieving the plus No. 200 material through a series of sieves to determine the distribution of the plus No. 200 material. The hydrometer plus sieving results were used to develop the particle-size distribution curves down to 0.002 mm. Table 2 below shows the tabular results of S&W grain size analysis. Figure B3 in this appendix presents the results of the Grain-Size Analysis.

TABLE 2
Grain-Size Analysis

Boring	Depth, ft	Percent Gravel	Percent Sand	Percent Fines	Classification
IB-1	10	--	--	60.8	ML
IB-1	20	--	--	87.2	ML
IB-2	22	0.0	52.2	47.8	SM
IB-4	17	--	--	60.7	ML
IB-4	35	--	--	42.0	SM
IB-5	22	0.0	43.2	56.8	ML
IB-8	5	--	--	83.8	ML
IB-9	15	0.0	17.9	82.1	ML
IB-9	22	--	--	76.8	ML
IB-10	30	--	--	45.2	SM
IB-12	10	--	--	61.1	ML
IB-12	12.5	--	--	70.0	ML

IB-12	15	0	10.3	89.7	
IB-12	20	--	--	55.6	ML
IB-13	10	--	--	58.4	ML
IB-13	12.5	0	44.9	32.0	
IB-13	15	--	--	40.6	SM

B.1.4 Unit Weight of Undisturbed Samples

The unit weights, or densities, from the thin-walled Shelby tube samples were determined in the laboratory. Results from S&W testing are below in Table 3. The results from all Unit weight measurements performed on-site are presented in this appendix.

TABLE 3
Unit Weight of Undisturbed Samples

Boring	Depth, ft	Dry Density pcf
IB-2	20	73.87
IB-4	15	84.37
IB-5	20	95.56
IB-8	20	91.0
IB-9	10	83.3

B.1.5 Consolidation Test

Shannon & Wilson performed one consolidation test on a sample from the Alluvial Silts at a depth of 20 ft, in the vicinity of the UV disinfection building. A consolidation test indicates the amount of deformation that a soil may undergo when subjected to a certain load. The consolidation test indicated that the soils at under the UV building have exhibit compressive characteristics as shown on Figure B4, in this appendix. The results from all consolidation tests performed on-site are presented on Figure B1, with the full lab results presented in Appendix D.

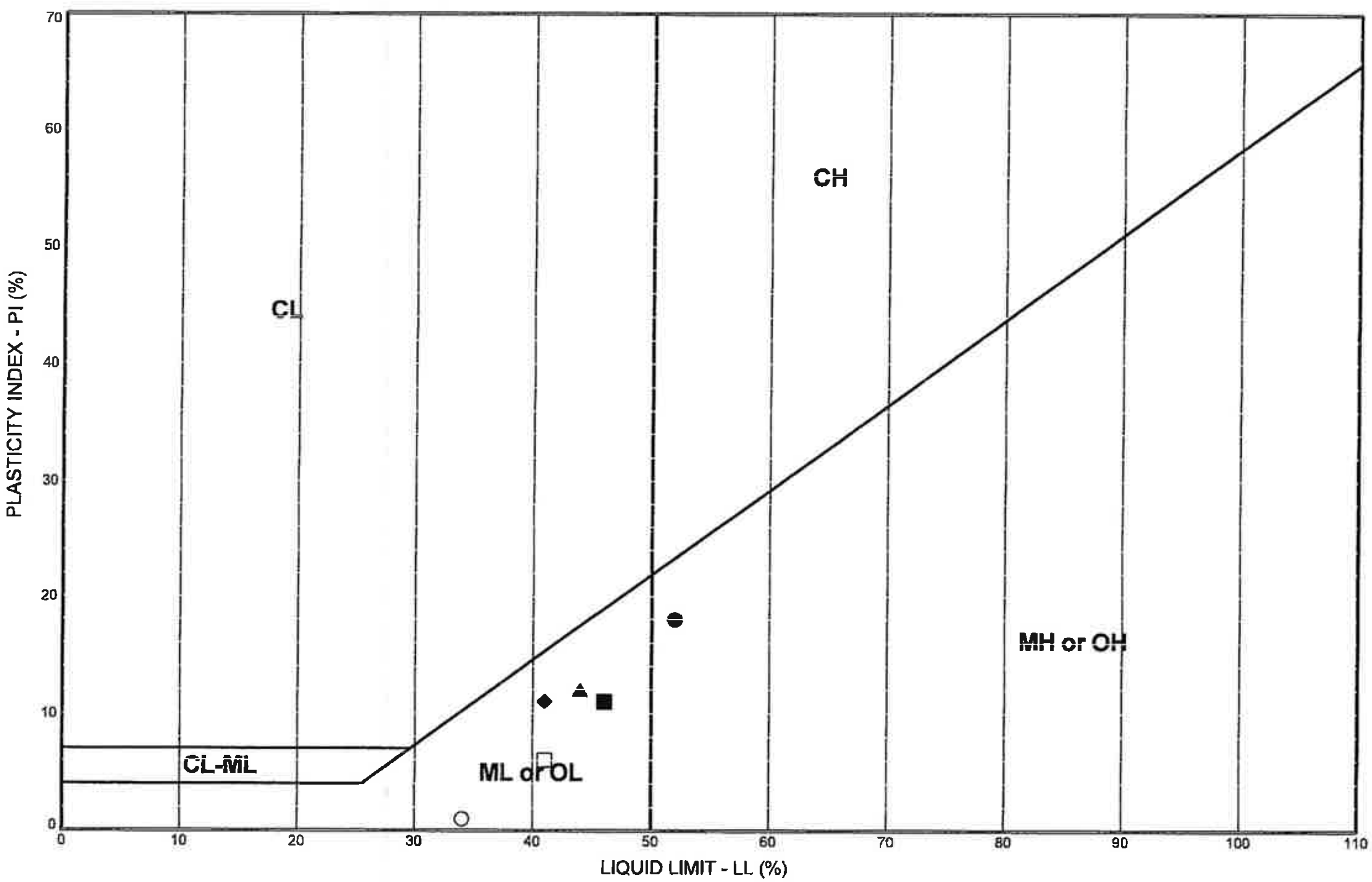
FIGURE B1 - LAB TESTING SUMMARY

Boring	Sample Number	Sample Type	SPT N-value	Sample Depth (ft) Top	Bottom	Rec. (ft)	Geologic Unit	USCS	Classification	Water Content (%)	Atterberg Limits L.L.	P.L.	P.I.	Grain Size Distribution Gravel (%)	Sand (%)	Fines (%)	C_c	C_u	Unit Weight (pcf) Wet	Dry	Direct Shear C' (psf)	ϕ (deg)	Laboratory Data Source, Date
B-101	SS-1	SPT	23	2.5	4		SILT	ML		30.0													CH_2M Hill, 2002
B-101	SS-8	SPT	7	27.5	29		SILT	ML		45.0	42	31	11										CH2M Hill, 2002
B-102	SS-3	SPT	11	10	11.5		SILT	ML		42.0													CH2M Hill, 2002
B-102	SO-6	Shelby	N/A	22.5	24.5		SILT	ML		43.0	48	32	26						110	77			CH2M Hill, 2002
B-102	SS-7	SPT	9	24.5	26		SILT	ML		45.0													CH2M Hill, 2002
B-102	SS-10	SPT	27	30.5	32		Silty SAND	SM								19.0							CH2M Hill, 2002
B-103	SS-4	SPT	2	15	16.5		SILT	ML		50.0	44	31	14										CH2M Hill, 2002
B-103	SS-6	SPT	4	22.5	24		SILT	ML		46.0													CH2M Hill, 2002
B-103	SS-8	SPT	15	27	28.5		Silty SAND	SM								29.0							CH2M Hill, 2002
B-103	SS-11	SPT	35	36	37.5		Silty GRAVEL	GM								6.0							CH2M Hill, 2002
B-104	SS-1	SPT	54-11"	5	5.92		SILT	ML		34.0													CH2M Hill, 2002
B-104	SS-4	SPT	9	26	27.5		Silty SAND	SM		37.0						47.0							CH2M Hill, 2002
B-105	SS-1	SPT	19	5	6.5		SILT	ML		32.0													CH2M Hill, 2002
B-105	SS-4	SPT	6	15	16.5		SILT	ML		35.0													CH2M Hill, 2002
B-105	SS-7	SPT	6	25	26.5		SILT	ML		47.0	42	36	6										CH2M Hill, 2002
B-106	SO-6	Shelby	N/A	23	24.5		SILT	ML		47.0	47	38	9						104	70.8			CH2M Hill, 2002
B-106	SS-8	SPT	12	27.5	29		Silty SAND	SM								35.0							CH2M Hill, 2002
B-6	SS-3	SPT	7	15	16.5		Silty SAND	SM								43.0	2	28					CH2M Hill, 1982
B-7	ST-3	Shelby	N/A	15	16.5		SILT	ML													200	32.3	CH2M Hill, 1982
B-15	SS-5	SPT	5	15	16.5		SILT	ML			NP	41	NP										CH2M Hill, 1982
B-16	ST-4	Shelby	N/A	10	12		Sandy SILT	ML		52.0	NP	50	NP			82.0	3	21	102	57			CH2M Hill, 1982
B-17	SS-1	SPT	4	5	6.5		SILT	MH		81.0	51	35	16										CH2M Hill, 1982
B-17	ST-3	Shelby	N/A	13	15		SILT	ML		54.0					6.0	94.0	5	33	107	69.4			CH2M Hill, 1982
B-18	ST-4	Shelby	N/A	10	12		Silty SAND	SM		30.0	NP	NP	NP		53.0	47.0	1	25			0	35.5	CH2M Hill, 1982
B-17	ST-3	Shelby	N/A	13	15		SILT	ML		54.0					2.0	98.0	2	6					CH2M Hill, 1982
B-17	ST-7	Shelby	N/A	23	25		Sandy SILT	ML		52.0					32.0	58.0	2	10	105	69			CH2M Hill, 1982
IB-1	S-1	SPT	5	5	6.5		SILT	ML		39.7													Shannon & Wilson, 2007
IB-1	S-2	SPT	4	10	11.5		Sandy SILT	ML		34.8						60.8							Shannon & Wilson, 2007
IB-1	S-3	SPT	3	15	16.5		Sandy SILT	ML		43.7													Shannon & Wilson, 2007
IB-1	S-4	SPT	3	20	21.5		Sandy SILT	ML		42.8						87.2							Shannon & Wilson, 2007
IB-1	S-5	SPT	39	25	26.5		Sandy GRAVEL	GM/GP															Shannon & Wilson, 2007
IB-2	S-1	SPT	13	5	6.5		SILT	ML		35.6													Shannon & Wilson, 2007
IB-2	S-2	SPT	7	10	11.5		SILT	ML		45.0													Shannon & Wilson, 2007
IB-2	S-3	SPT	12	15	16.5		SILT	ML		43.3	44	32	12										Shannon & Wilson, 2007
IB-2	S-4	Shelby	N/A	20	22		Silty SAND	SM		21.0									89.35	73.87			Shannon & Wilson, 2007
IB-2	S-5	SPT	5	22	23.5		Silty SAND	SM		32.3					52.2	47.8							Shannon & Wilson, 2007
IB-2	S-6	SPT	100	25	25.25		Sandy GRAVEL	GP															Shannon & Wilson, 2007
IB-3	S-2	SPT	3	10	11.5		SILT	ML		43.1													Shannon & Wilson, 2007
IB-3	S-3	SPT	2	15	18.5		SILT	ML		44.1													Shannon & Wilson, 2007
IB-3	S-4	SPT	3	20	21.5		SILT	ML		41.3	41	30	11										Shannon & Wilson, 2007
IB-3	S-5	SPT	4	25	26.5		SILT	ML															Shannon & Wilson, 2007
IB-3	S-6A	SPT	52	30	31		Silty SAND	SM		35.6													Shannon & Wilson, 2007
IB-4	S-1	SPT	15	5	6.5		SILT	ML		32.7													Shannon & Wilson, 2007
IB-4	S-3	Shelby	N/A	15	17		Sandy SILT	ML		33.3	34	33	1						112.5	84.37			Shannon & Wilson, 2007
IB-4	S-4	SPT	2	17	18.5		Sandy SILT	ML		45.2						60.7							Shannon & Wilson, 2007
IB-4	S-5	SPT	0	20	21.5		SILT	ML		47.4													Shannon & Wilson, 2007
IB-4	S-6	SPT	0	25	26.5		SILT	ML		52.0													Shannon & Wilson, 2007
IB-4	S-7	SPT	0	30	31.5		SILT	ML		48.8	41	35	6										Shannon & Wilson, 2007
IB-4	S-8	SPT	3	35	36.5		Silty SAND	SM		41.6						42.0							Shannon & Wilson, 2007
IB-4	S-9	SPT	43	40	41.5		SILTSTONE	SILTST.		55.3													Shannon & Wilson, 2007
IB-5	S-2	SPT	4	10	11.5		SILT	ML		36.9													Shannon & Wilson, 2007
IB-5	S-4	Shelby	N/A	20	22		Silty SAND	SM		23.0									117.6	95.56			Shannon & Wilson, 2007
IB-5	S-5	SPT	12	22	23.5		Silty SAND	SM		20.4					43.2	56.8							Shannon & Wilson, 2007
IB-5	S-6	SPT	100	25	26.4		Silty Sandy GRAVEL	GM		34.3													Shannon & Wilson, 2007
IB-8	S-1	SPT	3	5	6.5					46.4						83.8							Shannon & Wilson, 2008
IB-8	S-2	Shelby	N/A	10	12																		Shannon & Wilson, 2008
IB-8	S-3	SPT	4	12	13.5					37.7													Shannon & Wilson, 2008
IB-8	S-4	SPT	0	15	16.5					40.1													Shannon & Wilson, 2008
IB-8	S-5	Shelby	N/A	20	22					31.2									119.4	91			Shannon & Wilson, 2008
IB-8	S-6	SPT	4	22	23.5					38.8													Shannon & Wilson, 2008
IB-9	S-2	Shelby	N/A	10	12					44.3									120.2	83.3			Shannon & Wilson, 2008
IB-9	S-3	SPT	3	12	13.5					46.6													Shannon & Wilson, 2008
IB-9	S-4	SPT	0	15	16.5					50.7				0.0	17.9	82.1							Shannon & Wilson, 2008
IB-9	S-5	Shelby	N/A	20	22						NP	NP	NP										Shannon & Wilson, 2008
IB-9	S-6	SPT	0	22	23.5					50.2						76.6							Shannon & Wilson, 2008
IB-9	S-7	SPT	2	25	26.5					49.8													Shannon & Wilson, 2008
IB-10	S-4	SPT	2	20	21.5						52	34	18										Shannon & Wilson, 2008
IB-10	S-6	SPT	6	27	28.5					18.2													Shannon & Wilson, 2008
IB-10	S-7	SPT	24	30	31.5					31.2						45.2							Shannon & Wilson, 2008
IB-10	S-8	SPT	100	35	36.5					8.0													Shannon & Wilson, 2008
IB-11	S-4	SPT	1	20	21.5					52.7													Shannon & Wilson, 2008
IB-11	S-5	SPT	0	25	26.5					65.3													Shannon & Wilson, 2008

FIGURE B1 - LAB TESTING SUMMARY

Boring	Sample Number	Sample Type	SPT N-value	Sample Depth (ft) Top	Bottom	Rec. (ft)	Geologic Unit	USCS	Classification	Water Content (%)	Atterberg Limits L.L	P.L	P.I	Grain Size Distribution Gravel (%)	Sand (%)	Fines (%)	C_c	C_u	Unit Weight (pcf) Wet	Dry	Direct Shear C' (psf)	ϕ (deg)	Laboratory Data Source, Date
IB-11	S-6	SPT	2	30	31.5					60.6													Shannon & Wilson, 2008
IB-11	S-7	SPT	0	35	36.5					49.5													Shannon & Wilson, 2008
IB-11	S-8	SPT	1	40	41.5					71.0													Shannon & Wilson, 2008
IB-12	S-1	SPT	11	2.5	4					17.9													Shannon & Wilson, 2008
IB-12	S-2	SPT	4	5	6.5					31.0													Shannon & Wilson, 2008
IB-12	S-3	SPT	5	7.5	9					33.2													Shannon & Wilson, 2008
IB-12	S-4	SPT	6	10	11.5					34.6						61.1							Shannon & Wilson, 2008
IB-12	S-5	SPT	4	12.5	14					44.1						70.0							Shannon & Wilson, 2008
IB-12	S-6	SPT	4	15	16.5									0.0	10.3	89.7							Shannon & Wilson, 2008
IB-12	S-7	SPT	4	20	21.5					36.1						55.6							Shannon & Wilson, 2008
IB-12	S-8	SPT	6	25	26.5					21.2													Shannon & Wilson, 2008
IB-13	S-3	SPT	4	7.5	9						45	35	11										Shannon & Wilson, 2008
IB-13	S-4	SPT	4	10	11.5					30.3						58.4							Shannon & Wilson, 2008
IB-13	S-5	SPT	3	12.5	14									0.0	44.9	32.0							Shannon & Wilson, 2008
IB-13	S-6	SPT	3	15	16.5					37.5						40.6							Shannon & Wilson, 2008

*Split Sample, if two water contents were taken, the higher was reported.



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	FINES %
● IB-10, S-4	20.0	MH	Brown sandy SILT	52	34	18		
■ IB-13, S-3	7.5	ML	Brown sandy SILT	46	35	11		
▲ IB-2, S-3	15.0	ML	Brown SILT, medium plasticity	44	32	12	43.3	
◆ IB-3, S-4	20.0	ML	Brown SILT, medium plasticity	41	30	11	41.3	
○ IB-4, S-3	15.0	ML	Brown SILT with sand to sandy SILT, non-plastic	34	33	1	44.6	
□ IB-4, S-7	30.0	ML	Brown SILT, low plasticity	41	35	6	48.7	
IB-9, S-5	20.0	ML	Brown SILT with sand	NP	NP	NP		

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ATTERBERG LIMITS RESULTS

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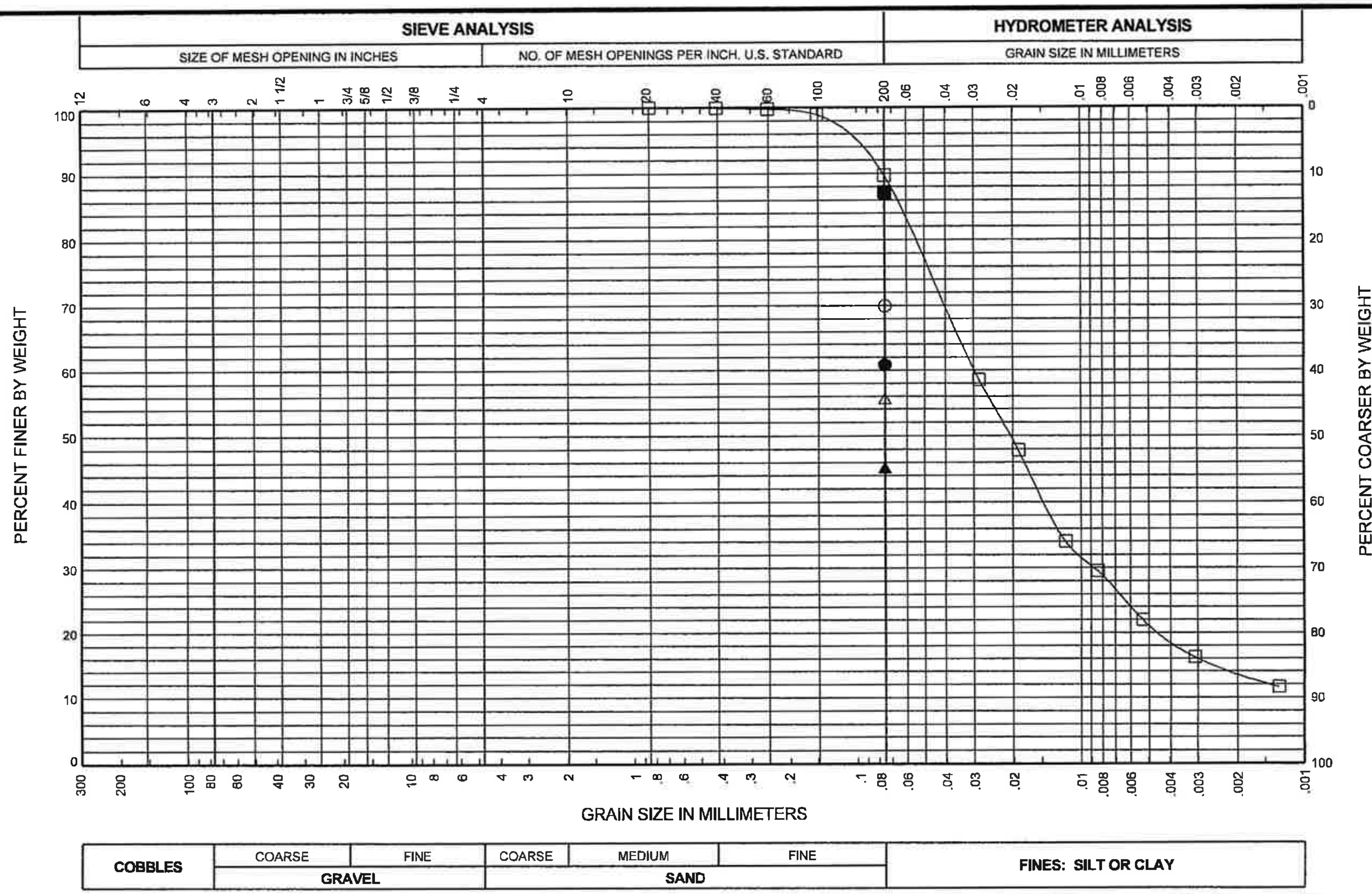
FIG. B1

FIG. B1



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	GRAVEL %	SAND %	FINES %	NAT. W.C. %	DRY DENSITY PCF
● IB-1, S-2	10.0	ML	Brown sandy SILT, non-plastic	0.0	0.0	60.8	34.8	
■ IB-1, S-4	20.0	ML	Brown SILT with sand, low plasticity	0.0	0.0	87.2	42.8	
▲ IB-10, S-7	30.0	ML	Brown sandy, gravelly SILT	0.0	0.0	45.2	31.2	
◆ IB-12, S-4	10.0	ML	Brown sandy SILT	0.0	0.0	61.1	34.6	
○ IB-12, S-5	12.5	ML	Brown sandy SILT	0.0	0.0	70.0	44.1	
□ IB-12, S-6	15.0	ML	Brown SILT with sand	0.0	10.3	89.7	29.7	
△ IB-12, S-7	20.0	ML	Brown sandy SILT	0.0	0.0	55.6	36.1	

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GRAIN SIZE DISTRIBUTION

May 2008 24-1-03420-001

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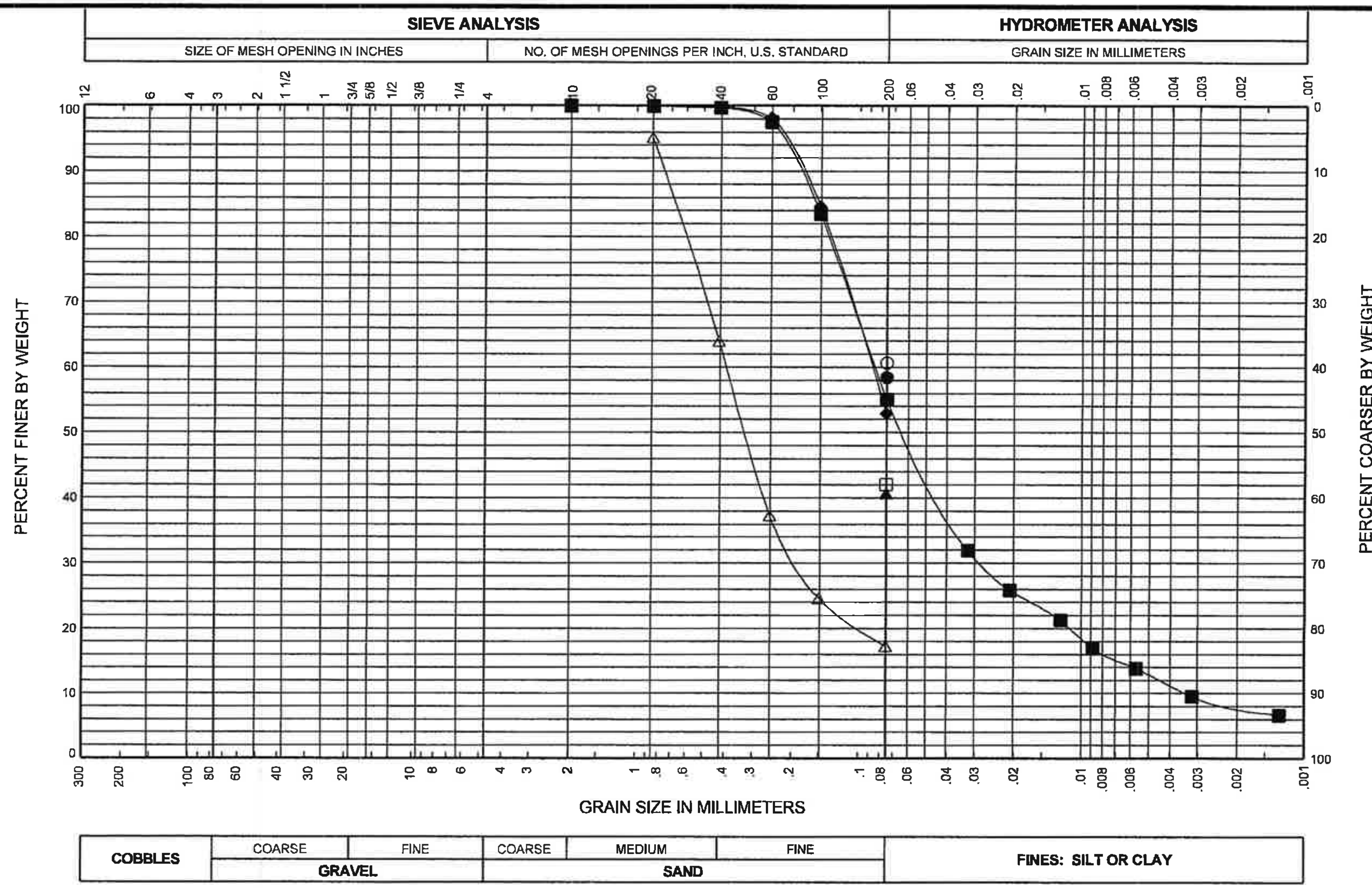
Geotechnical and Environmental Consultants

FIG. B2
Sheet 1 of 3

FIG. B2



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	GRAVEL %	SAND %	FINES %	NAT. W.C. %	DRY DENSITY PCF
● IB-13, S-4	10.0	ML	Brown sandy SILT	0.0	0.0	58.4	30.3	
■ IB-13, S-5	12.5	ML	Brown sandy SILT	0.0	44.9	55.1	32.0	
▲ IB-13, S-6	15.0	SM	Brown silty SAND	0.0	0.0	40.6	37.5	
◆ IB-2, S-5	22.0	ML/SM	Brown sandy SILT to silty SAND, non-plastic	0.0	46.9	52.9	32.3	
○ IB-4, S-4	17.0	ML	Brown sandy SILT, non-plastic	0.0	0.0	60.7	45.2	
□ IB-4, S-8	35.0	SM	Grey and brown silty SAND, non-plastic	0.0	0.0	42.0	41.6	
△ IB-5, S-5	22.0	SM	Brown silty SAND, non-plastic	0.0	77.9	17.3	20.4	

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

GRAIN SIZE DISTRIBUTION

May 2008

24-1-03420-001

SHANNON & WILSON, INC.
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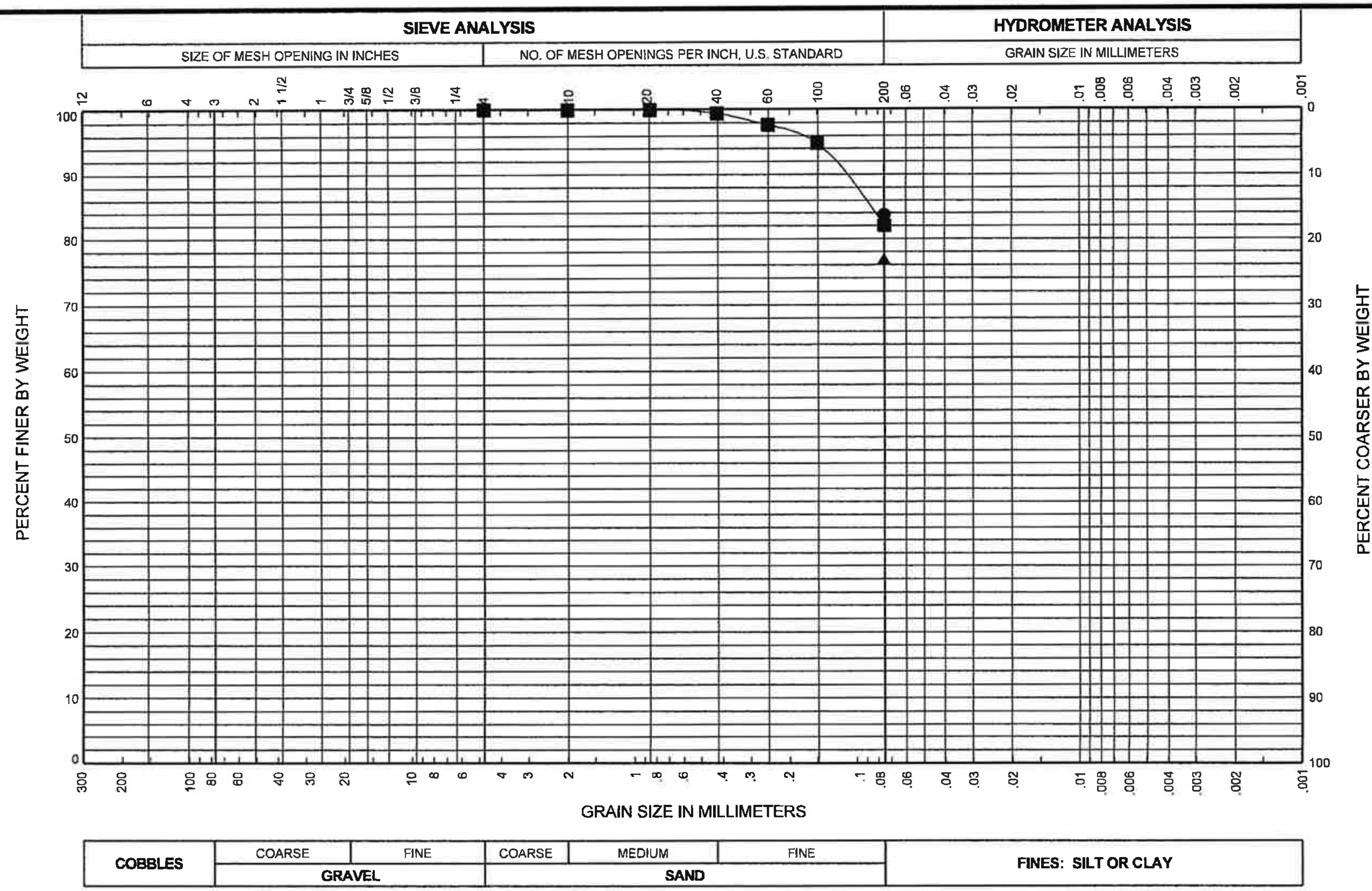
FIG. B2
Sheet 2 of 3

FIG. B2

GSA MAIN TRI-CITY WWTP.GPJ SHAN WIL.GDT 8/7/08



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	GRAVEL %	SAND %	FINES %	NAT. W.C. %	DRY DENSITY PCF
● IB-8, S-1	5.0	ML	Brown SILT with sand	0.0	0.0	83.8	46.4	
■ IB-9, S-4	15.0	ML	Brown SILT with sand	0.0	17.9	82.1	50.7	
▲ IB-9, S-6	22.0	ML	Brown SILT with sand	0.0	0.0	76.8	50.2	

Tri-City WPCP
Phase 1 Expansion
Clackamas County, Oregon

GRAIN SIZE DISTRIBUTION

May 2008

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FIG. B2
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FIG. B2

APPENDIX C

PERVIOUS PAVEMENT

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APPENDIX C

PERVIOUS PAVEMENT

C.1 GENERAL

This appendix contains a previous technical memorandum regarding the subgrade permeability beneath pervious pavement. The memo documents Shannon & Wilson's procedures for estimating subgrade permeability and recommendations for additional efforts regarding on-site measurements.

January 11, 2008

MWH Americas, Inc.
5100 SW Macadam Avenue, Suite 420
Portland, Oregon 97239

Attn: Ed Barhhurst, P.E.

RE: **PERVOIUS PAVEMENT SUBGRADE SOIL PERMEABILITY**
TRI-CITY WATER POLLUTION CONTROL PLANT
CLACKAMAS COUNTY, OREGON

Shannon & Wilson has completed an estimate of the soil permeability parameters to support the design of pervious pavements for the Tri-City WPCP expansion. The attached figure illustrates our estimates of soil Coefficient of Permeability. We evaluated and grouped soils into zones that may exhibit similar hydraulic properties based on soil type. Soil types were collected from a number of sources including, subsurface explorations conducted for this project, geotechnical reports from previous plant projects, and geotechnical reports completed for projects on adjacent properties. Once we grouped the soils into zones, we estimated the Coefficient of Permeability for each zone based on correlations developed by the Army Corps of Engineers and published by the Joint Departments of the Army, the Navy, and the Air Force in the Dewatering and Groundwater Control manual (see reference below).

In general, Coefficient of Permeability of soils can be roughly estimatted by the effective grain size of the soil (that is, the particle size of the soil for which 10% by mass of the soil has a smaller particle size and 90% by mass of the soil has a larger particle size.). Obviously we have made some very rough and approximate over simplifications by grouping soils, which have fairly complex stratigraphy, into a small number of zones. Therefore, the ranges of estimated Coefficient of Permeability for each zone are numerically quite large (one order of magnitude), but fall within the variation commonly accepted as "normal" for estimates based on grain size and soil type. We would recommend that in-situ field permeability be measured along the roadway subgrades if more precise soil properties are required or preferred for the design of the pervious pavement sections.

Sincerely,

SHANNON & WILSON, INC.

Derrick Hayes
Engineering Staff

Jerry L. Jacksha, PE
Senior Associate

DRH/JLJ/drh

ATTACHMENT:
Figure - Estimated Soil Permeability

REFERENCES

Joint Departments of the Army, the Navy, and the Air Force, Dewatering and Groundwater Control: Army TM 5-818-5, Navy NAVFAC p-418, Air Force AFM 88-5, Chapter 6, November 1983.

CH2M Hill, Tri-City WPCP Liquids Expansion Geotechnical Data Report, prepared for TSD and Clackamas County, August 2002.

CH2M Hill, Tri-City Sewerage Treatment Plant Soils Report, prepared for TSD and Clackamas County, December 1982.

URS Corporation, Phase I and Phase II Environmental Site Assessment, Tax Lot 502 Oregon City Oregon, prepared for TSD and Clackamas County, August 2001.

URS Corporation, Remedial Action Work Plan, Unpermitted Rossman Landfill, prepared for TSD and Clackamas County, June 2000.

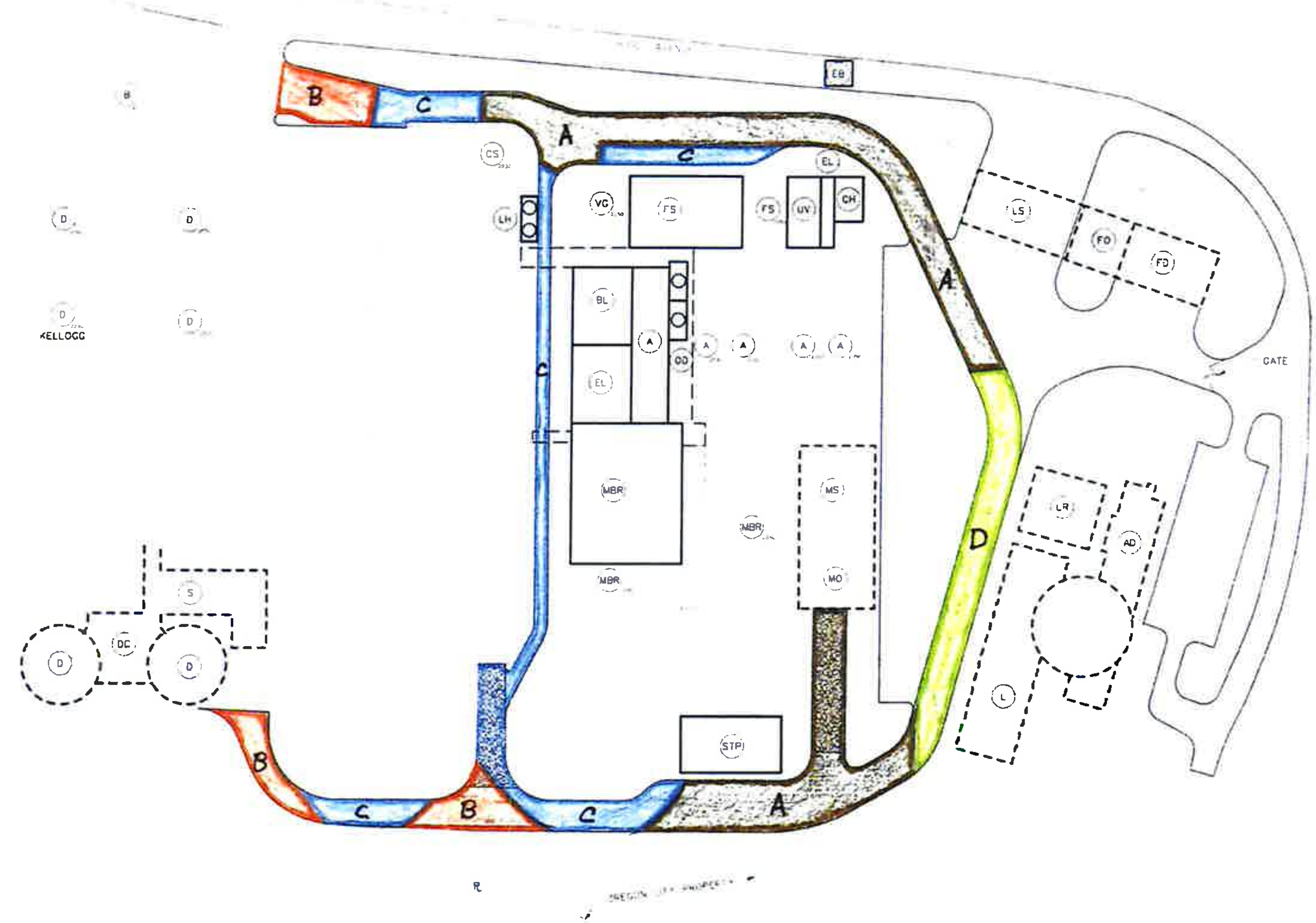
MWH test pit photographs to support the remediation of the Unpermitted Rossman Landfill, 2007

Shannon & Wilson subsurface explorations to support the design of the WPCP expansion, 2007.

PLANT NORTH

BUILDOUT PHASING

- FS — PHASE I STRUCTURE
- FS — PHASE II STRUCTURE
- MS — YR 2030 STRUCTURE
- UV — YR 2050 STRUCTURE



LEGEND

A — $1x10^{-4}$ TO $1x10^{-5}$

B — $1x10^{-3}$ TO $1x10^{-4}$

C — K- $1x10^{-2}$ - $1x10^{-3}$

D — $<1 \cdot 10^{-3}$ TO $1x10^{-4}$

MWH Portland Oregon

WATER ENVIRONMENT SERVICES A Department of Clackamas County

TRI-CITY WPCP INTERIM EXPANSION

ESTIMATED SOIL PERMEABILITY

70-C-02

APPENDIX D
PREVOIUS FIELD EXPLORATIONS

APPENDIX D

PREVIOUS FIELD EXPLAORATIONS

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APPENDIX D

PREVIOUS FIELD EXPLAORATIONS

D.1 GENERAL

This appendix contains logs from previous exploratory borings on site. The approximate location of the borings is shown on Figure 2, Site Plan. Exploratory borings from adjacent properties are not included in this appendix.

NOTES:

1. THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN SOIL BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

2. BORING LOCATIONS ARE SHOWN ON FIGURE 2.

3. BORINGS WERE LOGGED IN THE FIELD BY A CH2M HILL ENGINEERING GEOLOGIST.

4. BORINGS WERE DRILLED BY DON KENNER OF OREGON, INC. OF SHERWOOD, OREGON. BORINGS B-1 AND B-3 WERE DRILLED IN DECERMBER, 1981, USING A TRUCK-MOUNTED CME-55. THE REMAINDER OF THE BORINGS WERE DRILLED WITH A TRUCK MOUNTED CME-75 IN DECEMBER, 1981, AND IN JANUARY AND MAY, 1982.

5. TRANSITIONS BETWEEN SOIL TYPES MAY BE GRADUAL AND ARE APPROXIMATELY AT THE ELEVATIONS SHOWN.

6. SEE THE BORING LOGS FOR DETAILED DESCRIPTIONS OF THE SUBSURFACE CONDITIONS.

LEGEND

B-1 — BORING NUMBER

7 — SPLIT-SPOON SAMPLE (ASTM D1586), "N"-VALUE

STANDARD PENETRATION TEST:

BLOWS - THE NUMBER OF BLOWS FOR THREE 6-INCH INCREMENTS REQUIRED FROM A 140-LB HAMMER FALLING 30 INCHES TO DRIVE A STANDARD 2-INCH O.D. SPLIT-BARREL SAMPLER (ASTM D1586).

"N" - THE SUM OF BLOWS FOR THE SECOND AND THIRD 6- INCH INCREMENTS. IF THE SAMPLER IS DRIVEN LESS THAN 18-INCHES, THEN "N" IS THE NUMBER OF BLOWS FOR THE FRACTION OF THE LAST 2 6-INCH INCREMENTS.

FIGURE C-6
LEGEND AND NOTES
Tri-City Sewage Treatment Plant

BORING LOG LEGEND:

SAMPLE TYPE:

- S - SPLIT-BARREL (ASTM D1586 UNLESS OTHERWISE NOTED)
- ST - SHELBY TUBE
- W - WASH SAMPLE
- OT - OSTERBERG TUBE
- NX - DIAMOND CORE BARREL

STANDARD PENETRATION TEST:

BLOWS - THE NUMBER OF BLOWS FOR THREE 6-INCH INCREMENTS REQUIRED FROM A 140-LB HAMMER FALLING 30 INCHES TO DRIVE A STANDARD 2-INCH O.D. SPLIT-BARREL SAMPLER (ASTM D1586).

"N" - THE SUM OF BLOWS FOR THE SECOND AND THIRD 6-INCH INCREMENTS. IF THE SAMPLER IS DRIVEN LESS THAN 18 INCHES, THEN "N" IS THE NUMBER OF BLOWS FOR THE LAST TWO 6-INCH INCREMENTS.

UNIFIED SOIL CLASSIFICATION SYMBOL:

GROUP SYMBOL AS PER ASTM D 2487

NOTES:

1. BORINGS WERE DRILLED BY DON KENNER OF OREGON, INC. OF SHERWOOD, OREGON. BORINGS B-1 AND B-3 WERE DRILLED IN DECEMBER, 1981, USING A TRUCK-MOUNTED CME-55. THE REMAINDER OF THE BORINGS WERE DRILLED WITH A TRUCK-MOUNTED CME-75 IN DECEMBER, 1981, AND IN JANUARY AND MAY, 1982.

2. ENGINEERING PROPERITES OF SUBSURFACE MATERIALS ARE OPINION OF THE ENGINEERING GEOLOGIST, EXCEPT WHERE LABORATORY TESTING WAS CONDUCTED.

3. THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

4. TRANSITIONS BETWEEN SOIL TYPES MAY BE GRADUAL AND ARE APPROXIMATELY AT THE ELEVATIONS SHOWN.

5. STANDARD PENETRATION TESTS WERE TAKEN IN APPROXIMATE ACCORDANCE WITH ASTM D1586.

6. SAMPLES WERE EXAMINED IN THE FIELD AND VISUALLY CLASSIFIED IN APPROXIMATE ACCORDANCE WITH ASTM 2488.

7. OPEN STANDPIPE PIEZOMETERS WERE INSTALLED IN BORINGS B-1, 3, 5, 7, 11, 13, 14, AND 21. ALL PIEZOMETERS CONSISTED OF A PERVIOUS PVC TIP THAT IS 18-INCHES LONG, 1.5-INCH INSIDE DIAMETER, AND HAS NOMINAL 0.010-INCH SLOTTED OPENINGS WITH 1/4-INCH SPACINGS. ALL TIPS WERE PACKED WITH 3/8-INCH PEA GRAVEL. RISER PIPE CONSISTS OF 3/4-INCH PVC PIPE, WITH APPROXIMATELY 0.5-FEET OF STANDPIPE ABOVE THE GROUND SURFACE. SEE INDIVIDUAL BORING LOGS FOR POSITION OF PERVIOUS TIP, ZONE OF GRAVEL-PACKING, AND LOCATION OF BENTONITE SEAL(S).

MAJOR DIVISION		LETTER DESIGNATION	GRAPHIC SYMBOL	DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOIL	GW		Well-graded gravel or gravel-sand mixtures, little or no fines
		GP		Poorly-graded gravel or gravel-sand mixtures, little or no fines
		GM		Silty gravel, gravel-sand-silt mixtures
		GC		Clayey gravel, gravel-sand-clay mixtures
	SAND AND SANDY SOIL	SW		Well-graded sand or gravelly sand, little or no fines
		SP		Poorly graded sand or gravelly sand, little or no fines
		SM		Silty sand, sand-silt mixtures
		SC		Clayey sand, sand-silt mixtures
FINE-GRAINED SOILS	SILTS AND CLAYS OF LOW PLASTICITY	ML		Inorganic silt of low to medium plasticity, gravelly silt, sandy silt, clayey silt
		CL		Inorganic clay of low to medium plasticity, gravelly clay, sandy clay, silty clay
		OL		Organic silts of low plasticity
	SILTS AND CLAYS OF HIGH PLASTICITY	MH		Inorganic silts of high plasticity
		CH		Inorganic clays of high plasticity
		OH		Organic clay and silt of medium to high plasticity
	HIGHLY ORGANIC SOILS	PT		Peat and other highly organic soils
	FILL			Fill, variable composition
	ROCK			Siltstone

GRAPHIC COLUMN LEGEND

CH2M HILL

CH2M HILL

PROJECT NUMBER
P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON
DRILLING METHOD ROTARY MUD, CME-55 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC.
ELEVATION 42.51 FEET BORE HOLE: B-1
WATER LEVEL SEE TEXT DATE: START: 12/21/81 FINISH: 12/22/82 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
									START DRILLING AT 11:25 LANDOWNER NOTES FILL MIGHT HAVE BEEN DUMPED ON SITE DURING CONSTRUCTION OF I-205
5	5.0–7.0	ST-1	21	---	–	SAND, SIMILAR TO S-1 (SEE BELOW)			BEGIN WITH DRAG BIT CHANGE TO ROLLER BIT AT 24.9 FT.
	7.0–8.5	S-1	7	2-2-2	4	SAND, FINE SAND WITH LESS THAN 5% NON-PLASTIC FINES, BROWN, MOIST, VERY LOOSE.		SP	
10	10.0–11.5	S-2	7	2-1-2	3	SAND, SAME AS S-1		SP	
15	15.0–16.5	S-3	7	2-3-5	8	SAND, SAME AS S-1		SP	
20	20.0–21.5	S-4	17	2-2-2	4	SILTY SAND, SIMILAR TO S-1 EXCEPT 20-25% NON-PLASTIC FINES		SM	
									DRILLER NOTES HARD DRILLING AT 24.9 FT, MIX MORE MUD AT 25 FT.
25 (EL 17.5)	25.0–26.5	S-5	14	26-46-46	92	SANDY GRAVEL, POORLY GRADED, WELL ROUNDED GRAVEL AT LEAST TO 1¼ INCH, 20% FINE-TO-COARSE SAND, MOSTLY MEDIUM, ABOUT 5% NON-PLASTIC FINES, WET, BROWN AND BLACK, VERY DENSE.		GP	SLOW ROUGH DRILLING TO 46 FT.

FORM D 1586 5/78

CH2M HILL

SHEET 2 OF 3

PROJECT NUMBER P15600. A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON
DRILLING METHOD MUD ROTARY, CME-55 DRILLERS & EQUIPMENT DON KENNER OF OREGON, INC.
ELEVATION 42.51 FEET BORE HOLE: B-1
WATER LEVEL SEE TEXT DATE: START: 12/21/81 FINISH: 12/22/81 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	RECOVERY (INCHES)	SPT BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
30	30 – 31.5	S-6	8	55-60/6"	105/12"	SANDY GRAVEL, SIMILAR TO S-5, WITH ABOUT 30% GRAVEL		GP	LOST CIRCULATION AT 31.5 FT, 32 AND 35 FT, REQUIRED MIXING MORE MUD.
35	35.0 – 35.5	S-7	0	60/5"	60/5"	NO RECOVERY			SAME COARSE, ANGULAR SAND CUTTINGS IN SAMPLE TUB. DRILLER NOTES SAND LENS AT 37-38 FT.
40	40.0 – 41.5	S-8	0	60/3"	60/3"	NO RECOVERY			SAMPLER BOUNCED DURING SPT. LOSE CIRCULATION AT 43 FT. VERY HARD, SLOW DRILLING, ADD NEW TRI CONE BIT AT 43 FT.
45	45.0 – 46.5	S-9	0	60/4"	60/4"	NO RECOVERY			DRILLER NOTES CHANGE IN DRILLING RATE (UP) AT 46 FT. SAMPLE SS-6 PROBABLY FELL OUT OF TUBE ON TRIP UP, SILTY SAND CAKED ON SAMPLER
50	50.0 – 51.5	S-10	18	7-11-16	27	SILTSTONE, HIGHLY WEATHERED PLASTICITY, 5-10% FINE-TO-MEDIUM SAND IN UPPER 9 INCHES, DARK GRAYISH-GREEN WITH ORANGE BROWN AND YELLOWISH MOTTLING, MOIST, VERY STIFF.		ML	
55	55.0 – 57.0	ST-2	12	— —	—				
	57.0 – 58.5	SS-11	18	5-11-16	27	SILT, SAME AS S-10		ML	
60						END BORING AT 58.5 FEET			FINISHED DRILLING AT 1:00

FORM D 1586 5/78

SHEET 3 OF 3

CH2M HILL

PROJECT NUMBER P15600. A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY, CME-55 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC.

ELEVATION 42.51 FT. BORE HOLE: B-1

WATER LEVEL SEE TEXT DATE: START: 12/21/81 FINISH: 12/22/81 INSPECTOR CWH

DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
						PIEZOMETER INSTALLATION	(SEE	NOTES,	BORING LOG LEGEND)
						PLACEMENT OF PERVIOUS TIP: AT 40.0FT.	TOP	AT 38.5 FT,	BOTTOM
						GRAVEL PACK: FROM 58.5 FT	TO	24.9	FT.
						BENTONITE SEAL: FROM 22.9	TO	24.9	FT.
						RISER-PIPE LENGTH: 40 FEE	T.		

FORM D 1586 5/78

SHEET 1 OF 3

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY, CME-55 DRILLERS & EQUIPMENT DON KENNER OF OREGON, INC

ELEVATION 46.13 FT. BORE HOLE: B-3

WATER LEVEL SEE TEXT DATE: START: 12/22/81 FINISH: 12/23/81 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
									START DRILLING AT 2:35
									BEGIN WITH DRAG BIT, CHANGE TO ROLLER BIT AT 25.3 FT.
5	5.0 – 6.5	S-1	8	1/12" -2	2	SANDY SILT, NON TO SLIGHTLY PLASTIC FINES, ABOUT 25% FINE SAND, BROWN, MOIST, VERY SOFT.		ML	
	7.0 – 9.0	ST-1	21	- - -	-				
10	10.0 – 11.5	S-2	8	2-2-2	4	SANDY SILT, SIMILAR TO S-1, WITH 30-40% FINE SAND.		ML	
15	15.0 – 17.0	ST-2	19	- - -	-	SILTY SAND: FINE SAND WITH 15-20% NON TO SLIGHTLY PLASTIC FINES, BROWN, WET, VERY SOFT TO FIRM.		SM	
20	20.0 – 21.5	S3	2	3-4-5	9	SILTY SAND: SIMILAR TO ST-2, WITH 10-15% FINES.		SM	DRILLER NOTES GRAVEL AT 23.5 FT.
25	24.5 – 26.0	S-4	2	19-28-32	60	SANDY GRAVEL: POORLY-GRADED ROUNDED GRAVEL TO AT LEAST 1 1/4 INCH MAXIMUM SIZE, 5-10% NON PLASTIC FINES, BROWN TO BLACK, WET, VERY DENSE.		GP-GM	SLOW, ROUGH DRILLING TO 48.5 FT.
30									

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY WWTP LOCATION OREGON CITY, OREGON
DRILLING METHOD MUD ROTARY; CME-55 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC
ELEVATION 46.13 FEET BORE HOLE: B-3
WATER LEVEL SEE TEXT DATE: START: 12/22/81 FINISH: 12/23/81 INSPECTOR CWH

DEPTH BELOW SURFACE (FEET)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
30	30.0–31.5	S-5	3	24-28-16	44	SANDY GRAVEL, SAME AS S-4.		GP-GM	LAST 6" OF DRIVE FOR SS-5 MIGHT BE A SAND LENS.
35	35.0–35.2	S-6	0	60/2"	60/2"	NO RECOVERY			
40	40.0–41.3	S-7	3	60/4"	60/4"	SANDY GRAVEL, SAME AS S-4		GP-GM	
45	45.0–45.2	S8	0	60/2"	60/2"	NO RECOVERY			DRILLER NOTES CHANGE IN DRILLING RATE (UP) AT 48.5 FT.
50	50.0–51.5	S-9	14	26-54-60/3"	114/9"	SILTSTONE: HIGHLY WEATHERED, 10-15% FINE TO MEDIUM SAND, MEDIUM HARD, GRAY WITH BLUE-GREEN AND WHITISH MOTTLING, SLIGHTLY MOIST, VERY DENSE.			
55	55.0–56.0	S-10	14	25-60/4"	85/10"	SILTSTONE, SAME AS S-9.			
						END BORING AT 56.0 FEET			FINISH DRILLING AT 1:00

FORM D 1586 5/78

SHEET 1 OF 3

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY WTP LOCATION OREGON CITY, OREGON
DRILLING METHOD ROTARY MUD; CME-75 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC
ELEVATION 44.75 FEET BORE HOLE: B-5
WATER LEVEL SEE TEXT DATE: START: 1/12/82 FINISH: 1/13/82 INSPECTOR LWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
									START DRILLING AT 2:10
5	5.0								
	6.5	S-1	9	1-1-1	2	SANDY SILT NON PLASTIC, ABOUT 35% FINE SAND BROWN, MOIST, VERY SOFT TO SOFT.		ML	
	8.0	ST-1	24	---	—				
10	10.0								
	11.5	S-2	12	1-1-1	2	SANDY SILT, SAME AS S-1.		ML	
15	15.0								
	16.5	S-3	9	1-2-1	3	SANDY SILT, SIMILAR TO S-1, WITH ABOUT 40% FINE SANDS		ML	
	18.0	ST-2	24	---	—				
20	20								
	21.5	S-4	14	1-1-3	4	SANDY SILT, SAME AS S-1		ML	
25	25.0								
	26.5	S-5	3	5-3-7	10	SAND, POORLY GRADED FINE SAND, 5-10% NON PLASTIC FINES, BROWN, MOIST, LOOSE		SP-SM	
									DRILLER NOTES GRAVEL AT 27FEET
30									

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON
DRILLING METHOD MUD ROTARY, CME-75 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC.
ELEVATION 44.75 FT BORE HOLE: B-5
WATER LEVEL SEE TEXT DATE: START: 1/12/82 FINISH: 1/13/82 INSPECTOR CWH

DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE NUMBER	RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
60									DRILLER NOTICES NO CHANGE IN DRILLING RATES TO 65 FT.
65	65.0 – 65.9	S-12	9	28-60/3½	88/9½"	SILTSTONE, SIMILAR TO S-11, EXCEPT FOR LOCAL BLUE-GREEN AND ORANGE-BROWN MOTTLING			
70									DRILLER NOTES UNIFORM DRILLING TO 75 FT, EXCEPT FOR OCCASSIONAL lenses of harder material, possibly gravel
75	75.0 – 75.5	S-13	5	60/5	60/5"	SILTSTONE, SIMILAR TO S-11, EXCEPT FOR BLUE-GREEN AND ORANGE-PINK MOTTLING.			

END BORING AT 75.5 FT

PIEZOMETER INSTALLATION: (see notes on Boring Log Legend)
PLACEMENT OF PERVIOUS TIP: TOP AT 38.5 FT, BOTTOM AT 40.0 FT.
GRAVEL PACK: FROM 76.5 FT TO GROUND SURFACE.
BENTONITE SEAL: FROM 12-14 FT
RISER PIPE LENGTH: 40 FT.

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600-A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY, CME-75 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC

ELEVATION 42.14 feet BORE HOLE: B-6

WATER LEVEL NOT MEASURED DATE: START: 1/11/82 FINISH: 1/12/82 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
						SILTY TOPSOIL AT SURFACE			START DRILLING AT 3:30
5	5.0–6.5	S-1	9	2-1-1	3	SANDY SILT, LOW PLASTICITY, 30-40% FINE SAND, BROWN, MOIST, VERY SOFT, TRACE OF ORGANIC MATERIAL		ML	
	8.0–10.0	ST-1	20	---	-	SILT, LOW PLASTICITY, ABOUT 10% FINE SAND, BROWN, MOIST, VERY SOFT		ML	
10	10.0–11.5	S-2	14	2-2-4	6	SILT, SAME AS S-1.		ML	
15	15.0–16.5	S-3	9	3-3-4	7	SILTY SAND, LOW PLASTICITY, 58% FINE SAND, 32% SILT, 10% CLAY, BROWN, WET, LOOSE.		SM	
20	20.0–22.0	ST-2	13	---	—				ENCOUNTERED GRAVEL AT 21 FT, SHELBY TUBE BENT
	22.8	S-4	6	32-60/4½"	92/10½"	SANDY GRAVEL, ROUNDED GRAVEL TO AT LEAST 1¼" ABOUT 25% FINE TO COARSE SAND, 5-10% NON PLASTIC FINES, BROWN, VERY DENSE.		GP-GM	LOSE CIRCULATION AT 23 FT, MIX MORE MUD, SOFTER DRILLING 23-25 FT.
25	25.0–26.5	S-5	0	14-20-5	25	NO RECOVERY			POSS. SAND LENS FROM 23-26 FT? LOSE CIRCULATION AT 26 FT, MIX MORE MUD, SLOW ROUGH DRILLING TO 50 FT.

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600. A5

SOIL BORING LOG

PROJECT TRI CITY STP   LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY   DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC

ELEVATION 42.14 FEET   BORE HOLE: B-6

WATER LEVEL NOT MEASURED DATE: ______ START: 1/11/82 FINISH: 1/12/82 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
30	30.4	S-6	0	60/5"	60/5"	NO RECOVERY			SAMPLER BOUNCED DURING SS-6 SPT. MIX MORE MUD AT 30 AND 33FT.
35	35.0 – 35.2	S-7	0	60/3"	60/3"	NO RECOVERY			SAMPLER BOUNCES DURING SS-7 SPT. DRILLER NOTES LARGE ROCKS IN HOLE
40	40.0 – 41.5	S-8	6	48-45-60/3"	105/9"	SANDY GRAVEL, POORLY GRADED ROUNDED GRAVEL TO ATLEAST 1¼ INCH, ABOUT 25% FINE TO COARSE SAND, 5-10% NON PLASTIC FINES, BROWN, WET, VERY DENSE		GP-GM	SAMPLER BOUNCES DURING SS-8 SPT
45	45.0 – 45.2	S-9	0	60/2½	60/2½"	NO RECOVERY			MIX MORE MUD AT 45FT. DRILLER NOTES CHANGE IN DRILLING rate (up) at 50 FT.
50	50.5 – 52.0	S-10	12	14-26-47	73	SILTSTONE, HIGHLY WEATHERED TO SILT AND CLAY SIZED PARTICLES, ABOUT 10% ROUNDED FINE TO MEDIUM SAND, GRAY, MOIST.			FINISH DRILLING AT 1:15
						END BORING AT 52.0 FEET			
55									

FORM D 1586 5/78

SHEET 1 OF 2

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY, CME-55 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC.

ELEVATION 41.33 FEET BORE HOLE: B-7

WATER LEVEL SEE TEXT DATE: START: 1/11/81 FINISH: 1/11/82 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
									START DRILLING AT 8:55
5	5.0								
	6.5	S-1	5	1-2-1	3	SANDY SILT, LOW PLASTICITY, ABOUT 40% FINE SAND, BROWN, MOIST, SOFT.		ML	
	8.0								
10	10.0	ST-1	24	---	—	SILT, SIMILAR TO S-1, EXCEPT NO FINE SAND.		ML	
	11.5	S-2	7	1-3-2	5	SILTY SAND, FINE SAND WITH ABOUT 40% NON PLASTIC FINES, BROWN, MOIST, LOOSE.		SM	
15	15.0								
	16.5	S-3	6	2-2-2	4	SILTY SAND, SIMILAR TO S-2 EXCEPT ABOUT 65% FINE SAND		SM	
20	20.0								
	22.0	ST-2	18	---	-	SILTY SAND, SIMILAR TO S-3		SM	HIT ROCK OR STONE AT BOTTOM OF ST-2
	21.5	S-4	6	12-13-17	30	SANDY GRAVEL, POORLY GRADED, ROUNDED GRAVEL TO AT LEAST 1¼ INCH, 20-30% FINE SAND, ABOUT 5% NON PLASTIC FINES, BROWN, WET, COMPACT.		GP-GM	DRILLER NOTES GRAVEL AT 22 FT.
25	25.0								
	26.5	S-5	6	30-49-100/5	109/11"	SANDY GRAVEL, SIMILAR TO S-4, EXCEPT ABOUT 15% FINE SAND		GP-GM	SAMPLER BOUNCES DURING S-5 SPT.
									MIX MORE MUD; SLOW, ROUGH DRILLING TO 44.9 FT.
30									

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON

DRILLING METHOD MUD ROTARY, CME-75 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC

ELEVATION 41.33 FEET BORE HOLE: B-7

WATER LEVEL SEE TEXT DATE: START: 1/11/92 FINISH: 1/11/92 INSPECTOR WWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
30	30.0–31.5	S-6	2	24-39-46	85	SANDY GRAVEL, SAME AS S-4		GP-GM	DRILLER NOTES TEMPORARY SMOOTH DRILLING FROM 33.5-34.5 FT, POSSIBLE SAND LENS.
35	35.0–35.4	S-7	0	60/4½	60/4½	NO RECOVERY			
40	40.0–40.2	S-8	0	60/2½	60/2½"	NO RECOVERY			CAVING IN HOLE TO 33 FT, HAD TO REDRILL TO 40 TO TAKE SS-8. SAMPLER BOUNCES DURING SS-8 SPT. DRILLER NOTES CHANGE IN DRILLING RATE (UP) AT 44.9 FT.
45	45.0–46.5	S-9	18	11-30-60/4	90/8"	SILTSTONE, HIGHLY WEATHERED AND OXIDIZED PARTICLES COMPOSED OF SILT AND CLAY SIZED MATERIAL, SLIGHTLY PLASTIC, LIGHT BLUE-GREY, ORANGE, AND DARK GRAY, MOIST, RELICT TEXTURE OF MORE COARSE-GRAINED ROCK APPARENT			
50	50.0–51.5	S-10	12	15-28-42	70	SILTSTONE, SAME AS S-9 EXCEPT FOR UNIFORM LIGHT BLUE-GREY COLOR			
						END BORING AT 51.5 FT			FINISH DRILLING AT 1:45

PIEZOMETER INSTALLATION: (See notes on Boring Log Legend)

PLACEMENT OF PERVIOUS TIP: TOP AT 35 FT, BOTTOM AT 37.5 FT

GRAVEL PACK: FROM 51.5 FT TO SURFACE

BENTONITE SEAL: FROM 18 TO 20 FEET

RISER PIPE LENGTH: 37.5 FT.

FORM D 1586 5/78

CH2M HILL

PROJECT NUMBER P15600.A5

SOIL BORING LOG

PROJECT TRI CITY STP LOCATION OREGON CITY, OREGON
DRILLING METHOD MUD ROTARY, CME-55 DRILLERS & EQUIPMENT D. KENNER OF OREGON, INC.
ELEVATION 42.50 FEET BORE HOLE: B-11
WATER LEVEL SEE TEXT DATE: START: 12/28/81 FINISH: 12/28/81 INSPECTOR CWH

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER	SAMPLE RECOVERY (INCHES)	STANDARD PENETRATION TEST RESULTS BLOWS 6"-6"-6"	BPF "N"	SOIL DESCRIPTION (COLOR, RELATIVE DENSITY OR CONSISTENCY, MOISTURE, GRAIN SHAPE AND TYPE, STRUCTURE, CEMENTATION, ORGANICS, MATERIAL)	GRAPHIC LOG	UNIFIED SOIL CLASSIFICATION SYMBOL	COMMENTS (DRILLING PROGRESS, LOST CIRCULATION, TYPE OF DEPOSIT, PROBLEMS, ETC.)
									START DRILLING AT 10:00
5	5.0–6.5	S-1	6	1-1-2	3	SILT, LOW TO MEDIUM PLASTICITY, ABOUT 5% FINE SAND, BROWN, VERY MOIST, SOFT.		ML	
10	10.0–11.5	S-2	10	1-2-2	4	SILT, LOW TO MEDIUM PLASTICITY, 10-15% FINE SAND, BROWN, MOIST, SOFT, TRACE OF ORGANIC MATERIAL.		ML	
	13.0–15.0	ST-1	24	— — —	—				
15	15.0–16.5	S-3	18	1-1/12"	1	SILT, SAME AS S-2		ML	
20	20.0–21.5	S-4	18	1-1-1	2	SANDY SILT, SIMILAR TO S-2 EXCEPT FOR 20-30% FINE TO MEDIUM SAND, MOSTLY FINE		ML	EL [illegible] (18 FT)
									DRILLER NOTES GRAVEL AT 24.5 FT
25	25.0–25.9	S-5	6	28-60/4"	88/10"	SANDY GRAVEL, POORLY GRADED, ROUNDED GRAVEL TO AT LEAST 1 1/4 INCH, 20-25% FINE TO MEDIUM SAND, 5-10% FINES WITH LOW TO MEDIUM PLASTICITY, BROWN, WET, VERY DENSE		GP-GM	SLOW, ROUGH DRILLING TO 30 FT.
									LOSE CIRCULATION AT 28 FT.

D-16