October 5, 2021 Ecora File No.: 201706-18

BC Ministry of Transportation and Infrastructure
4B-940 Blanshard Steet,
Victoria, BC, V8W 9T5

Attention: **Jillian Jackson, P.Eng.**

Reference: **Intrusive Geotechnical Investigation of Daly Bridge**

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1. Introduction

1.1 General

Ecora Engineering & Resource Group Ltd. (Ecora) was retained by the BC Ministry of Transportation and Infrastructure (MoTI) to undertake an intrusive geotechnical investigation in support of the replacement of Daly Bridge near Lumby, BC.

Ecora understands that Daly Bridge currently has a load rating restriction, prohibiting certain farming equipment and supply trucks from crossing the bridge. It was also noted in discussions with neighbouring property owners that the side railing of the bridge was struck by the road maintenance contractor with a grader during snow removal, which has raised concerns of the structural integrity of the bridge. It is Ecora's understanding that MoTI has not yet finalized a bridge design, however, the foundation structure is likely to be supported by steel pipe piles. Once the bridge design has been finalized, it is likely that construction will commence in 2022.

1.2 Scope of Works

The proposed scope of work was set-out in Ecora's Geotechnical Work Plan titled "Geotechnical Work Plan – Daly Bridge, Lumby, BC" dated June 09, 2021 which included the following:

- **Phase 1: Project Planning, Coordination and Project Management** which comprised supporting the project start up, a background review, the preparation of a project specific safety plan, and the coordination of subcontractors;
- **Phase 2: Intrusive Geotechnical Site Investigation and Laboratory Testing** comprising the advancement of sonic test holes (TH) to a maximum depth of 21.0 m below ground level (mbgl) within each abutment. Adjacent to each sonic test hole, cone penetration tests were advanced to a maximum depth of 30.3 mbgl, while test pits were excavated along the roadway shoulder. After the intrusive geotechnical site investigation was completed, geotechnical laboratory soil classification was performed on select samples;

- **Phase 3: Geotechnical Factual Reporting** which consisted of the compilation of the factual data obtained during the geotechnical site investigation and providing a description of the subsurface conditions.

Ecora's services are being provided in accordance with the BC Ministry of Transportation Contract No. 862CS1673 titled "As & When Geotechnical Engineering Services" dated January 8, 2021.

1.3 Site Description

Daly Bridge is located approximately 2.1 km southeast of the town centre of Lumby, BC, along a section of Creighton Valley Road that is approximately 1.2 km to the southeast of the intersection of Hwy 6 and Creighton Valley Road. The general terrain within the project area is typically flat as the project site is situated at the bottom of Creighton Valley, with Creighton Creek flowing to the northwest under the existing bridge structure. It should be noted that Creighton Creek is salmon spawning habitat. Further to the north and south the topography typically remains flat along the Creighton Valley bottom until the topography rises to mountainous terrain elevations of 880 meters above sea level (masl) and 1080 masl, respectively. The approximate elevation of the roadway as determined by the elevation of the test holes performed during the geotechnical site investigation is approximately 504.5 masl. The general site layout is shown in Figure 1.3.

The existing bridge structure currently consists of a single span wood deck bridge, likely situated upon shallow foundations. The abutments and wing walls are constructed of timber which in turn supports timber stringers which the Ecora field representative estimated to be approximately 7.0 m in length.

According to the Regional District of the North Okanagan (RDNO) GIS parcel viewer and the anticipated construction footprint, the majority of the construction footprint will remain in the MoTI Right of Way (ROW); however, it is anticipated that certain aspects of the design may impact the following neighbouring properties and construction access/easement may be required:

- 69 Creighton Valley Road, District Lot 17, Osoyoos Div of Yale Land District, Except Plan B1304 B3655 2281 16341 37372
- 182 Creighton Valley Road, District Lot 182, Osoyoos Div of Yale Land District, Except Plan 4580 24793 KAP54400
- 130 Creighton Valley Road, Lot 1, Plan KAP54400, District Lot 182, Osoyoos Div of Yale Land District
- 142 Creighton Valley Road, Lot 2, Plan KAP4580, District Lot 182, Osoyoos Div of Yale Land District

2. Background Review

2.1 Published Surficial Geology

Reference to the BC Ministry of Environments Technical Report 18 titled "Soils of the Okanagan and Similkameen Valleys" dated March 1986 indicates that the surficial deposits over the subject site consist of "recent fluvial floodplain" deposits. The fluvial deposits are typically deposited by post-glacial streams such as Creighton Creek within the floodplain zone, and fluvial fans which occur on flat or gently sloping valley bottom lands and consist of stream deposited gravel, sand, or silt. Moderate to high groundwater tables are usual for parts of the year and flooding during freshet periods is common.

2.2 Published Bedrock Geology

Reference to Schiarizza, P. and Church., N., 1996. The Geology of the Thompson - Okanagan Mineral Assessment Region. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 1996-20 indicates that the bedrock geology underneath the project site likely comprises sedimentary bedrock consisting of mudstone, siltstone, shale fine clastic sedimentary bedrock. Based on the completed investigation, bedrock in not anticipated to be encountered within the project limits.

2.3 Groundwater Monitoring Wells

Reference to the Provincial Well Database, iMapBC, indicates that 2 water wells (#37177 and #112048) were installed approximately 70 m east and 400 m north west from the centre of the subject site, respectively. The water well data is summarized in Table 2.3.a, and the detailed water well logs have been attached in Appendix A.

Table 2.3.a Water Well Summary

Water Well No.	Approx. Distance from Center of Site (m)	Lithology	Depth (m bgl)	Static Groundwater (m bgl)
37177	70 m (E)	Silty Sand & Gravelly Soil	0.0 – 2.4	1.5
		Silty Clay	2.4 – 5.5	
		Water-Bearing Sand & Gravel	5.5 – 8.2	
112048	400 m (NW)	Silt	0.0 – 0.6	2.3
		Clay Silt	0.6 – 4.6	
		Silt, Clay	4.6 – 8.5	
		Gravel, Sand	8.5 – 10.1	
		Silt	10.1 – 18.6	
		Sand, Gravel	18.6 – 18.9	
		Silt, Gravel, Clay, Sand	18.9 – 22.3	
		Sand, Gravel	22.3 – 23.7	
		Clay, Gravel	23.7 – 24.1	

*Data taken from iMapBC Water Well Reports (https://maps.gov.bc.ca/ess/hm/imap4m/)

2.4 Background Reports

2.4.1 Creighton Valley Road Bridge Summary Logs (1996)

MoTI previously performed a geotechnical site investigation for a nearby bridge along Creighton Valley Road approximately 600 m Southeast of the subject site and provided summary logs based on the subsurface investigation findings. MoTI completed the geotechnical site investigation between October 16 and 21, 1996 which comprised the advancement of two test holes using the hollow stem auger drilling methodology to a maximum termination depth of 18.9 mbgl.

The test holes were performed within the south and north abutments of the bridge to determine the consistency and material composition beneath the proposed abutment structures. The MoTI logs indicate that the subsurface soils typically comprised very loose to compact sands, with varying amounts of silts and gravels with "SPT-N values" ranging between 1 to 19 with an average of 12 (Compact). It was also noted that within the sand were interbedded layers of silts and clays, typically less than 1.5 m less in thickness.

It was noted in the test hole logs groundwater was encountered at 3.1 mbgl within each test hole, and that the soils beneath the groundwater table were typically saturated, with the fine grained soils plasticity index typically recorded above the liquid limit. The historical test hole logs have been appended in Appendix B.

3. Intrusive Geotechnical Site Investigation

3.1 General

Ecora conducted an intrusive geotechnical site investigation between July 5 and July 7, 2021. The geotechnical site investigation comprised test holes utilizing several different investigative techniques consisting of sonic drilling, CPT's, and test pits. The sonic DB2 track mounted drill rig was operated by Mud Bay Drilling Ltd., from Lake Country, BC and the excavator was provided by a local contractor hired by MoTI. The geotechnical drilling was supervised by Ecora field personnel, Mr. Dylan Bryce, EIT, who logged the encountered material and collected representative soil samples for laboratory testing while the test pitting portion of the geotechnical site investigation was supervised by MoTI field personnel Jillian Jackson, P.Eng.

3.2 Sonic Drilling

The sonic drilling comprised the advancement of two test holes (TH21-01 and TH21-02) within the proposed bridge abutment locations to depths of 18.0 mbgl and 21.0 mbgl, respectively. The sonic drilling technique employs the use of high-frequency, resonant energy generated inside the sonic head to advance the core barrel into the subsurface soil formations by strongly reducing the friction on the drill string and drill bit due to liquefaction, inertia effects, and temporary reduction of porosity of the soil caused by the vibrations.

Standard Penetration Testing (SPT) was carried out at regular intervals within the depth zone investigated by each test hole. The SPT is an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil. It comprises a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of 650 mm. This is driven into the ground at the bottom of a test hole by blows from a drop hammer with a weight of 63.5 kg (140 lb) falling through a distance of 760 (30 in). The sample tube is driven into the ground and the number of blows needed for the tube to penetrate increments of 150 mm (6 in) up to 450 mm (18 in) is recorded. The sum of the number of blows required for the second and third 150 mm (6 in) increments of penetration is termed the "standard penetration resistance" or the "N-value".

It should be noted that in certain soil types the sonic drilling technique can disturb the soils in advance of the core barrel that can result in conservative SPT N-Values.

3.3 Cone Penetration Tests

Following the completion of the advancement of the sonic test holes, Ecora advanced two CPT's (CPT21-01 and CPT21-02) adjacent to TH21-01 and TH21-02 to depths of 30.3 mbgl and 8.7 mbgl. The CPT's were performed by Conetec Investigations Ltd., which were advanced with a portable ramset attached to the sonic DB2 track mounted drill rig.

CPT's are a technique whereby a 15 cm^2 cone affixed to the end of a series of rods is hydraulically pushed into the ground at a constant rate to obtain continuous measurements of the resistance to penetration of the cone tip and of a surface sleeve. Pore Water pressures are also typically recorded during penetration from a piezo element located behind the cone tip. Dissipation testing was undertaken at various depths to determine the groundwater table and pore water pressures in certain stratigraphy layers.

3.4 Test Pitting

To provide further data for the subsurface stratigraphy and road structure leading up to the bridge, MoTI conducted a limited geotechnical investigation comprising the advancement of two test pits (TP21-01 and TP21-02) on July 5, 2021 using a Caterpillar 315 GC Excavator. The two test pits were performed on the eastern side of the existing bridge, within the northern and southern shoulder of the Creighton Valley Road. The test pits were advanced to a maximum depth of 4.0 mbgl, which was the maximum extent that the excavation could reasonably advance given the subsurface soil conditions.

3.5 Geodetic Survey

The locations and elevations of the test holes and test pits were established using a Leica GS14 Global Positioning System (GPS) receiver of horizontal and vertical accuracy of +/- 20 mm and 40 mm, respectively following the completion of the drilling and test pitting program. Table 3.5.a provides a summary of the test hole/test pit locations and termination depths. The location of the test holes/ test pits is also shown on the attached Figure 1.3. Detailed logs are included in Appendix C.

Table 3.5.a Summary of Test Holes and Test Pit Locations

Test Hole No.	Northing (m)	Easting (m)	Elevation (masl)	Termination Depth (mbgl)	Termination Reason
TH21-01	5567268.5	361772.5	504.5	18.0	Heaving Sands
TH21-02	5567275.9	361794.8	504.5	21.0	Heaving Sands
CPT21-01	5567268.5	361773.6	504.5	30.3	Target Depth Reached
CPT21-02	5567275.6	361793.9	504.5	8.7	Refusal on Very Dense Layer
TP21-01	5567270.4	361805.8	504.4	4.0	Target Depth Reached
TP21-02	5567278.3	361794.5	504.4	3.5	Target Depth Reached

4. Encountered Subsurface Conditions

4.1 Soil Conditions

Based on the results of our intrusive geotechnical site investigation program, and laboratory testing, the following soil types were encountered within the west abutment side of the proposed bridge (TH21-01 and CPT21-01) and within the depth zone investigated in the following sequence:

- **Asphalt,** 100 mm thick; which in turn is underlain by,
- **Fill,** comprising loose to compact sand and gravels and varying amounts of silt. The fill material was described as moist to saturated, medium to coarse grained subrounded to subangular sand, fine to coarse subrounded to subangular gravel, brown to grey, with “SPT N-values” in the range of 4 to 10 (Average of 7). The fill material extends from 0.1 m to 4.9 m, which in turn is underlain by,
- **Fluvial Deposits,** comprising very loose to compact silts, clays, and sand, with varying amounts of gravel. The deposits were typically bedded in thin stratigraphic layers less than 2.0

m in thickness. The coarse grained fluvial deposits were typically described as wet to saturated, fine to coarse grained sand, fine to coarse subrounded gravel, brown to grey while the fine grained fluvial deposits were typically described as wet to saturated, non-plastic to medium plasticity, with fine grained sand, and grey. The fluvial deposits had “SPT N-values” in the range of 0 to 14 (Average of 4). These deposits extended from 4.9 m to 14.6 m, which in turn is overlying;

- **Glaciofluvial Deposits,** comprising very dense gravel and sand with varying amounts of silt and cobbles. The glaciofluvial deposits were typically described as wet to saturated, medium to coarse grained sand, fine to coarse subrounded to subangular gravel, brown to grey, with “SPT N-values” in excess of 50. These deposits extended to the maximum depth zone investigated by TH21-01 (18.0 mbgl), however, CPT21-01 indicates that this layer extends to a depth of 26.2 mbgl;
- **Glaciolacustrine Deposits,** comprising firm to hard clay with varying amounts of silts. The information gathered on the glaciolacustrine deposits were collected solely from CPT21-01, which indicated that the qt and fs resistance typically averaged 2.5 mPa and 0.025 mPa, respectively. These deposits extended to the maximum depth zone investigated by CPT21-01 (30.3 mbl).

Subsurface conditions on the east abutment side of the proposed bridge (TH21-02, CPT21-02, TP21-01 and TP21-02) within the depth zone investigated were encountered in the following sequence:

- **Asphalt,** 100 mm thick; which in turn is underlain by,
- **Fill,** comprising loose sand, with varying amounts of gravel and silt. The fill material was described as moist, medium to coarse grained sand, fine to coarse subrounded to subangular gravel, brown to grey, with no SPT’s performed in this stratigraphy unit. The fill material extends from 0.1 m to 1.5 m, which in turn is underlain by,
- **Fluvial Deposits,** comprising loose to sand, with varying amounts of silt, clay, and gravel. The fluvial deposits were typically bedded in thin stratigraphic layers less than 2.0 m in thickness. The fine grained fluvial deposits were typically described as wet to saturated, fine grained sand, fine to coarse subrounded gravel, non-plastic to medium plasticity, brown to grey, with “SPT N-values” in the range of 4 to 7 (Average of 5). It should be noted that a compact to dense layer of gravel and sand with varying amounts of silt was noted between 4.0 and 10.4 m with “SPT N-values” in the range of 7 to 39, and these values were excluded from the fine grained deposits “SPT-N values”. These deposits extended from 1.5 m to 17.4 m, which in turn is overlying;
- **Glaciofluvial Deposits,** comprising loose to dense gravel and sand with varying amounts of silt and cobbles. The glaciofluvial deposits were typically described as wet to saturated, medium to coarse grained sand, fine to coarse subrounded to subangular gravel, brown to grey, with “SPT N-values” in excess of 50. These deposits extended to the maximum depth zone investigated by TH21-02 (21.0 mbgl).

Detailed test hole and CPT logs are included in Appendix C and Appendix D, respectively.

4.2 Groundwater Conditions

Groundwater was established at a depth of 1.1 and 1.2 mbgl in CPT21-01 and CPT21-02, respectively (El. 503.4 masl and 503.3 masl). Based on the pore pressure response, the interpreted phreatic surface corresponds with the field observations from TH21-01 and TH21-02 where the measured depth to the groundwater table was 1.5 and 1.8 mbgl, respectively. The soil samples were typically described as saturated beneath the groundwater table elevation. It should be noted that groundwater levels may be higher during certain time of year, especially periods of heavy rainfall and snow-melt.

4.3 Soil Laboratory Testing

4.3.1 General

Following completion of the geotechnical drilling investigation, a selection of representative samples were sent to Ecora's Penticton laboratory, and CARO Analytical Services (CARO) for the following testing:

- **Ecora Engineering & Resource Group Laboratory Testing**
  - Grain Size Analysis (ASTM C136 & ASTM D7928);
  - Moisture content tests (ASTM D2216);
  - Atterberg Limits (ASTM D4318-17e1).
- **Caro Analytical Services Testing**
  - Soluble sulphate testing (CSA A23.2-3B / CSA A23.2-2B);
  - Soluble chloride testing (ASTMC1218-97 / ASTM C114-15(21)); and,
  - Soil PH testing (Carter 16.2 / SM 4500-H+ B (2017).

4.3.2 Soil Classification Testing

Laboratory testing was conducted on select representative samples to confirm the field observations and geotechnical index properties of the subsurface soils. Testing was conducted in general conformance with the relevant ASTMs at Ecora's laboratory, certified by the Canadian Council of Independent Laboratories (CCIL). A total of 8 hydrometers, two sieves, two atterberg limits, and one moisture content in soil were completed.

Table 4.3.a and Table 4.3.b provides a summary of the laboratory testing results, results are also reported on the test hole logs in Appendix C and the detailed lab results are presented in Appendix E.

Table 4.3.a Summary of Grain Size Analysis and Hydrometer Laboratory Test Results

Test Hole	Depth (m bgl)	Moisture Content (%)	Grain Size Distribution (%)			
			Gravel	Sand	Fines	
					Silt	Clay
TH21-01	5.2	302	-	-	-	
TH21-01	5.5 – 5.8	30.2	0	26	51	23
TH21-01	8.8 – 9.1	28.1	4	41	45	10
TH21-01	10.4 – 11.0	22.7	3	67	30	
TH21-01	11.9 – 12.5	28.5	0	66	26	9
TH21-01	13.4 – 13.7	34.7	0	27	57	16
TH21-02	2.1 – 2.4	59.0	1	30	60	10
TH21-02	4.9 – 5.2	8.7	63	35	2	
TH21-02	10.4 – 10.7	35.7	0	7	66	27
TH21-02	12.5 – 12.8	25.5	0	47	45	8

Test Hole	Depth (m bgl)	Moisture Content (%)	Grain Size Distribution (%)			
			Gravel	Sand	Fines	
					Silt	Clay
TH21-02	14.3 – 14.6	31.3	0	22	64	14

Table 4.3.b Summary of Atterberg Limits Laboratory Test Results

Test Hole	Depth (m bgl)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Above or Below A-Line	USGS Soil Classification Description
TH21-01	13.4-13.7	20	31	11	Above	Medium Plastic Clay
TH21-02	10.4-10.7	23	42	19	Above	Medium Plastic Clay

4.3.3 Soil Chemical Testing

Select samples were also sent to CARO Analytical Services (CARO) for Soluble Sulphate and Chloride content testing in accordance with MoTI requirements (CSA 23.A). pH testing was also conducted at CARO's Richmond laboratory in accordance with Carter 16.2 / SM 4500-H+ B (2017). Test results are summarized in Table 4.3.c below and detailed results are attached in Appendix E.

Table 4.3.c Summary of Chemical Test Results

Test Hole	Depth (m)	Soluble Sulphate Content (%)	Chloride Content (%)	pH
TH21-01	2.6 – 2.9	<0.050	<0.002	7.13
TH21-02	3.1 – 3.4	<0.050	<0.002	6.50

5. Closure

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Sincerely

Ecora Engineering & Resource Group Ltd.

Prepared by:

Dylan Bryce

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Reviewed & Approved by:

M. J. LAWS
36691
2021-10-05

ECORA ENGINEERING & RESOURCE GROUP LTD.
ENGINEERS AND GEOSCIENTISTS OF BRITISH COLUMBIA
PERMIT TO PRACTICE # 1001040
RESPONSIBLE REGISTRANT
2021-10-05
DATE

Michael J. Laws, P.Eng.
Senior Geotechnical Engineer
michael.laws@ecora.ca

Version Control and Revision History

Version	Date	Prepared By	Reviewed & Approved By	Notes/Revisions
0	2021-10-05	DB	MJL	Issued for Use

References

Gough, N.A., 1994. Soil Management Handbook for the Okanagan and Similkameen Valleys. British Columbia Ministry of Agriculture, Fisheries and Food.

Schiarizza, P. and Church., N., 1996. The Geology of the Thompson - Okanagan Mineral Assessment Region. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 1996-20

Figures

SITE PLAN

GEOTECHNICAL ASSESSMENT
DALY BRIDGE
LUMBY, BC

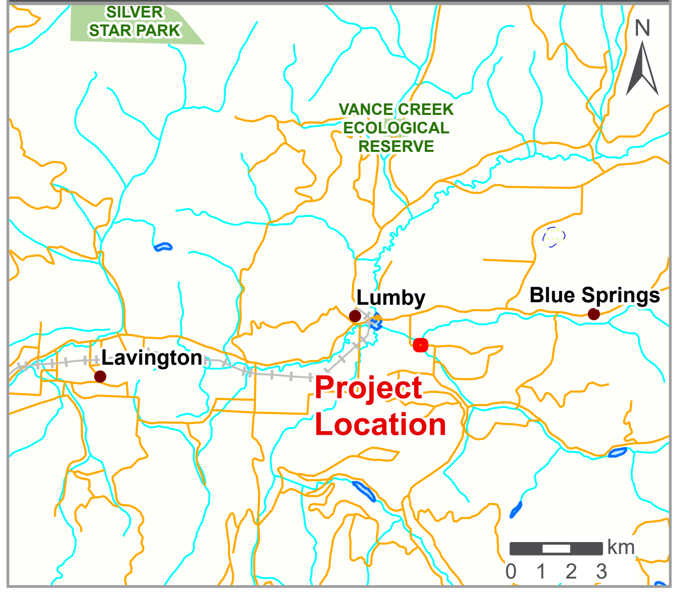
Legend

⊕	Test Hole & CPT Locations
✚	Test Pit Locations
┄	20m TRIM Contour Lines
─	Fresh Water Atlas Streams
─	Digital Atlas Roads
⬚	PMBC Legal Parcels

References

Aerial Imagery: Vivid Maxar. Imagery Date: 9/27/2016

LOCATION MAP



1:500

Meters
0 5 10 15

Project No.: 201706-18
Client: Ministry of Transportation & Infrastructure
NAD 1983 UTM Zone 11N

Date: 2021/10/04
Drawn: ML Check:

Figure 1.3

Appendix A

Water Well Logs

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 37177
Well Identification Plate Number:
Owner Name: ERIC ALP
Intended Water Use: Unknown Well Use
Artesian Condition: No

Well Status: New
Well Class: Unknown
Well Subclass:
Aquifer Number: 316

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Alternative specs submitted: No

Licensing Information

Licensed Status: Unlicensed

Licence Number:

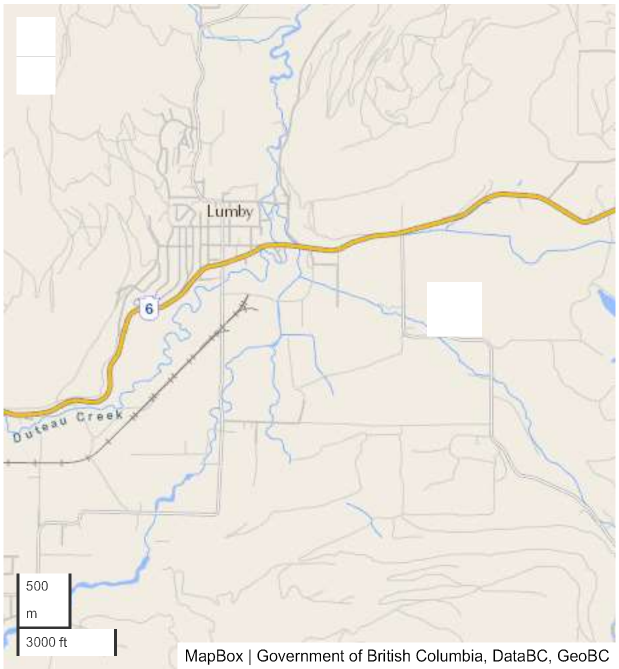
Location Information

Street Address: CREIGHTON VALLEY RD
Town/City: LUMBY

Legal Description:

Lot	1
Plan	4580
District Lot	182
Block	
Section	
Township	
Range	
Land District	41
Property Identification Description (PID)	

Description of Well Location:



Geographic Coordinates - North American Datum of 1983 (NAD 83)
Latitude: 50.241336
Longitude: -118.937418
UTM Easting: 361852
UTM Northing: 5567260
Zone: 11
Coordinate Acquisition Code: (100 m accuracy) Digitized from old Dept. of Lands, Forests and Water Resources maps

Well Activity

Activity	Work Start Date	Work End Date	Drilling Company	Date Entered
Legacy record	1977-05-10	1977-05-10	P. McConnell Well Drilling	August 13th 2003 at 8:02 AM

Well Work Dates

Start Date of Construction	End Date of Construction	Start Date of Alteration	End Date of Alteration	Start Date of Decommission	End Date of Decommission
1977-05-10	1977-05-10				

Well Completion Data

Total Depth Drilled:
Finished Well Depth: 27 ft bgl
Final Casing Stick Up:
Depth to Bedrock:
Ground elevation:

Estimated Well Yield: 5 USgpm
Well Cap:
Well Disinfected Status: Not Disinfected
Drilling Method: Other
Method of determining elevation: Unknown

Static Water Level (BTOC): 5 feet btoc
Artesian Flow:
Artesian Pressure (head):
Artesian Pressure (PSI):
Orientation of Well: VERTICAL

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
0	8	SILTY SAND & GRAVELLY SOIL						
8	18	SILTY CLAY						
18	27	WATER-BEARING SAND & GRAVEL						

Casing Details

From (ft bgl)	To (ft bgl)	Casing Type	Casing Material	Diameter (in)	Wall Thickness (in)	Drive Shoe
There are no records to show						

Surface Seal and Backfill Details

Surface Seal Material:
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Depth:

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner from:

Liner Thickness:
Liner to:

Liner perforations

From (ft bgl)	To (ft bgl)
There are no records to show	

Screen Details

Intake Method:
Type:
Material:
Opening:
Bottom:

Installed Screens

From (ft bgl)	To (ft bgl)	Diameter (in)	Assembly Type	Slot Size
There are no records to show				

Well Development

Developed by:

Development Total Duration:

Well Yield

Estimation Method:
Static Water Level Before Test:
Hydrofracturing Performed: No

Estimation Rate:
Drawdown:
Increase in Yield Due to Hydrofracturing:

Estimation Duration:

Well Decommission Information

Reason for Decommission:
Sealant Material:
Decommission Details:

Method of Decommission:
Backfill Material:

Comments

METHOD OF DRILLING = DRILLED

Alternative Specs Submitted: Yes

Documents

- WTN 37177_Well Record.pdf

Disclaimer

Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 112048
Well Identification Plate Number: 38596
Owner Name: AL DOLMAN
Intended Water Use: Private Domestic
Artesian Condition: Yes

Well Status: New
Well Class: Water Supply
Well Subclass: Not Applicable
Aquifer Number: 316

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Alternative specs submitted: No

Licensing Information

Licensed Status: Unlicensed

Licence Number:

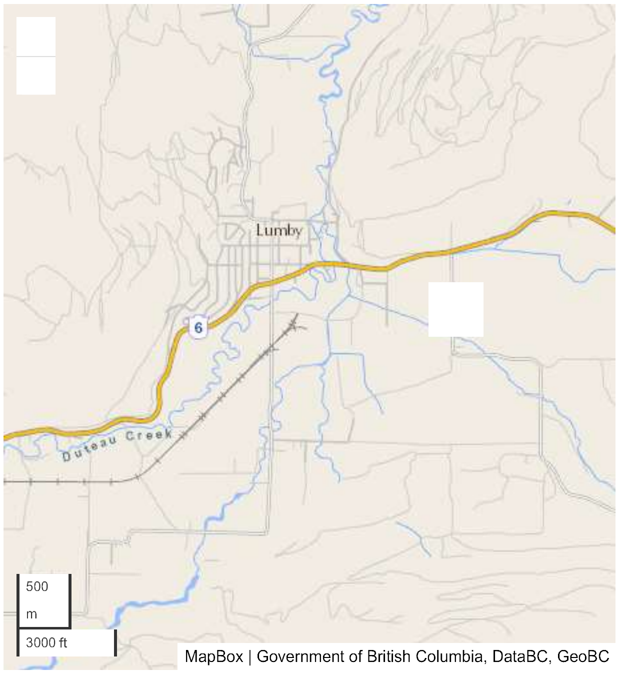
Location Information

Street Address: 62 CREIGHTON VALLEY ROAD
Town/City: LUMBY

Legal Description:

Lot	
Plan	
District Lot	
Block	
Section	
Township	
Range	
Land District	
Property Identification Description (PID)	

Description of Well Location: NOT PROVIDED



MapBox | Government of British Columbia, DataBC, GeoBC

Geographic Coordinates - North American Datum of 1983 (NAD 83)

Latitude: 50.24292	**Longitude:** -118.94378
UTM Easting: 361403	**UTM Northing:** 5567448
Zone: 11	**Coordinate Acquisition Code:** (10 m accuracy) Handheld GPS with accuracy of +/- 10 metres

Well Activity

Activity	Work Start Date	Work End Date	Drilling Company	Date Entered
Legacy record	2016-09-19	2016-09-26	Aqua Source Drilling Ltd.	November 16th 2016 at 3:05 AM

Well Work Dates

Start Date of Construction	End Date of Construction	Start Date of Alteration	End Date of Alteration	Start Date of Decommission	End Date of Decommission
2016-09-19	2016-09-26				

Well Completion Data

Total Depth Drilled: 79 ft bgl
Finished Well Depth: 78 ft bgl
Final Casing Stick Up: 36 inches
Depth to Bedrock:
Ground elevation: 1621 feet

Estimated Well Yield: 36 USgpm
Well Cap: WELDED FLANGE
Well Disinfected Status: Not Disinfected
Drilling Method: Air Rotary
Method of determining elevation: GPS

Static Water Level (BTOC): 7.5 feet btoc
Artesian Flow: 4.5 USgpm
Artesian Pressure (head):
Artesian Pressure (PSI):
Orientation of Well: VERTICAL

Lithology

From (ft bgl)	To (ft bgl)	Raw Data	Description	Moisture	Colour	Hardness	Observations	Water Bearing Flow Estimate (USGPM)
78	78	CLAY, GRAVEL			grey	Soft		
74	78	SAND, GRAVEL			grey	Soft		36
62	74	SILT, GRAVEL, CLAY, SAND			grey	Soft		
61	62	SAND, GRAVEL			brown	Soft		8
33	61	SILT			grey	Soft		
28	33	GRAVEL, SAND			black	Soft		6
15	28	SILT, CLAY			grey	Soft	WET	
2	15	CLAY SILT			grey	Soft		
0	2	SILT			brown	Soft		

Casing Details

From (ft bgl)	To (ft bgl)	Casing Type	Casing Material	Diameter (in)	Wall Thickness (in)	Drive Shoe
0	12		Steel	12	0.25	Not Installed
0	20		Steel	8	0.25	Installed
0	74		Steel	6	0.25	Installed

Surface Seal and Backfill Details

Surface Seal Material: Other
Surface Seal Installation Method: Pumped
Surface Seal Thickness: 2 inches
Surface Seal Depth: 18 feet

Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

Liner Material:
Liner Diameter:
Liner from:

Liner Thickness:
Liner to:

Liner perforations

From (ft bgl)	To (ft bgl)
There are no records to show	

Screen Details

Intake Method: Screen
Type: Telescope
Material: Stainless Steel
Opening: Continuous Slot
Bottom: Bail

Installed Screens

From (ft bgl)	To (ft bgl)	Diameter (in)	Assembly Type	Slot Size
74.00	78.00	6.00	K_PACKER	40.00

Well Development

Developed by: Air lifting

Development Total Duration: 5 hours

Well Yield

Estimation Method: Air Lifting
Static Water Level Before Test:
Hydrofracturing Performed: No

Estimation Rate: 36 USgpm
Drawdown:
Increase in Yield Due to Hydrofracturing:

Estimation Duration: 5 hours

Well Decommission Information

Reason for Decommission: **Method of Decommission:**
Sealant Material: **Backfill Material:**
Decommission Details:

Comments

SS TYPE=CEMENT; SCREEN TYPE=K-PACKER AND SCREEN

Alternative Specs Submitted: Yes

Documents

- WTN 112048_WID_38596 Well Record.JPG
- WTN 112048_Well Construction.pdf

Disclaimer

Appendix B

Historic Test Hole Logs

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Engineering

TEST HOLE No. 96-01

Project Creighton Valley Road Bridge
Location Sta. 111+00 O/S 3.50m Rt
Driller R. Dixon
Method Hollow Stem Augers
Elevation
Dates 96-10-16

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation %			Index Properties			Classification	Description	Other Tests
						Gravel	Sand	Fines	wL	wP	w			
													Road Base Gravels.	
													0.61m	
	1													
	2	S	11	0.36		–	55	45	–	–	–	SC4	Compact, grey-brown, SAND and CLAY. Clay fraction is medium plastic and above the plastic limit.	
													2.44m	
▽ 96-10-16	3	T	–	0.61	Lv=8 Torvane=18 R=1	10	55	35	42 23	25 18	28 23	(CL) SC4	Very loose, saturated, grey-brown, silty, SAND, with clay layers.	
	4												4.27m	
	5	S	1	0.30		–	86	14	–	–	–	SM1	Very loose, grey-brown, saturated, SAND, with some silt.	
	6												6.10m	
		S	9	0.30		–	55	45	–	–	25	SC4	Loose, brown, silty, saturated, SAND.	
	7												7.32m	
	8	S	13	0.30		5	84	11	–	–	–	SP–SM	Compact, brown, saturated, SAND with trace gravel, and some fines.	
													8.53m	
	9	S	5	0.51		–	35	65	–	–	–	ML	Soft to very soft, blue gray, interbedded SILTS and CLAYS, above the liquid limit.	
	10												10.82m	
	11	S	3	0.61		–	7	93	36	20	38	CL	(Lab Pocket Pen indicates, stiff, 49kPa)	
	12	T	–	0.00		(–	20	80)	–	–	–	(ML/OL)	Very soft, blue gray, SILT.	
													12.80m	
	13											SB	Very dense layer with SMALL BOULDERS, probably a clean gravel.	
													13.41m	
	14	S	16	0.61		–	85	15	–	–	–	SM1		
	15	S	17	0.61		–	90	10	–	–	–	SP–SM		
	16												Compact, grey brown, saturated, fine grained, SAND with some silt seams.	
	17	S	16	0.61		–	80	20	–	–	24	SM2		

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
U – Unconfined Compression
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
wL,wP – Liquid, Plastic Limits
W – Moisture Content

Blowcount – Standard Penetration Test (ASTM–1586)

FILE No. 2M3–40–25
PREPARED By: TNH
SHEET 1 of 2

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Engineering

TEST HOLE No. 96-02

Project Creighton Valley Road Bridge
Location Sta. 129+04 O/S 5.50m Lt
Driller R. Dixon
Method Hollow Stem Augers
Elevation
Dates 96–10–21

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation %			Index Properties			Classification	Description	Other Tests
						Gravel	Sand	Fines	wL	wP	w			
	1												Granular fill material with wood debris.	
	2	S	15	0.46		16	60	24	–	–	–	~~SM2~~	1.83m	
													Compact, brown, fine grained, silty, SAND.	
													2.44m	
▽ 96–10–21	3	S	4	0.61		–	25	75	30	22	35	CL	Very soft, brown, medium plastic CLAY, above the liqiud limit.	
	4												4.57m	
	5	S	17	0.36		33	51	17	–	–	–	SM1		
	6	S	5	0.61		42	46	12	–	–	12	SP–SM		
	7												Loose to compact, grey brown, saturated, SAND, with trace silt and some gravel layers.	
	8	S	18	0.56		46	48	6	–	–	–	SP–SM		
	9	S	9	0.61		33	62	5	–	–	–	SP–SM		
	10												10.67m	
	11	S	13	0.51		–	6	94	37	22	35	CL	Stiff, blue, medium plastic, CLAY, above the plastic limit. (lab Pocket Pen indicates stiff, 73kPa)	
													11.58m	
	12	S	53	0.46		60	32	8	–	–	–	GP–GM	Very dense, damp, orange–grey, sandy, GRAVEL, with trace fines.	
	13												13.41m	
	14	S	14	0.61		–	44	57	–	–	26	ML	Stiff, grey, SILT and SAND, saturated.	
													14.94m	
	15	S	19	0.61		–	60	40	–	–	21	SM4		
	16													
	17	S	17	0.61		–	93	7	–	–	–	SP–SM	Compact, grey, fine grained, saturated, SAND with some silt, and silty layers.	

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
U – Unconfined Compression
Fv – Field Vane
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TESTS
M – Mechanical Analysis
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Blowcount – Standard Penetration Test (ASTM–1586)

FILE No. 2M3–40–25
PREPARED By: TNH
SHEET 1 of 2

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Engineering

TEST HOLE No. 96-01

Project Creighton Valley Road Bridge
Location Sta. 111+00 O/S 3.50m Rt
Driller R. Dixon
Method Hollow Stem Augers
Elevation
Dates 96–10–16

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation %			Index Properties			Classification	Description	Other Tests
						Gravel	Sand	Fines	wL	wP	w			
		S	16	0.61		–	93	7	–	–	–	SP–SM		
	19												18.90m END OF HOLE	
	20													
	21													
	22													
	23													
	24													
	25													
	26													
	27													
	28													
	29													
	30													
	31													
	32													
	33													
	34												NOTE: Brackets ( ) denote Drillers estimate	
	35													

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
U – Unconfined Compression
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
wL,wP – Liquid, Plastic Limits
W – Moisture Content

Blowcount – Standard Penetration Test (ASTM–1586)

FILE No. 2M3–40–25
PREPARED By: TNH
SHEET 2 of 2

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Engineering

TEST HOLE No. 96-02

Project Creighton Valley Road Bridge
Location Sta. 129+04 O/S 5.50m Lt
Driller R. Dixon
Method Hollow Stem Augers
Elevation
Dates 96–10–21

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation %			Index Properties			Classification	Description	Other Tests
						Gravel	Sand	Fines	wL	wP	w			
		S	17	0.61		–	86	14	–	–	–	SM1		
	19												18.90m END OF HOLE	
	20													
	21													
	22													
	23													
	24													
	25													
	26													
	27													
	28													
	29													
	30													
	31													
	32													
	33													
	34												NOTE: Brackets ( ) denote Drillers estimate	
	35													

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
U – Unconfined Compression
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
wL,wP – Liquid, Plastic Limits
W – Moisture Content

Blowcount – Standard Penetration Test (ASTM–1586)

FILE No. 2M3–40–25
PREPARED By: TNH
SHEET 2 of 2

MATERIALS CLASSIFICATION LEGEND

MAJOR DIVISIONS		SYMBOL	SOIL TYPE
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	WELL GRADED GRAVELS OR GRAVEL-SAND MIXTURES, < 5% FINES
		GP	POORLY-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, < 5% FINES
		GM*	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
		GC*	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	SW	WELL-GRADED SANDS OR GRAVELLY SANDS, < 5% FINES
		SP	POORLY-GRADED SANDS OR GRAVELLY SANDS, < 5% FINES
		SM*	SILTY SANDS SAND-SILT MIXTURES
		SC*	CLAYEY SANDS SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS WI <50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		OL	ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS WI >50	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, PLASTIC SILTS
		CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
		OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
ORGANIC SOILS		Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS
TOPSOIL		TS	TOPSOIL WITH ROOTS, ETC.
COBBLES		SB	ROCK FRAGMENTS AND COBBLES, PARTICLE SIZE 75mm TO 300mm
BOULDERS		LB	BOULDERS, PARTICLE SIZE OVER 300mm
BEDROCK		BR	BEDROCK

FOR SOILS HAVING 5 - 12% PASSING .075 SIEVE, USE DUAL SYMBOL

*GM1; GC1; SM1; SC1;	12 - 20%	PASSING .075mm SIEVE
GM2; GC2; SM2; SC2;	20 - 30%	
GM3; GC3; SM3; SC3;	30 - 40%	
GM4; GC4; SM4; SC4;	40 - 50%	

REV. 89-12-01

INFORMATION NOTES

NOTE 1) Information provided herein is intended to be used by the Ministry of Transportation and Highways in conjunction with all other data relevant to the site. The soil and ground water conditions shown are representative at the test hole locations on the dates indicated. Conditions are subject to change with time. The Ministry of Transportation and Highways shall not be held liable for any claims or actions arising from the use or interpretation of the data herein provided.

NOTE 2) Field logs and laboratory test results are available for viewing from Geotechnical and Materials Engineering in Kamloops. (Phone No. 828-4606)

NOTE 3) Gradation and classification of soil are based on a visual estimate unless otherwise noted under 'other tests'.

NOTE 4) Cobble and boulder sizes are driller's estimate of the dimension encountered.

NOTE 5) BR - Bedrock
Intact Rock Strength (See Canadian Foundation Manual, 2nd Edition, Page 35.)

REVISIONS

Rev	Date	Description	Init	Neg. No.

SCALE 1:100

0 1:100 5m

Province of British Columbia
MINISTRY OF TRANSPORTATION AND HIGHWAYS
GEOTECHNICAL AND MATERIALS ENGINEERING

OKANAGAN / SHUSWAP
CREIGHTON VALLEY ROAD BRIDGE
SUMMARY LOGS
CROSSING #31 CREIGHTON VALLEY ROAD

PREPARED BY
DATE 97/05/28

T. N. HARBICHT

REVIEWED BY
DATE 97/05/28

DESIGNED			NEGATIVE No.		PROJECT No.	DRAWING No.
CHECKED			CAD No.	CRTN-TH		7477-9
DRAWN	DLB	97-01-23	FILE No.	2M3-40-25	REGION No. 2	

H-517 (90-03-30)

CANCEL PRINTS BEARING PREVIOUS LETTER

Appendix C

Test Hole Logs

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

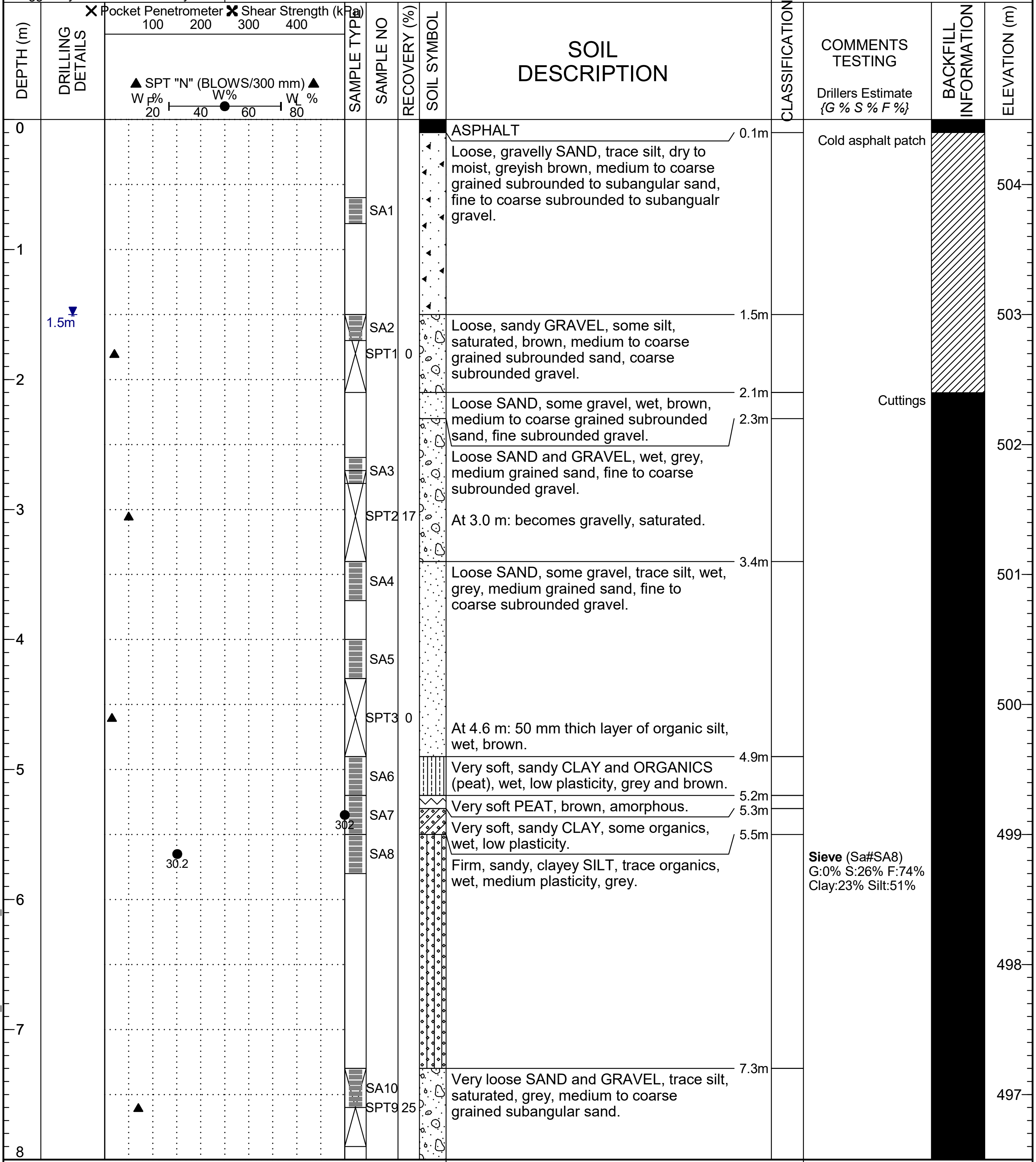
SUMMARY LOG

Drill Hole #: **TH21-01**

Project: **Daly Bridge**
Location: Daly Bridge
Datum: 11U
Northing/Easting: 5567268.5 , 361772.5
Elevation: 504.5 m
Alignment:
Station/Offset:

Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL

Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic



Depth	Soil Description	Comments / Testing
0 – 0.1m	ASPHALT	Cold asphalt patch
0.1m – 1.5m	Loose, gravelly SAND, trace silt, dry to moist, greyish brown, medium to coarse grained subrounded to subangular sand, fine to coarse subrounded to subangualr gravel.	
1.5m – 2.1m	Loose, sandy GRAVEL, some silt, saturated, brown, medium to coarse grained subrounded sand, coarse subrounded gravel.	
2.1m – 2.3m	Loose SAND, some gravel, wet, brown, medium to coarse grained subrounded sand, fine subrounded gravel.	Cuttings
2.3m – 3.4m	Loose SAND and GRAVEL, wet, grey, medium grained sand, fine to coarse subrounded gravel. At 3.0 m: becomes gravelly, saturated.	
3.4m – 4.9m	Loose SAND, some gravel, trace silt, wet, grey, medium grained sand, fine to coarse subrounded gravel. At 4.6 m: 50 mm thich layer of organic silt, wet, brown.	
4.9m – 5.2m	Very soft, sandy CLAY and ORGANICS (peat), wet, low plasticity, grey and brown.	
5.2m – 5.3m	Very soft PEAT, brown, amorphous.	
5.3m – 5.5m	Very soft, sandy CLAY, some organics, wet, low plasticity.	
5.5m – 7.3m	Firm, sandy, clayey SILT, trace organics, wet, medium plasticity, grey.	**Sieve** (Sa#SA8) G:0% S:26% F:74% Clay:23% Silt:51%
7.3m –	Very loose SAND and GRAVEL, trace silt, saturated, grey, medium to coarse grained subangular sand.	

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

Legend Installation: Sand Grout Cement Bentonite Drill Cuttings Slotted Slough Piezometer

Final Depth of Hole: 18.0 m
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

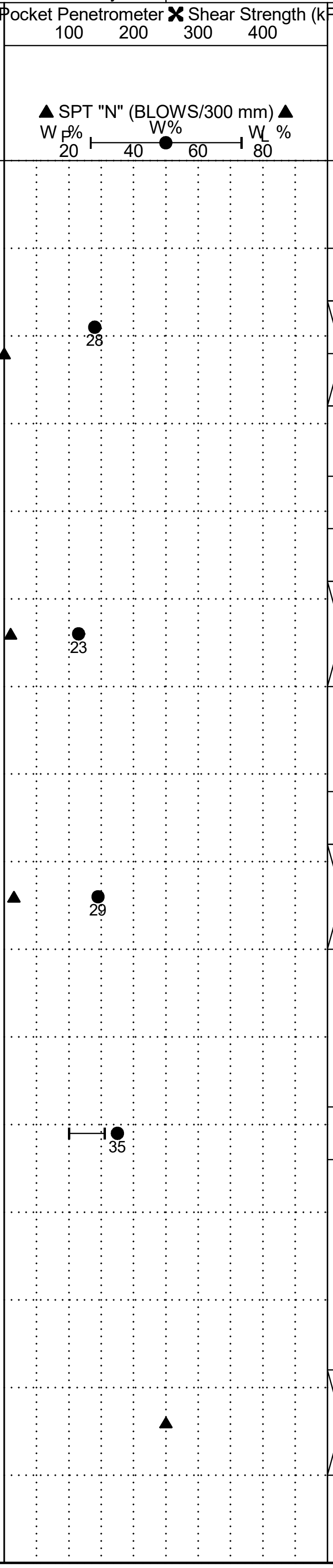
SUMMARY LOG

Drill Hole #: TH21-01

Project: **Daly Bridge**
Location: Daly Bridge
Datum: 11U
Northing/Easting: 5567268.5 , 361772.5
Elevation: 504.5 m
Alignment:
Station/Offset:

Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL

Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic



Depth (m)	Sample Type / No	Recovery (%)	Soil Description	Comments / Testing (Drillers Estimate {G % S % F %})
8			Very loose SAND and GRAVEL, trace silt, saturated, grey, medium to coarse grained subangular sand. *(continued)*	
8.5m	SA11 SA13 SPT12	 0	Very loose SILT and SAND, some clay, trace gravel, saturated, uniformly graded sand.	**Sieve** (Sa#SA13) G:4% S:41% F:55% Clay:10% Silt:45%
9.4m	SA14		Very loose, silty, SAND, trace gravel, uniformly graded, saturated, fine grained sand.	
10.1m	SA15		Very loose SAND and GRAVEL, trace silt, wet, greyish brown, medium to coarse grained sand, fine to coarse subrounded gravel.	
10.4m	SPT16	100	Very loose, silty SAND, trace gravel, wet, dilatant, greyish brown, fine angular gravel.	**Sieve** (Sa#SPT16) G:3% S:67% F:30%
11.6m	SA17		Very soft, silty CLAY, trace sand, saturated, low plasticity, grey.	
11.9m	SPT18	100	Loose, silty SAND, trace clay, trace gravel, uniformly graded, dilatant, brown, fine grained sand.	**Sieve** (Sa#SPT18) G:0% S:66% F:34% Clay:9% Silt:26%
13.1m	SA19		Soft, sandy, silty CLAY, trace gravel, wet, medium plasticity, slow dilatency, grey, fine grained sand.	**Atterberg** (Sa#SA19) PL:20% LL:31% **Sieve** (Sa#SA19) G:0% S:27% F:73% Clay:16% Silt:57%
14.3m			Loose SAND, trace silt, uniformly graded sand, saturated, grey, fine grained sand, material oxidization caused brown streaks.	
14.6m	SPT21	29	Very dense GRAVEL and SAND, trace silt, trace cobbles, wet, brown, medium to coarse grained subrounded to subangular sand, fine to coarse rounded to subrounded gravel.	

Elevation (m): 496, 495, 494, 493, 492, 491, 490, 489

Depth (m): 8, 9, 10, 11, 12, 13, 14, 15, 16

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

Legend Installation: Sand, Grout, Cement, ■ Bentonite, ▨ Drill Cuttings, Slotted, Slough, Piezometer

Final Depth of Hole: 18.0 m
Depth to Top of Rock:

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

Drill Hole #: **TH21-01**

Project: **Daly Bridge**
Location: Daly Bridge

Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL

Datum: 11U
Northing/Easting: 5567268.5 , 361772.5
Elevation: 504.5 m
Alignment:
Station/Offset:

Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic

DEPTH (m)	DRILLING DETAILS	✕ Pocket Penetrometer ✕ Shear Strength (kPa) 100 200 300 400 ▲ SPT "N" (BLOWS/300 mm) ▲ W P% W% W L % 20 40 60 80	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	BACKFILL INFORMATION	ELEVATION (m)
16							Very dense GRAVEL and SAND, trace silt, trace cobbles, wet, brown, medium to coarse grained subrounded to subangular sand, fine to coarse rounded to subrounded gravel. *(continued)*		Cuttings		488
17							17.1m Very dense SAND and GRAVEL, trace silt, trace cobbles, wet, fine to coarse subrounded to subangular gravel, small cobbles.				487
18							18.0m End of hole at 18 m due to heaving sand and thunder.		Heave		486
19											485
20											484
21											483
22											482
23											481
24											

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

Legend Installation: Sand, Grout, Cement, ■ Bentonite, ▨ Drill Cuttings, Slotted, Slough, Piezometer

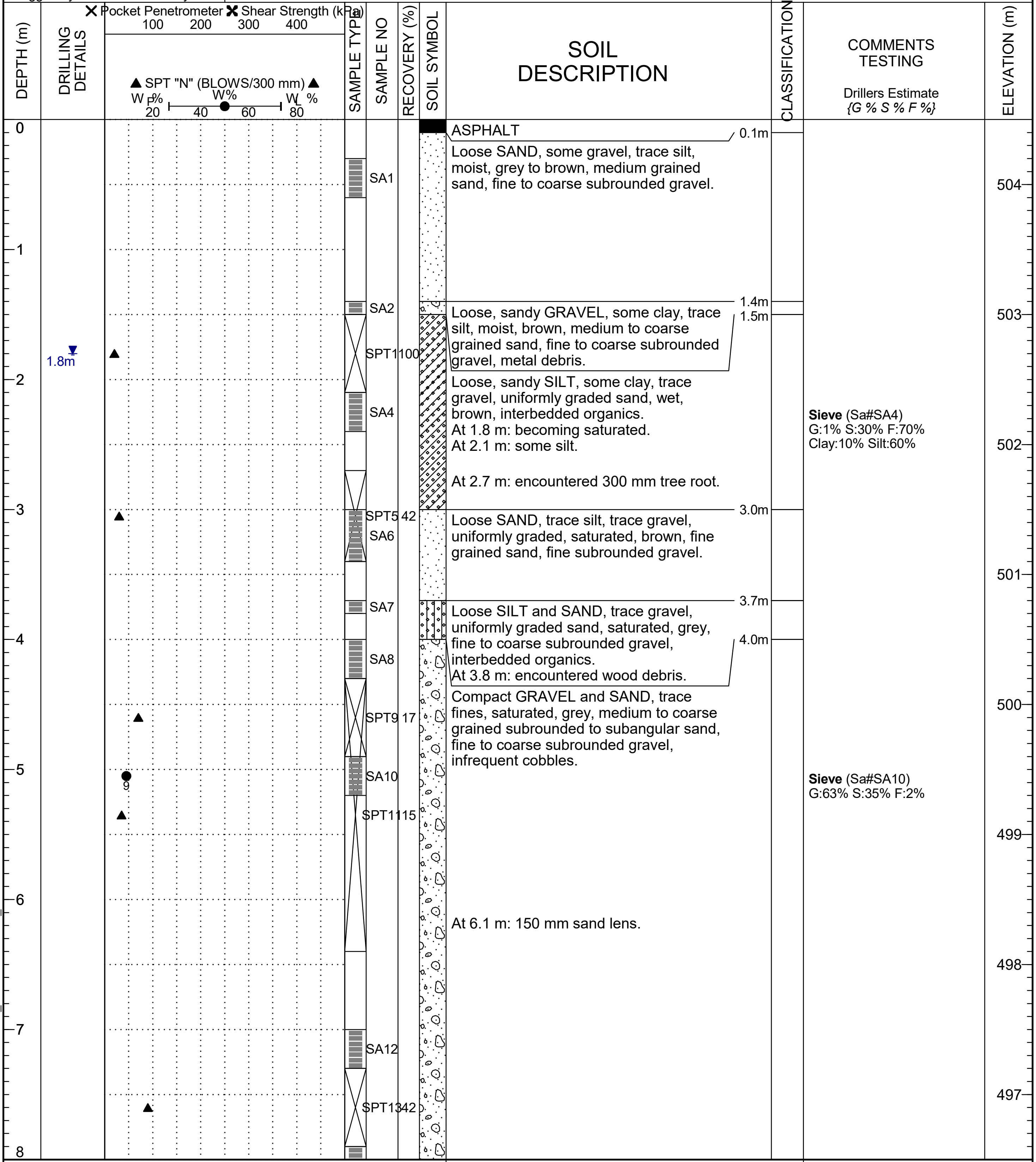
Final Depth of Hole: 18.0 m
Depth to Top of Rock:

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

Drill Hole #: TH21-02

Project: **Daly Bridge**
Location: Daly Bridge
Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL
Datum: 11U
Northing/Easting: 5672275.9 , 361794.8
Elevation: 504.5 m
Alignment:
Station/Offset:
Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic



SOIL DESCRIPTION

ASPHALT

Loose SAND, some gravel, trace silt, moist, grey to brown, medium grained sand, fine to coarse subrounded gravel.

Loose, sandy GRAVEL, some clay, trace silt, moist, brown, medium to coarse grained sand, fine to coarse subrounded gravel, metal debris.

Loose, sandy SILT, some clay, trace gravel, uniformly graded sand, wet, brown, interbedded organics.
At 1.8 m: becoming saturated.
At 2.1 m: some silt.

At 2.7 m: encountered 300 mm tree root.

Loose SAND, trace silt, trace gravel, uniformly graded, saturated, brown, fine grained sand, fine subrounded gravel.

Loose SILT and SAND, trace gravel, uniformly graded sand, saturated, grey, fine to coarse subrounded gravel, interbedded organics.
At 3.8 m: encountered wood debris.

Compact GRAVEL and SAND, trace fines, saturated, grey, medium to coarse grained subrounded to subangular sand, fine to coarse subrounded gravel, infrequent cobbles.

At 6.1 m: 150 mm sand lens.

COMMENTS TESTING

Drillers Estimate
{G % S % F %}

Sieve (Sa#SA4)
G:1% S:30% F:70%
Clay:10% Silt:60%

Sieve (Sa#SA10)
G:63% S:35% F:2%

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: 21.0 m
Depth to Top of Rock:
Page 1 of 3

MOTI-SOIL-REV3 201706-18.GPJ MOTI_DATATEMPLATE_REV3.GDT 21/10/4

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

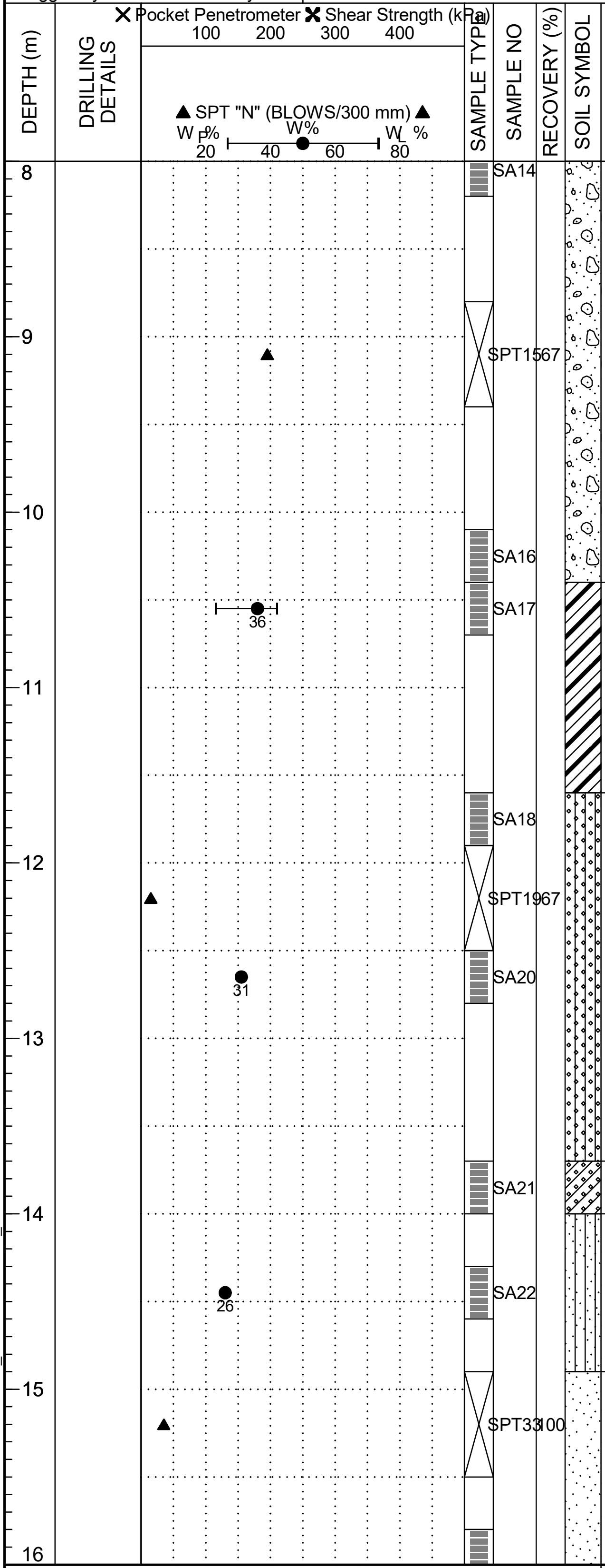
SUMMARY LOG

Drill Hole #: TH21-02

Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL

Project: **Daly Bridge**
Location: Daly Bridge
Datum: 11U
Northing/Easting: 5672275.9 , 361794.8
Elevation: 504.5 m
Alignment:
Station/Offset:

Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic



Depth	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
	Compact GRAVEL and SAND, trace fines, saturated, grey, medium to coarse grained subrounded to subangular sand, fine to coarse subrounded gravel, infrequent cobbles. *(continued)* At 8.8 m: becoming dense.			496 495
10.4m	Soft CLAY, some silt, moist, medium plasticity, grey, interbedded layers of silty sand, small amount of interbedded amorphous peat.		**Atterberg** (Sa#SA17): PL:23% LL:42% **Sieve** (Sa#SA17) G:0% S:7% F:93% Clay:27% Silt:66%	494 493
11.6m	Very loose, sandy SILT, some clay, wet, brown, interbedded 50 mm layers of clay, mottled.		**Sieve** (Sa#SA20) G:0% S:22% F:78% Clay:14% Silt:64%	492 491
13.7m	Stiff, sandy CLAY, trace sand, moist, grey, mottled.			
14.0m	Loose SAND and SILT, trace clay, saturated, non plastic, dilatant, fine to medium grained sand, 50 mm lenses of clean sand.		**Sieve** (Sa#SA22) G:0% S:47% F:53% Clay:8% Silt:45%	490
14.9m	Loose SAND, trace silt, uniformly graded, saturated, brown.			489

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: 21.0 m
Depth to Top of Rock:

SUMMARY LOG

Drill Hole #: **TH21-02**

Project: **Daly Bridge**
Location: Daly Bridge
Datum: 11U
Northing/Easting: 5672275.9 , 361794.8
Elevation: 504.5 m
Alignment:
Station/Offset:

Prepared by: 201706-18
Ecora Engineering and Resource Group
Logged by: DB Reviewed by: MJL

Date(s) Drilled: 2021-07-05
Company: Mud Bay
Driller:
Drill Make/Model:
Drilling Method: Sonic

DEPTH (m)	DRILLING DETAILS	✕ Pocket Penetrometer ✕ Shear Strength (kPa) 100 200 300 400 ▲ SPT "N" (BLOWS/300 mm) ▲ W P% W% W L % 20 40 60 80	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
16			▤	SA24			Loose SAND, trace silt, uniformly graded, saturated, brown. *(continued)*			
16.6m			▤	SA25			Loose, sandy SILT, saturated, dilatant, mottled grey and brown, fine grained sand.			488
17.4m			▤	SA26			Compact SAND and GRAVEL, wet, grey, medium to coarse grained sand, fine to coarse subrounded gravel. At 18 m: heaved 0.9 m, drilled out then heaved 1.5 m.			487
18.9m							Dense SAND, uniformly graded, brown, wet, fine grained sand. No SPT due to 0.9 m heave.			485
21.0m							End of hole at 21 m due to heaving.			483

Depth scale (m): 16, 17, 18, 19, 20, 21, 22, 23, 24
Elevation scale (m): 488, 487, 486, 485, 484, 483, 482, 481

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: 21.0 m
Depth to Top of Rock:

Appendix D

Conetec Report

PRESENTATION OF SITE INVESTIGATION RESULTS

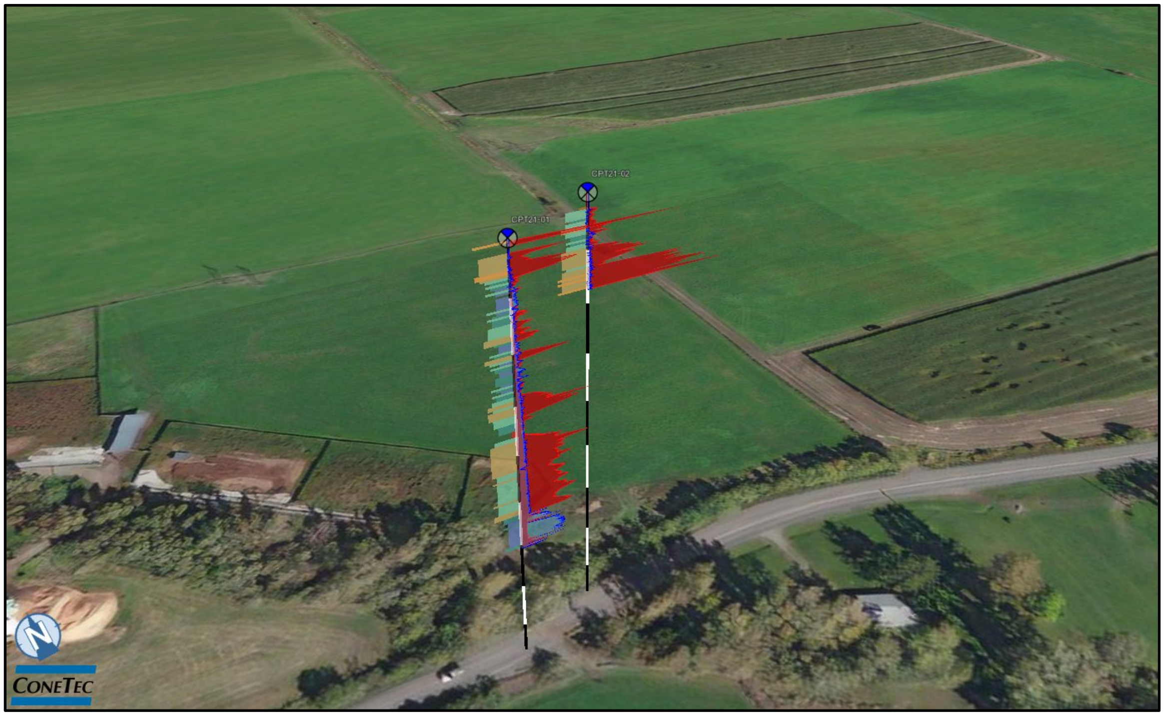
Daly Bridge, Creighton Valley

Prepared for:

Ministry of Transportation and Infrastructure

ConeTec Job No: 21-02-22683

Project Start Date: 07-Jul-2021
Project End Date: 07-Jul-2021
Report Date: 12-Jul-2021
Revised Report Date: 19-Jul-2021



Prepared by:

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Burnaby, BC V5A4W2

Tel: (604) 273-4311
Fax: (604) 273-4066
Toll Free: (800) 567-7969

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www.conetecdataservices.com

Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Investigations Ltd. for the Ministry of Transportation and Infrastructure at the Daly Bridge on Creighton Valley Rd, south east of Lumby, BC. The program consisted of 2 cone penetration tests (CPTu). Please note that this report, which also includes all accompanying data, are subject to the 3rd Party Disclaimer and Client Disclaimer that follow in the 'Limitations' section of this report.

Project Information

Project	
Client	Ministry of Transportation and Infrastructure
Project	Daly Bridge, Creighton Valley
ConeTec project number	21-02-22683

An aerial overview from Google Earth including the CPTu test locations is presented below.

Rig Description	Deployment System	Test Type
Track mounted drill rig (DB2)	Portable ramset	CPTu

Coordinates		
Test Type	Collection Method	EPSG Number
CPTu	Consumer grade GPS	32611

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (bar)
750:T1500F15U35	750	15	225	1500	15	35
Cone 750 was used for all CPTu soundings.						

Cone Penetration Test (CPTu)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	• Standard plots with expanded range • Advanced plots with Ic, Su, phi and N1(60) • Soil Behaviour Type (SBT) scatter plots

Calculated Geotechnical Parameter Tables	
Additional information	The Normalized Soil Behaviour Type Chart based on Q_{tn} (SBT Q_{tn}) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPTu parameters have been generated and are provided in Excel format files in the release folder. The CPTu parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s) and pore pressure (u_2). Effective stresses are calculated based on unit weights that have been assigned to the individual soil behaviour type zones and the assumed equilibrium pore pressure profile. Soils were classified as either drained or undrained based on the Q_{tn} Normalized Soil Behaviour Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures (zone 4).

Closure

Thank you for the opportunity to work on this project. The equipment used and the field procedures followed complied with current accepted practice standards. This report has been prepared under my supervision and I have reviewed and approved the content.

ConeTec Investigations Ltd.

PROFESSIONAL
PROVINCE OF
I. A. WEEMEES
23638
BRITISH COLUMBIA
ENGINEER

Ilmar Weemees, P.Eng.

Limitations

3rd Party Disclaimer

This report titled “Daly Bridge, Creighton Valley”, referred to as the (“Report”), was prepared by ConeTec for Ministry of Transportation and Infrastructure. The Report is confidential and may not be distributed to or relied upon by any third parties without the express written consent of ConeTec. Any third parties gaining access to the Report do not acquire any rights as a result of such access. Any use which a third party makes of the Report, or any reliance on or decisions made based on it, are the responsibility of such third parties. ConeTec accepts no responsibility for loss, damage and/or expense, if any, suffered by any third parties as a result of decisions made, or actions taken or not taken, which are in any way based on, or related to, the Report or any portion(s) thereof.

Client Disclaimer

ConeTec was retained by Ministry of Transportation and Infrastructure to collect and provide the raw data (“Data”) which is included in this report titled “Daly Bridge, Creighton Valley”, which is referred to as the (“Report”). ConeTec has collected and reported the Data in accordance with current industry standards. No other warranty, express or implied, with respect to the Data is made by ConeTec. In order to properly understand the Data included in the Report, reference must be made to the documents accompanying and other sources referenced in the Report in their entirety. Any analysis, interpretation, judgment, calculations and/or geotechnical parameters (collectively “Interpretations”) included in the Report, including those based on the Data, are outside the scope of ConeTec’s retainer and are included in the Report as a courtesy only. Other than the Data, the contents of the Report (including any Interpretations) should not be relied upon in any fashion without independent verification and ConeTec is in no way responsible for any loss, damage or expense resulting from the use of, and/or reliance on, such material by any party.

Cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd., a subsidiary of ConeTec.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and two geophone sensors for recording seismic signals. All signals are amplified and measured with minimum sixteen-bit resolution down hole within the cone body, and the signals are sent to the surface using a high bandwidth, error corrected digital interface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm^2 and 15 cm^2 tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first appendix. The 15 cm^2 penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm^2 piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 millimeters diameter over a length of 32 millimeters with tapered leading and trailing edges) located at a distance of 585 millimeters above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u_2" position (ASTM Type 2). The filter is six millimeters thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meets or exceeds those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

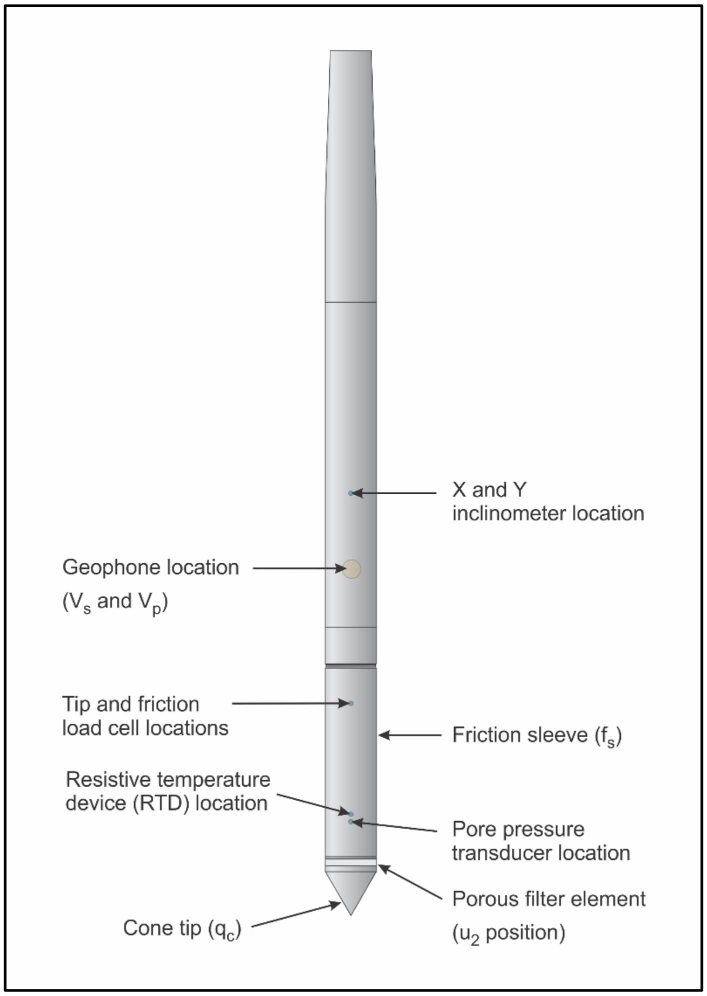


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The ConeTec data acquisition systems consist of a Windows based computer and a signal interface box and power supply. The signal interface combines depth increment signals, seismic trigger signals and the downhole digital data. This combined data is then sent to the Windows based computer for collection and presentation. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording interval is 2.5 centimeters; custom recording intervals are possible.

The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPTu operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of two centimeters per second, within acceptable tolerances. Typically one meter length rods with an outer diameter of 38.1 millimeters are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil under vacuum pressure prior to use
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson et al. (1986) and Robertson (1990, 2009). It should be noted that it is not always possible to accurately identify a soil behaviour type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behaviour type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al. (1986):

$$q_t = q_c + (1\text{-}a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

References

ASTM D5778-20, 2020, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM International, West Conshohocken, PA. DOI: 10.1520/D5778-20.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, "Cone Penetration Testing in Geotechnical Practice", Blackie Academic and Professional.

Mayne, P.W., 2013, "Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests", Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420. DOI: 10.1061/9780784412770.027.

Mayne, P.W. and Peuchen, J., 2012, "Unit weight trends with cone resistance in soft to firm clays", Geotechnical and Geophysical Site Characterization *4,* Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Mayne, P.W., 2014, "Interpretation of geotechnical parameters from seismic piezocone tests", CPT'14 Keynote Address, Las Vegas, NV, May 2014.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27: 151-158. DOI: 10.1139/T90-014.

Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", Canadian Geotechnical Journal, Volume 46: 1337-1355. DOI: 10.1139/T09-065.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

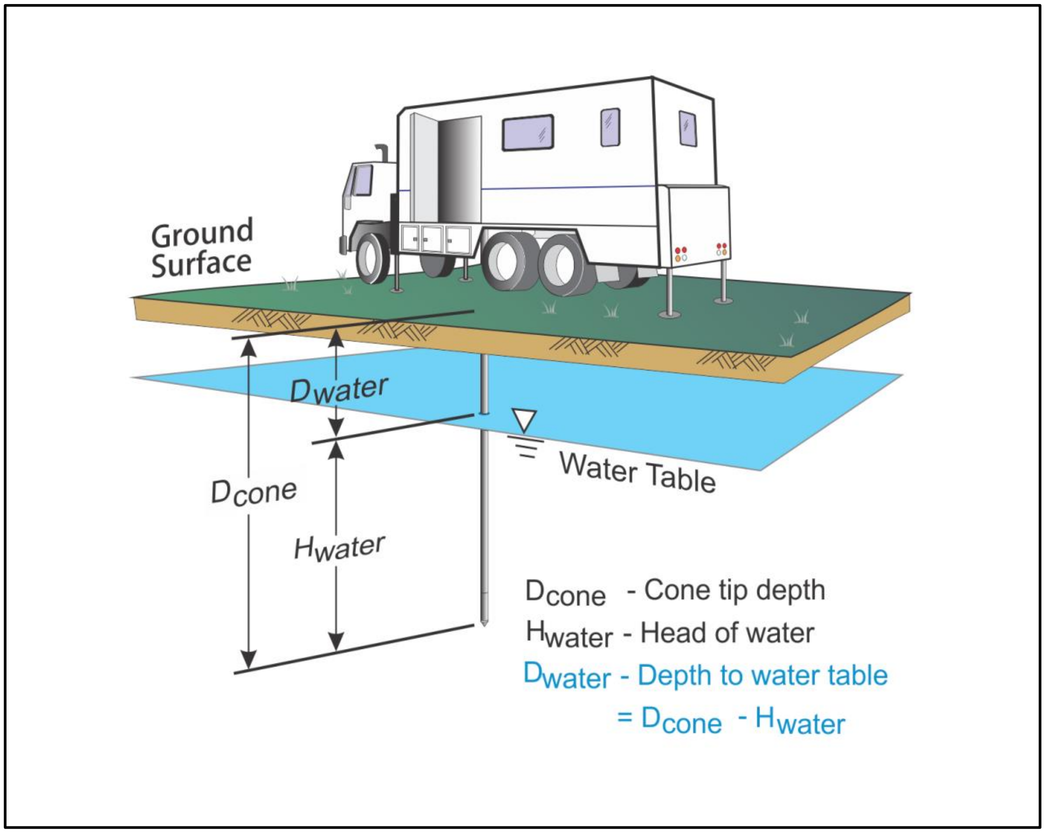


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behaviour.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

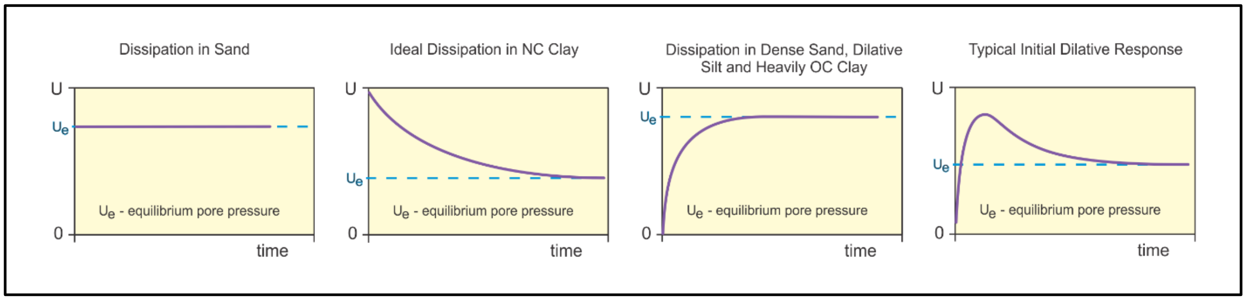


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve in Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100}. In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100}. A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

T^* is the dimensionless time factor (Table Time Factor)
a is the radius of the cone
I_r is the rigidity index
t is the time at the degree of consolidation

Table Time Factor. T* versus degree of dissipation (Teh and Houlsby (1991))

Degree of Dissipation (%)	20	30	40	50	60	70	80
T^* (u_2)	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50}, dissipation tests must be taken to a pressure less than u_{50}. The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100}. To estimate u_{50}, both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby (1991)), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50}. In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r, the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50}, other methods should be applied to confirm the results for c_h.

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

References

Burns, S.E. and Mayne, P.W., 1998, “Monotonic and dilatory pore pressure decay during piezocone tests”, Canadian Geotechnical Journal 26 (4): 1063-1073. DOI: 1063-1073/T98-062.

Burns, S.E. and Mayne, P.W., 2002, “Analytical cavity expansion-critical state model cone dissipation in fine-grained soils”, Soils & Foundations, Vol. 42(2): 131-137.

Jones, G.A. and Van Zyl, D.J.A., 1981, “The piezometer probe: a useful investigation tool”, Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering, Vol. 3, Stockholm: 489-495.

Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, “Estimating coefficient of consolidation from piezocone tests”, Canadian Geotechnical Journal, 29(4): 539-550. DOI: 10.1139/T92-061.

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, “An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils”, Canadian Geotechnical Journal, 36(2): 369-381. DOI: 10.1139/T98-105.

Teh, C.I., and Houlsby, G.T., 1991, “An analytical study of the cone penetration test in clay”, Geotechnique, 41(1): 17-34. DOI: 10.1680/geot.1991.41.1.17.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Standard Cone Penetration Test Plots with Expanded Range
- Advanced Cone Penetration Test Plots with Ic, Su(Nkt), Phi, and N1(60)Ic
- Soil Behaviour Type (SBT) Scatter Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots
- Description of Methods for Calculated CPT Geotechnical Parameters

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

CONETEC

CONETEC

Job No: 21-02-22683
Client: Ministry of Transportation and Infrastructure
Project: Daly Bridge, Creighton Valley
Start Date: 07-Jul-2021
End Date: 07-Jul-2021

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Cone Area (cm^2)	Assumed Phreatic Surface[1] (m)	Final Depth (m)	Northing[2] (m)	Easting[2] (m)	Refer to Notation Number
CPT21-01	21-02-22683_CP01	07-Jul-2021	750:T1500F15U35	15	1.1	30.300	5567267	361773	
CPT21-02	21-02-22683_CP02	07-Jul-2021	750:T1500F15U35	15	1.2	8.650	5567276	361795	

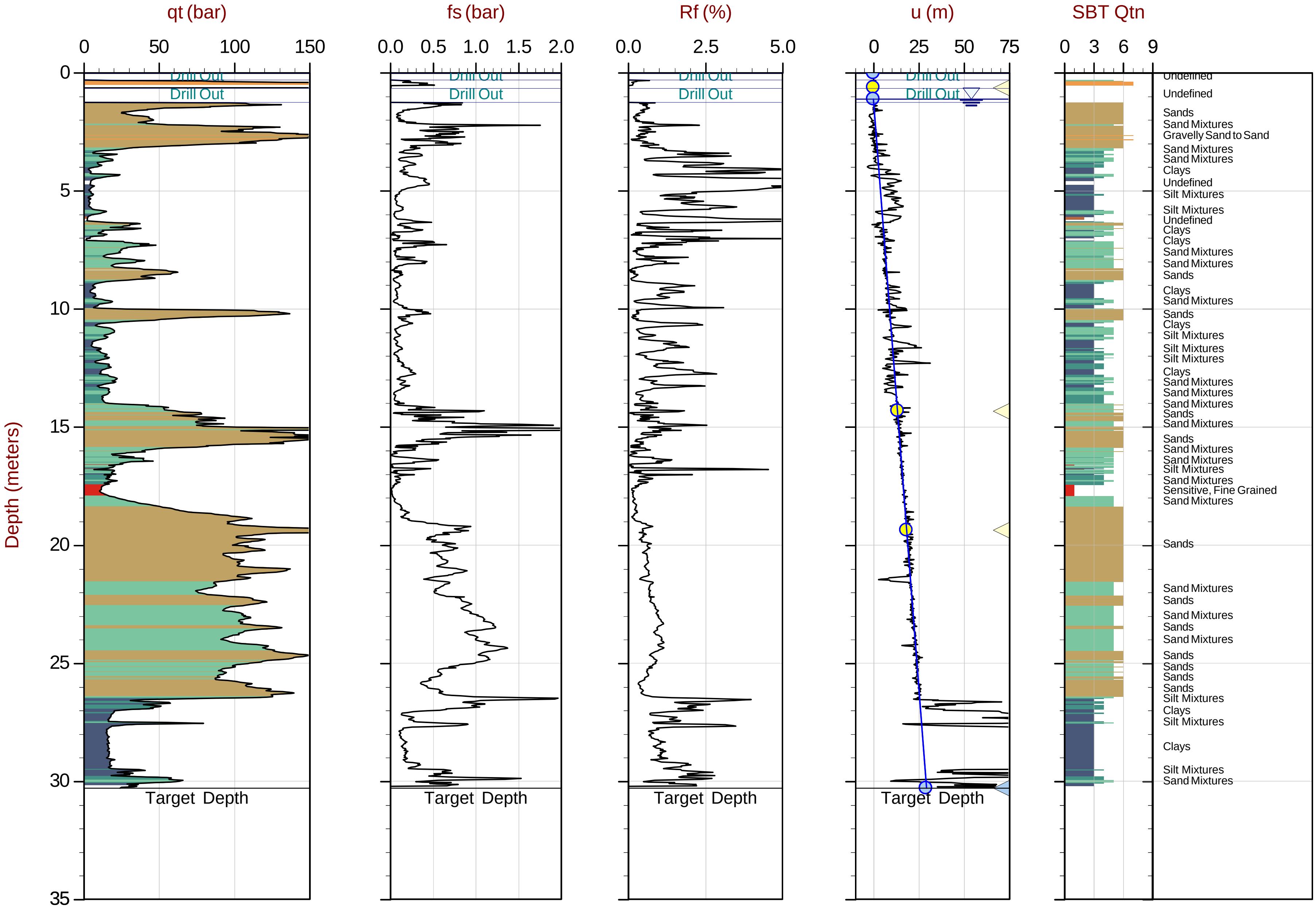
1. The assumed phreatic surface was based on pore pressure dissipation tests. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were collected with consumer grade GPS equipment. Datum: WGS 1984 / UTM Zone 11 North.

CONETEC

MoTI

Job No: 21-02-22683
Date: 2021-07-07 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 30.300 m / 99.41 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N: 5567267m E: 361773m
Page No: 1 of 1

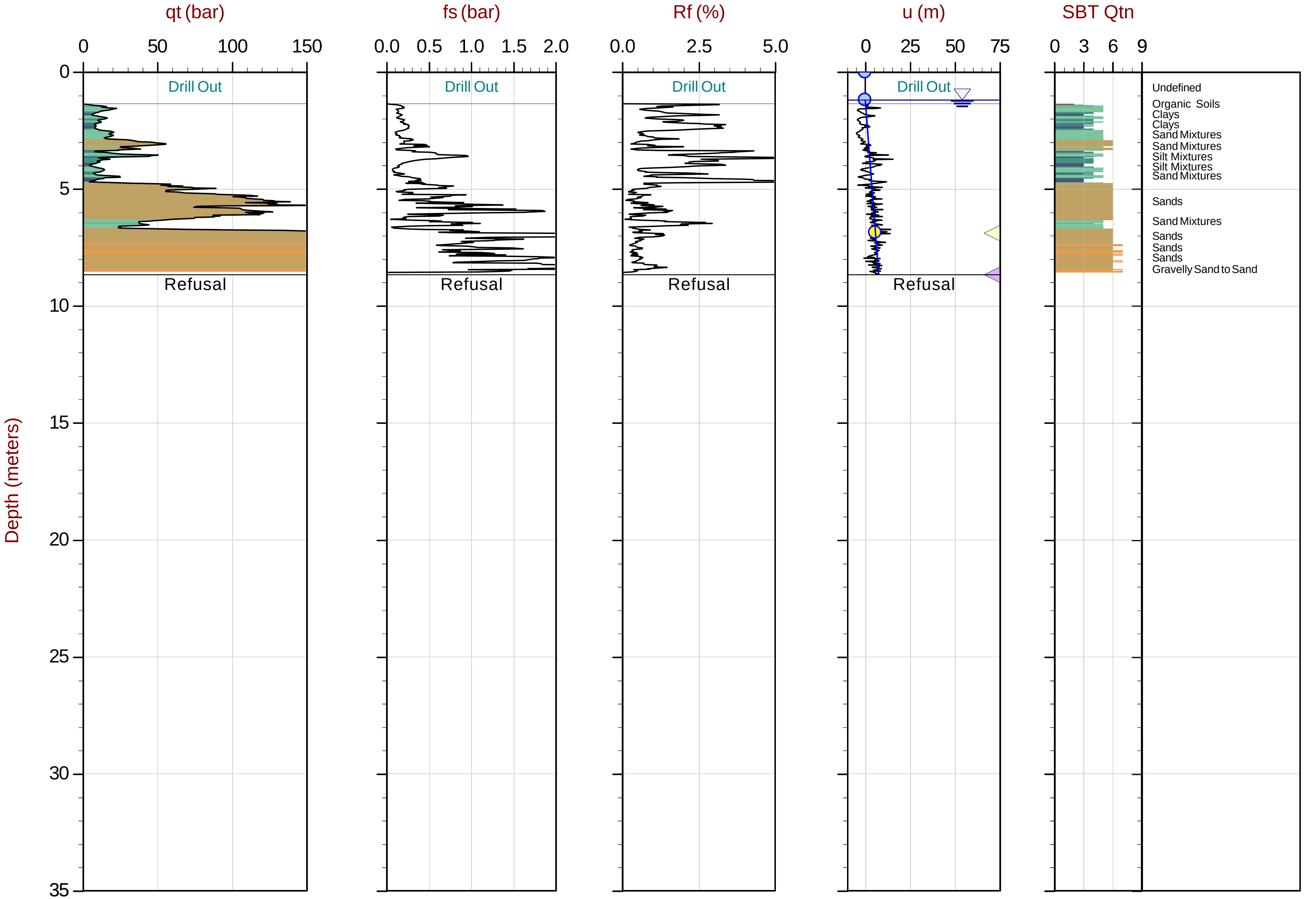
Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

MoTI

Job No: 21-02-22683
Date: 2021-07-07 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 8.650 m / 28.38 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N:5567276m E:361795m
Page No: 1 of 1

Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

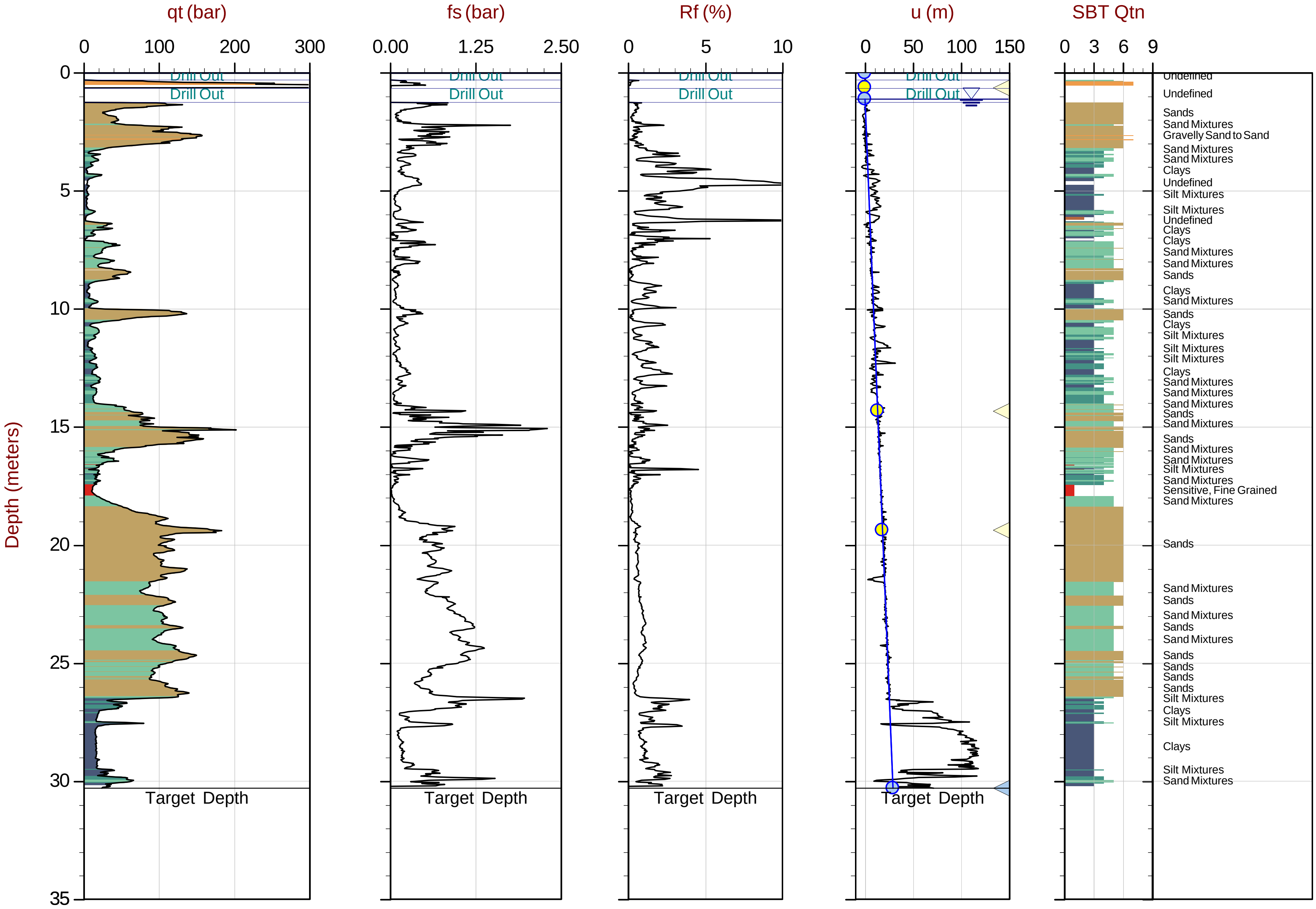
Standard Cone Penetration Test Plots with Expanded Range

ConeTec

MoTI

Job No: 21-02-22683
Date: 2021-07-07 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 30.300 m / 99.41 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N: 5567267m E: 361773m
Page No: 1 of 1

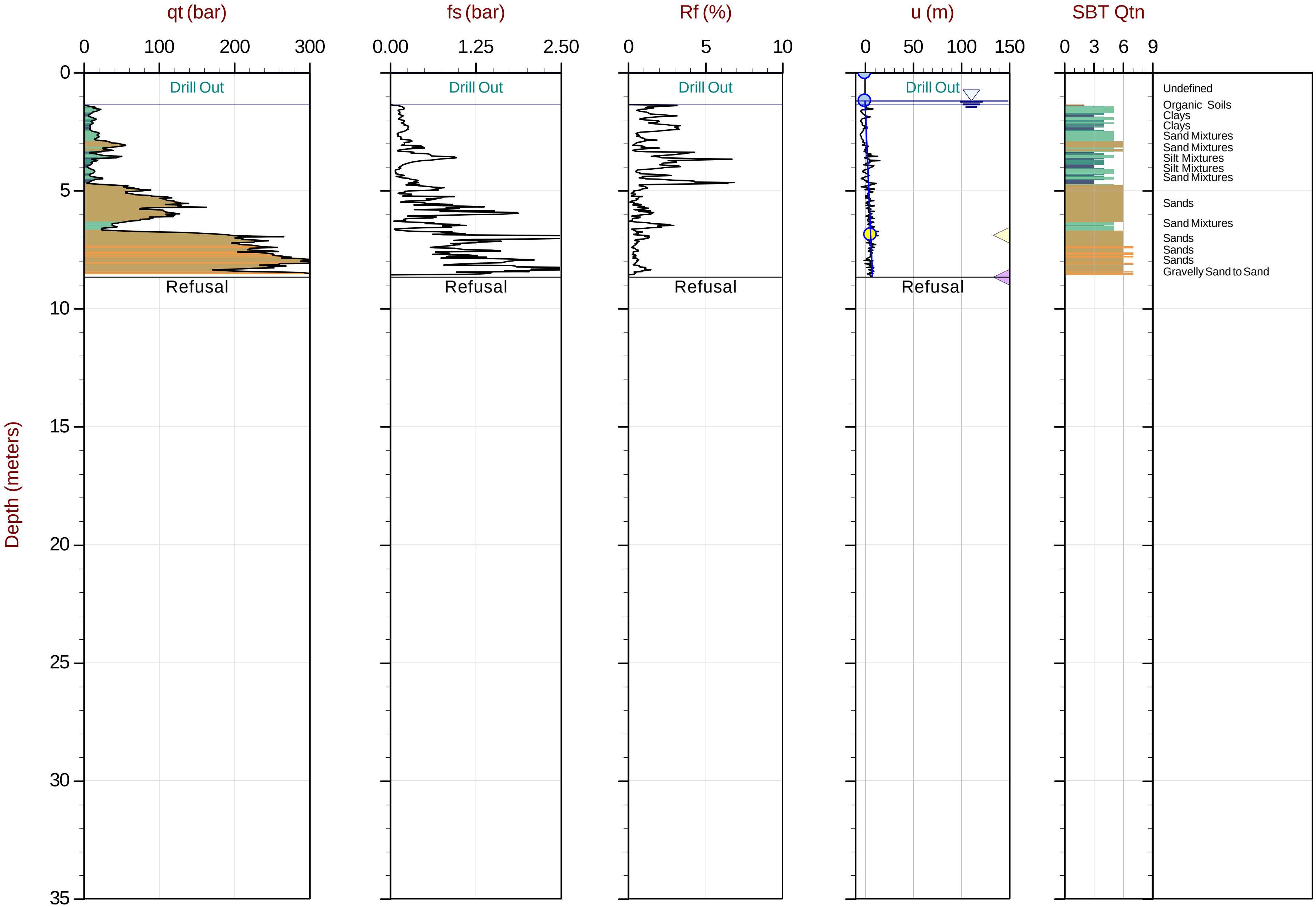
Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

MoTI

Job No: 21-02-22683
Date: 2021-07-07 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 8.650 m / 28.38 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N:5567276m E:361795m
Page No: 1 of 1

Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Advanced Cone Penetration Plots with Ic, Su(Nkt), Phi, and N1(60)lc

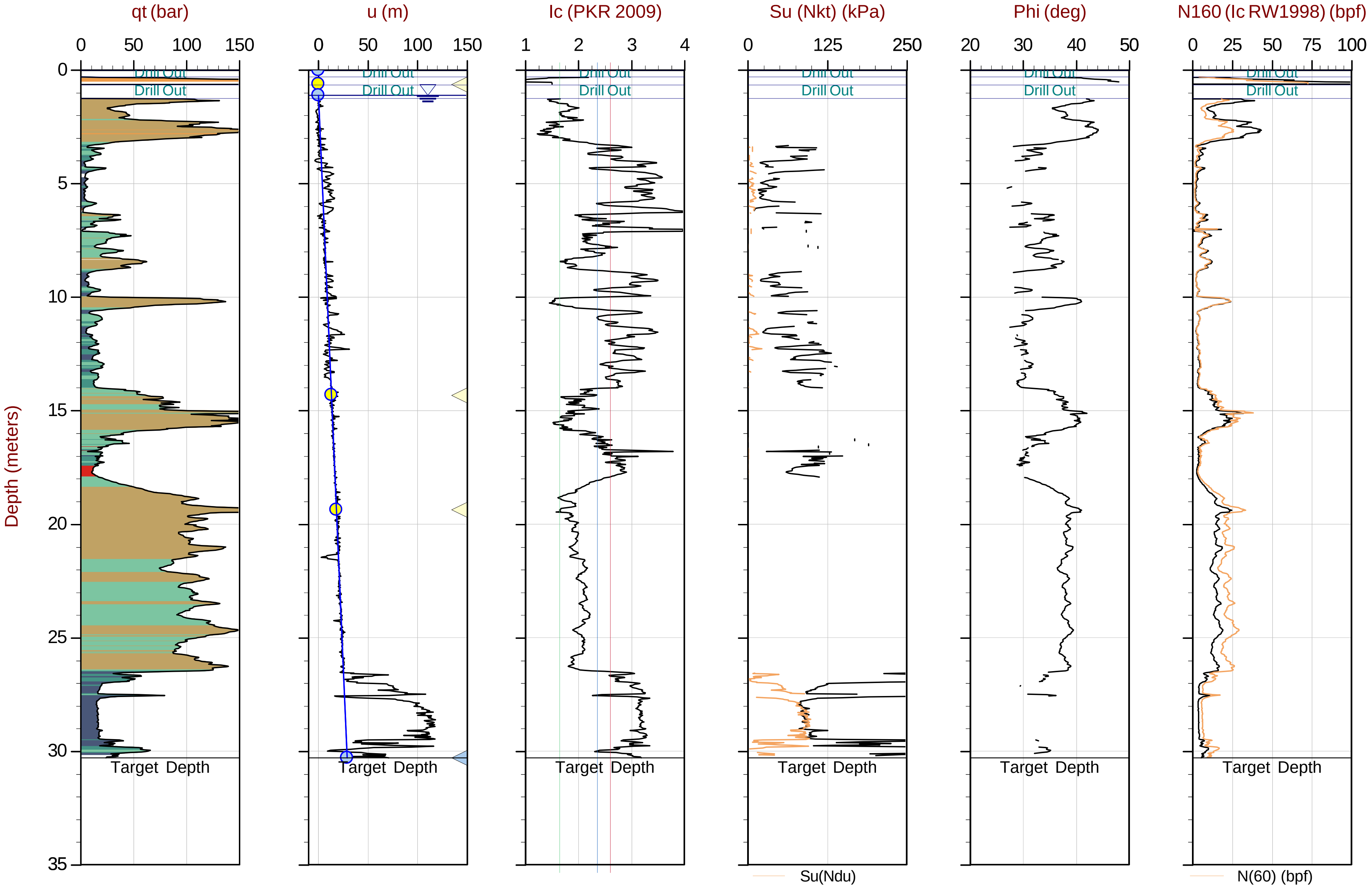
ConeTec

CONETEC

MoTI

Job No: 21-02-22683
Date: 2021-07-07 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 30.300 m / 99.41 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP01.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt/Ndu: 12.0 / 9.0

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N:5567267m E:361773m
Page No: 1 of 1

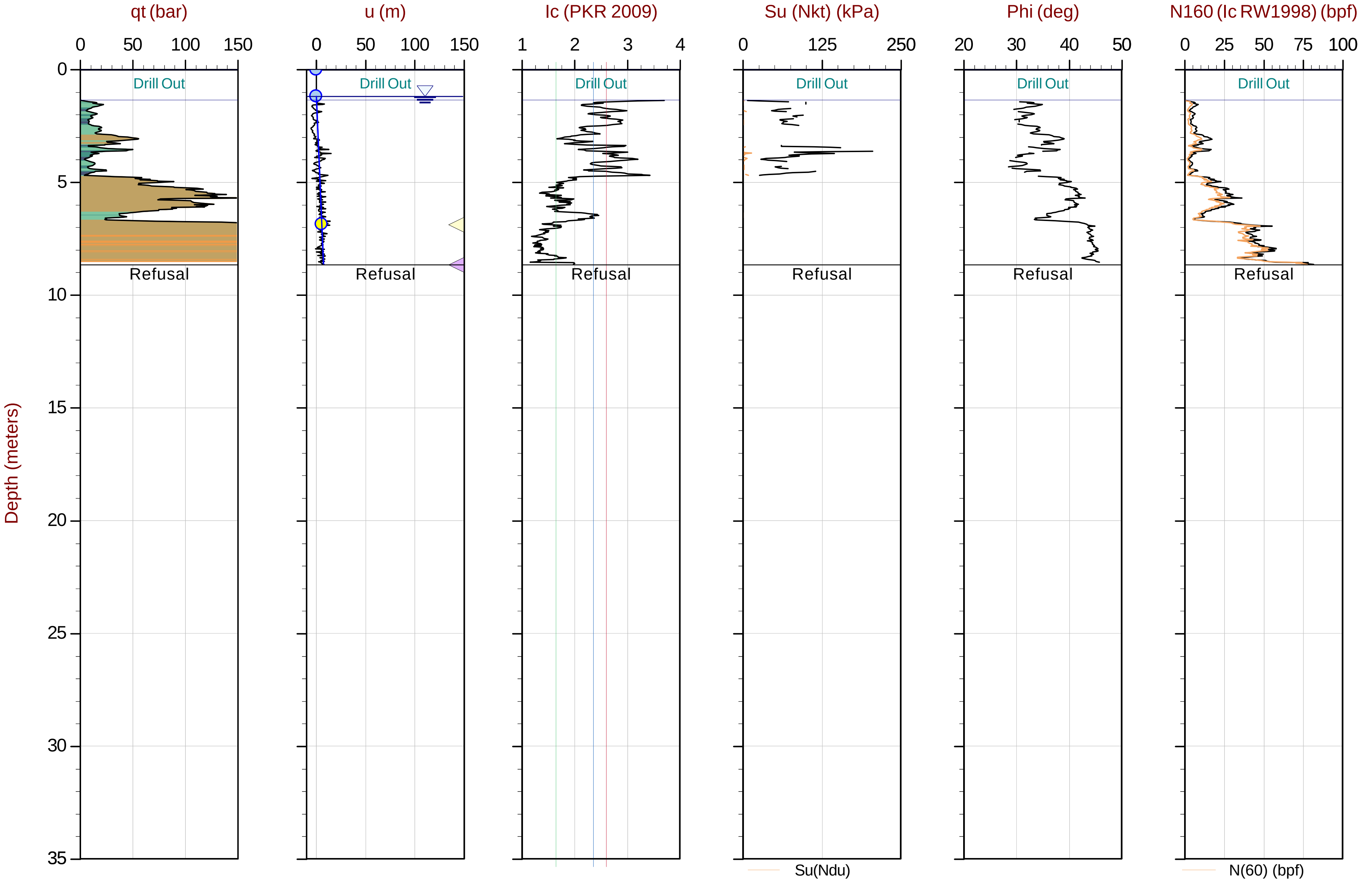
Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

MoTI

Job No: 21-02-22683
Date: 2021-07-07 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35 Area=15 cm2



Max Depth: 8.650 m / 28.38 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-02-22683_CP02.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt/Ndu: 12.0 / 9.0

SBT: Robertson, 2009 and 2010
Coords: UTM 11N N: 5567276m E: 361795m
Page No: 1 of 1

Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Ueq Line — Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Soil Behaviour Type (SBT) Scatter Plots

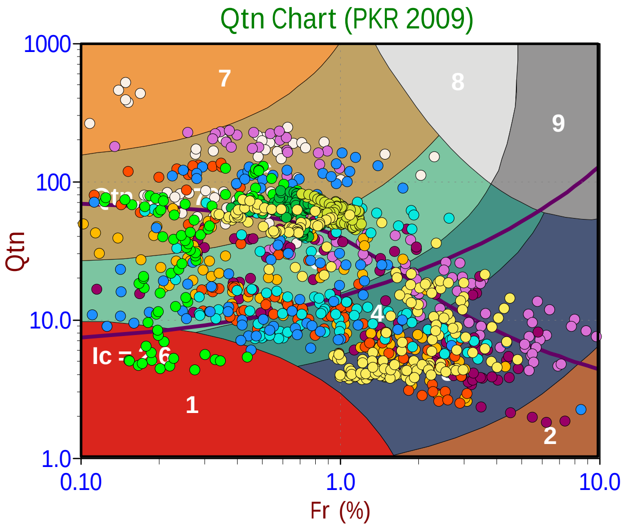
CONETEC

MoTI

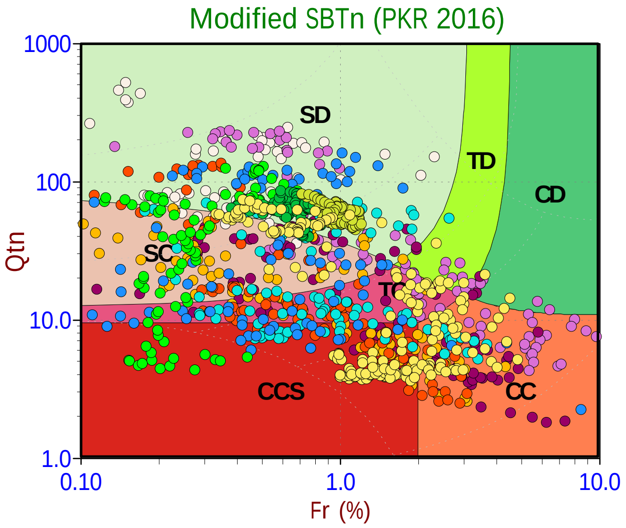
Job No: 21-02-22683
Date: 2021-07-07 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35

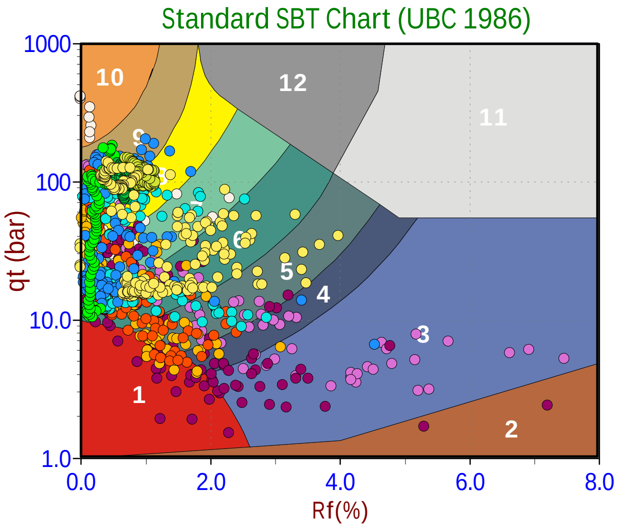
Qtn Chart (PKR 2009)



Modified SBTn (PKR 2016)



Standard SBT Chart (UBC 1986)



Depth Ranges
- ● >0.0 to 2.5 m
- ● >2.5 to 5.0 m
- ● >5.0 to 7.5 m
- ● >7.5 to 10.0 m
- ● >10.0 to 12.5 m
- ● >12.5 to 15.0 m
- ● >15.0 to 17.5 m
- ● >17.5 to 20.0 m
- ● >20.0 to 22.5 m
- ● >22.5 to 25.0 m
- ● >25.0 m

Legend
- ■ Sensitive, Fine Grained
- ■ Organic Soils
- ■ Clays
- ■ Silt Mixtures
- ■ Sand Mixtures
- ■ Sands
- ■ Gravelly Sand to Sand
- ■ Stiff Sand to Clayey Sand
- ■ Very Stiff Fine Grained

Legend
- ■ CCS (Cont. sensitive clay like)
- ■ CC (Cont. clay like)
- ■ TC (Cont. transitional)
- ■ SC (Cont. sand like)
- ■ CD (Dil. clay like)
- ■ TD (Dil. transitional)
- ■ SD (Dil. sand like)

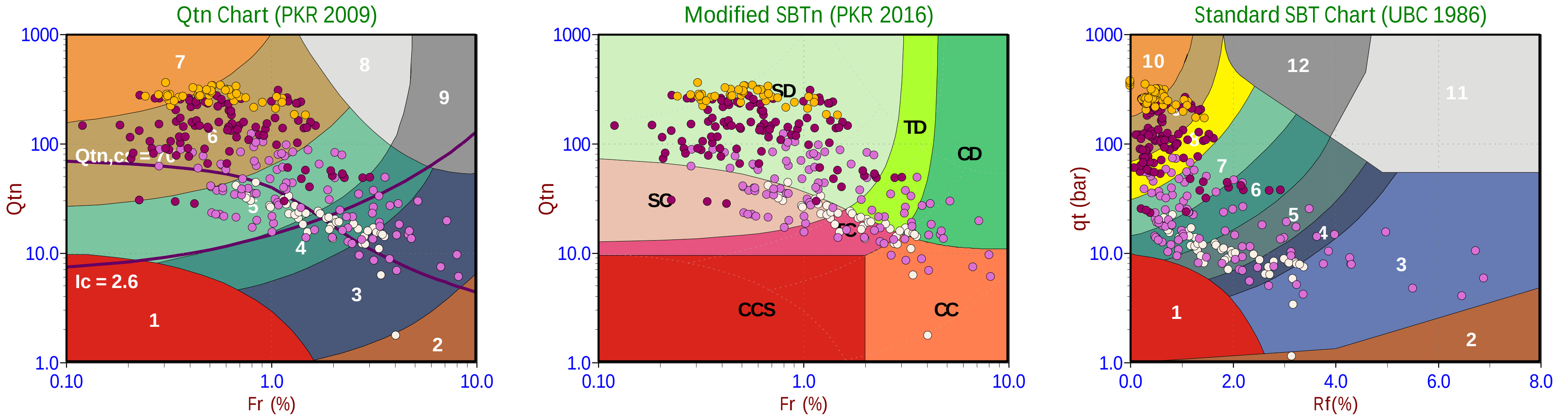
Legend
- ■ Sensitive Fines
- ■ Organic Soil
- ■ Clay
- ■ Silty Clay
- ■ Clayey Silt
- ■ Silt
- ■ Sandy Silt
- ■ Silty Sand/Sand
- ■ Sand
- ■ Gravelly Sand
- ■ Stiff Fine Grained
- ■ Cemented Sand

CONETEC

MoTI

Job No: 21-02-22683
Date: 2021-07-07 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35



Depth Ranges

- ⚪ >0.0 to 2.5 m
- 🟣 >2.5 to 5.0 m
- 🟣 >5.0 to 7.5 m
- 🟠 >7.5 to 10.0 m
- 🔴 >10.0 to 12.5 m
- 🔵 >12.5 to 15.0 m
- 🔵 >15.0 to 17.5 m
- 🟢 >17.5 to 20.0 m
- 🟢 >20.0 to 22.5 m
- 🟡 >22.5 to 25.0 m
- 🟡 >25.0 m

Legend

- 🟥 Sensitive, Fine Grained
- 🟫 Organic Soils
- 🟦 Clays
- 🟩 Silt Mixtures
- 🟩 Sand Mixtures
- 🟫 Sands
- 🟧 Gravelly Sand to Sand
- ⬜ Stiff Sand to Clayey Sand
- ⬛ Very Stiff Fine Grained

Legend

- 🟥 CCS (Cont. sensitive clay like)
- 🟧 CC (Cont. clay like)
- 🟥 TC (Cont. transitional)
- 🟫 SC (Cont. sand like)
- 🟩 CD (Dil. clay like)
- 🟩 TD (Dil. transitional)
- 🟩 SD (Dil. sand like)

Legend

- 🟥 Sensitive Fines
- 🟫 Organic Soil
- 🟦 Clay
- 🟦 Silty Clay
- 🟩 Clayey Silt
- 🟩 Silt
- 🟩 Sandy Silt
- 🟨 Silty Sand/Sand
- 🟫 Sand
- 🟧 Gravelly Sand
- ⬜ Stiff Fine Grained
- ⬛ Cemented Sand

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Job No:	21-02-22683
Client:	Ministry of Transportation and Infrastructure
Project:	Daly Bridge, Creighton Valley
Start Date:	07-Jul-2021
End Date:	07-Jul-2021

CPTu PORE PRESSURE DISSIPATION SUMMARY

Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (m)	Equilibrium Pore Pressure U_{eq} (m)	Estimated Equilibrium Pore Pressure U_{eq} (m)	Calculated Phreatic Surface (m)	t_{50}[a] (s)	Assumed Rigidity Index (I_r)	c_h[b] (cm^2/min)
CPT21-01	21-02-22683_CP01	15	660	0.625	0.0					
CPT21-01	21-02-22683_CP01	15	365	14.325	13.2		1.1			
CPT21-01	21-02-22683_CP01	15	310	19.375	18.1		1.3			
CPT21-01	21-02-22683_CP01	15	355	30.300	Not Achieved	29.0	1.3	143	100	4.9
CPT21-02	21-02-22683_CP02	15	305	6.875	5.7		1.2			
CPT21-02	21-02-22683_CP02	15	430	8.650	Not Achieved					

a. Time is relative to where umax occurred.

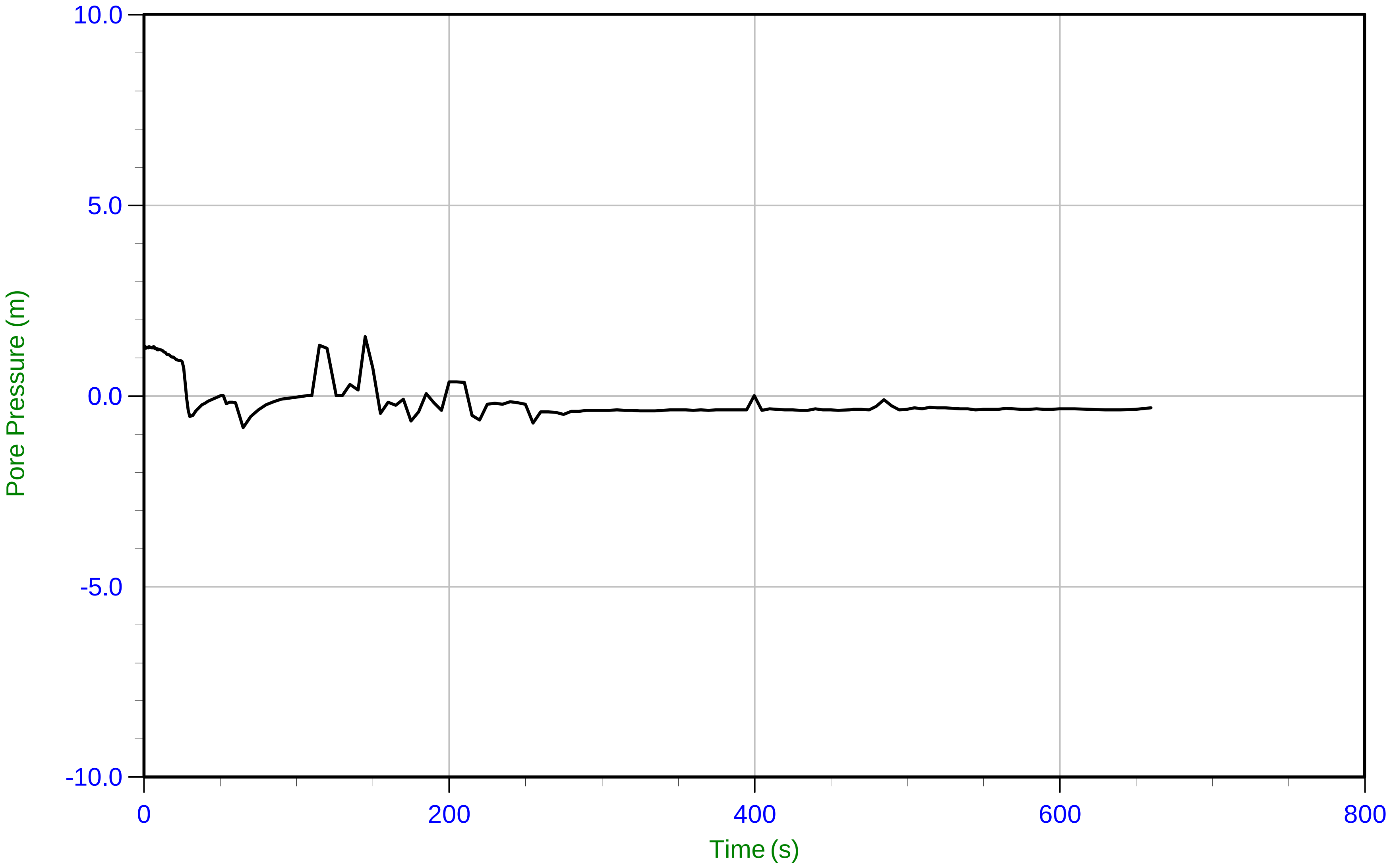
b. Houlsby and Teh, 1991.

CONETEC

MoTI

Job No: 21-02-22683
Date: 07/07/2021 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35 Area=15 cm²



Trace Summary:

Filename: 21-02-22683_CP01.PPF
Depth: 0.625 m / 2.050 ft
Duration: 660.0 s

u Min: -0.8 m
u Max: 1.6 m
u Final: -0.3 m

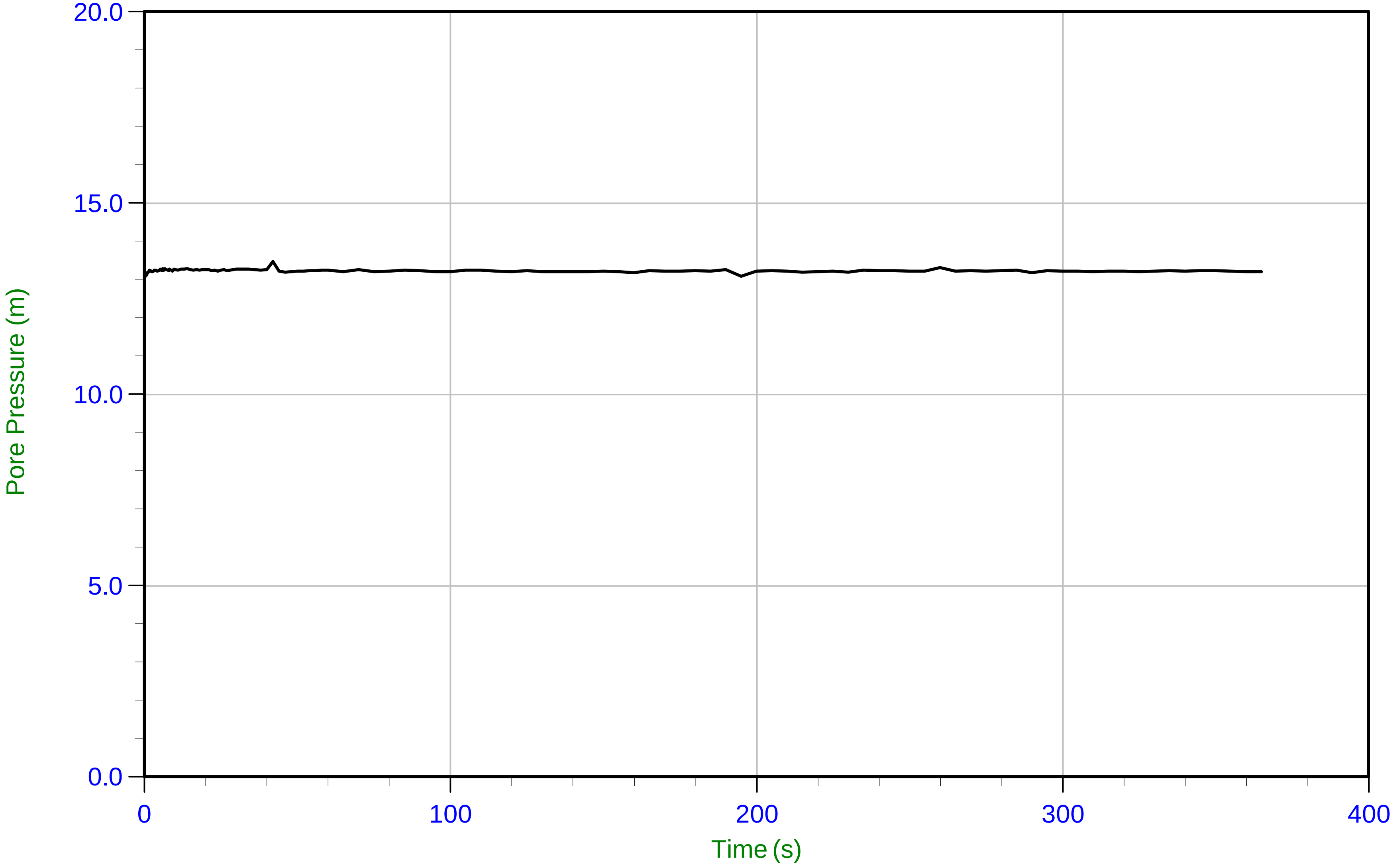
WT: 0.625 m / 2.050 ft
Ueq: 0.0 m

CONETEC

MoTI

Job No: 21-02-22683
Date: 07/07/2021 08:54
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-01
Cone: 750:T1500F15U35 Area=15 cm²

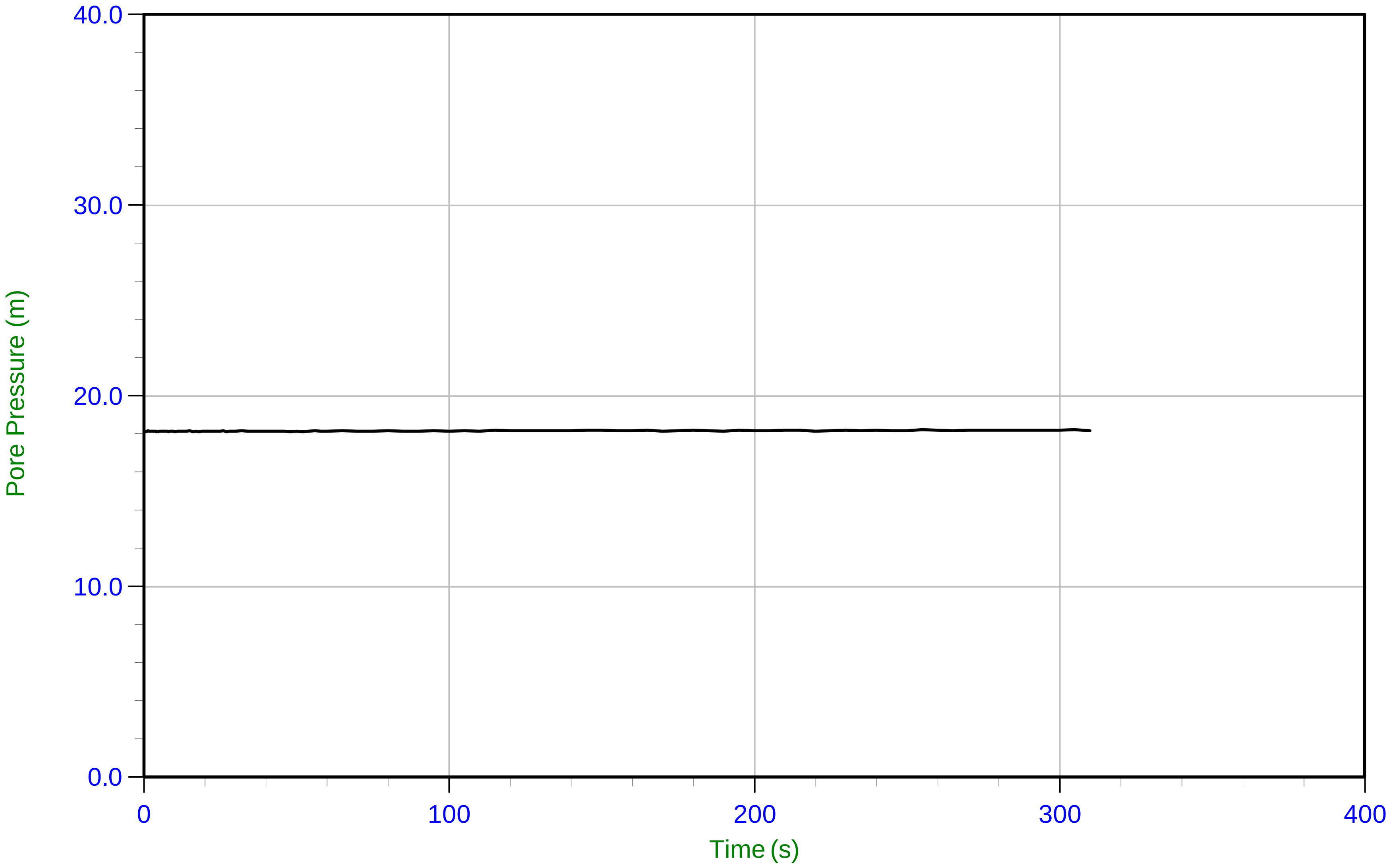


Trace Summary:

Filename: 21-02-22683_CP01.PPF
Depth: 14.325 m / 46.997 ft
Duration: 365.0 s

u Min: 13.0 m
u Max: 13.5 m
u Final: 13.2 m

WT: 1.114 m / 3.655 ft
Ueq: 13.2 m

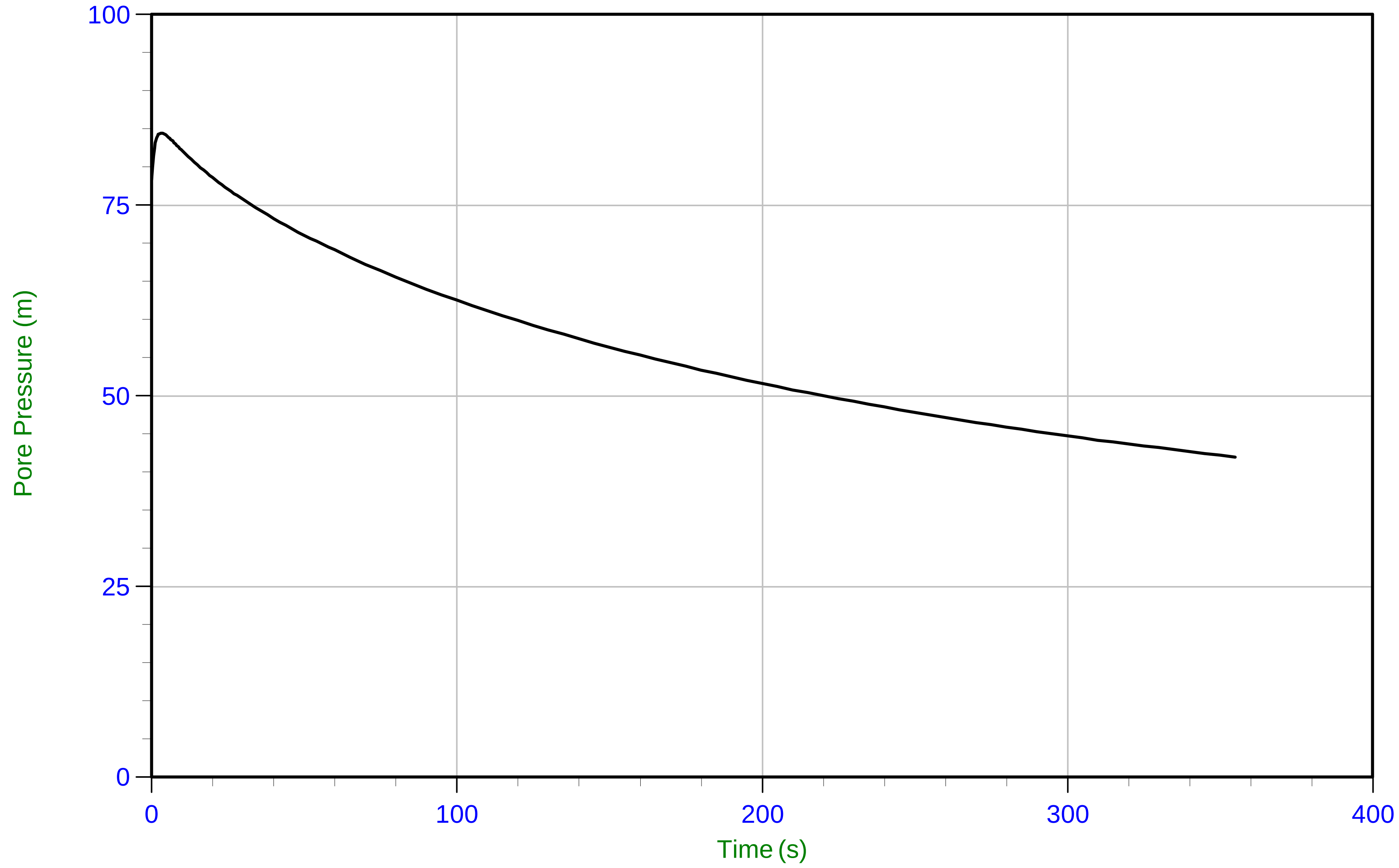


Trace Summary:

Filename: 21-02-22683_CP01.PPF
Depth: 19.375 m / 63.566 ft
Duration: 310.0 s

u Min: 18.1 m
u Max: 18.2 m
u Final: 18.2 m

WT: 1.270 m / 4.167 ft
Ueq: 18.1 m



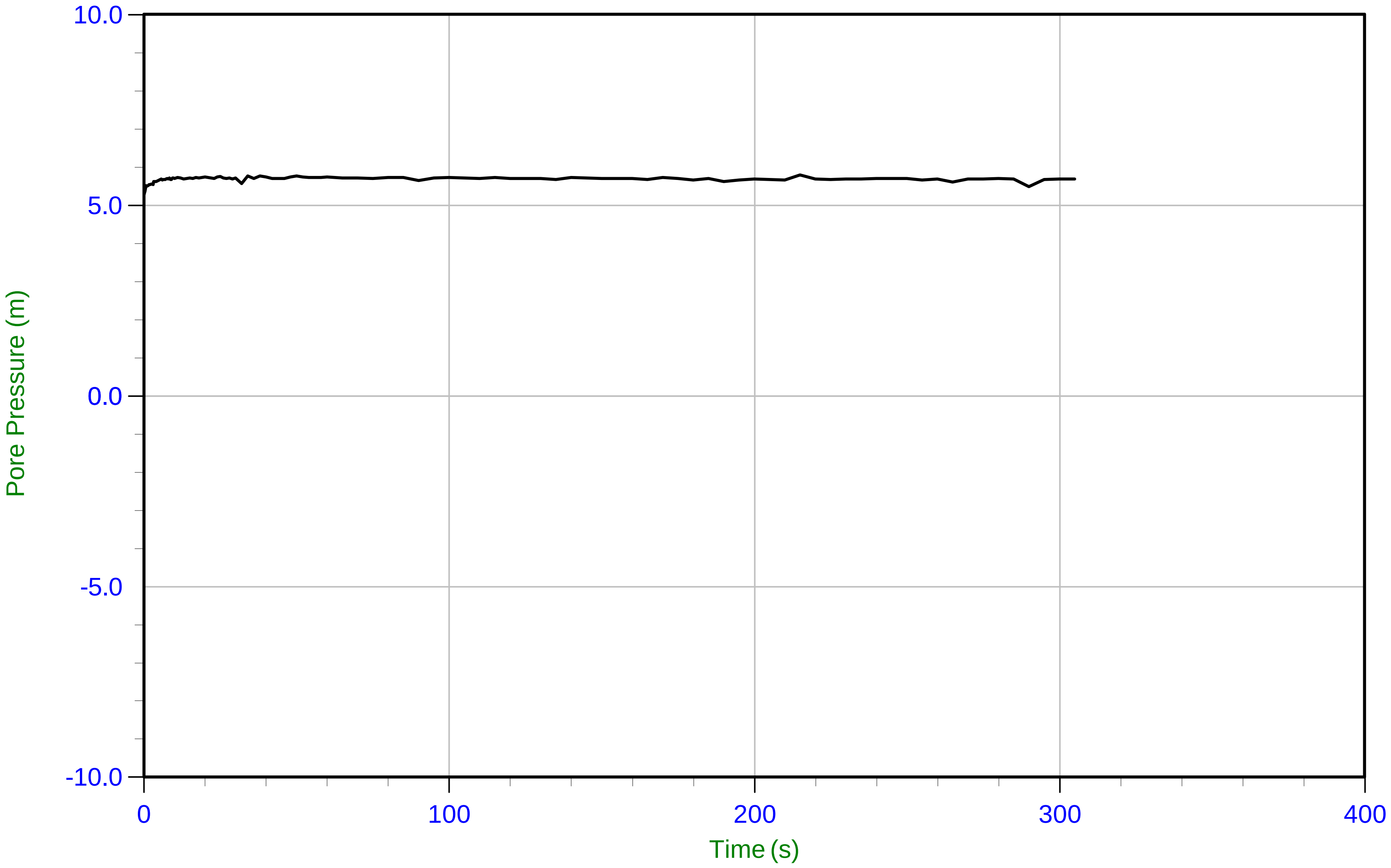
Trace Summary:

Filename: 21-02-22683_CP01.PPF	u Min: 42.0 m	WT: 1.270 m / 4.167 ft	T(50): 143.3 s
Depth: 30.300 m / 99.408 ft	u Max: 84.5 m	Ueq: 29.0 m	Ir: 100
Duration: 355.0 s	u Final: 42.0 m	U(50): 56.74 m	Ch: 4.9 cm²/min

MoTI

Job No: 21-02-22683
Date: 07/07/2021 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35 Area=15 cm²



Trace Summary:

Filename: 21-02-22683_CP02.PPF
Depth: 6.875 m / 22.556 ft
Duration: 305.0 s

u Min: 5.3 m
u Max: 5.8 m
u Final: 5.7 m

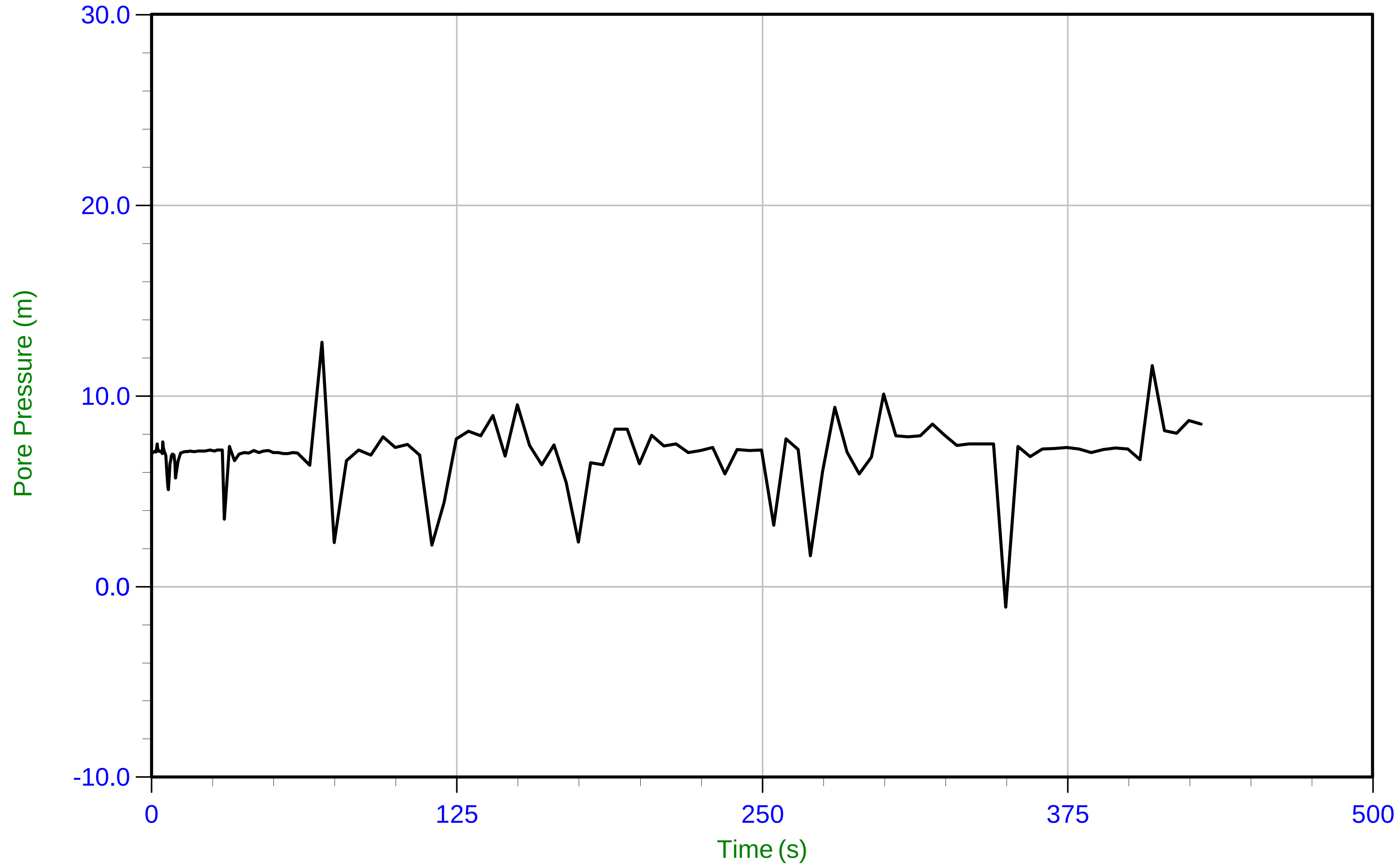
WT: 1.191 m / 3.907 ft
Ueq: 5.7 m

CONETEC

MoTI

Job No: 21-02-22683
Date: 07/07/2021 12:48
Site: Daly Bridge Creighton Valley Rd

Sounding: CPT21-02
Cone: 750:T1500F15U35 Area=15 cm²



Trace Summary:

Filename: 21-02-22683_CP02.PPF
Depth: 8.650 m / 28.379 ft
Duration: 430.0 s

u Min: -1.1 m
u Max: 12.8 m
u Final: 8.5 m

Description of Methods for Calculated CPT Geotechnical Parameters

CALCULATED CPT GEOTECHNICAL PARAMETERS

A Detailed Description of the Methods Used in ConeTec's CPT Geotechnical Parameter Calculation and Plotting Software

Revision SZW-Rev 14

Revised November 26, 2019
Prepared by Jim Greig, M.A.Sc, P.Eng (BC)

Limitations

The geotechnical parameter output was prepared specifically for the site and project named in the accompanying report subject to objectives, site conditions and criteria provided to ConeTec by the client. The output may not be relied upon by any other party or for any other site without the express written permission of ConeTec Group (ConeTec) or any of its affiliates. For this project, ConeTec has provided site investigation services, prepared factual data reporting and produced geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

To understand the calculations that have been performed and to be able to reproduce the calculated parameters the user is directed to the basic descriptions for the methods in this document and the detailed descriptions and their associated limitations and appropriateness in the technical references cited for each parameter.

ConeTec's Calculated CPT Geotechnical Parameters as of November 26, 2019

ConeTec's CPT parameter calculation and plotting routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. Due to drainage conditions and the basic assumptions and limitations of the correlations, not all geotechnical parameters provided are considered applicable for all soil types. The results are presented only as a guide for geotechnical use and should be carefully examined for consideration in any geotechnical design. Reference to current literature is strongly recommended. ConeTec does not warranty the correctness or the applicability of any of the geotechnical parameters calculated by the program and does not assume liability for any use of the results in any design or review. For verification purposes we recommend that representative hand calculations be done for any parameter that is critical for design purposes. The end user of the parameter output should also be fully aware of the techniques and the limitations of any method used by the program. The purpose of this document is to inform the user as to which methods were used and to direct the end user to the appropriate technical papers and/or publications for further reference.

The geotechnical parameter output was prepared specifically for the site and project named in the accompanying report subject to objectives, site conditions and criteria provided to ConeTec by the client. The output may not be relied upon by any other party or for any other site without the express written permission of ConeTec Group (ConeTec) or any of its affiliates.

The CPT calculations are based on values of tip resistance, sleeve friction and pore pressures considered at each data point or averaged over a user specified layer thickness (e.g. 0.20 m). Note that q_t is the tip resistance corrected for pore pressure effects and q_c is the recorded tip resistance. The corrected tip resistance (corrected using u_2 pore pressure values) is used for all of the calculations. Since all ConeTec cones have equal end area friction sleeves pore pressure corrections to sleeve friction, f_s, are not required.

The tip correction is: $q_t = q_c + (1-a) \bullet u_2$ (consistent units are implied)

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the cone (typically 0.80 for ConeTec cones)

The total stress calculations are based on soil unit weight values that have been assigned to the Soil Behavior Type (SBT) zones, from a user defined unit weight profile, by using a single uniform value throughout the profile, through unit weight estimation techniques described in various technical papers or from a combination of these methods. The parameter output files indicate the method(s) used.

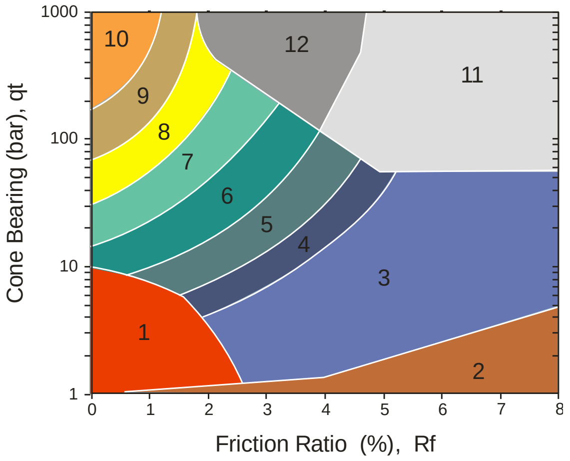
Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (typically obtained from CPT dissipation tests) or a combination of the two. For over water projects the stress effects of the column of water above the mudline have been taken into account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at the mudline). The parameter output files indicate the method(s) used.

A majority of parameter calculations are derived or driven by results based on material types as determined by the various soil behavior type charts depicted in Figures 1 through 5. The parameter output files indicate the method(s) used.

The Soil Behavior Type classification chart shown in Figure 1 is the classic non-normalized SBT Chart developed at the University of British Columbia and reported in Robertson, Campanella, Gillespie and Greig (1986). Figure 2 shows the original normalized (linear method) SBT chart developed by Robertson (1990). The Bq classification charts shown in Figures 3a and 3b incorporate pore pressures into the SBT classification and are based on the methods described in Robertson (1990). Many of these charts have been summarized in Lunne, Robertson and Powell (1997). The

Jefferies and Davies SBT chart shown in Figure 3c is based on the techniques discussed in Jefferies and Davies (1993) which introduced the concept of the Soil Behavior Type Index parameter, I_c. Please note that the I_c parameter developed by Robertson and Fear (1995) and Robertson and Wride (1998) is similar in concept but uses a slightly different calculation method than that used by Jefferies and Davies (1993) as the latter incorporates pore pressure in their technique through the use of the Bq parameter. The normalized Qtn SBT chart shown in Figure 4 is based on the work by Robertson (2009) utilizing a variable stress ratio exponent, n, for normalization based on a slightly modified redefinition and iterative approach for I_c. The boundary curves drawn on the chart are based on the work described in Robertson (2010).

Figure 5 shows a revised behavior based chart by Robertson (2016) depicting contractive-dilative zones. As the zones represent material behavior rather than soil gradation ConeTec has chosen a set of zone colors that are less likely to be confused with material type colors from previous SBT charts. These colors differ from those used by Dr. Robertson.

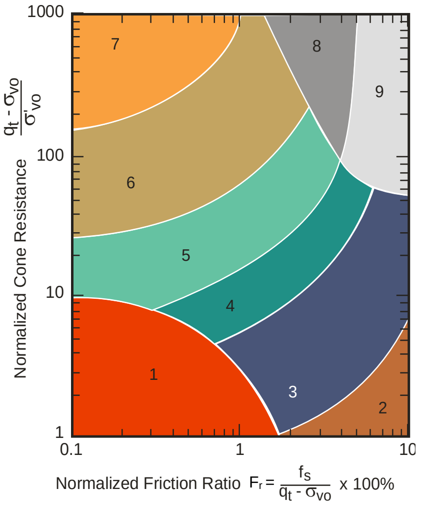


Zone		qt / N	Soil Behavior Type
1	🟥	2	sensitive fine grained
2	🟫	1	organic material
3	🟦	1	clay
4	🟦	1.5	silty clay to clay
5	🟩	2	clayey silt to silty clay
6	🟩	2.5	sandy silt to clayey silt
7	🟩	3	silty sand to sandy silt
8	🟨	4	sand to silty sand
9	🟫	5	sand
10	🟧	6	gravelly sand to sand
11	⬜	1	very stiff fine grained *
12	⬛	2	sand to clayey sand *

* overconsolidated or cemented

$$Rf = \left(\frac{fs}{qt}\right) \cdot 100\%$$

Figure 1. Non-Normalized Soil Behavior Type Classification Chart (SBT)



Zone		Normalized Soil Behavior Type
1	🟥	sensitive fine grained
2	🟫	organic material
3	🟦	clay to silty clay
4	🟩	clayey silt to silty clay
5	🟩	silty sand to sandy silt
6	🟫	clean sands to silty sands
7	🟧	gravelly sand to sand
8	⬛	very stiff sand to clayey sand
9	⬜	very stiff fine grained

Figure 2. Normalized Soil Behavior Type Classification Chart (SBTn)

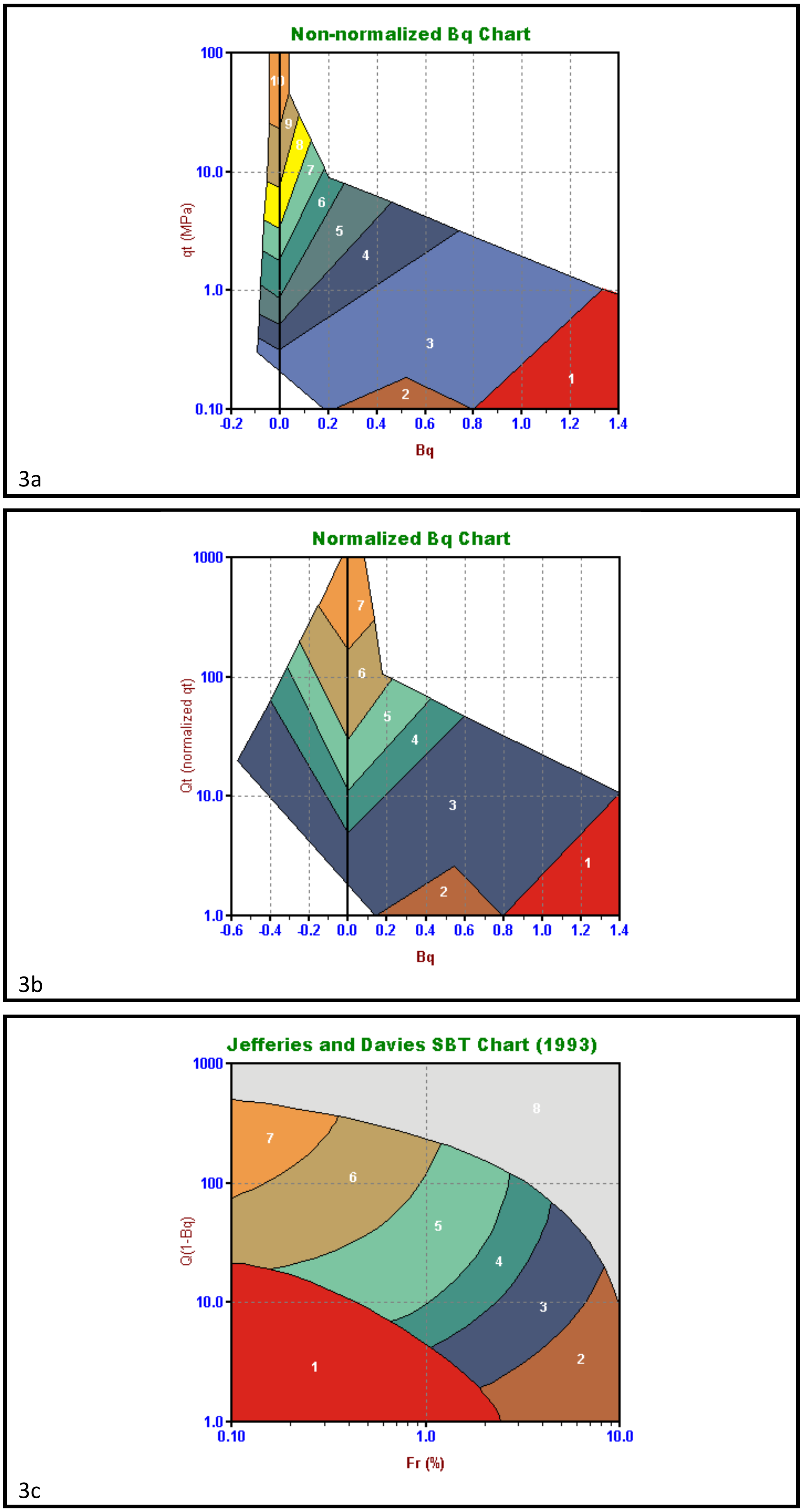


Figure 3. Alternate Soil Behavior Type Charts

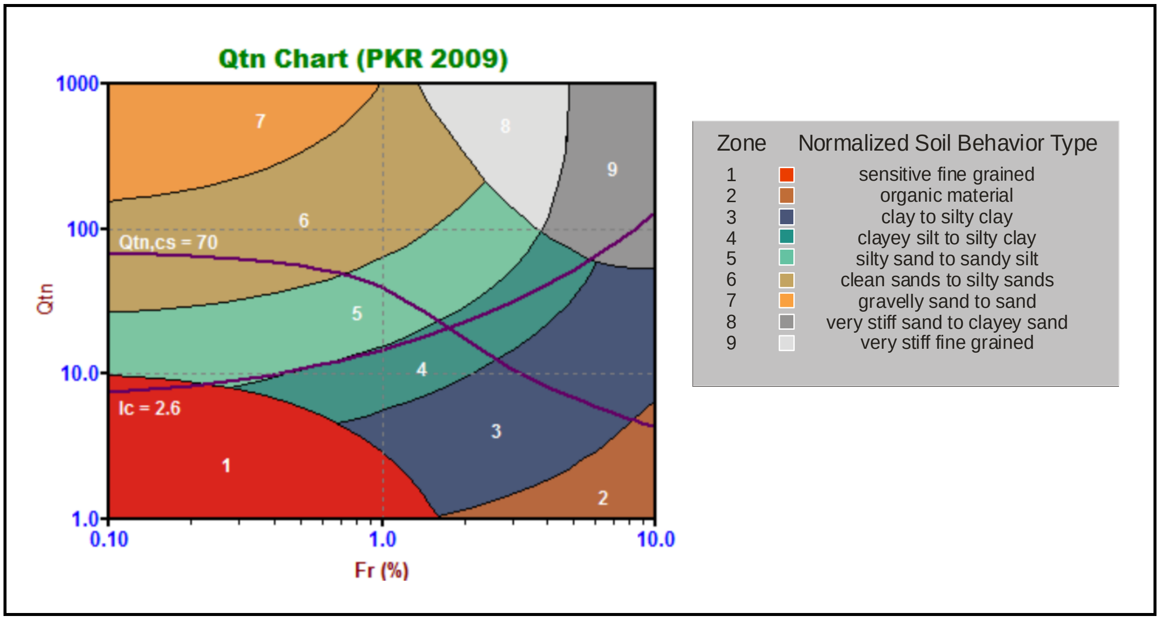


Figure 4. Normalized Soil Behavior Type Chart using Q_{tn} (SBT Qtn)

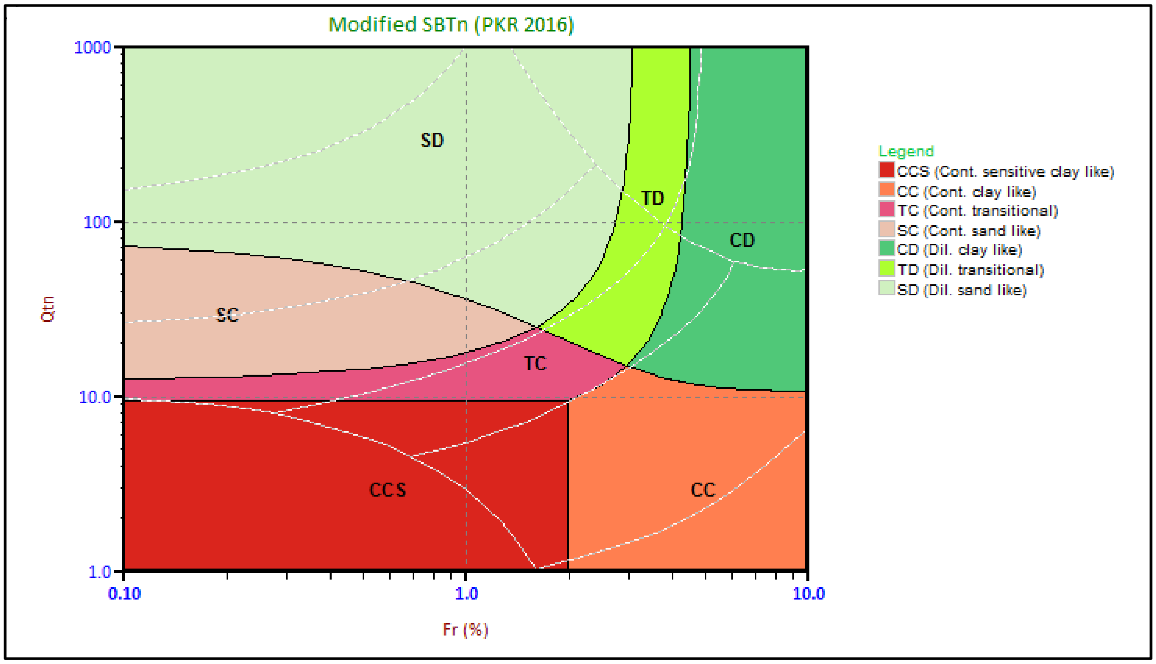


Figure 5. Modified SBTn Behavior Based Chart

Details regarding the geotechnical parameter calculations are provided in Tables 1a and 1b. The appropriate references cited are listed in Table 2. Non-liquefaction specific parameters are detailed in Table 1a and liquefaction specific parameters are detailed in Table 1b.

Where methods are based on charts or techniques that are too complex to describe in this summary the user should refer to the cited material. Specific limitations for each method are described in the cited material.

Where the results of a calculation/correlation are deemed *'invalid'* the value will be represented by the text strings "-9999", "-9999.0", the value 0.0 (Zero) or an empty cell. Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).
2. Where the calculation method is inappropriate, for example, drained parameters in a material behaving as an undrained material (and vice versa).
3. Where input values are beyond the range of the referenced charts or specified limitations of the correlation method.
4. Where pre-requisite or intermediate parameter calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the calculated parameters listed in Table 1 may be included in the output files delivered with this report.

The output files are typically provided in Microsoft Excel XLS or XLSX format. The ConeTec software has several options for output depending on the number or types of calculated parameters desired or requested by the client. Each output file is named using the original COR file base name followed by a three or four letter indicator of the output set selected (e.g. BSC, TBL, NLI, NL2, IFI, IFI2) and possibly followed by an operator selected suffix identifying the characteristics of the particular calculation run.

Table 1a. CPT Parameter Calculation Methods – Non liquefaction Parameters

Calculated Parameter	Description	Equation	Ref
Depth	Mid Layer Depth *(where calculations are done at each point then Mid Layer Depth = Recorded Depth)*	*[Depth (Layer Top) + Depth (Layer Bottom)]/ 2.0*	CK*
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client or through site survey	Elevation = Collar Elevation - Depth	CK*
Avg qc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n}\sum_{i=1}^{n} q_c$ *n=1 when calculations are done at each point*	CK*
Avg qt	Averaged corrected tip (q_t) where: $q_t = q_c + (1-a) \bullet u_2$	$Avgqt = \frac{1}{n}\sum_{i=1}^{n} q_t$ *n=1 when calculations are done at each point*	1
Avg fs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n}\sum_{i=1}^{n} fs$ *n=1 when calculations are done at each point*	CK*
Avg Rf	Averaged friction ratio (R_f) where friction ratio is defined as: $Rf = 100\% \bullet \frac{fs}{q_t}$	$AvgRf = 100\% \cdot \frac{Avgfs}{Avgqt}$ *n=1 when calculations are done at each point*	CK*
Avg u	Averaged dynamic pore pressure *(u)*	$Avgu = \frac{1}{n}\sum_{i=1}^{n} u_i$ *n=1 when calculations are done at each point*	CK*

Calculated Parameter	Description	Equation	Ref
Avg Res	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$AvgRes = \frac{1}{n}\sum_{i=1}^{n} Resistivity_i$ *n=1 when calculations are done at each point*	CK*
Avg UVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$AvgUVIF = \frac{1}{n}\sum_{i=1}^{n} UVIF_i$ *n=1 when calculations are done at each point*	CK*
Avg Temp	Averaged Temperature (this data is not always available since it requires specialized calibrations)	$AvgTemp = \frac{1}{n}\sum_{i=1}^{n} Temperature_i$ *n=1 when calculations are done at each point*	CK*
Avg Gamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$AvgGamma = \frac{1}{n}\sum_{i=1}^{n} Gamma_i$ *n=1 when calculations are done at each point*	CK*
SBT	Soil Behavior Type as defined by Robertson et al 1986 (often referred to as Robertson and Campanella, 1986)	See Figure 1	1, 5
SBTn	Normalized Soil Behavior Type as defined by Robertson 1990 (linear normalization)	See Figure 2	2, 5
SBT-Bq	Non-normalized Soil Behavior type based on the Bq parameter	See Figure 3	1, 2, 5
SBT-Bqn	Normalized Soil Behavior based on the Bq parameter	See Figure 3	2, 5
SBT-JandD	Soil Behavior Type as defined by Jeffries and Davies	See Figure 3	7
SBT Qtn	Soil Behavior Type as defined by Robertson (2009) using a variable stress ratio exponent for normalization based on I_c	See Figure 4	15
Modified SBTn (contractive /dilative)	Modified SBTn chart as defined by Robertson (2016) indicating zones of contractive/dilative behavior.	See Figure 5	30
Unit Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) value assigned to each SBTn zone 4) value assigned to SBTn zone as determined from Robertson and Wride (1998) based on q_{c1n} 5) values assigned to SBT Qtn zones 6) Mayne fs (sleeve friction) method 7) Robertson 2010 method 8) user supplied unit weight profile The last option may co-exist with any of the other options	See references	3, 5, 15, 21, 24, 29

Calculated Parameter	Description	Equation	Ref
TStress σ_v	Total vertical overburden stress at Mid Layer Depth *A layer is defined as the averaging interval specified by the user where depths are reported at their respective mid-layer depth.* *For data calculated at each point layers are defined using the recorded depth as the mid-point of the layer. Thus, a layer starts half-way between the previous depth and the current depth unless this is the first point in which case the layer start is at zero depth. The layer bottom is half-way from the current depth to the next depth unless it is the last data point.* *Defining layers affects how stresses are calculated since the unit weight attributed to a data point is used throughout the entire layer. This means that to calculate the stresses the total stress at the top and bottom of a layer are required. The stress at mid layer is determined by adding the incremental stress from the layer top to the mid-layer depth. The stress at the layer bottom becomes the stress at the top of the subsequent layer. Stresses are NOT calculated from mid-point to mid-point.* *For over-water work the total stress due to the column of water above the mud line is taken into account where appropriate.*	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ *where* γ_i is layer unit weight h_i is layer thickness	CK*
EStress σ_v'	Effective vertical overburden stress at mid-layer depth	$\sigma_v' = \sigma_v - u_{eq}$	CK*
Equil u u_{eq} or u_0	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic below water table 2) user supplied profile 3) combination of those above When a user supplied profile is used/provided a linear interpolation is performed between equilibrium pore pressures defined at specific depths. If the profile values start below the water table then a linear transition from zero pressure at the water table to the first defined pointed is used. Equilibrium pore pressures may come from dissipation tests, adjacent piezometers or other sources. Occasionally, an extra equilibrium point (“assumed value”) will be provided in the profile that does not come from a recorded value to smooth out any abrupt changes or to deal with material interfaces. These “assumed” values will be indicated on our plots and in tabular summaries.	For hydrostatic option: $u_{eq} = \gamma_w \cdot (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	CK*
K_0	Coefficient of earth pressure at rest, K_0	$K_0 = (1 - \sin\Phi')\ OCR^{\sin\Phi'}$	17
C_n	Overburden stress correction factor used for $(N_1)_{60}$ and older CPT parameters	$C_n = (P_a/\sigma_v')^{0.5}$ where $0.0 < C_n < 2.0$ *(user adjustable, typically 1.7)* P_a *is atmospheric pressure (100 kPa)*	12
C_q	Overburden stress normalizing factor	$C_q = 1.8 / (0.8 + (\sigma_v'/P_a))$ where $0.0 < C_q < 2.0$ *(user adjustable)* P_a *is atmospheric pressure (100 kPa)*	3, 12

Calculated Parameter	Description	Equation	Ref
N_{60}	SPT N value at 60% energy calculated from q_t/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	*See Figure 1*	5
(N1)60	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = C_n \bullet N_{60}$	4
N60Ic	SPT N_{60} values based on the I_c parameter [as defined by Roberston and Wride 1998 (5), or by Robertson 2009 (15)].	$(q_t/P_a)/ N_{60} = 8.5\ (1 – I_c/4.6)$ $(q_t/P_a)/ N_{60} = 10^{\ (1.1268 – 0.2817Ic)}$ Pa being atmospheric pressure	5 15, 31
(N1)60Ic	SPT N_{60} value corrected for overburden pressure (using N_{60} I_c). User has 3 options.	1) $(N_1)_{60}Ic = C_n \bullet (N_{60}\, I_c)$ 2) $q_{c1n}/\ (N_1)_{60}I_c = 8.5\ (1 – I_c/4.6)$ 3) $(Q_{tn})/\ (N_1)_{60}I_c\ = 10^{\ (1.1268 – 0.2817Ic)}$	4 5 15, 31
Su or Su (Nkt)	Undrained shear strength based on q_t S_u factor N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
Su or Su (Ndu)	Undrained shear strength based on pore pressure S_u factor $N_{\Delta u}$ is user selectable	$Su = \frac{u_2 - u_{eq}}{N_{\Delta u}}$	1, 5
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann (1978) d) Jamiolkowski (1985) - All Sands e) Jamiolkowski et al (2003) (various compressibilities, K_o)	See reference (methods a through d) Jamiolkowski et al (2003) reference	5 14
PHI ϕ	Friction Angle determined from one of the following user selectable options (methods a through d are for sands and method e is for silts and clays): a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu d) Kulhawy and Mayne e) NTH method (clays and silts)	See appropriate reference	5 5 5 11 23
Delta U/qt	Differential pore pressure ratio (older parameter used before B_q was established)	$= \frac{\Delta u}{qt}$ *where:* $\Delta u = u - u_{eq}$ *and* *u = dynamic pore pressure* u_{eq} *= equilibrium pore pressure*	CK*
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ where : $\Delta u = u - u_{eq}$ *and* *u = dynamic pore pressure* u_{eq} *= equilibrium pore pressure*	1, 2, 5
Net qt or qtNet	Net tip resistance (used in many subsequent correlations)	$qt - \sigma_v$	CK*
qe	Effective tip resistance (using the dynamic pore pressure u_2 and not equilibrium pore pressure)	$qt - u_2$	CK*

Calculated Parameter	Description	Equation	Ref
qeNorm	Normalized effective tip resistance	$\frac{qt - u_2}{\sigma_v'}$	CK*
Q_t or Norm: Qt	Normalized q_t for Soil Behavior Type classification as defined by Robertson (1990) using a linear stress normalization. Note this is different from Q_{tn}.	$Qt = \frac{qt - \sigma_v}{\sigma_v'}$	2, 5
F_r or Norm: Fr	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson (1990)	$Fr = 100\% \cdot \frac{fs}{qt - \sigma_v}$	2, 5
Q(1-Bq)	Q(1-Bq) grouping as suggested by Jefferies and Davies for their classification chart and the establishment of their I_c parameter	$Q \cdot (1 - Bq)$ *where Bq is defined as above and Q is the same as the normalized tip resistance, Q_t, defined above*	6, 7
qc1	Normalized tip resistance, q_{c1}, using a fixed stress ratio exponent, n (this method has stress units)	$q_{c1} = q_t \cdot (Pa/\sigma_v')^{0.5}$ where: Pa = atmospheric pressure	21
qc1 (0.5)	Normalized tip resistance, q_{c1}, using a fixed stress ratio exponent, n (this method is unit-less)	$q_{c1}\ (0.5) = (q_t/P_a) \cdot (Pa/\sigma_v')^{0.5}$ where: Pa = atmospheric pressure	5
qc1 (Cn)	Normalized tip resistance, q_{c1}, based on C_n (this method has stress units)	$q_{c1}(Cn) = C_n * q_t$	5, 12
qc1 (Cq)	Normalized tip resistance, q_{c1}, based on C_q (this method has stress units)	$q_{c1}\ (Cq) = C_q * q_t$ (some papers use q_c)	5, 12
qc1n	normalized tip resistance, q_{c1n}, using a variable stress ratio exponent, n (where n=0.0, 0.70, 1.0) (this method is unit-less)	$q_{c1n} = (q_t / P_a)(P_a/\sigma_v')^n$ where: P_a = atm. Pressure and n varies as described below	3, 5
I_c or Ic (RW1998)	Soil Behavior Type Index as defined by Robertson and Fear (1995) and Robertson and Wride (1998) for estimating grain size characteristics and providing smooth gradational changes across the SBTn chart	$I_c = [(3.47 - \log_{10}Q)^2 + (\log_{10} Fr + 1.22)^2]^{0.5}$ *Where:* $Q = \left(\frac{qt - \sigma_v}{P_a}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *Or* $Q = q_{c1n} = \left(\frac{qt}{P_a}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *depending on the iteration in determining I_c* *And Fr is in percent* *P_a = atmospheric pressure* *n varies between 0.5, 0.70 and 1.0 and is selected in an iterative manner based on the resulting I_c*	3, 5, 21
Ic (PKR 2009)	Soil Behavior Type Index, I_c (PKR 2009) based on a variable stress ratio exponent n, which itself is based on I_c (PKR 2009). An iterative calculation is required to determine Ic (PKR 2009) and its corresponding n (PKR 2009).	I_c (PKR 2009) = $[(3.47 - \log_{10}Q_{tn})^2 + (1.22 + \log_{10}F_r)^2]^{0.5}$	15

Calculated Parameter	Description	Equation	Ref
n (PKR 2009)	Stress ratio exponent n, based on I_c (PKR 2009). An iterative calculation is required to determine n (PKR 2009) and its corresponding Ic (PKR 2009).	n (PKR 2009) = $0.381\ (I_c) + 0.05\ (\sigma_v'/P_a) - 0.15$	15
Qtn (PKR 2009)	Normalized tip resistance using a variable stress ratio exponent based on I_c (PKR 2009) and n (PKR 2009). An iterative calculation is required to determine Qtn (PKR 2009).	$Q_{tn} = [(qt - \sigma_v)/P_a](P_a/\sigma_v')^n$ where P_a = atmospheric pressure (100 kPa) n = stress ratio exponent described above	15
FC	Apparent fines content (%)	$FC=1.75(Ic^{3.25}) - 3.7$ $FC=100$ for $I_c > 3.5$ $FC=0$ for $I_c < 1.26$ $FC = 5\%$ if $1.64 < I_c < 2.6$ AND $F_r<0.5$	3
I_c Zone	This parameter is the Soil Behavior Type zone based on the I_c parameter (valid for zones 2 through 7 on SBTn or SBT Qtn charts)	$I_c < 1.31$ Zone = 7 $1.31 < I_c < 2.05$ Zone = 6 $2.05 < I_c < 2.60$ Zone = 5 $2.60 < I_c < 2.95$ Zone = 4 $2.95 < I_c < 3.60$ Zone = 3 $I_c > 3.60$ Zone = 2	3
State Param or State Parameter or ψ	The state parameter index, ψ, is defined as the difference between the current void ratio, e, and the critical void ratio, e_c. Positive ψ - contractive soil Negative ψ - dilative soil This is based on the work by Been and Jefferies (1985) and Plewes, Davies and Jefferies (1992) - vertical effective stress is used rather than a mean normal stress	See reference	6, 8
Yield Stress σ_p'	Yield stress is calculated using the following methods a) General method b) 1st order approximation using q_tNet (clays) c) 1st order approximation using Δu_2 (clays) d) 1st order approximation using q_e (clays)	All stresses in kPa a) $\sigma_p' = 0.33\cdot(q_t - \sigma_v)^{m'}\ (\sigma_{atm}/100)^{1-m'}$ where $m'=1-\frac{0.28}{1+(I_c/2.65)^{25}}$ b) $\sigma_p' = 0.33\cdot(q_t - \sigma_v)$ c) $\sigma_p' = 0.54\cdot(\Delta u_2)$ $\Delta u_2 = u_2 - u_0$ d) $\sigma_p' = 0.60\cdot(q_t - u_2)$	19 20 20 20
OCR OCR(JS1978) OCR(Mayne2014) OCR (qtNet) OCR (deltaU) OCR (qe) OCR (Vs) OCR (PKR2015)	Over Consolidation Ratio based on a) Schmertmann (1978) method involving a plot plot of S_u/σ_v' /($S_u/\sigma_v')_{NC}$ and OCR b) based on Yield stresses described above c) approximate version based on qtNet d) approximate version based on Δu e) approximate version based on effective tip, q_e f) approximate version based on shear wave velocity, V_s g) based on Qt	a) requires a user defined value for NC S_u/P_c' ratio b through f) *based on yield stresses* g) OCR = $0.25\cdot(Qt)^{1.25}$	9 19 20 20 20 18 32

Calculated Parameter	Description	Equation	Ref
Es/qt	Intermediate parameter for calculating Young's Modulus, E, in sands. It is the Y axis of the reference chart.	Based on Figure 5.59 in the reference	5
Es Young's Modulus E	Young's Modulus based on the work done in Italy. There are three types of sands considered in this technique. The user selects the appropriate type for the site from: a) OC Sands b) Aged NC Sands c) Recent NC Sands Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in the E_s/q_t chart. Es is evaluated for an axial strain of 0.1%.	Mean normal stress is evaluated from: $\sigma'_m = \frac{1}{3}(\sigma'_v + \sigma'_h + \sigma'_h)^3$ where σ_v'= vertical effective stress σ_h'= horizontal effective stress *and* $\sigma_h = K_o \bullet \sigma_v'$ with K_o assumed to be 0.5	5
Delta U/TStress	Differential pore pressure ratio with respect to total stress	$= \frac{\Delta u}{\sigma_v}$ *where:* $\Delta u = u - u_{eq}$	CK*
Delta U/Estress, P Value, Excess Pore Pressure Ratio	Differential pore pressure ratio with respect to effective stress. Key parameter (P, Normalized Pore Pressure Parameter, Excess Pore Pressure Ratio) in the Winckler et. al. static liquefaction method.	$= \frac{\Delta u}{\sigma'_v}$ *where:* $\Delta u = u - u_{eq}$	25, 25a, CK*
Su/EStress	Undrained shear strength ratio with respect to vertical effective overburden stress using the S_u (N_{kt}) method	$= Su(N_{kt}) / \sigma_v'$	CK*
Gmax	G_{max} determined from SCPT shear wave velocities (not estimated values)	$G_{max} = \rho V_s^2$ where ρ is the mass density of the soil determined from the estimated unit weights at each test depth	27
qtNet/Gmax	Net tip resistance ratio with respect to the small strain modulus G_{max} determined from SCPT shear wave velocities (not estimated values)	$= (qt - \sigma_v) / G_{max}$ where $G_{max} = \rho V_s^2$ and ρ is the mass density of the soil determined from the estimated unit weights at each test depth	15, 28, 30

*CK – common knowledge

Table 1b. CPT Parameter Calculation Methods – Liquefaction Parameters

Calculated Parameter	Description	Equation	Ref
K_{SPT}	Equivalent clean sand factor for $(N_1)60$	$K_{SPT} = 1 + ((0.75/30) \bullet (FC - 5))$	10
K_{CPT} or K_C (RW1998)	Equivalent clean sand correction for q_{c1N}	$K_{cpt} = 1.0$ for $I_c \leq 1.64$ $K_{cpt} = f(I_c)$ for $I_c > 1.64$ (see reference) $K_c = -0.403\ I_c^4 + 5.581\ I_c^3 - 21.63 I_c^2 + 33.75\ I_c - 17.88$	3, 10
Kc (PKR 2010)	Clean sand equivalent factor to be applied to Q_{tn}	$K_c = 1.0$ for $I_c \leq 1.64$ $K_c = -0.403\ I_c^4 + 5.581\ I_c^3 - 21.63 I_c^2 + 33.75\ I_c - 17.88$ for $I_c > 1.64$	16
$(N_1)_{60cs}$Ic	Clean sand equivalent SPT $(N_1)_{60}I_c$. User has 3 options.	1) $(N_1)_{60cs}Ic = \alpha + \beta((N_1)_{60}I_c)$ 2) $(N_1)_{60cs}Ic = K_{SPT} * ((N_1)_{60}I_c)$ 3) $(q_{c1ncs})/ (N_1)_{60cs}I_c = 8.5 (1 - I_c/4.6)$ FC ≤ 5%: $\alpha = 0$, $\beta=1.0$ FC ≥ 35% $\alpha = 5.0$, $\beta=1.2$ 5% < FC < 35% $\alpha = \exp[1.76 - (190/FC^2)]$ $\beta = [0.99 + (FC^{1.5}/1000)]$	10 10 5
q_{c1ncs}	Clean sand equivalent q_{c1n}	$q_{c1ncs} = q_{c1n} \bullet K_{cpt}$	3
Qtn,cs (PKR 2010)	Clean sand equivalent for Q_{tn} described above - Q_{tn} being the normalized tip resistance based on a variable stress exponent as defined by Robertson (2009)	$Q_{tn,cs} = Q_{tn} \cdot K_c$ (PKR 2016)	16
Su(Liq)/ESv	Liquefied shear strength ratio as defined by Olson and Stark	$\dfrac{Su(Liq)}{\sigma_v'} = 0.03 + 0.0143(q_{c1})$ Note: σ_v' and s_v' are synonymous	13
Su(Liq)/ESv (PKR 2010)	Liquefied shear strength ratio as defined by Robertson (2010)	$\dfrac{Su(Liq)}{\sigma_v'}$ Based on a function involving $Q_{tn,cs}$	16
Su (Liq) (PKR 2010)	Liquefied shear strength derived from the liquefied shear strength ratio and effective overburden stress		16
Cont/Dilat Tip	Contractive / Dilative qc1 Boundary based on $(N_1)_{60}$	$(\sigma_v')_{boundary} = 9.58 \times 10^{-4} [(N_1)_{60}]^{4.79}$ *qc1* is calculated from specified qt(MPa)/N ratio	13
CRR	Cyclic Resistance Ratio (for Magnitude 7.5)	$q_{c1ncs} < 50$: $CRR_{7.5} = 0.833 [q_{c1ncs}/1000] + 0.05$ $50 \leq q_{c1ncs} < 160$: $CRR_{7.5} = 93 [q_{c1ncs}/1000]^3 + 0.08$	10
Kg	Small strain Stiffness Ratio Factor, Kg	$[Gmax/qt]/[qc1n^{-m}]$ m = empirical exponent, typically 0.75	26

Calculated Parameter	Description	Equation	Ref
SP Distance	State Parameter Distance, Winckler static liquefaction method	Perpendicular distance on Qtn chart from plotted point to state parameter Ψ = -0.05 curve	25
URS NP Fr	Normalized friction ratio point on Ψ = -0.05 curve used in SP Distance calculation		25
URS NP Qtn	Normalized tip resistance (Qtn) point on Ψ = -0.05 curve used in SP Distance calculation		25

Table 2. References

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Appendix E

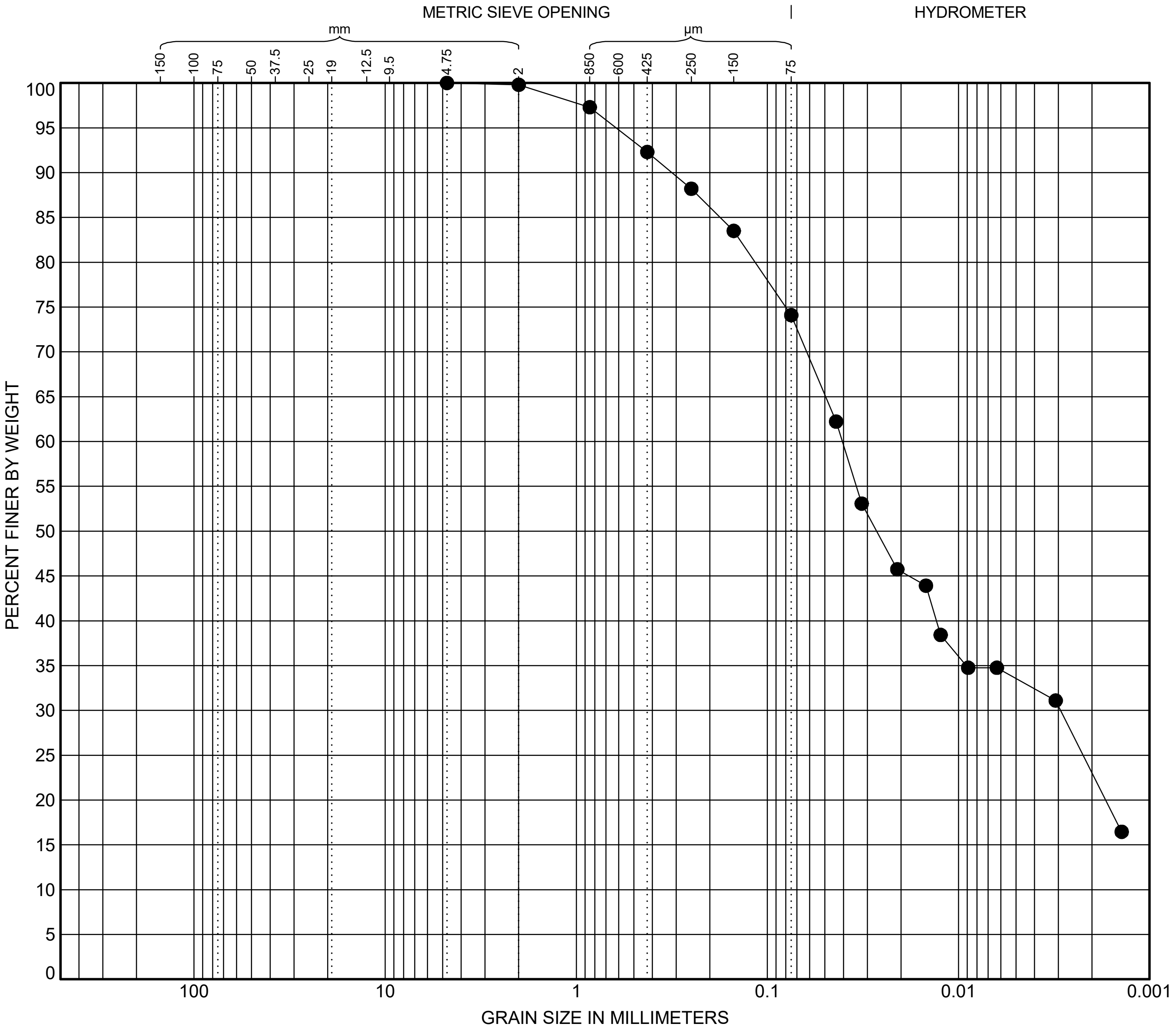
Soil Laboratory Testing Results

GRAIN SIZE DISTRIBUTION ASTM D422

ecora™

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-01

Project No: 201706-18
Client: Ministry of Transportation
Depth: 5.5 m to 5.8 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
4.75	**0.177**	**0.041**	**0.003**					**0.0**	**25.9**	**51.1**	**23.0**

Description: Sandy, clayey SILT
Natural Moisture Content: 30.2 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

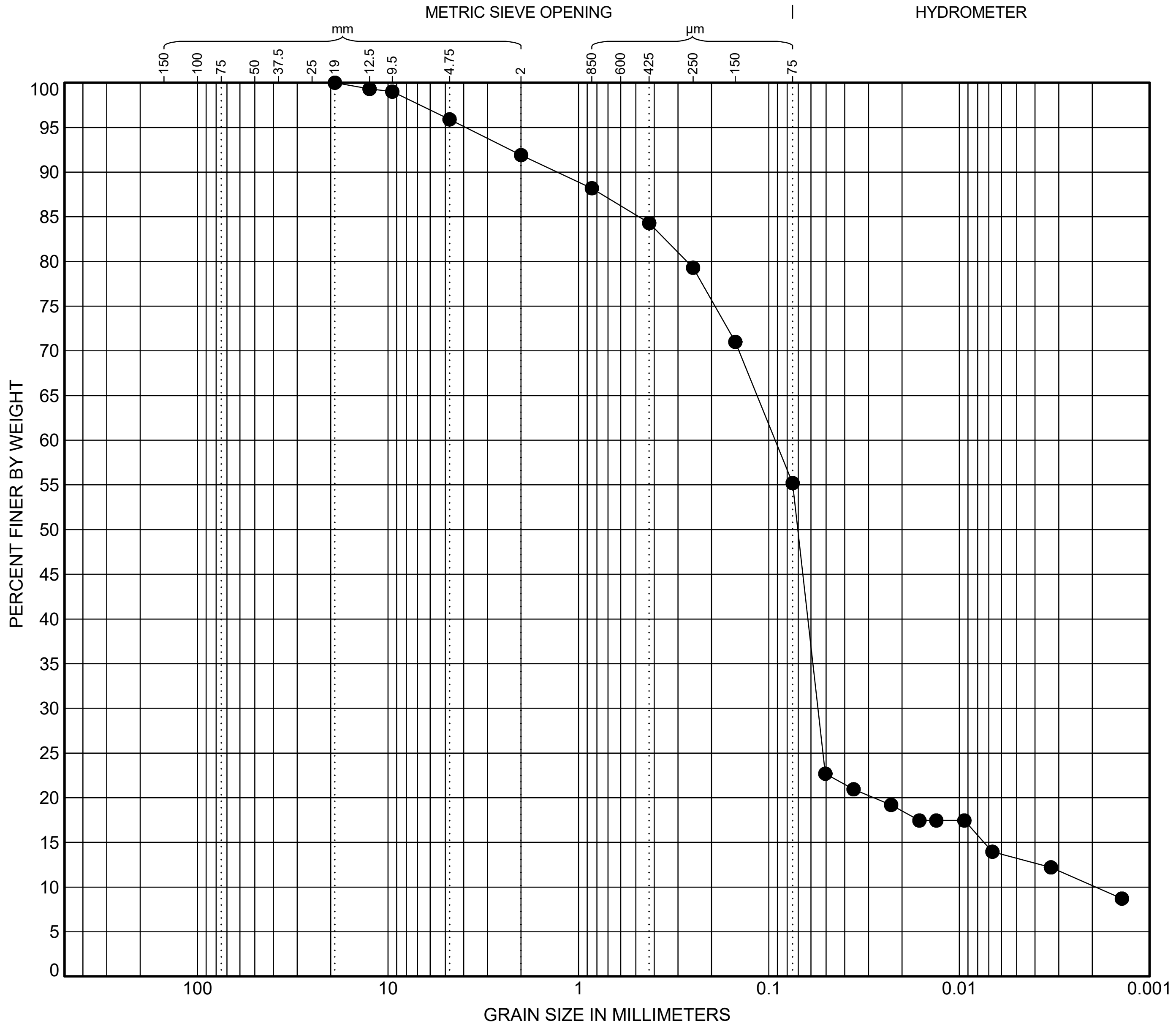
Sample Number: 21-309
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-01

Project No: 201706-18
Client: Ministry of Transportation
Depth: 8.8 m to 9.1 m



<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>coarse</td><td>fine</td><td>coarse</td><td>medium</td><td>fine</td></tr>
</table>

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
19	**0.481**	**0.093**	**0.055**	**0.007**	**0.002**	**17.13**	**48.19**	**4.1**	**40.7**	**45.0**	**10.2**

Description: SILT and SAND, some clay, trace gravel
Natural Moisture Content: 28.1 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

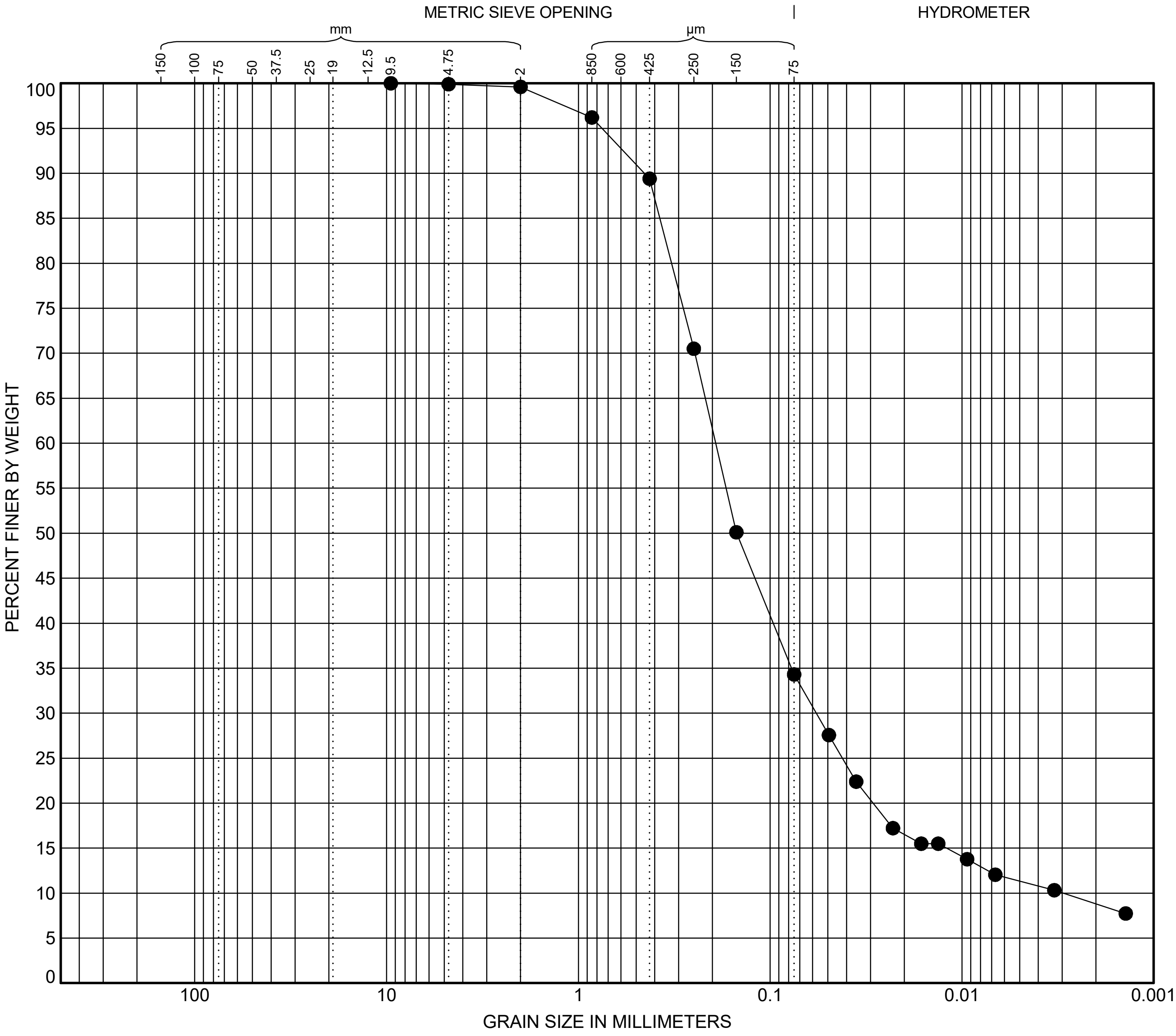
Sample Number: 21-310
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-01

Project No: 201706-18
Client: Ministry of Transportation
Depth: 11.9 m to 12.5 m



<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>coarse</td><td>fine</td><td>coarse</td><td>medium</td><td>fine</td></tr>
</table>

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
9.5	**0.376**	**0.192**	**0.057**	**0.012**	**0.003**	**5.79**	**64.75**	**0.1**	**65.6**	**25.5**	**8.8**

Description: Silty SAND, trace clay, trace gravel
Natural Moisture Content: 28.5 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

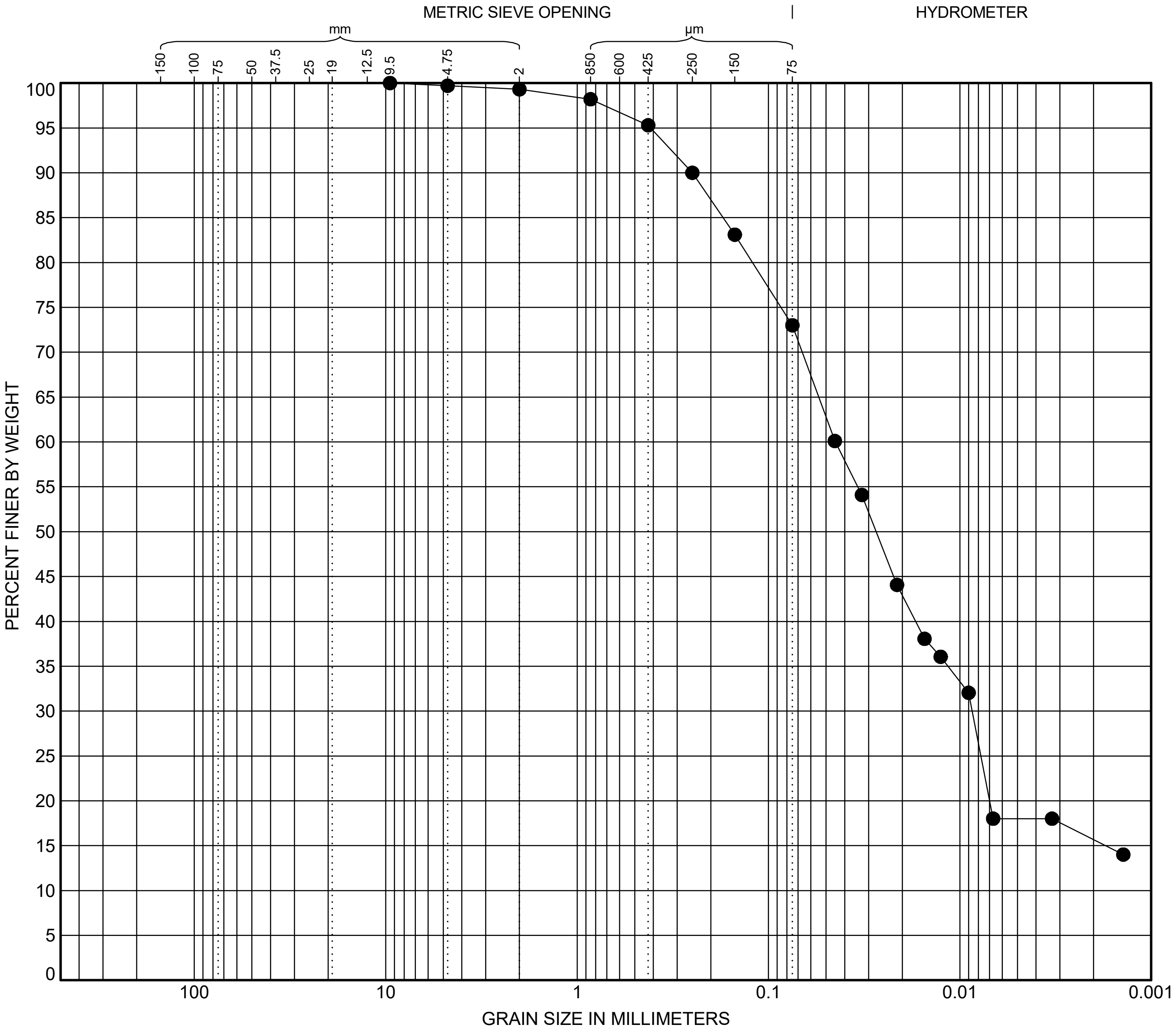
Sample Number: 21-311
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-01

Project No: 201706-18
Client: Ministry of Transportation
Depth: 13.4 m to 13.7 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
9.5	**0.173**	**0.045**	**0.009**	**0.002**				**0.3**	**26.7**	**57.3**	**15.7**

Description: Sandy SILT, some clay, trace gravel
Natural Moisture Content: 34.7 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

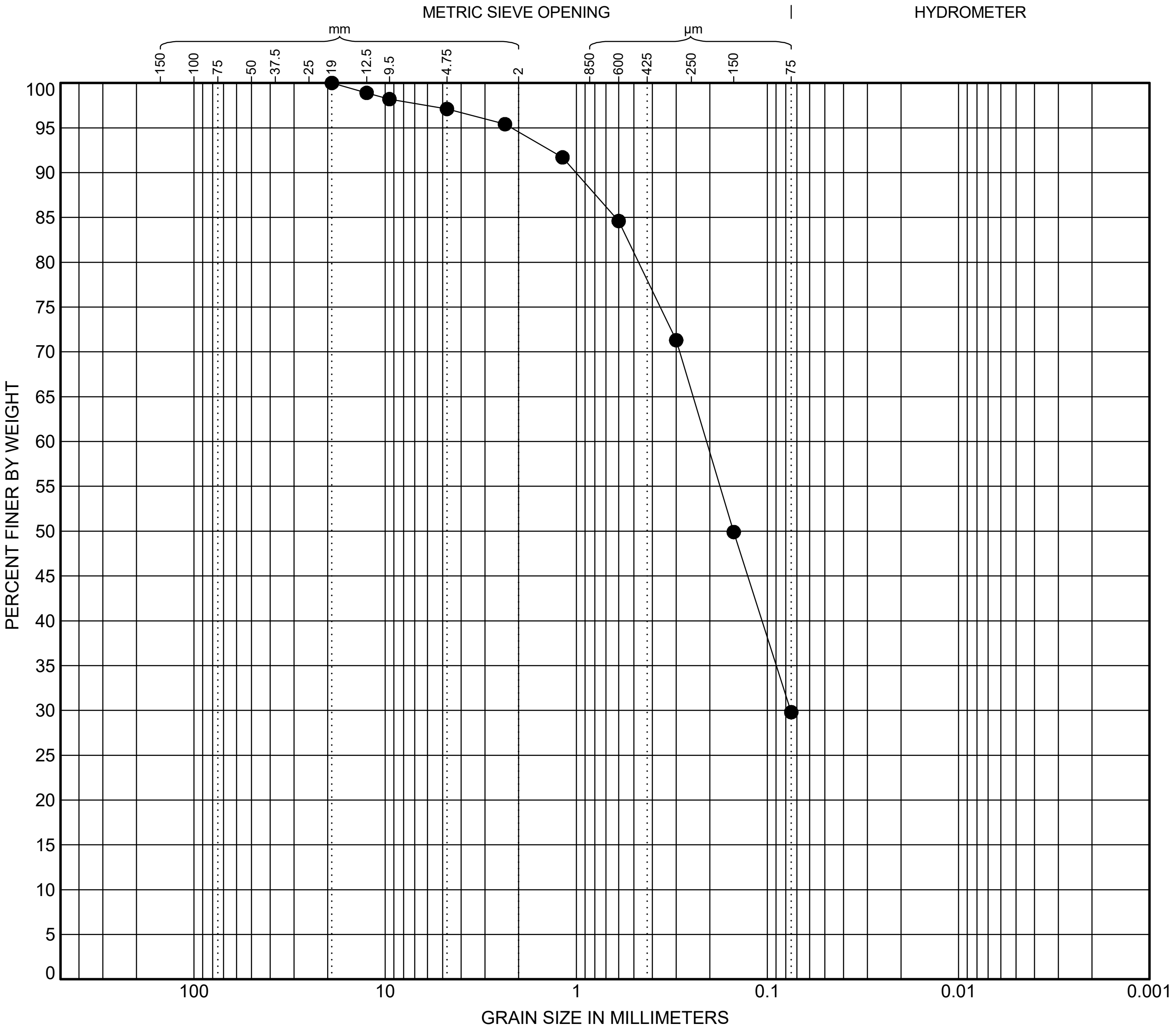
Sample Number: 21-312
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM C136

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-01

Project No: 201706-18
Client: Ministry of Transportation
Depth: 10.4 m to 11 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
19	**0.623**	**0.208**	**0.076**					**2.9**	**67.3**	**29.8**	

Description: Silty SAND, trace gravel
Natural Moisture Content: 22.7 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

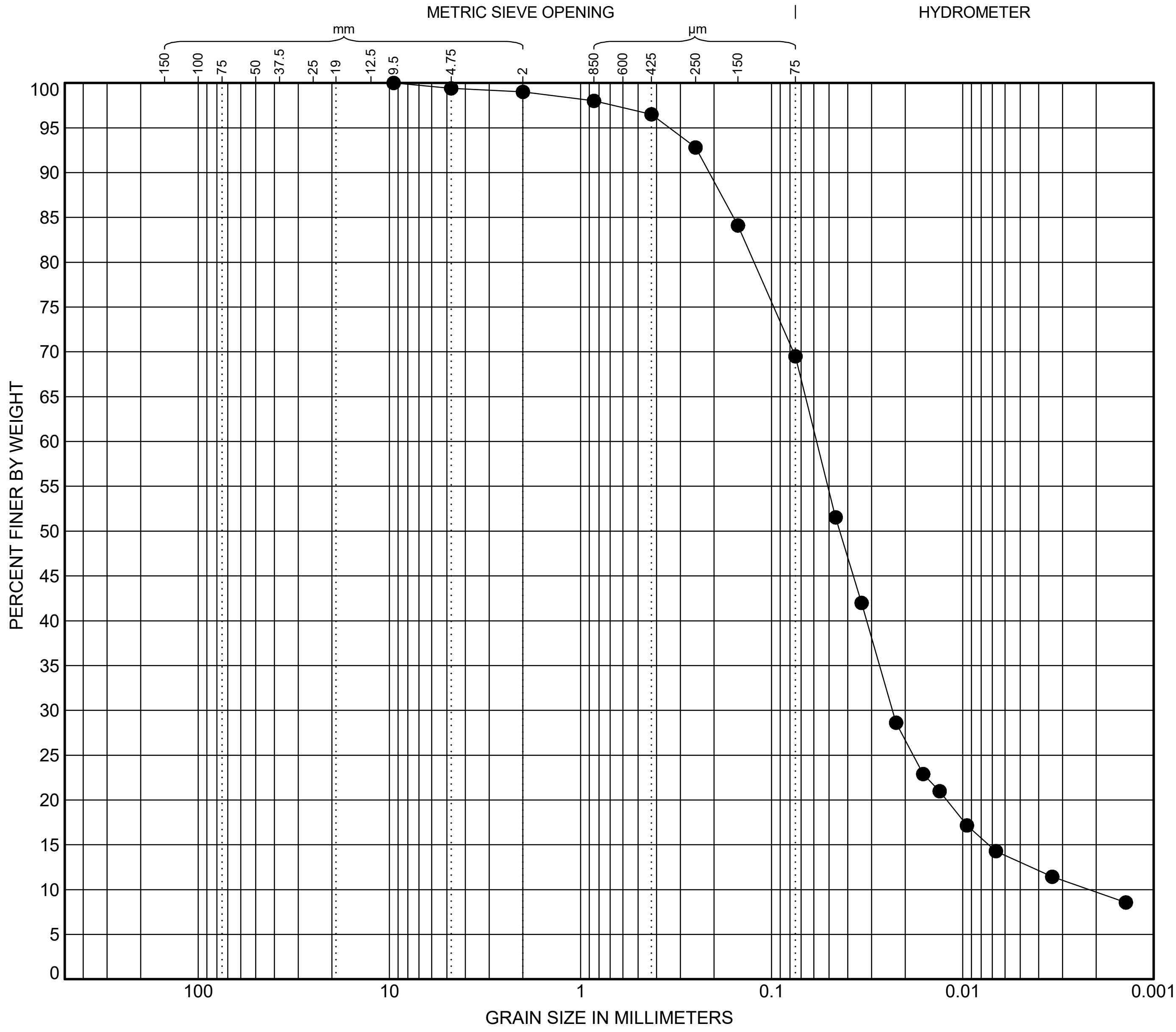
Sample Number: 21-313
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-02

Project No: 201706-18
Client: Ministry of Transportation
Depth: 2.1 m to 2.4 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
9.5	**0.158**	**0.058**	**0.023**	**0.007**	**0.002**	**4.28**	**26.59**	**0.6**	**29.9**	**59.8**	**9.7**

Description: Sandy SILT, some clay, trace gravel
Natural Moisture Content: 59 %
Material Specification: N/A
Intended Use: N/A
Comments: Sample contained significant amount of organics.

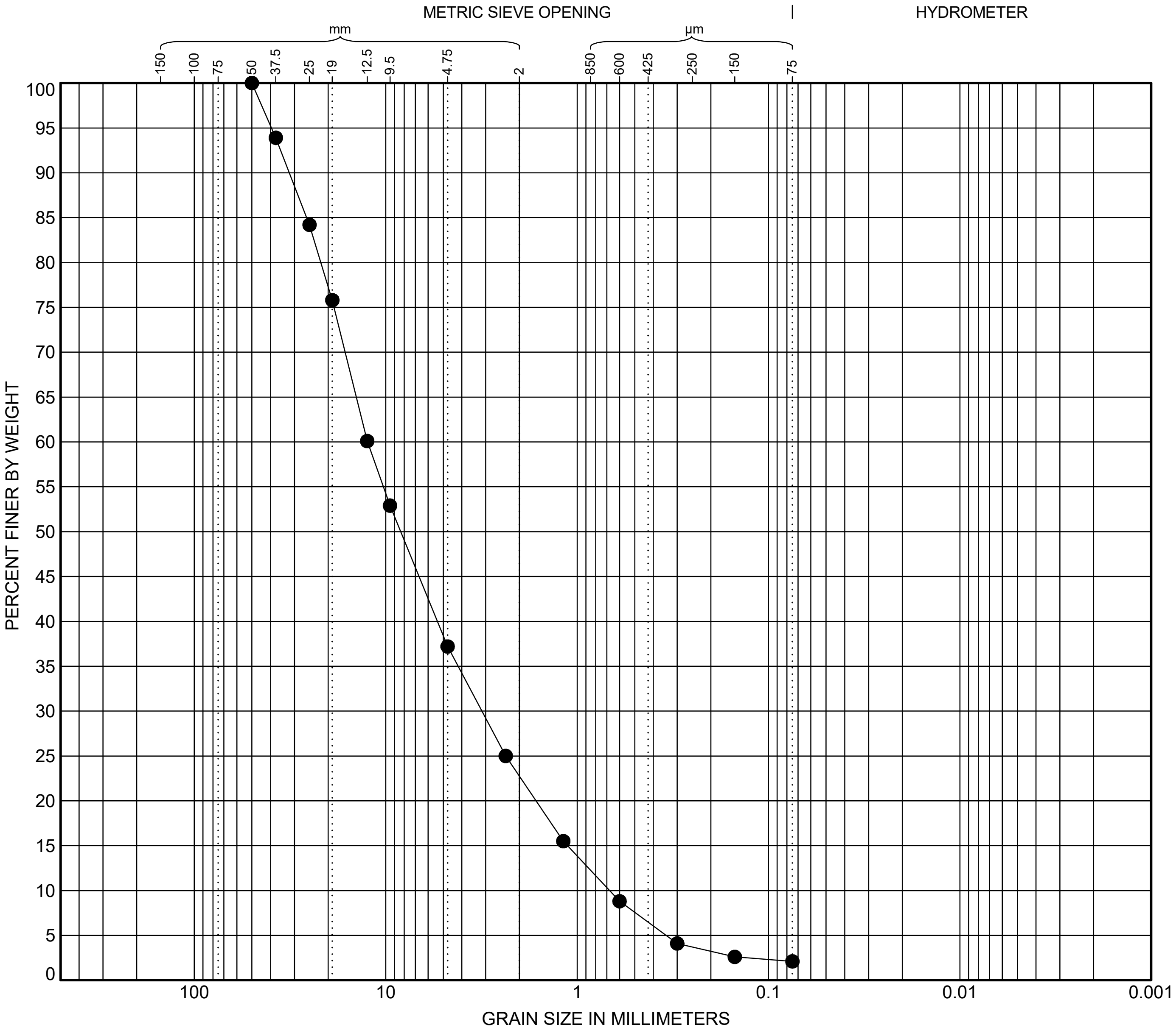
Sample Number: 21-314
Date Tested: 2021-08-12
Tested By: SK

Checked By: ________________________

GRAIN SIZE DISTRIBUTION ASTM C136

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-02

Project No: 201706-18
Client: Ministry of Transportation
Depth: 4.9 m to 5.2 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
50	**25.85**	**12.452**	**3.143**	**1.122**	**0.677**	**1.17**	**18.39**	**62.8**	**35.1**	**2.1**	

Description: GRAVEL and SAND, trace fines
Natural Moisture Content: 8.7 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

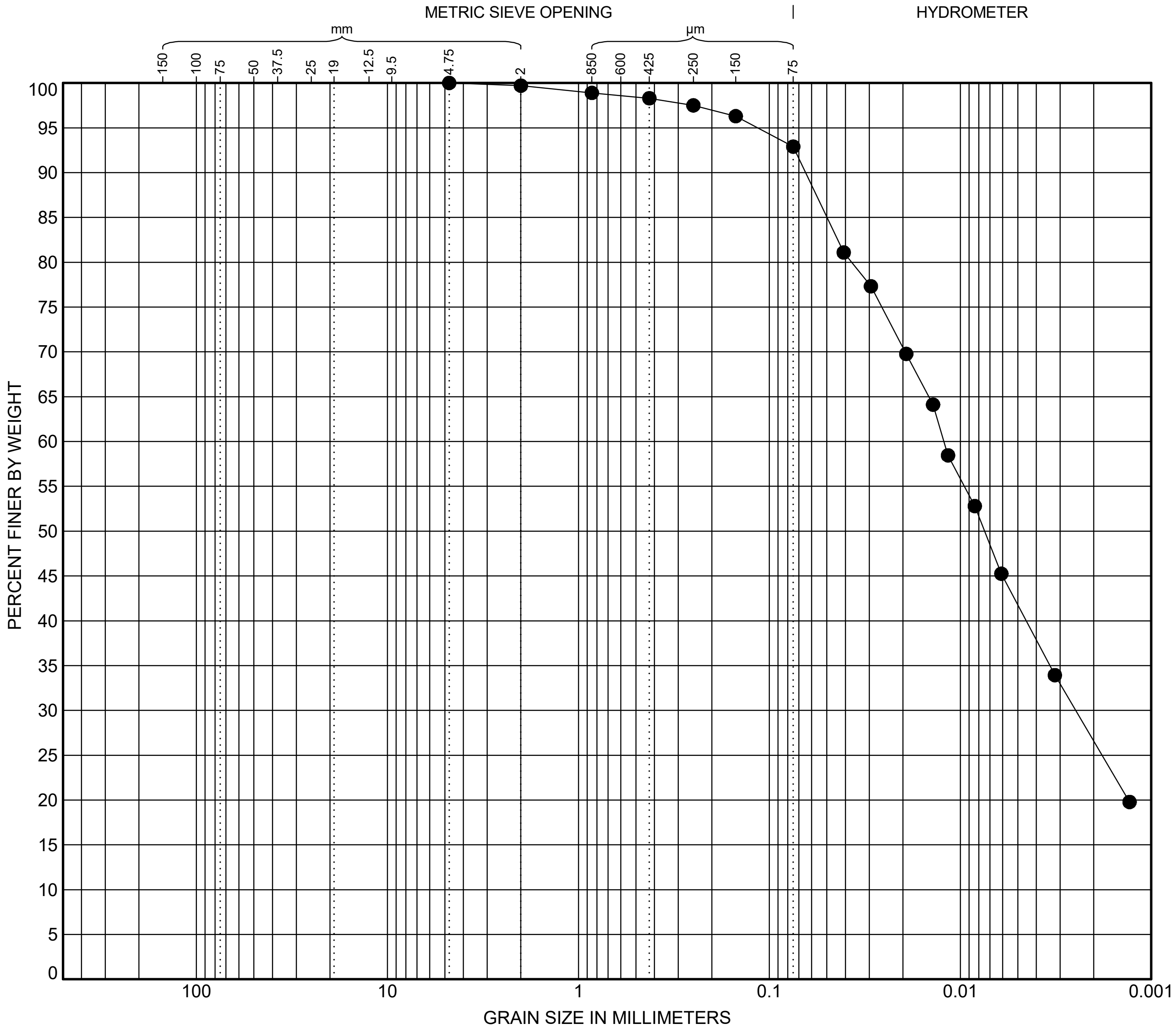
Sample Number: 21-315
Date Tested: 2021-08-12
Tested By: SK

Checked By: ______________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-02

Project No: 201706-18
Client: Ministry of Transportation
Depth: 10.4 m to 10.7 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
4.75	**0.05**	**0.012**	**0.002**					**0.0**	**7.1**	**66.4**	**26.5**

Description: Clayey SILT, trace sand
Natural Moisture Content: 35.7 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

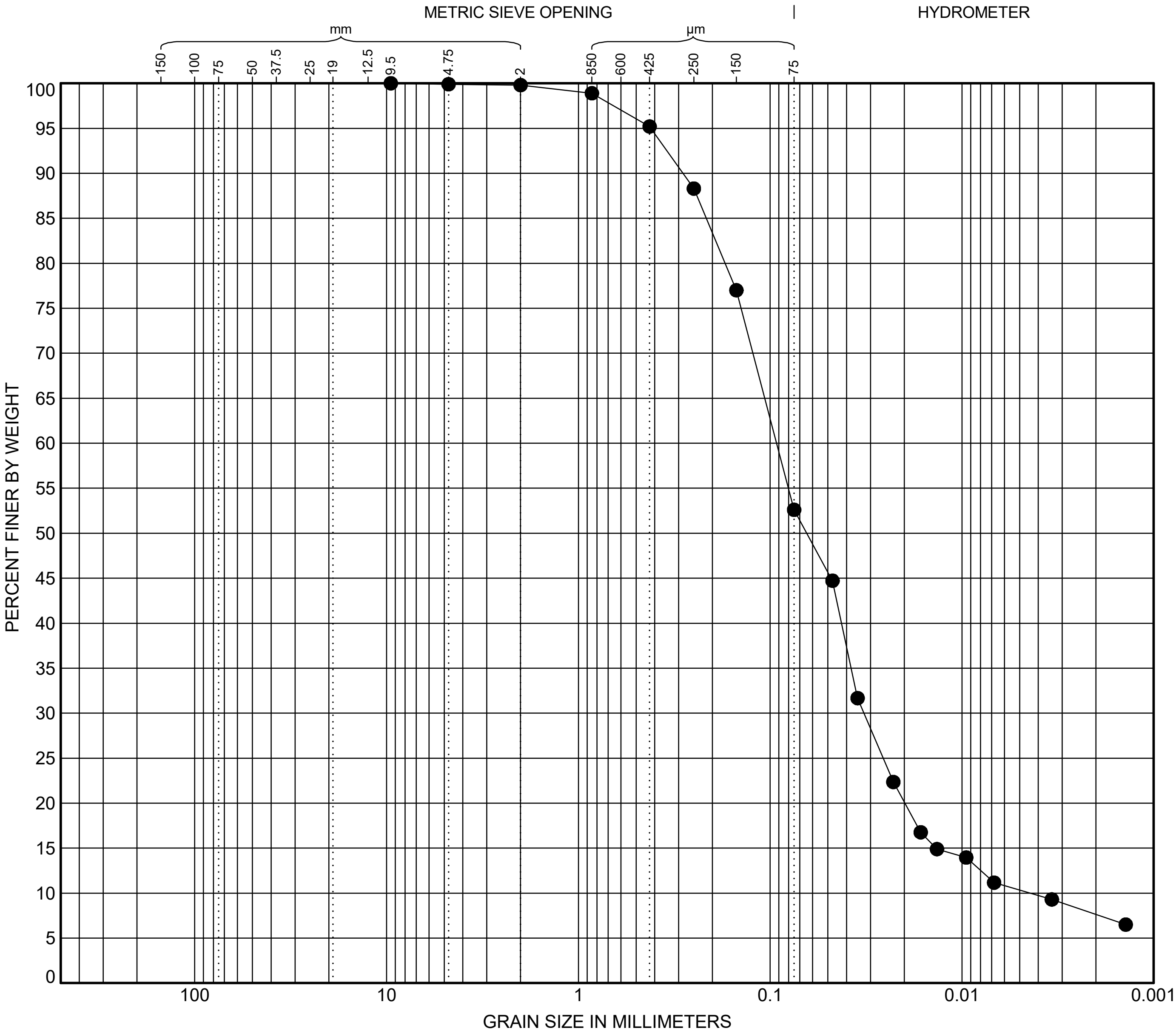
Sample Number: 21-316
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-02

Project No: 201706-18
Client: Ministry of Transportation
Depth: 14.3 m to 14.6 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
9.5	**0.215**	**0.093**	**0.032**	**0.014**	**0.004**	**2.57**	**20.94**	**0.1**	**47.3**	**45.0**	**7.6**

Description: SAND and SILT, trace clay, trace gravel
Natural Moisture Content: 25.5 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

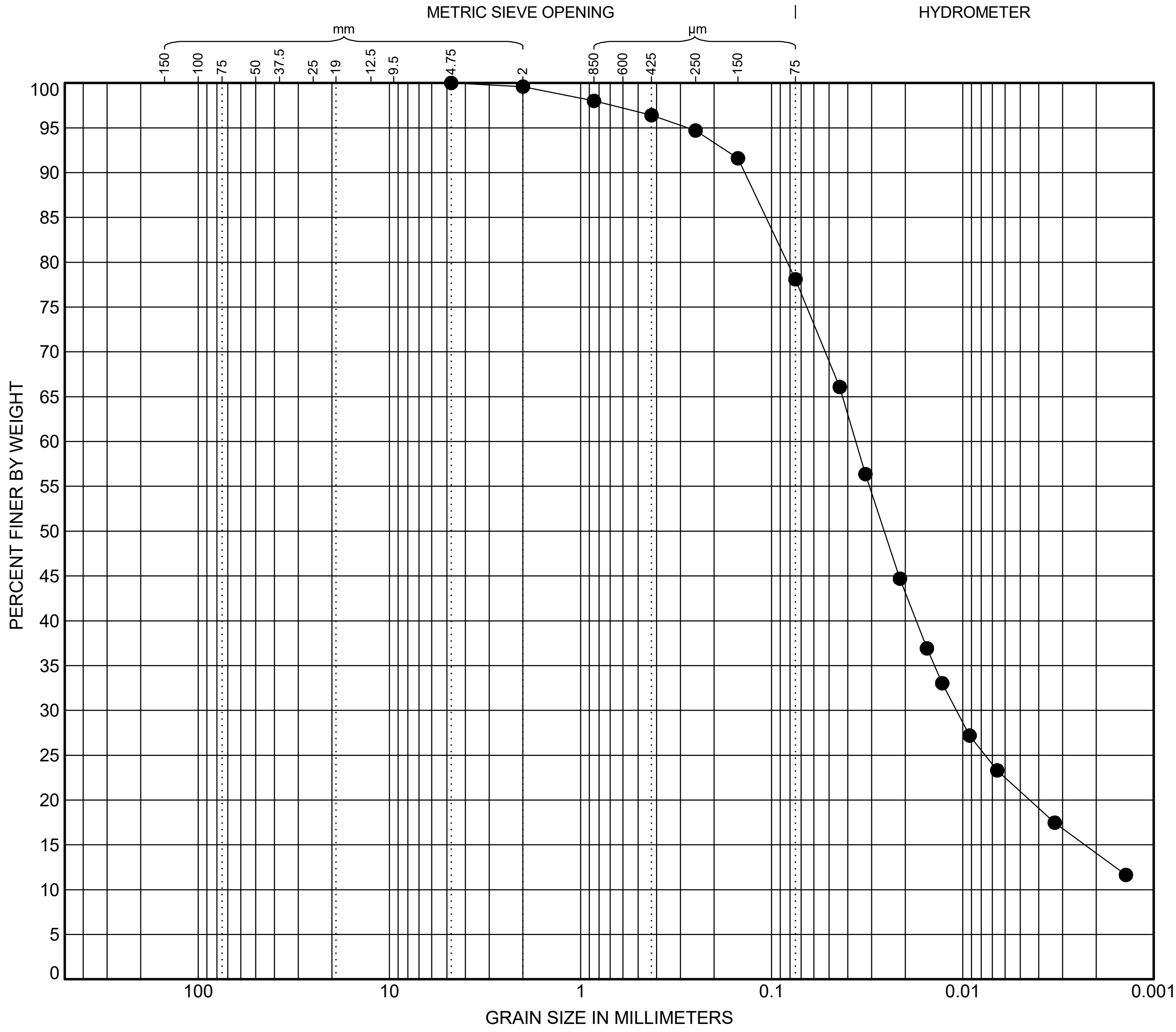
Sample Number: 21-317
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

GRAIN SIZE DISTRIBUTION ASTM D422

Project: Daly Bridge
Location: Daly Bridge
Sample Location/Source: TH21-02

Project No: 201706-18
Client: Ministry of Transportation
Depth: 12.5 m to 12.8 m



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

D_{100}	D_{85}	D_{60}	D_{30}	D_{15}	D_{10}	C_c	C_u	%Gravel	%Sand	%Silt	%Clay
4.75	**0.107**	**0.036**	**0.011**	**0.002**				**0.0**	**21.9**	**64.0**	**14.1**

Description: Sandy SILT, some clay
Natural Moisture Content: 31.3 %
Material Specification: N/A
Intended Use: N/A
Comments: N/A

Sample Number: 21-318
Date Tested: 2021-08-12
Tested By: SK

Checked By: ____________________

CARO
ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

REPORTED TO Ecora (Kelowna)
579 Lawrence Avenue
Kelowna, BC V1Y 6L8

ATTENTION Dylan Bryce

PO NUMBER
PROJECT 201706
PROJECT INFO

WORK ORDER 21H1336

RECEIVED / TEMP 2021-08-11 15:34 / 26.5°C
REPORTED 2021-08-19 13:51
COC NUMBER B095701

Introduction:

CARO Analytical Services is a testing laboratory full of smart, engaged scientists driven to make the world a safer and healthier place. Through our clients' projects we become an essential element for a better world. We employ methods conducted in accordance with recognized professional standards using accepted testing methodologies and quality control efforts. CARO is accredited by the Canadian Association for Laboratories Accreditation (CALA) to ISO/IEC 17025:2017 for specific tests listed in the scope of accreditation approved by CALA.

Big Picture Sidekicks

You know that the sample you collected after snowshoeing to site, digging 5 meters, and racing to get it on a plane so you can submit it to the lab for time sensitive results needed to make important and expensive decisions (whew) is VERY important. We know that too.

We've Got Chemistry

It's simple. We figure the more you enjoy working with our fun and engaged team members; the more likely you are to give us continued opportunities to support you.

Ahead of the Curve

Through research, regulation knowledge, and instrumentation, we are your analytical centre for the technical knowledge you need, BEFORE you need it, so you can stay up to date and in the know.

If you have any questions or concerns, please contact me at bwhitehead@caro.ca

Authorized By:

Brent Whitehead
Client Scientist - Team Lead

TEST RESULTS

REPORTED TO Ecora (Kelowna)
PROJECT 201706

WORK ORDER 21H1336
REPORTED 2021-08-19 13:51

Analyte	Result	RL	Units	Analyzed	Qualifier
201706 - 18 TH21-01 8'6" - 9'2" (21H1336-01) | Matrix: Soil | Sampled: 2021-07-05 08:30					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2021-08-19	
Chloride, Water-Soluble	< 0.002	0.002	%	2021-08-18	
pH (1:2 H2O Solution)	**7.13**	0.10	pH units	2021-08-19	
201706 - 18 TH21-02 10' - 11' (21H1336-02) | Matrix: Soil | Sampled: 2021-07-05 08:30					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2021-08-19	
Chloride, Water-Soluble	< 0.002	0.002	%	2021-08-18	
pH (1:2 H2O Solution)	**6.50**	0.10	pH units	2021-08-19	

APPENDIX 1: SUPPORTING INFORMATION

REPORTED TO	Ecora (Kelowna)	**WORK ORDER**	21H1336
PROJECT	201706	**REPORTED**	2021-08-19 13:51

Analysis Description	Method Ref.	Technique	Accredited	Location
Chloride, Water Soluble in Soil	ASTM C1218-97	Hot Water Extraction / Hot Water Extraction		Richmond
pH in Soil	Carter 16.2 / SM 4500-H+ B (2017)	1:2 Soil/Water Slurry / Electrometry	✓	Richmond
Sulfate, Water-Soluble in Soil	CSA A23.2-3B / CSA A23.2-2B	Extraction (HCl) / Gravimetry (Barium Sulfate Precipitation)		Richmond

Glossary of Terms:

RL	Reporting Limit (default)
%	Percent
<	Less than the specified Reporting Limit (RL) - the actual RL may be higher than the default RL due to various factors
pH units	pH < 7 = acidic, ph > 7 = basic
ASTM	ASTM International Test Methods
CSA	Canadian Standards Association Chemical Test Methods
SM	Standard Methods for the Examination of Water and Wastewater, American Public Health Association

General Comments:

The results in this report apply to the samples analyzed in accordance with the Chain of Custody document. This analytical report must be reproduced in its entirety. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued or once samples expire, whichever comes first. Longer hold is possible if agreed to in writing.

Results in **Bold** indicate values that are above CARO's method reporting limits. Any results that are above regulatory limits are highlighted **red**. Please note that results will only be highlighted red if the regulatory limits are included on the CARO report. Any Bold and/or highlighted results do not take into account method uncertainty. If you would like method uncertainty or regulatory limits to be included on your report, please contact your Account Manager:bwhitehead@caro.ca

Please note any regulatory guidelines applied to this report are added as a convenience to the client, at their request, to help provide some initial context to analytical results obtained. Although CARO makes every effort to ensure accuracy of the associated regulatory guideline(s) applied, the guidelines applied cannot be assumed to be correct due to a variety of factors and as such CARO Analytical Services assumes no liability or responsibility for the use of those guidelines to make any decisions. The original source of the regulation should be verified and a review of the guideline(s) should be validated as correct in order to make any decisions arising from the comparison of the analytical data obtained to the relevant regulatory guideline for one's particular circumstances. Further, CARO Analytical Services assumes no liability or responsibility for any loss attributed from the use of these guidelines in any way.

APPENDIX 2: QUALITY CONTROL RESULTS

REPORTED TO Ecora (Kelowna)
PROJECT 201706

WORK ORDER 21H1336
REPORTED 2021-08-19 13:51

The following section displays the quality control (QC) data that is associated with your sample data. Groups of samples are prepared in “batches” and analyzed in conjunction with QC samples that ensure your data is of the highest quality. Common QC types include:

- **Method Blank (Blk)**: A blank sample that undergoes sample processing identical to that carried out for the test samples. Method blank results are used to assess contamination from the laboratory environment and reagents.
- **Duplicate (Dup)**: An additional or second portion of a randomly selected sample in the analytical run carried through the entire analytical process. Duplicates provide a measure of the analytical method's precision (reproducibility).
- **Blank Spike (BS)**: A sample of known concentration which undergoes processing identical to that carried out for test samples, also referred to as a laboratory control sample (LCS). Blank spikes provide a measure of the analytical method's accuracy.
- **Matrix Spike (MS)**: A second aliquot of sample is fortified with with a known concentration of target analytes and carried through the entire analytical process. Matrix spikes evaluate potential matrix effects that may affect the analyte recovery.
- **Reference Material (SRM)**: A homogenous material of similar matrix to the samples, certified for the parameter(s) listed. Reference Materials ensure that the analytical process is adequate to achieve acceptable recoveries of the parameter(s) tested.

Each QC type is analyzed at a 5-10% frequency, i.e. one blank/duplicate/spike for every 10-20 samples. For all types of QC, the specified recovery (% Rec) and relative percent difference (RPD) limits are derived from long-term method performance averages and/or prescribed by the reference method.

Analyte	Result	RL	Units	Spike Level	Source Result	% REC	REC Limit	% RPD	RPD Limit	Qualifier
General Parameters, Batch B1H1427										
Blank (B1H1427-BLK1)				Prepared: 2021-08-18, Analyzed: 2021-08-18						
Chloride, Water-Soluble	< 0.002	0.002	%							
Duplicate (B1H1427-DUP1)		**Source: 21H1336-02**		Prepared: 2021-08-18, Analyzed: 2021-08-18						
Chloride, Water-Soluble	0.002	0.002	%		0.002					
General Parameters, Batch B1H1580										
Blank (B1H1580-BLK1)				Prepared: 2021-08-17, Analyzed: 2021-08-19						
Sulfate, Water-Soluble	< 0.050	0.050	%							

ATTERBERG LIMITS ASTM D423, D424

Project: Daly Bridge Geotechnical Investigation
Location: Creighton Valley Road, BC.
Sample Location/Source: BH21-01 @ 13.4 m - 13.5 m

Project No.: 201706-18
Client: BC Ministry of Transportation
& Infastructure

LIQUID LIMIT
(ASTM Designation D 423)

Trial Number	1	2	3
Tare Number	L1	L2	L3
Number of Blows	20	31	15
Mass of Wet Soil and Tare (g)	38.34	41.74	43.59
Mass of Dry Soil and Tare (g)	32.94	35.69	36.84
Mass of Tare (g)	15.8	15.75	15.8
Mass of Moisture (g)	5.4	6.05	6.75
Mass of Dry Soil (g)	17.14	19.94	21.04
Moisture Content(%)	31.5	30.3	32.1

PLASTIC LIMIT
(ASTM Designation D 424)

Trial Number	1	2
Tare Number	P1	P2
Mass of Wet Soil and Tare (g)	23.14	22.48
Mass of Dry Soil and Tare (g)	21.95	21.45
Mass of Tare (g)	16.09	16.19
Mass of Moisture (g)	1.19	1.03
Mass of Dry Soil (g)	5.86	5.26
Moisture Content (%)	20.3	19.6

Test Results

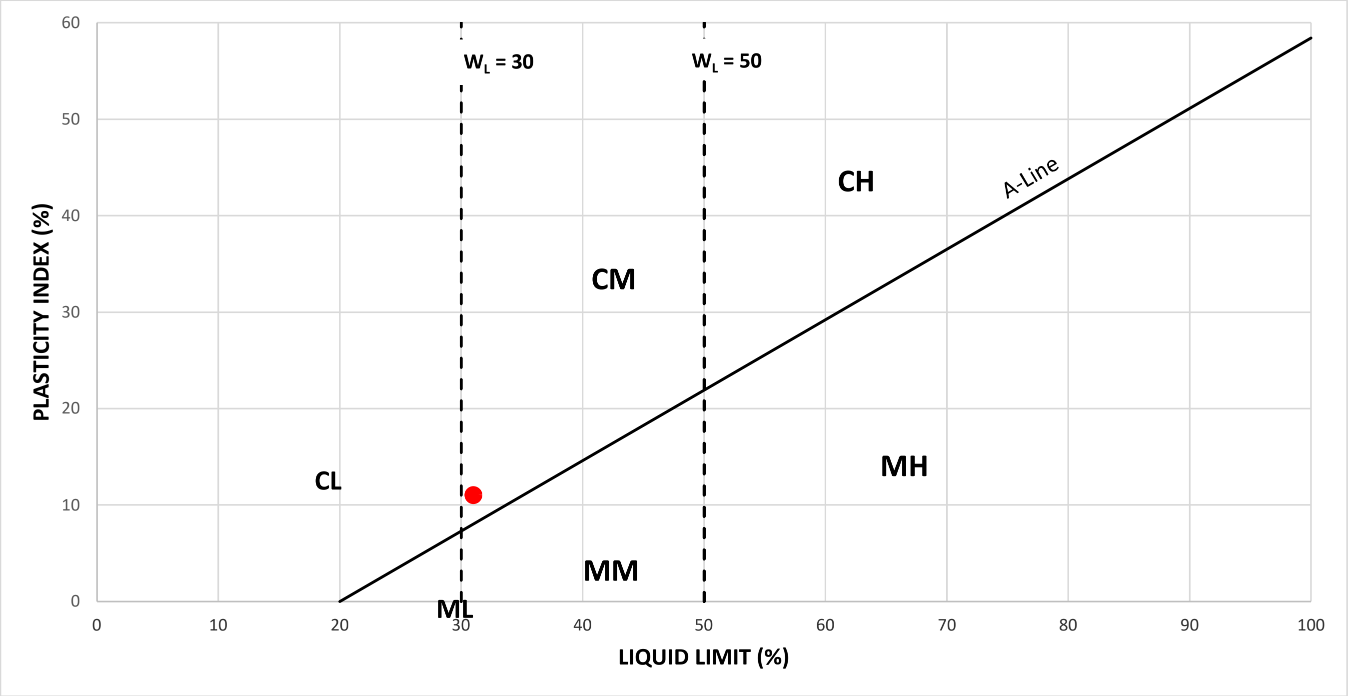
Liquid Limit:	**31**
Plastic Limit:	**20**
Plasticity Index:	11

Plasticity Classification (based on Liquid Limit W_L)

0 to 30	Low Plasticity
30 to 50	Medium Plasticity
> 50	High Plasticity

Sample Description: CM - Medium Plastic Clay
Natural Moisture Content: 34.7%
Comments:

Sample Number: 21-312
Date Tested: 12-Aug-2021
Tested by: SK
Checked by: SK



ATTERBERG LIMITS ASTM D423, D424

Project: Daly Bridge Geotechnical Investigation
Location: Creighton Valley Road, BC.
Sample Location/Source: BH21-02 @ 34' - 35'

Project No.: 201706-18
Client: BC Ministry of Transportation
& Infastructure

LIQUID LIMIT
(ASTM Designation D 423)

Trial Number	1	2	3
Tare Number	L1	L2	L3
Number of Blows	22	18	33
Mass of Wet Soil and Tare (g)	47.03	30.1	36.44
Mass of Dry Soil and Tare (g)	37.76	25.72	30.62
Mass of Tare (g)	15.66	15.73	16.05
Mass of Moisture (g)	9.27	4.38	5.82
Mass of Dry Soil (g)	22.1	9.99	14.57
Moisture Content(%)	41.9	43.8	39.9

PLASTIC LIMIT
(ASTM Designation D 424)

Trial Number	1	2
Tare Number	P1	P2
Mass of Wet Soil and Tare (g)	17.73	22.10
Mass of Dry Soil and Tare (g)	17.40	20.93
Mass of Tare (g)	15.98	15.85
Mass of Moisture (g)	0.33	1.17
Mass of Dry Soil (g)	1.42	5.08
Moisture Content (%)	23.2	23.0

Test Results

Liquid Limit:	**42**
Plastic Limit:	**23**
Plasticity Index:	19

Plasticity Classification (based on Liquid Limit W_L)

0 to 30	Low Plasticity
30 to 50	Medium Plasticity
> 50	High Plasticity

Sample Description: CM - Medium Plastic Clay
Natural Moisture Content: 35.7%
Comments:

Sample Number: 21-316
Date Tested: 12-Aug-2021
Tested by: SK
Checked by: SK