Appendix F-4

Geotechnical Investigation Report

Puyallup River Basin
Flood Risk Reduction Feasibility Study

Department of the Army
Seattle District, US Army Corps of Engineers

PUYALLUP RIVER BASIN LEVEE GEOTECHNICAL INVESTIGATION

PIERCE COUNTY, WASHINGTON

GEOTECHNICAL DATA REPORT
PIERCE COUNTY WORK ORDER NO. 1361-124-03

Prepared for:
Pierce County Public Works and Utilities, Tacoma, Washington
United States Army Corps of Engineers, Seattle District, Seattle, Washington

January 17, 2012

URS
1501 Fourth Avenue, Suite 1400
Seattle, Washington 98101-1616

URS

January 17, 2011

Mr. Randy Brake
Senior Project Manager
Pierce County Public Works and Utilities
Department of Surface Water Management
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Puyallup River Basin Levee
Geotechnical Investigation
Geotechnical Data Report
Pierce County Work Order No. 1361-124-03

Dear Mr. Brake:

URS Corporation submits herewith a final Geotechnical Data Report for the Puyallup River Basin Levee Geotechnical Investigation. Work on this project was authorized under Work Order No. 1361-124-03 and has been performed in general accordance with the final scope of work.

On September 29, 2011, URS submitted the draft Geotechnical Data Report (GDR) to Pierce County and the United States Army Corps of Engineers (USACE) for review and comments. This final GDR is based on the reviews and comments from Pierce County and USACE.

Please call us if you have questions or need any additional information.

Sincerely,
URS Corporation

Ken G. Yang, PE
Geotechnical Engineer

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Senior Geotechnical Engineer

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GEOTECHNICAL DATA REPORT
PUYALLUP RIVER BASIN LEVEE GEOTECHNICAL INVESTIGATION

for

Pierce County and United States Army Corps of Engineers

1.0 INTRODUCTION

The US Army Corps of Engineers, Seattle District (USACE) and Pierce County, is conducting a General Investigation Study of the Puyallup River Basin to identify opportunities for constructing flood reduction projects. The Puyallup River Basin Levee System is comprised of a wide variety of levees offering protection from five-year storm events in agricultural areas to 100-year protection of residential and commercial property in the lower Puyallup reach area.

This contract will provide geotechnical support as necessary for others to complete Without Project Conditions data support and reporting, design and analysis. As part of the development of the Without Project Conditions Report, USACE requires a Levee Fragility Curve analysis to determine the probability of failure as water surface elevations increase along the levees in the Puyallup River basin. Levee failure can occur through a number of mechanisms (i.e. levee overtopping, seepage, etc.). In order to create a Fragility Curve (by others), which encompasses all possible modes of failure, subsurface exploration is required.

The study area consists of approximately 38.2 miles of levee segments along the Puyallup River, Carbon River, and White River in Pierce and King Counties. Several problem areas have been identified and ten preliminary boring locations have been selected, see Section 3.1 on next page.

The ten boring locations were identified during a field investigation with USACE and Pierce County on July 28, 2011. There are three borings beside the Carbon River, and the remaining seven borings are beside the Puyallup River.

2.0 GEOLOGIC SETTING

The Geologic Map of Washington – Southwest Quadrant (Walsh, et al, 1987) indicates that the sites are near a contact between Alluvium (Qa), Lahars (Qvl), and Pre-Fraser Glacial Sediments (Qap & Qgp). Alluvium is described as sorted combinations of silt, sand, and gravel deposited in streambeds and alluvial fans. The Lahar unit is described as unsorted to poorly sorted, generally unstratified mixtures of cobbles and boulders supported by a matrix of sand or mud. Pre-Fraser Glacial Sediments are described as stratified clay, silt, sand, gravel of fluvial, deltaic, lacustrine and/or estuarine origin, contains mixtures of till and outwash.

The liquefaction potential of the ten boring sites is indicated as “high or moderate to high” on the Liquefaction Susceptibility Map of Pierce County, Washington (Palmer et al, 2004).

3.0 FIELD EXPLORATION PROGRAM

3.1 DRILLING AND SAMPLING

Subsurface investigations are required for the purpose of characterizing the types of soils associated with the levee prisms and foundations. After the locations of the ten borings to be drilled were provided by USACE, URS performed geotechnical drilling and sampling at these drilling locations from August 1 to 9, 2011. The ten boring locations, listed in chronological order as drilled, are:

1. UF-1-11 at Ford, located along the right bank levee of the Puyallup River, southeast of Orting, WA and upstream of the Calistoga Bridge.
2. UOS-1-11 at Old Solders Home, located along the left bank levee of the Puyallup River (downstream of the Ford location), southeast of Orting, WA and upstream of the Calistoga Bridge.
3. UBS-1-11 at Bridge Street, located along the left bank levee of the Carbon River, in the southeast section of Orting, WA and downstream of Guy West.
4. UL-1-11 at Lindsay, located along the located along the right bank of the Carbon River, north of Orting, WA and downstream of Bridge Street.
5. UR-1-11 at Riddell, located along the left bank levee of the Carbon River, north of Orting, WA and downstream of Lindsay. Also located upstream of the confluence of the Puyallup and Carbon Rivers.
6. UG-1-11 at Guy West, located along the left bank levee of the Carbon River, east of Orting, WA and downstream of Alward Segment 1.
7. UA-1-11 at Alward Segment 1, located along the left bank levee of the Carbon River and east of Orting, WA.
8. ULE-1-11 at Leach Road, located along the left bank levee of the Puyallup River, west of Orting, WA and downstream of Old Solders Home and the Calistoga Bridge.
9. US-1-11 at Sportsmen, located along the left bank levee of the Puyallup River, north of Orting, WA and downstream of the confluence of the Puyallup and Carbon Rivers.
10. UP-1-11 at Puyallup Authorized RB, located along the right bank of the Puyallup River, N Levee Rd, west of Ferguson Rd E, Tacoma, WA.

Subsurface exploration was conducted on the existing levees using hollow stem auger equipment operated by Boretec Drilling. Borings were drilled at the levee crown centerline at every identified levee site. Borings were drilled to a depth of about 40 feet below the levee toe. Boring depths range from 55 feet to 66.5 feet below the ground surface. All borings were finally sealed using bentonite, in accordance with Washington Administrative Code (WAC 173-160-450) upon the completion of all testing and analysis. Standard Penetration Test (SPT, ASTM D 1556) sampling was performed at 2.5-foot intervals for the first 20 feet in depth, followed by 5-foot intervals for the rest of the boring. Several undisturbed samples were collected from some of the levee borings utilizing Shelby tubes. The SPT and Shelby tube samples were used to describe soils in the field and to obtain soils information for material description and laboratory testing. A summary of the ten borings is listed on Table A-1, and the boring logs are attached in Appendix A.

3.2 PIEZOMETER INSTALLATION

During the drilling, 1 ¼-inch inner diameter piezometers (water level observation wells) were installed at the Bridge Street, Guy West, and Alward Segment 1 locations, respectively, under the inspection of a URS engineer after it was determined that the soils there were too dense or coarse for piezometer installation by the preferred Direct Drive Point method . From August 10 to 12, 2011, ESN Northwest Company developed these three installed wells, then used Direct Drive Point equipment to install 1inch inner diameter (I.D.) wells within about 5 feet of the remaining seven boring locations, under the supervision of a URS Engineer. Installation of the Direct Drive Point method piezometers was accomplished using an AMS Power Probe rig with the following steps:

- Percussion drive a temporary 3 ½'' outer diameter (O.D.), 2 ½'' I.D. steel casing down to a designed bottom-of-screen depth;
- Put one 1'' I.D. PVC pipe with designed screen length inside the casing;
- Take the temporary casing out while placing a fill sand filter outside the screen;
- Seal the upper part outside the PVC riser pipe with bentonite;
- Install temporary flush monument with concrete and on-site soil near ground surface.

All piezometer screens were 5-foot long, and screen depths ranged from 1.7 feet to 17.6 feet below ground surface. Some of the screens were embedded within levee soils and others within foundation soils. Screen depths were selected by the USACE. A graphical depiction of the construction of these ten piezometers is presented on the boring logs in Appendix A, and the screen depth intervals are listed on Table A-1.

3.3 FALLING HEAD PERMEABILITY (SLUG) TESTING

At each boring location, a falling head permeability (slug) test was conducted to measure the permeability of a selected soil layer. The location or depth of the slug test was determined from the boring logs by USACE and URS. The three boring wells at Bridge Street, Guy West, and Alward Segment 1, were developed by the driller and other piezometers were installed by ESN Northwest Company with direct driving near the remaining seven borings in order to conduct the slug tests. URS conducted falling head permeability (slug) testing at each of the ten wells from August 15 to 17, 2011. To process the slug test data, URS used Hvorslev's 1949 Method for a "wellpoint filter in a uniform soil" (as described in Fang, 1991). These tests were performed at the levee or levee foundation level with soil types typically ranging from silty SAND to silty GRAVEL. The slug was applied by filling the piezometer with water as rapidly as possible. The ensuing water levels were measured manually using an electronic water level meter over a period of up to 4 hours until the water level dropped to its pre-test level. At four locations (Ford, Leach Road, Lindsay, and Riddell) the water discharged from the screened interval essentially as fast as it could be poured into the piezometer, and a slug "head" more than a few inches could not be developed. At these locations a rough estimate of permeability was calculated by assuming that the water level actually rose to half the distance to the ground surface from the pre-test water level, and that the head dissipated within the 5 to 10 seconds it took to get the water level meter down to the half of the top of the water column. A summary of the measured permeability values for each boring location is presented on Table B-1 in Appendix B. This appendix also contains the raw test data at each location, entered in a spreadsheet which calculates the incremental and average permeability by the method listed above.

4.0 LABORATORY TESTING PROGRAM

All laboratory tests were conducted by HWA Geosciences Inc., which is certified for soils testing by the USACE. The laboratory testing program was selected by USACE Seattle, and included tests for moisture content (ASTM D2216), particle size gradation (sieve and hydrometer, ASTM D422), Atterberg Limits (ASTM D4318), unit weight (ASTM D2937), ash and organic matter (ASTM D2974) on selected samples. Materials were visually and laboratory classified based on the Unified Soil Classification System (ASTM D 2487, ASTM D 2488). The results of all testing were submitted to URS by HWA, and the package is presented in its entirety in Appendix C. The package includes a summary table of samples tested and test results, as well as the graphical results of tests for Atterberg Limits and particle size analysis.

5.0 SUMMARY OF INVESTIGATION

This general geotechnical investigation study of levees in the Puyallup River Basin can be summarized as follows: One boring was drilled to depths up to 60 feet at each of ten levee locations; there is usually 5 to 12 feet thick levee fill consisting of gravel or silty sand; underlying foundation soils are typically thick deposits of silty sand, except silt or organic silt thin layers existing in Borings UOS-1-11, ULE-1-11, and UP-1-11; the groundwater depths range from 7.5 to 17.3 feet below ground surface during investigation period; the slug test was conducted at each of the ten boring locations, and test results show that the permeability range of tested silty gravel and silty sand layers change from 8.5×10^{-6} cm/sec to 2.6×10^{-2} cm/sec, gravelly soil layer's permeability values are usually higher than sandy soil layer's; total 167 soil samples were selected for lab testing on moisture content, organic content, unit weight, Atterbeg Limits, and particle size analysis. The lab testing results are used to identify soil types and properties in this investigation study.

6.0 LIMITATIONS

The descriptions presented in this report are based on soil conditions disclosed by the borings drilled during this investigation at the site. The existing subsurface information referred to herein does not constitute a direct or implied warranty that the soil conditions around boring locations can be directly extrapolated, or that subsurface conditions and soil variations different from those disclosed by the borings will not be revealed. If, during future construction, subsurface conditions different from those described herein are observed, such conditions should be reviewed and the conclusions and interpretations given herein revised as necessary. Similarly, changes to the levee including modified height, width, etc. should be brought to our attention so that the potential effect of these changes can be assessed.

7.0 REFERENCES

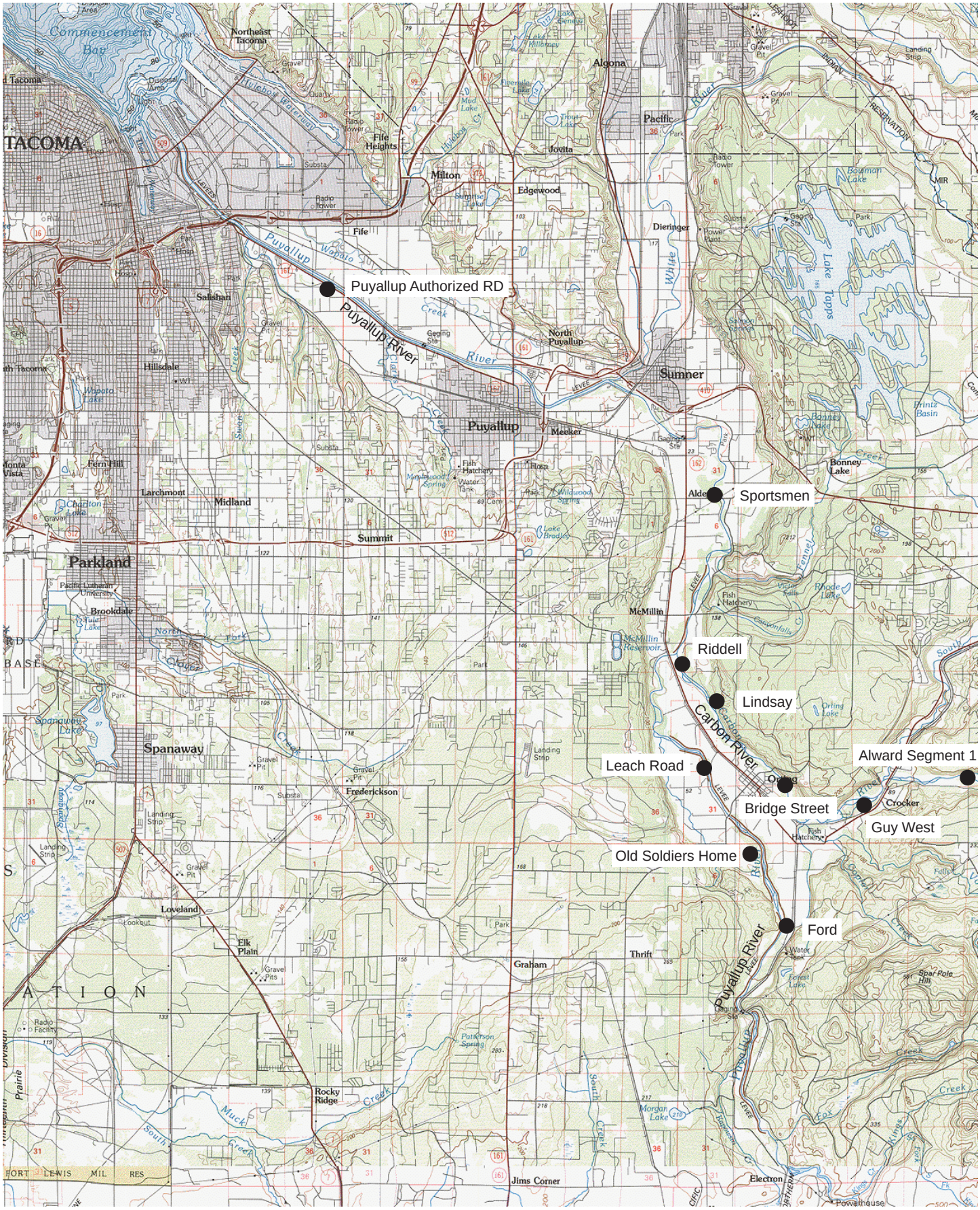
Fang, H.Y. (1991) Foundation Engineering Handbook, Van Nostrand Reinhold, NY

Palmer, S.P., Magrino, S.L., Bilderback, E.L., Poelstra, J.L., Folger, D.S. and Niggegam, R.A. (2004) Liquefaction susceptibility and site class maps of Washington State by county, Open File Report 2004-20, WA Department of Natural Resources.

Walsh, T.J., Korosec, M.A., Philips, W.M., Logan, R.L., and Schasse, H.W. (1987) Geologic Map of Washington, Southwest Quadrant, Geologic Map GM-34, WA Department of Natural Resources.

FIGURES

33763084-1.ai



0 2 4

Scale in Miles

Legend:

● URS Borings

Figure 1

Site Location Map

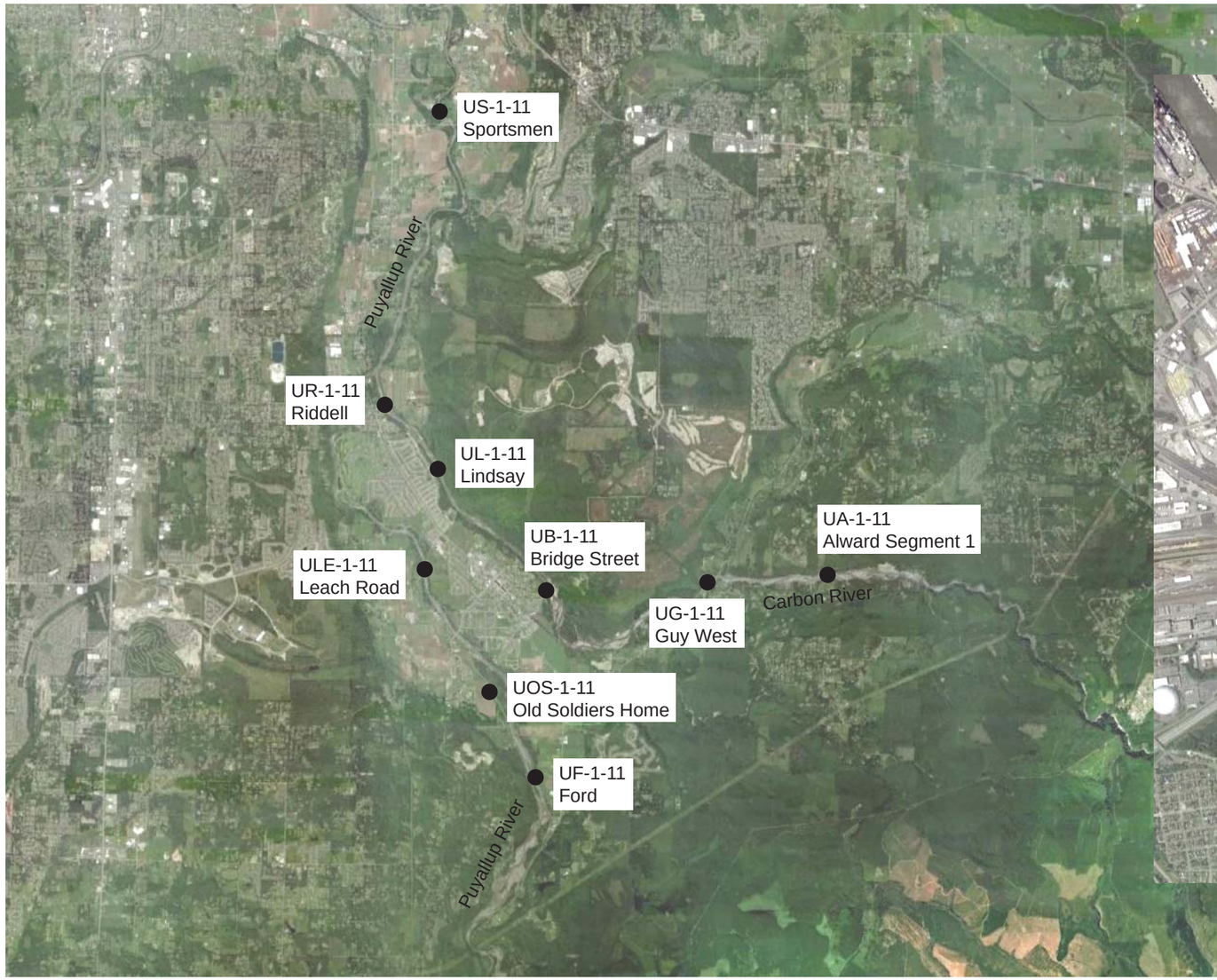
Job No. 33763084

URS

Puyallup River Basin Levee

GEROTECHNICAL INVESTIGATION

33763084-2.ai



Levee	Northing	Easting
Alward Segment 1	38609.45	1318187.93
Guy West	36806.29	1310047.58
Ford	26016.78	1301688.60
Bridge Street	36941.46	1302181.42
Old Soldiers Home	31413.09	1299167.67
Leach Road	40833.55	1294256.18
Lindsay	48842.96	1292442.46
Riddell	46163.97	1295226.66
Sportsmen	65433.96	1295934.46
Puyallup Authorized RB	89890.16	1253850.96

N

0 5 10

Scale in Miles

N

0 1 2

Scale in Miles

Legend:

● URS Borings

Job No. 33763084

URS

Figure 2

Boring Locations Plan

Puyallup River Basin Levee

GEROTECHNICAL INVESTIGATION

APPENDIX A - BORING LOGS

Table A-1: Summary of Borings

Boring Site	Boring #	Ground Surface EL. (ft)**	Coordinates***		Depth (ft)	GW Depth (ft)	GW Measure Time	Piezometer Screen Depth (ft)	Piezometer Type
			Northing	Easting					
Ford	UF-1-11	282	26016.78	1301688.60	61.5	11.4	During Drilling	13 - 18	direct-push
Old Soldiers Home*	UOS-1-11	243	31413.09	1299167.67	61.5	7.5	Interpretation	1.7-6.7	direct-push
Bridge Street	UBS-1-11	194	36941.46	1302181.42	55	10.5	During Drilling	9.9 - 14.9	boring
Guy West	UG-1-11	272	36806.29	1310047.58	61.5	12.5	During Drilling	12.6 - 17.6	boring
Alward Segment 1	UA-1-11	377	38609.45	1318187.93	61.5	9.3	8/5/11 After Drilling	8.5-13.5	boring
Leach Road	ULE-1-11	172	40833.55	1294256.18	61.5	8.5	During Drilling	2 - 7	direct-push
Lindsay	UL-1-11	128	48842.96	1292442.46	61.5	11.5	During Drilling	12 - 17	direct-push
Riddell	UR-1-11	177	46163.97	1295226.66	61.5	13	During Drilling	12.5 - 17.5	direct-push
Sportsmen	US-1-11	79	65433.96	1295934.46	66.5	15.8	During Drilling	1.7-6.7	direct-push
Puyallup Authorized RB	UP-1-11	16	89890.16	1253850.96	61.5	17.3	During Drilling	4.9-9.9	direct-push

Notes:

* GW depth is approximate based on interpretation from field logs.

** Ground surface elevations are approximate based on online http://www.heywhatsthat.com/profiler.html.

*** Based on Washington State Plane NAD83.

Project: Puyallup River Basin Geotechnical Support
Project Location: Piece County and King County, WA
Project Number: 33763084

Key to Log of Boring and Descriptive Terms for Soil

Unified Soil Classification System (ASTM D2487 & D2488)

Major Divisions			Symbols Graph	Symbols Letter	Typical Descriptions
Coarse Grained Soils More than 50% of No. 200 Sieve Size	**Gravels** More than 50% of Coarse Fraction Retained in No. 4 Sieve	**Clean Gravels** (less than 5% fines)		GW	Well-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
				GP	Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
		Gravels with Fines (more than 12 % fines)		GM	Silty Gravels, Gravel-Sand-Silt Mixtures
				GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	Sands More than 50% of Coarse Fraction Passing through No. 4 Sieve	**Clean Sand** (less than 5% fines)		SW	Well-Graded Sands, Gravelly Sands, Little or no Fines
				SP	Poorly Graded Sands, Gravelly Sands, Little or no Fines
		Sands with Fines (more than 12 % fines)		SM	Silty Sands, Sand-Clay Mixtures
				SC	Clayey Sands, Sand-Clay Mixtures
Fine Grained Soils More than 50% of Material is Smaller than No. 200 Sieve Size	**Silts and Clays** Liquid Limit Less than 50%			ML	Inorganic Silts and very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity
				CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
				OL	Organic Silts and Organic Silty Clays of Low Plasticity
	Silts and Clays Liquid Limit Greater than 50%			MH	Inorganic Silts, Micaceous or Diatomaceous Fine Sand or Silty Soils
				CH	Inorganic Clays of High Plasticity, Fat Clays
				OH	Organic Clays of Medium to High Plasticity, Organic Silts
Highly Organic Soils				PT	Peat, Humus, Swamp Soils with High Organic Contents (see ASTM D4427-92)

Abbreviations

SA	Sieve Analysis
M	Moisture
DD	Dry Density
AL	Atterberg Limits
HA	Hydrometer Analysis
C	Consolidation
Pc	Constant Head Permeability
Pf	Falling Head Permeability
DS	Direct Shear
TX	Triaxial
TV	Torvane Shear
LV	Laboratory Vane Shear
PP	Pocket Penetrometer
OVA	Organic Vapor Analyzer
OC	Organic Content
N	Number of hammer blows for last 12 inches sampled

Field Test Symbols

Pocket Penetrometer Test

Hand Vane Shear Test

Relative Density or Consistency

Coarse-Grained Soils		Fine-Grained Soils	
Relative Density	**N, SPT Blows / ft**	**Relative Consistency**	**N, SPT Blows / ft**
Very loose sand	0 - 4	Very soft	< 2
Loose	4 - 10	Soft	2 - 4
Medium dense	10 - 30	Medium stiff	4 - 8
Dense	30 - 50	Stiff	8 - 15
Very dense	Over 50	Very stiff	15 - 30
		Hard	Over 30

Sampler Symbols

3" O.D. Split Spoon Sample with brass rings

3" O.D. Shelby Tube Sample

Core

Piston Sample

Non-standard penetration test

Grab Sample

2" O.D. Split Spoon with 140lb Hammer and 30-inch drop (SPT)

Minor Descriptors

Trace	0 - 5%
Slightly (clayey, silty, sandy, gravelly)	5 - 12%
Clayey, silty, sandy, gravelly	12 - 30%
Very (clayey, silty, sandy, gravelly)	30 - 50%

Moisture Content

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

NOTES:

1. Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.
2. Dual Symbols are used to indicate borderline soil classifications

USCS 6 W:\PIERCE CO. PUY. R. GI GEOTECH SUPPORT\BORING LOGS\GINT BORING AND WELL LOGS\PUYALLUP RIVER BASIN GEOTECHNICAL SUPPORT.GPJ URSSEA3B.GLB URSSEA3.GDT 9/22/11

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Alward Segment Levee
Project Number: 33763084

Log of Boring UA-1-11

Date(s) Drilled	**8/4/11 - 8/5/11**	Logged By	**K. Yang**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**377.0**
Groundwater Level and Date Measured	**9.3 feet bgs, 8/5/2011**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Observation Well Installed**	Location	**The middle of south side levee, about 200ft east of 226th Ave Ct E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GM	**SILTY GRAVEL WITH SAND,** grey, dry, very dense. Fine to coarse, angular, homogeneous. [FILL]		Start drilling at 1515. Flush mount monument in cement installed. 1.25" schedule 80 PVC in bentonite 1.2-8 feet bgs.
375			D-1	50/1"	0			*No recovery.*		Driller notes cobbles.
	5		D-2	24	5			*Becomes medium dense, angular to subrounded.*		
370			D-3	56/9"	4		SW-SM	**Well Graded SAND WITH SILT and GRAVEL,** dark grey, moist, very dense. Fine to coarse sand, fine gravel, subangular, homogeneous, occasional cobbles.		1.25" schedule 80 PVC in 10-20 silica sand 8-9 feet bgs. 1.25" screened 0.010 schedule 80 PVC in 10-20 silica sand 9-14 feet bgs.
	10		D-4	48	10			*Becomes gravel with silt and sand, dense, no cobbles.* 46% gravel, 11% fines.		
365			D-5	50/6"	5			*Becomes wet, very dense.* 40% gravel, 8% fines.		End cap. 10-20 silica sand 14-15 feet bgs. Bentonite backfill 15-61.5 feet bgs.
	15		D-6	62/11"	12		SW-SM	**WELL GRADED SAND WITH SILT AND GRAVEL,** dark brown, wet, very dense. Fine to coarse, angular to subangular, homogeneous.		
360			D-7	54	15					
	20		D-8	62	14					45% gravel, 7% fines
355										
	25		D-9	69/12"	12					
350										
	30									

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Project: Puyallup River Basin Geotechnical Support
Project Location: Alward Segment Levee
Project Number: 33763084

Log of Boring UA-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30		D-10	42	11		SM	**SILTY SAND WITH GRAVEL,** dark brown, wet, dense. Fine to coarse, angular to rounded sand and gravel, homogeneous.		
345										
	35		D-11	54	3			Same as above except very dense.		
340										
	40		D-12	57/11"	12		SM	**SILTY SAND,** dark grey, wet, very dense, trace of fine gravel. Fine to coarse, subangular, homogeneous.		
335										
	45		D-13	50/5"	4			*As above, no gravel.*		
330										
	50		D-14	50/6"	0			*No recovery. Very dense.*		
325										
	55		D-15	52	16			*Grades to dark brown, trace of fine gravel.*		
320										
	60		D-16	40	16			*Becomes dark olive brown, dense, trace of black organics.*		
315								Boring terminated at a depth of 61.5 feet bgs and observation well installed on 08/5/2011.		Complete drilling at 1130.
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-ALWARD SEGMENT.GPJ; 9/23/2011 UA-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Bridge Street Levee
Project Number: 33763084

Log of Boring UBS-1-11

Date(s) Drilled	**8/2/11**	Logged By	**P. Craig**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**55.0 feet**
Drill Rig Type	**Custom EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**194.0**
Groundwater Level and Date Measured	**10.5 feet**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips**	Location	**West side levee, about 2500 ft south of Bridge St. SE, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GW	**WELL GRADED GRAVEL WITH SAND AND COBBLES,** brown/grey, dry, very dense, subrounded. [FILL]		Drilled in three seperate locations. Start drilling Location 3 at 0930. Flush mount monument in cement installed. 1.25" schedule 80 PVC in bentonite 1-9 feet bgs.
			D-1	50/8"	8					
190										
	5							*Becomes medium dense.*		
			D-2	25	4					
			D-3	93/11"	9			*Becomes very dense.*		
185										125" schedule 80 PVC in 10-20 silica sand 9-10 feet bgs.
	10						SM	**SILTY SAND WITH GRAVEL,** brown, wet, medium dense, fine subrounded gravel, max. size 1.5".		1.25" screened 0.010 schedule 80 PVC in 10-20 silica sand 10-15 feet bgs.
			D-4	26	7					
			D-5	26	13			39% gravel, 14% fines		
180										
	15							*Becomes poorly graded SAND with silt and gravel, subrounded.*		End cap. Bentonite backfill 15-55 feet bgs. 34% gravel, 6% fines
			D-6	24	18					
			D-7	48	18			*Becomes dense.*		
175										
	20		D-8	31	6					
170										
	25		D-9	50/6"	17			*Becomes very dense.*		No disturbance per driller.
165										
	30									

URS

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-BRIDGE STREET.GPJ; 9/16/2011 UBS-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Bridge Street Levee
Project Number: 33763084

Log of Boring UBS-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30							*Grades to olive-grey, dense.*		
			D-10	37	11					Disturbed upper portion of sample discarded.
160										
	35							*Grades to brown, medium dense, subangular.*		
			D-11	21	7					Disturbed upper portion of sample discarded.
155										
	40							Becomes dense.		
			D-12	36	12					14% gravel, 18% fines 60% gravel, 24% fines
150										
	45							Becomes loose.		
			D-13	8	9					Disturbed upper portion of sample discarded.
							GW	**WELL GRADED GRAVEL WITH SAND,** occasionally with cobble, brown, wet, very dense, trace silt.		
145										
	50									
			D-14	57	9.5					
140										
			D-15	50/0"	0			*Same as above.*		
	55							Boring terminated at a depth of 55.0 feet bgs and piezometer monitoring well installed on 08/2/2011.		Complete drilling at 1530.
135										
	60									
130										
	65									

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Ford Levee
Project Number: 33763084

Log of Boring UF-1-11

Date(s) Drilled	**8/1/11**	Logged By	**P. Craig**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**282.0**
Groundwater Level and Date Measured	**11.3 feet bgs**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips**	Location	**East side levee, about 1200 ft northwest of Orville Rd E and Card Rd E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GW-GM	**WELL GRADED GRAVEL with Silt and Sand,** brown, dry, very dense, subrounded, coarse sand and gravel, occasional cobble. [FILL]		Start drilling at 0922. Flush mount monument in cement installed. 1" schedule 80 PVC in bentonite chips 1.5-11 feet bgs.
280			D-1	50/4"	2					
	5		D-2	38	1/2			*Becomes dense.*		
275			D-3	62	11			*Grades to poorly graded GRAVEL with silt and sand, grey/brown, very dense.* 50% gravel, 10% fines.		
	10		D-4	80	11		SW-SM	**WELL GRADED SAND WITH SILT AND GRAVEL,** dark brown, wet, very dense, subrounded, coarse sand and gravel.		1" schedule 80 PVC in 10-20 silica sand 11-13 feet bgs.
270			D-5	25	12			*Becomes medium dense.*		End cap. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 13-18 feet bgs.
	15		D-6	13	10.5					11% gravel, 10% fines
265			D-7	26	12			*Becomes medium silty sand with gravel.*		
	20		D-8	30	18			*Grades to brown.*		
260										
	25		D-9	46	9.5			*Becomes grey/brown, trace fine gravel, dense.*		
255										
							SM	**SILTY SAND, sometimes with Gravel,** dark grey to black, wet, very dense, medium to coarse sand.		
	30									

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Ford Levee
Project Number: 33763084

Log of Boring UF-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30		D-10	71	18			*As above but trace gravel.*		
250										
	35		D-11	48	18			Grades to dense.		
245										
	40		D-12	28	18			*Becomes medium dense.*		
240										
	45		D-13	21	18			*Becomes light grey.*		
235										
	50		D-14	43	18			*Becomes dark grey, dense, trace coarse gravel.*		
230										
	55		D-15	56	18			*Becomes very dense, medium sand and gravel.*		
225										
	60		D-16	35	18			*Becomes dense, medium sand, coarse gravel.*		
220								Boring terminated at a depth of 61.5 feet bgs on 08/1/2011 and backfilled with bentonite chips on 8/1/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 3.5-ft south from boring location on 8/11/2011.		Complete drilling at 1215.
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-FORD.GPJ; 9/16/2011 UF-1-11

Project: Puyallup River Basin Geotechnical Support **Project Location: Guy West Levee** **Project Number: 33763084**	**Log of Boring UG-1-11** Sheet 1 of 2

Date(s) Drilled	**8/4/11**	Logged By	**K. Yang**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**AMS Power Probe 9630 PRO-PTO**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**272.0**
Groundwater Level and Date Measured	**12.5 feet bgs**	Sampling Method(s)	**SPT/Shelby Tubes**	Hammer Data	**140 lb manual**
Borehole Backfill	**Observation Well Installed**	Location	**South side levee, near 800 ft NWW of Pioneer Way E and Patterson Rd E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GP	**POORLY GRADED GRAVEL WITH SAND,** angular. [FILL]		Start drilling at 0750. Flush mount monument in cement installed.
							SM	**SILTY SAND WITH GRAVEL,** grey, dry, very dense. Fine to medium sand, fine subangular gravel, homogeneous. [FILL]		1.25" schedule 80 PVC in bentonite 2-11.5 feet bgs.
270			D-1	81/11"	8					
	5		D-2	38	10			*Becomes dense.* 39% gravel, 16% fines.		
265			D-3	33	9			*Becomes moist, with wood debris.*		
	10		D-4	50/6"	7			*Grades to dark grey, moist to wet, very dense, fine sand, trace fine gravel.*		
260							SM	**SILTY SAND WITH GRAVEL,** dark grey, wet, dense. Fine to coarse, subangular gravel, homogeneous. ▽		1.25" schedule 80 PVC in 10-20 silica sand 11.5-12.5 feet bgs. 1.25" screened 0.010 schedule 80 PVC in 10-20 silica sand 12.5-17.5 feet bgs.
			D-5	48	10					
	15		D-6	49	16			Become poorly graded SAND with silt and gravel. 31% gravel, 10% fines.		
255			D-7	17	16			*Becomes silty SAND with gravel, medium dense.*		End cap. Bentonite backfill 17.5-61.5 feet bgs.
	20		D-8	34	16			*Becomes dense, fine to coarse, subangular to subrounded sand and gravel.*		
250										
	25		D-9	29	9			Becomes medium dense.		
245										
	30									

URS

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-GUY WEST.GPJ; 9/16/2011 UG-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Guy West Levee
Project Number: 33763084

Log of Boring UG-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30		D-10	76/8"	8			Becomes very dense.		
240										Siginificant drill chatter at 32.5 feet bgs.
	35		D-11	56/11"	11			*As above, fine to coarse sand, fine gravel.*		Driller notes increase in gravel content, possible cobbles.
235										
	40		D-12	34	18		SW	**WELL GRADED SAND WITH GRAVEL,** dark grey, wet, dense. Fine to coarse, subangular, homogeneous.		Difficulty removing SPT sampler from borehole.
230										
	45		D-13	94/11"	11		SM	**SILTY SAND, sometimes with gravel,** dark grey, wet, very dense. Fine to coarse, angular to subrounded, homogeneous.		
225										
	50		D-14	75/11"	11			*Same as above except trace fine gravel.*		Siginificant drill chatter at 50 feet bgs.
220										
	55		D-15	95/11"	15			*As above except with fine to coarse gravel, angular to rounded.*		
215										
	60		D-16	15	5		SM	**SILTY SAND,** grey, wet, medium dense, trace of gravel. Fine to coarse, subangular to subrounded sand, fine gravel, homogeneous.		
210								Boring terminated at a depth of 61.5 feet bgs on 08/4/2011 and backfilled with bentonite chips.		Complete drilling at 1245.
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-GUY WEST.GPJ; 9/16/2011 UG-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Leach Road Levee
Project Number: 33763084

Log of Boring ULE-1-11

Date(s) Drilled	**8/5/11**	Logged By	**K. Yang**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**AMS Power Probe 9630 PRO-PTO**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**172.0**
Groundwater Level and Date Measured	**8.5 feet bgs**	Sampling Method(s)	**SPT/Shelby**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips/Standpipe Piezometer Installed 6 feet north**	Location	**West side levee, near 1300 ft north of Leach Rd E and 159th Ave E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GM	**SILTY GRAVEL WITH SAND,** light grey, dry, medium dense to dense. Fine to coarse, angular to rounded. [FILL]		Start drilling at 1330. Flush mount monument in cement installed. 1" schedule 80 PVC in bentonite 0.2-1.5 feet bgs. 1" schedule 80 PVC in 10-20 silica sand 1.5-2 feet bgs. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 2-7 feet bgs.
170										
			D-1	32	3			46% gravel, 13% fines		
	5						SM	**SILTY SAND WITH GRAVEL,** light grey, dry, medium dense. Fine to coarse, angular to rounded, homogeneous, trace of organics. [FILL]		
			D-2	27	2					
165										End cap.
							ML	**Sandy SILT with Gravel,** dark brown, wet, medium stiff. Fine to medium, angular.		Bentonite backfill 7-61.5 feet bgs.
			D-3	15	6				▽	PP=0.25 tsf
	10							*Grades to dark grey to blue grey.*		
			D-4	16	14					PP=0.25 tsf, 14% gravel, 55% fines, Non-plastic
160										
			S-5		1					Disturbed shelby tube sample.
							SM	**SILTY SAND WITH GRAVEL,** dark grey, wet, medium dense. Fine to coarse, angular to rounded, homogeneous.		
	15									
			D-6	25	14					47% gravel, 14% fines
155										
							SW-SM	**WELL GRADED SAND WITH SILT,** dark grey, wet, loose. Trace of fine gravel, fine to coarse, subangular to rounded, homogeneous.		
			D-7	6	15					
	20							*Trace of dark brown organics and gravel, angular to subrounded.*		
			D-8	6	10					
150										
	25									
			D-9	5	18					
							ML	**Silty SAND to Sandy SILT, with gravel** dark grey, wet, loose or stiff, stratified. Gravel coarse, subangular, sand fine to coarse.		PP=0.5 tsf
145										
	30									

URS

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-LEACH ROAD.GPJ; 9/16/2011 ULE-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Leach Road Levee
Project Number: 33763084

Log of Boring ULE-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30		D-10	2	18			*Grades to soft, trace sand and gravel.*		PP=<0.25 tsf, 22% gravel, 26% fines
140			S-11		0			*No recovery.*		
	35		D-12	8	18			*Becomes medium stiff or loose.*		PP=0.25 tsf
135										
	40		D-13	5	16			*As above, gravel fine to coarse, angular to subangular.*		PP=0.25 tsf
130										
	45		D-14	10	18			*Becomes medium stiff to stiff or medium dense.*		PP=0.5 tsf
125										
	50		D-15	8	18					
120										
							SM	**SILTY SAND WITH GRAVEL,** red-brown to grey, moist, dense, stratified. Fine to coarse, angular.		
	55		D-16	50	10					
115										
	60		D-17	15	5			*As above except medium dense.*		
110								Boring terminated at a depth of 61.5 feet bgs, backfilled with bentonite chips on 8/5/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 6-ft north from boring location on 8/11/2011.		Complete drilling at 1615.
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-LEACH ROAD.GPJ; 9/16/2011 ULE-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Lindsay Levee
Project Number: 33763084

Log of Boring UL-1-11

Date(s) Drilled	**8/3/11**	Logged By	**P. Craig**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**128.0**
Groundwater Level and Date Measured	**11.5 feet**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips**	Location	**West side levee, near 500 ft north of east end of 145th St E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GP-GM	**POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES,** dark grey, dry, very dense. Coarse, angular gravel. Cobbles max. size 6" to 4 feet bgs. Occasional boulders. [FILL]		Start drilling at 0800. Grass at surface. Flush mount monument in cement installed. 1" schedule 80 PVC in bentonite chips 1.5-12 feet bgs.
125			D-1	65/12"	6					
	5		D-2	30	5			Become light brown grey Silty SAND with gravel, dense.		Larger cobbles and/or gravel fractured during sampling.
120			D-3	48	12					
	10		D-4	62	16			Becomes very dense. 47% gravel, 11% fines	∇	At 11-11.5 feet bgs water on outside of sampling device.
							SP-SM	**POORLY GRADED SAND WITH SILT and GRAVEL,** dark brown/grey, wet, medium dense, angular, max. size 1.25".		1" schedule 80 PVC in 10-20 silica sand 12-12.5 feet bgs. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 12.5-17.5 feet bgs.
115			D-5	12	5					
	15		D-6	13	16			41% gravel, 5% fines		Sandy soil as stated by driller. Disturbed portion of sample (SP) discarded.
110			D-7	20	7					
	20		D-8	32	7			*Becomes dense, subrounded to angular.*		Disturbed upper portion of sample (SP) discarded.
105										
	25		D-9	35	9					Disturbed upper portion of sample (SP) discarded.
							SM	**SILTY SAND WITH GRAVEL,** brown/grey, wet, dense.		
100										
	30									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-LINDSAY.GPJ; 9/16/2011 UL-1-11

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Lindsay Levee
Project Number: 33763084

Log of Boring UL-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30						GM	*Becomes medium dense.*		
			D-10	23	10					Disturbed upper portion of sample (SP) discarded.
95										
	35							*Becomes very dense.*		
			D-11	58	9					Disturbed upper portion of sample (SP) discarded.
90										
	40							*Becomes grey, with some red speckles, dense.*		
			D-12	30	12					
85							SM	**SILTY SAND,** trace gravel, dark grey, wet, loose.		
	45									
			D-13	7	12					PP=1.25 tsf at top of sample, PP=0 tsf at tip of sample.
80										
			S-14		0					Shelby sample at 48 feet bgs. No recovery. Had empty spoon, got intrusion into sampler, discarded.
	50							*Becomes medium dense.*		
			D-15	17	12					
75										
	55							*Becomes loose.*		
			D-16	6	16					
70										
	60							*Becomes medium dense.*		
			D-17	18	13.5					Complete drilling at 1030.
65								Boring terminated at a depth of 61.5 feet bgs, backfilled with bentonite chips on 8/3/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 9-ft south from boring location on 8/11/2011.		
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-LINDSAY.GPJ; 9/16/2011 UL-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Old Soldier Levee
Project Number: 33763084

Log of Boring UOS-1-11

Date(s) Drilled	**8/1/11**	Logged By	**P. Craig**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**243.0**
Groundwater Level and Date Measured	**7.5 feet bgs**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips**	Location	**West side levee, near 5000 ft southeast of Calistoga St W bridge, Puyallup, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GP-GM	**POORLY GRADED GRAVEL WITH SILT AND SAND,** dark brown, dry to moist, dense, subrounded, fine. [FILL]		Flush mount monument in cement installed.
							SM	**SILTY SAND WITH GRAVEL,** dark brown, moist, very dense. [FILL]		1" schedule 80 PVC in bentonite chips 1.1-1.5 feet bgs. 1" schedule 80 PVC in 10-20 silica sand 1.5-1.7 feet bgs. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 1.7-6.7 feet bgs.
240			D-1	89/11"	15					
	5		D-2	46	12			*Becomes dense, organic odor.*34% gravel,22% fines.		End cap.
235			D-3	17	16			*Becomes moist, medium dense.*	▽	
							ML	**SANDY SILT,** dark brown, wet, stiff, with woody debris.		
	10		D-4	9	18					70% fines
							SM	**SILTY SAND WITH GRAVEL,** dark brown, wet, loose.		
230			D-5	6	10					
	15		D-6	7	18					31% gravel, 19% fines
225			D-7	6	18			Same as above except Silty SAND.		
	20		D-8	4	18			*Grades to green/grey, trace organics.*		
220										
	25		D-9	3	18			*Becomes very loose, grades to fine to coarse.*		
215							ML	**SANDY SILT,** trace of organics, dark grey, wet, soft, low plasticity.		
	30									

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Old Soldier Levee
Project Number: 33763084

Log of Boring UOS-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30						ML	*As above.*		PP=0-0.5 tsf, 95% fines, LL=25%, PI=8%
			D-10	3	6					
210										
	35							Same as above except medium stiff.		PP=0-0.25 tsf
			D-11	5	16					
205										
	40							*Grades to grey, trace gravel, stiff.*		PP=0 tsf
			D-12	10	18					
200							ML	**CLAYEY SILT WITH SAND,** dark grey, wet, medium stiff, low plasticity.		
	45									PP=0 tsf
			D-13	9	18					
195										
	50							Light grey ash below thin layer of dark brown organics.		
			D-14	7	6					
							ML	**SANDY SILT WITH GRAVEL,** dark grey, wet, very stiff.		
190										
	55									
			D-15	20	18					
							SM	**SILTY SAND**, light grey ash, wet, medium dense, trace organic.		
185										
	60									
			D-16	11	18					
								Boring terminated at a depth of 61.5 feet bgs, backfilled with bentonite chips on 8/1/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 5-ft north from boring location on 8/11/2011.		Complete drilling at 1615.
180										
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-OLD SOLDIER.GPJ; 9/23/2011 UOS-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Puyallup Authorized RB Levee
Project Number: 33763084

Log of Boring UP-1-11

Date(s) Drilled	**8/9/11**	Logged By	**K. Yang**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**16.0**
Groundwater Level and Date Measured	**17.3 feet bgs**	Sampling Method(s)	**SPT/Shelby**	Hammer Data	**140 lb manual**
Borehole Backfill	**Observation Well Installed**	Location	**North side levee, near 300 ft northwest of N Levee Rd E & Ferguson Rd E, Tacoma, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						SM	**SILTY SAND WITH GRAVEL,** light grey, dry to moist, medium dense. Fine to coarse, angular, homogeneous. [FILL]		Start drilling at 1400. Flush mount monument in cement installed. 1" schedule 80 PVC in bentonite chips 1.1-5 feet bgs.
15								*Grades to light grey to brown-grey, moist.*28% gravel, 20% fines.		
			D-1	24	6					
							SM	**SILTY SAND,** red-brown, fine, moist, loose, trace of fine gravel, subangular, homogeneous. [FILL]		
	5									1" schedule 80 PVC in 10-20 silica sand 5-6 feet bgs.
10			D-2	7	1					1" screened 0.010 schedule 80 PVC in 10-20 silica sand 6-11 feet bgs.
								No gravel.		
			D-3	5	2					
	10									
5			D-4	5	2					End cap. Bentonite backfill 11-61.5 feet bgs.
							ML	**SILT,** brown, wet, soft, low plasticity, homogeneous.		
			D-5	3	14					PP=0.25 tsf, 2% gravel, 91% fines, LL=28%, PI=1%
							SM	**SILTY SAND,** dark grey brown, wet, loose, stratified, fine to coarse, subangular.		
	15									
0			D-6	3	18					PP=0.25-0.5 tsf
							OL	**ORGANIC SILT,** dark grey, wet, soft.	▽	
			D-7	3	18					PP=0.5 tsf, LL=38%, PI=5%
	20						SM	**SILTY SAND,** dark brown, trace organics, wet, medium dense, stratified, fine to coarse, subangular.		
-5			S-8		18					
			D-9	12	18					
	25						ML	**CLAYEY SILT WITH SAND,** olive-grey, wet, medium stiff, low plasticity, homogeneous, trace of organic fibers.		
-10			D-10	12	18					81% fines, non-plastic
	30									Driller notes very difficult drilling 29-30 feet bgs.

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Puyallup Authorized RB Levee
Project Number: 33763084

Log of Boring UP-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30									
-15			S-11		0		ML	*As above.*		
			D-12	16	16		SM	**SILTY SAND,** dark brown, wet, medium dense, homogeneous, trace of fine wood debris.		
	35							*As above, no wood debris.*		
-20			D-13	17	17					
	40							*Becomes loose.*		
-25			D-14	7	16					
			S-15		0					
	45						ML	**SILT,** olive-grey, wet, medium stiff, low plasticity, homogeneous, trace of organic fibers.		PP=0.5 tsf
-30			D-16	5	18					
	50									
-35			D-17	14	18			Becomes stiff, trace organics.		PP=1.0 tsf
	55									PP=0.5 tsf
-40			D-18	11	18		SM	**SILTY SAND,** dark grey, moist, medium dense.		
	60							*Becomes loose.*		
-45			D-19	8	18					
								Boring terminated at a depth of 66.5 feet bgs, backfilled with bentonite chips on 08/9/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 10-ft south from boring location on 8/12/2011.		
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-PUYALLUP AUTHORIZED RB.GPJ; 9/23/2011 UP-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Riddell Levee
Project Number: 33763084

Log of Boring UR-1-11

Date(s) Drilled	**8/3/11**	Logged By	**P. Craig**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**EC-85**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**177.0**
Groundwater Level and Date Measured	**13.0 feet**	Sampling Method(s)	**SPT**	Hammer Data	**140 lb manual**
Borehole Backfill	**Bentonite Chips**	Location	**North side levee, near 5000 ft southeast of McCutcheon Rd E and 159th Ave E, Orting, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	REMARKS
	0					GW	**WELL GRADED SANDY GRAVEL WITH COBBLES,** grey/brown, dry, medium dense. Max. gravel size 1.25". Subrounded to rounded sand, gravel and cobbles. [FILL]	Start drilling at 1215. Flush mount monument in cement installed. 1" schedule 80 PVC in bentonite chips 1.2-12 feet bgs.
175						SM	**SILTY SAND WITH GRAVEL,** dark brown, moist, medium dense, trace organics, fine to coarse, max. size 1.25". [FILL]	
			D-1	14	7.5			
	5							
			D-2	18	12		31% gravel, 12% fines.	
170								
			D-3	15	4			
						SM	**SILTY SAND WITH GRAVEL,** dark brown, moist to wet, medium dense, fine to coarse, max. size 1.25".	
	10							
			D-4	27	11			
165							*Becomes wet.*	1" schedule 80 PVC in 10-20 silica sand 12-13 feet bgs. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 13-18 feet bgs.
			D-5	26	6.5			
						GP	**POORLY GRADED GRAVEL WITH SAND,** dark brown, wet, medium dense, fine to coarse.	
	15							
			D-6	25	11		62% gravel, 2% fines.	
160						SM	**SILTY SAND WITH GRAVEL,** dark brown, wet, dense, fine to coarse, max. size 1.25".	End cap. 6" of slough at top discarded. Fractured rock in tip. Bentonite backfill 18-61.5 feet bgs.
			D-7	40	12			
	20						*Becomes medium dense.*	
			D-8	27	6			
155						SP-SM	**POORLY GRADED GRAVELLY SAND TO SANDY GRAVEL,** dark brown, wet, loose, fine to coarse, max. size 1.25".	
	25							
			D-9	5	9			27% gravel, 8% fines Pulled sample before drilling to next interval. Not fine so did not take shelby tube sample 25-30 feet bgs. At 25 feet sample about 7" of poorly graded sand slough discarded.
150								
						SM	**SILTY SAND,** Occasionally with gravel, grey, wet, very loose.	
	30							

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-RIDDELL.GPJ; 9/28/2011 UR-1-11

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Riddell Levee
Project Number: 33763084

Log of Boring UR-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30		D-10	3	18		SM	*As above.*		At 30 feet approximately 10" of poorly graded sand slough discarded from top of sample. PP=0 tsf
145										
	35		D-11	8	18			*Becomes loose, higher sand content.*		PP=0 tsf
140										
	40		D-12	6	18			*Trace organics.*		Move sample due to intrusion. Full sampler, top 5" discarded. PP=0 tsf
135										
	45		D-13	24	18			*Becomes medium dense.*		Rock in sampler tip. Full sampler, top 4" disturbed, discarded.
130										
	50		D-14	17	14.5					Rock in sampler tip.
125										
	55		D-15	16	18			*As above excepth with gravel.*		
120										
	60		D-16	25	15					PP=0-0.5 tsf. Complete drilling at 1415.
115								Boring terminated at a depth of 61.5 feet bgs, backfilled with bentonite chips on 8/3/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 9-ft west from boring location on 8/12/2011.		
	65									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-RIDDELL.GPJ; 9/28/2011 UR-1-11

Project: Puyallup River Basin Geotechnical Support **Project Location: Sportsmen Levee** **Project Number: 33763084**	**Log of Boring US-1-11** Sheet 1 of 3

Date(s) Drilled	**8/9/11**	Logged By	**K. Yang**	Checked By	**M. McCabe**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**3 1/4" I. D.**	Total Depth of Borehole	**66.5 feet**
Drill Rig Type	**EC-52**	Drilling Contractor	**Boretec, Inc.**	Approximate Surface Elevation	**79.0**
Groundwater Level and Date Measured	**15.8 feet bgs**	Sampling Method(s)	**SPT/Shelby**	Hammer Data	**140 lb manual**
Borehole Backfill	**Observation Well Installed**	Location	**West side levee, near 400 ft north of the gate at 15795, 96th St E, Puyallup, WA**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	0						GM	**SILTY GRAVEL WITH SAND,** light grey, dry, very dense. Fine to coarse, angular to rounded, homogeneous. [FILL]		Start drilling at 0830. Flush mount monument in cement installed. 1" schedule 80 PVC in 10-20 silica sand 1.2-2 feet bgs. 1" screened 0.010 schedule 80 PVC in 10-20 silica sand 2-7 feet bgs.
			D-1	50/6"	3			*Grades to olive-grey, moist.*		
75										
	5		D-2	21	3			Becomes medium dense. 47% gravel, 21% fines.		
							SP-SM	**POORLY GRADED SAND WITH SILT,** yellow-brown, moist, medium dense. Fine to coarse, angular, homogeneous.		End cap. Bentonite backfill 7-66.5 feet bgs.
			D-3	12	12					
70										
	10		D-4	6	10					
			D-5	46	8		SM	**SILTY SAND WITH GRAVEL,** dark grey, moist, dense. Fine to medium sand, fine gravel, rounded, homogeneous.		40% gravel, 11% fines
65										
	15		D-6	42	7			*Grades to red-brown, angular to subangular.*	▽	
			D-7	18	14			*Becomes wet, medium dense, fine to coarse sand and gravel.*		
60										
	20		D-8	10	18		SC	**CLAYEY SAND,** yellow-brown, wet, loose, stratified, fine to coarse, subangular.		PP=1.0 tsf, 10% gravel, 30% fines, LL=33%, PI=14%
55										
	25		D-9	3	18		SM	**SILTY SAND,** dark brow to grey, wet, very loose to loose, trace of fine to coarse gravel, subangular.		PP=0.25 tsf
50										
	30									

URS

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-SPORTSMEN.GPJ; 9/28/2011 US-1-11

Project: Puyallup River Basin Geotechnical Support
Project Location: Sportsmen Levee
Project Number: 33763084

Log of Boring US-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	30							*No recovery.*		
			S-10		0					
								Becomes loose.		PP=0.5 tsf
			D-11	6	18					
45										
	35							Trace organics.		1% organic
			S-12		24					
										PP=0.5 tsf
			D-13	7	18					
40										
	40									PP=0.5 tsf
			D-14	7	18					
							SM	**SILTY SAND WITH GRAVEL,** dark brown, wet, loose, angular, homogeneous.		
35										
	45									
			D-15	10	18					
30										
	50							Becomes dense.		
			D-16	47	18					
							SM	**SILTY SAND,** trace gravel, dark brown, wet, medium dense, fine to coarse, angular gravel, homogeneous.		
25										
	55									
			D-17	11	18					
20										
	60									PP=0.5-0.75 tsf
			D-18	13	18					
15										
	65									

URS

Project: Puyallup River Basin Geotechnical Support
Project Location: Sportsmen Levee
Project Number: 33763084

Log of Boring US-1-11

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, Blows/12 in.	Recovery (in.)	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Graphic	REMARKS
	65		D-19	6	18		SM	*As above except loose, trace of wood fibers.*		PP=0.25-0.5 tsf
								Boring terminated at a depth of 66.5 feet bgs, backfilled with bentonite chips on 08/9/2011, and drive point piezo installed by ESN Northwest using 3-inch O.D. steel casing at approx 10-ft south from boring location on 8/12/2011.		
10	70									
5	75									
0	80									
-5	85									
-10	90									
-15	95									
-20	100									

Report: PORT_GEO_WELL_NO_DD_NO_MC; File: PUYALLUP RIVER GEOTECH-SPORTSMEN.GPJ; 9/28/2011 US-1-11

APPENDIX B - SLUG TESTING RESULTS

Table B-1: Summary of Slug Testing Results

Boring Site	Boring #	Groundwater Depth (ft)	Permeability (cm/sec)	Piezometer Screen Depth (ft)	Soil Type at Screen Level	Test Date
Ford**	UF-1-11	11.4	2.61E-02	13 - 18	Sand with silt and gravel	8/16/2010
Old Soldiers Home*	UOS-1-11	7.5	8.52E-06	1.7-6.7	Silty Sand with gravel	8/16/2011
Bridge Street	UBS-1-11	10.5	6.57E-05	9.9 - 14.9	Silty Sand with gravel	8/17/2012
Guy West	UG-1-11	12.5	1.62E-05	12.6 - 17.6	Silty Sand with gravel	8/15/2013
Alward Segment 1	UA-1-11	9.3	4.89E-05	8.5-13.5	Sand with silt	8/15/2014
Leach Road**	ULE-1-11	8.5	3.32E-02	2 - 7	Silty Gravel to Sand	8/16/2015
Lindsay**	UL-1-11	11.5	6.46E-02	12 - 17	Sand with silt and gravel	8/17/2016
Riddell**	UR-1-11	13	4.21E-02	12.5 - 17.5	Silty Sand to gravel	8/17/2017
Sportsmen	US-1-11	15.8	1.67E-04	1.7-6.7	Silty Gravel with Sand	8/15/2018
Puyallup Authorized RB	UP-1-11	17.3	4.91E-05	4.9-9.9	Silty Sand	8/16/2019

Notes:

* GW depth is approximate based on interpretation from field logs.

** High discharge rate, unable to detect slug head. Assume slug height is half distance from bottom to ground surface, and head returns to pretest level in 7.5 seconds.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UO-1-11 (Old Soldier)
Type of Test: Falling Head

Start Date: 8/15/2011
Test By: Ken Yang

Well Data

Total Depth (ft):	6.7	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	1.7	
Top of Filter Pack Depth (ft):	1.5	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 6.7 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -6.1 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	17:04	0	0.6	-6.1	6.3969297	0.002083					8.52E-06
		0.25	0.82	-5.88	6.3969297	0.002083	0.036732	0.25	0.001958	8.29E-05	
		0.5	0.94	-5.76	6.3969297	0.002083	0.020619	0.25	0.001099	4.65E-05	2.79E-07
		0.75	0.99	-5.71	6.3969297	0.002083	0.008718	0.25	0.000465	1.97E-05	(ft/sec)
		1	1.05	-5.65	6.3969297	0.002083	0.010563	0.25	0.000563	2.38E-05	
		1.25	1.11	-5.59	6.3969297	0.002083	0.010676	0.25	0.000569	2.41E-05	
		1.5	1.16	-5.54	6.3969297	0.002083	0.008985	0.25	0.000479	2.03E-05	
		1.75	1.2	-5.5	6.3969297	0.002083	0.007246	0.25	0.000386	1.64E-05	
		2	1.24	-5.46	6.3969297	0.002083	0.007299	0.25	0.000389	1.65E-05	
		2.25	1.27	-5.43	6.3969297	0.002083	0.00551	0.25	0.000294	1.24E-05	
		2.5	1.29	-5.41	6.3969297	0.002083	0.083308	2.25	0.000493	2.09E-05	
		2.75	1.3	-5.4	6.3969297	0.002083	0.00185	0.25	9.86E-05	4.18E-06	
		3	1.31	-5.39	6.3969297	0.002083	0.001854	0.25	9.88E-05	4.18E-06	
		3.25	1.315	-5.385	6.3969297	0.002083	0.000928	0.25	4.95E-05	2.09E-06	
		3.5	1.32	-5.38	6.3969297	0.002083	0.000929	0.25	4.95E-05	2.10E-06	
		3.75	1.321	-5.379	6.3969297	0.002083	0.000186	0.25	9.91E-06	4.19E-07	
		4	1.322	-5.378	6.3969297	0.002083	0.000186	0.25	9.91E-06	4.20E-07	
		4.25	1.424	-5.276	6.3969297	0.002083	0.019148	0.25	0.001021	4.32E-05	
		4.5	1.326	-5.374	6.3969297	0.002083	0.010367	2.25	6.14E-05	2.60E-06	
		4.75	1.328	-5.372	6.3969297	0.002083	0.000372	0.25	1.98E-05	8.40E-07	
		5	1.33	-5.37	6.3969297	0.002083	0.000372	0.25	1.99E-05	8.40E-07	
		5.5	1.331	-5.369	6.3969297	0.002083	0.000186	0.5	4.96E-06	2.10E-07	
		6	1.332	-5.368	6.3969297	0.002083	0.000186	0.5	4.96E-06	2.10E-07	
		6.5	1.334	-5.366	6.3969297	0.002083	0.000373	0.5	9.93E-06	4.20E-07	
		7	1.336	-5.364	6.3969297	0.002083	0.000373	0.5	9.94E-06	4.21E-07	
		7.5	1.338	-5.362	6.3969297	0.002083	0.000373	0.5	9.94E-06	4.21E-07	
		8	1.35	-5.35	6.3969297	0.002083	0.00224	0.5	5.97E-05	2.53E-06	
		8.5	1.38	-5.32	6.3969297	0.002083	0.005623	0.5	0.00015	6.34E-06	
		9	1.4	-5.3	6.3969297	0.002083	0.003766	0.5	0.0001	4.25E-06	
		9.5	1.41	-5.29	6.3969297	0.002083	0.001889	0.5	5.03E-05	2.13E-06	
		10	1.43	-5.27	6.3969297	0.002083	0.003788	0.5	0.000101	4.27E-06	
		11	1.49	-5.21	6.3969297	0.002083	0.011451	1	0.000153	6.46E-06	
		12	1.5	-5.2	6.3969297	0.002083	0.001921	1	2.56E-05	1.08E-06	
		13	1.52	-5.18	6.3969297	0.002083	0.036023	8	6E-05	2.54E-06	

	14	1.59	-5.11	6.3969297	0.002083	0.013606	1	0.000181	7.68E-06
	15	1.61	-5.09	6.3969297	0.002083	0.003922	1	5.23E-05	2.21E-06
	16	1.64	-5.06	6.3969297	0.002083	0.005911	1	7.88E-05	3.34E-06
	17	1.73	-4.97	6.3969297	0.002083	0.07629	10	0.000102	4.30E-06
	18	1.8	-4.9	6.3969297	0.002083	0.014185	1	0.000189	8.00E-06
	19	1.87	-4.83	6.3969297	0.002083	0.014389	1	0.000192	8.12E-06
	20	1.93	-4.77	6.3969297	0.002083	0.0125	1	0.000167	7.05E-06
	21	1.98	-4.72	6.3969297	0.002083	0.179847	20	0.00012	5.07E-06
	22	2.05	-4.65	6.3969297	0.002083	0.014942	1	0.000199	8.43E-06
	23	2.11	-4.59	6.3969297	0.002083	0.012987	1	0.000173	7.33E-06
	24	2.18	-4.52	6.3969297	0.002083	0.015368	1	0.000205	8.67E-06
	25	2.23	-4.47	6.3969297	0.002083	0.20006	23	0.000116	4.91E-06
	26	2.29	-4.41	6.3969297	0.002083	0.013514	1	0.00018	7.62E-06
	27	2.33	-4.37	6.3969297	0.002083	0.009112	1	0.000121	5.14E-06
	28	2.4	-4.3	6.3969297	0.002083	0.016148	1	0.000215	9.11E-06
	29	2.46	-4.24	6.3969297	0.002083	0.239982	26	0.000123	5.21E-06
17:34	30	2.5	-4.2	6.3969297	0.002083	0.009479	1	0.000126	5.35E-06
	32	2.64	-4.06	6.3969297	0.002083	0.033902	2	0.000226	9.56E-06
	34	2.73	-3.97	6.3969297	0.002083	0.022417	2	0.000149	6.32E-06
	36	2.84	-3.86	6.3969297	0.002083	0.331649	32	0.000138	5.85E-06
	38	2.92	-3.78	6.3969297	0.002083	0.020943	2	0.00014	5.91E-06
17:44	40	2.99	-3.71	6.3969297	0.002083	0.018692	2	0.000125	5.27E-06
	42	3.08	-3.62	6.3969297	0.002083	0.024558	2	0.000164	6.93E-06
	44	3.19	-3.51	6.3969297	0.002083	0.425212	39	0.000145	6.15E-06
	46	3.3	-3.4	6.3969297	0.002083	0.031841	2	0.000212	8.98E-06
17:52	48	3.38	-3.32	6.3969297	0.002083	0.023811	2	0.000159	6.72E-06
	50	3.45	-3.25	6.3969297	0.002083	0.02131	2	0.000142	6.01E-06
	52	3.53	-3.17	6.3969297	0.002083	0.525978	45	0.000156	6.59E-06
17:58	54	3.6	-3.1	6.3969297	0.002083	0.022329	2	0.000149	6.30E-06
	56	3.66	-3.04	6.3969297	0.002083	0.019545	2	0.00013	5.51E-06
	58	3.73	-2.97	6.3969297	0.002083	0.023296	2	0.000155	6.57E-06
16:04	60	3.79	-2.91	6.3969297	0.002083	0.599554	51	0.000157	6.63E-06
	65	2.86	-3.84	6.3969297	0.002083	0.055711	33	2.25E-05	9.52E-07
	70	4.05	-2.65	6.3969297	0.002083	0.370913	5	0.000989	4.19E-05
	75	4.19	-2.51	6.3969297	0.002083	0.054277	5	0.000145	6.12E-06
	80	4.32	-2.38	6.3969297	0.002083	0.814472	75.5	0.000144	6.09E-06
	85	4.42	-2.28	6.3969297	0.002083	0.042925	5	0.000114	4.84E-06
	90	4.53	-2.17	6.3969297	0.002083	0.049448	5	0.000132	5.58E-06
	95	4.62	-2.08	6.3969297	0.002083	0.042359	5	0.000113	4.78E-06
	100	4.73	-1.97	6.3969297	0.002083	0.545742	54	0.000135	5.70E-06
	105	4.8	-1.9	6.3969297	0.002083	0.03618	5	9.64E-05	4.08E-06
	110	4.88	-1.82	6.3969297	0.002083	0.043017	5	0.000115	4.85E-06
	115	4.95	-1.75	6.3969297	0.002083	1.119721	107.5	0.000139	5.88E-06
17:04	120	5.02	-1.68	6.3969297	0.002083	0.040822	5	0.000109	4.61E-06
	130	5.14	-1.56	6.3969297	0.002083	0.074108	10	9.88E-05	4.18E-06
	140	5.28	-1.42	6.3969297	0.002083	0.094029	10	0.000125	5.30E-06
	150	5.38	-1.32	6.3969297	0.002083	0.790521	90	0.000117	4.96E-06
	160	5.47	-1.23	6.3969297	0.002083	0.070618	10	9.41E-05	3.98E-06
	170	5.58	-1.12	6.3969297	0.002083	0.093685	10	0.000125	5.29E-06
18:04	180	5.66	-1.04	6.3969297	0.002083	1.609438	168	0.000128	5.40E-06

Notes:

1. kh = $\frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: ULE-1-11 (Leach Road)
Type of Test: Falling Head

Start Date: 8/15/2011 (1st time)
Test By: KY

Well Data

Total Depth (ft):	6.94	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	2	
Top of Filter Pack Depth (ft):	1.5	
Top of Riser Depth (ft):	0.2	(i.e. "stickup")

Test Data

D_0 (ft) = 6.94 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -3.47 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	1540	0	6.64	-0.3	6.39693	0.002083					
	1542	2	6.73	-0.21	6.39693	0.002083	0.356675	2	0.002377	1.01E-04	
	1546	6	6.82	-0.12	6.39693	0.002083	0.559616	4	0.001864	7.89E-05	
	1552	14	6.91	-0.03	6.39693	0.002083	1.386294	8	0.002309	9.78E-05	
Note - could not create more than a few inches of head, water flows out too fast; k value not representative.											
Try making assumptions as described in Note #2 to get a more representative k value:											
		0	3.47	-3.47	6.39693	0.002083					3.32E-02
Assume 5 sec.s		0.083333	6.935	-0.005	6.39693	0.002083	6.542472	0.0833	1.046293	4.43E-02	
											1.09E-03
Assume 10 sec.s		0	3.47	-3.47	6.39693	0.002083					(ft/sec)
		0.166667	6.935	-0.005	6.39693	0.002083	6.542472	0.1667	0.523147	2.21E-02	

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"
2. Assumed the water level changed from half of the well depth to the bottom in half of the screen in 5 seconds, and 10 seconds, respectively. Water flows out only from bottom 2.5 ft of screened interval.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UF-1-11 (Ford)
Type of Test: Falling Head

Start Date: 8/15/2011 (1st time)
Test By: KY

Well Data

Total Depth (ft):	18.02	
Casing Diameter (in):	1	
Screen Length (ft):	2.5	**Assumed**
Top of Screen Depth (ft):	13.02	
Top of Filter Pack Depth (ft):	12	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 10.13 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -5.13 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone) **Assumed**
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
Note - could not create more than a few inches of head, water flows out too fast; k value not representative.											
Try making assumptions as described in Note #2 to get a more representative k value:											
8/15/2011	12:50	0	5	-5.13	6.39693	0.002083					2.61E-02
Assume 5 sec.s		0.083333	10.1	-0.03	6.39693	0.002083	5.141664	0.0833	0.822272	3.48E-02	
											8.57E-04
Assume 10 sec.s		0	5	-5.13	6.39693	0.002083					(ft/sec)
		0.166667	10.1	-0.03	6.39693	0.002083	5.141664	0.1667	0.411136	1.74E-02	

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"
2. Assumed the water level changed from half of the depth to the water table in the screen in 5 seconds, and 10 seconds, respectively. Since water table is above top of screen, assume water flows out entire screened interval.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: US-1-11 (Sportsman)
Type of Test: Falling Head

Start Date: 8/15/2011 (First Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	6.7	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	1.7	
Top of Filter Pack Depth (ft):	1.2	
Top of Riser Depth (ft):	0.4	(i.e. "stickup")

Test Data

D_0 (ft) = 6.7 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -2.17 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	14:00	0	4.53	-2.17	6.3969297	0.002083					2.35E-04
		0.25	4.6	-2.1	6.3969297	0.002083	0.03279	0.25	0.001748	7.40E-05	
		0.5	4.76	-1.94	6.3969297	0.002083	0.079249	0.25	0.004225	1.79E-04	7.70E-06
		0.75	4.8	-1.9	6.3969297	0.002083	0.020834	0.25	0.001111	4.70E-05	(ft/sec)
		1	4.93	-1.77	6.3969297	0.002083	0.070874	0.25	0.003778	1.60E-04	
		1.25	5	-1.7	6.3969297	0.002083	0.040351	0.25	0.002151	9.11E-05	
		1.5	5.15	-1.55	6.3969297	0.002083	0.092373	0.25	0.004924	2.08E-04	
		1.75	5.3	-1.4	6.3969297	0.002083	0.101783	0.25	0.005426	2.30E-04	
		2	5.41	-1.29	6.3969297	0.002083	0.08183	0.25	0.004362	1.85E-04	
		2.25	5.5	-1.2	6.3969297	0.002083	0.072321	0.25	0.003855	1.63E-04	
		2.5	5.69	-1.01	6.3969297	0.002083	0.731987	2.25	0.004336	1.84E-04	
		2.75	5.8	-0.9	6.3969297	0.002083	0.115311	0.25	0.006147	2.60E-04	
		3	5.98	-0.72	6.3969297	0.002083	0.223144	0.25	0.011895	5.04E-04	
		3.25	6.05	-0.65	6.3969297	0.002083	0.102279	0.25	0.005452	2.31E-04	
		3.5	6.11	-0.59	6.3969297	0.002083	0.09685	0.25	0.005163	2.19E-04	
		3.75	6.15	-0.55	6.3969297	0.002083	0.070204	0.25	0.003742	1.58E-04	
		4	6.19	-0.51	6.3969297	0.002083	0.075508	0.25	0.004025	1.70E-04	
		4.25	6.24	-0.46	6.3969297	0.002083	0.103184	0.25	0.005501	2.33E-04	
		4.5	6.28	-0.42	6.3969297	0.002083	1.049822	2.25	0.006218	2.63E-04	
		4.75	6.3	-0.4	6.3969297	0.002083	0.04879	0.25	0.002601	1.10E-04	
		5	6.33	-0.37	6.3969297	0.002083	0.077962	0.25	0.004156	1.76E-04	
		5.5	6.39	-0.31	6.3969297	0.002083	0.176931	0.5	0.004716	2.00E-04	
		6	6.46	-0.24	6.3969297	0.002083	0.255933	0.5	0.006822	2.89E-04	
		6.5	6.5	-0.2	6.3969297	0.002083	0.182322	0.5	0.00486	2.06E-04	
		7	6.54	-0.16	6.3969297	0.002083	0.223144	0.5	0.005948	2.52E-04	
		7.5	6.61	-0.09	6.3969297	0.002083	0.575364	0.5	0.015336	6.49E-04	
		8	6.65	-0.05	6.3969297	0.002083	0.587787	0.5	0.015667	6.63E-04	
		8.5	6.7	0							

Notes:

1. kh = $\frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: US-1-11 (Sportsman)
Type of Test: Falling Head

Start Date: 8/15/2011 (Second Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	6.7	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	1.7	
Top of Filter Pack Depth (ft):	1.2	
Top of Riser Depth (ft):	0.4	(i.e. "stickup")

Test Data

D_0 (ft) = 6.7 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -2.3 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	14:30	0	4.4	-2.3	6.3969297	0.002083					1.47E-04
		0.25	4.5	-2.2	6.3969297	0.002083	0.044452	0.25	0.00237	1.00E-04	
		0.5	4.66	-2.04	6.3969297	0.002083	0.075508	0.25	0.004025	1.70E-04	4.82E-06
		0.75	4.7	-2	6.3969297	0.002083	0.019803	0.25	0.001056	4.47E-05	(ft/sec)
		1	4.76	-1.94	6.3969297	0.002083	0.030459	0.25	0.001624	6.87E-05	
		1.25	4.8	-1.9	6.3969297	0.002083	0.020834	0.25	0.001111	4.70E-05	
		1.5	4.88	-1.82	6.3969297	0.002083	0.043017	0.25	0.002293	9.71E-05	
		1.75	4.9	-1.8	6.3969297	0.002083	0.01105	0.25	0.000589	2.49E-05	
		2	4.99	-1.71	6.3969297	0.002083	0.051293	0.25	0.002734	1.16E-04	
		2.25	5.05	-1.65	6.3969297	0.002083	0.035718	0.25	0.001904	8.06E-05	
		2.5	5.12	-1.58	6.3969297	0.002083	0.331033	2.25	0.001961	8.30E-05	
		2.75	5.2	-1.5	6.3969297	0.002083	0.05196	0.25	0.00277	1.17E-04	
		3	5.28	-1.42	6.3969297	0.002083	0.054808	0.25	0.002922	1.24E-04	
		3.25	5.374	-1.326	6.3969297	0.002083	0.06849	0.25	0.003651	1.55E-04	
		3.5	5.45	-1.25	6.3969297	0.002083	0.059023	0.25	0.003146	1.33E-04	
		3.75	5.5	-1.2	6.3969297	0.002083	0.040822	0.25	0.002176	9.21E-05	
		4	5.65	-1.05	6.3969297	0.002083	0.133531	0.25	0.007118	3.01E-04	
		4.25	5.7	-1	6.3969297	0.002083	0.04879	0.25	0.002601	1.10E-04	
		4.5	5.83	-0.87	6.3969297	0.002083	0.640037	2.25	0.003791	1.60E-04	
		4.75	5.9	-0.8	6.3969297	0.002083	0.083881	0.25	0.004472	1.89E-04	
		5	6.01	-0.69	6.3969297	0.002083	0.14792	0.25	0.007885	3.34E-04	
		5.5	6.07	-0.63	6.3969297	0.002083	0.090972	0.5	0.002425	1.03E-04	
		6	6.14	-0.56	6.3969297	0.002083	0.117783	0.5	0.003139	1.33E-04	
		6.5	6.2	-0.5	6.3969297	0.002083	0.113329	0.5	0.003021	1.28E-04	
		7	6.25	-0.45	6.3969297	0.002083	0.105361	0.5	0.002808	1.19E-04	
		7.5	6.3	-0.4	6.3969297	0.002083	0.117783	0.5	0.003139	1.33E-04	
		8	6.44	-0.26	6.3969297	0.002083	0.430783	0.5	0.011482	4.86E-04	
		8.5	6.37	-0.33	6.3969297	0.002083	-0.238411	0.5	-0.006355	-2.69E-04	
		9	6.42	-0.28	6.3969297	0.002083	0.164303	0.5	0.004379	1.85E-04	
		9.5	6.48	-0.22	6.3969297	0.002083	0.241162	0.5	0.006428	2.72E-04	
		10	6.49	-0.21	6.3969297	0.002083	0.04652	0.5	0.00124	5.25E-05	
		11	6.57	-0.13	6.3969297	0.002083	0.479573	1	0.006391	2.71E-04	
		12	6.65	-0.05	6.3969297	0.002083	0.955511	1	0.012734	5.39E-04	

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: US-1-11 (Sportsman)
Type of Test: Falling Head

Start Date: 8/15/2011 (3rd Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	6.7
Casing Diameter (in):	1
Screen Length (ft):	5
Top of Screen Depth (ft):	1.7
Top of Filter Pack Depth (ft):	1.2
Top of Riser Depth (ft):	0.4 (i.e. "stickup")

Test Data

D_0 (ft) = 6.7 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -2.25 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	15:15	0	4.45	-2.25	6.3969297	0.002083					1.18E-04
		0.25	4.5	-2.2	6.3969297	0.002083	0.022473	0.25	0.001198	5.07E-05	
		0.5	4.59	-2.11	6.3969297	0.002083	0.041769	0.25	0.002227	9.43E-05	3.88E-06
		0.75	4.65	-2.05	6.3969297	0.002083	0.028848	0.25	0.001538	6.51E-05	(ft/sec)
		1	4.72	-1.98	6.3969297	0.002083	0.034743	0.25	0.001852	7.84E-05	
		1.25	4.77	-1.93	6.3969297	0.002083	0.025577	0.25	0.001363	5.77E-05	
		1.5	4.8	-1.9	6.3969297	0.002083	0.015666	0.25	0.000835	3.54E-05	
		1.75	4.86	-1.84	6.3969297	0.002083	0.032088	0.25	0.001711	7.24E-05	
		2	4.92	-1.78	6.3969297	0.002083	0.033152	0.25	0.001767	7.48E-05	
		2.25	4.97	-1.73	6.3969297	0.002083	0.028492	0.25	0.001519	6.43E-05	
		2.5	5.02	-1.68	6.3969297	0.002083	0.269664	2.25	0.001597	6.76E-05	
		2.75	5.07	-1.63	6.3969297	0.002083	0.030214	0.25	0.001611	6.82E-05	
		3	5.12	-1.58	6.3969297	0.002083	0.031155	0.25	0.001661	7.03E-05	
		3.25	5.19	-1.51	6.3969297	0.002083	0.045315	0.25	0.002416	1.02E-04	
		3.5	5.26	-1.44	6.3969297	0.002083	0.047467	0.25	0.00253	1.07E-04	
		3.75	5.34	-1.36	6.3969297	0.002083	0.057158	0.25	0.003047	1.29E-04	
		4	5.42	-1.28	6.3969297	0.002083	0.060625	0.25	0.003232	1.37E-04	
		4.25	5.49	-1.21	6.3969297	0.002083	0.05624	0.25	0.002998	1.27E-04	
		4.5	5.57	-1.13	6.3969297	0.002083	0.425904	2.25	0.002523	1.07E-04	
		4.75	5.65	-1.05	6.3969297	0.002083	0.073427	0.25	0.003914	1.66E-04	
		5	5.75	-0.95	6.3969297	0.002083	0.100083	0.25	0.005335	2.26E-04	
		5.5	5.92	-0.78	6.3969297	0.002083	0.197168	0.5	0.005255	2.22E-04	
		6	6.03	-0.67	6.3969297	0.002083	0.152016	0.5	0.004052	1.72E-04	
		6.5	6.11	-0.59	6.3969297	0.002083	0.127155	0.5	0.003389	1.43E-04	
		7	6.12	-0.58	6.3969297	0.002083	0.017094	0.5	0.000456	1.93E-05	
		7.5	6.17	-0.53	6.3969297	0.002083	0.090151	0.5	0.002403	1.02E-04	
		8	6.23	-0.47	6.3969297	0.002083	0.120144	0.5	0.003202	1.36E-04	
		8.5	6.28	-0.42	6.3969297	0.002083	0.112478	0.5	0.002998	1.27E-04	
		9	6.31	-0.39	6.3969297	0.002083	0.074108	0.5	0.001975	8.36E-05	
		9.5	6.35	-0.35	6.3969297	0.002083	0.108214	0.5	0.002884	1.22E-04	
		10	6.38	-0.32	6.3969297	0.002083	0.089612	0.5	0.002389	1.01E-04	
		11	6.46	-0.24	6.3969297	0.002083	0.287682	1	0.003834	1.62E-04	
		12	6.51	-0.19	6.3969297	0.002083	0.233615	1	0.003113	1.32E-04	
		13	6.59	-0.11	6.3969297	0.002083	2.155982	8	0.003592	1.52E-04	

14	6.65	-0.05	6.3969297	0.002083	0.788457	1	0.010508	4.45E-04

Notes:

1. kh = $\frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UP-1-11 (Puyallup Auth RB)
Type of Test: Falling Head

Start Date: 8/15/2011 (1st Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	10.9	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	4.9	
Top of Filter Pack Depth (ft):	5	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 10.9 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -9.24 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	14:00	0	1.66	-9.24	6.3969297	0.002083					4.71E-05
		0.25	1.9	-9	6.3969297	0.002083	0.026317	0.25	0.001403	5.94E-05	
		0.5	2.25	-8.65	6.3969297	0.002083	0.039665	0.25	0.002114	8.95E-05	1.55E-06
		0.75	2.5	-8.4	6.3969297	0.002083	0.029328	0.25	0.001563	6.62E-05	(ft/sec)
		1	2.75	-8.15	6.3969297	0.002083	0.030214	0.25	0.001611	6.82E-05	
		1.25	3.1	-7.8	6.3969297	0.002083	0.043894	0.25	0.00234	9.91E-05	
		1.5	3.43	-7.47	6.3969297	0.002083	0.043229	0.25	0.002304	9.76E-05	
		1.75	3.74	-7.16	6.3969297	0.002083	0.042385	0.25	0.002259	9.56E-05	
		2	4.05	-6.85	6.3969297	0.002083	0.044261	0.25	0.002359	9.99E-05	
		2.25	4.28	-6.62	6.3969297	0.002083	0.034153	0.25	0.001821	7.71E-05	
		2.5	4.52	-6.38	6.3969297	0.002083	0.344056	2.25	0.002038	8.63E-05	
		2.75	4.66	-6.24	6.3969297	0.002083	0.022188	0.25	0.001183	5.01E-05	
		3	4.8	-6.1	6.3969297	0.002083	0.022691	0.25	0.00121	5.12E-05	
		3.25	4.88	-6.02	6.3969297	0.002083	0.013202	0.25	0.000704	2.98E-05	
		3.5	4.95	-5.95	6.3969297	0.002083	0.011696	0.25	0.000623	2.64E-05	
		3.75	5.07	-5.83	6.3969297	0.002083	0.020374	0.25	0.001086	4.60E-05	
		4	5.11	-5.79	6.3969297	0.002083	0.006885	0.25	0.000367	1.55E-05	
		4.25	5.2	-5.7	6.3969297	0.002083	0.015666	0.25	0.000835	3.54E-05	
		4.5	5.3	-5.6	6.3969297	0.002083	0.167329	2.25	0.000991	4.20E-05	
		4.75	5.38	-5.52	6.3969297	0.002083	0.014389	0.25	0.000767	3.25E-05	
		5	5.47	-5.43	6.3969297	0.002083	0.016439	0.25	0.000876	3.71E-05	
		5.5	5.62	-5.28	6.3969297	0.002083	0.028013	0.5	0.000747	3.16E-05	
		6	5.78	-5.12	6.3969297	0.002083	0.030772	0.5	0.00082	3.47E-05	
		6.5	5.92	-4.98	6.3969297	0.002083	0.027725	0.5	0.000739	3.13E-05	
		7	6.05	-4.85	6.3969297	0.002083	0.026451	0.5	0.000705	2.98E-05	
		7.5	6.16	-4.74	6.3969297	0.002083	0.022942	0.5	0.000611	2.59E-05	
		8	6.29	-4.61	6.3969297	0.002083	0.027809	0.5	0.000741	3.14E-05	
		8.5	6.4	-4.5	6.3969297	0.002083	0.02415	0.5	0.000644	2.72E-05	
		9	6.52	-4.38	6.3969297	0.002083	0.027029	0.5	0.00072	3.05E-05	
		9.5	6.63	-4.27	6.3969297	0.002083	0.025435	0.5	0.000678	2.87E-05	
		10	6.76	-4.14	6.3969297	0.002083	0.030918	0.5	0.000824	3.49E-05	
		11	6.98	-3.92	6.3969297	0.002083	0.054604	1	0.000728	3.08E-05	
		12	7.2	-3.7	6.3969297	0.002083	0.057759	1	0.00077	3.26E-05	
		13	7.43	-3.47	6.3969297	0.002083	0.447785	8	0.000746	3.16E-05	

14	7.61	-3.29	6.3969297	0.002083	0.053267	1	0.00071	3.01E-05
15	7.78	-3.12	6.3969297	0.002083	0.053055	1	0.000707	2.99E-05
16	7.94	-2.96	6.3969297	0.002083	0.052644	1	0.000702	2.97E-05
17	8.1	-2.8	6.3969297	0.002083	0.549359	10	0.000732	3.10E-05
18	8.25	-2.65	6.3969297	0.002083	0.05506	1	0.000734	3.11E-05
19	8.39	-2.51	6.3969297	0.002083	0.054277	1	0.000723	3.06E-05
20	8.53	-2.37	6.3969297	0.002083	0.057393	1	0.000765	3.24E-05
21	8.68	-2.22	6.3969297	0.002083	1.300511	20	0.000867	3.67E-05
22	8.81	-2.09	6.3969297	0.002083	0.060343	1	0.000804	3.40E-05
23	8.93	-1.97	6.3969297	0.002083	0.059131	1	0.000788	3.34E-05
24	9.04	-1.86	6.3969297	0.002083	0.057457	1	0.000766	3.24E-05
25	9.15	-1.75	6.3969297	0.002083	1.364633	23	0.000791	3.35E-05
26	9.26	-1.64	6.3969297	0.002083	0.06492	1	0.000865	3.66E-05
27	9.37	-1.53	6.3969297	0.002083	0.069429	1	0.000925	3.92E-05
28	9.48	-1.42	6.3969297	0.002083	0.074611	1	0.000994	4.21E-05
29	9.59	-1.31	6.3969297	0.002083	1.538262	26	0.000788	3.34E-05
30	9.7	-1.2	6.3969297	0.002083	0.087706	1	0.001169	4.95E-05
32	9.88	-1.02	6.3969297	0.002083	0.162519	2	0.001083	4.58E-05
34	10.04	-0.86	6.3969297	0.002083	0.170626	2	0.001137	4.81E-05
36	10.2	-0.7	6.3969297	0.002083	2.112807	32	0.00088	3.72E-05
38	10.32	-0.58	6.3969297	0.002083	0.188052	2	0.001253	5.30E-05
40	10.43	-0.47	6.3969297	0.002083	0.210295	2	0.001401	5.93E-05
42	10.56	-0.34	6.3969297	0.002083	0.323787	2	0.002158	9.13E-05
44	10.65	-0.25	6.3969297	0.002083	3.078233	39	0.001052	4.45E-05
46	10.76	-0.14	6.3969297	0.002083	0.579818	2	0.003864	1.64E-04

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UP-1-11 (Puyallup Auth RB)
Type of Test: Falling Head

Start Date: 8/15/2011 (2nd Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	10.9	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	4.9	
Top of Filter Pack Depth (ft):	5	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 10.9 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -10.6 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	14:00	0	0.3	-10.6	6.3969297	0.002083					5.10E-05
		0.25	0.59	-10.31	6.3969297	0.002083	0.02774	0.25	0.001479	6.26E-05	
		0.5	0.88	-10.02	6.3969297	0.002083	0.028531	0.25	0.001521	6.44E-05	1.67E-06
		0.75	1.22	-9.68	6.3969297	0.002083	0.034521	0.25	0.00184	7.79E-05	(ft/sec)
		1	1.56	-9.34	6.3969297	0.002083	0.035756	0.25	0.001906	8.07E-05	
		1.25	2.03	-8.87	6.3969297	0.002083	0.051631	0.25	0.002752	1.17E-04	
		1.5	2.5	-8.4	6.3969297	0.002083	0.054443	0.25	0.002902	1.23E-04	
		1.75	2.85	-8.05	6.3969297	0.002083	0.04256	0.25	0.002269	9.60E-05	
		2	3.21	-7.69	6.3969297	0.002083	0.045751	0.25	0.002439	1.03E-04	
		2.25	3.46	-7.44	6.3969297	0.002083	0.03305	0.25	0.001762	7.46E-05	
		2.5	3.72	-7.18	6.3969297	0.002083	0.361815	2.25	0.002143	9.07E-05	
		2.75	3.98	-6.92	6.3969297	0.002083	0.036884	0.25	0.001966	8.32E-05	
		3	4.24	-6.66	6.3969297	0.002083	0.038296	0.25	0.002041	8.64E-05	
		3.25	4.46	-6.44	6.3969297	0.002083	0.033591	0.25	0.001791	7.58E-05	
		3.5	4.69	-6.21	6.3969297	0.002083	0.036368	0.25	0.001939	8.21E-05	
		3.75	4.8	-6.1	6.3969297	0.002083	0.017872	0.25	0.000953	4.03E-05	
		4	4.98	-5.92	6.3969297	0.002083	0.029952	0.25	0.001597	6.76E-05	
		4.25	5.04	-5.86	6.3969297	0.002083	0.010187	0.25	0.000543	2.30E-05	
		4.5	5.11	-5.79	6.3969297	0.002083	0.250739	2.25	0.001485	6.29E-05	
		4.75	5.16	-5.74	6.3969297	0.002083	0.008673	0.25	0.000462	1.96E-05	
		5	5.24	-5.66	6.3969297	0.002083	0.014035	0.25	0.000748	3.17E-05	
		5.5	5.42	-5.48	6.3969297	0.002083	0.032319	0.5	0.000861	3.65E-05	
		6	5.58	-5.32	6.3969297	0.002083	0.029632	0.5	0.00079	3.34E-05	
		6.5	5.71	-5.19	6.3969297	0.002083	0.02474	0.5	0.000659	2.79E-05	
		7	5.86	-5.04	6.3969297	0.002083	0.029328	0.5	0.000782	3.31E-05	
		7.5	6	-4.9	6.3969297	0.002083	0.028171	0.5	0.000751	3.18E-05	
		8	6.1	-4.8	6.3969297	0.002083	0.020619	0.5	0.00055	2.33E-05	
		8.5	6.14	-4.76	6.3969297	0.002083	0.008368	0.5	0.000223	9.44E-06	
		9	6.26	-4.64	6.3969297	0.002083	0.025533	0.5	0.000681	2.88E-05	
		9.5	6.35	-4.55	6.3969297	0.002083	0.019587	0.5	0.000522	2.21E-05	
		10	6.5	-4.4	6.3969297	0.002083	0.033523	0.5	0.000894	3.78E-05	
		11	6.72	-4.18	6.3969297	0.002083	0.051293	1	0.000684	2.89E-05	
		12	7.01	-3.89	6.3969297	0.002083	0.071902	1	0.000958	4.06E-05	
		13	7.2	-3.7	6.3969297	0.002083	0.425091	8	0.000708	3.00E-05	

14	7.4	-3.5	6.3969297	0.002083	0.05557	1	0.000741	3.14E-05
15	7.61	-3.29	6.3969297	0.002083	0.061875	1	0.000825	3.49E-05
16	7.79	-3.11	6.3969297	0.002083	0.056265	1	0.00075	3.17E-05
17	7.94	-2.96	6.3969297	0.002083	0.532217	10	0.000709	3.00E-05
18	8.12	-2.78	6.3969297	0.002083	0.062738	1	0.000836	3.54E-05
19	8.25	-2.65	6.3969297	0.002083	0.047891	1	0.000638	2.70E-05
20	8.42	-2.48	6.3969297	0.002083	0.066301	1	0.000884	3.74E-05
21	8.55	-2.35	6.3969297	0.002083	1.379891	20	0.000919	3.89E-05
22	8.68	-2.22	6.3969297	0.002083	0.056908	1	0.000758	3.21E-05
23	8.82	-2.08	6.3969297	0.002083	0.065139	1	0.000868	3.67E-05
24	8.95	-1.95	6.3969297	0.002083	0.064539	1	0.00086	3.64E-05
25	9.06	-1.84	6.3969297	0.002083	1.430155	23	0.000829	3.51E-05
26	9.19	-1.71	6.3969297	0.002083	0.073272	1	0.000976	4.13E-05
27	9.31	-1.59	6.3969297	0.002083	0.072759	1	0.00097	4.10E-05
28	9.4	-1.5	6.3969297	0.002083	0.058269	1	0.000777	3.29E-05
29	9.5	-1.4	6.3969297	0.002083	1.559647	26	0.000799	3.38E-05
30	9.61	-1.29	6.3969297	0.002083	0.08183	1	0.001091	4.62E-05
32	9.82	-1.08	6.3969297	0.002083	0.177681	2	0.001184	5.01E-05
34	9.99	-0.91	6.3969297	0.002083	0.171272	2	0.001141	4.83E-05
36	10.15	-0.75	6.3969297	0.002083	2.066019	32	0.00086	3.64E-05
38	10.29	-0.61	6.3969297	0.002083	0.206614	2	0.001377	5.83E-05
40	10.41	-0.49	6.3969297	0.002083	0.219054	2	0.00146	6.18E-05
42	10.52	-0.38	6.3969297	0.002083	0.254234	2	0.001694	7.17E-05
44	10.64	-0.26	6.3969297	0.002083	3.080498	39	0.001053	4.46E-05
46	10.74	-0.16	6.3969297	0.002083	0.485508	2	0.003235	1.37E-04

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UA-1-11 (Alward Segment 1)
Type of Test: Falling Head

Start Date: 8/15/2011 (1st Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	13.48
Casing Diameter (in):	1 1/4
Screen Length (ft):	5
Top of Screen Depth (ft):	8.48
Top of Filter Pack Depth (ft):	6
Top of Riser Depth (ft):	0.3 (i.e. "stickup")

Test Data

D_0 (ft) = 10.61 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -1.52 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	9:33	0	9.09	-1.52	6.1737861	0.003255					4.73E-05
		0.25	9.13	-1.48	6.1737861	0.003255	0.026668	0.25	0.002144	9.08E-05	
		0.5	9.17	-1.44	6.1737861	0.003255	0.027399	0.25	0.002203	9.32E-05	1.55E-06
		0.75	9.19	-1.42	6.1737861	0.003255	0.013986	0.25	0.001124	4.76E-05	(ft/sec)
		1	9.21	-1.4	6.1737861	0.003255	0.014185	0.25	0.00114	4.83E-05	
		1.25	9.23	-1.38	6.1737861	0.003255	0.014389	0.25	0.001157	4.90E-05	
		1.5	9.25	-1.36	6.1737861	0.003255	0.014599	0.25	0.001174	4.97E-05	
		1.75	9.28	-1.33	6.1737861	0.003255	0.022306	0.25	0.001793	7.59E-05	
		2	9.29	-1.32	6.1737861	0.003255	0.007547	0.25	0.000607	2.57E-05	
		2.25	9.3	-1.31	6.1737861	0.003255	0.007605	0.25	0.000611	2.59E-05	
		2.5	9.32	-1.29	6.1737861	0.003255	0.1374	2.25	0.001227	5.20E-05	
		2.75	9.33	-1.28	6.1737861	0.003255	0.007782	0.25	0.000626	2.65E-05	
		3	9.34	-1.27	6.1737861	0.003255	0.007843	0.25	0.00063	2.67E-05	
		3.25	9.36	-1.25	6.1737861	0.003255	0.015873	0.25	0.001276	5.40E-05	
		3.5	9.39	-1.22	6.1737861	0.003255	0.024293	0.25	0.001953	8.27E-05	
		3.75	9.4	-1.21	6.1737861	0.003255	0.00823	0.25	0.000662	2.80E-05	
		4	9.405	-1.205	6.1737861	0.003255	0.004141	0.25	0.000333	1.41E-05	
		4.25	9.41	-1.2	6.1737861	0.003255	0.004158	0.25	0.000334	1.41E-05	
		4.5	9.43	-1.18	6.1737861	0.003255	0.104513	2.25	0.000934	3.95E-05	
		4.75	9.45	-1.16	6.1737861	0.003255	0.017094	0.25	0.001374	5.82E-05	
		5	9.46	-1.15	6.1737861	0.003255	0.008658	0.25	0.000696	2.95E-05	
		5.5	9.49	-1.12	6.1737861	0.003255	0.026433	0.5	0.001062	4.50E-05	
		6	9.53	-1.08	6.1737861	0.003255	0.036368	0.5	0.001462	6.19E-05	
		6.5	9.56	-1.05	6.1737861	0.003255	0.028171	0.5	0.001132	4.79E-05	
		7	9.59	-1.02	6.1737861	0.003255	0.028988	0.5	0.001165	4.93E-05	
		7.5	9.61	-1	6.1737861	0.003255	0.019803	0.5	0.000796	3.37E-05	
		8	9.63	-0.98	6.1737861	0.003255	0.020203	0.5	0.000812	3.44E-05	
		8.5	9.66	-0.95	6.1737861	0.003255	0.031091	0.5	0.00125	5.29E-05	
		9	9.68	-0.93	6.1737861	0.003255	0.021277	0.5	0.000855	3.62E-05	
		9.5	9.7	-0.91	6.1737861	0.003255	0.02174	0.5	0.000874	3.70E-05	
		10	9.72	-0.89	6.1737861	0.003255	0.022223	0.5	0.000893	3.78E-05	
		11	9.75	-0.86	6.1737861	0.003255	0.034289	1	0.000689	2.92E-05	
		12	9.78	-0.83	6.1737861	0.003255	0.035507	1	0.000714	3.02E-05	
		13	9.79	-0.82	6.1737861	0.003255	0.338213	8	0.00085	3.60E-05	

14	9.81	-0.8	6.1737861	0.003255	0.024693	1	0.000496	2.10E-05
15	9.87	-0.74	6.1737861	0.003255	0.077962	1	0.001567	6.63E-05
16	9.92	-0.69	6.1737861	0.003255	0.069959	1	0.001406	5.95E-05
17	9.96	-0.65	6.1737861	0.003255	0.450586	10	0.000906	3.83E-05
18	9.99	-0.62	6.1737861	0.003255	0.047253	1	0.00095	4.02E-05
19	10.04	-0.57	6.1737861	0.003255	0.084083	1	0.00169	7.15E-05
20	10.08	-0.53	6.1737861	0.003255	0.072759	1	0.001462	6.19E-05
21	10.1	-0.51	6.1737861	0.003255	1.009817	20	0.001015	4.30E-05
22	10.14	-0.47	6.1737861	0.003255	0.081678	1	0.001641	6.95E-05
23	10.16	-0.45	6.1737861	0.003255	0.043485	1	0.000874	3.70E-05
24	10.19	-0.42	6.1737861	0.003255	0.068993	1	0.001387	5.87E-05
25	10.2	-0.41	6.1737861	0.003255	1.16923	23	0.001022	4.32E-05
26	10.24	-0.37	6.1737861	0.003255	0.102654	1	0.002063	8.73E-05
27	10.26	-0.35	6.1737861	0.003255	0.05557	1	0.001117	4.73E-05
28	10.28	-0.33	6.1737861	0.003255	0.058841	1	0.001183	5.01E-05
29	10.3	-0.31	6.1737861	0.003255	1.4102	26	0.00109	4.61E-05
30	10.32	-0.29	6.1737861	0.003255	0.066691	1	0.00134	5.67E-05
32	10.37	-0.24	6.1737861	0.003255	0.189242	2	0.001902	8.05E-05
34	10.4	-0.21	6.1737861	0.003255	0.133531	2	0.001342	5.68E-05
36	10.43	-0.18	6.1737861	0.003255	1.901278	32	0.001194	5.05E-05
38	10.45	-0.16	6.1737861	0.003255	0.117783	2	0.001184	5.01E-05
40	10.46	-0.15	6.1737861	0.003255	0.064539	2	0.000649	2.75E-05
42	10.48	-0.13	6.1737861	0.003255	0.143101	2	0.001438	6.09E-05
44	10.49	-0.12	6.1737861	0.003255	2.260025	39	0.001165	4.93E-05
46	10.5	-0.11	6.1737861	0.003255	0.087011	2	0.000874	3.70E-05
48	10.51	-0.1	6.1737861	0.003255	0.09531	2	0.000958	4.05E-05
50	10.52	-0.09	6.1737861	0.003255	0.105361	2	0.001059	4.48E-05
52	10.53	-0.08	6.1737861	0.003255	2.545531	45	0.001137	4.81E-05
54	10.535	-0.075	6.1737861	0.003255	0.064539	2	0.000649	2.75E-05
56	10.54	-0.07	6.1737861	0.003255	0.068993	2	0.000693	2.93E-05
58	10.55	-0.06	6.1737861	0.003255	0.154151	2	0.001549	6.56E-05
60	10.555	-0.055	6.1737861	0.003255	2.827851	51	0.001114	4.72E-05

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UA-1-11 (Alward Segment 1)
Type of Test: Falling Head

Start Date: 8/15/2011 (2nd Time)
Test By: Ken Yang

Well Data

Total Depth (ft):	13.48
Casing Diameter (in):	1 1/4
Screen Length (ft):	5
Top of Screen Depth (ft):	8.48
Top of Filter Pack Depth (ft):	6
Top of Riser Depth (ft):	0.3 (i.e. "stickup")

Test Data

D_0 (ft) = 10.61 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -1.97 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	10:35	0	8.64	-1.97	6.1737861	0.003255					5.04E-05
		0.25	8.825	-1.785	6.1737861	0.003255	0.098615	0.25	0.007927	3.36E-04	
		0.5	9.01	-1.6	6.1737861	0.003255	0.109415	0.25	0.008796	3.72E-04	1.65E-06
		0.75	9.08	-1.53	6.1737861	0.003255	0.044736	0.25	0.003596	1.52E-04	(ft/sec)
		1	9.15	-1.46	6.1737861	0.003255	0.046831	0.25	0.003765	1.59E-04	
		1.25	9.18	-1.43	6.1737861	0.003255	0.020762	0.25	0.001669	7.07E-05	
		1.5	9.19	-1.42	6.1737861	0.003255	0.007018	0.25	0.000564	2.39E-05	
		1.75	9.2	-1.41	6.1737861	0.003255	0.007067	0.25	0.000568	2.40E-05	
		2	9.21	-1.4	6.1737861	0.003255	0.007117	0.25	0.000572	2.42E-05	
		2.25	9.22	-1.39	6.1737861	0.003255	0.007168	0.25	0.000576	2.44E-05	
		2.5	9.24	-1.37	6.1737861	0.003255	0.264608	2.25	0.002363	1.00E-04	
		2.75	9.25	-1.36	6.1737861	0.003255	0.007326	0.25	0.000589	2.49E-05	
		3	9.26	-1.35	6.1737861	0.003255	0.00738	0.25	0.000593	2.51E-05	
		3.25	9.27	-1.34	6.1737861	0.003255	0.007435	0.25	0.000598	2.53E-05	
		3.5	9.28	-1.33	6.1737861	0.003255	0.007491	0.25	0.000602	2.55E-05	
		3.75	9.29	-1.32	6.1737861	0.003255	0.007547	0.25	0.000607	2.57E-05	
		4	9.3	-1.31	6.1737861	0.003255	0.007605	0.25	0.000611	2.59E-05	
		4.25	9.305	-1.305	6.1737861	0.003255	0.003824	0.25	0.000307	1.30E-05	
		4.5	9.31	-1.3	6.1737861	0.003255	0.066939	2.25	0.000598	2.53E-05	
		4.75	9.315	-1.295	6.1737861	0.003255	0.003854	0.25	0.00031	1.31E-05	
		5	9.32	-1.29	6.1737861	0.003255	0.003868	0.25	0.000311	1.32E-05	
		5.5	9.33	-1.28	6.1737861	0.003255	0.007782	0.5	0.000313	1.32E-05	
		6	9.35	-1.26	6.1737861	0.003255	0.015748	0.5	0.000633	2.68E-05	
		6.5	9.37	-1.24	6.1737861	0.003255	0.016	0.5	0.000643	2.72E-05	
		7	9.38	-1.23	6.1737861	0.003255	0.008097	0.5	0.000325	1.38E-05	
		7.5	9.39	-1.22	6.1737861	0.003255	0.008163	0.5	0.000328	1.39E-05	
		8	9.4	-1.21	6.1737861	0.003255	0.00823	0.5	0.000331	1.40E-05	
		8.5	9.42	-1.19	6.1737861	0.003255	0.016667	0.5	0.00067	2.84E-05	
		9	9.44	-1.17	6.1737861	0.003255	0.01695	0.5	0.000681	2.88E-05	
		9.5	9.46	-1.15	6.1737861	0.003255	0.017242	0.5	0.000693	2.93E-05	
		10	9.49	-1.12	6.1737861	0.003255	0.026433	0.5	0.001062	4.50E-05	
		11	9.55	-1.06	6.1737861	0.003255	0.05506	1	0.001107	4.68E-05	
		12	9.58	-1.03	6.1737861	0.003255	0.02871	1	0.000577	2.44E-05	
		13	9.63	-0.98	6.1737861	0.003255	0.274845	8	0.00069	2.92E-05	

14	9.66	-0.95	6.1737861	0.003255	0.031091	1	0.000625	2.65E-05
15	9.69	-0.92	6.1737861	0.003255	0.032088	1	0.000645	2.73E-05
16	9.73	-0.88	6.1737861	0.003255	0.044452	1	0.000893	3.78E-05
17	9.76	-0.85	6.1737861	0.003255	0.369533	10	0.000743	3.14E-05
18	9.8	-0.81	6.1737861	0.003255	0.048202	1	0.000969	4.10E-05
19	9.82	-0.79	6.1737861	0.003255	0.025001	1	0.000502	2.13E-05
20	9.85	-0.76	6.1737861	0.003255	0.038715	1	0.000778	3.29E-05
21	9.89	-0.72	6.1737861	0.003255	0.706941	20	0.00071	3.01E-05
22	9.94	-0.67	6.1737861	0.003255	0.071973	1	0.001446	6.12E-05
23	9.97	-0.64	6.1737861	0.003255	0.04581	1	0.000921	3.90E-05
24	10.01	-0.6	6.1737861	0.003255	0.064539	1	0.001297	5.49E-05
25	10.04	-0.57	6.1737861	0.003255	0.898591	23	0.000785	3.32E-05
26	10.09	-0.52	6.1737861	0.003255	0.091808	1	0.001845	7.81E-05
27	10.11	-0.5	6.1737861	0.003255	0.039221	1	0.000788	3.34E-05
28	10.13	-0.48	6.1737861	0.003255	0.040822	1	0.00082	3.47E-05
29	10.15	-0.46	6.1737861	0.003255	1.076633	26	0.000832	3.52E-05
30	10.18	-0.43	6.1737861	0.003255	0.067441	1	0.001355	5.74E-05

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UG-1-11 (Guy West)
Type of Test: Falling Head

Start Date: 8/15/2011
Test By: Ken Yang

Well Data

Total Depth (ft):	17.58
Casing Diameter (in):	1 1/4
Screen Length (ft):	5
Top of Screen Depth (ft):	12.58
Top of Filter Pack Depth (ft):	11
Top of Riser Depth (ft):	0.3 (i.e. "stickup")

Test Data

D_0 (ft) = 12.35 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -2.08 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	12:00	0	10.27	-2.08	6.1737861	0.003255					1.62E-05
		0.25	10.44	-1.91	6.1737861	0.003255	0.085265	0.25	0.006854	2.90E-04	
		0.5	10.49	-1.86	6.1737861	0.003255	0.026527	0.25	0.002132	9.03E-05	5.33E-07
		0.75	10.56	-1.79	6.1737861	0.003255	0.038361	0.25	0.003084	1.31E-04	(ft/sec)
		1	10.61	-1.74	6.1737861	0.003255	0.028331	0.25	0.002277	9.64E-05	
		1.25	10.65	-1.7	6.1737861	0.003255	0.023257	0.25	0.00187	7.91E-05	
		1.5	10.71	-1.64	6.1737861	0.003255	0.035932	0.25	0.002888	1.22E-04	
		1.75	10.75	-1.6	6.1737861	0.003255	0.024693	0.25	0.001985	8.40E-05	
		2	10.78	-1.57	6.1737861	0.003255	0.018928	0.25	0.001522	6.44E-05	
		2.25	10.79	-1.56	6.1737861	0.003255	0.00639	0.25	0.000514	2.17E-05	
		2.5	10.8	-1.55	6.1737861	0.003255	0.208848	2.25	0.001865	7.90E-05	
		2.75	10.805	-1.545	6.1737861	0.003255	0.003231	0.25	0.00026	1.10E-05	
		3	10.81	-1.54	6.1737861	0.003255	0.003241	0.25	0.000261	1.10E-05	
		3.25	10.813	-1.537	6.1737861	0.003255	0.00195	0.25	0.000157	6.64E-06	
		3.5	10.816	-1.534	6.1737861	0.003255	0.001954	0.25	0.000157	6.65E-06	
		3.75	10.817	-1.533	6.1737861	0.003255	0.000652	0.25	5.24E-05	2.22E-06	
		4	10.818	-1.532	6.1737861	0.003255	0.000653	0.25	5.25E-05	2.22E-06	
		4.25	10.819	-1.531	6.1737861	0.003255	0.000653	0.25	5.25E-05	2.22E-06	
		4.5	10.82	-1.53	6.1737861	0.003255	0.019418	2.25	0.000173	7.34E-06	
		4.75	10.821	-1.529	6.1737861	0.003255	0.000654	0.25	5.26E-05	2.22E-06	
		5	10.8215	-1.5285	6.1737861	0.003255	0.000327	0.25	2.63E-05	1.11E-06	
		5.5	10.822	-1.528	6.1737861	0.003255	0.000327	0.5	1.32E-05	5.57E-07	
		6	10.8225	-1.5275	6.1737861	0.003255	0.000327	0.5	1.32E-05	5.57E-07	
		6.5	10.823	-1.527	6.1737861	0.003255	0.000327	0.5	1.32E-05	5.57E-07	
		7	10.8235	-1.5265	6.1737861	0.003255	0.000327	0.5	1.32E-05	5.57E-07	
		7.5	10.824	-1.526	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.57E-07	
		8	10.8245	-1.5255	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.58E-07	
		8.5	10.825	-1.525	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.58E-07	
		9	10.8255	-1.5245	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.58E-07	
		9.5	10.826	-1.524	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.58E-07	
		10	10.8265	-1.5235	6.1737861	0.003255	0.000328	0.5	1.32E-05	5.58E-07	
		11	10.827	-1.523	6.1737861	0.003255	0.000328	1	6.6E-06	2.79E-07	
		12	10.83	-1.52	6.1737861	0.003255	0.001972	1	3.96E-05	1.68E-06	
		13	10.835	-1.515	6.1737861	0.003255	0.008871	8	2.23E-05	9.43E-07	

12:14	14	10.84	-1.51	6.1737861	0.003255	0.003306	1	6.64E-05	2.81E-06
	15	10.85	-1.5	6.1737861	0.003255	0.006645	1	0.000134	5.65E-06
	16	10.86	-1.49	6.1737861	0.003255	0.006689	1	0.000134	5.69E-06
	17	10.87	-1.48	6.1737861	0.003255	0.030935	10	6.22E-05	2.63E-06
	18	10.873	-1.477	6.1737861	0.003255	0.002029	1	4.08E-05	1.73E-06
	19	10.876	-1.474	6.1737861	0.003255	0.002033	1	4.09E-05	1.73E-06
	20	10.88	-1.47	6.1737861	0.003255	0.002717	1	5.46E-05	2.31E-06
	21	10.885	-1.465	6.1737861	0.003255	0.17203	20	0.000173	7.32E-06
	22	10.89	-1.46	6.1737861	0.003255	0.003419	1	6.87E-05	2.91E-06
	23	10.9	-1.45	6.1737861	0.003255	0.006873	1	0.000138	5.85E-06
	24	10.91	-1.44	6.1737861	0.003255	0.00692	1	0.000139	5.89E-06
	25	10.915	-1.435	6.1737861	0.003255	0.089911	23	7.86E-05	3.33E-06
	26	10.92	-1.43	6.1737861	0.003255	0.00349	1	7.01E-05	2.97E-06
	27	10.925	-1.425	6.1737861	0.003255	0.003503	1	7.04E-05	2.98E-06
	28	10.93	-1.42	6.1737861	0.003255	0.003515	1	7.06E-05	2.99E-06
	29	10.94	-1.41	6.1737861	0.003255	0.088193	26	6.82E-05	2.89E-06
	30	10.945	-1.405	6.1737861	0.003255	0.003552	1	7.14E-05	3.02E-06
	32	10.95	-1.4	6.1737861	0.003255	0.003565	2	3.58E-05	1.52E-06
	34	10.96	-1.39	6.1737861	0.003255	0.007168	2	7.2E-05	3.05E-06
	36	10.97	-1.38	6.1737861	0.003255	0.104491	32	6.56E-05	2.78E-06
	38	10.98	-1.37	6.1737861	0.003255	0.007273	2	7.31E-05	3.09E-06
	40	10.99	-1.36	6.1737861	0.003255	0.007326	2	7.36E-05	3.12E-06
	42	11.01	-1.34	6.1737861	0.003255	0.014815	2	0.000149	6.30E-06
	44	11.02	-1.33	6.1737861	0.003255	0.139108	39	7.17E-05	3.03E-06
	46	11.03	-1.32	6.1737861	0.003255	0.007547	2	7.58E-05	3.21E-06
	48	11.04	-1.31	6.1737861	0.003255	0.007605	2	7.64E-05	3.23E-06
	50	11.06	-1.29	6.1737861	0.003255	0.015385	2	0.000155	6.54E-06
	52	11.07	-1.28	6.1737861	0.003255	0.176117	45	7.87E-05	3.33E-06
	54	11.08	-1.27	6.1737861	0.003255	0.007843	2	7.88E-05	3.34E-06
	56	11.09	-1.26	6.1737861	0.003255	0.007905	2	7.94E-05	3.36E-06
	58	11.1	-1.25	6.1737861	0.003255	0.007968	2	8.01E-05	3.39E-06
13:00	60	11.15	-1.2	6.1737861	0.003255	0.239345	51	9.43E-05	3.99E-06
	65	11.12	-1.23	6.1737861	0.003255	0.129458	33	7.88E-05	3.34E-06
	70	11.15	-1.2	6.1737861	0.003255	0.024693	5	9.92E-05	4.20E-06
	75	11.19	-1.16	6.1737861	0.003255	0.033902	5	0.000136	5.77E-06
	80	11.21	-1.14	6.1737861	0.003255	0.294239	75.5	7.83E-05	3.32E-06
	85	11.24	-1.11	6.1737861	0.003255	0.026668	5	0.000107	4.54E-06
	90	11.26	-1.09	6.1737861	0.003255	0.018182	5	7.31E-05	3.09E-06
	95	11.29	-1.06	6.1737861	0.003255	0.027909	5	0.000112	4.75E-06
	100	11.31	-1.04	6.1737861	0.003255	0.238411	54	8.87E-05	3.76E-06
	105	11.33	-1.02	6.1737861	0.003255	0.019418	5	7.8E-05	3.30E-06
	110	11.37	-0.98	6.1737861	0.003255	0.040005	5	0.000161	6.81E-06
	115	11.43	-0.92	6.1737861	0.003255	0.506032	107.5	9.46E-05	4.00E-06
14:00	120	11.46	-0.89	6.1737861	0.003255	0.033152	5	0.000133	5.64E-06
	130	11.52	-0.83	6.1737861	0.003255	0.069796	10	0.00014	5.94E-06
	140	11.53	-0.82	6.1737861	0.003255	0.012121	10	2.44E-05	1.03E-06
	150	11.56	-0.79	6.1737861	0.003255	0.418044	90	9.33E-05	3.95E-06

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UBS-1-11 (Bridge Street)
Type of Test: Falling Head

Start Date: 8/17/2011
Test By: AIT

Well Data

Total Depth (ft):	14.85
Casing Diameter (in):	1 1/4
Screen Length (ft):	5
Top of Screen Depth (ft):	9.85
Top of Filter Pack Depth (ft):	9
Top of Riser Depth (ft):	0.3 (i.e. "stickup")

Test Data

D_0 (ft) = 10.31 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -3.12 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 60 (Length of screened/filter pack zone)
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
8/16/2011	9:02	0	7.19	-3.12	6.1737861	0.003255					6.57E-05
		0.25	8.59	-1.72	6.1737861	0.003255	0.595509	0.25	0.047872	2.03E-03	
		0.5	8.8	-1.51	6.1737861	0.003255	0.130215	0.25	0.010468	4.43E-04	2.16E-06
		0.75	9.02	-1.29	6.1737861	0.003255	0.157467	0.25	0.012658	5.36E-04	(ft/sec)
		1	9.1	-1.21	6.1737861	0.003255	0.064022	0.25	0.005147	2.18E-04	
		1.25	9.13	-1.18	6.1737861	0.003255	0.025106	0.25	0.002018	8.54E-05	
		1.5	9.15	-1.16	6.1737861	0.003255	0.017094	0.25	0.001374	5.82E-05	
		1.75	9.18	-1.13	6.1737861	0.003255	0.026202	0.25	0.002106	8.92E-05	
		2	9.2	-1.11	6.1737861	0.003255	0.017858	0.25	0.001436	6.08E-05	
		2.25	9.25	-1.06	6.1737861	0.003255	0.046091	0.25	0.003705	1.57E-04	
		2.5	9.28	-1.03	6.1737861	0.003255	0.512765	2.25	0.00458	1.94E-04	
		2.75	9.31	-1	6.1737861	0.003255	0.029559	0.25	0.002376	1.01E-04	
		3	9.35	-0.96	6.1737861	0.003255	0.040822	0.25	0.003282	1.39E-04	
		3.25	9.37	-0.94	6.1737861	0.003255	0.021053	0.25	0.001692	7.16E-05	
		3.5	9.4	-0.91	6.1737861	0.003255	0.032435	0.25	0.002607	1.10E-04	
		3.75	9.42	-0.89	6.1737861	0.003255	0.022223	0.25	0.001786	7.56E-05	
		4	9.46	-0.85	6.1737861	0.003255	0.045985	0.25	0.003697	1.56E-04	
		4.25	9.48	-0.83	6.1737861	0.003255	0.023811	0.25	0.001914	8.10E-05	
		4.5	9.5	-0.81	6.1737861	0.003255	0.26899	2.25	0.002403	1.02E-04	
		4.75	9.51	-0.8	6.1737861	0.003255	0.012423	0.25	0.000999	4.23E-05	
		5	9.53	-0.78	6.1737861	0.003255	0.025318	0.25	0.002035	8.62E-05	
		5.5	9.56	-0.75	6.1737861	0.003255	0.039221	0.5	0.001576	6.67E-05	
		6	9.58	-0.73	6.1737861	0.003255	0.027029	0.5	0.001086	4.60E-05	
		6.5	9.62	-0.69	6.1737861	0.003255	0.056353	0.5	0.002265	9.59E-05	
		7	9.64	-0.67	6.1737861	0.003255	0.029414	0.5	0.001182	5.00E-05	
		7.5	9.67	-0.64	6.1737861	0.003255	0.04581	0.5	0.001841	7.79E-05	
		8	9.68	-0.63	6.1737861	0.003255	0.015748	0.5	0.000633	2.68E-05	
		8.5	9.69	-0.62	6.1737861	0.003255	0.016	0.5	0.000643	2.72E-05	
		9	9.7	-0.61	6.1737861	0.003255	0.016261	0.5	0.000654	2.77E-05	
		9.5	9.703	-0.607	6.1737861	0.003255	0.00493	0.5	0.000198	8.39E-06	
		10	9.71	-0.6	6.1737861	0.003255	0.011599	0.5	0.000466	1.97E-05	
		11	9.73	-0.58	6.1737861	0.003255	0.033902	1	0.000681	2.88E-05	
		12	9.76	-0.55	6.1737861	0.003255	0.05311	1	0.001067	4.52E-05	
		13	9.79	-0.52	6.1737861	0.003255	0.405465	8	0.001019	4.31E-05	

9:16	14	9.79	-0.52	6.1737861	0.003255	0	1	0	0.00E+00
	15	9.8	-0.51	6.1737861	0.003255	0.019418	1	0.00039	1.65E-05
	16	9.81	-0.5	6.1737861	0.003255	0.019803	1	0.000398	1.68E-05
	17	9.83	-0.48	6.1737861	0.003255	0.333492	10	0.00067	2.84E-05
	18	9.84	-0.47	6.1737861	0.003255	0.021053	1	0.000423	1.79E-05
	19	9.85	-0.46	6.1737861	0.003255	0.021506	1	0.000432	1.83E-05
	20	9.86	-0.45	6.1737861	0.003255	0.021979	1	0.000442	1.87E-05
	21	9.88	-0.43	6.1737861	0.003255	1.03459	20	0.00104	4.40E-05
	22	9.884	-0.426	6.1737861	0.003255	0.009346	1	0.000188	7.95E-06
	23	9.89	-0.42	6.1737861	0.003255	0.014185	1	0.000285	1.21E-05
	24	9.9	-0.41	6.1737861	0.003255	0.024098	1	0.000484	2.05E-05
9:27	25	9.902	-0.408	6.1737861	0.003255	1.000848	23	0.000875	3.70E-05
	26	9.904	-0.406	6.1737861	0.003255	0.004914	1	9.88E-05	4.18E-06
	27	9.906	-0.404	6.1737861	0.003255	0.004938	1	9.92E-05	4.20E-06
	28	9.91	-0.4	6.1737861	0.003255	0.00995	1	0.0002	8.47E-06
	29	9.912	-0.398	6.1737861	0.003255	0.880481	26	0.000681	2.88E-05
	30	9.914	-0.396	6.1737861	0.003255	0.005038	1	0.000101	4.29E-06
	32	9.92	-0.39	6.1737861	0.003255	0.015267	2	0.000153	6.49E-06
	34	9.922	-0.388	6.1737861	0.003255	0.005141	2	5.17E-05	2.19E-06
	36	9.924	-0.386	6.1737861	0.003255	0.789399	32	0.000496	2.10E-05
	38	9.926	-0.384	6.1737861	0.003255	0.005195	2	5.22E-05	2.21E-06
	40	9.93	-0.38	6.1737861	0.003255	0.010471	2	0.000105	4.45E-06
	42	9.935	-0.375	6.1737861	0.003255	0.013245	2	0.000133	5.63E-06
	44	9.94	-0.37	6.1737861	0.003255	0.745791	39	0.000384	1.63E-05
	46	9.945	-0.365	6.1737861	0.003255	0.013606	2	0.000137	5.79E-06
	48	9.95	-0.36	6.1737861	0.003255	0.013793	2	0.000139	5.87E-06
	50	9.955	-0.355	6.1737861	0.003255	0.013986	2	0.000141	5.95E-06
	52	9.96	-0.35	6.1737861	0.003255	0.649345	45	0.00029	1.23E-05
	54	9.963	-0.347	6.1737861	0.003255	0.008608	2	8.65E-05	3.66E-06
	56	9.966	-0.344	6.1737861	0.003255	0.008683	2	8.73E-05	3.69E-06
	58	9.97	-0.34	6.1737861	0.003255	0.011696	2	0.000118	4.98E-06
13:00	60	9.972	-0.338	6.1737861	0.003255	0.590413	51	0.000233	9.85E-06
	65	9.974	-0.336	6.1737861	0.003255	0.149036	33	9.08E-05	3.84E-06
	70	9.977	-0.333	6.1737861	0.003255	0.008969	5	3.6E-05	1.53E-06
	75	9.98	-0.33	6.1737861	0.003255	0.00905	5	3.64E-05	1.54E-06
	80	9.983	-0.327	6.1737861	0.003255	0.907074	75.5	0.000241	1.02E-05
	85	9.986	-0.324	6.1737861	0.003255	0.009217	5	3.7E-05	1.57E-06
	90	9.99	-0.32	6.1737861	0.003255	0.012423	5	4.99E-05	2.11E-06
	95	9.993	-0.317	6.1737861	0.003255	0.009419	5	3.79E-05	1.60E-06
	100	9.996	-0.314	6.1737861	0.003255	0.150504	54	5.6E-05	2.37E-06
	105	10	-0.31	6.1737861	0.003255	0.012821	5	5.15E-05	2.18E-06
	110	10.003	-0.307	6.1737861	0.003255	0.009725	5	3.91E-05	1.65E-06
	115	10.006	-0.304	6.1737861	0.003255	0.74444	107.5	0.000139	5.89E-06
14:00	120	10.01	-0.3	6.1737861	0.003255	0.013245	5	5.32E-05	2.25E-06
	130	10.015	-0.295	6.1737861	0.003255	0.016807	10	3.38E-05	1.43E-06
	140	10.02	-0.29	6.1737861	0.003255	0.017094	10	3.44E-05	1.45E-06
	150	10.023	-0.287	6.1737861	0.003255	0.163564	90	3.65E-05	1.55E-06
	160	10.026	-0.284	6.1737861	0.003255	0.010508	10	2.11E-05	8.94E-07
	170	10.03	-0.28	6.1737861	0.003255	0.014185	10	2.85E-05	1.21E-06
	180	10.033	-0.277	6.1737861	0.003255	0.685901	168	8.21E-05	3.47E-06
	190	10.036	-0.274	6.1737861	0.003255	0.010889	10	2.19E-05	9.26E-07
	200	10.04	-0.27	6.1737861	0.003255	0.014706	10	2.96E-05	1.25E-06
	210	10.045	-0.265	6.1737861	0.003255	0.033398	20	3.36E-05	1.42E-06
	220	10.05	-0.26	6.1737861	0.003255	0.063336	40	3.18E-05	1.35E-06
	230	10.051	-0.259	6.1737861	0.003255	0.0563	40	2.83E-05	1.20E-06
13:02	240	10.052	-0.258	6.1737861	0.003255	0.045462	40	2.28E-05	9.67E-07

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"

2. Highlighted values in the column of d - Depth to Water (ft) are interpolated.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UL-1-11 (Lindsay)
Type of Test: Falling Head

Start Date: 8/17/2011 (1st time)
Test By: AIT

Well Data

Total Depth (ft):	12.49	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	12	
Top of Filter Pack Depth (ft):	11	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 12.49 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -6.245 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 30 (Length of screened/filter pack zone) **Assumed**
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
Note - could not create more than a few inches of head, water flows out too fast; k value not representative.											
Try making assumptions as described in Note #2 to get a more representative k value:											
8/16/2011	14:59	0	6.245	-6.245	5.7037825	0.004167					6.46E-02
		0.083333	12.485	-0.005	5.7037825	0.004167	7.130099	0.083	2.033427	8.61E-02	
Assume 5 sec.s											2.12E-03
		0	6.245	-6.245	5.7037825	0.004167					(ft/sec)
Assume 10 sec.s		0.166667	12.485	-0.005	5.7037825	0.004167	7.130099	0.167	1.016713	4.30E-02	

Notes:

1. $kh = \frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"
2. Assumed the water level changed from half of the well depth to the bottom in half of the screen in 5 seconds, and 10 seconds, respectively. Water flows out only from bottom 2.5 ft of screened interval.

URS	Slug Test For Hydraulic Properties of Aquifers (ASTM D-4044-96)

Job Name: Puyallup River
Job No.: 33763084
Well No.: UR-1-11 (Ridell)
Type of Test: Falling Head

Start Date: 8/17/2011 (1st time)
Test By: AIT

Well Data

Total Depth (ft):	17.5	
Casing Diameter (in):	1	
Screen Length (ft):	5	
Top of Screen Depth (ft):	12.5	
Top of Filter Pack Depth (ft):	12	
Top of Riser Depth (ft):	0.3	(i.e. "stickup")

Test Data

D_0 (ft) = 13.58 (Depth to water below ground surface before slug)
H_0 (ft) = {d (ft) at time zero - D_0 } = -4.83 (Initial test head after slug)
D (in) = 4.88 (Borehole diameter)
L (in) = 48 (Length of screened/filter pack zone) **Assumed**
m = 5 (" = SQRT (k_h x k_v)) - - assumed value

Field-Measured Data					Intermediate Calculated Quantities				Permeability		
Date	Time (24-hr)	t Elapsed Time (min)	d Depth to Water (ft)	H Head (ft)	A ln(2mL/d)	B d2/8L	C ln(H1/H2)	D t2-t1	k ABC\D (in/min)	k (cm/sec)	Average k (cm/sec)
Note - could not create more than a few inches of head, water flows out too fast; k value not representative.											
Try making assumptions as described in Note #2 to get a more representative k value:											
8/17/2011	16:55	0	8.75	-4.83	6.1737861	0.002604					4.21E-02
Assume 5 sec.s		0.083333	13.575	-0.005	6.1737861	0.002604	6.873164	0.083	1.326045	5.61E-02	
		0	8.75	-4.83	6.1737861	0.002604					1.38E-03 (ft/sec)
Assume 10 sec.s		0.166667	13.575	-0.005	6.1737861	0.002604	6.873164	0.167	0.663023	2.81E-02	

Notes:

1. kh = $\frac{d^2 \ln(2mL/D) \ \ln(H1/H2)}{8 L \ (t_2 - t_1)}$ from Hvorslev (1949) , for "wellpoint filter in uniform soil"
2. Assumed the water level changed from half of the well depth to the bottom in 5 seconds, and 10 seconds, respectively. Water flows out only the 4 ft of screen that is below the water table.

APPENDIX C - LABORATORY TESTING RESULTS FROM HWA GEOSCIENCES INC.

1. HWA Geosciences Inc. letter on September 2, 2011
2. Summary of material properties by HWA Geosciences Inc.
3. LL, PL and PI figures of soils by HWA Geosciences Inc.
4. Particle-size analysis figures of soils by HWA Geosciences Inc.
5. HWA Geosciences Inc. letter on October 4, 2011

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering · Hydrogeology · Geoenvironmental · Planning & Permitting · Inspection & Testing

September 2, 2011
HWA Project No. 2011-081-23

URS Corporation
1501 4th Avenue, Suite 1400
Seattle, Washington 98101

Attention: Mr. John Gillespie, PE

Subject: **Materials Laboratory Report**
Index Property Testing
Puyallup Basin Levees

Dear Mr. Gillespie;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: The samples were picked up by HWA personnel on August 15, and August 22, 2011. The samples were in plastic bags and Shelby tubes. The sample descriptions are included in Figures 1 through 9.

MOISTURE CONTENT OF SOIL: The moisture content of selected soil samples (percent by dry mass) was determined in general accordance with ASTM D 2216. The data is summarized on the attached Figures 1-9.

LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ATTERBERG LIMITS): Selected samples were tested using method ASTM D 4318, multi-point method. Three samples were prepared and found to be non-plastic. These three were billed as one-point tests. The results are reported on the attached Liquid Limit, Plastic Limit, and Plasticity Index reports, Figures 10-11.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle distribution of material in general accordance with ASTM D422. The results are summarized on the attached Particle Size Distribution reports, Figures 12-21, which also provide information regarding the classification of the sample and the moisture content at the time of testing.

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UNIT WEIGHT OF SOIL: The wet density of a portion of the soil extruded from the Shelby tubes was measured in general accordance with ASTM D2937. The wet density of the extruded soil is summarized on Figures 1-9.

MOISTURE CONTENT, ASH, AND ORGANIC MATTER: Selected samples were tested in general accordance with method ASTM D 2974, using moisture content method 'A' (oven dried at 105° C) and ash content method 'C' (burned at 440° C). The test results are summarized on Figures 1-9. The results are percent by weight of dry soil.

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Harold Benny
Materials Laboratory Manager

Steven E. Greene, LEG, LG
Vice President

Attachments:

Figures 1-9	Material Summary Figures
Figures 10-11	Liquid Limit, Plastic Limit and Plasticity Index of Soils
Figures 12-21	Particle Size Distribution Report

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UA-1-11	5.0	6.5	1.5									GW-GM	Grayish brown, well graded GRAVEL with silt and sand
UA-1-11	7.5	8.2	2.3									SM	Dark grayish brown, silty SAND with gravel
UA-1-11	10.0	12.5	6.3						46.4	43.1	10.5	GW-GM	Dark brown, well graded GRAVEL with silt and sand
UA-1-11	12.5	15.0	8.6						40.4	51.3	8.3	SW-SM	Dark grayish brown, well graded SAND with silt and gravel
UA-1-11	15.0	16.4	8.9									SM	Dark olive brown, silty SAND with gravel
UA-1-11	17.5	19.0	8.0									SM	Dark olive brown, silty SAND
UA-1-11	20.0	21.5	9.7						44.9	48.1	7.0	SW-SM	Dark brown, well graded SAND with silt and gravel
UA-1-11	25.0	26.0	8.8									SM	Dark olive brown, silty SAND with gravel
UA-1-11	30.0	31.5	12.6									SM	Dark olive brown, silty SAND with gravel
UA-1-11	35.0	36.5	13.8									SM	Olive brown, silty SAND with gravel
UA-1-11	40.0	40.9	13.6									SM	Dark olive brown, silty SAND
UA-1-11	45.0	45.4	19.1									SM	Olive brown, silty SAND
UA-1-11	55.0	56.5	18.5									SM	Olive brown, silty SAND
UA-1-11	60.0	61.5	23.7									SM	Dark olive brown, silty SAND
UBS-1-11	2.5	4.0	3.3									SM	Light gray, silty SAND with gravel
UBS-1-11	5.0	6.5	2.0									SM	Light brownish gray, silty SAND with gravel
UBS-1-11	7.5	9.0	3.5									SM	Grayish brown, silty SAND with gravel
UBS-1-11	12.5	14.0	9.1						38.6	47.5	13.9	SM	Dark olive brown, silty SAND with gravel
UBS-1-11	15.0	16.5	11.0						34.2	59.6	6.2	SP-SM	Dark brown, poorly graded SAND with silt and gravel
UBS-1-11	17.5	18.5	20.0									SM	Very dark grayish brown, silty SAND

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 1

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UBS-1-11	18.5	19.0	4.5									SM	Very dark grayish brown, silty SAND with gravel
UBS-1-11	20.0	21.0	17.3									SM	Dark olive brown, silty SAND
UBS-1-11	21.0	21.5	7.0									SM	Dark olive brown, silty SAND with gravel
UBS-1-11	25.0	26.5	9.3									SM	Dark olive brown, silty SAND with gravel
UBS-1-11	30.0	31.5	8.9									SM	Olive brown, silty SAND with gravel
UBS-1-11	35.0	36.5	8.8									SM	Dark olive brown, silty SAND with gravel
UBS-1-11	40.0	40.5	15.9			NP	NP	NP	14.1	67.6	18.3	SM	Dark olive brown, silty SAND
UBS-1-11	40.5	41.5	14.9			22	18	4	16.4	60.1	23.5	SM	Olive gray, silty SAND with gravel
UBS-1-11	45.0	46.5	8.3									SM	Dark olive brown, silty SAND with gravel
UF-1-11	2.5	4.0	1.2									GW-GM	Light brownish gray, well graded GRAVEL with silt and sand
UF-1-11	5.0	6.5	0.5									SM	Grayish brown, silty SAND with gravel
UF-1-11	7.5	10.0	1.7						49.6	40.4	10.0	GP-GM	Brownish gray, Poorly graded GRAVEL with silt and sand
UF-1-11	10.0	11.5	3.4									SM	Very dark grayish brown, silty SAND with gravel
UF-1-11	12.5	14.0	13.4									GW-GM	Olive brown, well graded GRAVEL with silt and sand
UF-1-11	15.0	17.5	21.3						11.0	78.9	10.1	SP-SM	Very dark brown, poorly graded SAND with silt
UF-1-11	17.5	19.0	13.4									SM	Dark olive brown, silty SAND with gravel
UF-1-11	20.0	21.5	14.5									SM	Dark olive brown, silty SAND with gravel
UF-1-11	25.0	26.5	23.0									SM	Very dark grayish brown, silty SAND
UF-1-11	30.0	31.5	26.3									SM	Very dark grayish brown, silty SAND
UF-1-11	35.0	36.5	16.7									SM	Very dark gray, silty SAND with gravel

Notes:
1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 2

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UF-1-11	40.0	41.5	14.7									SM	Very dark gray, silty SAND
UF-1-11	45.0	46.5	12.8									SM	Dark olive gray, silty SAND with gravel
UF-1-11	50.0	51.5	15.6									SM	Very dark gray, silty SAND
UF-1-11	55.0	56.5	15.0									SM	Very dark grayish brown, silty SAND
UF-1-11	60.0	61.5	20.2									SM	Very dark gray, silty SAND
UG-1-11	2.5	4.0	5.7									SM	Olive brown, silty SAND with gravel
UG-1-11	5.0	7.5	6.1						38.9	45.6	15.5	SM	Light grayish brown, silty SAND with gravel
UG-1-11	7.5	9.0	7.1									SM	Olive brown, silty SAND with gravel
UG-1-11	10.0	11.5	16.0									SM	Dark olive brown, silty SAND
UG-1-11	12.5	14.0	10.0									SM	Very dark grayish brown, silty SAND with gravel
UG-1-11	15.0	17.5	11.8						30.5	59.2	10.2	SP-SM	Very dark brown, poorly graded SAND with silt and gravel
UG-1-11	17.5	19.0	15.0									SM	very dark grayish brown, silty SAND with gravel
UG-1-11	20.0	21.5	11.9									SM	Dark olive brown, silty SAND with gravel
UG-1-11	25.0	26.5	10.4									SM	Dark olive brown, silty SAND with gravel
UG-1-11	30.0	30.6	9.2									SM	Very dark grayish brown, silty SAND with gravel
UG-1-11	35.0	36.4	10.1									SM	Very dark grayish brown, silty SAND with gravel
UG-1-11	40.0	41.5	14.6									SM	Very dark brown, silty SAND
UG-1-11	45.0	46.4	14.1									SM	Olive brown, silty SAND with gravel
UG-1-11	50.0	50.9	9.4									SM	Dark grayish brown, silty SAND
UG-1-11	55.0	56.4	8.6									SM	Dark grayish brown, silty SAND with gravel

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 3

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UG-1-11	60.0	61.5	16.8									SM	Very dark grayish brown, silty SAND
UL-1-11	2.5	4.0	2.9									GW-GM	Olive brown, well graded GRAVEL with silt and sand
UL-1-11	5.0	6.5	3.8									SM	Light brownish gray, silty SAND with gravel
UL-1-11	7.5	9.0	2.2									SM	Dark grayish brown, silty SAND with gravel
UL-1-11	10.0	12.5	2.4						47.4	41.3	11.3	GP-GM	Grayish brown, poorly graded GRAVEL with silt and sand
UL-1-11	12.5	14.0	15.5									SM	Very dark brown, silty SAND with gravel
UL-1-11	15.0	17.5	15.7						41.2	53.6	5.2	SP-SM	Dark yellowish brown, poorly graded SAND with silt and gravel
UL-1-11	17.5	19.0	10.4									SM	Dark olive brown, silty SAND with gravel
UL-1-11	20.0	21.5	13.2									SM	Dark olive brown, silty SAND with gravel
UL-1-11	25.0	26.5	8.6									SM	Dark olive brown, silty SAND with gravel
UL-1-11	30.0	31.5	10.6									SM	Very dark grayish brown, silty SAND with gravel
UL-1-11	35.0	36.5	8.0									SM	Very dark grayish brown, silty SAND with gravel
UL-1-11	40.0	41.5	7.6									SM	Very dark grayish brown, silty SAND with gravel
UL-1-11	45.0	46.5	17.1									SM	Dark gray, silty SAND
UL-1-11	50.0	51.5	16.3									SM	Dark gray, silty SAND
UL-1-11	55.0	56.5	17.9									SM	Dark gray, silty SAND
UL-1-11	60.0	61.5	17.5									SM	Dark gray, silty SAND
ULE-1-11	2.5	5.0	1.6						46.0	41.1	12.9	GM	Light brown, silty GRAVEL with sand
ULE-1-11	5.0	6.5	2.0									SW	Olive brown, well graded SAND with gravel
ULE-1-11	7.5	9.0	26.7									ML	Dark olive brown, sandy SILT with gravel

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 4

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
ULE-1-11	10.0	12.5	30.2			NP	NP	NP	14.3	30.6	55.1	ML	Dark grayish brown, sandy SILT
ULE-1-11	12.5	13.2	22.7									SM	Dark olive brown, silty SAND
ULE-1-11	15.0	17.5	14.0						46.8	38.8	14.4	GM	Dark brownish gray, silty GRAVEL with sand
ULE-1-11	17.5	19.0	14.1									SM	Very dark grayish brown, silty SAND with gravel
ULE-1-11	20.0	21.5	18.5									SM	Very dark grayish brown, silty SAND with gravel
ULE-1-11	25.0	25.5	19.9									SM	Dark olive brown, silty SAND
ULE-1-11	25.5	26.0	17.9									SM	Very dark grayish brown, silty SAND
ULE-1-11	30.0	32.5	18.1			32	27	5	22.1	52.1	25.8	SM	Gray, silty SAND with gravel
ULE-1-11	35.0	36.5	19.8									SM	Very dark grayish brown, silty SAND
ULE-1-11	40.0	41.5	20.9									SM	Very dark grayish brown, silty SAND
ULE-1-11	45.0	46.5	17.1									SM	Very dark grayish brown, silty SAND
ULE-1-11	50.0	51.5	16.9									SM	Dark olive brown, silty SAND with gravel
ULE-1-11	55.0	56.5	6.7									SM	Dark yellowish brown, silty SAND with gravel
UOS-1-11	2.5	4.0	5.3									SM	Dark olive brown, silty SAND with gravel
UOS-1-11	5.0	7.5	7.5						33.7	44.4	21.9	SM	Dark brown, silty SAND with gravel
UOS-1-11	7.5	9.0	12.1									SM	Very dark brown, silty SAND with gravel
UOS-1-11	10.0	11.0	23.5						0.3	30.0	69.7	ML	Dark grayish brown, sandy SILT
UOS-1-11	11.0	11.5	31.2									SM	Very dark brown, silty SAND
UOS-1-11	12.5	14.0	16.3									SM	Very dark grayish brown, silty SAND with gravel
UOS-1-11	15.0	17.5	19.7						31.1	49.6	19.2	SM	Dark grayish brown, silty SAND with gravel

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 5

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UOS-1-11	17.5	19.0	25.9									SM	Very dark grayish brown, silty SAND
UOS-1-11	20.0	21.5	31.0									SM	Very dark grayish brown, silty SAND
UOS-1-11	25.0	26.0	23.0									SM	Black, silty SAND
UOS-1-11	26.0	26.5	16.2									SM	Very dark gray, silty SAND
UOS-1-11	30.0	31.5	39.2			25	17	8	0.0	5.1	94.9	ML	Dark grayish brown, SILT
UOS-1-11	35.0	36.5	29.6									ML	Very dark grayish brown, Sandy SILT
UOS-1-11	40.0	41.5	28.7									ML	Very dark grayish brown, Sandy SILT
UOS-1-11	45.0	46.5	28.7									ML	Very dark grayish brown, SILT with sand
UOS-1-11	50.0	51.0	22.7									ML	Very dark grayish brown, SILT with sand
UOS-1-11	51.0	51.5	14.2									SM	Gray, silty SAND
UOS-1-11	55.0	56.0	21.6									ML	Very dark grayish brown, sandy SILT with gravel
UOS-1-11	56.0	56.5	14.4									SM	Gray, silty SAND
UOS-1-11	60.0	61.5	20.7									SM	Dark gray, silty SAND
UP-1-11	2.5	5.0	6.6						27.9	51.9	20.3	SM	Brown, silty SAND with gravel
UP-1-11	5.0	6.5	19.4									SM	Dark olive brown, silty SAND
UP-1-11	7.5	9.0	20.8									SM	Dark yellowish brown, silty SAND
UP-1-11	10.0	11.5	19.7									SM	Dark brown, silty SAND
UP-1-11	12.5	15.0	36.3			28	27	1	1.7	7.2	91.0	ML	Brown, SILT
UP-1-11	15.0	16.5	33.5									SM	Very dark grayish brown, silty SAND
UP-1-11	17.5	19.0	64.9			38	33	5				OL	Light brown, organic SILT

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 6

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UP-1-11	20.0	22.0	28.1	0.7%	113.5 / 88.6							SM	Dark grayish brown, silty SAND
UP-1-11	22.5	24.0	33.0									SM	Dark olive brown, silty SAND
UP-1-11	25.0	27.5	26.9			NP	NP	NP	0.0	18.6	81.4	ML	Dark olive brown, SILT with sand
UP-1-11	32.5	34.0	24.8									SM	Dark grayish brown, silty SAND
UP-1-11	35.0	36.5	30.1									ML	Very dark grayish brown, sandy SILT
UP-1-11	40.0	41.5	27.0									SM	Very dark grayish brown, silty SAND
UP-1-11	45.0	46.5	39.9									ML	Very dark grayish brown, SILT with sand
UP-1-11	50.0	51.5	56.4									ML	Dark olive brown, SILT
UP-1-11	52.5	54.0	6.3									SM	Very dark gray, silty SAND with gravel
UP-1-11	55.0	55.7	57.3									ML	Dark olive brown, SILT
UP-1-11	55.7	56.5	32.4									SM	Very dark grayish brown, silty SAND
UP-1-11	60.0	61.5	25.0									SM	Black, silty SAND
UR-1-11	2.5	4.0	2.5									SM	Dark olive brown, silty SAND with gravel
UR-1-11	5.0	7.5	2.7						30.9	56.7	12.4	SM	Dark brown, silty SAND with gravel
UR-1-11	7.5	9.0	2.1									SM	Dark olive brown, silty SAND with gravel
UR-1-11	10.0	11.5	2.2									SM	Dark olive brown, silty SAND with gravel
UR-1-11	12.5	14.0	8.8									SM	Very dark grayish brown, silty SAND with gravel
UR-1-11	15.0	17.5	8.5						61.8	35.9	2.3	GM	Dark brown, poorly graded GRAVEL with sand
UR-1-11	17.5	19.0	11.0									SM	Very dark grayish brown, silty SAND with gravel
UR-1-11	20.0	21.5	8.0									SM	Very dark grayish brown, silty SAND with gravel

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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PROJECT NO.: 2011-081 FIGURE: 7

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
UR-1-11	25.0	27.5	16.5						26.8	65.6	7.6	SP-SM	Dark brown, poorly graded SAND with silt and gravel
UR-1-11	30.0	31.5	19.1									SM	Very dark gray, silty SAND
UR-1-11	35.0	36.5	17.0									SM	Very dark gray, silty SAND
UR-1-11	40.0	41.5	18.7									SM	Dark gray, silty SAND
UR-1-11	45.0	46.5	17.2									SM	Dark gray, silty SAND
UR-1-11	50.0	51.5	17.7									SM	Very dark grayish brown, silty SAND
UR-1-11	55.0	56.0	15.5									SM	Very dark grayish brown, silty SAND with gravel
UR-1-11	56.0	56.5	18.1									SM	Very dark grayish brown, silty SAND
UR-1-11	60.0	61.5	16.3									SM	Very dark grayish brown, silty SAND
US-1-11	2.5	3.0	5.9									GP-GM	Dark olive brown, poorly graded GRAVEL with silt and sand
US-1-11	5.0	6.5	4.6						47.4	31.5	21.1	GM	Olive brown, silty GRAVEL with sand
US-1-11	7.5	9.0	9.8									SP	Brown, poorly graded SAND
US-1-11	10.0	11.5	15.5									SM	Dark brown, silty SAND
US-1-11	12.5	15.0	4.3						40.0	48.7	11.3	SP-SM	Dark brown, poorly graded SAND with silt and gravel
US-1-11	15.0	16.5	16.7									SM	Very dark brown, silty SAND with gravel
US-1-11	17.5	19.0	21.5									SM	Dark brown, silty SAND with gravel
US-1-11	20.0	21.5	20.4			33	19	14	9.9	60.2	30.0	SC	Olive gray, clayey SAND
US-1-11	25.0	26.5	17.6									SM	Dark grayish brown, silty SAND
US-1-11	32.5	34.0	18.1									SM	Dark grayish brown, silty SAND
US-1-11	35.0	37.0	19.4	0.7%	131.1 / 109.8							SM	Gray, silty SAND

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

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SUMMARY OF MATERIAL PROPERTIES

PROJECT NO.: 2011-081 FIGURE: 8

EXPLORATION DESIGNATION	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	UNIT WEIGHT	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
						LL	PL	PI					
US-1-11	37.5	39.0	18.4									SM	Dark grayish brown, silty SAND
US-1-11	40.0	41.5	20.5									SM	Dark grayish brown, silty SAND
US-1-11	45.0	46.5	18.3									SM	Very dark grayish brown, silty SAND with gravel
US-1-11	50.0	51.5	15.6									SM	Dark gray, silty SAND with gravel
US-1-11	55.0	56.5	19.0									SM	Dark grayish brown, silty SAND
US-1-11	60.0	61.5	18.0									SM	Dark grayish brown, silty SAND
US-1-11	65.0	66.5	17.8									SM	Dark grayish brown, silty SAND

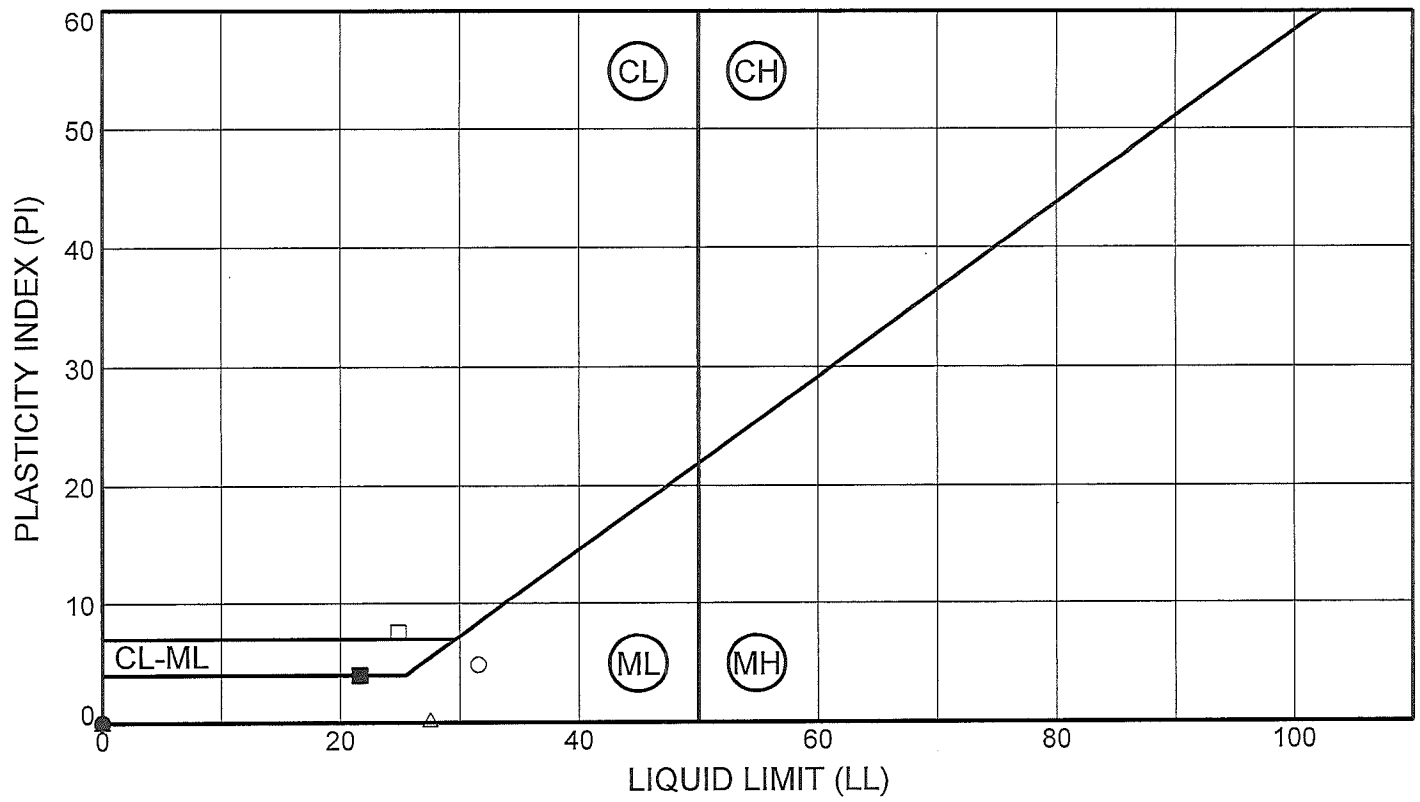
Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. The classification of soils in this table is based on ASTM D2487 and D2488 as applicable.

HWA GEOSCIENCES INC.

Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

SUMMARY OF
MATERIAL PROPERTIES

PROJECT NO.: 2011-081 FIGURE: 9



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	UBS-1-11	D-12A	40.0 - 41.5	(SM) Dark olive brown, silty SAND	16	NP	NP	NP	18.3
■	UBS-1-11	D-12B	41.5 - 43.0	(SM) Olive gray, silty SAND with gravel	15	22	18	4	23.5
▲	ULE-1-11	D-4	10.0 - 12.5	(ML) Dark grayish brown, sandy SILT	30	NP	NP	NP	55.1
○	ULE-1-11	D-10	30.0 - 32.5	(SM) Gray, silty SAND with gravel	18	32	27	5	25.8
□	UOS-1-11	D-10	30.0 - 35.0	(ML) Dark grayish brown, SILT	39	25	17	8	94.9
△	UP-1-11	D-5	12.5 - 15.0	(ML) Brown, SILT	36	28	27	1	91.0

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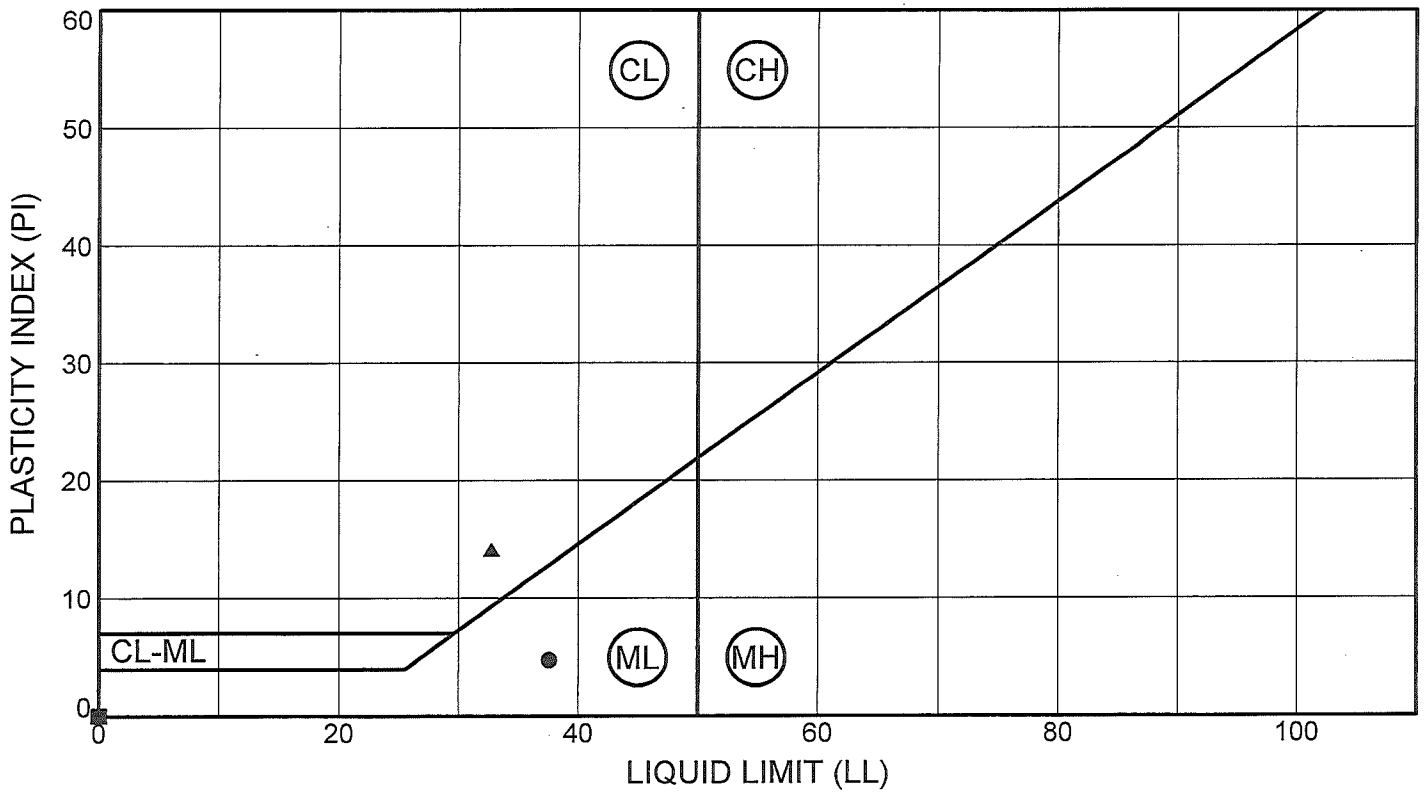
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS
METHOD ASTM D4318

PROJECT NO.: 2011-081 FIGURE: 10



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	UP-1-11	D-7	17.5 - 19.0	(OL) Light brown, organic SILT	65	38	33	5	
■	UP-1-11	D-10	25.0 - 27.5	(ML) Dark olive brown, SILT with sand	27	NP	NP	NP	81.4
▲	US-1-11	D-8	20.0 - 25.0	(SC) Olive gray, clayey SAND	20	33	19	14	30.0

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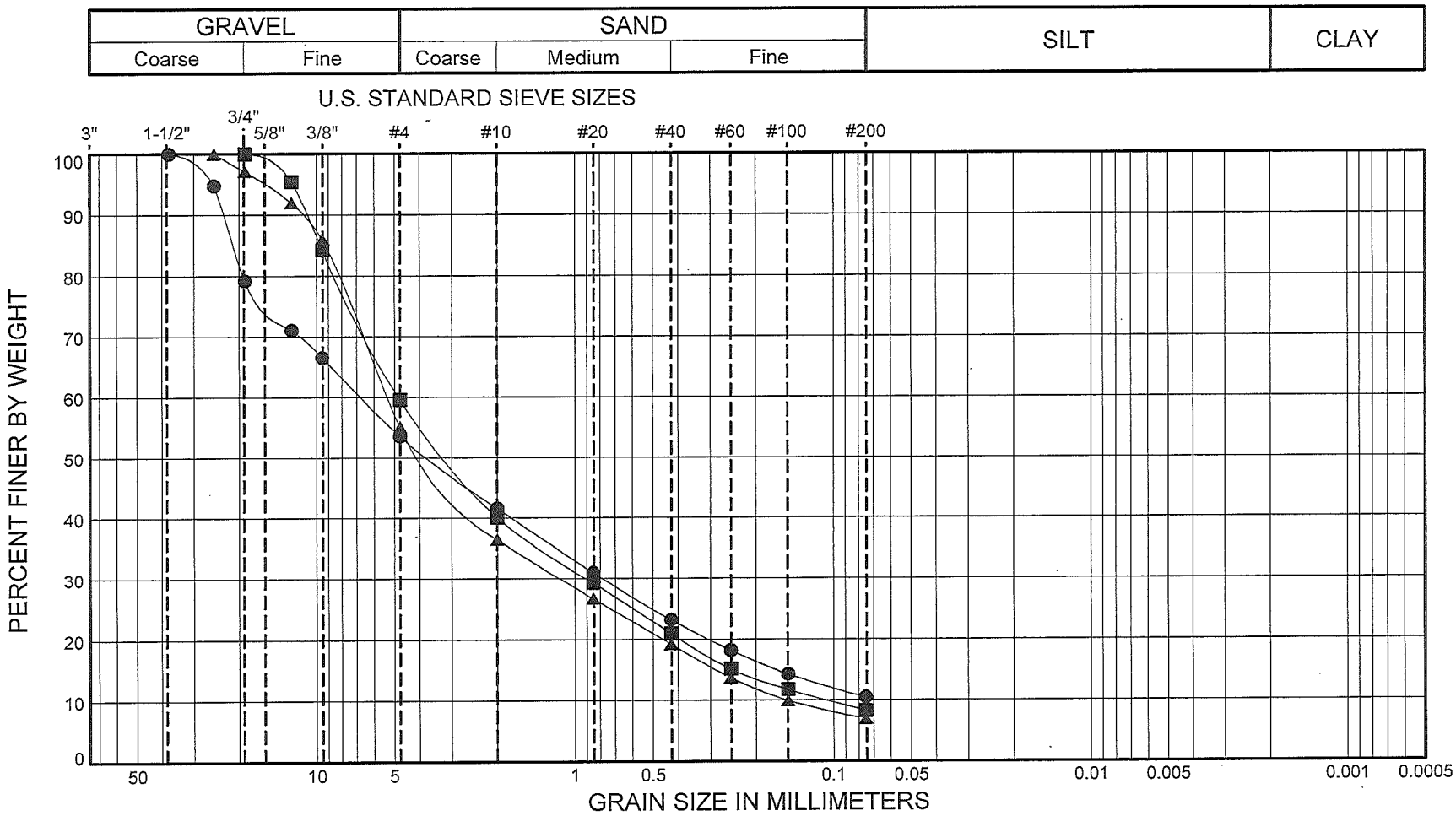
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS
METHOD ASTM D4318

PROJECT NO.: 2011-081 FIGURE: 11



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UA-1-11	D-4	10.0 - 12.5	(GW-GM) Dark brown, well graded GRAVEL with silt and sand	6				46.4	43.1	10.5
■	UA-1-11	D-5	12.5 - 15.0	(SW-SM) Dark grayish brown, well graded SAND with silt and gravel	9				40.4	51.3	8.3
▲	UA-1-11	D-8	20.0 - 21.5	(SW-SM) Dark brown, well graded SAND with silt and gravel	10				44.9	48.1	7.0

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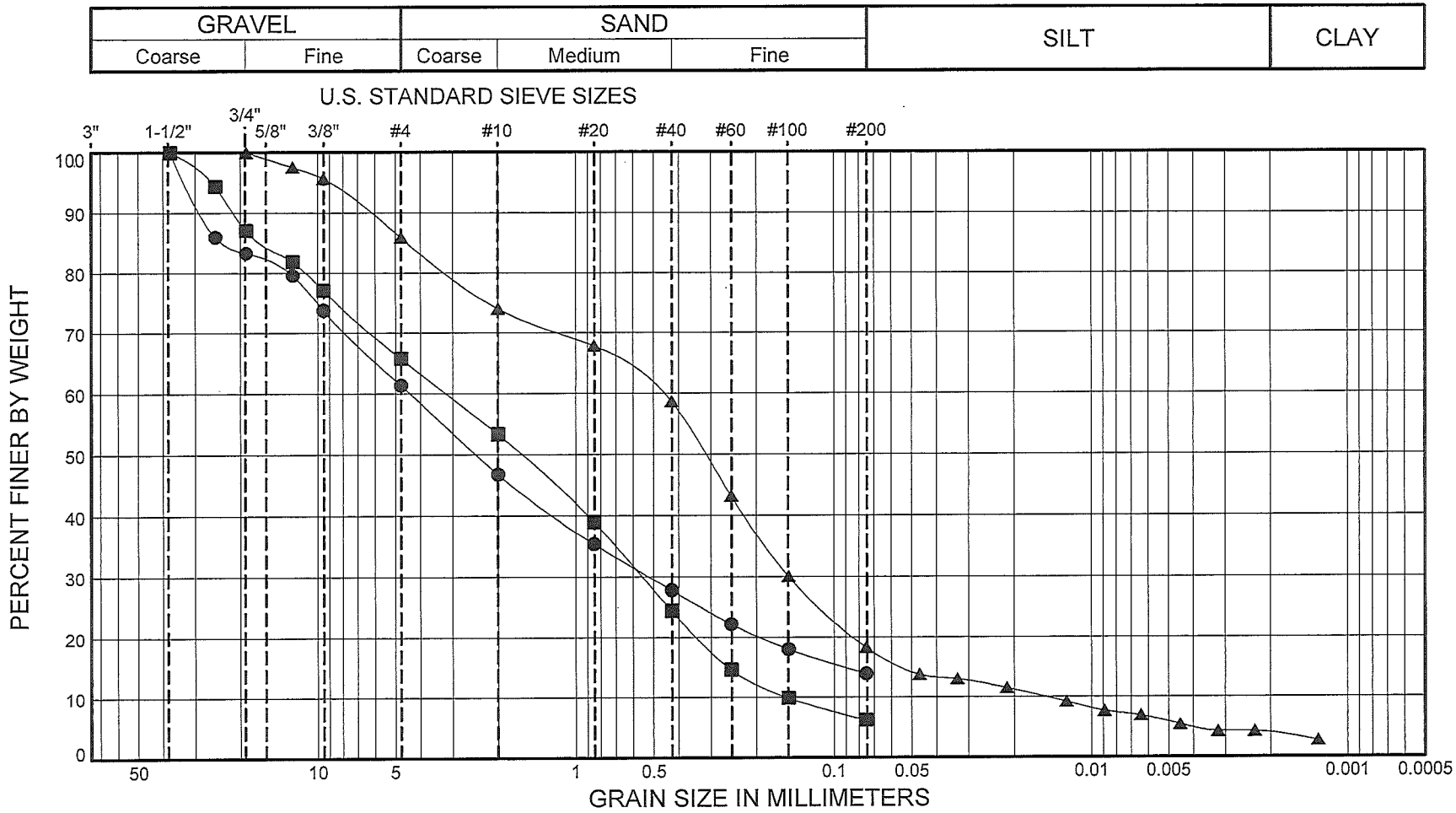
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 12

HWAGRSZ 2011-081.GPJ 9/2/11



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UBS-1-11	D-5	12.5 - 14.0	(SM) Dark olive brown, silty SAND with gravel	9				38.6	47.5	13.9
■	UBS-1-11	D-6	15.0 - 16.5	(SP-SM) Dark brown, poorly graded SAND with silt and gravel	11				34.2	59.6	6.2
▲	UBS-1-11	D-12A	40.0 - 40.5	(SM) Dark olive brown, silty SAND	16	NP	NP	NP	14.1	67.6	18.3

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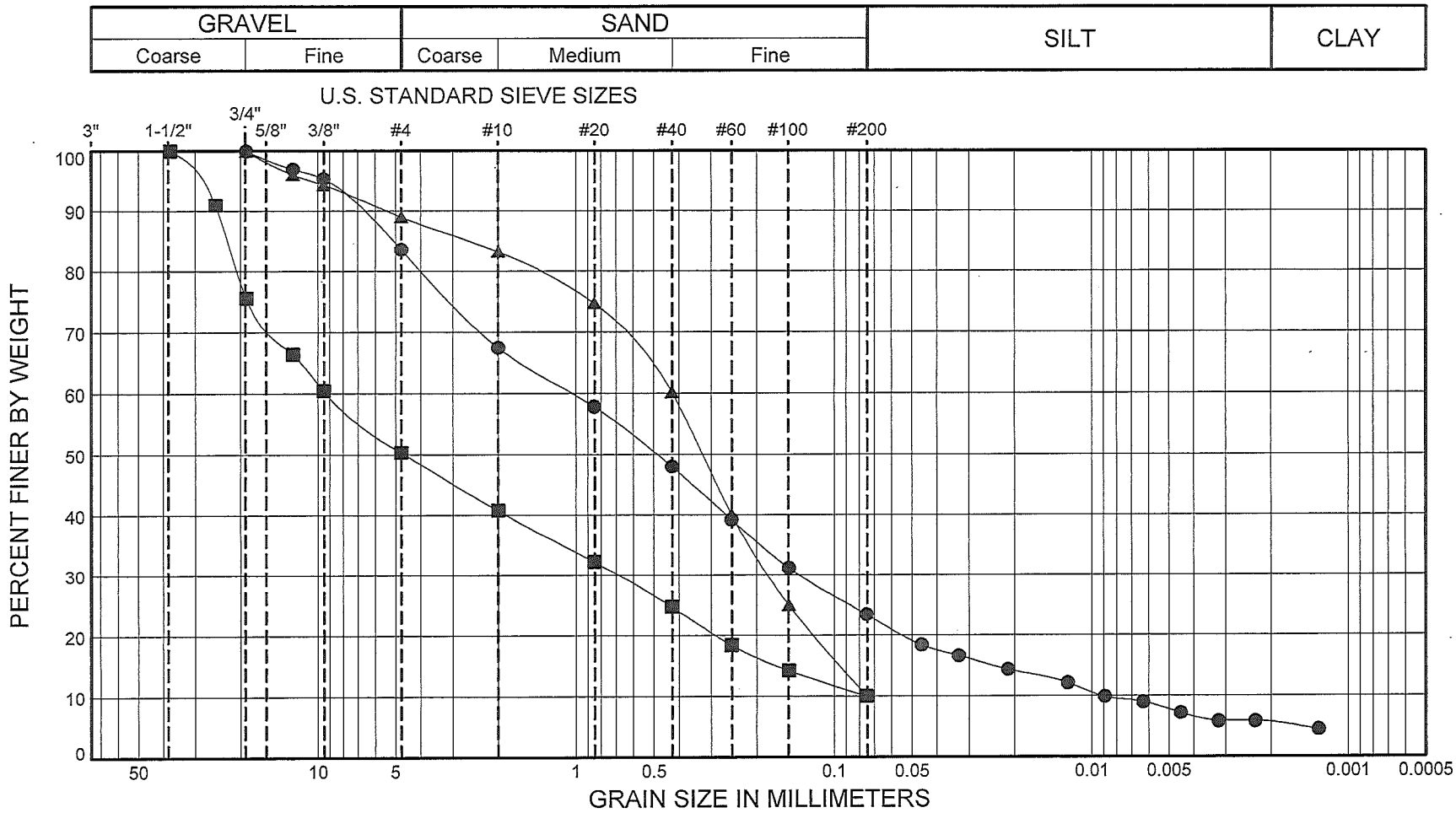
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 13

HWAGRSZ 2011-081.GPJ 9/2/11



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UBS-1-11	D-12B	40.5 - 41.5	(SM) Olive gray, silty SAND with gravel	15	22	18	4	16.4	60.1	23.5
■	UF-1-11	D-3	7.5 - 10.0	(GP-GM) Brownish gray, Poorly graded GRAVEL with silt and sand	2				49.6	40.4	10.0
▲	UF-1-11	D-6	15.0 - 17.5	(SP-SM) Very dark brown, poorly graded SAND with silt	21				11.0	78.9	10.1

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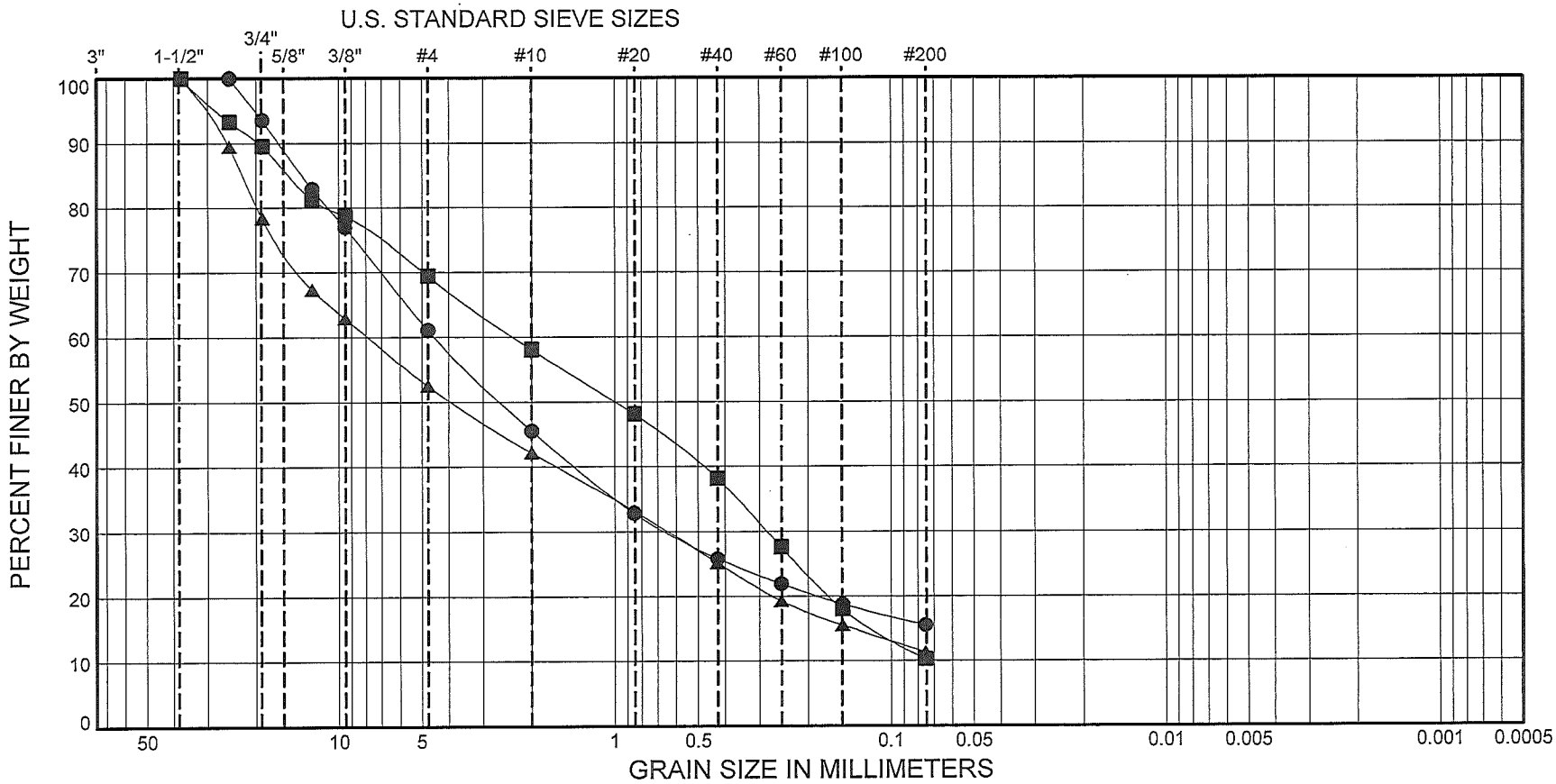
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 14



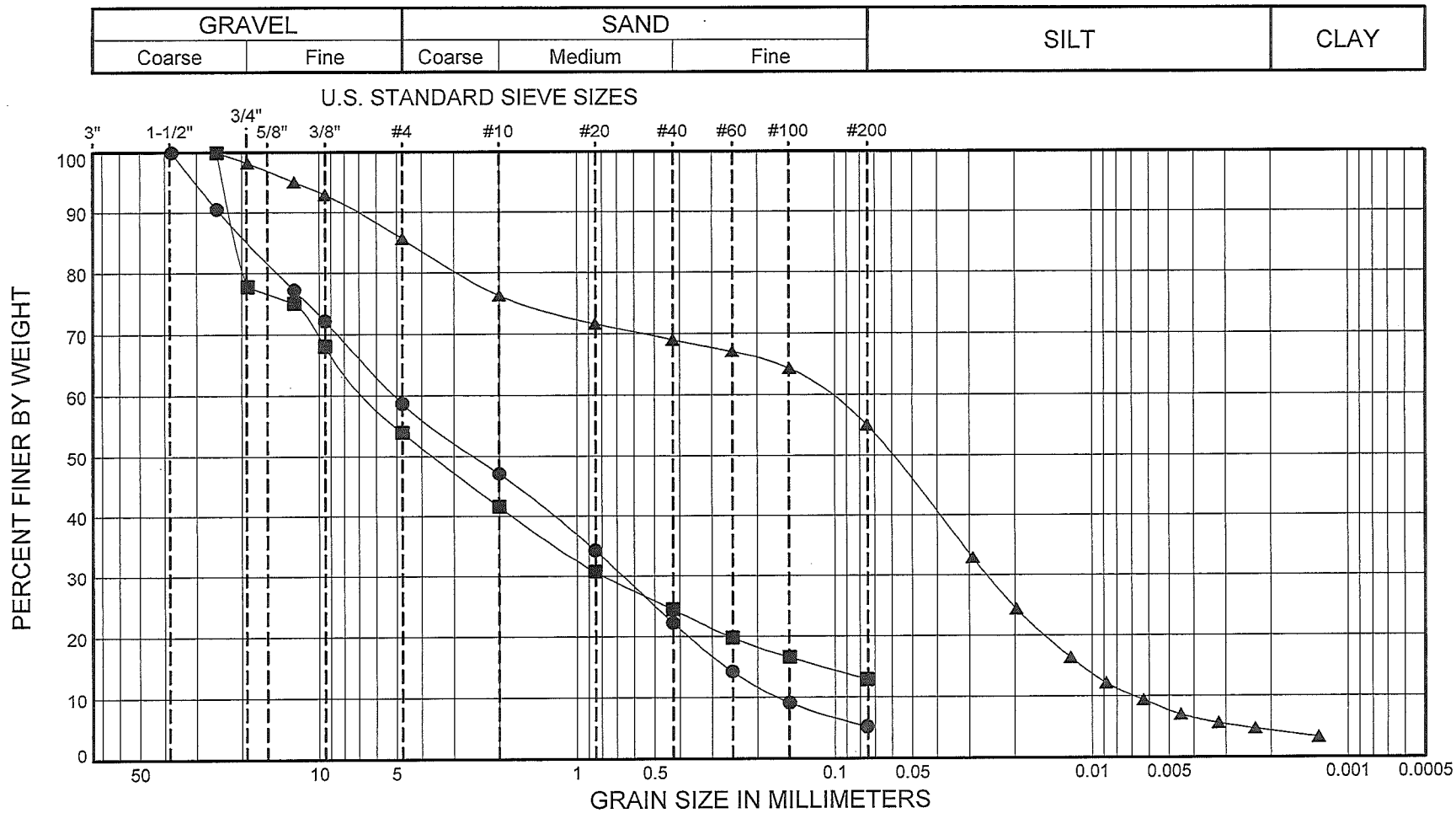
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UG-1-11	D-2	5.0 - 7.5	(SM) Light grayish brown, silty SAND with gravel	6				38.9	45.6	15.5
■	UG-1-11	D-6	15.0 - 17.5	(SP-SM) Very dark brown, poorly graded SAND with silt and gravel	12				30.5	59.2	10.2
▲	UL-1-11	D-4	10.0 - 12.5	(GP-GM) Grayish brown, poorly graded GRAVEL with silt and sand	2				47.4	41.3	11.3

HWA GEOSCIENCES INC.

Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 15



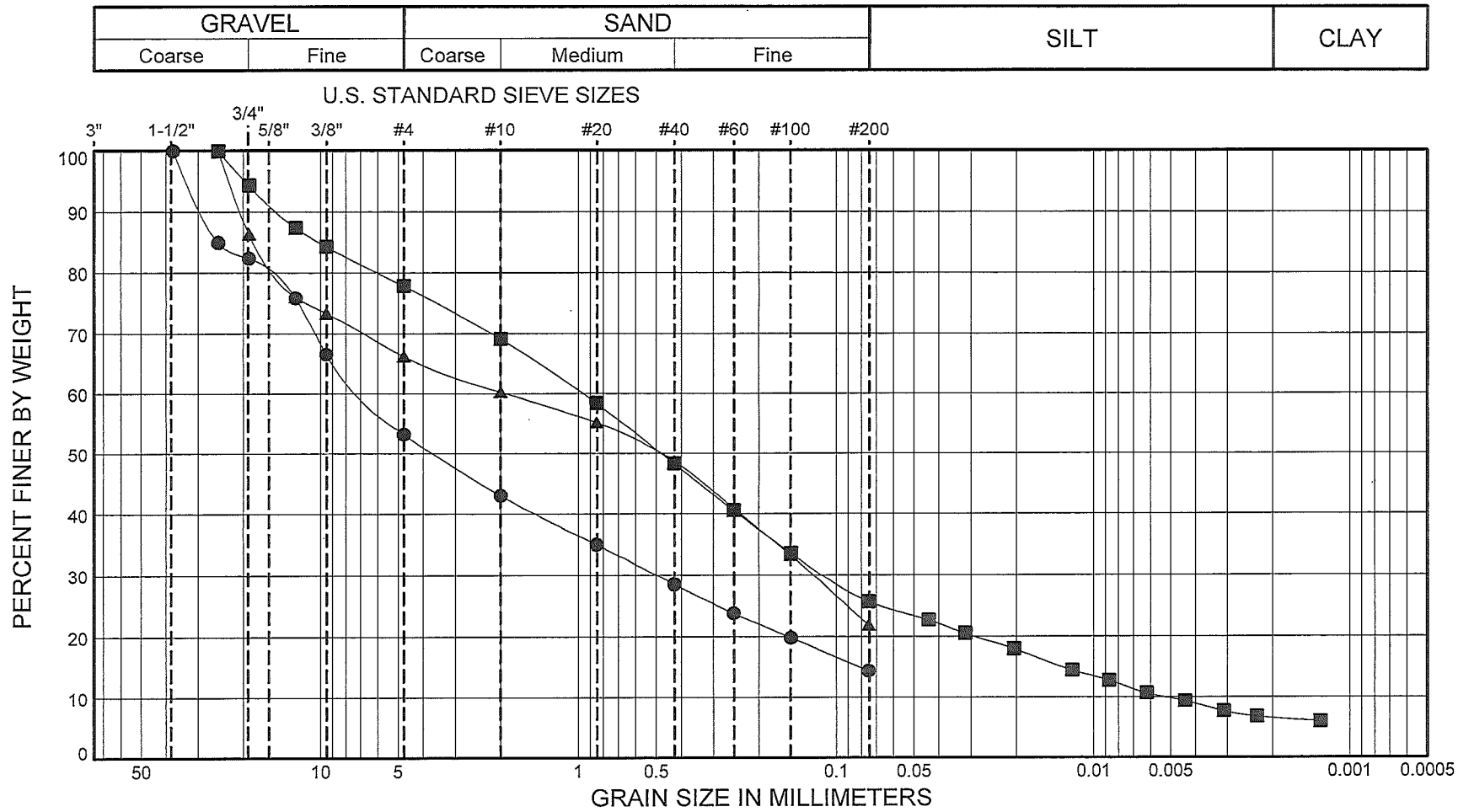
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UL-1-11	D-6	15.0 - 17.5	(SP-SM) Dark yellowish brown, poorly graded SAND with silt and gravel	16				41.2	53.6	5.2
■	ULE-1-11	D-1	2.5 - 5.0	(GM) Light brown, silty GRAVEL with sand	2				46.0	41.1	12.9
▲	ULE-1-11	D-4	10.0 - 12.5	(ML) Dark grayish brown, sandy SILT	30	NP	NP	NP	14.3	30.6	55.1

HWA GEOSCIENCES INC.

Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 16



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	ULE-1-11	D-6	15.0 - 17.5	(GM) Dark brownish gray, silty GRAVEL with sand	14				46.8	38.8	14.4
■	ULE-1-11	D-10	30.0 - 32.5	(SM) Gray, silty SAND with gravel	18	32	27	5	22.1	52.1	25.8
▲	UOS-1-11	D-2	5.0 - 7.5	(SM) Dark brown, silty SAND with gravel	8				33.7	44.4	21.9

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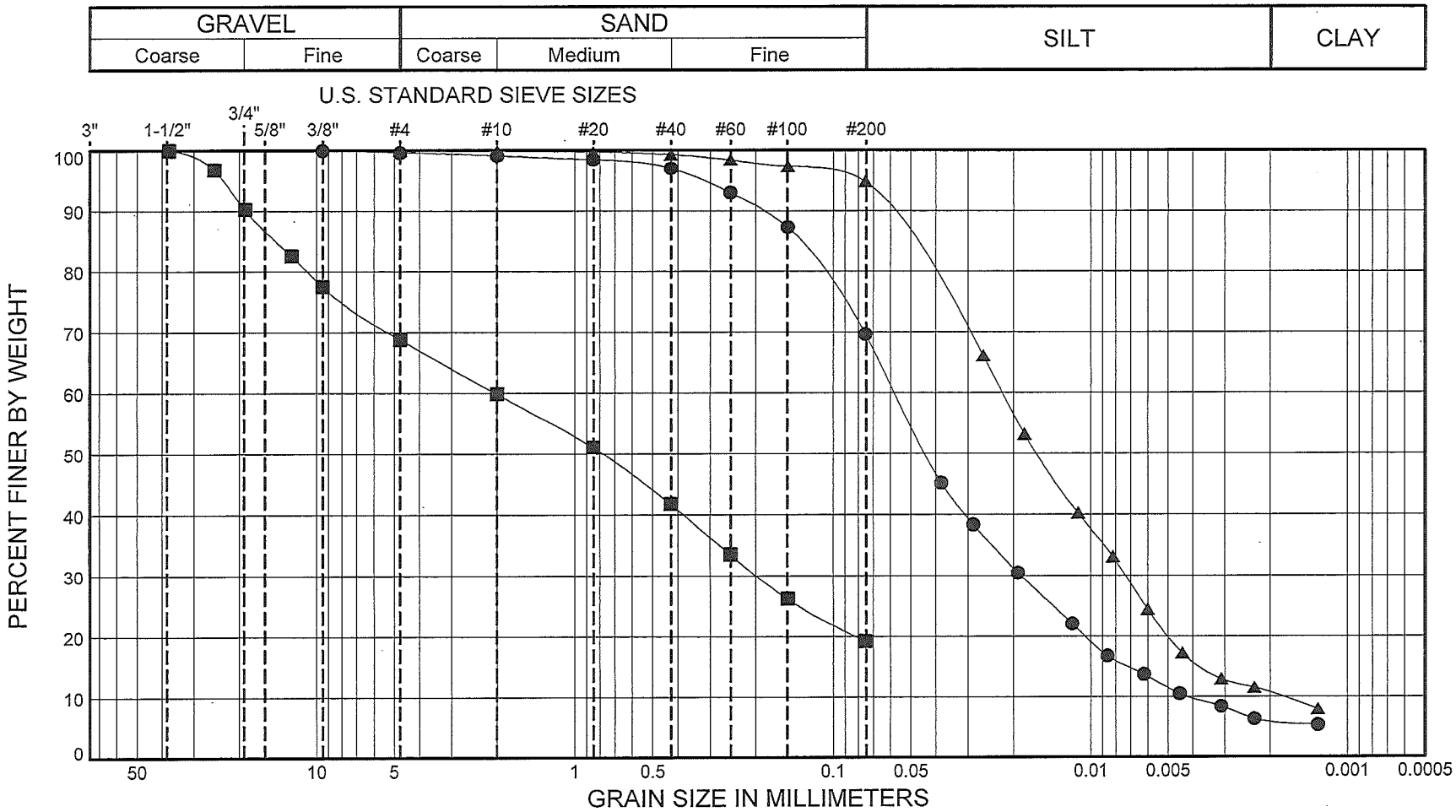
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 17

HWAGRSZ 2011-081.GPJ 9/2/11



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UOS-1-11	D-4	10.0 - 11.0	(ML) Dark grayish brown, sandy SILT	24				0.3	30.0	69.7
■	UOS-1-11	D-6	15.0 - 17.5	(SM) Dark grayish brown, silty SAND with gravel	20				31.1	49.6	19.2
▲	UOS-1-11	D-10	30.0 - 31.5	(ML) Dark grayish brown, SILT	39	25	17	8	0.0	5.1	94.9

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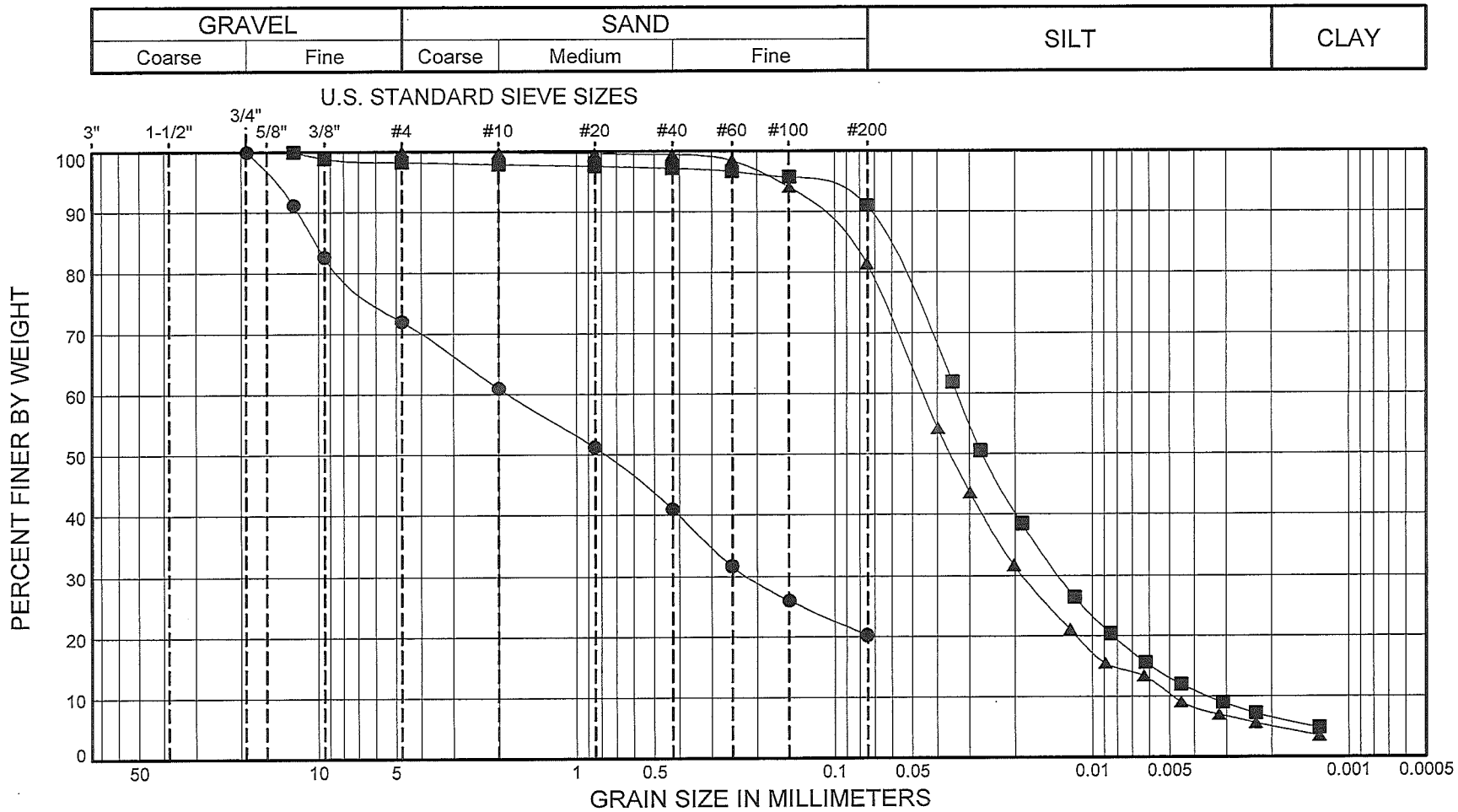
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 18



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UP-1-11	D-1	2.5 - 4.0	(SM) Brown, silty SAND with gravel	7				27.9	51.9	20.3
■	UP-1-11	D-5	12.5 - 15.0	(ML) Brown, SILT	36	28	27	1	1.7	7.2	91.0
▲	UP-1-11	D-10	25.0 - 27.5	(ML) Dark olive brown, SILT with sand	27	NP	NP	NP	0.0	18.6	81.4

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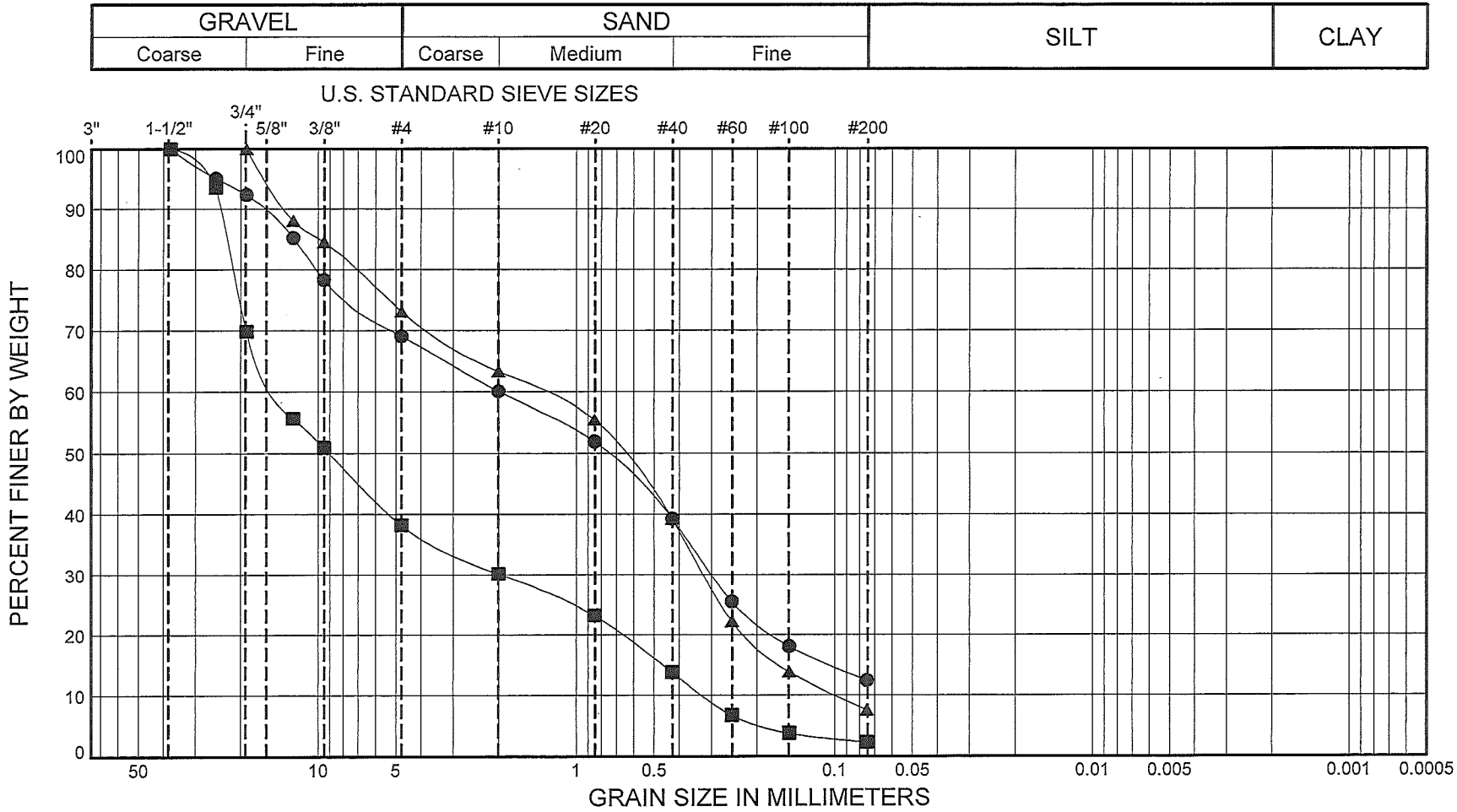
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 19



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	UR-1-11	D-2	5.0 - 7.5	(SM) Dark brown, silty SAND with gravel	3				30.9	56.7	12.4
■	UR-1-11	D-6	15.0 - 17.5	(GM) Dark brown, poorly graded GRAVEL with sand	9				61.8	35.9	2.3
▲	UR-1-11	D-9	25.0 - 27.5	(SP-SM) Dark brown, poorly graded SAND with silt and gravel	17				26.8	65.6	7.6

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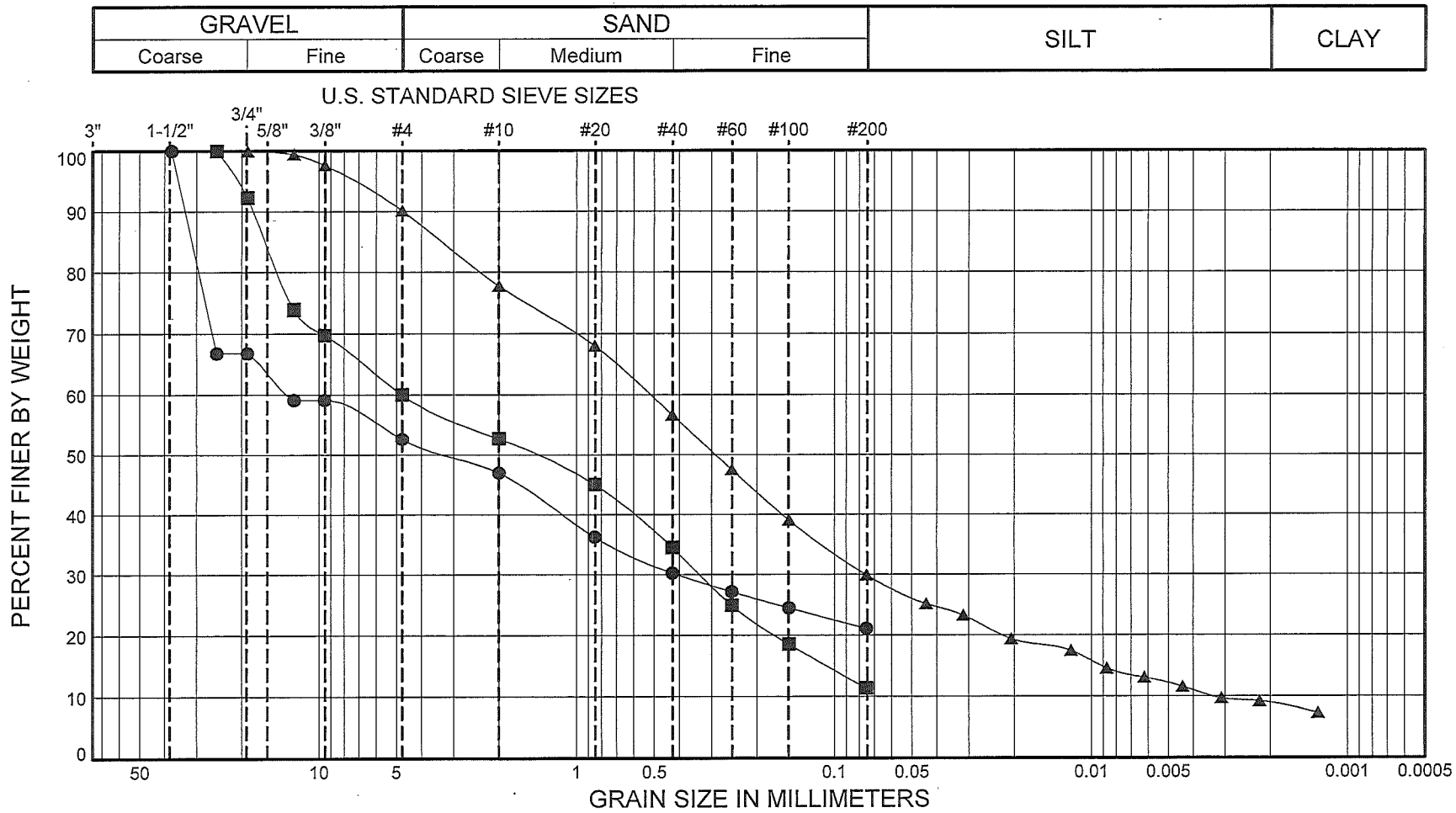
Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 20

HWAGRSZ 2011-081.GPJ 9/2/11



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	US-1-11	D-2	5.0 - 6.5	(GM) Olive brown, silty GRAVEL with sand	5				47.4	31.5	21.1
■	US-1-11	D-5	12.5 - 14.0	(SP-SM) Dark brown, poorly graded SAND with silt and gravel	4				40.0	48.7	11.3
▲	US-1-11	D-8	20 - 21.5	(SC) Olive gray, clayey SAND	20	33	19	14	9.9	60.2	30.0

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Puyallup River General Investigation for Levees
Lab Testing for URS Corporation

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-081 FIGURE: 21

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering · Hydrogeology · Geoenvironmental · Planning & Permitting · Inspection & Testing

October 4, 2011
HWA Project No. 2011-081-23

URS Corporation
1501 4th Avenue, Suite 1400
Seattle, Washington 98101

Attention: Mr. John Gillespie, PE

Subject: **Materials Laboratory Report**
Organic Matter Content Testing
Puyallup Basin Levees

Dear Mr. Gillespie;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: The sample was delivered by URS personnel on September 30, 2011. The sample was in a small plastic bag. The sample description was as follows:

UP-1-11 D-7 at 17.5-19 ft Grayish brown SILT with organics

MOISTURE CONTENT, ASH, AND ORGANIC MATTER: The sample was tested in general accordance with method ASTM D 2974, using moisture content method 'A' (oven dried at 105° C) and ash content method 'C' (burned at 440° C). The test results are summarized on the Table below.

SAMPLE ID	MOISTURE CONTENT	ORGANIC MATTER
UP-1-11, D-7 at 17.5-19 ft	**103%**	**16.7%**

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no

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Fax: 425.774.2714
www.hwageo.com

knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Harold Benny
Materials Laboratory Manager

George Minassian, Ph.D., P.E.
Geotechnical Engineer

Appendix F-5

Geotechnical Conceptual Design

Puyallup River Basin
Flood Risk Reduction Feasibility Study

Department of the Army
Seattle District, US Army Corps of Engineers

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DRAFT

Geotechnical Conceptual Design

The information in this appendix describes the future with project conditions for the proposed tentatively selected plan: Alternative 2. This section of the Engineering appendix provides pertinent information as indicated in guidance document ER 1110-2-1150: Engineering and Design for Civil Works Projects.

Geology

The Puyallup, White, and Carbon Rivers originate from the glaciers of Mount Rainier. This origin provides significant sediment load to the rivers that has resulted in significant channel migration. In addition, lahar flows from the volcano have significantly shaped the river valley most recently the 500-year old Electron lahar flow.

The Geologic Map of Washington – Southwest Quadrant (Walsh, et al, 1987) indicates that the Puyallup General Investigation project sites are near a contact between Alluvium (Qa), Lahars (Qvl), and Pre-Fraser Glacial Sediments (Qap & Qgp). Alluvium is described as sorted combinations of silt, sand, and gravel deposited in streambeds and alluvial fans. The Lahar unit is described as unsorted to poorly sorted, generally unstratified mixtures of cobbles and boulders supported by a matrix of sand or mud. Pre-Fraser Glacial Sediments are described as stratified clay, silt, sand, gravel of fluvial, deltaic, lacustrine and/or estuarine origin, contains mixtures of till and outwash.

Existing Subsurface Explorations & Soils Classification

In 2011, a geotechnical investigation was performed by URS for Pierce County and the USACE. The exploration involved 10 hollow stem auger borings and representative sampling. In addition, 10 piezometers were used to determine the hydraulic conductivity of select soil intervals. Seven direct drive point piezometers were installed and three piezometers were developed from the boring where dense or coarse material prevented the preferred drive point method. Falling head permeability (slug) testing was performed. The summary of the URS geotechnical report dated January 17, 2012 is described below:

"This general geotechnical investigation study of levees in the Puyallup River Basin can be summarized as follows: One boring was drilled to depths up to 60 feet at each of ten levee locations; there is usually 5 to 12 feet thick levee fill consisting of gravel or silty sand; underlying foundation soils are typically thick deposits of silty sand, except silt or organic silt thin layers existing in Borings UOS-1-11, ULE-1-11, and UP-1-11; the groundwater depths range from 7.5 to 17.3 feet below ground surface during investigation period; the slug test was conducted at each of the ten boring locations, and test results show that the permeability range of tested silty gravel and silty sand layers change from 8.5 ×10-6 cm/sec to 2.6 ×10-2 cm/sec, gravelly soil layer's permeability

values are usually higher than sandy soil layer's; total 167 soil samples were selected for lab testing on moisture content, organic content, unit weight, Atterberg Limits, and particle size analysis. The lab testing results are used to identify soil types and properties in this investigation study."

Existing soil information from project as-builts and previous subsurface explorations were also reviewed and can be found in appendix F-4.

Earthquake Studies

The liquefaction potential of the Puyallup GI project sites are indicated as "high or moderate to high" on the Liquefaction Susceptibility Map of Pierce County, Washington (Palmer et al, 2004). The lower Puyallup region from approximately Sumner to Commencement Bay is classified as "high" while the upper reaches of the White, Puyallup, and Carbon are classified as "moderate to high". The Washington State Department of Natural Resources Site Class Map of Pierce County, Washington (Palmer et al, 2004) classifies the project sites within Site Class D to E.

Earthquake loadings are not normally considered in analyzing the stability of levees because of the low risk associated with an earthquake coinciding with periods of high water. The severity of the expected earthquake and the consequences of levee failure are considered. The alluvial deposits composing the levee foundation have liquefaction potential, but seismic design is not anticipated for this site based on low coincident loading probability.

Groundwater Studies

No specific groundwater studies have been performed or plan to be performed for the Puyallup GI. The static groundwater level was recorded in available subsurface exploration reports, including the 2011 borings performed for this study. Design Considerations: Levee Modification Alternative

Conceptual levee design was completed based on existing soil information, existing design information, and past levee performance history. The majority of the existing soil information and laboratory testing on the non-Federal levees comes from the 2011 geotechnical exploration report in Appendix F-4. Levee modifications for raising the levee in place were qualitatively assessed for the additional hydraulic loading. Increases in hydraulic loading, known soft foundation soils, and recent levee design information informed the conceptual typical section design. Any interior drainage culvert penetrations will be upgraded to current USACE standards for culverts within urban levees. See the Civil Appendix F for engineering design drawings and details on upgraded and modified utilities.

Levee Vegetation

Existing levee embankments within the Puyallup General Investigation study have significant unwanted vegetation growth deficiencies. Engineering Technical Letter No. 1110-2-571, *Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures* (Vegetation ETL) establishes minimum guidelines to assure that landscape and vegetation management provide aesthetic and environmental benefits without compromising the reliability of flood damage–reduction projects. The Vegetation ETL establishes a vegetation-free zone to provide a reliable corridor of access to, and along, levees, floodwalls, embankment dams, and apparent structures to assure adequate access by personnel and equipment for surveillance, inspection, maintenance, monitoring, and flood fighting (Figure 1). In the case of levees, such as those proposed for the levee modification alternative, the vegetation-free zone includes the levee and 15 feet on both sides of the levee measured from the levee toe.

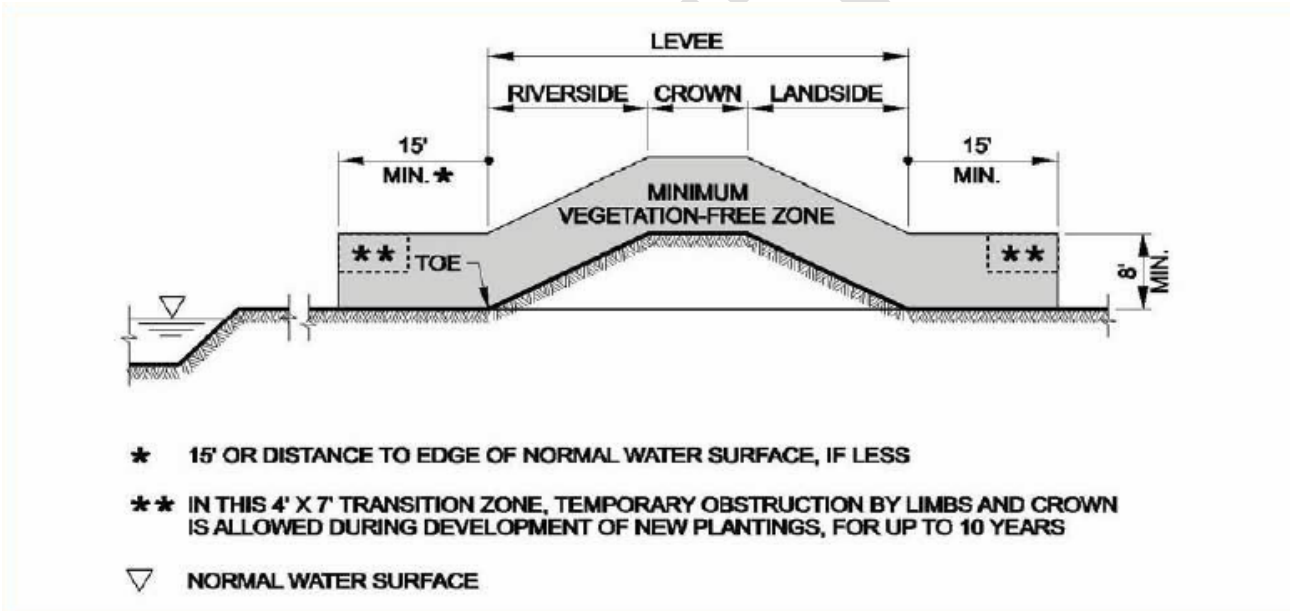

Figure 1. Illustration from Chapter 6, Engineering Technical Letter 1110-2-571

At this conceptual design level, vegetation growth is assumed to be removed from all modified existing structures. Future design may consider a vegetation variance as allowed by the vegetation ETL so long as the integrity and operation/maintenance of the levee is retained.

Lower Puyallup Levee Design Considerations

Lower Puyallup Levee modifications include levee raises and setbacks that would achieve 1 percent annual chance exceedance flood protection with 3 feet of freeboard. The design includes minor levee raises to the upstream portions of Federal Puyallup Left and Right Bank Levees. Improvement is required to approximately 7,300 and 4,000 linear feet respectively. The levee raise is a maximum of 2 feet to the Federal projects and maintaining the design section of 18-foot crown width with 2H:1V riverward and 3H:1V landward slopes. The landside slope modification to 3H:1V is considered sufficient to lengthen the seepage path and arrest seepage concerns. Further

exploration and design is necessary to confirm these assumptions. Sod cover will provide erosion protection for the raised freeboard sections.

The existing River Road levee will gain freeboard from the proposed construction of a T-wall floodwall. Further description of this design component can be found in the Structural design section. The opposite bank, North Levee Road is planned to be a levee setback to provide additional channel capacity as well as having ancillary environmental benefits. The levee will extend to a total of approximately 32,000 linear feet. A large levee setback is proposed at the downstream end of the project. (See Alternative Map for alignment.) This setback levee sections will be typical 18-foot crown width with 2H:1V riverward and 3H:1V landward slopes. The levee crown will be topped with 6 inches of crushed surface top course to maintain the access route. Riverside erosion protection for the new levee setback sections was developed with input from the hydraulic engineers and the HEC-RAS model. An 18" blanket of class I riprap and a 5-foot scour depth was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket. The upstream segment will be an 80 to 100 foot setback of the existing levee. The levee crown will replace the North Levee Road roadway and have a comparable 24-foot crown. The pavement section was discussed with Pierce County Engineers, but documentation of the existing section was not available. The levee section was developed from projects with loading conditions similar to those of North Levee Road. The proposed pavement section will consist of a 4-inch asphalt pavement layer underlain by a 3-inch top course and a 12" base course. Existing utilities in the levee prism will need to be relocated. Ideally, the utilities should be relocated to outside of the levee prism if real estate easements can be acquired. Due to the unknown foundation soils and the likelihood of unsuitable fine-grained and organic soils, a foundation overexcavation of 24 inches was assumed for the design and quantity calculation. The upstream nearly 1 mile of North Levee Road is a widened 52-foot road. This levee width will be maintained in the future setback alignment. The North Levee Road upstream tie-In to high ground is not anticipated to need any extension based on the current hydraulic modeling.

Due to the increased level of protection, an upstream portion of the left bank of the Puyallup River, upstream of River Road, will require a new levee section. This new levee has been named the "River Road Extension" and is approximately 7,100 linear feet. The levee design section will be the same as North Levee Road setback except for a 10-foot asphalt pedestrian trail on the levee crown to replace existing.

Highway 410 Levee Design Considerations

The existing River Grove levee is planned to be raised and extended to provide increased flood protection to the area. The upstream portions will utilize a T-Wall floodwall because of spatial constraints. The downstream portion will transition from floodwall to levee embankment for

approximately 1,700 linear feet before tying into the railroad bridge abutment near E Main Avenue to complete the flood control system. The levee height varies along the length of the project with a maximum of 12 feet, but more typical heights of 3 to 6 feet. A minimum levee prism of a 12-foot crown width and 2H:1V slopes were assumed to be applicable for this reach. Foundation overexcavation was estimated at 12 inches. Limited to no soil information presents a risk to the assumptions. Poor soil conditions may require a more robust levee section or additional design components to mitigate. Riverside erosion protection for the new levee setback sections was developed with input from the hydraulic engineers and the HEC-RAS model. An 18" blanket of class I riprap and a 7-foot scour depth was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket.

Jones Levee Design Considerations

Improvement to the approximately 6,500 linear foot Jones levee is planned to increase flood protection to the Jones/Calistoga/High Cedars Levee System which protects a significant portion of Orting, WA. The levee modification includes levee raise as well as the incorporation of a more competent erosion protection system. Riverside erosion protection was developed with input from the hydraulic engineers and the HEC-RAS model. A 36" blanket of class IV riprap and a 5-foot deep by 10-foot wide buried toe was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket. Significant vegetation maintenance, including tree removal, is anticipated to perform the riverside erosion protection upgrades. The design toe of the riprap slope was designed to match the existing toe of the riprap slope to avoid channel encroachment. The current design incorporates a buried toe that will involve excavation of the channel bed in low flow. The existing levee prism varies quite significantly along the levee alignment. The design sections attempt to incorporate some of the existing levee widths to maintain consistent operation and performance. The minimum levee design width was set at 15-feet, while some sections are designed as 20-feet to match existing widened sections. Riverward and landward design slopes will be a minimum of 2H:1V. The levee raise typically varies from 1.5 to 4 feet; however, the upstream approximately 1500 linear feet has levee raises of 6 to 7 feet.

The upstream end of the levee forms a tie-back along the "Matlock Cutoff" to restrict some level of flooding if the upstream Ford levee were to fail as it has in previous high water events. Although not explicitly analyzed in the conceptual designs. Improvements to the Matlock cutoff would be prudent. Flow deflectors are proposed along the Ford Levee to direct the thalweg away from the Ford levee and increase the reliability of this levee.

Carbon River Levee Design Considerations

The Carbon River levees include, from upstream to downstream; Bridge Street, Orting Treatment Plant, and Riddell Levee. The carbon levee improvement includes levee raise and installation of a

more competent erosion protection for 3,500 linear feet of the Bridge Street Levee, 7,100 linear feet of the Orting Treatment Plant levee, and 7,800 linear feet of the Riddell Levee. The downstream end of the Riddell levee will be modified to tie-in to high ground via a new 650 linear foot levee section approximately 8-feet in height. The Riddell tie-in is designed as a 15-foot crown width typical of minimum levee widths for the Upper Puyallup and Carbon River reaches. A nearby boring from the 2011 exploration shows foundation soils as medium dense silty sand with gravel. Soft or organic layers were not discovered in the exploration; therefore, a 6" stripping was assumed to remove top soil and vegetation. Riverside erosion protection was developed with input from the hydraulic engineers and the HEC-RAS model. A 36" blanket of class IV riprap and a 5-foot deep by 10-foot wide buried toe was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket. Significant vegetation maintenance, including tree removal, is anticipated to perform the riverside erosion protection upgrades. The design toe of the riprap slope was designed to match the existing toe of the riprap slope to avoid channel encroachment. The current design incorporates a buried toe that will involve excavation of the channel bed in low flow.

Where portions of the levee are already at or above the desired level of protection, the erosion protection and the levee crown will be improved. A 6" lift of crushed gravel will be placed to improve the levee crown. Areas of the levee with sections exceeding the minimum 15-foot crown width will be improved up to a 24-foot width of the levee crown.

Lower White Levee Design Considerations

The new levee is proposed to be approximately 14,250 linear feet with levee heights ranging from 3 to 11 feet, with 5 to 6 feet being typical. Geotechnical information along the river bank of the White River is extremely limited because of the lack of existing levees in these areas. For the conceptual design of the Lower White levee, the designed section and geotechnical investigations of the County Line setback were used. A 15-foot crown width with flatter 2.5H:1V slopes were incorporated into the design. A 12" foundation soil stripping was included based on the County Line setback information. Borings for the County Line Setback showed loose to very silt layers with organic material within the first 5 feet of native soils which may have prompted the wider levee section. Further geotechnical exploration along proposed alignments will be required to confirm foundation soils and conceptual design.

Near station 115+00, existing drainage swales create an approximately 10-foot embankment. Raising this location an additional 3 to 4 feet, may result in seepage concerns. This location will need to be analyzed during 35% design. Maintaining interior drainage for the area may increase the scope of this project. Near station 50+00 an existing channel appears to be present, which will prompt a culvert installation and control gate,

Riverside erosion protection was developed with input from the hydraulic engineers and the HEC-RAS model. The upstream approximately 1,000 linear feet of levee forms the outside bend of the White River. This section requires a more significant erosion protection than normal. A 30" blanket of class III riprap and a 5-foot deep by 12-foot wide buried toe was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket. Downstream from this outside bend and continuing to the downstream end of the levee, a 2-foot blanket of class II riprap with a 5-foot scour depth was found to be necessary.

Pacific Park Levee & Butte Ave Levee Design Considerations

The new Pacific Park Levee is proposed to be approximately 5,400 linear feet with levee heights ranging from 4 to 13 feet, with 5 to 7 feet being typical. The new Butte Ave Levee is proposed to be approximately 3,400 linear feet with levee heights ranging from 2 to 6.5 feet. Similar to the Lower White Levee, the conceptual designs were based on geotechnical foundation information from nearby County Line Setback design. A 15-foot crown width with flatter 2.5H:1V slopes were incorporated into the design. A 12" foundation soil stripping was included based on the County Line setback information.

Riverside erosion protection was developed with input from the hydraulic engineers and the HEC-RAS model. A 30" blanket of class III riprap and a 5-foot scour depth was selected based on expected velocities. A 1-foot filter layer will underlie the riprap blanket.

Levee Design Criteria

Each levee section will be designed during 35% design to meet appropriate factors of safety for slope stability and seepage and piping. All geotechnical analyses will be assessed with the water surface at the top of the levee crest. Settlement analysis will also be performed for new levee construction. Slope erosion and scour protection will be performed by a Hydrology and Hydraulics engineer to complete required riprap design.

Global stability analyses will be performed for short-term (end of construction), static, steady state seepage, and rapid drawdown loading conditions in accordance with EM 1110-2-1913 Design and Construction of Levees, Section 6 (USACE, 2000). Rapid drawdown analysis will only be performed on embankment soils that are not considered free draining. Slope stability analyses will be performed using the modeling program, Slope/W.

Loading Condition	Factor of Safety Required
End of Construction	1.3
Steady-State	1.4
Rapid Drawdown	1.0 or 1.2*

* Cases where water levels are expected to persist for short periods or long periods, respectively

1) **End of construction (Static).** End of construction analysis did not account for significant development of pore pressures in the shallow embankment soils. Foundation soils are relatively permeable and deposited in relatively thin strata. A static slope stability utilizing piezometric surface equivalent to the groundwater table at the time of the soil exploration and effective strengths of soils were used. This assumption can be confirmed in later design phases when time rate of consolidation is explored and construction phases are determined. The minimum required FS is 1.3 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
2) **Steady-state**. This condition represents the long-term stability where the water level on the levee is at the design high water level. Effective soil strength parameters were used for the foundation soils. Pore pressures were imported from the steady state seepage model for use in this stability model. This condition is applicable to the landside slope, the minimum required FS is 1.4 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
3) **Rapid drawdown.** The rapid drawdown loading condition was not analyzed. Based on indications of available levee fill sources and design permeability, the levee soils will be relatively permeable and not develop significant excess pore water pressures along the riverward slope. This assumption can be confirmed at a later design phase.

The levees will be designed to resist underseepage and seepage using methods presented in USACE manuals (EM 1110-2-1913, April 30, 2000; EM 1110-2-1901, February, 2005) as well as regional Northwest Division (NWD) underseepage design guidance replacing the expired ETL 1110-2-569. The analysis will be accomplished using the finite element modeling program, Seep/W. The required factor of safety for the resistance of underseepage is 1.6 at the levee landward toe using vertical exit gradients. If a seepage berm design is necessary, the required factors of safety for the seepage berm will be 1.6 at the levee toe and 1.1 at the berm toe. Seepage berms are not anticipated to be a necessary design feature based on current understanding of the foundation soils. However, subsurface exploration for much of the levee alignments is limited. In the upper basin, existing levee embankment soils are relatively permeable without the presence of impermeable confining layers. Seepage through the foundation is considered likely due to the permeability of the soils, but exit gradients resulting in the piping are not anticipated. The geologic setting in the Puyallup basin coupled with moderate levee heights does not pose a significant risk of requiring seepage mitigation features beyond the widened levee section and 3H:1V for levees in the Lower Puyallup. Design factors of safety for exit gradients will be in accordance with the above guidelines to ensure that piping does not initiate.

Through seepage will be a potential issue on the upper basin levees constructed of sands and gravels. Design criteria to address through seepage will look at the exit point of the phreatic surface and exit gradients along the free discharge face.

Vertical settlement analyses will be performed using one-dimensional vertical consolidation theory. Software Settle^{3D} developed by RocScience (2008) will be used to model Boussinesq stress distributions for complex embankment configurations and to estimate the elastic and time-rate primary consolidation settlement estimates

Design Considerations: *Dredge Alternative*

Levees are required to add freeboard, where dredging depth restrictions cannot provide the needed channel capacity to contain the design flood. The assumption for the dredge alternative was that the scope of the levee construction would be smaller than the levee alternative alone; resulting in shorter new levee and existing levee raises. The design sections for the levee modification alternative were assumed to be applicable for the reduced design heights.

The North Levee Road setback alternative described in the levee modification alternative is not applicable to the dredge alternative. A raise of the North Levee Road was selected. The existing paved 24-foot crown will be kept as a design component for the proposed raised levee.

Risk, Next Steps, & Future Studies

Risk

Assumptions about soil conditions without adequate soil testing may lead to a design and footprint of projects that could underestimate the soil conditions requiring an increase in design effort as well project cost. Future levee exploration and soil testing along project alignments as well as identifying potential borrow sources based on anticipated soil quantities will reduce the risk of design and cost errors.

Levee Exploration & Testing

Geotechnical explorations will be completed during the next phase of the feasibility study to provide more comprehensive subsurface soil information. A subsurface exploration plan, scope of work, and an estimated laboratory testing schedule should be developed. The exploration is recommended to include borings (hollow stem auger and for areas with heaving sands, mud rotary methods), test pits, and cone penetration testing (CPTs) and include index testing.

The spacing of borings usually varies from 200 feet to 1,000 feet along the alignment, being closer spaced in problem areas and wider spaced in non-problem areas. The depth of these borings should be sufficient to account for modeling needs. Approximately 3 times the levee height or 30

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foot minimum depth should be sufficient. Test pits can be as deep as the levee height but not less than 10 feet.[1]

Preliminary strength estimates can be estimated from standard penetration testing.

Laboratory testing should include Atterberg limit testing for fine-grained soils, visual classifications, organics, and grain size analysis (gradation). Consolidation and/or shear strength testing could be done if design requires or if soils are weaker than expected.

Potential Borrow Guidelines

Identifying potential borrow sources for the levee and road construction is a critical next step to assess the project feasibility and to update cost assumptions. Especially for the levee modification alternative, the ability to locate such a large volume of suitable levee fill is a significant risk for the project and is being tracked by the vertical team in the risk register. For the conceptual design cost estimates, all excavated soil was assumed to require off-site disposal. Fill was assumed to be imported at a haul distance of 20 to 30 miles except for the North Levee Road levee setback in which approximately 75% of the material from the existing levee degrade was assumed to satisfy or at least be processed to meet the levee fill specification. These assumptions will be validated during the future feasibility level design phase.

For levee fill, the following soil specifications are recommended as a typical levee gradation used for Northwest levee construction: USCS soil classification of SP-SM or SM, free of organics and debris, with LL<50, and a gradation meeting the following specifications in Table 1-1.

Table 1-1. Typical Levee Fill Gradation

Sieve Designation	Percent Passing
3 inch	90-100
1 inch	70-95
½ inch	60-90
No. 4	50-85
No. 40	20-55
No. 200	10-20

Unsuitable soil includes wet, fine-grained soils or highly organic soils. Almost all other soil types are suitable for levee construction. Accessibility and proximity are controlling factors in selecting borrow sources. The water content of the borrow soil is also a significant factor in selection. The water content needs to be near the soils optimum water content to allow for proper compaction.

[1] EM 1110-2-1913 Design and Construction of Levees

This may affect the construction season. Borrow source volumes should be about 125 percent of the required volume to account for shrinkage, hauling and other losses.

Summary of Future Steps

1. Subsurface exploration and laboratory testing within conceptual design footprints.
2. Preliminary levee design based on gathered soil information. Perform settlement, seepage, and stability analyses per EM 1110-2-1913: Design and Construction of Levees. Analyze overtopping sections.
3. Selection of available borrow sources.

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