TECHNICAL MEMORANDUM

DATE August 10, 2017 **DOCUMENT No.** 1777229_TM0006_RevA

TO Jenny Wheaton, Simon Armstrong-Bayliss
Mcelhanney Consulting Services Ltd.

CC Gilles Lussier, Parks Canada

FROM Anupama Amaratunga and Cory Smith
Golder Associates Ltd.

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ILLECILLEWAET CURVE – SLOPE STABILITY REVIEW

Golder Associates Ltd. (Golder) has prepared this technical memorandum to provide updated geotechnical comments and recommendations for the Retaining Walls at km 27.1 and km 28.0 of Illecillewaet Curve Safety Improvement Project based on the revised slope topography and wall geometries provided on July 25, 2017, and observations of subgrade soils made during Golder's site visit on July 28, 2017. This updated information should be read in conjunction with Golder's geotechnical report titled "Final Geotechnical Report TransCanada Highway-Illecillewaet Curve/Summit Ponding at Roger's Pass Glacier National Park, British Columbia" dated July 27, 2016 (the Report).

As per the previous stability review completed in the Report, the analysis and modelling was completed to result in least impact to the global stability of the slope (i.e. by the addition of the wall, the analysis and design was completed to maintain or increase the global stability). It is understood that this design process is acceptable by the client.

The use of this report is subject to the conditions outlined in the *Important Information and Limitations of this Repot* that follows the main text and forms an integral part of this document. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of the report.

Retaining Wall at km 28.0

At the time of preparing the Report, the Retaining Wall height at km 28.0 varied from approximately 1.2 m to 5.2 m. Based on the original geometry provided (based on LIDAR), the results of the stability analysis indicated reinforcement embedment (i.e. reinforcement length) of 150% for wall heights 2.5 m and higher, and an embedment of 100% of the wall height or minimum 1.8 m (per AASHTO 2012) for wall sections less than 2.5 m high.

Based on the current wall heights and slope topography provided (based on site survey), the slope geometry has changed and the proposed retaining wall heights now vary from 7.4 m to 1.1 m. Three cross sections were selected based on the cross-sections provided (cross-sections were provided for stationing at 10 m intervals along the wall) and the stability of the slope was analysed for local and global stability with and without the wall. The soil model used for the analysis remains the same as used in the Report. Table 1 presents a summary of the results. Figures A1 to A8 in Appendix A provides figures showing the results from the slope stability analysis.

Table 1: Slope Stability Analysis Results - Retaining Wall at km 28.0

Station (km)	Wall Height Above Grade (m)	Minimum Wall Embedment Below Grade (m)	Total Wall Height (m)	Reinforcement Length to Wall Height (%)	Calculated Global Factor of Safety of the Existing Slope[(1)]	Calculated Factor of Safety After Construction of the Wall	
						Local Stability	Global Stability[(1)]
28+010	5.8	1.5	7.3	100	1.2	1.5	1.5
28+050	4.0	1.0	5.0	125	1.3	1.5	1.5
28+090	2.5	0.6	3.1	125	1.4	1.6	1.4

(1) – Ignoring shallow surficial failures

To achieve calculated factor of safety of 1.5 for local stability of the wall and to result in least impact to the existing slope stability, reinforcement lengths equivalent to 100% of the wall height is recommended for wall heights between 7.0 m to 7.4 m. For wall heights less than 7.0 m, reinforcement lengths equivalent to 125% of the wall height or a minimum of 1.8 m (per AASHTO) is recommended.

A minimum wall embedment depth of 20% of the total wall height or 0.6 m, whichever is greater and a minimum 1 m distance from the front toe of the wall to the slope is recommended.

It should also be noted that the temporary cut slopes during construction of the wall may extend into the existing road and pavement structure, depending on final design reinforcement lengths. Disturbance to the existing pavement structure may be required to accommodate construction of the retaining wall.

The internal stability and design of the retaining wall is to be completed by others.

Retaining Wall at km 27.1

At the time of preparing the Report the maximum wall height at Retaining Wall at km 27.1 was 2.7 m, and embedment (i.e. reinforcement length) of 100% of the wall height or minimum 1.8 m (per AASHTO 2012) was recommended. Subsurface conditions comprising sand and gravel with an internal friction angle of 38 degrees was used in the analysis along with assumed groundwater conditions (i.e. no seepage).

The construction of this retaining wall has started (i.e. excavation work) and the wall designers (Horizon Engineering Inc.) have made an observation that the soil conditions in the area of the exposed subgrade between Stations 27+200 to 27+180, are different than used in the Report. It is also understood that the slope geometry and wall geometry has changed based on the ground survey conducted for construction (i.e. the ground survey is different than LIDAR used for original analysis). As a result of the changed topography, wall design and observation of subgrade conditions (on portion of the wall) Golder was requested to provide comments on the stability of the retaining wall based on the observed conditions.

Site Visit

Golder made a site visit on July 28, 2017 to observe the exposed subgrade at retaining wall foundation level from Station 27+200 to 27+180. At the time of the site visit, the exposed subgrade generally consisted of silty sand with variable gravel content (some gravel to gravelly).

Three test pits, TP17-01 to -03 were excavated at Stations 27+120, 27+150, and 27+195, respectively, with an excavator available at site. Test Pit TP17-01 was excavated to 3 m below existing ground surface (i.e. at crest of slope). The test pit was generally located in the area between the existing slope surface and front face of the retaining wall. The base of the test pit was about 1 m below the base elevation of the retaining wall. Test Pit TP17-

02 was excavated to 3.4 m below existing grade to about base elevation of the retaining wall. Test Pit TP17-02 was also excavated between the existing slope surface and front face of the retaining wall. These two test pits could not be excavated below the footprint of the retaining walls due to access constraints due to the presence of a live Telus line and proximity to the highway and traffic. Test Pit TP-03 was excavated below the footprint of the wall to approximately 2 m below the base of the wall. Scanned copies of the field test pit logs TP17-01 to -03 are provided in Appendix B. Generally silty sand with variable gravel content (generally some gravel to gravelly) was encountered in all three test pits. In Test Pit TP-03, sand and gravel was encountered near the base of the test pit. Cobbles about 300 mm size range was observed at this depth. Sieve analysis. was conducted on two samples collected from the test pits from elevations below the design MSE base elevation and results are provided in Appendix B and summarized below.

Table 2: Results from the Sieve Analysis

Test Pit Number	TP17-01	TP17-03
Sample Number	GS02	GS03
Sample Depth	3.0 m	3.0
Gravel Content	15%	43%
Sand Content	62%	31%
Fines Content	23%	26%
Sample Description	(SM) gravelly SILTY SAND	(GM) sandy SILTY GRAVEL

No seepage was observed from the slope or within the test pits.

The soil descriptions discussed in this memorandum are based on commonly accepted methods of classification and identification employed in geotechnical practice and in accordance to the Soil Classification System chart, provided in Appendix A. Classification and identification of soil involves judgment and Golder does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice. The depths of stratigraphic changes are generally approximate and inferred since there is often a gradual transition between soil types. It should be noted that it is expected that variations in the subsurface conditions may occur between and beyond the test pits.

Stability Analysis

Based on the current wall heights and slope topography provided (based on site survey), the slope geometry has changed and the proposed retaining wall heights now vary from 1.1 m to 2.2 m from Station 27+110 to 27+207 along the wall. Based on the cross-sections provided a critical section, considered to be representative of the entire wall was selected and the slope was analysed for local and global stability with and without the wall. Stability analysis was conducted for subsurface conditions comprising silty sand some gravel to gravelly with an internal friction angle of 36 degrees around the wall and 38 degrees below the wall (as shown in the figures), and assumed groundwater conditions (i.e. no slope seepage). Table 3 presents a summary of the results. Figures C1 to C3 in Appendix C provides figures showing the results from the slope stability analysis.

Table 3: Slope Stability Analysis Results - Retaining Wall at km 28.0

Station (km)	Wall Height Above Grade (m)	Wall Embedment Below Grade (m)	Total Wall Height (m)	Reinforcement Length to Wall Height (%)	Calculated Global Factor of Safety of the Existing Slope[(1)]	Calculated Factor of Safety After Construction of the Wall	
						Local Stability	Global Stability[(1)]
27+140	1.6	0.6	2.2	130	1.4	1.5	1.4

(1) – Ignoring shallow surficial failures

To achieve a calculated factor of safety of 1.5 for local stability of the wall and to result in least impact to the existing slope stability, reinforcement lengths equivalent to 130% of the wall height or a minimum of 1.8 m (per AASHTO) is recommended.

A minimum wall embedment depth of 0.6 m and a minimum 1 m distance from the front toe of the wall to the slope is recommended.

It should also be noted that the temporary cut slopes during construction of the wall may extend into the existing road and pavement structure, depending on final design reinforcement lengths. Disturbance to the existing pavement structure may be required to accommodate construction of the retaining wall.

The internal stability and design of the retaining wall is to be completed by others.

The prepared subgrade should be compacted to minimum 98% SPMDD prior to start of construction of the wall.

SUITABILITY OF SGSB AS SUBGRADE FILL BELOW LEVELLING PAD FOR FROST PROTECTION

Due to the content of silt found in the subgrade below the MSE wall base elevation at Retaining Wall at km 27.1, it is understood that Horizon has recommended to replace the subgrade below the MSE wall face with non-frost susceptible soil to a depth of 1.3 m below the underside of the levelling pad within a zone 2.1 m wide that extend 1.1 m beyond the exterior edge of the levelling pad. A gradation analysis report (provided by McElhanney and attached as Appendix D) of SGSB (Sand and Gravel Sub Base) was provided for review. Based on the test results provided, the proposed fill material contains about 40% gravel and 57.7% sand and about 2.3% fines and is classified as sand and gravel. Based on these results, the SGSB material is considered suitable to be used as non-frost susceptible backfill below the MSE wall levelling pad.

The fill should be placed in lifts with a maximum thickness of 200 m when compacted, and should be compacted uniformly to minimum 98% SPMDD (Standard Proctor Maximum Dry Density) at ± 2% of the optimum water content.

CLOSURE

Based on the revised slope survey and retaining wall heights provided, and Golder's site visit and review of the slope stability at proposed MSE locations (27.1 km and 28.0 km, the revised recommendations presented above should be reviewed by the designer and implemented into the wall design and construction for global stability. Golder should be contacted if changed conditions from those presented above and in the Report are encountered during construction.

We trust that the information presented meets your present requirements. If you have any questions, please contact the undersigned.

Yours truly,

GOLDER ASSOCIATES LTD.

APEGA PERMIT TO PRACTICE # 05122

Anupama Amaratunga, M.Sc., P.Eng.
Geotechnical Engineer

Cory Smith, P.Eng.
Principal, Senior Geotechnical Engineer

AA/CS/ak/kpl/al

Attachments:

Appendix A; Stability Analysis Figures – Retaining Wall at km 28.0

Appendix B; Field Test Pit Logs and Laboratory Test Results

Appendix C; Stability Analysis Figures – Retaining Wall at km 27.1

Appendix D; Sieve Analysis Results for SGSB – provided by McElhanney

https://capws.golder.com/sites/p1538900thc4laningrogerspassgeotechnical/document control/tm_technical memo/fy 17-18 cu 25 1777229/tm0006_i-curve mse wall review/rev 0/1777229_tm0006_mse wall review_aug 10, 2017_rev 0.docx

Appendix A
Stability Analysis Figures – Retaining Wall at km 28.0

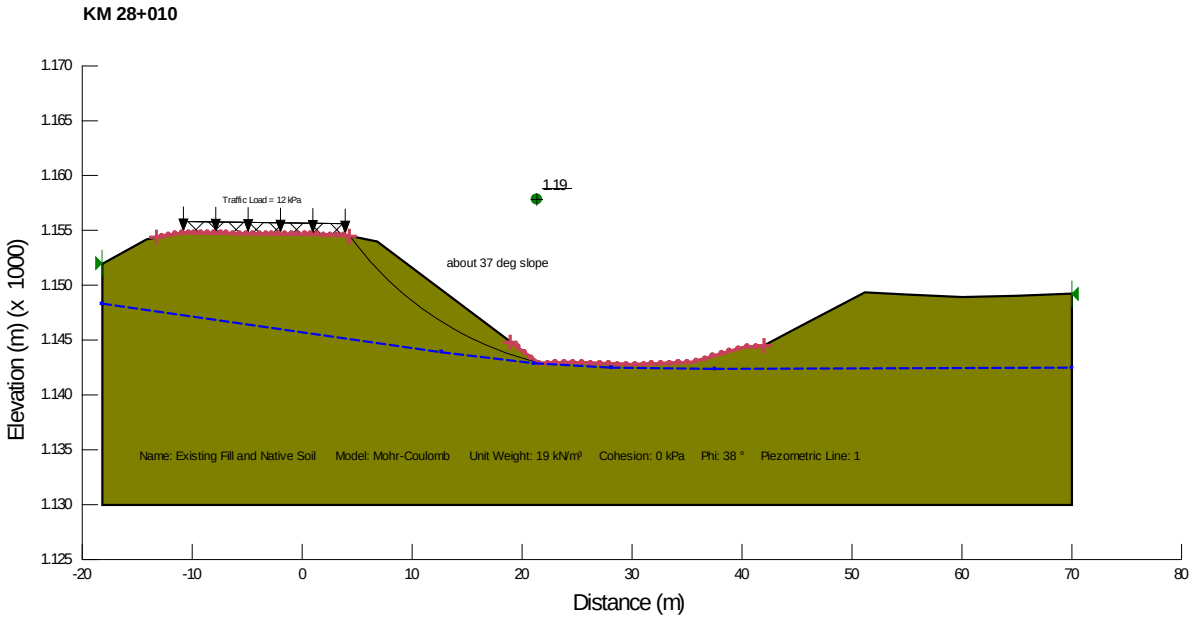


Figure A1- Station 28+010 - Global Stability of the Existing Slope

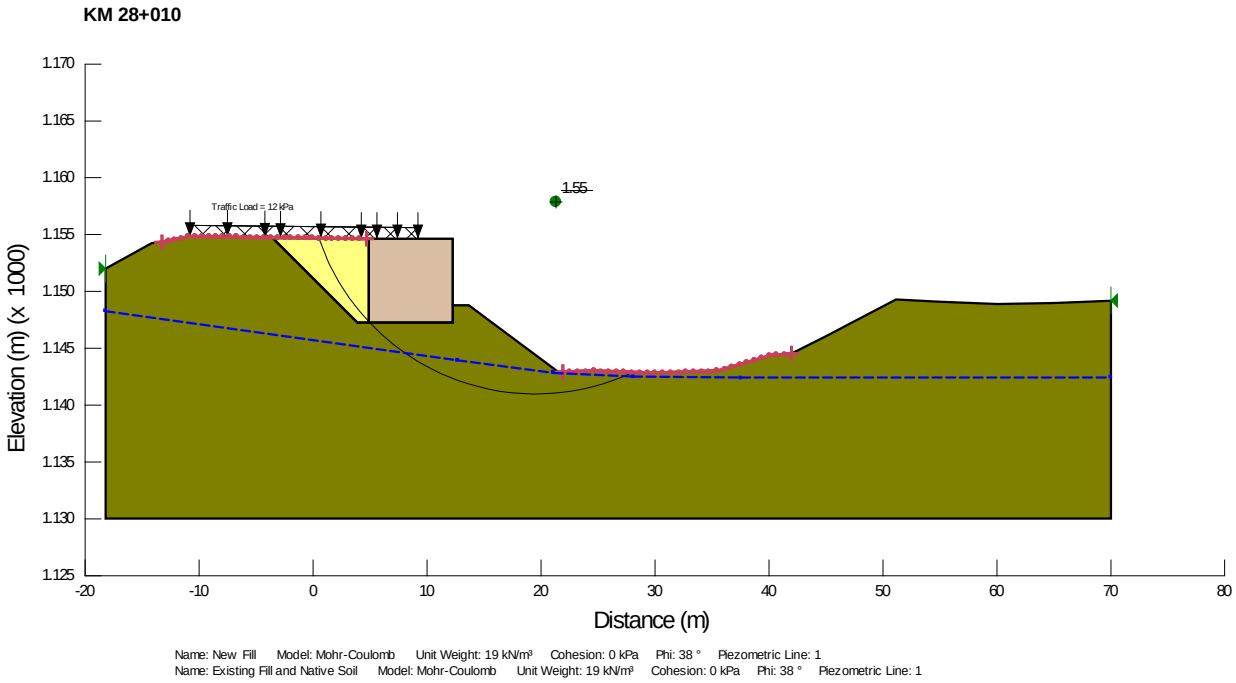


Figure A2- Station 28+010 - Global and Local Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height - 7.3 m, Wall Embedment below Finish Grade - 1.5 m, Reinforcement Length - 7.3 m)

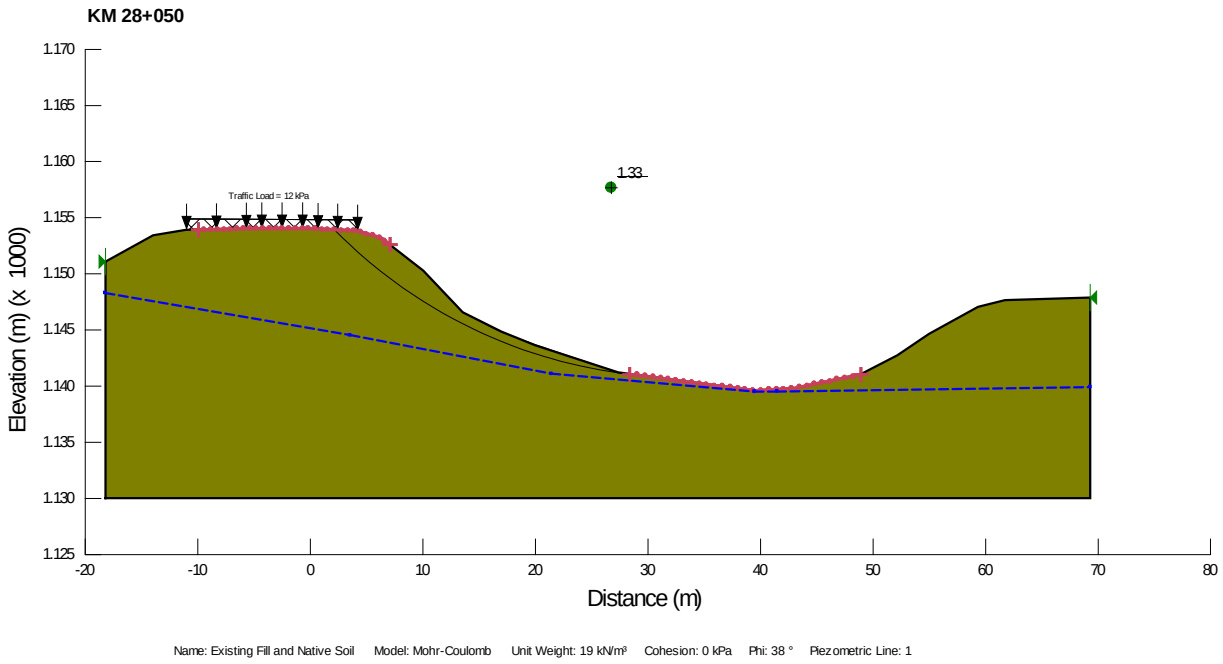


Figure A3- Station 28+050 - Global Stability of the Existing Slope

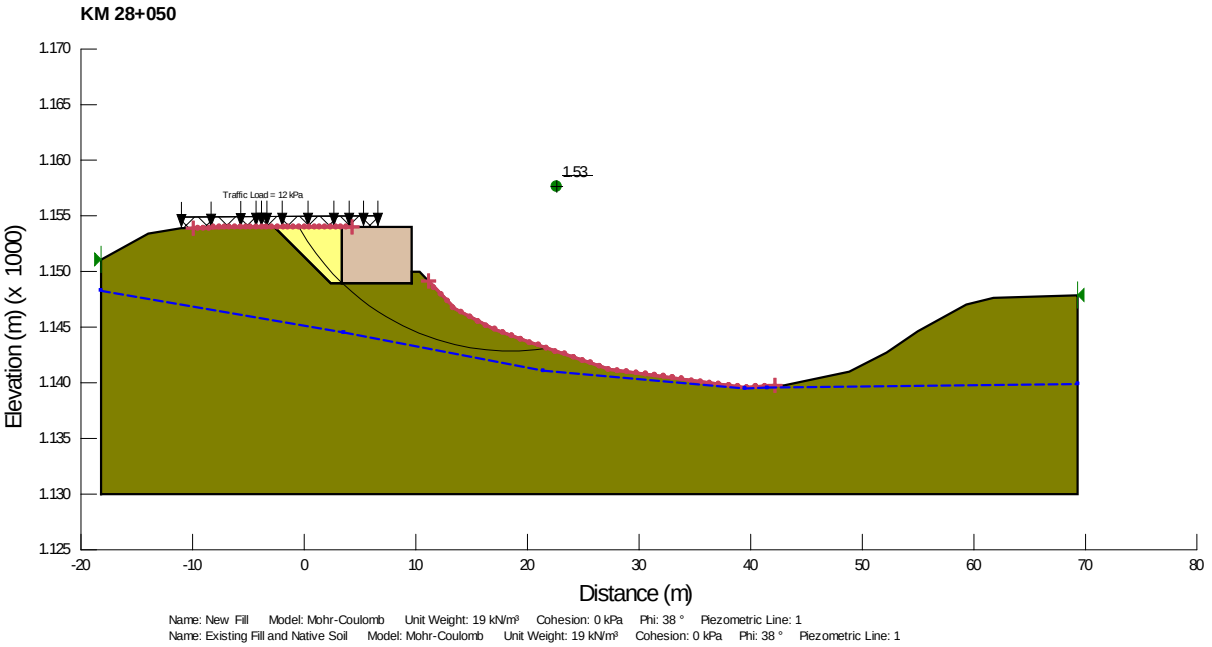


Figure A4- Station 28+050- Local Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height - 5.0 m, Wall Embedment below Finish Grade - 1.0 m, Reinforcement Length - 6.3 m)

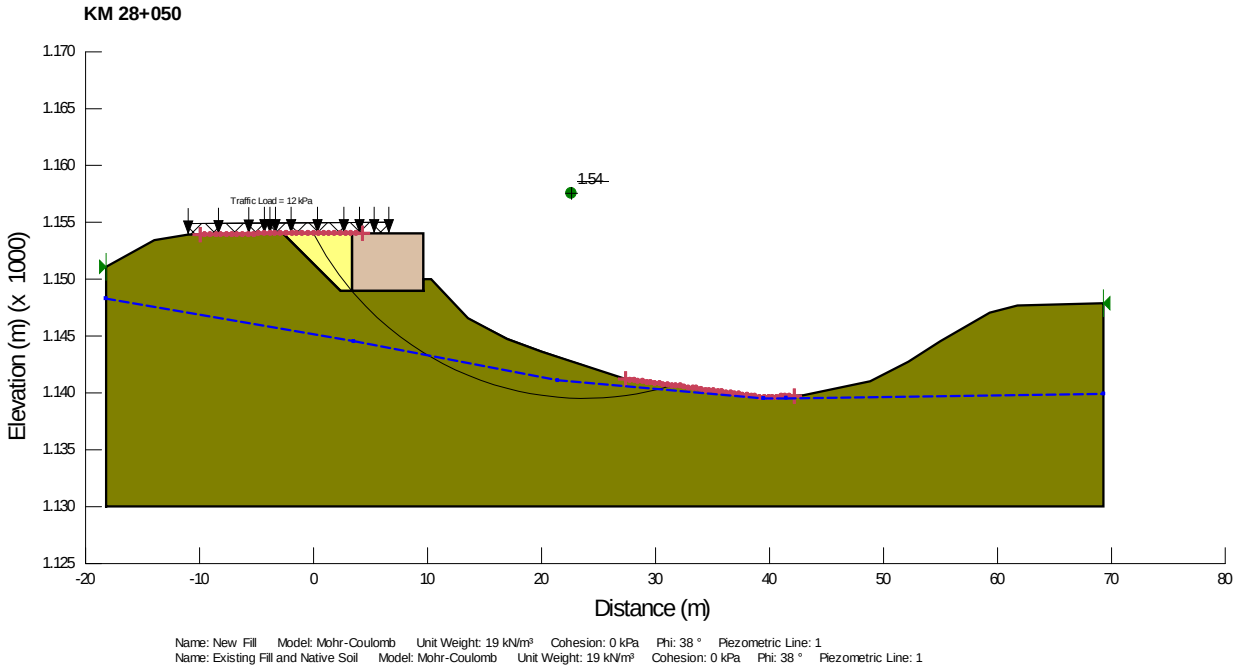


Figure A5- Station 28+050- Global Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height - 5.0 m, Wall Embedment below Finish Grade - 1.0 m, Reinforcement Length - 6.3 m)

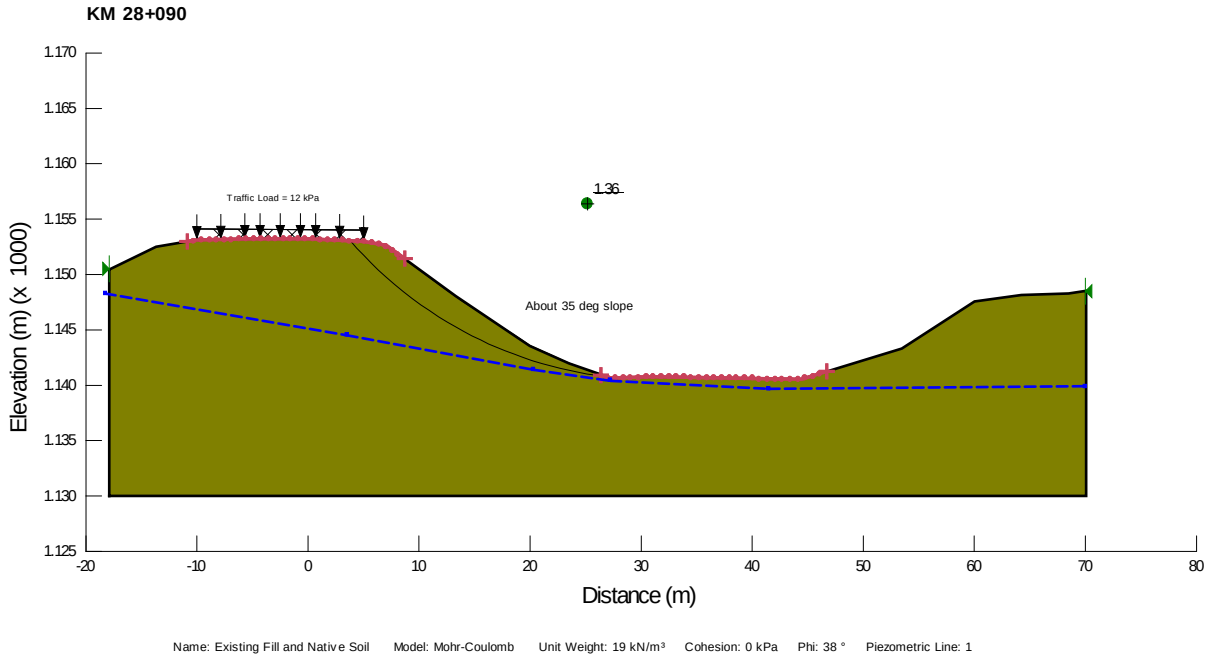


Figure A6- Station 28+090 - Global Stability of the Existing Slope

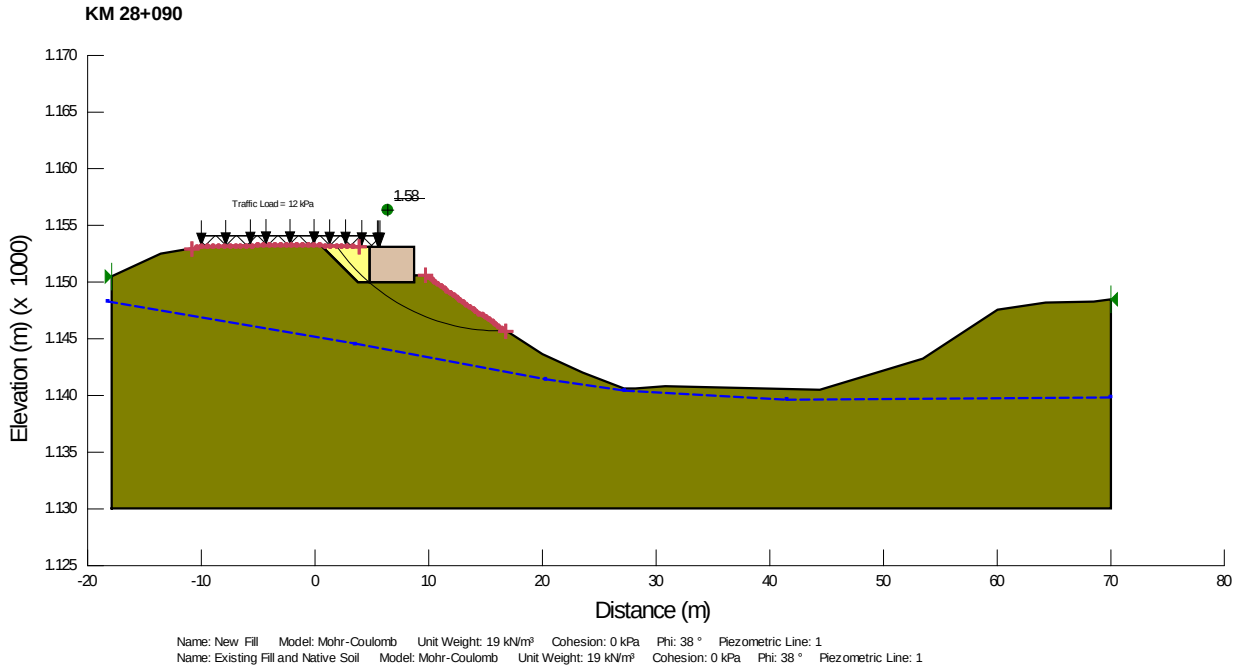


Figure A7- Station 28+090- Local Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height - 3.1 m, Wall Embedment below Finish Grade - 0.6 m, Reinforcement Length - 3.9 m)

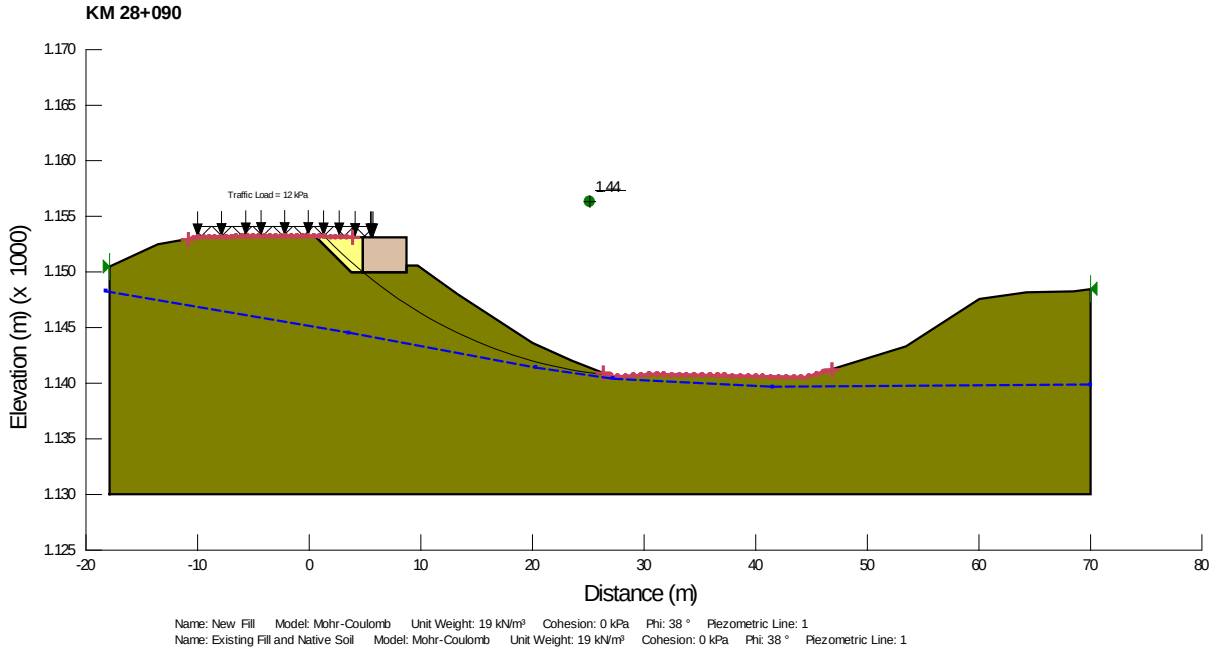


Figure A8- Station 28+090- Global Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height - 3.1 m, Wall Embedment below Finish Grade - 0.6 m, Reinforcement Length - 3.9 m)

Appendix B
Field Test Pit Logs and Laboratory Rest Results

FIELD TEST PIT LOG

Job No. 1777229 Project I-Curve, Mounds, BVP Phase 2

Date July 28/17 Inspected by Hamdan Mawani

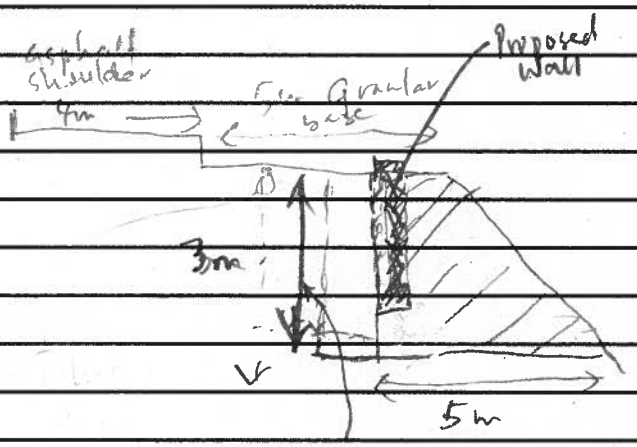
Location 27+120 (km 27.1 MSE wall) Excavation method Excavator CAT (60cm bucket)

Elev. - Dimensions 2.5 x 5m x 3m depth.

Reason for terminating hole

D464343 E 5679799 N

DEPTH (m)	STRATUM DESCRIPTION	SAMPLE No.	SAMPLE DEPTH	REMARKS and TESTING
0 to 0.6	Sand & Gravel, granular base			
0.6 to 3.0	Silty Sand, some gravel to gravelly brown	1	2.0	plastic bag
2.7 to 3.0	- becoming gravelly at approx 2.7m	2	3.0	plastic bag
	Terminated at 3.0m (approx. 1m below base.			



Telus line

Depth to seepage NA Rate of seepage NA

Depth to standing water NA

T.P. 17-01

PROJECT No. DRAWN REVIEWED DATE

GA.103

Golder Associates

FIELD TEST PIT LOG

Job No. 1777 229 Project I-Curve, Mounds, BVP Phase 2

Date July 28, 2017 Inspected by Hamed Marwan

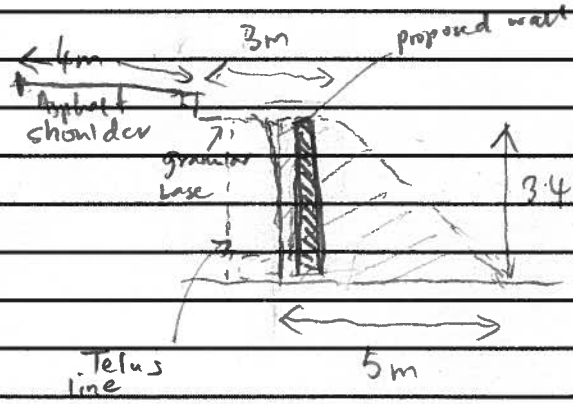
Location 27 + 150 (km 27.1 MSE wall) Excavation method Excavator CAT.

Elev. Dimensions 3 m x 5m x 3.4m depth

Reason for terminating hole

11 U 0464314E 5679780 N

DEPTH (m)	STRATUM DESCRIPTION	SAMPLE No.	SAMPLE DEPTH	REMARKS and TESTING
0 to 0.6m	Sand & Gravel - Granular base	GS		
0.6 to 2.1 m	Silty Sand, some gravel, brown	GS 1	1.5m	(Pail)
2.1 to 3.4	Silty Sand, some gravel to gravelly, brown.	GS 2	3.0	Pail
	Same as above.	GS3	3.4	Pail



Depth to seepage No water Rate of seepage NA

Depth to standing water NA

T.P. 17-02

PROJECT No. DRAWN REVIEWED DATE

GA.103

Golder Associates

FIELD TEST PIT LOG

Job No. 1777229 Project I-Curve, Mounds, BVP Phase 2

Date July 28/2017 Inspected by Hamdan Marwasi'

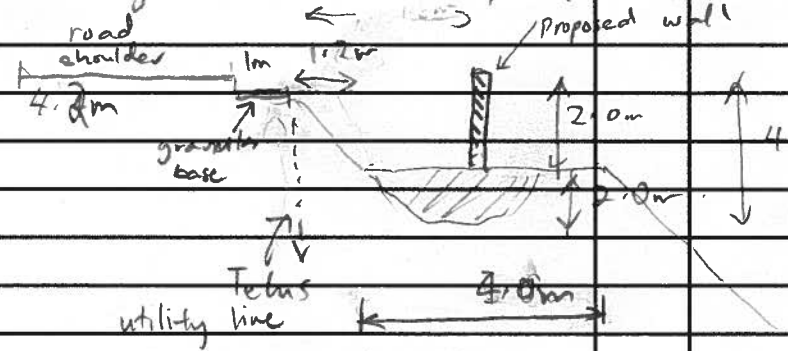
Location 27+195 (km 27.1 MSE wall) Excavation method Excavator CAT

Elev. ! Dimensions 3m x 4m x 2 m depth.

Reason for terminating hole

11U 0464278E 5679763N

DEPTH (m)	STRATUM DESCRIPTION (Reference stratum from Road shoulder)	SAMPLE (m) No.	SAMPLE (m) DEPTH	REMARKS and TESTING
0–150mm	Asphalt			
150 to 600mm	Sand & Gravel Granular Sub base & base.			
0.6 to 1.2m	Silty Sand, some gravel to gravelly, brown,	GS 1	1.2m	Plastic bag.
1.2 to 2.0m	Silty sand, gravelly, brown, (excavated earlier)	GS 2	2.0m	(Pail)
2.0 to 3.8m	Silty sand, gravelly, brown.	GS 3	3.0	(Pail)
3.8 to 4.0m	Sand & gravel, some cobbles (300m), brown	GS 4	4.0m	(Pail)



Depth to seepage No water seepage Rate of seepage —

Depth to standing water N/A

T.P. 17-03

Test Pit on Jul 28, 2017

Excavated Slope 1:0.75

PROJECT No. DRAWN REVIEWED DATE

GA.103

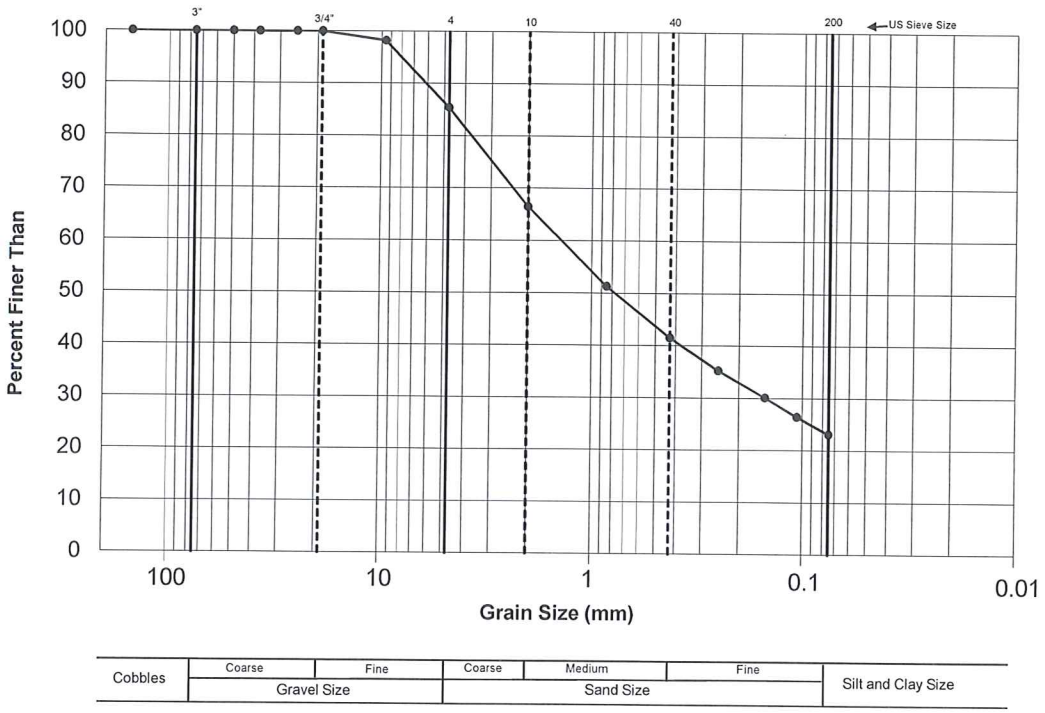
Golder Associates

Particle Size Distribution of Soils using Sieve Analysis

(ASTM D6913-04)

Project No.:	1777229	Phase:	2000		Date:	2-Aug-17
Short Title:	PCA/GNP-CU25/I-Curve,Mounds,BVP Ph2					
Sub Sampled By:	FC	Washed By:	FC		Sieved By:	DS
Field Tag No.:	-	Location:	-		BH or TP No.:	TP17-01
Lab No.:	C397-02	Northing:	-	m	Sample No.:	GS02
Sampled By:	H.Marwasi	Easting:	-	m	Depth From:	3.0 m
Sample Date:	28-Jul-17	Elevation:	-	m	Depth To:	3.0 m

Test Method:	A	Drying Method:	Moist	
Composite Sieve:	Yes	if Yes, Split on:	4.75	mm
Material Excluded from Sieve:	No	Describe:		
Prior Testing on Sample:	No	Describe:		



Sieve Size (mm)	Passing %
150.0	100
75.0	100
50.0	100
37.5	100
25.0	100
19.0	100
9.50	98
4.75	85
2.00	66
0.850	51
0.425	42
0.250	35
0.150	30
0.106	26
0.075	23

Received Water Content (%)
2.1

Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)
0	15	62	23

D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
1.5	0.1	N/A	N/A	N/A

Sample Description: (SM) gravelly SILTY SAND, fine to coarse sand, fine gravel; light brown; non-cohesive, loose, dry

USCS Classification: SM

Remarks:

Bay 8, 820 - 28 St. NE
Calgary, AB T2A 6K1

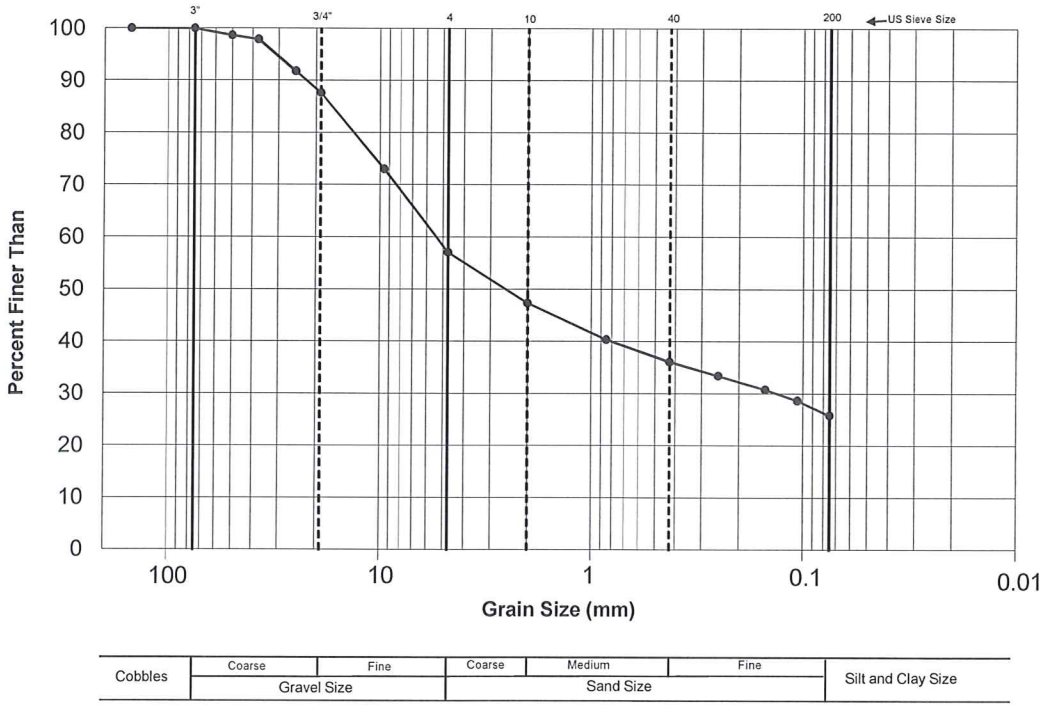
Reviewed by: _____

Particle Size Distribution of Soils using Sieve Analysis

(ASTM D6913-04)

Project No.:	1777229	Phase:	2000		Date:	2-Aug-17
Short Title:	PCA/GNP-CU25/I-Curve,Mounds,BVP Ph2					
Sub Sampled By:	FC	Washed By:	FC		Sieved By:	FC
Field Tag No.:	-	Location:	-		BH or TP No.:	TP17-03
Lab No.:	C397-01	Northing:	-	m	Sample No.:	GS03
Sampled By:	H.Marwasi	Easting:	-	m	Depth From:	3.0 m
Sample Date:	28-Jul-17	Elevation:	-	m	Depth To:	3.0 m

Test Method:	A	Drying Method:	Moist	
Composite Sieve:	Yes	if Yes, Split on:	4.75	mm
Material Excluded from Sieve:	No	Describe:		
Prior Testing on Sample:	No	Describe:		



Sieve Size (mm)	Passing %
150.0	100
75.0	100
50.0	99
37.5	98
25.0	92
19.0	88
9.50	73
4.75	57
2.00	47
0.850	40
0.425	36
0.250	33
0.150	31
0.106	29
0.075	26

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
15.4	0	43	31	26	5.6	0.1	N/A	N/A	N/A

Sample Description: (GM) sandy SILTY GRAVEL, fine to coarse gravel, some fine to coarse sand; light brown; non-cohesive, moist

USCS Classification: GM

Remarks:

Bay 8, 820 - 28 St. NE
Calgary, AB T2A 6K1

Reviewed by: _____

Appendix C
Stability Analysis Figures – Retaining Wall at km 27.1

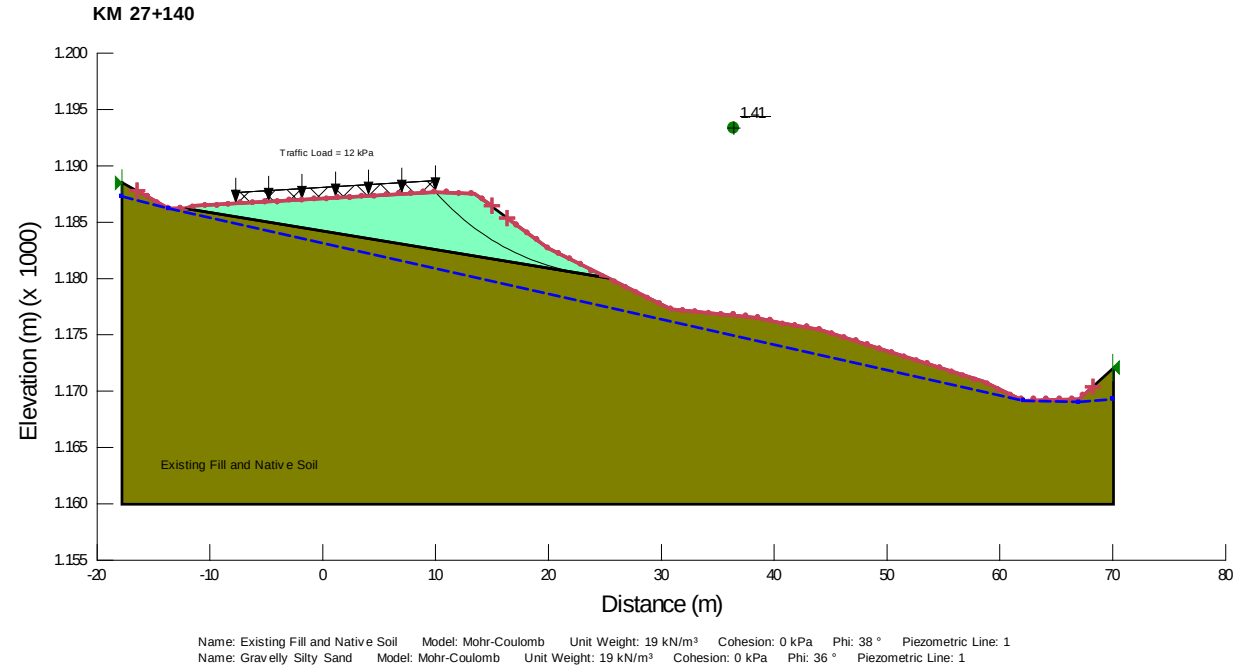


Figure C1- Station 27+140 - Global Stability of the Existing Slope

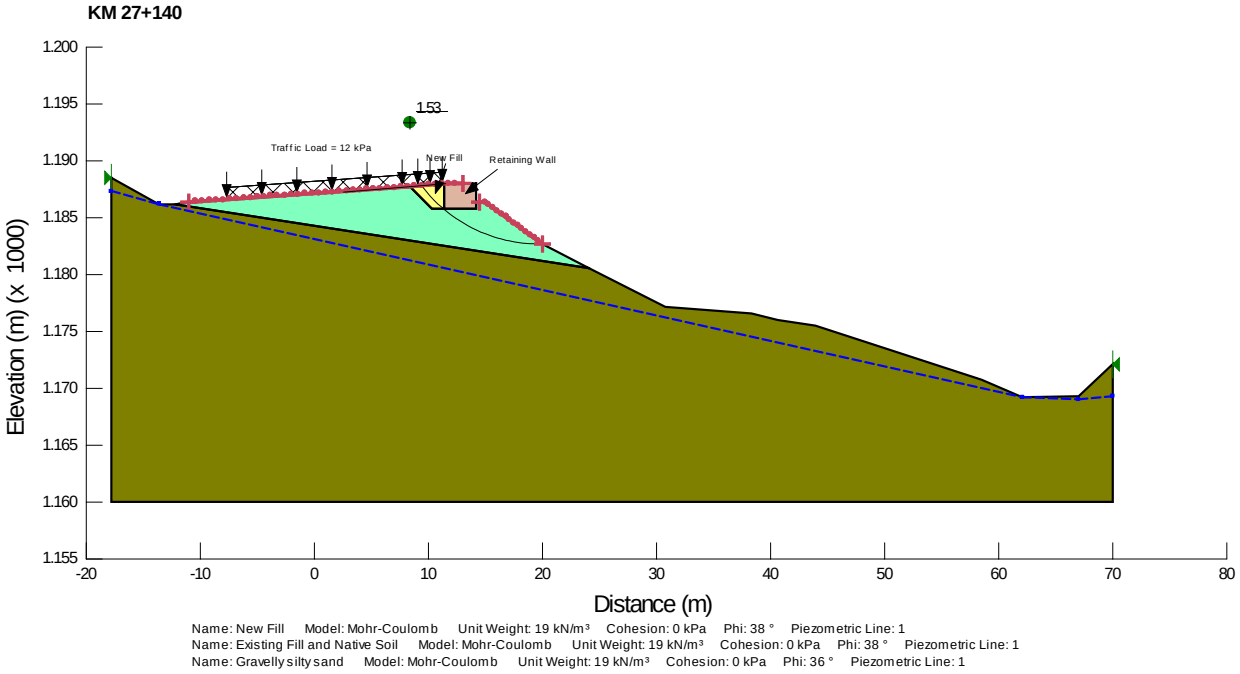


Figure C2- Station 27+140 – Local Stability after Construction of the Retaining Wall (Retaining Wall Height – 2.2 m, Wall Embedment below Finish Grade – 0.6 m, Reinforcement Length – 2.9 m)

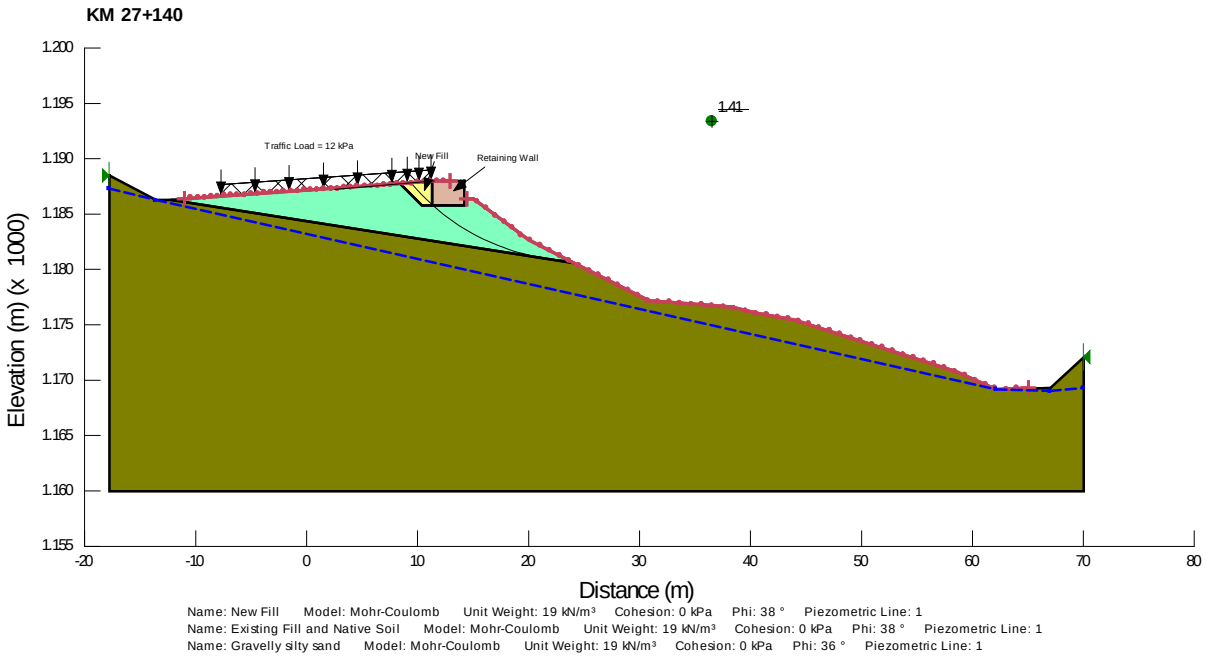


Figure C3- Station 27+140 – Global Stability of the Slope after Construction of the Retaining Wall (Retaining Wall Height – 2.2 m, Wall Embedment below Finish Grade – 0.6 m, Reinforcement Length – 2.9 m)

Appendix D

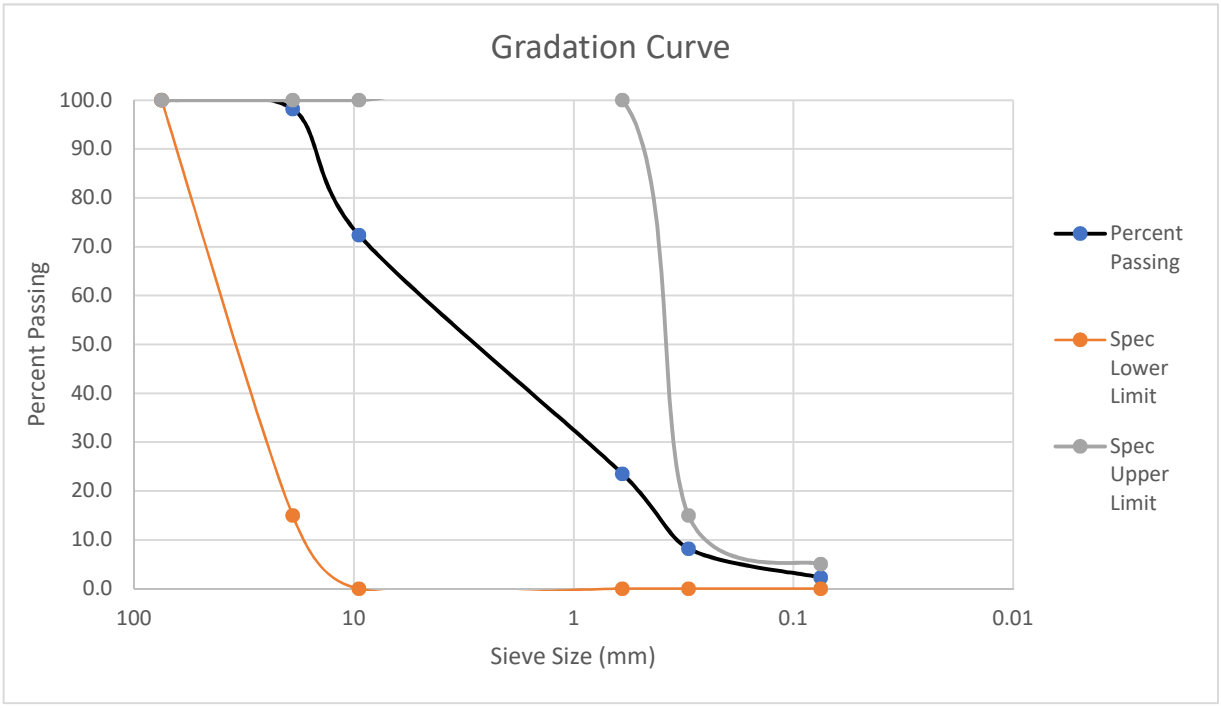
Sieve Analysis Results for SGSB – provided by McElhanney

Gradation Analysis Report

Date: June 19, 2017 Project: ICSI Phase 1

Sample Source: Valley Blacktop Westside Spec: MoTI SGSB

Sieve Size (mm)	Percent Passing	Spec Lower Limit	Spec Upper Limit
75	100.0	100	100
19	98.2	15	100
9.5	72.4	0	100
0.6	23.5	0	100
0.3	8.2	0	15
0.075	2.3	0	5



Tested in accordance with ASTM C136 and ASTM C123