Technical Memorandum

Date:	August 20, 2021
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	HDR Andrew Little
Subject:	Quarry Operations
Attachments:	Attachment A. Figures Attachment B. Quarry Boring Logs

1.0 Introduction and Purpose

The State Environmental Policy Act (SEPA) and National Environmental Policy Act (NEPA) Draft Environment Impact Statements (EIS) considered three potential quarry locations (North Quarry, South Quarry, and Huckleberry Ridge) to support construction of the proposed (Flood Retention Only - Expandable) FRE facility (Figure 1; all figures located in Attachment A). Since the release of the Draft EISs, the Chehalis Basin Flood Control Zone District (District) has determined that the Huckleberry Ridge location is not a viable option. To inform Final EIS development, this technical memorandum (TM) advances the concept of the viable quarry sites and further refines the assumptions for site location and extent of quarry development and operations during construction of the FRE facility. The previous work completed by HDR and Shannon & Wilson is the basis for this TM which advances the technical quantities of the quarries. Relevant boring logs are provided in Attachment B.

The FRE facility would require development of about 890,000 cubic yards (CY) or 1.7 million tons of aggregate materials (based on a bulking factor of 1.25 resulting from laboratory testing of the basalt that shows a density of 162 pounds per cubic foot [pcf] and assuming in place bulk density of 130 pcf). The amount of material required for road base and riprap have not been defined in detail. However, a quarry capable of generating up to 2 times the aggregate required for the FRE facility is expected to provide a sufficient margin of safety required to the combined aggregate, road base, and riprap with a suitable allowance for waste associated with unacceptable rock such as weathered basalt or interbedded siltstone materials. It is unlikely the quarry rock would be suitable for conventional concrete and material would need to be furnished from off-site.

1.1 Quarry Descriptions

Potential quarry sites for obtaining construction materials for the proposed flood retention structure (aggregate for roller compacted concrete [RCC], road base and riprap) were first identified through a regional geologic mapping and assessment process. Following identification of a candidate quarry site, a sequence of site investigations, laboratory testing, and engineering assessments were performed.

The following quarry descriptions provide the quarry locations and a summary of the field investigations that have been completed including geotechnical borings and seismic refraction survey lines. For site investigation methodology details and results refer to the Phase 2 Site Characterization TM (HDR 2017) and the Phase 3 Geotechnical Data Report (Shannon & Wilson, Inc. 2019).

North Quarry: The North Quarry is located about 1.2 miles directly southeast (2.14 miles by road) of the proposed FRE facility site and within the limits of the detention pool. The site is accessed off the main Road 1000 by Road 1013 (Figure 1). One seismic refraction survey line and four borings (one in 2016 and three in 2018) have been completed at this potential quarry site (Figure 2).

South Quarry: The South Quarry is located about 2.5 miles directly south (4.3 miles by road) of the proposed FRE facility site and also within the limits of the detention pool. The site is accessed off the main Road 1000 by the Road 1020 southwest of the site as it rises to the northeast and exposes a basalt outcrop along the southeastern margin of the site (Figure 1). This quarry site was added following the Phase 2 investigation when a Weyerhaeuser contractor improved the grade of the 1020 Road, west of the mainstem Chehalis River, exposing basalt not previously visible. A grab sample of the rock from that road cut was tested in early 2018 and tests indicated that the rock may be promising for use as aggregate. Consequently, a boring was included in the Phase 3 investigation (Figure 3), but no seismic refraction survey has been performed.

2.0 Quarry Quantity Estimates

Limited investigations have been performed at both quarry sites. Hence, significant uncertainties remain regarding depth of overburden, thickness of quality rock, and the lateral extents that would be required. Further drilling investigations would be required to develop a final quarry plan. Therefore, the quantity estimates described in the following sections should only be considered a rough order of magnitude and subject to future verification.

2.1 North Quarry

Figure 2 shows the proposed extents of the North Quarry and the locations of the four borings and one seismic refraction survey line conducted to assess the quality and quantity of basalt to be used as aggregate, road base, and riprap. The area of the potential quarry is estimated at 820,000 square feet (sf) or 18.8 acres (ac). Table 1 shows the estimated overburden and basalt bedrock thicknesses from each of the four borings and the potential total volume of overburden waste and processed rock that could be produced using the estimated quarry area.

Table 1. North Quarry Boring Result Summary

Boring ID	Thickness (ft)	
	Overburden	Basalt
RNQ-16-301 (QB1)	38	76
RNQ-18-301	75	45
RNQ-18-302	48	30
RNQ-18-303	45	55
Average:	**51.5**	**51.5**
Volume (CY):	**1,564,074**	**1,564,074**

By averaging the thickness for both overburden and basalt between the four borings, the volume of each is about 1.5 million CY. The boring logs indicate only a few siltstone interbeds on the order of 6 inches thick. This would result in a minimal amount of waste material (expected to be less than 10%) within the basalt resulting in about 1.4 million CY or about 3.1 million tons of usable rock. The necessary volume of aggregate is about 890,000 CY for the RCC dam (HDR 2018), or about 1.7 million tons resulting in a calculated factor of safety of 1.8. Some of this excess material would be used for road base and riprap but quantities for these are not well defined and can be assumed to be included in the factor of safety.

It should be noted that the seismic refraction survey was not consistent with the boring data and displayed an overburden thickness ranging from 70 to 90 feet. Also, below the basalt is a layer of siltstone that is the lower boundary of useable bedrock. If the overburden thickness is greater than what is shown in the boring logs, as indicated by the seismic refraction survey, then the lateral extents of the quarry area may need to be increased to mine sufficient quantities of basalt for all the aggregate, road base, and riprap that may be required for the project.

2.2 South Quarry

The proposed extents of the South Quarry are shown on Figure 3 as well as the location of the boring conducted to assess the quality and quantity of basalt for use as aggregate, road base, and riprap. The area of the potential quarry is estimated at 750,000 sf or 17.2 ac. Table 2 summarizes the boring log stratigraphy.

Table 2. South Quarry Boring Result Summary

Depth (ft)		Thickness (ft)	Description
From	To		
0	35	35	Overburden
35	133	98	Basalt
133	146	13	Breccia/siltstone
146	180	34	Basalt

Notes:
Total basalt thickness: 132 feet
The boring ended at 180 feet within basalt which may extend beyond the depth of the boring.

The single boring in the potential quarry indicates an overburden thickness of 35 feet which results in an estimated useable rock volume of about 980,000 CY. Within the potentially usable basalt bedrock, there is a layer of basalt breccia and siltstone that would be wasted resulting in a total thickness of usable basalt of 132 feet. The boring log indicates several zones of weak and highly weathered rock within the usable basalt, which is more variability than seen in the basalt at the North Quarry. A 30 percent waste factor was applied to be conservative. When a thickness of 132 feet is multiplied by the quarry area (750,000 sf) and reduced by the 30 percent waste factor, the resulting volume is about 2.6 million CY or about 6 million tons. This provides a factor of safety of 3.4, using the required tonnage (1.7 million tons). With only a single boring, there is significant uncertainty to the calculated quantities and thus a much higher factor of safety is appropriate for the South Quarry.

2.3 Quarry Quantity Summary

The quantities for each quarry are summarized based on the limited amount of existing data in Table 3. Further investigation and analysis is required to verify these values.

Table 3. Summary of Quarry Quantities

Item	Unit	North Quarry	South Quarry
Area	sf	819,760	755,714
Overburden Volume[1]	CY	1,564,074	978,704
Overburden Weight[2]	tons	2,639,375	1,651,563
Initial Basalt Volume	CY	1,564,074	3,691,111
Waste Factor	CY	10%	30%
Expected Waste Volume[1]	CY	156,407	1,107,333
Useable Basalt Volume	CY	1,407,667	2,583,778

Item	Unit	North Quarry	South Quarry
Useable Basalt Weight[3]	tons	3,078,568	5,650,722
Factor of Safety[4]	--	1.8	3.4

Notes:
1. No bulking factor was applied to the overburden volume.
2. A bulk density of 125 pcf was assumed for overburden.
3. Laboratory testing indicates a density of 162 pcf for the basalt.
4. Factor of Safety based on a need of 890,000 CY (HDR 2018) or 1,685,880 tons using a bulking factor of 1.25 based on laboratory results of the basalt and assuming an in-place density of 130 pcf.

3.0 Quarry Equipment and Operational Time

Quarry and aggregate processing assumptions reflect equipment and construction approaches typical of large-quantity, project-dedicated, stripping, quarrying, and quarried-rock aggregate processing. A wide variety of equipment and production approaches could be employed which the following assumptions should reasonably represent.

3.1 North Quarry

Overburden excavation equipment would involve large dozers (100,000 to 200,000 pounds, 350- to 550-horsepower [hp]), large excavators (100,000 to 230,000 pounds, 450- to 550-hp), and 35- to 45-ton (400- to 500-hp) articulated off-road haul trucks and/or 50- to 70-ton (500- to 800-hp) off-road haul trucks. Overburden excavation operations could be expected to take 8–12 months.

Similar equipment should be expected for the quarry drilling, blasting, and excavation for crusher feed; but including rock drills (400 hp +/-).

Crushing and processing equipment is likely to include large jaw primary crushing, cone, or vertical shaft impact secondary crushing, and vertical shaft impact tertiary crushing; together with associated feeders, conveyors, screen decks, and potentially aggregate washing equipment. Aggregate processing operations could be expected to utilize 1,000 to 2,000 operating horsepower over a period of 12 to 20 months.

3.2 South Quarry

South quarry operations would look similar to the north quarry operations but be expected to involve approximately half of the time for overburden excavation.

4.0 Summary

This memo clarifies the viability of the two proposed quarry sites, north and south quarry for suppling aggregate for the construction of the proposed FRE facility. This information is intended to refine the assumptions regarding the operations at either of these sites for development of the Final EISs. Additionally, each individual quarry site may supply sufficient material for construction of the proposed project. As the contractor develops the quarry, they may be able to utilize a single quarry or a portion of both quarries depending on quality and

quantity of rock, however further investigations will be required to determine if one or both quarries will be utilized.

5.0 Literature Cited

HDR Engineering, Inc. (HDR)

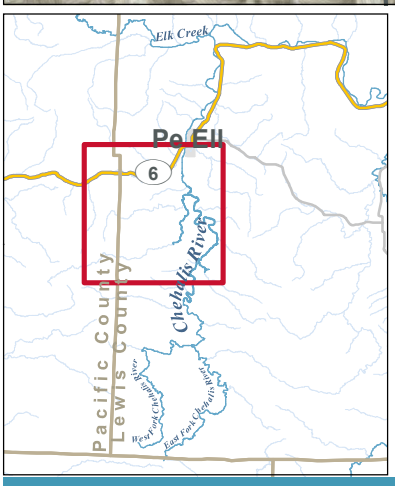
2017 Phase 2 Site Characterization Technical Memorandum.

2018 Combined Dam and Fish Passage Supplemental Design Report FRE Dam Alternative.

Shannon & Wilson (S&W)

2019 Phase 3 Chehalis Dam Geotechnical Data Report, Chehalis Basin Work Group, Pe Ell, Washington.

Attachment A. Figures



Quarry Site

Concrete Production Facility

Existing roads to be improved for quarry site access

Main channel OHWM

0 2,500 5,000

Feet

NAD 1983 STATE PLANE WASHINGTON SOUTH FT (FIPS 4602)

FIGURE 1

POTENTIAL QUARRY SITES UNDER CONSIDERATION

CHEHALIS RIVER BASIN FLOOD DAMAGE REDUCTION PROJECT

12/30/2020

Document Path: L:\Jobs\Chehalis\FIG-2_QR_SitePlan.mxd

RNQ-18-303

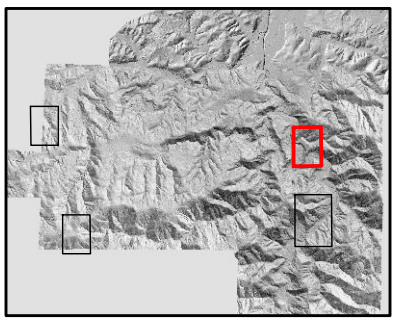
NORTH QUARRY

RNQ-18-302

RNQ-16-301(QB-1)

RNQ-18-301

Chehalis River



LEGEND

Landslide Location and Designation

LS-26

Quarry Site Location

Profile Location

Potential Dam Site Location

Completed Boring Locations

Recommended Boring Locations

NOTE:
Hillshade generated using ESRI 3D Analyst from LiDAR data provided by HDR. NAVD 88, Illumination 315

N
W E
S

0 300

Feet

Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

SITE PLAN

March 2019 21-1-21897-025

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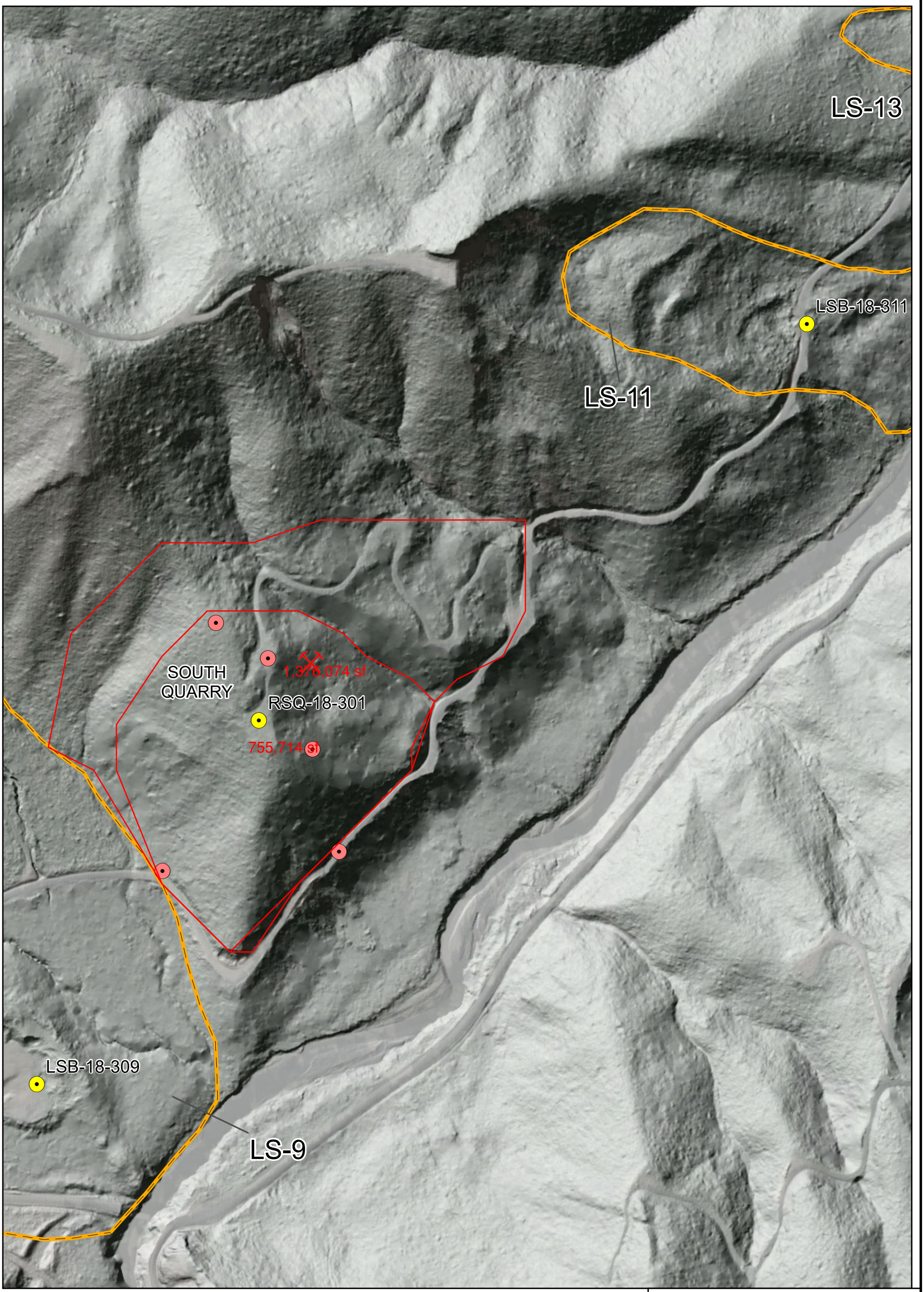
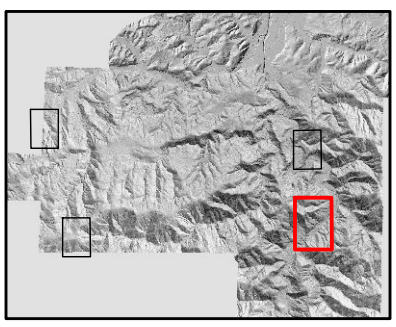
FIG. 2

Document Path: L:\Jobs\Chehalis\FIG-2_QR_SitePlan.mxd





LEGEND

Landslide Location and Designation
LS-26

Quarry Site Location

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NOTE:
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N W E S

0 300
Feet

Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

SITE PLAN

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FIG. 2

Attachment B. Quarry Boring Logs

Northing: 448782.15 | Easting: 939529.47 | Elevation: 804.2 ft | Driller/Rig Type: Holt/CME 850 truck rig | Hammer Type: Auto
Plunge: -90° | Azimuth: NA° | Total Depth: 150 ft | Soil Drilling Method: Mud Rotary | Soil Bit Diam: "
Start Date: 3/16/2016 | End Date: 3/21/2016 | Refusal Depth: 35 ft | Rock Drilling Method: wire-line core | Rock Bit Diam: HQ
Horz. Datum: WGS84 | Vert. Datum: NAVD88 | Logged By: RHW | Checked By: EAS
Coord. System: State Plane 4602 US Survey Feet | Location: Quarry Site 1

Groundwater Measurements

Date	Time	Depth (ft)

Chehalis Dam Site Characterization

Client: Anchor QEA | Phase 2 | Project No: 268421

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QB-1

Sheet 1 of 5

Elev. (ft)	Depth (ft)	Material Description
804.2	0	Medium stiff to stiff, mottled red-brown, brown and yellow-brown; Elastic Silt (MH) to Silt (ML); moist; trace fine to coarse sand; low to medium plasticity fines;trace to few organics; iron-oxide staining.
775	27.5	Stiff, mottled light gray to red-brown; Silt (ML) to Elastic Silt (MH); moist; low plasticity fines; few completely weathered bedrock clasts.
770	32.5	Very dense, dark gray and dark red-brown, Silty Sand with Gravel (SM); moist; fine angular gravel; fine to coarse sand; low plasticity fines; iron-oxide

Graphic | Laboratory Test Data

Samples: S-1 5–6.5; S-2 10–11.5; S-3 15–16.5; S-4 20–21.5; S-5 25–26.5; S-6 30–31.5

SPT ▲ Blows/Foot; Recovery (%) ▨; RQD (%) ▩ — 0 25 50 75 100

RMR (%): Very Poor | Poor | Fair | Good | Very Good — 20 40 60 80

Strength Index: 1 2 3 4 5 6

Weathering Index: 1 2 3 4 5

Discontinuity Data: Infilling | Angle | Symbol

Water Pressure Test Data: Depth (ft) | Max. Test Pressure (psi) | Flow Behavior | Hydraulic Conductivity (cm/sec) — Non Groutable | Moderately Groutable | Groutable — 1x10⁻⁴ 1x10⁻⁵ 1x10⁻⁶ 1x10⁻⁷ 1x10⁻⁸ 1x10⁻⁹ 1x10⁻¹⁰ 1.00

Unwrapped Televiewer Image (Azimuth): 90° 180° 270°

3D Core View: 0°

Structure (Tadpole points to Azimuth of Dip Direction) — Dip: 15° 45° 75°

Suspension Log Velocity (ft/s): P-Wave | S-Wave — 1000 2000 3000 4000 5000

Piezometer/ Groundwater

LITHOLOGY KEY

MH | CLAYSTONE | BRECCIA
ML | BASALT
SM | SILTSTONE

SAMPLES

#	TYPE
S-1	SPT Sample
S-2	Tube Sample
RC-1	Core Run

TEST DATA

● = Moisture Content (%)
◇ = Fines (<0.075mm) (%)
LL = Liquid Limit
PL = Plastic Limit
DD = Dry Density (pcf)
X = Slake Durability Test (Index% - type descriptions to the right)
BD = Bulk Density (pcf)
✳ = Unconfined Compressive Strength (psi)
⊕ = Point Load Test (psi)
SG = Specific Gravity
n = Porosity
⧫ = Peak Friction Angle (degrees)
c = Peak Cohesion (psi)
abs = Absorption (%)
ASR = Alkali Silica Reactivity (16 day avg. % length change)
LA = LA Abrasion (% loss)

SLAKE DURABILITY TEST

TYPE	Description
I	Retained specimen remains virtually unchanged
II	Retained specimen consists of large and small fragments
III	Retained specimen is exclusively small fragments

STRENGTH INDEX

TERM	INDEX	APPROX. UCS (psi x 1000)
Very Weak	1	<0.7
Weak	2	0.7 to 3.6
Medium Strong	3	3.6 to 7.2
Strong	4	7.2 to 14.5
Very Strong	5	14.5 to 36.25
Extremely Strong	6	>36.25

WEATHERING INDEX

TERM	INDEX	DESCRIPTION
Fresh	1	No evidence of alteration
Slightly	2	Slight discoloration on surface
Moderately	3	Discoloring evident, alteration well below rock surfaces
Highly	4	Entire mass discolored
Completely	5	Rock reduced to a soil with relict rock texture

DISCONTINUITY DATA

INFILLING: CA: Calcite; CL: Clay; FE: Iron Oxide; M: Mineral; S: Sand; G: Gouge; SS: Slickensides; H: Healed

ANGLE: Degrees relative to horizontal plane, (-) below plane

SYMBOL: Fracture; Healed; Rubble Zone; Gouge Zone; Core Loss

PIEZOMETER

Vibrating Wire Piezometer
Surface Cement Seal
Bentonite Cement Grout
Bentonite Seal
Sand Filter
Slough
Groundwater Level During Drilling
Groundwater Level and Date Read

STRUCTURE

Major open joint/fracture
Minor open joint/fracture
Partially open joint/fracture
Filled joint/fracture
Bedding/Banding/Foliation
Contact

DEFINITIONS
1. USCS: Unified Soil Classification System; Standard Practice for Classification of Soils for Engineering Purposes - ASTM D2487
2. SPT: Standard Penetration Testing; Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils - ASTM D1586
3. RQD: Rock Quality Designation; Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core - ASTM D6032
4. RMR: Rock Mass Rating; The Rock Mass Rating (RMR) System (Geomechanics Classification) in Engineering Practice - STP984 (see references)

NOTES
1. The contacts represent the approximate boundaries between lithology types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. The location of the discontinuities shown are approximate. For clarity not all discontinuities are shown.
4. Grab samples taken from the core for laboratory testing

REFERENCES
1. Discontinuity, weathering, strength and roughness terms used in Material Descriptions are from (Brown, E.T., Editor, 1981, Rock Characterization Testing and Monitoring, ISRM Suggested Methods, pp. 5, 31, 32.)
2. Discontinuity spacing and stratification spacing terms used in Material Descriptions are from (Deere, D.U., 1963, Technical Descriptions of Rock Cores for Engineering Purposes, p. 18.)
3. RMR values are derived using the method from (Bieniawski, Z.T. 1989. Engineering rock mass classifications. New York: Wiley)

Northing: 448782.15 | Easting: 939529.47 | Elevation: 804.2 ft | Driller/Rig Type: Holt/CME 850 truck rig | Hammer Type: Auto
Plunge: -90° | Azimuth: NA° | Total Depth: 150 ft | Soil Drilling Method: Mud Rotary | Soil Bit Diam: "
Start Date: 3/16/2016 | End Date: 3/21/2016 | Refusal Depth: 35 ft | Rock Drilling Method: wire-line core | Rock Bit Diam: HQ
Horz. Datum: WGS84 | Vert. Datum: NAVD88 | Logged By: RHW | Checked By: EAS
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Groundwater Measurements

Date	Time	Depth (ft)

Chehalis Dam Site Characterization

Client: Anchor QEA | Phase 2 | Project No: 268421

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Sheet 2 of 5

Elev. (ft) | Depth (ft) | Material Description

35 — staining.

CLAYSTONE and BASALT: near vertical contact between claystone and basalt; weak to medium strong, dark gray to dark gray-brown, fined grained; slightly to moderately weathered. (Tcs)

37.75

BASALT: strong to very stong, dark gray, fine grained to porphyritic; low to moderate angle, smooth to rough, close to very wide spaced joints, with mineral and iron-oxide infilling; slightly weathered with moderately weathered zones; slightly vesicular to 53 feet. (Tcb)

Graphic | Depth (ft) | Samples | Interval (ft) | Laboratory Test Data

Samples: S-7, R1, R2, R3, R4, R5, R6, R7, R8

Interval (ft): 35.33, 37.75, 40, 45, 50, 55, 60, 65

Laboratory Test Data: BD=158pcf ✳ = 5763psi; SG = 2.44 Abs = 6.46% ASR = 0.08 LA = 27.1%

SPT ▲ Blows/Foot — Recovery (%) ▨ — RQD (%) ▩ (0 25 50 75 100) | Depth (ft) | RMR (%) (Very Poor, Poor, Fair, Good, Very Good; 20 40 60 80) | Strength Index (1 2 3 4 5 6) | Weathering Index (1 2 3 4 5) | Depth (ft)

Discontinuity Data: Infilling | Angle | Symbol | Depth (ft)

Infilling: CL, FE; FE

Water Pressure Test Data: Max. Test Pressure (psi) | Flow Behavior | Hydraulic Conductivity (cm/sec): Non Groutable, Moderately Groutable, Groutable

Depth (ft) | Unwrapped Televiewer Image (Azimuth) (90° 180° 270°) | 3D Core View (0°) | Depth (ft) | Structure (Tadpole points to Azimuth of Dip Direction) Dip (15° 45° 75°)

Suspension Log Velocity (ft/s) (1000 2000 3000 4000 5000) — P-Wave — S-Wave | Piezometer/ Groundwater | Depth (ft) | Elev. (ft)

Depth (ft)	Elev. (ft)
35	
40	764
45	759
50	754
55	749
60	744
65	739

Elev. (ft): 765, 760, 755, 750, 745, 740, 735

LITHOLOGY KEY

MH | ML | SM | CLAYSTONE | BASALT | SILTSTONE | BRECCIA

SAMPLES

#	TYPE
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Vibrating Wire Piezometer
Surface Cement Seal
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Bentonite Seal
Sand Filter
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Groundwater Level During Drilling
Groundwater Level and Date Read

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Elev. (ft) | Depth (ft) | Material Description | Graphic | Depth (ft) | Samples | Interval (ft) | Laboratory Test Data | SPT ▲ Blows/Foot | Recovery (%) ▨ | RQD (%) ▩ (0 25 50 75 100) | Depth (ft) | RMR (%) (Very Poor, Poor, Fair, Good, Very Good; 20 40 60 80) | Strength Index (1 2 3 4 5 6) | Weathering Index (1 2 3 4 5) | Depth (ft) | Discontinuity Data: Infilling, Angle, Symbol | Water Pressure Test Data: Depth (ft), Max. Test Pressure (psi), Flow Behavior, Hydraulic Conductivity (cm/sec): Non Groutable, Moderately Groutable, Groutable | Depth (ft) | Unwrapped Televiewer Image (Azimuth) 90° 180° 270° | 3D Core View 0° | Depth (ft) | Structure (Tadpole points to Azimuth of Dip Direction) Dip 15° 45° 75° | Suspension Log Velocity (ft/s) P-Wave, S-Wave (1000 2000 3000 4000 5000) | Piezometer/ Groundwater | Depth (ft) | Elev. (ft)

Elev. (ft)	Depth (ft)	Material Description	Laboratory Test Data	Depth (ft)	Depth (ft)	Elev. (ft)
730	70			70	70	734
	75			75	75	729
725	80			80	80	724
720	85		BD=164pcf ✳ = 1834psi	85	85	719
715	90	- Claystone interbed from 90.3 to 90.9 feet.	SG = 2.53 Abs = 4.69% ASR = 0.076 LA = 26.8%	90	90	714
710	95			95	95	709
705	100			100	100	704
700						

R9 | R10 | R11 | R12 | R13 | R14 | R15

LITHOLOGY KEY

MH | ML | SM | CLAYSTONE | BASALT | SILTSTONE | BRECCIA

SAMPLES

#	TYPE
S-1	SPT Sample
S-2	Tube Sample
RC-1	Core Run

TEST DATA

● = Moisture Content (%)
◇ = Fines (<0.075mm) (%)
LL = Liquid Limit
PL = Plastic Limit
DD = Dry Density (pcf)
X = Slake Durability Test (Index% - type descriptions to the right)
BD = Bulk Density (pcf)
✳ = Unconfined Compressive Strength (psi)
⊕ = Point Load Test (psi)
SG = Specific Gravity
n = Porosity
♦ = Peak Friction Angle (degrees)
c = Peak Cohesion (psi)
abs = Absorption (%)
ASR = Alkali Silica Reactivity (16 day avg. % length change)
LA = LA Abrasion (% loss)

SLAKE DURABILITY TEST

TYPE	Description
I	Retained specimen remains virtually unchanged
II	Retained specimen consists of large and small fragments
III	Retained specimen is exclusively small fragments

STRENGTH INDEX

TERM	INDEX	APPROX. UCS (psi x 1000)
Very Weak	1	<0.7
Weak	2	0.7 to 3.6
Medium Strong	3	3.6 to 7.2
Strong	4	7.2 to 14.5
Very Strong	5	14.5 to 36.25
Extremely Strong	6	>36.25

WEATHERING INDEX

TERM	INDEX	DESCRIPTION
Fresh	1	No evidence of alteration
Slightly	2	Slight discoloration on surface
Moderately	3	Discoloring evident, alteration well below rock surfaces
Highly	4	Entire mass discolored
Completely	5	Rock reduced to a soil with relict rock texture

DISCONTINUITY DATA

INFILLING: CA: Calcite; CL: Clay; FE: Iron Oxide; M: Mineral; S: Sand; G: Gouge; SS: Slickensides; H: Healed

ANGLE: Degrees relative to horizontal plane. (-) below plane

SYMBOL: Fracture; Healed; Rubble Zone; Gouge Zone; Core Loss

PIEZOMETER

Vibrating Wire Piezometer
Surface Cement Seal
Bentonite Cement Grout
Bentonite Seal
Sand Filter
Slough
Groundwater Level During Drilling
Groundwater Level and Date Read

STRUCTURE

Major open joint/fracture
Minor open joint/fracture
Partially open joint/fracture
Filled joint/fracture
Bedding/Banding/Foliation
Contact

DEFINITIONS
1. USCS: Unified Soil Classification System; Standard Practice for Classification of Soils for Engineering Purposes - ASTM D2487
2. SPT: Standard Penetration Testing; Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils - ASTM D1586
3. RQD: Rock Quality Designation; Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core - ASTM D6032
4. RMR: Rock Mass Rating; The Rock Mass Rating (RMR) System (Geomechanics Classification) in Engineering Practice - STP984 (see references)

NOTES
1. The contacts represent the approximate boundaries between lithology types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. The location of the discontinuities shown are approximate. For clarity not all discontinuities are shown.
4. Grab samples taken from the core for laboratory testing

REFERENCES
1. Discontinuity, weathering, strength and roughness terms used in Material Descriptions are from (Brown, E.T., Editor, 1981, Rock Characterization Testing and Monitoring, ISRM Suggested Methods, pp. 5, 31, 32.)
2. Discontinuity spacing and stratification spacing terms used in Material Descriptions are from (Deere, D.U., 1963, Technical Descriptions of Rock Cores for Engineering Purposes, p. 18.)
3. RMR values are derived using the method from (Bieniawski, Z.T. 1989. Engineering rock mass classifications. New York: Wiley)

Northing: 448782.15 | Easting: 939529.47 | Elevation: 804.2 ft | Driller/Rig Type: Holt/CME 850 truck rig | Hammer Type: Auto
Plunge: -90° | Azimuth: NA° | Total Depth: 150 ft | Soil Drilling Method: Mud Rotary | Soil Bit Diam: "
Start Date: 3/16/2016 | End Date: 3/21/2016 | Refusal Depth: 35 ft | Rock Drilling Method: wire-line core | Rock Bit Diam: HQ
Horz. Datum: WGS84 | Vert. Datum: NAVD88 | Logged By: RHW | Checked By: EAS
Coord. System: State Plane 4602 US Survey Feet | Location: Quarry Site 1

Groundwater Measurements

Date	Time	Depth (ft)

Chehalis Dam Site Characterization

Client: Anchor QEA | Phase 2 | Project No: 268421

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

QB-1

Sheet 4 of 5

Elev. (ft) | Depth (ft) | Material Description | Graphic | Depth (ft) | Samples | Interval (ft) | Laboratory Test Data | SPT ▲ Blows/Foot | Recovery (%) ▨ | RQD (%) ▩ | Depth (ft) | RMR (%) | Very Poor | Poor | Fair | Good | Very Good | Strength Index | Weathering Index | Depth (ft) | Discontinuity Data | Infilling | Angle | Symbol | Water Pressure Test Data | Depth (ft) | Max. Test Pressure (psi) | Flow Behavior | Hydraulic Conductivity (cm/sec) | Non Groutable | Moderately Groutable | Groutable | Depth (ft) | Unwrapped Televiewer Image | (Azimuth) | 3D Core View | Depth (ft) | Structure | (Tadpole points to Azimuth of Dip Direction) | Dip | Suspension Log Velocity (ft/s) | P-Wave | S-Wave | Piezometer/ Groundwater | Depth (ft) | Elev. (ft)

Elev. (ft)	Depth (ft)	Material Description
695		
690	114.5	SILTSTONE: weak to medium strong, dark gray, fine grained; low to moderate, moderate spaced smooth to rough joints with mineral infillling; slightly weathered. (Tcs) - Basalt interbed from 116.1 to 116.7 feet.
685	119	BRECCIA: medium strong to strong, dark gray, fine grained; wide to extremely wide spaced low angle rough joints with mineral infilling; slighlty weathered; basalt and claystone clasts with clast sizes from 0.1 feet to 1.6 feet. (Tcb)
680		
675		
670		
665		

Samples: R16, R17, R18, R19, R20, R21, R22

BD=163pcf ✳ = 5237psi

SG = 2.3 Abs = 8.26% ASR = 0.124 LA = 27.5%

LITHOLOGY KEY

MH | CLAYSTONE | BRECCIA
ML | BASALT
SM | SILTSTONE

SAMPLES

#	TYPE
S-1	SPT Sample
S-2	Tube Sample
RC-1	Core Run

TEST DATA

● = Moisture Content (%)
◇ = Fines (<0.075mm) (%)
LL = Liquid Limit
PL = Plastic Limit
DD = Dry Density (pcf)
X = Slake Durability Test (Index% - type descriptions to the right)
BD = Bulk Density (pcf)
✳ = Unconfined Compressive Strength (psi)
⊕ = Point Load Test (psi)
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FE: Iron Oxide
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ANGLE
Degrees relative to horizontal plane, (-) below plane

SYMBOL
Fracture
Healed
Rubble Zone
Gouge Zone
Core Loss

PIEZOMETER

Vibrating Wire Piezometer
Surface Cement Seal
Bentonite Cement Grout
Bentonite Seal
Sand Filter
Slough
Groundwater Level During Drilling
Groundwater Level and Date Read

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Minor open joint/fracture
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Chehalis Dam Site Characterization

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SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

QB-1

Sheet 5 of 5

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Elev. (ft)	Depth (ft)	Material Description
660	150	End of Boring at 150 ft

Samples: R23, R24

Depth (ft) / Elev. (ft): 145 / 659; 150 / 654

LITHOLOGY KEY

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ML | BASALT
SM | SILTSTONE

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SYMBOL: Fracture; Healed; Rubble Zone; Gouge Zone; Core Loss

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Surface Cement Seal
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Sand Filter
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Groundwater Level During Drilling
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STRUCTURE

Major open joint/fracture
Minor open joint/fracture
Partially open joint/fracture
Filled joint/fracture
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SHANNON & WILSON, INC.

EXPLORATION LOG OF RNQ-18-301

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/9/2018 **Finish Date:** 7/11/2018 **Total Depth:** 120 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary **Drill Company:** Holt **Logged By:** BMC **Hole Diameter:** 6 in

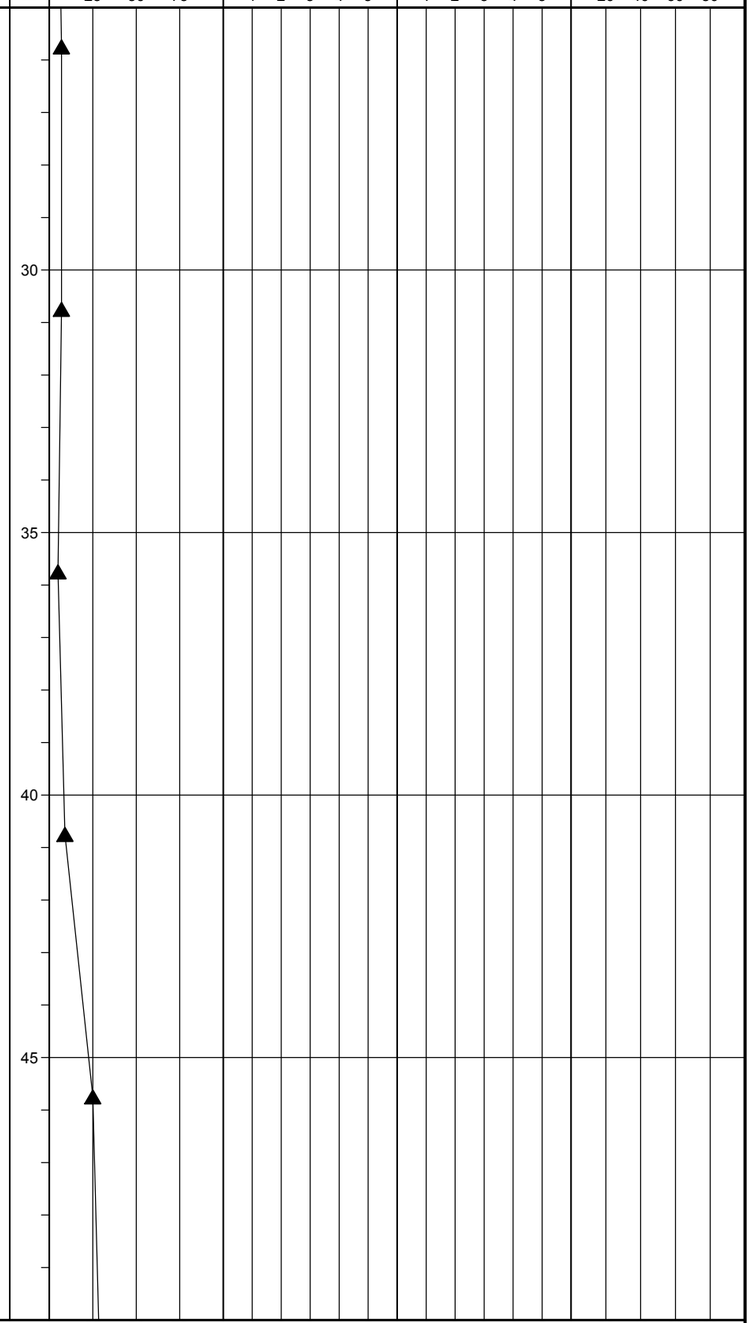
Elev. (ft)	Depth* (ft)	BORING RNQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		Loose, mottled red-brown to yellow *Silty with Sand (ML)*; moist; trace fine gravel; fine to coarse sand; nonplastic to low plasticity fines; iron oxide staining; trace organics. (Colluvium)		1	None Observed During Drilling								5						5	25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80
13.0		Medium stiff, mottled red-brown and yellow *Silt (ML)*; moist; trace fine to coarse sand; low plasticity fines; iron oxide staining. (Weathered Bedrock)		2									10						10				
				3									15						15				
				4									20						20				

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/9/2018 | Total Depth: 120 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary | Logged By: BMC
Finish Date: 7/11/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
				5														
				6									30					
				7									35					
38.0		Medium dense, mottled red-brown and yellow *Silt with Sand (ML)*; moist; fine sand; nonplastic to low plasticity fines. (Weathered Bedrock)		8									40					
43.0		Medium dense, yellow-brown, *Silty Sand (SM)*; moist; trace fine, angular gravel; fine to coarse sand; nonplastic to low plasticity fines; iron oxide staining. (Weathered Bedrock)		9									45					



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EXPLORATION LOG OF RNQ-18-301

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/9/2018 **Finish Date:** 7/11/2018 **Total Depth:** 120 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary **Drill Company:** Holt **Logged By:** BMC **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
	53.5	Very dense, brown to dark brown, *Silty Sand (SM)*; moist; trace fine, angular gravel; fine to coarse sand; nonplastic fines; trace highly weathered quartz veins. (Weathered Bedrock)		10									55						55	78			
	66.5	Very dense, dark gray, *Silty Sand (SM)*; moist; fine, angular gravel; fine to coarse sand; nonplastic fines; trace iron oxide staining. (Weathered Bedrock)		11									60						60	50/5"			
				12																			
				13									65						65	86			
				14									70						70	50/3"			

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Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/9/2018 | Total Depth: 120 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary | Logged By: BMC
Finish Date: 7/11/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
	75.0	BASALT: medium strong to strong, gray, porphyritic; slightly to moderately vesicular; slightly rough to rough; close to moderately spaced fractures, few with mineral infilling, few with iron-oxide staining; fresh to slightly weathered. - moderately vesicular from 75 to 81.6 feet.		R-1					17 13 13		-20 -35 -35		80						80	50/2"			
		- moderately vesicular from 87.1 to 90 feet.		R-2 R-3 R-4					19 5 9 13 9 7 15	M, FE CL	-40 0 45 20 50 60 25		85 90						85 90				
	94.3	BASALT BRECCIA: medium strong to strong, gray, porphyritic; slightly to moderately vesicular; slightly rough to rough; close to moderately spaced fractures, few with mineral infilling, few with iron-oxide staining; fresh to slightly weathered.		R-5					15 19 17 15	SS SS SS	-5 25 80 50		95						95				
	99.5																						

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Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/9/2018 | Total Depth: 120 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary | Logged By: BMC
Finish Date: 7/11/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		BASALT: medium strong to strong, gray, porphyritic; slightly to moderately vesicular; slightly rough to rough; close to moderately spaced fractures, few with mineral infilling, few with iron-oxide staining; fresh to slightly weathered.		R-6					17 7 7 7 7 15 5 5 7	FE FE M, FE FE FE FE FE FE	10 -65 -65 -65 -65 -75 -60 -45 -50		105						105	25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80
		- Moderately vesicular from 109 to 114.4 feet.		R-7					9 7 11 9	FE FE M, FE M, FE	-45 -45 60 20 -20		110						110				
				R-8					19 5 9 13 9	M M M	25 15 45 25 -5		115						115				
120.0		BOTTOM OF BORING COMPLETED 7/11/2018		R-9									120						120	25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80

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ROCK_LOG_NOTB 21-21897.GPJ SHAN_WIL.GDT 11/11/18 Logged By: BMC Reviewed By: EAS Typed By: LKN REV 2 - Log in Progress

SHANNON & WILSON, INC.

EXPLORATION LOG OF RNQ-18-302

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/7/2018 | Total Depth: 100.2 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/8/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-302 Material Description	Symbol	Runs
		Silty Gravel with Cobbles (GM) based on drill action. (Fill)		
	3.0	Medium stiff to stiff, red-brown to mottled red and brown, *Fat Clay (CH)*; moist; trace fine to coarse sand; medium to high plasticity fines. (Colluvium)		1
	14.0	Medium dense, mottled red-brown and brown, *Silty with Gravel (ML)*; moist; fine subangular gravel; few fine to coarse sand; low to medium plasticity fines. (Colluvium)		2
	18.0	Very soft to medium stiff, dark gray, *Lean Clay (CL)* to *Silt (ML)*; moist; trace fine gravel; trace fine to coarse sand; low to medium plasticity fines; trace to few organics and wood fragments. (Colluvium)		3
				4

Ground Water

Discontinuity Data: Joint Alteration[3] | Joint Roughness[3] | Q'[3] | JRC[4] | Infilling | Angle | Symbol

Test Data: BST (ksi) | UCS (ksi) | c (psi) | Φ (°) | K (m/s)

SPT (blows/ft) | Recovery (%) | RQD (%)

Strength Index[1] | Weathering Index[1] | Rock Mass Rating (RMR, 1989)[2]

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/7/2018 **Finish Date:** 6/8/2018 **Total Depth:** 100.2 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary & Rock Core **Drill Company:** Holt **Logged By:** EAS **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-302 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
				5																25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80
				6									30						30				
				7									35						35				
				8									40						40				
43.0		Dense, yellow-brown, *Silty Sand (SM)*; moist; trace fine gravel; fine to medium sand; nonplastic to low plasticity fines. (Weathered Bedrock)		9									45						45	50/1"			
47.5		BASALT: weak to medium strong, dark gray, fine grained to phorphyritic; close to widely spaced, smooth to slightly rough, low to high angle fractures, trace with clay infilling, few with mineral infilling, trace slickensides; fresh to slightly		10 R-1		9				CL	-45									25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/7/2018 | Total Depth: 100.2 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/8/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-302 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		weathered.		R-2					11		40												
				R-3					9 3 5 9 5	SS, CL SS, CA CA CA, CL M	25 -10 -20 -70 50		55						55				
				R-4					5 7	CA CA SS, MB	-30 40		65						60				
		- Brecciated from 66.8 to 67.7 feet.		R-5					11 7 7 7 3 5 3 7 5 3 3 5 5 5 3 5 13 11	CL SS, CA SS, CL CA SS, CL, RF SS SS CA	-10 -30 -10 -40 20 -20 -10 60 -30 -20 60 -45 60 -20 -80 -45 70 0		70						65				
				R-6					3 3 5 3 3 5 5 5 3	SS SS, M, RF CL, M, RF CL SS, M, RF RF SS, CL, M CL	-15 0 40 5 -10 40 0 40 -50 85								70				

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/7/2018 | Total Depth: 100.2 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/8/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-302 Material Description
	77.7	SILTSTONE: weak to medium strong, dark gray, fine grained; close to moderatley spaced, smooth to slightly rough, low angle fractures, few with mineral infilling, trace with clay infilling, trace with slickensides; few basalt clasts; fresh to slightly weathered.
		- Few brecciated basalt layers from 86.6 to 87.4 feet.
		- Basalt layer from 88.9 to 89.6 feet.
		- Core from 90 to 95 feet was redrilled after the core fell out of the core barrel during the first recovery attempt causing mechanical breaks throughout the core. Once recovered the core fell out of the core barrel making the orientation of the core unkown.
	95.3	BASALT: medium strong to strong, dark gray, fine grained; slightly vesicular; fresh.
	96.8	BASALTIC BRECCIA: medium strong, gray and dark gray, fine grained basalt clasts in a fine grained siltstone matrix; close to moderately spaced, slightly rough, low angle fractures, trace with clay infilling; fresh.

Symbol: R-7, R-8, R-9, R-10, R-11, R-12

Ground Water

Discontinuity Data						
Depth* (ft)	Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol
80				7			
				1	CL	0	
				1		-20	
				1		-50	
				5	CL	5	
				5		5	
				5		-5	
				3		0	
				3		0	
				3	CA	-10	
				3		-10	
				3		-10	
				3			
				1		20	
				3	CA	20	
				3	CA	20	
				3	CA	20	
				3	SS, M	-50	
				3		0	
85				5			
				11	CA	-20	
				7		-20	
				7		20	
				3	CA	20	
				1		CL	
				3	M	5	
90							
95							
				11	RF	40	
				11	RF	30	
				9	CA, RF	10	
				11	CA, RF	10	
				9	CL, RF	-5	

Test Data					
Depth* (ft)	BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)

▲ SPT (blows/ft)
Recovery (%)
RQD (%)
25 50 75

Strength Index[1]: 1 2 3 4 5

Weathering Index[1]: 1 2 3 4 5

Rock Mass Rating (RMR, 1989)[2]: 20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/7/2018 **Finish Date:** 6/8/2018 **Total Depth:** 100.2 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary & Rock Core **Drill Company:** Holt **Logged By:** EAS **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-302 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%) 25 50 75	Strength Index[1] 1 2 3 4 5	Weathering Index[1] 1 2 3 4 5	Rock Mass Rating (RMR, 1989)[2] 20 40 60 80
	100.2	BOTTOM OF BORING COMPLETED 6/8/2018																					

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuties shown on the boring logs are approximate. For clarity, not all of the discontinuties are shown. * Depth not adjusted for plunge and trend.

SHANNON & WILSON, INC.

EXPLORATION LOG OF RNQ-18-303

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/4/2018 | Total Depth: 100 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/6/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-303 Material Description
	0.3	Topsoil
		Poorly Graded Gravel (GP) based on drill action. (Fill)
	2.0	Stiff to very stiff, red-brown, *Fat Clay (CH)* to *Lean Clay (CL)*; moist; trace fine to medium sand; medium to high plasticity fines. (Colluvium)
	18.0	Stiff to very stiff, mottled red-brown and black, *Silt (ML)* to *Lean Clay (CL)*; moist; low to medium plasticity fines. (Weathered Bedrock)

Symbol | Runs | Ground Water

Discontinuity Data: Depth* (ft) | Joint Alteration[3] | Joint Roughness[3] | Q'[3] | JRC[4] | Infilling | Angle | Symbol

Test Data: Depth* (ft) | BST (ksi) | UCS (ksi) | c (psi) | Φ (°) | K (m/s)

▲ SPT (blows/ft)
Recovery (%)
RQD (%)
25 50 75

Strength Index[1]: 1 2 3 4 5

Weathering Index[1]: 1 2 3 4 5

Rock Mass Rating (RMR, 1989)[2]: 20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

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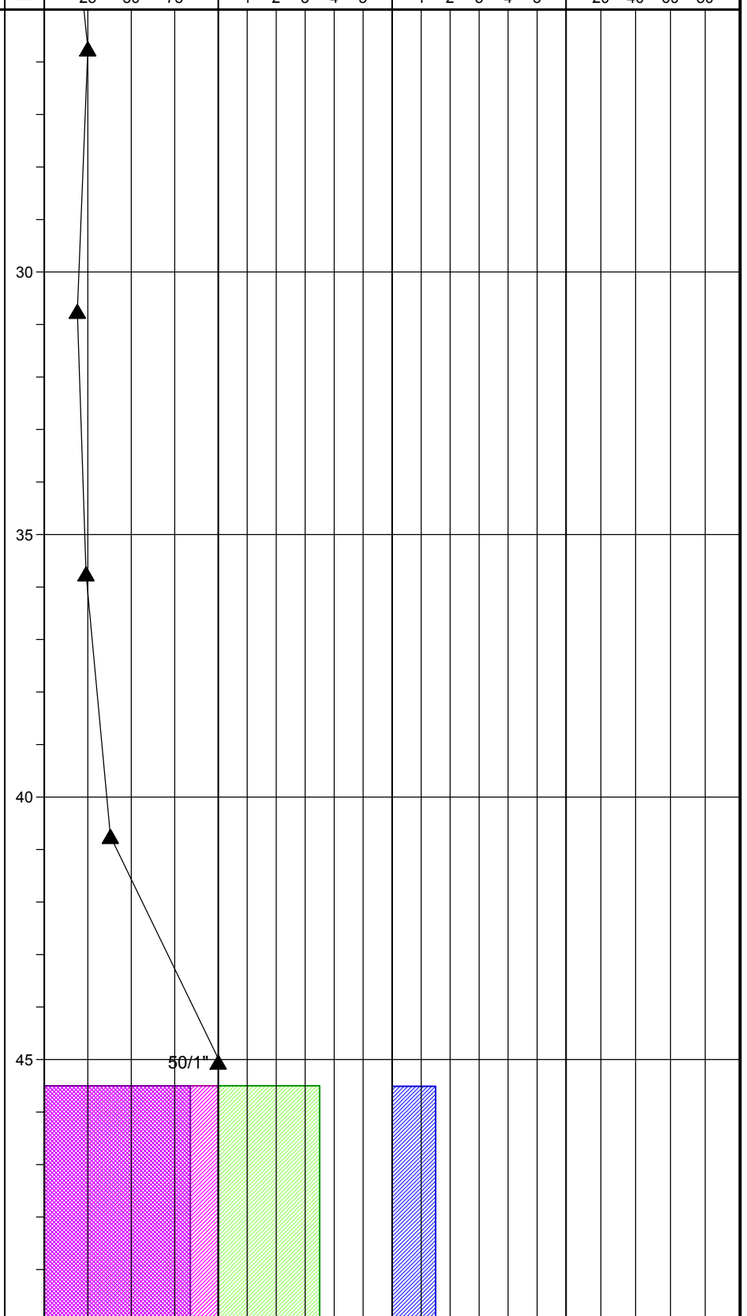
Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/4/2018 | Total Depth: 100 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS

Finish Date: 6/6/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-303 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
		- Trace fine gravel and fine to coarse sand below 40 feet.		5									30					
				6									35					
				7														
				8									40					
45.0		BASALT: weak to strong, dark gray, fine grained to slightly prophyritic; moderate to widely spaced, low to high angle, smooth to slightly rough fractures, trace with clay infilling, trace with calcite or green mineral infilling, trace calcite and quartz veins; slightly vesicular zones; fresh to slightly weathered.		9 R-1		7 9 5 7 11 5 5 5	 FE CL, FE RF CA CA 	5 -10 -10 -20 -20 25 10 20					45					



Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/4/2018 | Total Depth: 100 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/6/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-303 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
		- Slightly brecciated from 57.7 to 63.8 feet.		R-2					11 9	CA CA	30 10							
				R-3					7 5 7 3 7	RF RF MB RF	35 10 -20 40 -10							
				R-4					9	CA	-60							
		- Brecciated from 67.8 to 68.4 feet.		R-5					7 9 15 5 5 5 5 7 5 9 5	CA CL CL, CA	-35 10 -30 -50 15 -5 -40 0 15 -25 -5							
				R-6														
				R-7					9 9 3 3 3	M, FE FE	10 25 50 40 40							

Depth* (ft): 55, 60, 65, 70

SPT (blows/ft) / Recovery (%) / RQD (%): 25 50 75

Strength Index[1]: 1 2 3 4 5

Weathering Index[1]: 1 2 3 4 5

Rock Mass Rating (RMR, 1989)[2]: 20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuties shown on the boring logs are approximate. For clarity, not all of the discontinuties are shown. * Depth not adjusted for plunge and trend.

SHANNON & WILSON, INC.

EXPLORATION LOG OF RNQ-18-303

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/4/2018 | Total Depth: 100 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary & Rock Core | Logged By: EAS
Finish Date: 6/6/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-303 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
				R-8					5	CA, FE	50												
									5	CL	-50												
									3	1mm CA	60												
									5	CL	-50												
									5		-10												
				R-9									80						80				
									9		5												
				R-10									85						85				
									11	CA	-35												
									13		0		90						90				
				R-11					11		-5												
										MB			95						95				
				R-12					7		0												
									7	CA	5												
				R-13					5 9	CL, M, RF	30 -10												

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

EXPLORATION LOG OF RNQ-18-303

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 6/4/2018 **Finish Date:** 6/6/2018 **Total Depth:** 100 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary & Rock Core **Drill Company:** Holt **Logged By:** EAS **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RNQ-18-303 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	▲ SPT (blows/ft) / Recovery (%) / RQD (%) 25 50 75	Strength Index[1] 1 2 3 4 5	Weathering Index[1] 1 2 3 4 5	Rock Mass Rating (RMR, 1989)[2] 20 40 60 80
	100.0	BOTTOM OF BORING COMPLETED 6/6/2018																		25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

SHANNON & WILSON, INC.

EXPLORATION LOG OF RSQ-18-301

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 **Finish Date:** 8/3/2018 **Total Depth:** 180 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary **Drill Company:** Holt **Logged By:** BMC **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water
		Medium stiff, red-brown, *Lean Clay (CL)* to *Silt (ML)*; moist; trace fine sand; low to medium plasticity fines; iron oxide staining. (Colluvium)		1	None Observed During Drilling
	8.0	Medium dense, red-brown, *Silty Sand with Gravel (SM)*; moist; fine, subangular gravel; fine to coarse sand; low plasticity fines; iron oxide staining. (Colluvium)		2	
	13.0	Loose, mottled red-brown and yellow-brown, *Sandy Silt (ML)*; moist; fine to medium sand; low plasticity fines; iron oxide staining. (Weathered Bedrock)		3	
	23.0	Very dense, dark brown and red-brown, *Silty Sand (SM)*; moist; few fine, angular gravel; fine to coarse sand; nonplastic to low plasticity fines; iron oxide staining.		4	

Discontinuity Data

Depth* (ft)	Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol
5							
10							
15							
20							

Test Data

BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)

Depth* (ft)	▲ SPT (blows/ft) / Recovery (%) / RQD (%) (25 50 75)	Strength Index[1] (1 2 3 4 5)	Weathering Index[1] (1 2 3 4 5)	Rock Mass Rating (RMR, 1989)[2] (20 40 60 80)
5				
10				
15				
20				

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 | Finish Date: 8/3/2018 | Total Depth: 180 ft | Top Elevation: ~ | Northing: | Easting: | Vert. Datum: | Horiz. Datum: | Plunge: | Trend: | Drill Method: Mud Rotary | Drill Company: Holt | Logged By: BMC | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
		(Weathered Bedrock)		5														
				6									30					
	32.0	Very dense, black, *Silty Gravel (GM)*; wet; fine to coarse, angular gravel; fractured bedrock. (Weathered Bedrock)																
	35.0	BASALT: weak to very strong with zones of very weak rock, dark gray; fine-grained to porphyritic; slightly rough to rough; very close to moderately spaced fractures with mineral infilling, few with iron-oxide staining, few with slickensides; few siltstone interbeds; fresh to slightly weathered with moderately to highly weathered zones. - Pyrite in fracture at 38.3 feet.		7 R-1 R-2 R-3		9 15 7 7 9 19 11 15 7 13 7 11 11 11 7 15 15 5 19 9 11 15 19 17 15 15 11 9 9 5 5 7 9	M M M, FE SS, M M M M FE M, FE SS, M M M M, FE SS, M SS, M SS, M M M, FE M, FE M M M M, FE CL, M M M M M M, FE M M SS, M M	20 -20 50 25 -20 20 -15 25 -40 15 25 20 -40 15 -40 -20 10 60 -10 60 -20 60 -15 -5 15 35 5 -60 -20 -35 25 -30 45 35	35 40 45						

Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
	25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80
30	50/4"			
35	50/1"			
40				
45				

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

ROCK_LOG_NOTB 21-21897.GPJ SHAN_WIL.GDT 11/11/18 *Logged By: BMC Reviewed By: EAS Typed By: LKN REV 2 - Log in Progress*

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date:	7/25/2018	Total Depth:	180 ft	Northing:		Vert. Datum:		Plunge:	
Finish Date:	8/3/2018	Top Elevation:	~	Easting:		Horiz. Datum:		Trend:	

Drill Method:	Mud Rotary	Logged By:	BMC
Drill Company:	Holt	Hole Diameter:	6 in

BORING RSQ-18-301 Material Description

- Quartz vein between 58.9 to 59 feet.

- Brecciated zone from 73.4 to 73.9 feet.

Runs: R-4, R-5, R-6, R-7, R-8, R-9, R-10

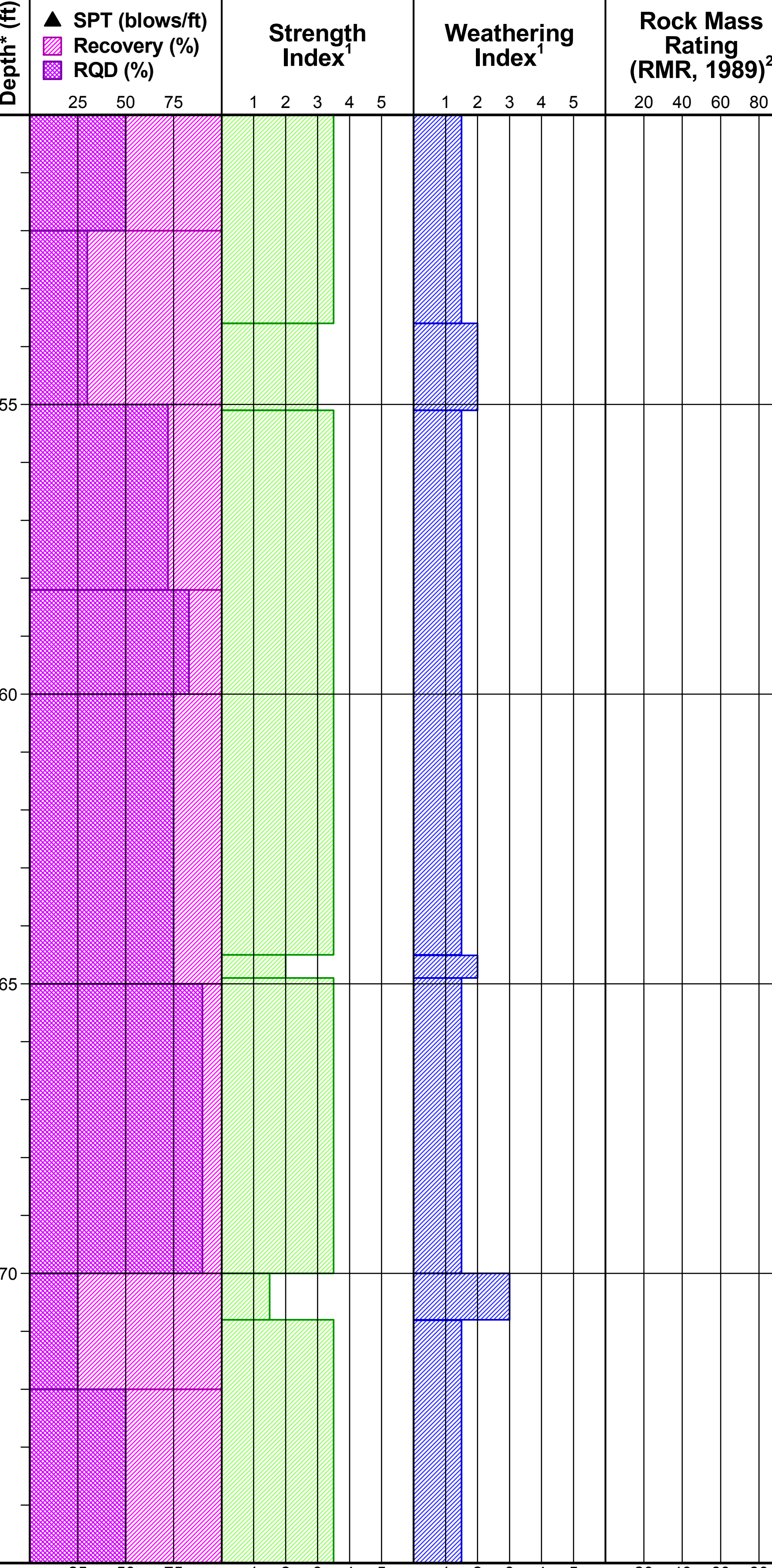
Depth* (ft): 55, 60, 65, 70

Discontinuity Data (Joint Alteration[3], Joint Roughness[3], Q'[3], JRC[4], Infilling, Angle, Symbol)

JRC[4] (top to bottom): 15, 7, 9, 7, 5, 11, 15, 13, 7, 13, 13, 11, 9, 7, 19, 17, 15, 9, 7, 11, 19, 15, 13, 7, 5, 5, 7, 11, 9, 5, 15, 7, 3, 7, 15, 7, 5, 7, 11, 5, 7, 15, 9, 13, 7, 11, 15, 7, 5, 9, 7, 7, 11, 9

Infilling	Angle
SS, M	-40
SS, M	-60
M	50
SS, M	-15
M	-15
SS, M	-15
M	20
M	-5
SS, M	-30
M	10
SS, M	-35
M	-10
SS, M	-45
M	20
M	-45
M	-15
SS, M	-40
SS, M	20
SS, M	-10
M	35
M	45
M	-15
M	-15
M	50
M	-25
M	40
M	-40
M	35
M	-35
SS, M	35
M	30
M	-50
M	-15
M	5
SS, M	35
M	-5
M	-35
SS, M	-40
M	5
M	-5
M, FE	-35
M, FE	-55
M, FE	-30
M, FE	-10
SS, M	-10
M	-5
SS, M	20
SS, M	15
SS, M	50
SS, M	0
M	-20
M	35
SS, M	-65

Test Data: BST (ksi), UCS (ksi), c (psi), Φ (°), K (m/s)



Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuities shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 | Finish Date: 8/3/2018 | Total Depth: 180 ft | Top Elevation: ~ | Northing: | Easting: | Vert. Datum: | Horiz. Datum: | Plunge: | Trend: | Drill Method: Mud Rotary | Drill Company: Holt | Logged By: BMC | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
		- Slightly brecciated from 86.5 to 98 feet.		R-11					9	M	-45							
									7	M	15							
									7	M	-40							
									9	SS, M	-35							
									7	SS, M	-10							
									5	M	-20							
									5	M	20							
									7	SS, M	-55							
									15	M	25							
									7	SS, M	-40							
									5	SS, M	45							
									9	M	-30							
									11	M	25		80					
									15	SS, M	-35							
									5	SS, M	20							
									7	SS, M	-20							
									5	M	-5							
				R-12					9	SS, M	-5							
									5	SS, M	-10							
									5	SS, M	60							
									7	M	-20							
									5	SS, M	-45							
									7	SS, M	-35							
									7	SS, M	25							
									7	M	-35							
									7	M	-35							
									5	M	-30							
									7	M	25							
									7	SS, M	-10							
									7	SS, M	25							
									5	M	10		85					
									5	SS, M	20							
									5	SS, M	10							
									7	SS, M	-30							
									7	M	20							
									7	M	-15							
									5	M	-30							
									11									
									7									
									15	SS, M	20							
									7	M	-40							
									5	SS, M	45							
									19	M	-15							
				R-13					15	SS, M	-15							
									7	SS, M	25							
									11	M	-45							
									11									
									15	SS, M	60							
									15	M	-55		90					
									9									
									11	SS, M	-5							
									5									
									13	SS, M	-15							
									15	SS, M	-50							
									9	M	20							
									15	SS, M	-30							
									5	SS, M	25							
									7	SS, M	-15							
									5	M	15							
									5	SS, M	-25							
									15									
									15	SS, M	25							
				R-14					9	SS, M	20							
									9	M	-50		95					
									9	M	55							
									15	SS, M	-50							
									17	CL, M	5							
									9	SS, M	20							
									15	SS, M	-30							
									5	M	20							
									15	SS, M	15							
									7	M	-30							
									5	SS, M	45							
									11	SS, M	-65							
									7	SS, M	20							
				R-15					11	M	-5							
									15									
									13	M	55							

▲ SPT (blows/ft)
Recovery (%)
RQD (%)
25 50 75

Strength Index[1]: 1 2 3 4 5

Weathering Index[1]: 1 2 3 4 5

Rock Mass Rating (RMR, 1989)[2]: 20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuties shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 | Total Depth: 180 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary | Logged By: BMC
Finish Date: 8/3/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		- Becomes slightly vesicular from approximately 99.2 to 102 feet. - White and black mineral infilling of vesicles from 100 to 102 feet.		R-17					9 11 11 7 5 9 11 5 5 5 7 7 7 7 7	SS, M SS, M M M SS, M SS, M SS, M M SS, M SS, M SS, M SS, M M SS, M M	45 30 -20 30 -25 40 -15 30 5 -25 -30 -15 -35 70 30 -40									
				R-18					7 11	M SS, M	-10 -10		105						105				
				R-19					15 11 11 7 9 5	CL, M SS, M SS, M SS, M SS, M SS, M	-25 -50 15 -5 -25 -20		110						110				
		- Trace vesiculs, infilled with blue-green minerals from 110 to 143.5 feet.		R-20					7 13 19 5 11 7	SS, M M M SS, M SS, M SS, M	25 -15 20 45 -40 0												
				R-21					5 7 7	SS, M SS, M SS, M	20 -45 55		115						115				
				R-22					9 7 5 5 5 3 7 5 9 7	M M SS, M SS, M SS, M SS, M SS, M SS, M SS, M SS, M	-10 35 20 -30 10 -35 -30 60 25 -10												
				R-23					15 17 15 3 15 9 5 17	SS, M M M SS, M SS, M SS, M SS, M M SS, M	30 20 -10 -45 -5 15 -20 -5 -50		120						120				

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Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 | Total Depth: 180 ft | Northing: | Vert. Datum: | Plunge: | Drill Method: Mud Rotary | Logged By: BMC
Finish Date: 8/3/2018 | Top Elevation: ~ | Easting: | Horiz. Datum: | Trend: | Drill Company: Holt | Hole Diameter: 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water
	132.7	BASALT BRECCIA: weak to medium strong, gray with dark gray matrix, fine grained clasts with fine grained matrix; very close to moderately spaced, smooth to rough fractures, with mineral infilling and slickensides; fresh to slightly weathered.		R-24, R-25, R-26, R-27	
	143.7	SILTSTONE: weak, dark gray, fine grained; close, smooth fractures, with mineral and clay infilling, trace with slickensides; fresh to slightly weathered.		R-27	
	145.7	BASALT: strong to very strong with very weak zones, dark gray, fine grained; smooth to rough, very close to widely spaced fractures, few with clay infilling, few with mineral infilling, trace with slickensides; fresh to slightly weathered with moderately weathered zones.		R-28	

Discontinuity Data

Depth* (ft)	Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol
130				9			
				5	SS, M	40	
				15	SS, M	30	
				7	SS, M	-50	
				9	SS, M	5	
				5	SS, M	35	
				9	M	-35	
				5	SS, M	-35	
				7	SS, M	40	
				3	SS, M	-55	
				15	SS, M	-55	
				5	SS, M	-25	
				7	SS, M	-20	
				9	SS, M	20	
				5	SS, M	30	
				9	SS, M	50	
				5	SS, M	-30	
				5	SS, M	-30	
				7	SS, M	-15	
				5	SS, M	25	
				7	SS, M	-20	
				7	M	-25	
				7	M	30	
				5	SS, M	35	
				19	SS, M	-30	
				5	M	10	
				5	M	10	
				9	SS, M	-50	
				11	SS, M	-30	
				17	M	-10	
				11	M	-35	
135				5	SS, M	-30	
				15	SS, M	30	
				15	M	-10	
				5	SS, M	25	
				9	SS, M	20	
				9	SS, M	-15	
				3	SS, M	-25	
				3	M	15	
				5	SS, M	-35	
				3	SS, M	10	
				5	SS, M	-5	
				3	SS, M	20	
140				5	SS, M	10	
				3	SS, M	-35	
				9	SS, M	20	
				15	SS, M	30	
				5	SS, M	-30	
				9	SS, M	-30	
				11	M, FE	-15	
				5	FE	-35	
				15	M, FE	15	
				15	SS, M		
				3	CL, M	10	
				9	M	-30	
				5	M	10	
				5	CL, M	10	
				5	M	10	
145				5	SS	10	
				7	CL	-15	
				7	CL	-10	
				9	M	-15	
				9	SS, M	-10	
				15	SS, M	-35	
				9	FE	-50	
				15	FE	-35	
				9		-45	
				15	FE	-25	
				19		-30	
				15	SS, M	55	
				11	M	-60	
				9			
				7			

Test Data

Depth* (ft)	BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)
130					
135					
140					
145					

▲ SPT (blows/ft)
Recovery (%)
RQD (%)
25 50 75

Strength Index[1]
1 2 3 4 5

Weathering Index[1]
1 2 3 4 5

Rock Mass Rating (RMR, 1989)[2]
20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuties shown on the boring logs are approximate. For clarity, not all of the discontinuities are shown. * Depth not adjusted for plunge and trend.

ROCK_LOG_NOTB 21-21897.GPJ SHAN_WIL.GDT 11/11/18 *Logged By: BMC Reviewed By: EAS Typed By: LKN REV 2 - Log in Progress*

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 **Finish Date:** 8/3/2018 **Total Depth:** 180 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary **Drill Company:** Holt **Logged By:** BMC **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		- Siltstone clast from 150.3 to 150.7 feet. - Few siltstone interbeds from 150.7 to 151.7 feet. - Trace quartz veins below 151.7 feet.		R-29					9	M	5									25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80
									9 11	M M	10 15		155						155			
				R-30					11	M	5												
													160						160			
		- 0.1-foot-thick siltstone interbed at 165.9 feet. - Siltstone, quartz and green mineralization from 167.2 to 167.4 feet. - Siltstone from 168.3 to 168.4 feet.		R-31					5 9	SS, M M	25 -5		165						165			
				R-32					5	M	-15												
									11	M	10		170						170			
		- Siltstone clast along the edge of core from 171.9 to 172.4 feet. - Below 174 feet becomes core lighter gray and slightly vesicular with few siltstone clasts.		R-33																			

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SHANNON & WILSON, INC.

EXPLORATION LOG OF RSQ-18-301

Chehalis Dam
Phase 2 Site Characterization
Technical Memorandum

Start Date: 7/25/2018 **Finish Date:** 8/3/2018 **Total Depth:** 180 ft **Top Elevation:** ~ **Northing:** **Easting:** **Vert. Datum:** **Horiz. Datum:** **Plunge:** **Trend:** **Drill Method:** Mud Rotary **Drill Company:** Holt **Logged By:** BMC **Hole Diameter:** 6 in

Elev. (ft)	Depth* (ft)	BORING RSQ-18-301 Material Description	Symbol	Runs	Ground Water	Discontinuity Data: Joint Alteration[3]	Joint Roughness[3]	Q'[3]	JRC[4]	Infilling	Angle	Symbol	Depth* (ft)	Test Data: BST (ksi)	UCS (ksi)	c (psi)	Φ (°)	K (m/s)	Depth* (ft)	SPT (blows/ft) / Recovery (%) / RQD (%)	Strength Index[1]	Weathering Index[1]	Rock Mass Rating (RMR, 1989)[2]
		- Becomes moderately vesicular at 176.6 feet.		R-34					7	SS, M	-55												
									7	SS, M	65												
									7	M	-60												
	180.0	BOTTOM OF BORING COMPLETED 8/3/2018											180						180	25 50 75	1 2 3 4 5	1 2 3 4 5	20 40 60 80

Notes: Contact depths are approximate and transitions may be gradual. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials. The locations of the discontinuties shown on the boring logs are approximate. For clarity, not all of the discontinuties are shown. * Depth not adjusted for plunge and trend.