BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

BRIARWOOD BRIDGE

GEOTECHNICAL SITE CHARACTERIZATION

MARCH 2023

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GEOTECHNICAL SITE CHARACTERIZATION

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

REPORT

PROJECT NO.: 20M-01141-06
DATE: MARCH 2023

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March 20, 2023

BC Ministry of Transportation and Infrastructure
3rd Floor - 2100 Labieux Road
Nanaimo, BC

Attention: **Ryan Gustafson, P.Eng.**

Subject: **Briarwood Bridge No. 10427 - Geotechnical Site Characterization**
Client ref.: 18003-2023

Dear sir,

WSP Canada Inc. (WSP) have prepared this geotechnical site characterization report for the BC Ministry of Transportation and Infrastructure (MoTI) for the proposed Briarwood Bridge near Mill Bay, BC. This information is intended to be used for information in support of the tendering process for this bridge.

If you have any comments or questions, please contact the undersigned at your convenience.

Yours sincerely,

Don Kaluza, P.Eng.
Senior Project Geotechnical Engineer

WSP ref.: 20M-01141-06

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2023-03-20

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2023-03-20

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TABLE OF CONTENTS

TABLES

APPENDICES

1 EXECUTIVE SUMMARY

In November 2021 an unprecedented rainfall event occurred in southern British Columbia that affected infrastructure across the province. On Briarwood Drive, near Mill Bay, this event washed out a culverted road crossing over Hollings Creek that temporarily isolated a small residential community. Following this washout, the MoTI installed a temporary bridge across Hollings Creek and requested WSP to review and assess the stability of the temporary bridge crossing and to provide recommendations for additional protection if required. WSP's assignment included a geotechnical assessment that included drilling at each bank, laboratory testing, and a review of the temporary stability of the bridge crossing. The results of the assessment determined that riprap armouring would be required to increase the temporary stability and the MoTI's contractor subsequently added riprap at each abutment of the temporary bridge.

WSP was also tasked to provide options for the permanent road crossing that resulted in adopting a shallow foundation geosynthetically reinforced soil integrated bridge system (GRS-IBS). WSP subsequently carried the GRS-IBS to detailed design. This geotechnical site characterization report is intended to be used in support of the tender package for the new GRS-IBS bridge.

2 TERMS OF REFERENCE

This geotechnical report is a factual document that is to be used as reference during the tendering of the Briarwood Bridge. This document follows the MoTI guidelines for geotechnical reports[2] but being factual in nature does not provide the results of detailed analyses and recommendations.

3 BACKGROUND INFORMATION

The project site is located at the Briarwood Drive crossing of Hollings Creek between Shawnigan Lake and Mill Bay on Vancouver Island, BC (Appendix A - Figure 1).

During the week of November 14th, 2021, an unprecedented amount of rain fell within southwestern BC resulting in significant flood damage. A washout occurred at the Briarwood Drive crossing of Hollings Creek which completely severed vehicle access to the residents along Briarwood Drive. Prior to this washout, the crossing of Briarwood Drive over Hollings Creek was accommodated with three (3) round 1.2m diameter CSP culverts and the MoTI was in the planning process for replacement of these culverts.

Upon notification of the washout, MoTI engaged their road maintenance contractor to install a temporary structure to restore access. A temporary bridge was installed, and vehicle access was reinstated on November 15th/16th, 2021. The temporary structure that was installed at this site is referred to as an all-steel portable bridge and is commonly used in the resource industry on forest access roads.

On November 22nd MoTI requested support from WSP to assess the temporary structure and to provide recommendations for additional protection, where required. In our first phase of work on the project, WSP was engaged to complete an assessment of the temporary structure accounting for structural, hydrotechnical, and geotechnical considerations, ensuring that the current structure could remain in place until a permanent replacement is constructed. In the second phase of work, WSP undertook an options study for the permanent structure, in which a shallow bridge foundation was agreed upon using GRS-IBS methodology. This geotechnical site characterization

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[2] MoTI Technical Bulletin No GM9801, Turgut Ersoy, Ph.D., P.Eng. Guidelines for Geotechnical Reports, 30 March 1998.

report is based on information obtained during the first phase of the project and also forms part of design of the permanent structure.

Representative site photos are included in Appendix B.

3.1 SURFICIAL GEOLOGY

Surficial Geology Map 15-1965[3] notes that the site location is in an area of Marine Deposits, including Glacio-Marine consisting of silt, clay, stony clay, and till-like mixtures up to 75 ft. (22.9m).

4 SITE CHARACTERIZATION

4.1 SURFACE CONDITIONS

In general, Briarwood Road is a two-lane asphalt surfaced road that slopes down towards Hollings Creek from Shawnigan Lake Road with a surface gradient of up to 10% and slopes back up from the creek at about 7% heading east away from the creek. Roadside ditches were present on both sides of the road west of Hollings Creek, and on the south side of the road immediately east of the creek.

The width of the stream between the banks of Hollings Creek was about 12.5m at the road crossing after the failure. The observed exposed soils within the west bank consisted of sand and gravel fill over sand bedding and culvert backfill. The exposed soils observed within the east bank consisted of sand and gravel fill over glacial till. The stream bed was observed to consist of rounded gravel, cobbles, and small boulders.

4.2 DRILLING PROGRAM

WSP coordinated and logged the ground conditions in a drilling program that was carried out by Drillwell Enterprises Ltd. at the Briarwood Road site on 21 December 2021. Prior to drilling, WSP submitted a BC 1 Call and the area was cleared of known buried services by a private utility locator. On the day of drilling, traffic control services were provided to safely direct traffic around the drilling equipment.

Two boreholes were advanced using solid stem augers with Standard Penetration Testing (SPT) conducted every 0.75m in the upper 3.0m, and every 1.5m below that to a depth of auger refusal. Field vanes were attempted, but the encountered soils were determined to be too stiff for the equipment to take a reading without damaging the equipment. Pocket penetrometer tests were performed on recovered samples to get a sense of the unconfined compressive strength, where applicable. The site and borehole locations are shown on Figure 1.

Details of the encountered subsurface conditions are presented on the borehole logs in Appendix C. In general, the encountered conditions are indicative of the published surficial geology map. The following provides a general description of the ground conditions in summary of the logs.

---

[3] Surficial Geology – Shawnigan, Map 15-1965, Paper 65-24

NW BANK SLOPE (BH21-01)

- Sand and Gravel FILL (0 to 0.2m depth); over
- Silty SAND and GRAVEL (0.2 to 1.0m depth); over
- Inorganic stiff sandy CLAY that transitioned to inorganic very stiff Clay of medium plasticity (1.0 to 6.0m depth); over
- Very dense to hard silty Sand and Gravel (6.0m to auger refusal at 7.2m).

Loose sand was observed in the NW bank slope on an earlier site visit. However, upon further review it was determined to be isolated and likely backfill that was part of the former culvert installation.

SE BANK SLOPE (BH21-02)

- Sand and Gravel FILL (0 to 0.7m depth); over
- Stiff silty clay FILL (0.7 to 1.5m depth); over
- Loose, transitioning to dense SAND and GRAVEL (1.5 to 3.0m depth); over
- Very dense to hard silty Sand and Gravel (3.0m to auger refusal at 5.7m).

A cross-section showing the borehole logs and the observed exposed soil conditions is shown on Figure 2. Note that the elevations shown on Figure 2 are relative only and are based on an assumed Temporary Benchmark (TMB) elevation of 100.00m. The TBM was a nail placed at the base of a Hydro pole located on the north side of the road, east of the temporary bridge crossing.

4.3 SHEAR WAVE VELOCITIES

Shear wave velocities (Vs) of the soils in the vicinity of boreholes BH21-01 and BH21-02 at the northwest and southeast abutments were estimated using WSP's Tromino Micro Tremor. The results are presented in Appendix D. The following tables provide a summary of the measurements which were estimated using the material boundaries recorded in the adjacent boreholes.

Table 1 INTERPRETED SHEAR WAVE VELOCITIES – NORTHWEST ABUTMENT

LAYER (M)	THICKNESS (M)	SHEAR WAVE VELOCITY (M/S)	POISSON RATIO	MATERIAL
0 to 0.7	0.7	110	0.45	Sand and gravel
0.7 to 6.0	5.3	235	0.42	Stiff silty clay
6.0 to 12.0	6.0	350	0.42	Glacial till
12 to Inf.	inf	520	0.42	To be determined

Table 2 INTERPRETED SHEAR WAVE VELOCITIES – SOUTHEAST ABUTMENT

LAYER (M)	THICKNESS (M)	SHEAR WAVE VELOCITY (M/S)	POISSON RATIO	MATERIAL
0 to 3.0	3.0	172	0.45	Sand and gravel
3.0 to 12.0	9.0	416	0.42	Glacial till
12.0 to 17.0	5.0	510	0.42	To be determined
17 to Inf.	inf	640	0.42	To be determined

5 LABORATORY TESTING

Laboratory testing comprised of moisture content determination, Atterberg Limits, aggregate gradation analysis, and direct shear testing on representative samples. From a slope stability modelling point of view, it was determined that the soils from the NW slope were more critical to carry out direct shear testing as the observed relative density of these soils appeared to be lower as compared to the exposed dense glacial soils that were observed on the SE side.

The results of the laboratory testing are shown graphically in Appendix E and summarized in the tables below.

Table 3 RESULTS OF AGGREGATE GRADATION ANALSYES

BH #	DEPTH (M)	% GRAVEL	% SAND	% FINES*
BH21-01	1.3	39.4	25.2	35.4
BH21-01	2.8	2.5	33.7	63.8
BH21-02	2.0	28.8	40.5	30.7
BH21-02	4.0	28.2	47.0	24.8

*Includes silt and clay sized particles

Table 4 - RESULTS OF ATTERBERG LIMITS

BH #	DEPTH (M)	% GRAVEL	% SAND	% FINES*	SOIL TYPE
BH21-01	4.2	15	43	25.2	Sandy Lean Clay

Table 5 - DIRECT SHEAR TESTING (DRAINED CONDITION)

BH21-01 SAMPLED AT 1.0M DEPTH						
NORMAL STRESS (KPA)	PEAK STRENGTH (KPA)	AVG. MOB PHI (DEG)	AVG. PEAK COHESION	RESIDUAL STRENGTH (KPA)	AVG. MOB PHI RESIDUAL (DEG)	AVG. RESIDUAL COHESION (KPA)
50	74	35.7	37.4	54	45.9	5.0
100	108	35.7	37.4	100	45.9	5.0
150	146	35.7	37.4	151	45.9	5.0
50	74	35.7	37.4	54	45.9	5.0

Table 6 - DIRECT SHEAR TESTING (DRAINED CONDITION)

BH21-01 SAMPLED AT 3.0M DEPTH						
NORMAL STRESS (KPA)	PEAK STRENGTH (KPA)	AVG. MOB PHI (DEG)	AVG. PEAK COHESION	RESIDUAL STRENGTH (KPA)	AVG. MOB PHI RESIDUAL (DEG)	AVG. RESIDUAL COHESION (KPA)
50	98	24.2	78.4	49	33.0	17.4
100	129	24.2	78.4	84	33.0	17.4
150	143	24.2	78.4	114	33.0	17.4
50	98	24.2	78.4	49	33.0	17.4

6 TEMPORARY REPAIR CONDITION

Upon completion of the drilling and laboratory testing, WSP completed a stability analysis to review the short-term stability of the temporary repair condition. To increase the stability, the MoTI’s contractor removed loose soils from the exposed creek banks, added a non-woven geotextile and placed riprap in the area of the temporary bridge crossing. The placed riprap ranged from about 1.5m at the toe to about 0.3m at the top.

7 CONCLUSIONS

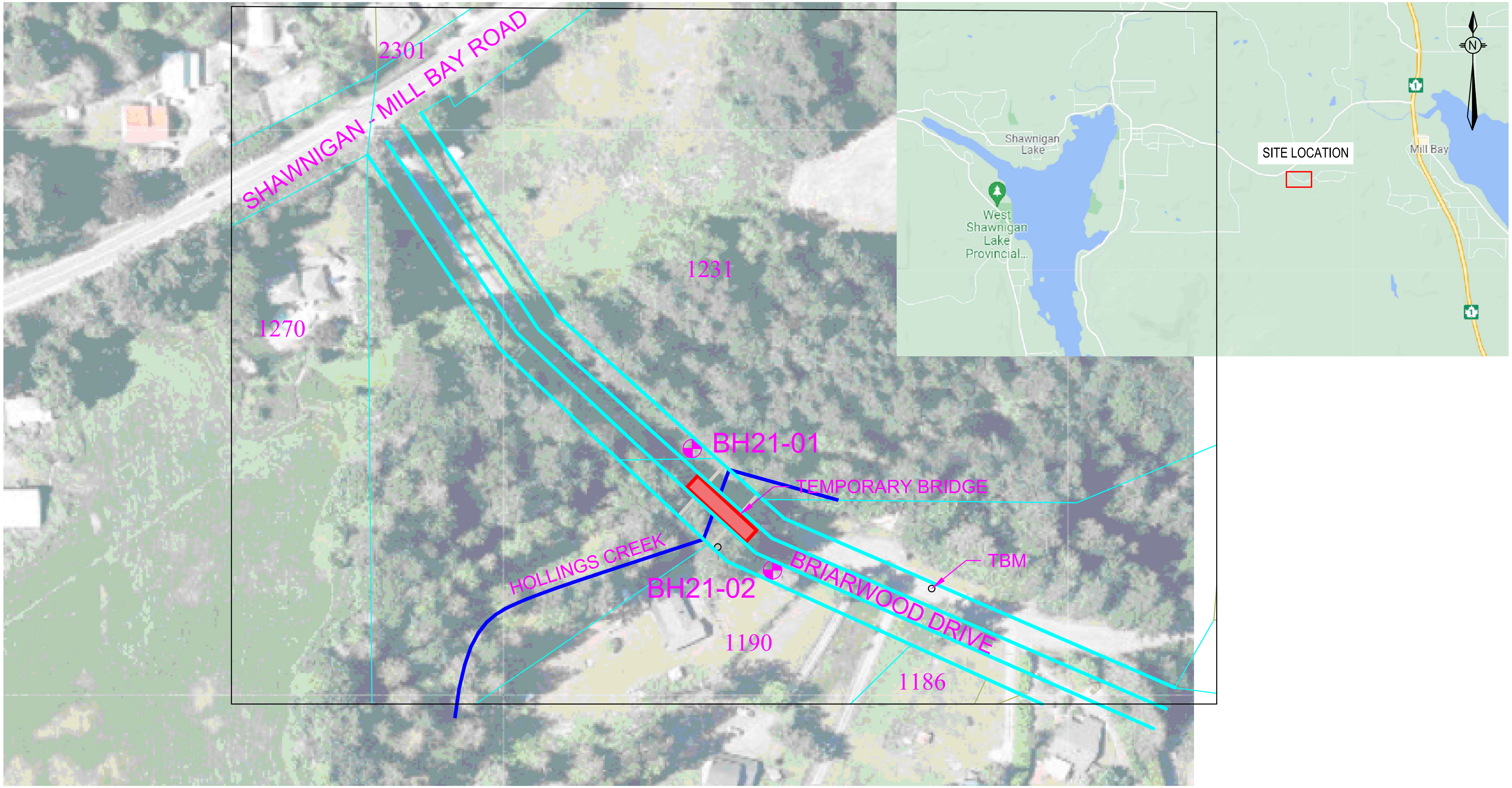
The encountered ground conditions, which generally match the conditions within published surficial geology maps, have led to the approved design of a shallow foundation GRS-IBS bridge along Briarwood Drive. WSP’s geotechnical design was based on these ground conditions and WSP is to be notified if there is an observed divergence from these conditions.

8 LIMITATIONS

This report has been prepared in accordance with the terms of our contract with the MoTI on this project and the Standard Limitations included in Appendix F.

APPENDIX

A FIGURES



◕ APPROXIMATE BOREHOLE LOCATION

BASE MAP OBTAINED FROM IMAP BC ON 2021-12-02 VIA https://maps.gov.bc.ca/ess/hm/imap4m/

DISCLAIMER:

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REVISION:

REV	DATE	DESCRIPTION	BY
0A	2023-03-13	ISSUED FOR TENDER	DK

3600 Uptown Blvd, Victoria, BC, V8Z 0B9
www.wsp.com

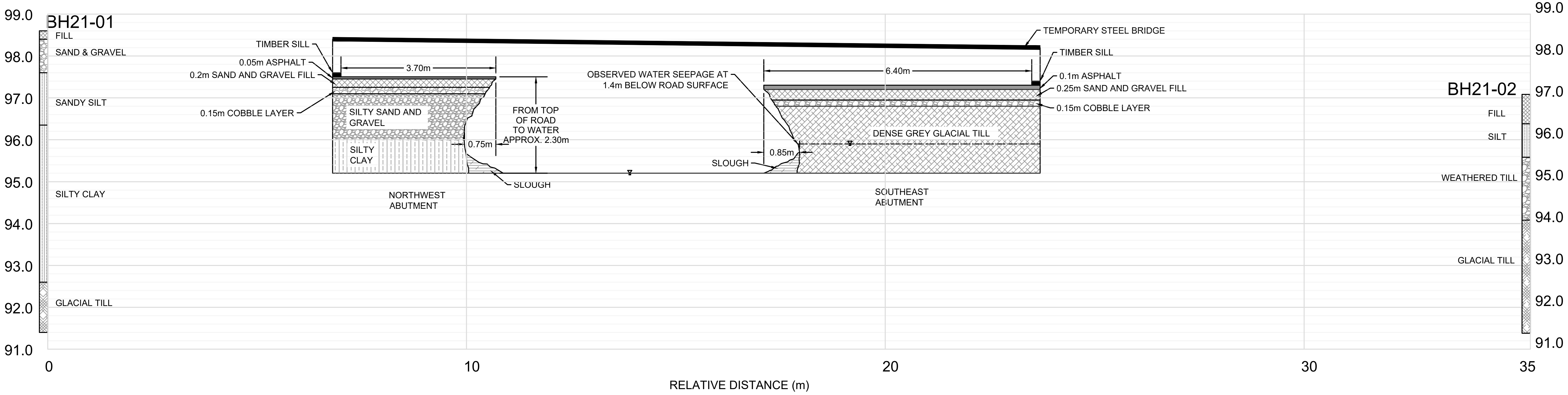
PROJECT NO: 20M-01141-06

SCALE: NTS
DATE: 13 March 2023
DESIGNED BY: DK
DRAWN BY: LL
CHECKED BY: RS

PROJECT: BRIARWOOD DRIVE
CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCURE
TITLE: SITE LOCATION PLAN
DRAWING: 01

L:_GEO\Projects\2021\211-13329-01_Briarwood_Drive\14 Tech & Prof Services\14.02 Subfolder per discipline\Permanent Solution\100% Design\CAD\BRIARWOOD DRIVE.dwg Mar 10, 2023-10:53am BY:(Donald.Kaluza)

ANSI B-REPORT VERSION 1.0



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ANSI B-REPORT VERSION 1.0

NOTES:

1. THE ELEVATIONS SHOWN ARE BASED ON A TEMPORARY BENCHMARK (TBM) AND BASED ON AN ASSUMED ELEVATION OF 100.00m AND NOT GEODETIC. THE TBM IS A NAIL IN THE BASE OF A HYDRO POLE THAT IS LOCATED ON THE NORTH SIDE OF BRIARWOOD, EAST OF THE CREEK.

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REVISION:

0A	2023-03-13	ISSUED FOR TENDER	DK
REV	DATE	DESCRIPTION	BY

3600 Uptown Blvd, Victoria, BC, V8Z 0B9
www.wsp.com

PROJECT NO: 20M-01141-06

SCALE: NTS
DATE: 13 March 2023
DESIGNED BY: DK
DRAWN BY: LL
CHECKED BY: RS

PROJECT: BRIARWOOD DRIVE
CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCURE
TITLE: SLOPE CONDITIONS WITH BOREHOLES
DRAWING: 02

APPENDIX

B SITE PHOTOS

Briarwood Photo Table

Photo	Description
	Photo: 1 Google Earth image looking east towards Hollings Creek (2014)
	Photo: 2 Google Earth image looking west towards Hollings Creek (2014)

Photo 3: West creek bank following washout Nov 2021

Photo 4: East creek bank following washout Nov 2021

Photo 5: Sloughed soils at west creek bank (30 Nov 2021)

Photo 6: Fill and glaciated soils at east creek bank (30 Nov 2021)

Photo 7: Creek bed conditions (Jan 2023)

Photo: 8 Temporary repair condition looking towards the west bank (Jan 2023)

Photo: 9 Temporary repair condition looking towards the east bank.

APPENDIX

C

BOREHOLE LOGS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

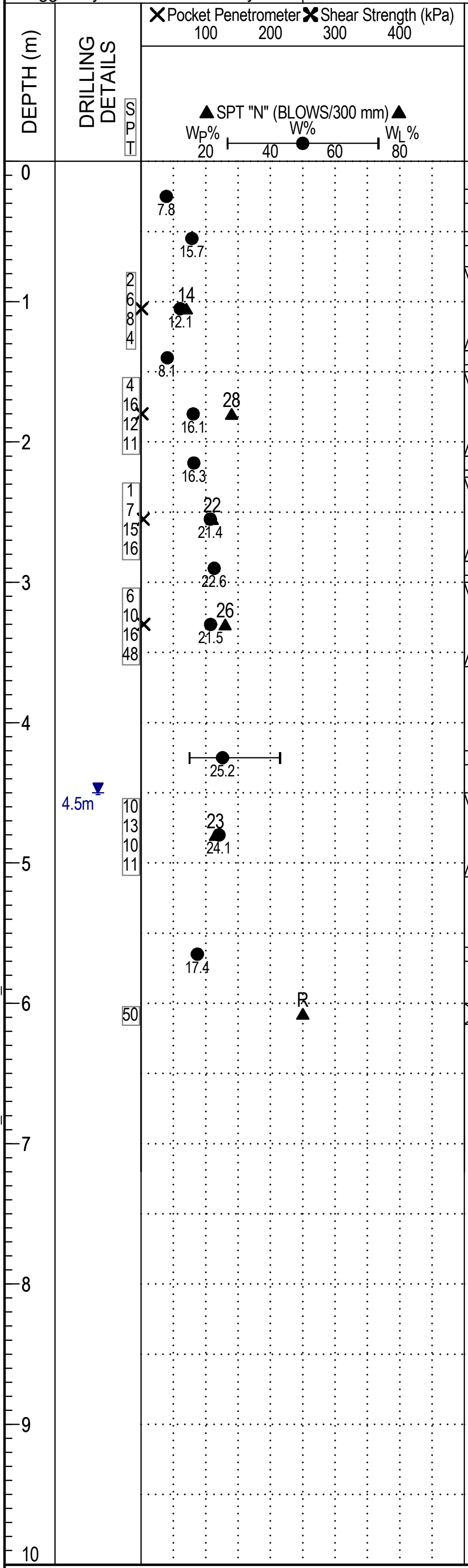
Drill Hole #: BH21-01

Project: **Briarwood Drive - Temporary Repair**
Location: Shawnigan Lake, BC

Prepared by: 20M-01141-06
WSP Canada Inc
Logged by: AB Reviewed by:

Datum: Geodetic
Northing/Easting: 46.6464 , -123.587
Elevation:
Alignment:
Station/Offset:

Date(s) Drilled: 2021-12-21
Company: Drillwell Enterprises
Driller:
Drill Make/Model:
Drilling Method: Solid Stem Auger



DEPTH (m)	SOIL DESCRIPTION	CLASSIFICATION
0.2m	Brown Sand and Gravel FILL, non plastic, moist, trace silt and rootlets. Gravel is subrounded to rounded	
1.0m	Brown silty SAND AND GRAVEL, medium plasticity, moist	
2.25m	Light brown stiff silty CLAY, some sand, trace gravel, low plasticity, moist. Gravel is subrounded to subangular ... becoming increasingly silty	
6.0m	Stiff to very stiff light brownish grey silty CLAY, tace sand, moist ... becoming grey	
7.2m	Grey Sand and Gravel TILL, trace cobbles, moist	
	Borehole terminated on assumed bedrock at 7.2m Borehole terminated on refusal in assumed dense glacial till / bedrock	

SAMPLE NO	RECOVERY (%)	COMMENTS TESTING Drillers Estimate *{G % S % F %}*
GS1		*{G:15 S:80 F:5}*
GS2		*{G:10 S:40 F:50}*
SPT1	83	*{G:10 S:40 F:50}*
GS3		*{G:10 S:40 F:50}*
SPT2	75	*{G:5 S:15 F:80}*
GS4		*{G:5 S:15 F:80}*
SPT3	100	*{G:0 S:10 F:90}*
GS5		*{G:0 S:10 F:90}*
SPT4	100	*{G:0 S:5 F:95}*
GS6		**Atterberg** (Sa#GS6): PL:15% LL:43% *{G:0 S:5 F:95}*
SPT5	75	*{G:0 S:5 F:95}*
GS7		*{G:0 S:5 F:95}*
SPT6	10	*{G:0 S:5 F:95}*

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 7.2 m
Depth to Top of Rock:

SUMMARY LOG

Drill Hole #: BH21-02

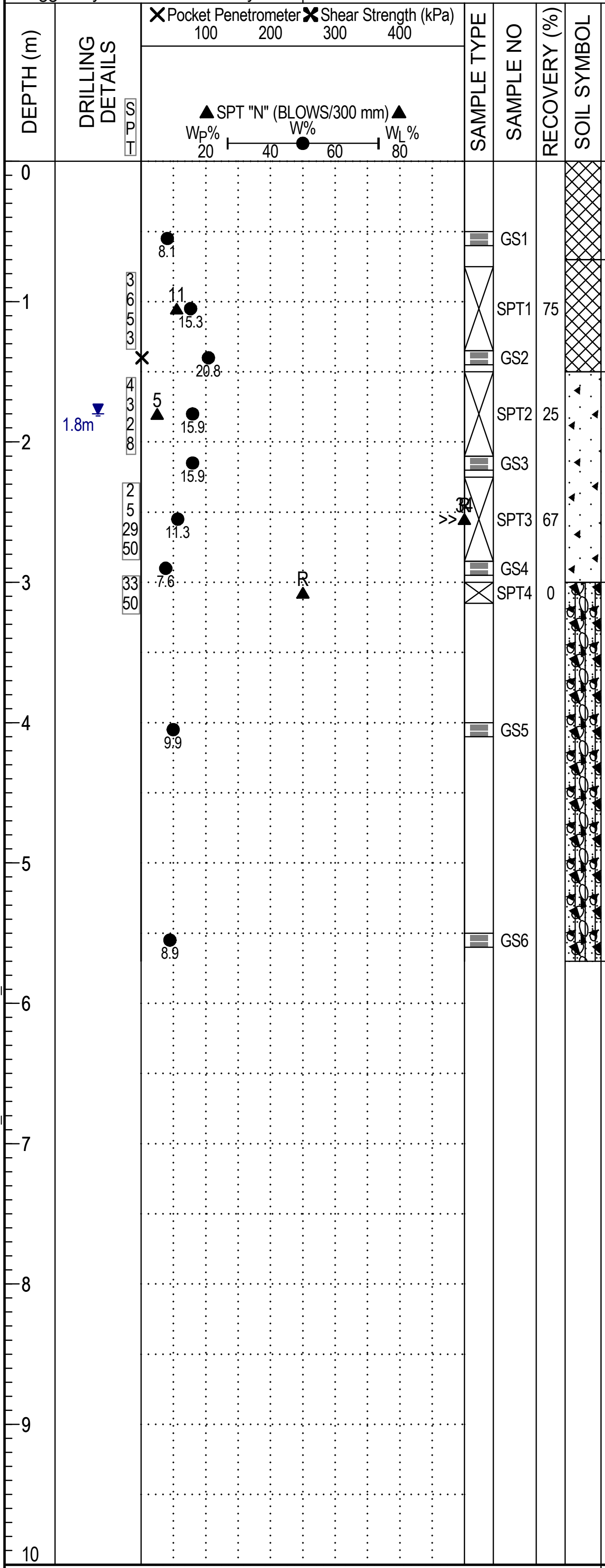
Project: **Briarwood Drive - Temporary Repair**
Location: Shawnigan Lake, BC

Prepared by: 20M-01141-06
WSP Canada Inc

Logged by: AB Reviewed by:

Datum: Geodetic
Northing/Easting: 46.6466 , -123.588
Elevation:
Alignment:
Station/Offset:

Date(s) Drilled: 2021-12-21
Company: Drillwell Enterprises
Driller:
Drill Make/Model:
Drilling Method: Solid Stem Auger



DEPTH (m)	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*
0	Brown silty Sand and Gravel FILL, trace silt, non plastic, moist ... trace organics in upper 0.3m		*{G:20 S:75 F:5}*
0.7m	Brownish grey FILL, trace gravel, trace sand, moist		*{G:10 S:10 F:80}* *{G:10 S:10 F:80}*
1.5m	Brown silty SAND AND GRAVEL, low plasticity, trace cobbles, moist		*{G:30 S:45 F:25}* *{G:30 S:45 F:25}* *{G:30 S:45 F:25}* *{G:30 S:45 F:25}*
3.0m	Grey Sand and Gravel TILL, trace silt, trace cobbles, moist		*{G:45 S:45 F:10}* *{G:45 S:45 F:10}* *{G:45 S:45 F:10}*
5.7m	Borehole terminated on refusal in assumed dense glacial till / bedrock		

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 5.7 m
Depth to Top of Rock:

APPENDIX

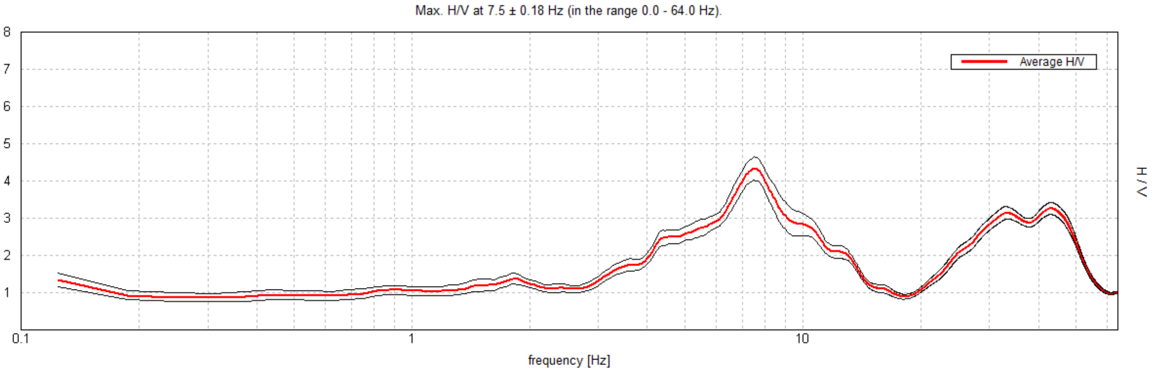
D VS ANALYSIS

BRIARWOOD DR, NW ABUTMENT

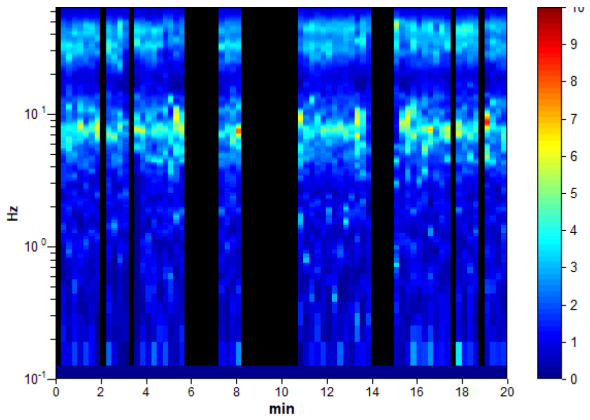
Instrument: TEB-0626/01-21
Data format: 16 bit
Full scale [mV]: 179
Start recording: 21/12/2021 12:13:15 End recording: 21/12/2021 12:33:15
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00''. Analyzed 69% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 15 s
Smoothing type: Triangular window
Smoothing: 10%

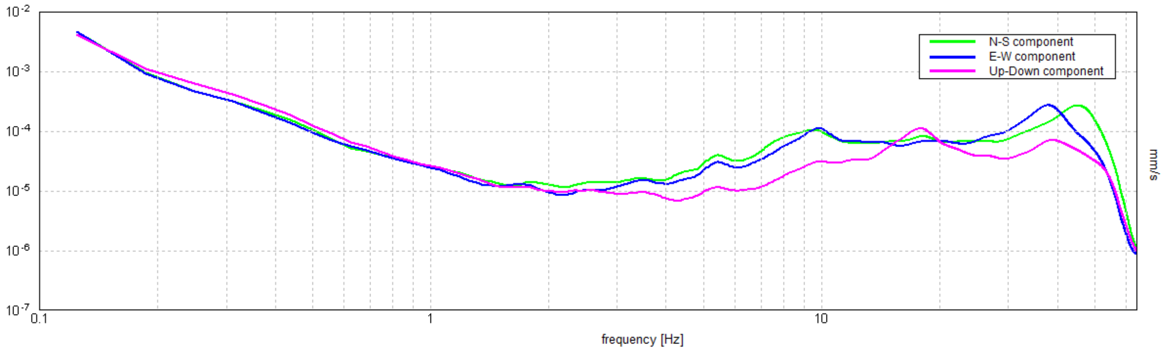
HORIZONTAL TO VERTICAL SPECTRAL RATIO



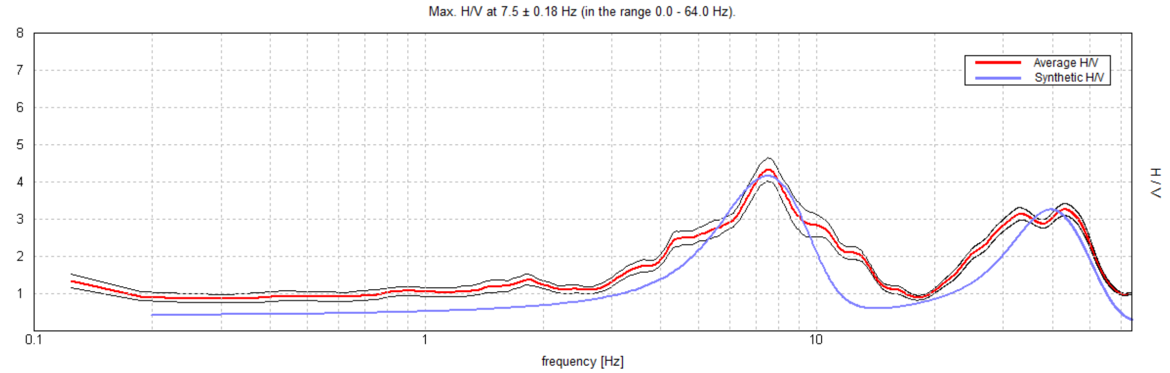
H/V TIME HISTORY



SINGLE COMPONENT SPECTRA

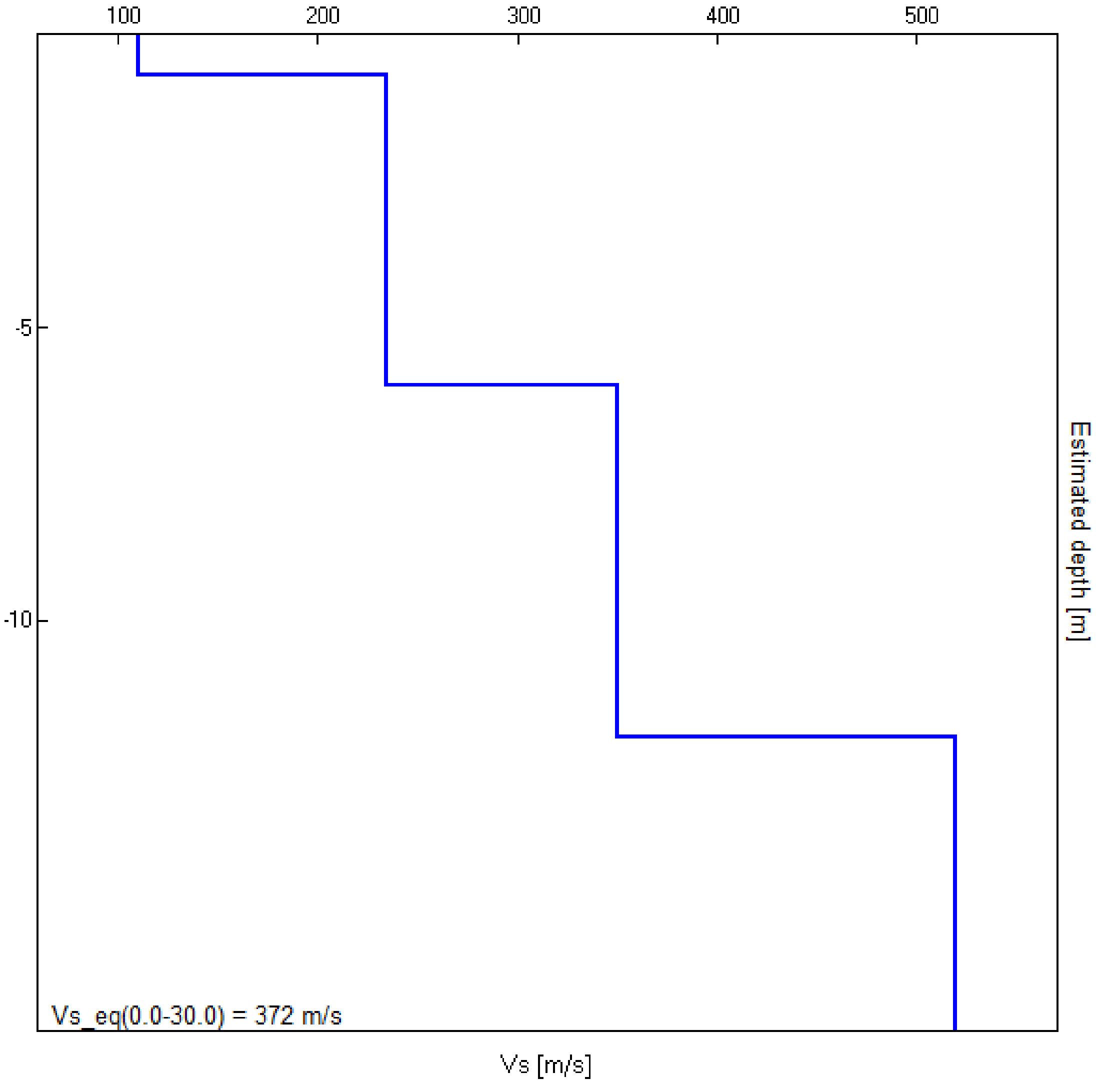


EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
0.70	0.70	110	0.45
6.00	5.30	235	0.42
12.00	6.00	350	0.42
inf.	inf.	520	0.42

Vs_eq(0.0-30.0) = 372 m/s


100
200
300
400
500
-5
-10
Estimated depth [m]
Vs_eq(0.0-30.0) = 372 m/s
Vs [m/s]

[According to the SESAME, 2005 guidelines. **Please read carefully the *Grilla* manual before interpreting the following tables**.]

Max. H/V at 7.5 ± 0.18 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

$f_0 > 10 / L_w$	7.50 > 0.67	OK	
$n_c(f_0) > 200$	6187.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 181 times	OK	

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	4.125 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	11.688 Hz	OK	
$A_0 > 2$	4.33 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02415| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.18114 < 0.375	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.3151 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$

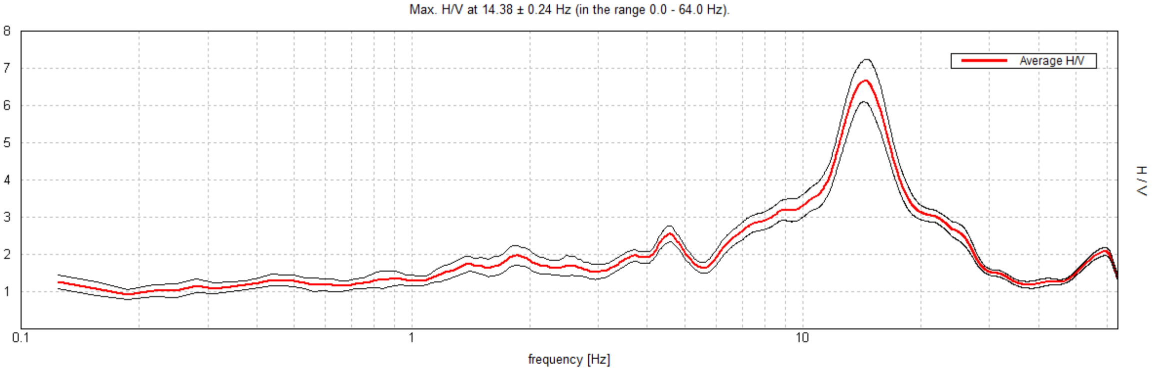
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

BRIARWOOD DR, SE ABUTMENT

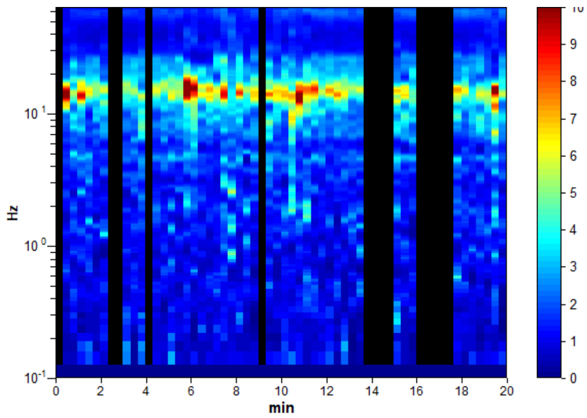
Instrument: TEB-0626/01-21
Data format: 16 bit
Full scale [mV]: 179
Start recording: 21/12/2021 11:11:19 End recording: 21/12/2021 11:31:19
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00''. Analyzed 77% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

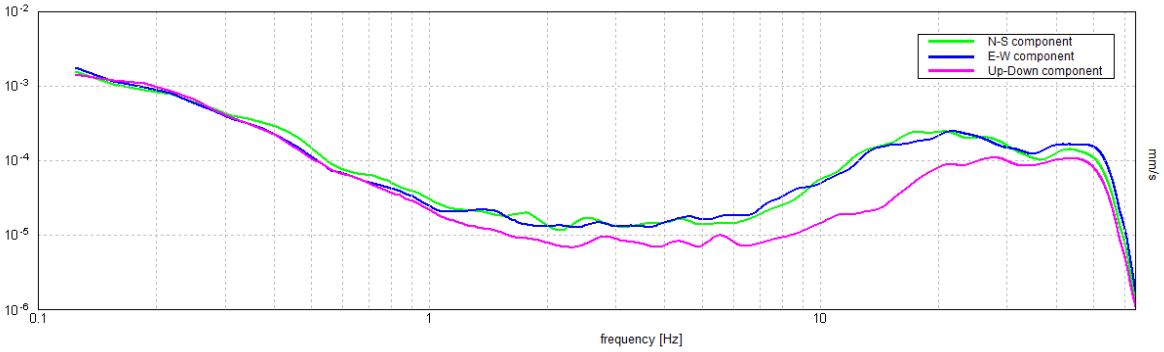
HORIZONTAL TO VERTICAL SPECTRAL RATIO



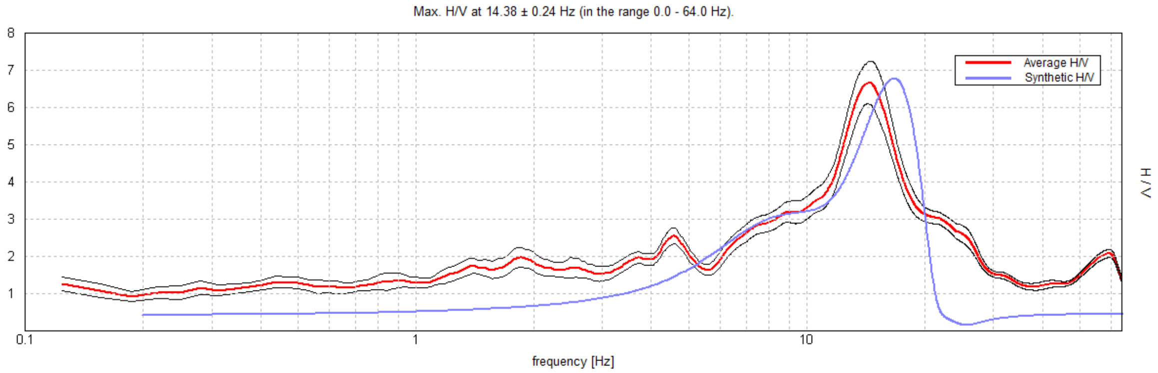
H/V TIME HISTORY



SINGLE COMPONENT SPECTRA

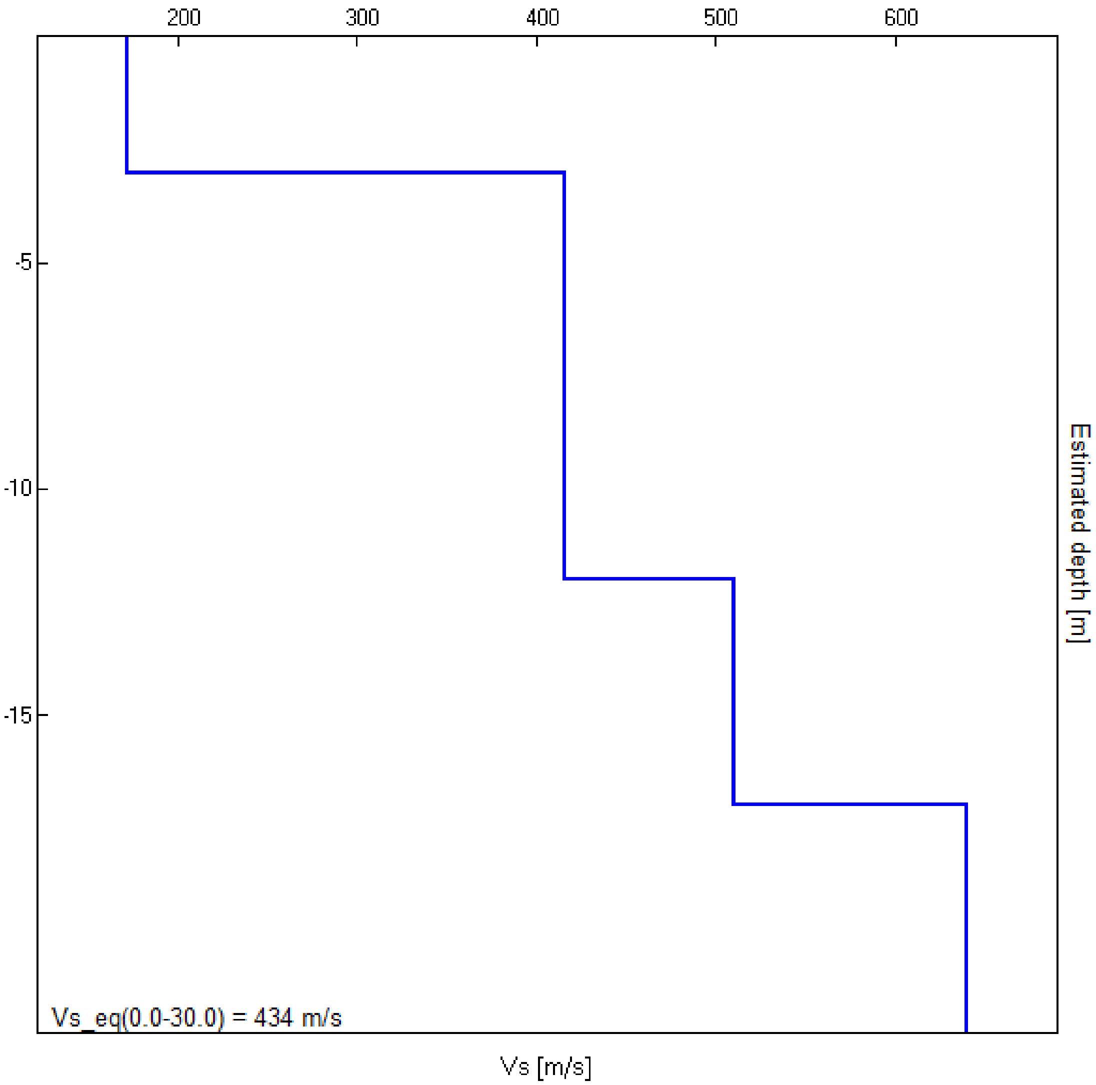


EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
3.00	3.00	172	0.45
12.00	9.00	416	0.42
17.00	5.00	510	0.42
inf.	inf.	640	0.42

Vs_eq(0.0-30.0) = 434 m/s


200
300
400
500
600
-5
-10
-15
Estimated depth [m]
Vs_eq(0.0-30.0) = 434 m/s
Vs [m/s]

[According to the SESAME, 2005 guidelines. **Please read carefully the *Grilla* manual before interpreting the following tables**.]

Max. H/V at 14.38 ± 0.24 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	$14.38 > 0.50$	**OK**	
$n_c(f_0) > 200$	$13225.0 > 200$	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 691 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	10.031 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	19.063 Hz	**OK**	
$A_0 > 2$	$6.66 > 2$	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$\|0.01699\| < 0.05$	**OK**	
$\sigma_f < \varepsilon(f_0)$	$0.24424 < 0.71875$	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	$0.5649 < 1.58$	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

APPENDIX

E

LABORATORY TESTING

WSP Canada Inc.
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Victoria, BC   V8Z 6R4
Phone +1 250-475-1000
WSP.com

Atterberg Limits

CLIENT: **Ministry of Transportation & Infrastructure**

PROJECT: **Briarwood Drive**

FILE: **20M-01141-06**
DATE: **January 12, 2022**
REPORT NO.: **1**
SAMPLE #: **GS6**

Plasticity Index 27.99
Liquidity Index 0.36

Class: CI

TP/BH: 21-Jan
Grab Number: 6
Sample Depth: 4.2m

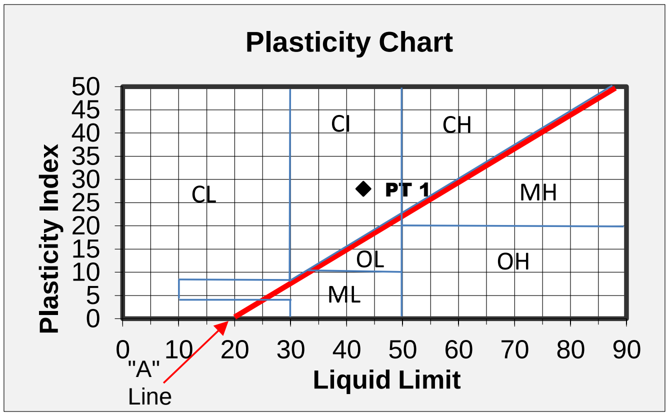
Natural MC: 25.2

Plastic Limit				**Liquid Limit**				
Trial	1	2	3	**Trial**	1	2	3	4
Wt of Wet + T	110.64	97.56	97.3	Number of Blows	32	26	24	17
Wt of Dry + T	110.27	97.33	97.13	Wt of Wet + T	10.54	11.32	10.84	103.39
Wt of Tare	107.81	95.52	96.07	Wt of Dry + T	8.65	9.11	8.85	101.1
Mass of Water	0.37	0.23	0.17	Wt of Tare	4.11	4.07	4.1	96.16
Mass of Dry Soil	2.46	1.81	1.06	Mass of Water	1.89	2.21	1.99	2.29
Moisture Content	15.04	12.71	16.04	Mass of Dry Soil	4.54	5.04	4.75	4.94
Average	15.04			Moisture Content	41.63	43.85	41.89	46.36
Material Passing 425µm:				Corrected Limit	43.03	44.09	41.69	44.15
Material Retained 425µm:				Average	43.03			

Sample Description: Lean Clay
Grey intermediate plastic

Comments:

Legend
ML = Silt
CL = Lean Clay
OL = Organic Clay
CI = CL or OL
CH = Fat Clay
MH = Elastic Silt
OH = Organic Clay



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AGGREGATE GRADATION CHART

IDENTIFICATION:

Client: Ministry of Transportation & Infrastrucutre

Project: Briarwood Drive

Sample Location: BH21-01 @ 1.3m

File No.: 20M-01141-06

Report No.: 1

Date: 13-Jan-22

SAMPLING INFORMATION:

Material: Silty brown sand with some gravel

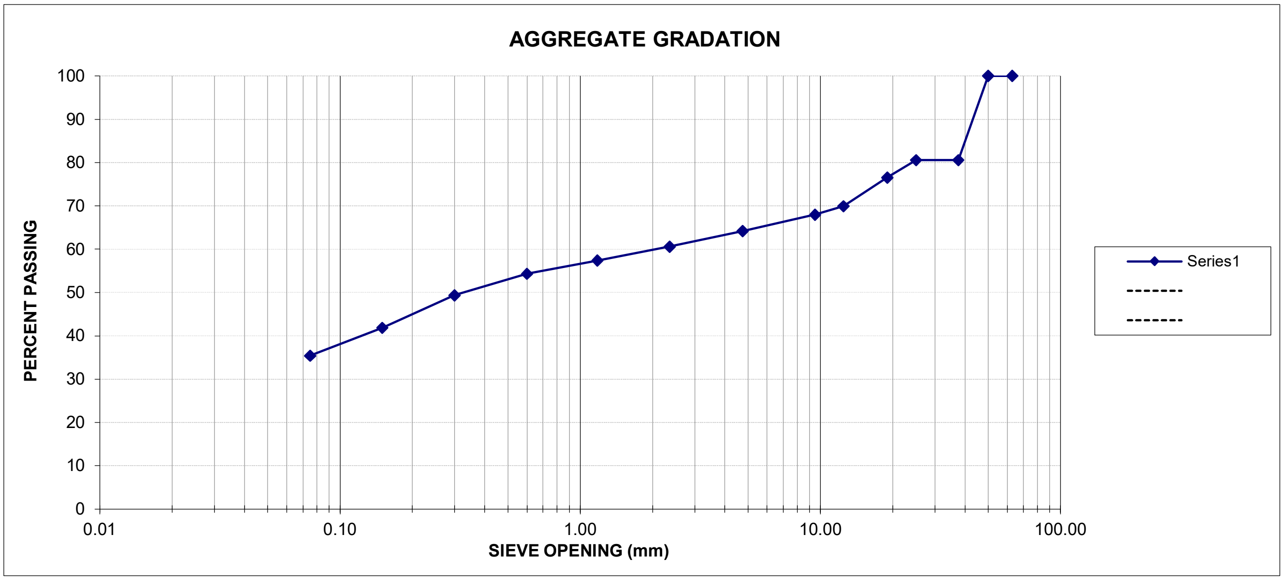
Specification: N/A

Date Sampled	21-Dec-21
Date Tested	05-Jan-22
Sample No:	1
Fracture by mass	n/a
Supplier:	N/A
Sampled by:	AB
Tested by:	BK

Sieve Analysis

Sieve	% Passing
75.0	
63.0	100.0
50.0	100.0
37.5	80.5
25.0	80.5
19.0	76.6
12.5	70.0
9.5	68.0
4.75	64.2
2.36	60.6
1.18	57.4
0.600	54.3
0.300	49.4
0.150	41.9
0.075	35.4

AGGREGATE GRADATION:



REMARKS: Tested according to ASTM C-: 136 and C-117

REPORTS TO:

WSP CANADA INC.

per:

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AGGREGATE GRADATION CHART

IDENTIFICATION:

Client Ministry of Transportation & Infrastrucutre
Project Briarwood Drive
Sample Location BH21-01 @ 2.8m

File No.: 20M-01141-06
Report No.: 2
Date: 13-Jan-22

SAMPLING INFORMATION:

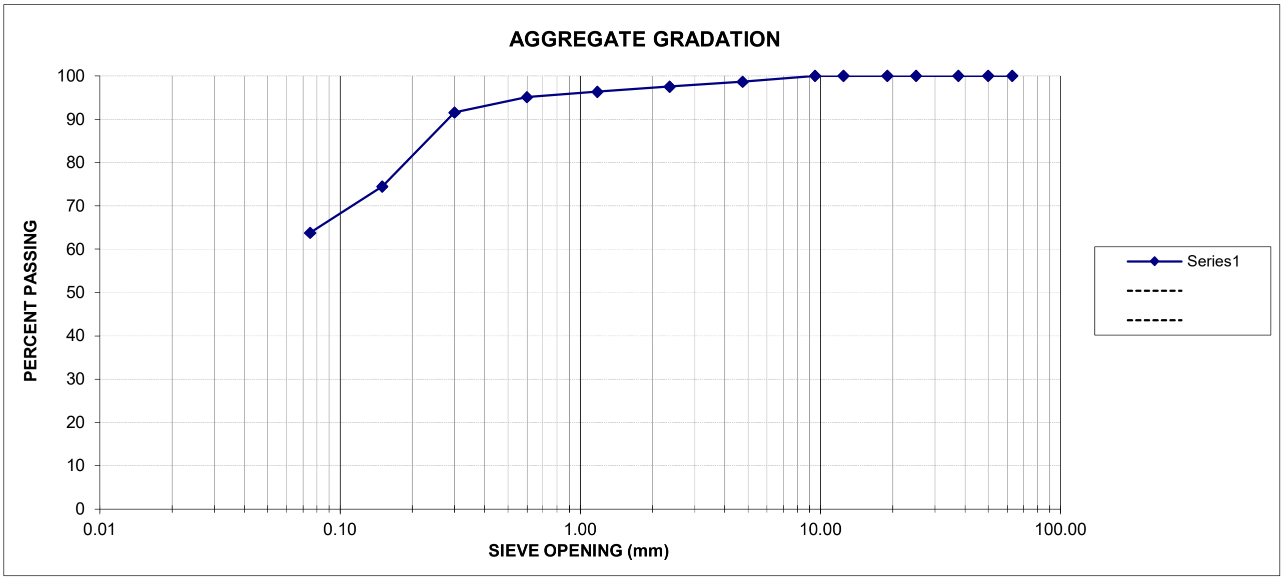
Material: Silt, some sand, trace gravel
Specification: N/A

Date Sampled 21-Dec-21
Date Tested 05-Jan-22
Sample No: 1
Fracture by mass n/a
Supplier: N/A
Sampled by: AB
Tested by: BK

Sieve Analysis

Sieve	% Passing
75.0	
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	100.0
12.5	100.0
9.5	100.0
4.75	98.7
2.36	97.5
1.18	96.4
0.600	95.1
0.300	91.6
0.150	74.5
0.075	63.8

AGGREGATE GRADATION:



REMARKS: Tested according to ASTM C-: 136 and C-117

REPORTS TO:

WSP CANADA INC.

per:

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AGGREGATE GRADATION CHART

IDENTIFICATION:

Client: Ministry of Transportation & Infrastrucutre

Project: Briarwood Drive

Sample Location: BH21-02 @ 2.0m

File No.: 20M-01141-06

Report No.: 3

Date: 14-Jan-22

SAMPLING INFORMATION:

Material: Sand, gravelly, clayey, brown.

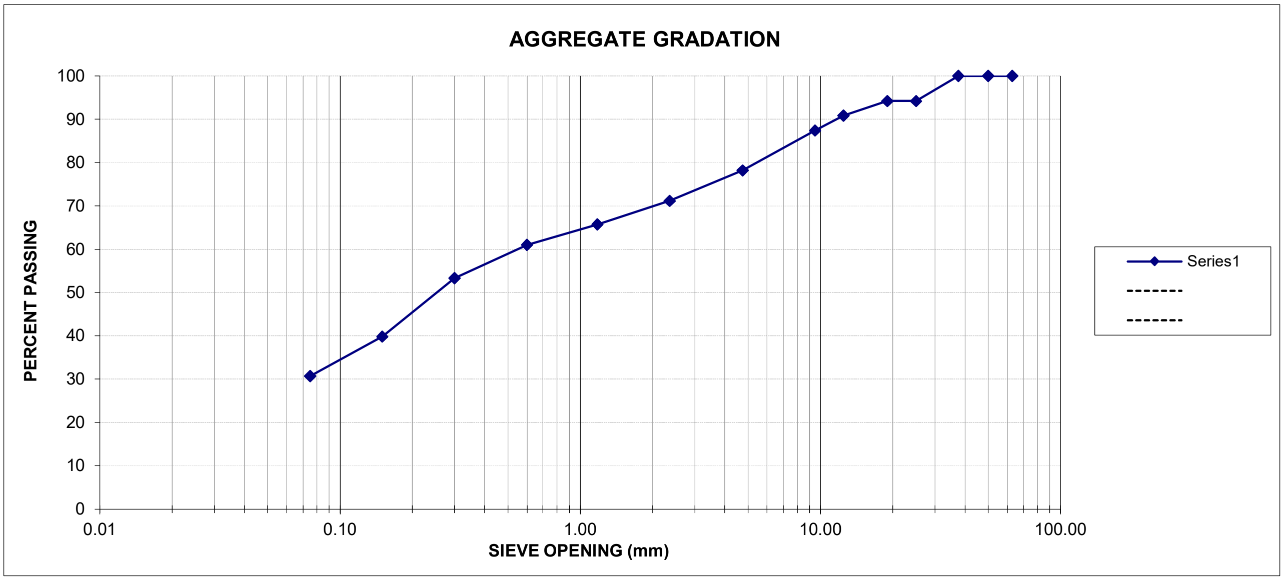
Specification: N/A

Date Sampled 21-Dec-21
Date Tested 13-Jan-22
Sample No: 3
Fracture by mass n/a
Supplier: N/A
Sampled by: AB
Tested by: BK

Sieve Analysis

Sieve	% Passing
75.0	
63.0	100.0
50.0	100.0
37.5	100.0
25.0	94.2
19.0	94.2
12.5	90.9
9.5	87.4
4.75	78.2
2.36	71.2
1.18	65.7
0.600	61.0
0.300	53.3
0.150	39.8
0.075	30.7

AGGREGATE GRADATION:



REMARKS: Tested according to ASTM C-: 136 and C-117

REPORTS TO:

WSP CANADA INC.

per:

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WSP.com

AGGREGATE GRADATION CHART

IDENTIFICATION:

Client: Ministry of Transportation & Infrastrucutre
Project: Briarwood Drive
Sample Location: BH21-02 @ 4.0m

File No.: 20M-01141-06
Report No.: 4
Date: 14-Jan-22

SAMPLING INFORMATION:

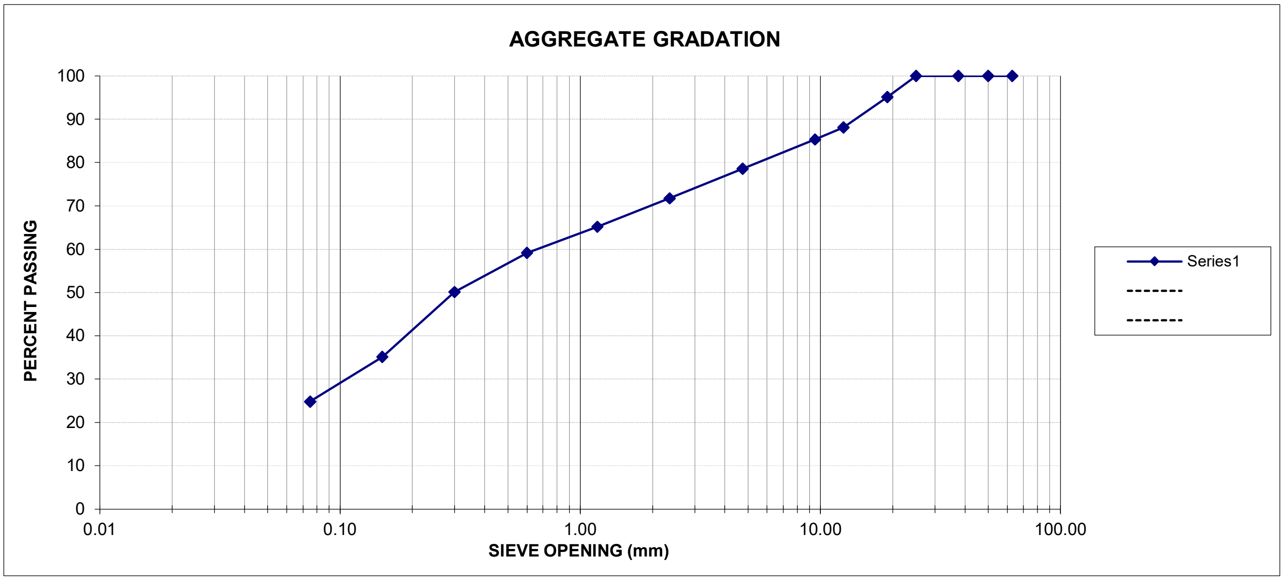
Material: Sand, gravelly, clayey, trace organics, grey.
Specification: N/A

Date Sampled 21-Dec-21
Date Tested 13-Jan-22
Sample No: 4
Fracture by mass n/a
Supplier: N/A
Sampled by: AB
Tested by: BK

Sieve Analysis

Sieve	% Passing
75.0	
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	95.1
12.5	88.2
9.5	85.4
4.75	78.6
2.36	71.8
1.18	65.2
0.600	59.1
0.300	50.1
0.150	35.2
0.075	24.8

AGGREGATE GRADATION:



REMARKS: Tested according to ASTM C-: 136 and C-117

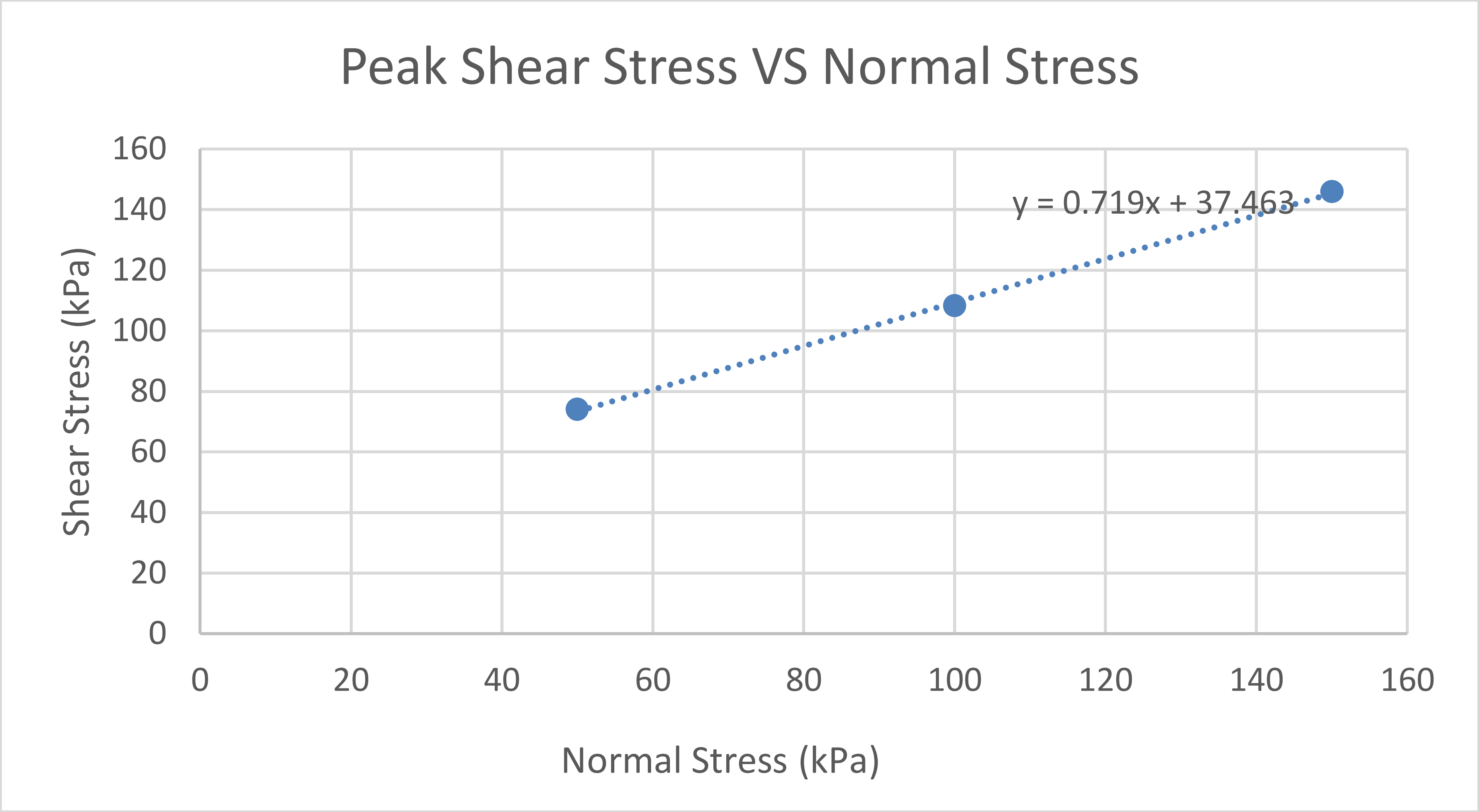
REPORTS TO:

WSP CANADA INC.

per:

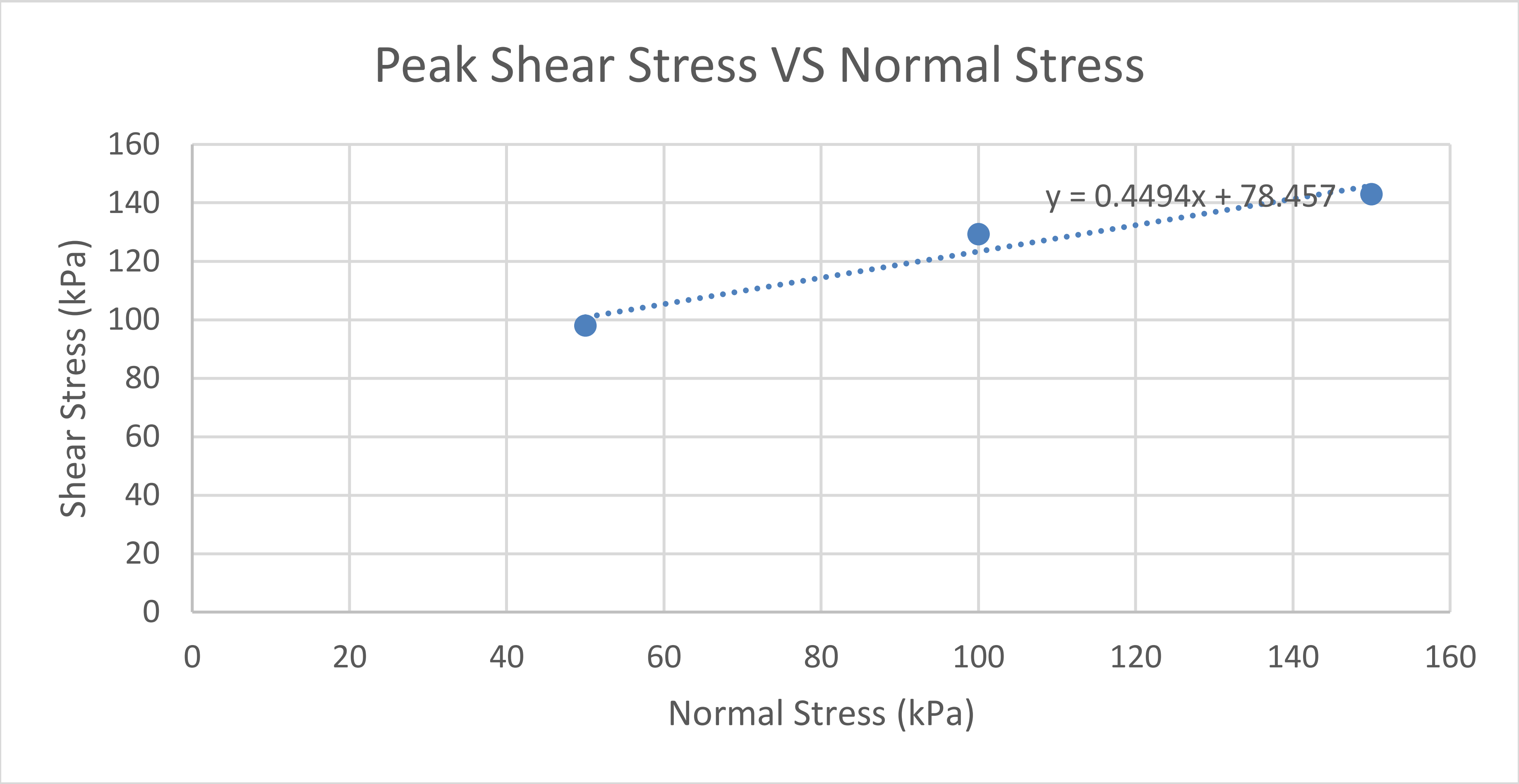
This report represents a testing service only. No engineering interpretation opinion is expressed or implied. Engineering review and interpretation can be provided on written request.

BH21-01
Sample from 1.0m depth



WSP Ref:20M-01141-06

BH21-01
Sample Depth 3.0m



APPENDIX

F

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The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation, using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by WSP and other engineering/scientific practitioners working under similar conditions, and subject to the same time, financial and physical constraints applicable to this project.

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Standard Limitations

Design recommendations given in this report are applicable only to the project and areas as described in the text and then only if constructed in accordance with the details stated in this report. The comments made in this report on potential construction issues and possible methods are intended only for the guidance of the designer. The number of testing and/or sampling locations may not be sufficient to determine all the factors that may affect construction methods and costs. We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.]

Overall conditions can only be extrapolated to an undefined limited area around these testing and sampling locations. The conditions that WSP interprets to exist between testing and sampling points may differ from those that actually exist. The accuracy of any extrapolation and interpretation beyond the sampling locations will depend on natural conditions, the history of Site development and changes through construction and other activities. In addition, analysis has been carried out for the identified chemical and physical parameters only, and it should not be inferred that other chemical species or physical conditions are not present. WSP cannot warrant against undiscovered environmental liabilities or adverse impacts off-Site.]

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