November 9, 2016

Amy Dammarell, PE
HDR, Inc.
1001 SW 5th Avenue, Suite 1800
Portland, Oregon 97204-1134

RE: PRELIMINARY GEOTECHNICAL REPORT
BOARDMAN WETLAND COMPLEX
OAK LODGE SANITARY DISTRICT
CLACKAMAS COUNTY, OREGON

Dear Ms. Dammarell:

Oak Lodge Sanitary District (OLSD) and its engineering consultant, HDR, Inc. (HDR), plan to replace a gravity sanitary sewer line and construct a pathway or boardwalk within the Boardman Wetland in Clackamas County, Oregon. The wetland is located within a residential block between SE Boardman and SE Jennings Avenues to the north and south, and between SE Addie and SE Cook Streets to the west and east. The project location is shown on the Vicinity Map, Figure 1. As a subconsultant to HDR, Shannon & Wilson, Inc. is providing geotechnical engineering services to support the project. The existing sewer line alignment is shown on the Site and Exploration Plan, Figure 2. Preliminary plans indicate that the proposed sewer line will generally follow the existing alignment. However, we understand that the design team is considering alternative alignments that will skirt the wetland. The layout of the proposed pathway/boardwalk is not known at this time. This geotechnical engineering report presents a summary of our field explorations, laboratory test results, and preliminary geotechnical engineering evaluations and recommendations.

**SCOPE OF SERVICES**

Our services were performed in accordance with the scope of services described in our Task Order, 10040058-01, with HDR, dated August 25, 2016. These services included the following outline of activities, assessments, and recommendations:
Perform a site reconnaissance to observe the existing site geologic conditions, including locating borings and hand auger borings (or test pit excavations) in the field.

- Drill two borings.
- Perform three test pits within the Boardman Wetland.
- Perform one suite of corrosivity tests.
- Perform preliminary geotechnical evaluations, including the following:
  - Characterize the subsurface soil conditions.
  - Develop design and construction recommendations for sewer pipeline and manholes.
  - Develop design and construction recommendations for pedestrian bridge and boardwalk foundations.
- Prepare this Preliminary Geotechnical Report as part of the project study.

**PROJECT UNDERSTANDING**

**Site Description**

The project site is currently a wetland surrounded by residential property (with the exception of the East Side Athletic Club, located to the northwest of the site). The wetland is vegetated with grass, low brush, and scattered trees. The wetland is fed via local storm lines and a 5-foot by 7-foot box culvert located at the south end of the wetland and drained at north end via an open channel. Topography at the site is relatively flat with elevations ranging from 70 to 72 feet. The existing sewer line, installed in 1961, runs down the center of the wetland. The existing sewer line is 14 inches in diameter and is embedded 14 to 15 feet below ground surface. There are four manholes located within the wetland and two manholes located in SE Boardman and SE Jennings Avenues.

**Project Description**

The OLSD plans to replace the existing sewer line and construct a pathway or boardwalk through the wetland that includes two pedestrian bridges. We understand that the proposed sewer line will tie into the existing manholes located at SE Boardman and SE Jennings Avenues. Preliminary plans indicate that the proposed sewer line will generally following the existing alignment. However, we understand that the design team is considering alternative alignments that will skirt the wetland. The existing manholes located within the wetland will be removed; up to two new manholes will be included in the new alignment. The proposed sewer line is 14
inches in diameter and embedded 14 to 15 feet below ground surface. The manholes will extend up to 2 feet below the pipeline, 16 to 17 feet below ground surface.

The OLSD plans to construct a pathway or boardwalk through the wetland. We understand that the design team is considering either a precast concrete or wood boardwalk supported on piles or a pathway paved with asphalt concrete constructed on fill material. Two pedestrian bridges will be included as a part of the pathway. The majority of the pathway/boardwalk will have only pedestrian traffic. However, we understand that a portion of the pathway/boardwalk will support vehicles used to access the manholes for maintenance. We understand that these vehicles will include 70,000-pound vacuum trucks.

GEOLOGIC SETTING

The project site is located in the Portland Basin, at the northeastern end of the Willamette Valley. Base-rock at the project site is composed of lava flows of the middle Miocene Age (approximately 17 to 6 million years old) Columbia River Basalt Group (CRBG). The CRBG is overlain at the project site by coarse grained alluvial deposits derived from late Pleistocene glacial-outburst floods of the upper Columbia River drainage. In the Portland Basin, flood deposits that blanket the basin floor consist largely of unconsolidated gravel and sand, although silty and clayey phases have also been mapped (Trimble, 1963; Madin, 1990; Beeson and others, 1989).

FIELD EXPLORATIONS & LABORATORY TESTING

Field Explorations

Our subsurface exploration program consisted of two geotechnical borings and three test pits. The borings, designated B-1 and B-2, were drilled in the north East Side Athletic Club parking lot and in the Addie Acres property on July 19, 2016. The test pits, designated TP-1 through TP-3, were excavated within the wetland on July 20, 2016. The location of these explorations are shown on the Figure 2, Site and Exploration Plan. Borings B-1 and B-2 extended to depths of 20 and 21.5 feet, respectively. Test pits were advanced to a depth of approximately 10 feet. A drive probe was used to extend the explored depths to between 14.2 and 14.8 feet. Details of the drilling and sampling procedures, as well as detailed logs of the materials encountered in the borings, are presented in Appendix A, Field Exploration Program.
Laboratory Testing

During the field explorations, representative samples were taken at selected depths and sealed for further examination in our laboratory. The laboratory testing program consisted of visual classifications for all applicable samples, natural moisture contents, and Atterberg limit determination tests. Analytical laboratory testing was also performed and included pH of Soil, Oxidation-Reduction Potential (Redox Potential), Soil Resistivity, and Sulfides tests. All test procedures were performed in accordance to applicable ASTM International Standards. Descriptions of the procedures and the results of laboratory tests completed on the soil samples are included in Appendix B.

SUBSURFACE CONDITIONS

Soils

Our interpretation of subsurface conditions at the project site is based on our explorations and regional information from published sources. Based on these data, we have grouped the materials underlying the site into three generalized units: Marsh Deposits, Catastrophic Flood Deposits Fine-Grained Facies, and Catastrophic Flood Deposits Coarse-Grained Facies. Fill was also encountered in Borings B-1 and B-2, and consisted of 4 inches of asphalt concrete over 8 inches of base aggregate in Boring B-1 and 6 inches of base aggregate Boring B-2.

In general, the Marsh Deposits consisted of wet, very soft, organic soil with medium to high plasticity. Moisture contents ranged from 39 to 107 percent and averaged 69 percent. A single field Standard Penetration Test value (SPT N-Values) was measured at 0 blows per foot (bpf). The thickness of the unit encountered was 4 feet in Boring B-1 and more than 10 feet in the test pits (TP-1 through TP-3). Test Pits TP-1 through TP-3 were terminated in this unit.

Catastrophic Flood Deposits Fine-Grained Facies (Fine-Grained CFD) were observed in Borings B-1 and B-2. Boring B-1, which is located within the wetland channel, encountered the Fine-Grained CFD from a depth of 5 to 15 feet. The lower half of the unit consisted of silty gravel. Boring B-2, which is located outside the wetland, encountered the Fine-Grained CFD near the ground surface to a depth of 12 feet. The Fine-Grained CFD encountered in Boring B-1 consisted of clay and silt, and in Boring B-2, the unit consisted of silty sand and poorly graded sand with silt. Field SPT N-Values ranged from 0 to 3 bpf in the clays and silt and averaged about 2 bpf. In the sands field, SPT N-Values ranged from 3 to 31 and averaged about 9 bpf.
Catastrophic Flood Deposits Coarse-Grained Facies (Coarse-Grained CFD) were observed in Borings B-1 and B-2 below depths of 15 and 12 feet, respectively. Both borings were terminated in this unit. The soil encountered in this unit generally consisted of medium dense to very dense silty gravel with cobbles and boulders.

We based these generalized geologic units on engineering properties and their distribution in the subsurface. Variations in subsurface conditions may exist away from the location of the boring. Contacts between the units may be more gradational than shown.

**Groundwater**

The borings were drilled using mud rotary drilling techniques, which make it difficult to discern the depth to groundwater, if it is encountered. No instrumentation or observation wells were installed in the borings. Groundwater/water levels observed in the test pits ranged from 6 inches above to less than 12 inches below the ground surface. Groundwater levels should be expected to vary seasonally, relative to the static water level of Boardman Wetland.

**BURIED PIPELINE DESIGN RECOMMENDATIONS**

**Bedding**

The pipe bedding should be constructed with imported, well-graded, clean crushed rock material suitable for compaction and allowing for flexible joints. The on-site excavation spoils, predominantly fine-grained, organic silts, will not be suitable for use as bedding material. The bedding material should consist of imported, ¾-inch minus crushed well-graded aggregate in accordance with Oregon Standard Specification for Construction (OSSC, 2015), Section 02630.10. Provided that the subgrade consists of competent coarse grained catastrophic flood deposits, the minimum thickness of bedding below the invert of the pipeline should be 6 inches.

High groundwater is present across the site. To stabilize the subgrade and to provide a drainage layer for sumping, we recommend the installation of a crushed rock drainage layer at least 12 inches thick be installed below the pipe to facilitate dewatering. The drainage layer should be constructed with open, free-draining crushed rock materials with a 1½-inch to 3/4-inch gradation conforming to OSSC Section 00430.11. We understand that the pipeline will be embedded 14 to 15 feet below ground surface. Based on our explorations, we anticipate that the pipe bedding will be founded in the Coarse-Grained CFD. During construction, if organic, soft, or disturbed
subgrade soils are encountered at the subgrade elevation, subgrade stabilization (subgrade overexcavation/replacement) will be required and will result in a thicker drainage.

Additionally, we recommend the use of a non-woven geotextile against the trench surfaces (subgrade and sides), completely surrounding the drainage layer and pipe zone material, to prevent the migration of native soil into the drainage layer and pipe zone material. The non-woven geotextile should conform to the geotextile properties presented in OSSC Section 02320, Table 02320-4 (Separation).

Pipe Zone
For the pipe zone material, ¾-inch minus crushed dense-graded aggregate, in accordance with OSSC Section 02630.11, should be used. Typically, the pipe zone materials should extend at least 6 inches above the top of the pipe, or as determined by the manufacturer. Pipe zone compaction should be to at least 85 percent of maximum density, as determined by ASTM D1557 (modified proctor).

Trench Backfill
Except for settlement-sensitive areas, such as structure or pavement areas, the pipeline trench backfill may consist of the excavated native soil. However, based on the soils encountered in the field explorations, the excavated native soil will generally consist of very wet and/or organic material that cannot be compacted and, as result, will settle significantly over time. To compensate for future settlement of the native soil trench backfill, we recommend mounding the surface of the trench backfill at least 12 inches. If future settlement is acceptable, mounding the surface of the trench backfill is not necessary.

If backfill is placed in settlement-sensitive areas, we recommend trench backfill meet OSSC 00405.14 (Class B Backfill), ¾-inch or 1-inch minus crushed aggregate. We recommend the backfill be compacted be to at least 85 percent of maximum density, as determined by ASTM D1557 (modified proctor).

MANHOLE DESIGN RECOMMENDATIONS

Foundation Recommendations
To stabilize the subgrade and to provide a drainage layer for sumping, we recommend that the footprint of the manhole be over-excavated a minimum 12 inches and extend a minimum 6
inches beyond the edge of the manhole foundation. The over-excavated material should be replaced with an engineered free-draining crushed rock materials with a 1½-inch to 3/4-inch gradation conforming to OSSC Section 00430.11, underlain by a layer of non-woven geotextile fabric conforming to OSSC, Section 02320, Table 02320-4 (Separation).

If the recommended crushed rock fills are constructed as described above, the proposed structures can be supported on conventional shallow foundations founded on the crushed rock mat with a net allowable bearing capacity of 2,000 psf. A total static settlement of less than 1 inch and a differential settlement on the order of 50 percent of the total settlement are estimated with the proposed structures supported on the crushed rock layer. Our settlement estimate assumes that no disturbance to the foundation soil subgrade would be allowed during excavation and fill placement.

**Lateral Earth Pressures on Embedded Walls**

The lateral earth pressures on embedded walls for manholes were evaluated as equivalent fluid pressures. In our analysis, we assume that the embedded walls will be designed as non-yielding walls under static loading conditions and will have a level backfill surface. We anticipate that the contractor will excavate for the manholes using shoring box methods or sheet piles. Therefore, we anticipate that backfill will be only be required within 3 feet of the embedded walls. We developed lateral earth pressures assuming strengths for undisturbed native soil. The backfill should consist of ¾-, 1-, or 1½-inch minus crushed dense-graded aggregate in accordance with OSSC, Section 02630.11, compacted to within 85 percent of maximum density, as determined by ASTM D1557 (modified proctor). For design, groundwater level should be at the ground surface or at the maximum anticipated water level in wetland.

Recommended lateral earth pressure values, as equivalent fluid pressures, are presented on Figure 3. In Figure 3, H is defined as the total height of the buried wall, and q is the surcharge load, with q in units of pounds per square foot.

**Uplift Design and Potential Flotation Effects**

We recommend that manholes be designed for uplift. The water table should be assumed to be at the ground surface or at the highest anticipated water level in the wetland. Uplift resistance should be based on the dead weight of the manhole. If additional resistance is needed,
consideration should be given to extending the foundation beyond the manhole sidewalls and using the dead weight of the backfill material directly above the foundation, as described above. For imported crushed rock backfill below the groundwater, a buoyant unit weight of 63 pcf should be used. The upper 12 inches of the backfill should be ignored.

**WETLAND PATHWAY/BOARDWALK**

**Boardwalk & Pedestrian Bridge Foundations**

Due to the very soft organic material, if the boardwalks and pedestrian bridges are supported on shallow foundations, significant settlement will occur. The boardwalks and bridges should be supported by deep foundations such as helical piles, driven pin piles, or drilled micropiles. Considering the site subsurface soil conditions, the piles should penetrate through the Marsh Deposits and soft Fine-Grained CFD and found into the competent, non-compressible, medium dense to very dense Coarse-Grained CFD located at approximately 15 feet below the ground surface.

Based preliminary descriptions of the boardwalks and bridges, we anticipate that the factored load on the piles will be less than 20 kips. This load magnitude is more suitable for helical piles or driven pin piles, especially when these piles can be founded on competent soil deposits for end bearing (in this case, the medium dense to very dense Coarse-Grained CFD). For drilled micropiles, the capacities are generated from shaft friction or bonding, not from the end bearing due to the very small pile tip area. Therefore, a relatively large embedment depth into the competent bearing stratus will be needed for the development of sufficient shaft friction or bonding.

Considering these factors, helical piles or driven 6- to 10-inch diameter pin piles are the recommended pile to utilize the end bearing from the Coarse-Grained CFD below a depth of 15 feet.

**Fill Pathway**

We understand that the design team is also considering a pathway paved with asphalt concrete constructed on fill material. Due to the very soft organic material, significant settlement will occur over the lifetime of the pathway. The majority the settlement will occur during construction and during the following year. After this initial period of settlement, secondary settlement caused by degradation of organic materials will continue to occur. Significant
maintenance, including placement of fill to level the pathway and repairs to the pavement, will be required on a yearly basis. Because significant maintenance is required throughout the lifetime of the pathway, we do not recommend this alternative.

**CONSTRUCTION CONSIDERATIONS**

**General**

Based on our field investigation, laboratory testing, and engineering analysis results, it is our opinion the primary geotechnical construction issue at the site is the excavation and groundwater control required to install the proposed sewer line.

**Excavation and Groundwater Control**

The majority of the excavation will be performed through the wetland. As discussed in the Groundwater section, groundwater was observed at the ground surface during our field explorations performed in July 2016. It is possible that water levels may rise higher than observed during explorations.

Seepage was observed in Test Pit TP-1 at approximately 4 feet below ground surface; however, the test pit did not fill with water during the excavation. Surface water was observed in the adjacent wetland channel at approximately 12 inches below ground surface at Test Pit TP-1. Test Pits TP-2 and TP-3 were performed in locations where water was at or above the ground surface. Once Test Pits TP-2 and TP-3 were started, water filled the excavation immediately. However, we estimate that the majority of the water that filled the excavation was surface water. Based on observations we made during the excavation of the test pits, the permeability in the Marsh Deposits and Fine-Grained CFD is likely relatively low. The Coarse-Grained CFD encountered in our explorations appeared to have a matrix of sand and silt. Therefore, we anticipate that the permeability is significantly greater than the marsh deposits, but low when compared to open gravels. The Coarse-Grained CFD and its permeability should be expected to vary significantly.

We recommend that the earthwork contractor be responsible for the design of the shoring and dewatering systems as well as the treatment and disposal of collected water. However, for planning and preliminary cost estimating purposes, we recommend the following:
The surface water in the wetland should be blocked so it does not flow directly into the pipeline and manhole excavations. Based on the subsurface conditions observed in our explorations and our preliminary evaluation, we recommend the use of a sheet pile shoring system. Sheet piles should be driven into the Coarse-Grained CFD. We anticipate that groundwater seepage can be controlled with pumping from localized, well-designed/constructed, filtered sumps. To stabilize the subgrade and provide a workable condition for the manholes and pipeline installation, the sumping system should be operated within the drainage layer discussed above. The sump pumps should be installed at sufficient spacing to keep the groundwater level below the surface of the drainage layer. If sheet piles are not used, we anticipate that an external dewatering system, consisting of wells or wellpoints, will be required.

**Trenchless Construction/Rehabilitation**

We understand that design team is considering the use of trenchless construction methods such as pipe jacking, directional drilling, pipe ramming, and auger boring. These methods involve either drilling or driving through the native soil. Based on the subsurface conditions encountered in our field explorations, we anticipate that the proposed sewer line will be embedded in the Coarse-Grained CFD, which consist of gravel with silt, cobbles, and boulders. Because of the cobbles and boulders and the variable nature of the material, the risk during construction is significantly elevated. We do not recommend the use of these trenchless construction methods.

The design team is also considering trenchless rehabilitation methods such as pipe bursting and cure-in-place pipe (CIPP). Because these methods do not required drilling or driving through the native soil, there is significantly less risk in construction. Based on the geotechnical risks during construction, we recommend these trenchless rehabilitation methods over the trenchless construction methods discussed above.

**Erosion Control**

Erosion of the soil at the site will occur as exposed surfaces are disturbed due to construction activities and exposure to climatic conditions. Excavated surfaces should be protected by a weather-resistant cover or erosion-control product, if left exposed. Temporary erosion and runoff control measures should be in place prior to and during construction. Erosion-control measures should remain in place and be maintained by the Contractor until disturbed areas are stabilized. The expected erosion control work consists of furnishing, installing, maintaining,
removing, and disposing of water sediments and should be executed in accordance with OSSC, Section 00280.

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.

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 the HDR and Oak Lodge Sanitary District in the design of the sewer line and pathway/boardwalk. The data and report should be provided to the contractors for their information, but 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.

Shannon & Wilson has prepared and included in Appendix C, “Important Information About Your Geotechnical/Environmental Report,” to assist you and others in understanding the use and limitations of our reports.

Sincerely,

SHANNON & WILSON, INC.

Ian C. LaVielle, PE
Senior Engineer

Risheng “Park” Piao, PE, GE
Vice President | Geotechnical Engineer

ICL:RPP/hrjaeb

Enclosures:
- Figure 1 – Vicinity Map
- Figure 2 – Site and Exploration Plan
- Figure 3 – Lateral Earth Pressure Distribution
- Appendix A – Field Exploration Program
- Appendix B – Laboratory Testing
- Appendix C – Important Information About Your Geotechnical/Environmental Report
REFERENCES


NOTES
1. Existing facilities from file "Boardman Wetland Complex.kmz", provided by HDR on July 11, 2016.
Note:
1. Backfill unit weight of 110 pcf
2. Backfill friction angle is 27 deg.
3. Wall backfill is assumed to be less than 3 feet of granular material placed against undisturbed native soil.
4. Seismic pressures provided for peak ground acceleration associated with the 2,500 year earthquakes (IBC).
APPENDIX A

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APPENDIX A

FIELD EXPLORATION PROGRAM

A.1 INTRODUCTION

The field exploration program for the Boardman Wetland Complex Project consisted of two borings, designated B-1 and B-2, completed on July 19, 2016 and three test pits, designated TP-1 through TP-3, completed on July 20, 2016. The locations shown in Figure 2, Site and Exploration Plan.

A.2 FIELD OPERATIONS

A.2.1 Drilling

Shannon & Wilson subcontracted exploration drilling to Western States Soil Conservation, Inc. of Hubbard, Oregon. The borings were drilled truck-mounted CME 75 rotary drill rigs. Borings were advanced using only open-hole mud-rotary tri-cone drilling techniques.

Borings were backfilled in accordance with Oregon Department of Water Resources, using bentonite chips or bentonite grout. Borings that penetrated pavement sections were finished at the surface with asphalt emulsion cold patch comparable in thickness to the layers encountered during drilling.

A.2.2 Test Pits

Test pit excavations were completed by Dan Fischer Excavation of North Plains. The excavations were made with a mini excavator. Test pits were generally 10 feet long, 2 feet wide, and were excavated to depths of approximately 10 feet below the ground surface. Test pits were backfill with uncompacted spoils.

A.2.3 Field Supervision

A Shannon & Wilson engineer or geologist was present during all exploratory drilling and excavating activities to observe and record soil conditions, collect samples and prepare field descriptions of the soils penetrated in the borings and test pits.
A.2.4 Disturbed Sampling

Disturbed soil samples were obtained in the borings at 2.5- to 5.0-foot depth intervals using a standard 2-inch O.D. split spoon sampler in conjunction with Standard Penetration Testing (SPT). In accordance with ASTM D1586, the Standard Penetration Test procedure consists of driving the sampler 18 inches into the soil using a 140 pound hammer dropped 30 inches. The number of blows required to drive the sampler the last 12 inches is defined as the standard penetration resistance, or N-value. The N-value provides a measure of in-situ relative density of granular soils, such as sand and gravel, and the consistency of cohesive soils, such as silt and clay. Samples were sealed to retain moisture and transported to our office for examination and testing.
Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

### S&W Inorganic Soil Constituent Definitions

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Fine-Grained Soils (50% or more fines)</th>
<th>Coarse-Grained Soils (less than 50% fines)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>Silt, Lean Clay, Elastic Silt, or Fat Clay</td>
<td>Sand or Gravel</td>
</tr>
<tr>
<td>Modifying (Secondary)</td>
<td>Precedes major constituent</td>
<td>More than 12% fine-grained: Silty or Clayey</td>
</tr>
<tr>
<td>Minor</td>
<td>30% or more coarse-grained: Sandy or gravelly</td>
<td>5% to 12% fine-grained: with Silt or Clay</td>
</tr>
<tr>
<td></td>
<td>15% to 30% coarse-grained: with Sand or with Gravel</td>
<td>6% to 12% fine-grained: Silty or Claeys</td>
</tr>
<tr>
<td></td>
<td>30% or more total coarse-grained and lesser coarse-grained constituent is 15% or more: with Sand or with Gravel</td>
<td>15% or more of a second coarse-grained constituent: with Sand or with Gravel</td>
</tr>
</tbody>
</table>

1. All percentages are by weight of total specimen passing a 3-inch sieve.
2. The order of terms is: Modifying Major with Minor.
3. Determined based on behavior.
4. Determined based on which constituent comprises a larger percentage.
5. Whichever is the lesser constituent.

### Moisture Content Terms

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

### Standard Penetration Test (SPT) Specifications

<table>
<thead>
<tr>
<th>Hammer</th>
<th>Sampler</th>
<th>N-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/2 rope turns, &gt; 100 rpm</td>
<td>10 to 30 inches long Shoe I.D. = 1.375 inches Barrel I.D. = 1.5 inches Barrel O.D. = 2 inches</td>
<td>Sum blow counts for second and third 6-inch increments. Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches.</td>
</tr>
</tbody>
</table>

**NOTE**: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.

### Soil Description and Log Key

November 2016 | 24-1-04055-001

**SHANNON & WILSON, INC.**

Geotechnical and Environmental Consultants

Boardman Wetland Complex

Clackamas County, Oregon

**SOIL DESCRIPTION AND LOG KEY**

![Soil Log Key]

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1. Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.
## Unified Soil Classification System (USCS)

*Modified from USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488*

<table>
<thead>
<tr>
<th>Major Divisions</th>
<th>Group/Graphic Symbol</th>
<th>Typical Identifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coarse-Grained Soils</strong>&lt;br&gt;(more than 50% retained on No. 200 sieve)</td>
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</tr>
<tr>
<td>Gravels&lt;br&gt;(more than 50% of coarse fraction retained on No. 4 sieve)</td>
<td>Gravel (less than 5% fines)</td>
<td>GW: Well-Graded Gravel; Well-Graded Gravel with Sand</td>
</tr>
<tr>
<td></td>
<td>Poorly Graded Gravel; Poorly Graded Gravel with Sand</td>
<td>GP</td>
</tr>
<tr>
<td></td>
<td>Silty or Clayey Gravel&lt;br&gt;(more than 12% fines)</td>
<td>GM: Silty Gravel; Silty Gravel with Sand</td>
</tr>
<tr>
<td></td>
<td>Clayey Gravel; Clayey Gravel with Sand</td>
<td>GC</td>
</tr>
<tr>
<td></td>
<td>Sand&lt;br&gt;(less than 5% fines)</td>
<td>SW: Well-Graded Sand; Well-Graded Sand with Gravel</td>
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<td></td>
<td>Poorly Graded Sand; Poorly Graded Sand with Gravel</td>
<td>SP</td>
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<tr>
<td></td>
<td>Silty or Clayey Sand&lt;br&gt;(more than 12% fines)</td>
<td>SM: Silty Sand; Silty Sand with Gravel</td>
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<tr>
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<td>Clayey Sand; Clayey Sand with Gravel</td>
<td>SC</td>
</tr>
<tr>
<td><strong>Fine-Grained Soils</strong>&lt;br&gt;(50% or more passes the No. 200 sieve)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silts and Clays&lt;br&gt;(liquid limit less than 50)</td>
<td>Inorganic</td>
<td>ML: Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt</td>
</tr>
<tr>
<td></td>
<td>CL: Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic</td>
<td>OL: Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay</td>
</tr>
<tr>
<td></td>
<td>MH: Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH: Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic</td>
<td>OH: Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay</td>
</tr>
<tr>
<td><strong>Highly-Organic Soils</strong>&lt;br&gt;Primarily organic matter, dark in color, and organic odor</td>
<td>PT: Peat or other highly organic soils (see ASTM D4427)</td>
<td></td>
</tr>
<tr>
<td><strong>Fill</strong>&lt;br&gt;Placed by humans, both engineered and nonengineered. May include various soil materials and debris.</td>
<td>The Fill graphic symbol is combined with the soil graphic that best represents the observed material</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. Dual symbols (symbols separated by a hyphen, i.e., SP-SM, Sand with Silt) are used for soils with between 5% and 12% 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, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand) indicate that the soil properties are close to the defining boundary between two groups.

3. The soil graphics above represent the various USCS identifications (i.e., GP, SM, etc.) and may be augmented with additional symbology to represent differences within USCS designations. Sandy Silt (ML), for example, may be accompanied by the ML soil graphic with sand grains added.
SOIL DESCRIPTION AND LOG KEY

Boardman Wetland Complex
Clackamas County, Oregon

November 2016

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

SOIL DESCRIPTION AND LOG KEY

November 2016  24-1-04055-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A1

Sheet 3 of 3

ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATD</td>
<td>At Time of Drilling</td>
</tr>
<tr>
<td>approx.</td>
<td>Approximate/Approximately</td>
</tr>
<tr>
<td>Diam.</td>
<td>Diameter</td>
</tr>
<tr>
<td>Elev.</td>
<td>Elevation</td>
</tr>
<tr>
<td>ft.</td>
<td>Feet</td>
</tr>
<tr>
<td>FeO</td>
<td>Iron Oxide</td>
</tr>
<tr>
<td>gal.</td>
<td>Gallons</td>
</tr>
<tr>
<td>Horiz.</td>
<td>Horizontal</td>
</tr>
<tr>
<td>HSA</td>
<td>Hollow Stem Auger</td>
</tr>
<tr>
<td>I.D.</td>
<td>Inside Diameter</td>
</tr>
<tr>
<td>in.</td>
<td>Inches</td>
</tr>
<tr>
<td>lbs.</td>
<td>Pounds</td>
</tr>
<tr>
<td>MgO</td>
<td>Magnesium Oxide</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>MnO</td>
<td>Manganese Oxide</td>
</tr>
<tr>
<td>NA</td>
<td>Not Applicable or Not Available</td>
</tr>
<tr>
<td>NP</td>
<td>Nonplastic</td>
</tr>
<tr>
<td>O.D.</td>
<td>Outside Diameter</td>
</tr>
<tr>
<td>OW</td>
<td>Observation Well</td>
</tr>
<tr>
<td>pcf</td>
<td>Pounds per Cubic Foot</td>
</tr>
<tr>
<td>PID</td>
<td>Photo-Ionization Detector</td>
</tr>
<tr>
<td>PMT</td>
<td>Pressuremeter Test</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per Million</td>
</tr>
<tr>
<td>psi</td>
<td>Pounds per Square Inch</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>rpm</td>
<td>Rotations per Minute</td>
</tr>
<tr>
<td>SPT</td>
<td>Standard Penetration Test</td>
</tr>
<tr>
<td>USCS</td>
<td>Unified Soil Classification System</td>
</tr>
<tr>
<td>q&lt;sub&gt;u&lt;/sub&gt;</td>
<td>Unconfined Compressive Strength</td>
</tr>
<tr>
<td>VWP</td>
<td>Vibrating Wire Piezometer</td>
</tr>
<tr>
<td>Vert.</td>
<td>Vertical</td>
</tr>
<tr>
<td>WOH</td>
<td>Weight of Hammer</td>
</tr>
<tr>
<td>WOR</td>
<td>Weight of Rods</td>
</tr>
<tr>
<td>Wt.</td>
<td>Weight</td>
</tr>
</tbody>
</table>

GRADATION TERMS

<table>
<thead>
<tr>
<th>Grading</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly Graded</td>
<td>Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2488, if tested.</td>
</tr>
<tr>
<td>Well-Graded</td>
<td>Full range and even distribution of grain sizes present. Meets criteria in ASTM D2488, if tested.</td>
</tr>
</tbody>
</table>

CEMENTATION TERMS

<table>
<thead>
<tr>
<th>Cemntation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>Crumbles or breaks with handling or slight finger pressure</td>
</tr>
<tr>
<td>Moderate</td>
<td>Crumbles or breaks with considerable finger pressure</td>
</tr>
<tr>
<td>Strong</td>
<td>Will not crumble or break with finger pressure</td>
</tr>
</tbody>
</table>

PLASTICITY

<table>
<thead>
<tr>
<th>Plasticity Index</th>
<th>Visual-Manual Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonplastic</td>
<td>A 1/8-in. thread cannot be rolled at any water content.</td>
</tr>
<tr>
<td>Low</td>
<td>A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.</td>
</tr>
<tr>
<td>Medium</td>
<td>A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit.</td>
</tr>
<tr>
<td>High</td>
<td>It take considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit.</td>
</tr>
</tbody>
</table>

ADDITIONAL TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mottled</td>
<td>Irregular patches of different colors.</td>
</tr>
<tr>
<td>Bioturbated</td>
<td>Soil disturbance or mixing by plants or animals.</td>
</tr>
<tr>
<td>Diamict</td>
<td>Nonsorted sediment; sand and gravel in silt and/or clay matrix.</td>
</tr>
<tr>
<td>Cuttings</td>
<td>Material brought to surface by drilling.</td>
</tr>
<tr>
<td>Slough</td>
<td>Material that caved from sides of borehole.</td>
</tr>
<tr>
<td>Sheared</td>
<td>Disturbed texture, mix of strengths.</td>
</tr>
</tbody>
</table>

PARTICLE ANGULARITY AND SHAPE TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular</td>
<td>Sharp edges and unpolished planar surfaces.</td>
</tr>
<tr>
<td>Subangular</td>
<td>Similar to angular, but with rounded edges.</td>
</tr>
<tr>
<td>Subrounded</td>
<td>Nearly planar sides with well-rounded edges.</td>
</tr>
<tr>
<td>Rounded</td>
<td>Smoothly curved sides with no edges.</td>
</tr>
<tr>
<td>Flat</td>
<td>Width/thickness ratio &gt; 3.</td>
</tr>
<tr>
<td>Elongated</td>
<td>Length/width ratio &gt; 3.</td>
</tr>
</tbody>
</table>

STRUCTURE TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interbedded</td>
<td>Alternating layers of varying material or color with layers at least 1/4-inch thick; singular; bed.</td>
</tr>
<tr>
<td>Laminated</td>
<td>Alternating layers of varying material or color with layers less than 1/4-inch thick; singular; lamination.</td>
</tr>
<tr>
<td>Fissured</td>
<td>Breaks along definite planes or fractures with little resistance.</td>
</tr>
<tr>
<td>Slickensided</td>
<td>Fracture planes appear polished or glossy; sometimes striated.</td>
</tr>
<tr>
<td>Blocky</td>
<td>Cohesive soil that can be broken down into small angular lumps that resist further breakdown.</td>
</tr>
<tr>
<td>Lensed</td>
<td>Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.</td>
</tr>
<tr>
<td>Homogeneous</td>
<td>Same color and appearance throughout.</td>
</tr>
</tbody>
</table>
**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.

- **Asphalt Concrete Base Aggregate**
  - Very soft, dark brown, *Organic Soil (OH)*; moist to wet; medium to high plasticity; trace rootlets.

- **MARSH DEPOSITS**
  - Very soft, gray, *Fat Clay (CH)*; wet; high plasticity.

- **CATASTROPHIC FLOOD DEPOSITS**
  - **FINE-GRAINED FACIES**
    - Very soft, gray, *Lean Clay (CL)*; wet; medium plasticity.
    - Material change at 9 ft based on drill action.
  - Very soft, gray, *Elastic Silt (MH)*; moist to wet; interbeded with gray, *Silty Gravel (GM)*; wet; 5- to 8-inch-thick gravel layers inferred from drill action.

- **CATASTROPHIC FLOOD DEPOSITS**
  - **COARSE-GRAINED FACIES**
    - Medium dense, dark gray, *Poorly Graded Gravel with Silt with cobbles and boulders (GP-GM)*; fine to coarse subangular to subrounded gravel; trace fine to coarse sand.
  - Possible boulder from 18 to 20 ft based on drill action.

Completed: July 19, 2016

---

**LOG OF BORING B-1**

Boardman Wetland Complex
Clackamas County, Oregon

November 2016

24-1-04055-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A2

---

**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. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.
**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.

<table>
<thead>
<tr>
<th>Elev. Depth (ft.)</th>
<th>Symbol</th>
<th>Samples</th>
<th>Ground Water Depth, ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>S-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>S-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>S-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>S-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>S-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td>S-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>S-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.5</td>
<td>S-8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CATASTROPHIC FLOOD DEPOSITS SAND FACIES**

Material change at 9 ft based on drill action.

- Medium dense, red-brown, *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic fines.

**CATASTROPHIC FLOOD DEPOSITS COARSE-GRAINED FACIES**

- Softer fine-grained layer from 17 to 19 ft inferred from drill action and cuttings.

- Dense, gray, *Poorly Graded Gravel with Silt and Sand (GP-GM)*; wet; fine to coarse subangular to subrounded gravel; fine to coarse sand; low plasticity fines.

Completed: July 19, 2016

**TABLE**

<table>
<thead>
<tr>
<th>Total Depth: 21.5 ft</th>
<th>Nothing: ~</th>
<th>Drilling Method: Mud Rotary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Elevation: ~</td>
<td>Easting: ~</td>
<td>Drilling Company: Western States</td>
</tr>
<tr>
<td>Vert. Datum: ~</td>
<td>Station: ~</td>
<td>Drill Rig Equipment: CME 75 Truck Rig #1</td>
</tr>
<tr>
<td>Horiz. Datum: ~</td>
<td>Offset: ~</td>
<td>Other Comments: Automatic</td>
</tr>
</tbody>
</table>

**Hammer Efficiency = 92.6%**

**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. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.
**SOIL PROFILE DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Symbol</th>
<th>Samples</th>
<th>Type</th>
<th>Ground Water</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td></td>
<td>S-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td>S-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.8</td>
<td></td>
<td>S-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.3</td>
<td></td>
<td>S-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Drive probe refusal at 14.8 ft.</td>
</tr>
</tbody>
</table>

**MARSH DEPOSITS**

- Brown, Organic Soil (OL); moist; nonplastic; little to some organics.
- Dark gray, Organic Soil to Silt (OL/ML); moist to wet; low plasticity; trace to few organics.

**GRAY MOTTLED**

- Dark brown, Organic Soil (OL); moist to wet; nonplastic; few to some woody organic debris including partially decomposed grasses and wood fragments.

- Gray mottled, Organic Soil to Silt (OL/ML); wet; nonplastic to low plasticity; few to little organics with wood fragments; heterogeneous soil with mixed brown Organic Soil and gray Silt.

**NOTES**

1. The description in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
2. Refer to Soil Classification and Log Key for explanation of "Symbols" and Definitions.
3. Group symbol is based on visual-manual identification.
4. Where possible, a 1/2-inch-diameter, steel T-bar probe was used to estimate the density of soil.

**LEGEND**

- Seepage
- Grab Sample

**Boardman Wetland Complex**
Clackamas County, Oregon

**LOG OF TEST PIT TP-1**

November 2016 24-1-04055-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

**FIG. A4**
### SOIL PROFILE DESCRIPTION

**Dark brown, Organic Soil (OL); wet; nonplastic to low plasticity; few to some organics.**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Symbol</th>
<th>Samples</th>
<th>Type</th>
<th>Ground Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8</td>
<td>S-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>S-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.2</td>
<td>S-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MARSH DEPOSITS**

Brown, Organic Soil (OL); wet; nonplastic; little to some partially decomposed grass and wood fragments.

- Drive Probe - Not Sampled
  - Drive probe refusal at 14.2 ft.

Completed: July 20, 2016

---

**NOTES**

1. The description in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
2. Refer to Soil Classification and Log Key for explanation of "Symbols" and Definitions.
3. Group symbol is based on visual-manual identification.
4. Where possible, a 1/2-inch-diameter, steel T-bar probe was used to estimate the density of soil.

**LEGEND**

- 🌪️ Seepage
- 🍃 Grab Sample

**Boardman Wetland Complex**

Clackamas County, Oregon

**LOG OF TEST PIT TP-2**

November 2016  
24-1-04055-001

SHANNON & WILSON, INC.  
Geotechnical and Environmental Consultants
### SOIL PROFILE DESCRIPTION

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Symbol</th>
<th>Samples</th>
<th>Type</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>S-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.8</td>
<td>S-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.4</td>
<td>S-3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dark to light brown, Organic Soil (OL); wet; nonplastic to low plasticity; few to some partially decomposed grass and wood debris.**

**MARSH DEPOSITS**

- Blue-gray mottled, Organic Soil to Silt (OL/ML): wet; nonplastic to low plasticity; heterogeneous soil with mixed brown Organic Soil and gray Silt.
- Drive Probe - Not Sampled
- Drive probe refusal at 14.4 ft.
- Completed: July 20, 2016

### TEST PIT PHOTOS

![Image of test pit photos]

### LOG OF TEST PIT TP-3

**Boardman Wetland Complex**  
Clackamas County, Oregon

**November 2016**  
24-1-04055-001

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**NOTES**

1. The description in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
2. Refer to Soil Classification and Log Key for explanation of "Symbols" and Definitions.
3. Group symbol is based on visual-manual identification.
4. Where possible, a 1/2-inch-diameter, steel T-bar probe was used to estimate the density of soil.
APPENDIX B

LABORATORY TESTING
TABLE OF CONTENTS

B.1 GENERAL ..........................................................................................................................1
B.2 GEOTECHNICAL SOIL TESTING ......................................................................................1
  B.2.1 Visual-Manual Classification .....................................................................................1
  B.2.2 Moisture Content Determination .............................................................................1
  B.2.3 Atterberg Limits .......................................................................................................2
B.3 ANALYTICAL TESTING ..................................................................................................2

FIGURES

  B1 Atterberg Limits Results

ATTACHMENT

B.1 GENERAL

This appendix contains descriptions of the procedures and the results of laboratory tests completed on the soil samples obtained from the explorations for the Boardman Wetland Complex. The geotechnical soil-testing program included visual-manual classification, moisture content determination, and Atterberg limits. Laboratory testing was performed at the Shannon and Wilson Laboratory in Lake Oswego, Oregon. Analytical testing was performed for corrosion susceptibility by Specialty Analytical or Clackamas, Oregon. Test methods were performed in accordance with applicable ASTM International (ASTM) standards.

B.2 GEOTECHNICAL SOIL TESTING

B.2.1 Visual-Manual Classification

Selected soil samples recovered from the borings were visually reclassified in our laboratory using a system based on the International ASTM Designation: D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Other terminology, such as the relative density or consistency of soil deposits, is used in general accordance with current local engineering practice. In determining the soil type (gravel, sand, silt or clay), the term that best describes the major portion of the sample is used. Modifying terms to further describe the soil samples are defined in Figure A1. Physical characteristics of the samples were noted, and field classifications were modified as necessary during laboratory Visual-Manual Classification.

B.2.2 Moisture Content Determination

The water content of selected soil samples recovered from the field explorations was determined in general accordance with ASTM D2216, Standard Method of Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. Comparison of water content of a soil with its index properties can be useful in characterizing soil unit weight, consistency, compressibility, and strength. Water contents are plotted on the boring logs presented in Appendix A.
B.2.3 Atterberg Limits

Atterberg limits were determined on selected samples in accordance with ASTM D4318. This analysis yields index parameters of the soil that are useful in soil identification, as well as in a number of analyses, including liquefaction analysis. An Atterberg limit test determines a soil’s liquid limit (LL) and plastic limit (PL). These are the maximum and minimum moisture contents at which the soil exhibits plastic behavior. A soil’s plasticity index (PI) can be determined by subtracting PL from LL. The LL, PL, and PI of tested samples are presented on the Figure B1, Atterberg Limits Results. The results are also shown graphically on the boring logs presented in Appendix A. We define the soil plasticity terms as follows:

- Nonplastic refers to soils with a PI less than 4,
- Low plasticity soils have a PI range of 4 to 10,
- Medium plasticity soils have a PI range of 10 to 20, and
- High plasticity soils have a PI greater than 20.

B.3 ANALYTICAL TESTING

Analytical testing included pH of Soil, Oxidation-Reduction Potential (Redox Potential), Soil Resistivity, and Sulfides. Analytical laboratory testing results are included as an attachment to this appendix. Analytical testing was performed by Specialty Analytical of Clackamas, Oregon.
NOTES
1) Atterberg limits tests were performed in general accordance with ASTM D4318 unless otherwise noted in the report.

2) Group Name and Group Symbol are in accordance with ASTM D2488 and are refined in accordance with ASTM D2487 where appropriate laboratory tests are performed.

3) Plasticity adjectives used in sample descriptions correspond to plasticity index as follows:
   - Nonplastic (NP) (< 4%)
   - Low Plasticity (4 to 10%)
   - Medium Plasticity (10 to 20%)
   - High Plasticity (> 20%)
August 12, 2016

Ian LaVielle
Shannon & Wilson
3990 SW Collins Way
Ste. 100
Lake Oswego, OR 97035
TEL: (503) 223-6147
FAX: (503) 223-6140
RE: Boardman Wetland Complex

Dear Ian LaVielle:

Specialty Analytical received 1 sample(s) on 8/4/2016 for the analyses presented in the following report.

There were no problems with the analysis and all data for associated QC met EPA or laboratory specifications, except where noted in the Case Narrative, or as qualified with flags. Results apply only to the samples analyzed. Without approval of the laboratory, the reproduction of this report is only permitted in its entirety.

If you have any questions regarding these tests, please feel free to call.

Sincerely,

Marty French
Lab Director
<table>
<thead>
<tr>
<th>Analyses</th>
<th>Result</th>
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<th>Qual</th>
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**QC SUMMARY REPORT**

**Client:** Shannon & Wilson  
**Project:** Boardman Wetland Complex  
**TestCode:** PH_AASHTO

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<th>Result</th>
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<th>%REC</th>
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**Qualifiers:**  
- **B:** Analyte detected in the associated Method Blank  
- **H:** Holding times for preparation or analysis exceeded  
- **ND:** Not Detected at the Reporting Limit  
- **R:** RPD outside accepted recovery limits  
- **S:** Spike Recovery outside accepted recovery
### Specialty Analytical

**Client:** Shannon & Wilson  
**Project:** Boardman Wetland Complex  
**TestCode:** REDOX_ASTM

<table>
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<th>Sample ID</th>
<th>SampType</th>
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<th>RunNo</th>
<th>Analysis Date</th>
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<td>REDOX_AST</td>
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**Sample ID:** ZZZZZZ  
**Batch ID:** R26211  
**TestNo:** G200  
**Analysis Date:** 8/5/2016  
**SeqNo:** 352976

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#### Qualifiers:
- **B:** Analyte detected in the associated Method Blank  
- **H:** Holding times for preparation or analysis exceeded  
- **ND:** Not Detected at the Reporting Limit  
- **O:** RSD is greater than RSDlimit  
- **R:** RPD outside accepted recovery limits  
- **S:** Spike Recovery outside accepted reco
## QC SUMMARY REPORT

**WO#:** 1608031  
**12-Aug-16**

### Specialty Analytical

**Client:** Shannon & Wilson  
**Project:** Boardman Wetland Complex  
**TestCode:** SULFIDE_S

---

### Sample Information

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<th>RunNo</th>
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**Client ID:** TP-2, S-4 (9-9.5)  
**Batch ID:** R26213  
**TestNo:** SW9030  
**Analysis Date:** 8/12/2016  
**SeqNo:** 352980

### Analyte Results

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<td>RMI</td>
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**Qualifiers:**  
B: Analyte detected in the associated Method Blank  
O: RSD is greater than RSDlimit  
H: Holding times for preparation or analysis exceeded  
R: RPD outside accepted recovery limits  
ND: Not Detected at the Reporting Limit  
S: Spike Recovery outside accepted reco
This sample contains a Gasoline Range Organic not identified as a specific hydrocarbon product. The result was quantified against gasoline calibration standards.

This sample contains a Diesel Range Organic not identified as a specific hydrocarbon product. The result was quantified against diesel calibration standards.

This sample contains a Lube Oil Range Organic not identified as a specific hydrocarbon product. The result was quantified against a lube oil calibration standard.

The result was determined to be Non-Detect based on hydrocarbon pattern recognition. The product was carry-over from another hydrocarbon type.

The product appears to be aged or degraded diesel.

The blank exhibited a positive result greater than the reporting limit for this compound.

See Case Narrative.

Result is based from a dilution.

Result exceeds the calibration range for this compound. The result should be considered as estimate.

The positive result for this hydrocarbon is due to single component contamination. The product does not match any hydrocarbon in the fuels library.

Result may be biased high due to biogenic interferences. Clean up is recommended.

Sample was analyzed outside recommended holding time.

At clients request, samples was analyzed outside of recommended holding time.

The result for this analyte is between the MDL and the PQL and should be considered as estimated concentration.

Diesel result is biased high due to amount of Oil contained in the sample.

Diesel result is biased high due to amount of Gasoline contained in the sample.

Oil result is biased high due to amount of Diesel contained in the sample.

Sample concentration is greater than 4x the spiked value, the spiked value is considered insignificant.

Result is outside control limits due to matrix interference.

Value determined by Method of Standard Addition.

Laboratory Control Standard (LCS) exceeded laboratory control limits, but meets CCV criteria. Data meets EPA requirements.

Detection levels elevated due to sample matrix.

RPD control limits were exceeded.

Duplicate failed due to result being at or near the method-reporting limit.

Matrix spike values exceed established QC limits; post digestion spike is in control.

Recovery is outside control limits.

Closing CCV or LCS exceeded high recovery control limits, but associated samples are non-detect. Data meets EPA requirements.

* The result for this parameter was greater that the maximum contaminant level of the TCLP regulatory limit.
APPENDIX C

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT
IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT’S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.
A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland