APPENDIX B

GEOTECHNICAL REPORT

DYREGROV ROBINSON INC.
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December 7, 2015

File No. 143691

Tetra Tech WEI
400 – 161 Portage Avenue East
Winnipeg, MB. R3B 0Y4

Attn: Kirby McRae, P.Eng., Senior Design Lead

Dear Mr. McRae:

RE: City of Winnipeg – Ferry Road Riverbend CSR (Contract 5 East)
Ecole Assiniboine Outfall – Riverbank Bank Stability Assessment

As requested, Dyregrov Robinson Inc. (DRI) has undertaken a stability analysis for the proposed Ecole Assiniboine outfall into the Assiniboine River. The outfall is a component of the proposed Ferry Road Riverbend Combined Sewer Relief project (Contract 5 East) located south of Portage Avenue between Bourkevale Drive and Riverbend Crescent in Winnipeg, Manitoba.

Proposed Outfall

The proposed outfall into the Assiniboine River is located east of Ecole Assiniboine in Scott Park. The park is located between Parkside Drive and Riverbend Crescent.

The outfall is located at an outside bend along the Assiniboine River. We understand the final alignment of the outfall piping (900 mm diameter corrugated steel pipe) will be located to minimize impacts to mature trees located along the river bank. The pipe will be installed perpendicular to the riverbank slope and then turned 45 degrees in the downstream direction. The outfall pipe invert will be around elevation 226.2 m and at the upstream end of the pipe, where it connects to the LDS, it will be at an elevation of 226.3 m. The two connecting LDS pipe inverts will be at elevations of 227.2 m (750mm diam. pipe from the southwest) and 229.7 m (600 mm diam. pipe from the northeast). Erosion protection of the river bank will be provided at the location of the outfall. The drawing attached in Appendix A shows the riverbank and river channel profiles and a plan view of the proposed pipe alignment.

Subsurface Conditions

The subsurface conditions for the stability modelling work are based on the test hole (TH 15-134) drilled at the top of the river bank. The test hole log is included in Appendix B. The general stratigraphy encountered in the test hole, from site grade, consists of silty clay overlying glacial silt till.

The silty clay is about 3.3 m thick and appears to be a lacustrine deposit. The clay is brown in color, moist with a stiff consistency and is of high plasticity. The moisture contents of the clay range from about 32 to 42 percent.

Glacial silt till was encountered at an elevation around 230 m at a depth of 3.3 m. The till in the Winnipeg area is known to be a heterogeneous mixture of sand, gravel, cobble and boulder size materials in a clay and/or silt matrix. The till encountered in the test hole is a brown silt till containing trace sand and trace gravel. It is compact and dry with moisture contents around 10 percent. Auger refusal was encountered at a depth of 4.9 m, around elevation 228.4 m.

No seepage or sloughing was noted in the test hole. The groundwater conditions should be expected to vary seasonally, from year to year and possibly as a result of construction activities.

River Bank Stability

The objective of the work was to evaluate the existing stability of the river bank and evaluate if any stabilization measures are required for the proposed outfall. The stability model was prepared using the cross-sections surveyed and provided to DRI by Tetra Tech WEI and the subsurface conditions encountered in the test hole.

The stability analysis was performed using Geo-Slope International's Slope/W software program. All models were run using the Morgenstern-Price Method with a half-sine side function.

Three cross-sections were surveyed by Tetra Tech, one along the centreline of the proposed outfall and one 15 m left and 15 m right from the proposed outfall. The profile of the riverbank and river channel was similar for all three sections.

Existing Conditions

The total height of the river bank about 7.4 m and the average slope angle is about 2.6H:1V. At the toe area of the riverbank there is a 5 m wide 'bench' with a local toe slope that is steeper than 1H:1V. The slope of the river channel is around 13H:1V. The bank is well vegetated with grass and trees and there are no signs of any deep seated movements of the river bank. We understand that there is an existing outfall (Riverbend Combined Sewer Outfall) is located downstream of the proposed outfall.

Soil Properties

The soil properties used for the stability analysis work are provided in Table 1. The shear strength parameters are conventional shear strength parameters that were assigned to the lacustrine clay and glacial till.

Table 1 – Soil Properties for Stability Analysis

Material	**c'** (kPa)	**Φ'** (degrees)	**Sat. Unit Weight** (kN/m^3)
Lacustrine Clay	5	17	17.0
Glacial Till	5	30	22.0

Groundwater and River Level Conditions

The groundwater level for all layers was assumed to be 2 m below general site grade. The winter river level was set at 225.5 m based on the ice level surveyed by Tetra Tech WEI.

Stability Modeling Results

The stability model outputs are provided in Appendix C. The model results for the existing conditions (Figure C1) indicate that the factor of safety associated with the global stability of the riverbank is 1.8 and the slip surface daylights about 24 m behind the toe of slope (i.e. 5 m behind the top of bank). The local slip surface at the toe area (Figure C2) of the river bank has a factor of safety around 1.6 and daylights about 3 to 4 m behind the toe of slope.

Discussion and Recommendations

The results of the stability modeling indicate that the existing stability of the river bank exceeds the typical target levels of safety for design (i.e. factor of safety of 1.5). The stability was also checked by setting the cohesion strength parameter of the glacial till to zero. The results showed that under this condition the global stability of the riverbank was slightly higher than 1.5 and some local slip surfaces at the over-steepened toe area of the riverbank had factors of safety around 1.

Local regrading of the toe area should be included in the final design to reduce the potential for localized failures to develop. A minimum slope angle of 3H:1V is recommended. A slip collar should be provided in the outfall pipe, it can be located about 4 m back from the toe of slope located at an elevation of 225.5 m.

Some maintenance of the river bank area upstream and downstream of the outfall zone may be required in the future should erosion related (localized) failures develop over time.

Closure

This report was prepared based on our understanding of the proposed Ecole Assiniboine outfall into the Assiniboine River, the subsurface conditions encountered in the test hole during the geotechnical investigation and the results of the river bank stability analysis. Subsurface conditions are inherently variable and should be expected to vary across the site.

This report was prepared for the exclusive use of The City of Winnipeg and Tetra Tech WEI for the Ecole Assiniboine outfall to be constructed for the Ferry Road Riverbend CSR Project (Contract 5 East). The information contained in this report shall not be used by any third parties for any other projects. The findings presented in this report have been prepared in accordance with generally accepted geotechnical engineering principles and practise. No other warranty, expressed or implied, is provided.

Please contact the undersigned if we can be of further assistance.

DYREGROV ROBINSON INC.

Gil Robinson

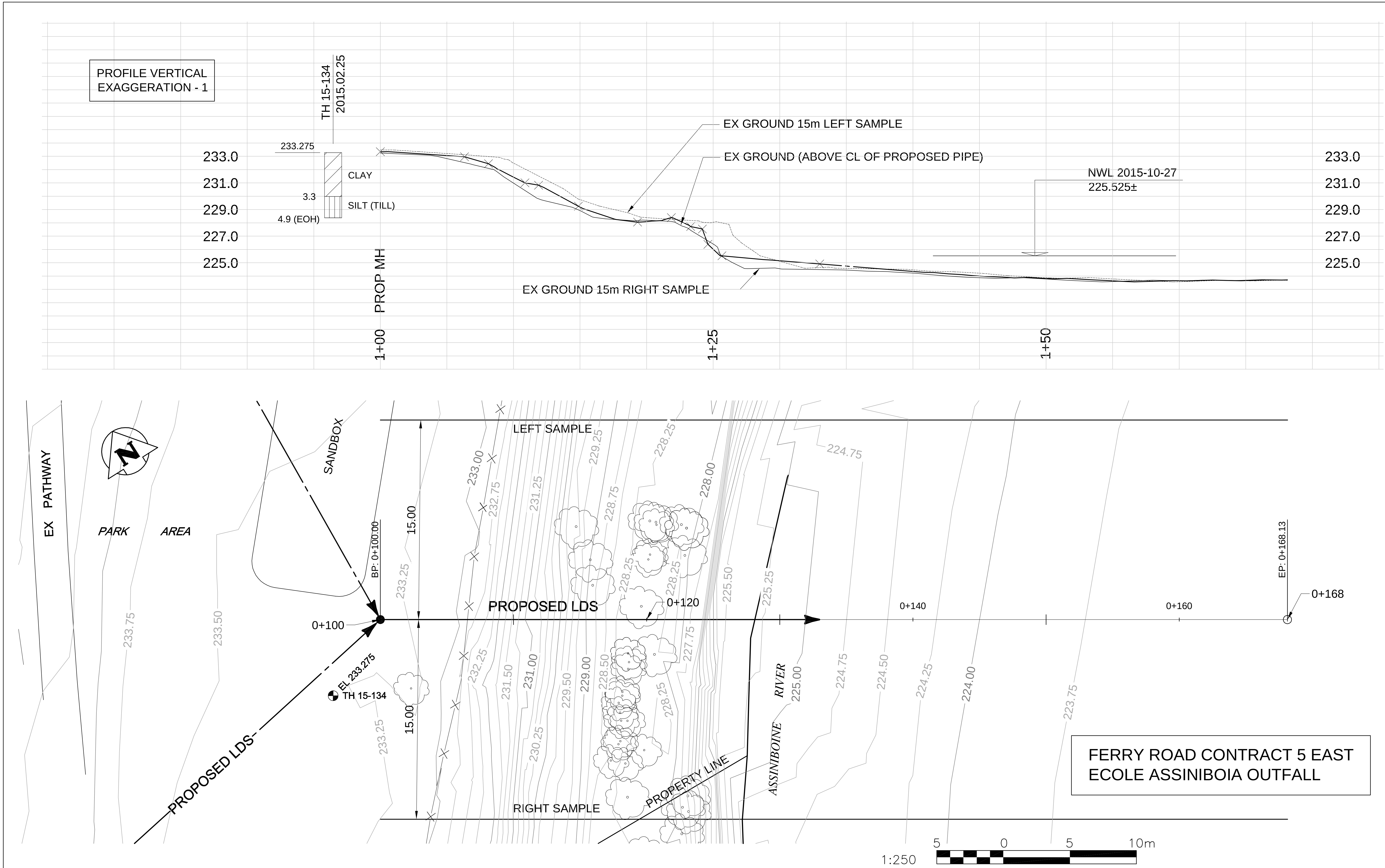
Gil Robinson, M.Sc., P.Eng.
President, Senior Geotechnical Engineer
gilrobinson@drgeotechnical.com

PROVINCE OF MANITOBA
GR
G.G.B.
ROBINSON
7 Dec 2015
REGISTERED PROFESSIONAL ENGINEER

APEGM
Certificate of Authorization
Dyregrov Robinson Inc.
No. 86 Date: 7 Dec 2015

Appendix A

Ecole Assiniboine Outfall Drawing



FERRY ROAD CONTRACT 5 EAST
ECOLE ASSINIBOIA OUTFALL

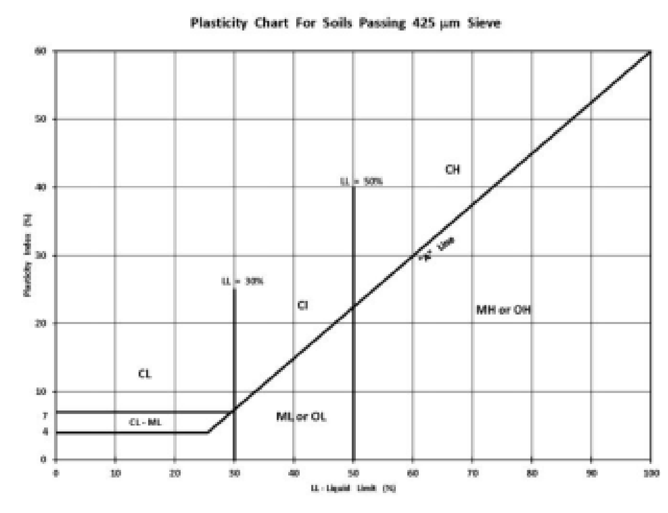
Appendix B

Test Hole Log

EXPLANATION OF TERMS & SYMBOLS

Description				TH Log Symbols	USCS Classification	Laboratory Classification Criteria			
						Fines (%)	Grading	Plasticity	Notes
COARSE GRAINED SOILS	GRAVELS (More than 50% of coarse fraction of gravel size)	CLEAN GRAVELS (Little or no fines)	Well graded gravels, sandy gravels, with little or no fines		GW	0-5	$C_U > 4$ $1 < C_C < 3$		Dual symbols if 5-12% fines. Dual symbols if above "A" line and 4<W_P<7 $C_U = \frac{D_{60}}{D_{10}}$ $C_C = \frac{(D_{30})^2}{D_{10} x D_{60}}$
			Poorly graded gravels, sandy gravels, with little or no fines		GP	0-5	Not satisfying GW requirements		
		DIRTY GRAVELS (With some fines)	Silty gravels, silty sandy gravels		GM	> 12		Atterberg limits below "A" line or W_P<4	
			Clayey gravels, clayey sandy gravels		GC	> 12		Atterberg limits above "A" line or W_P<7	
	SANDS (More than 50% of coarse fraction of sand size)	CLEAN SANDS (Little or no fines)	Well graded sands, gravelly sands, with little or no fines		SW	0-5	$C_U > 6$ $1 < C_C < 3$		
			Poorly graded sands, gravelly sands, with little or no fines		SP	0-5	Not satisfying SW requirements		
		DIRTY SANDS (With some fines)	Silty sands, sand-silt mixtures		SM	> 12		Atterberg limits below "A" line or W_P<4	
			Clayey sands, sand-clay mixtures		SC	> 12		Atterberg limits above "A" line or W_P<7	
FINE GRAINED SOILS	SILTS (Below 'A' line negligible organic content)	W_L<50	Inorganic silts, silty or clayey fine sands, with slight plasticity		ML			Classification is Based upon Plasticity Chart	
		W_L>50	Inorganic silts of high plasticity		MH				
	CLAYS (Above 'A' line negligible organic content)	W_L<30	Inorganic clays, silty clays, sandy clays of low plasticity, lean clays		CL				
		30<W_L<50	Inorganic clays and silty clays of medium plasticity		CI				
		W_L>50	Inorganic clays of high plasticity, fat clays		CH				
	ORGANIC SILTS & CLAYS (Below 'A' line)	W_L<50	Organic silts and organic silty clays of low plasticity		OL				
		W_L>50	Organic clays of high plasticity		OH				
HIGHLY ORGANIC SOILS			Peat and other highly organic soils		Pt	Von Post Classification Limit		Strong colour or odour, and often fibrous texture	

	Asphalt		Glacial Till		Bedrock (Igneous)	**DYREGROV ROBINSON INC.** CONSULTING GEOTECHNICAL ENGINEERS
	Concrete		Clay Shale		Bedrock (Limestone)	
	Fill				Bedrock (Undifferentiated)	



FRACTION		PARTICLE SIZE (mm) Min.	PARTICLE SIZE (mm) Max.
Boulders		>300	
Cobbles		75	300
Gravel	Coarse	19	75
	Fine	4.75	19
Sand	Coarse	2.0	4.75
	Medium	0.425	2.0
	Fine	0.075	0.425
Silt (non-plastic) or Clay (plastic)		< 0.075 mm	

RELATIVE PROPORTIONS (by weight) Percent	Descriptor
>35%	main fraction
35 - 50	"and"
20 – 35	Adjective e.g. silty, clayey
10 – 20	"some"
1 - 10	"trace"

Soil Classification Example

Clay 50% (main fraction), Silt 25%, Sand 17%, Gravel 8%

Clay – silty, some sand, trace gravel

TERMS and SYMBOLS

Laboratory and field tests are identified as follows:

Unconfined Comp.: undrained shear strength (kPa or psf) derived from unconfined compression testing.

Torvane: undrained shear strength (kPa or psf) measured using a Torvane

Pocket Pen.: undrained shear strength (kPa or psf) measured using a pocket penetrometer.

Unit Weight bulk unit weight of soil or rock (kN/m^3 or pcf).

SPT – N Standard Penetration Test: The number of blows (N) required to drive a 51 mm O.D. split barrel sampler 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

DCPT Dynamic Cone Penetration Test. The number of blows (N) required to drive a 50 mm diameter cone 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

M/C insitu soil moisture content in percent

PL Plastic limit, moisture content in percent

LL Liquid limit, moisture content in percent

The undrained shear strength (Su) of cohesive soil is related to its consistency as follows:

Su (kPa)	Su (psf)	CONSISTENCY
<12	250	very soft
12 – 25	250 – 525	soft
25 – 50	525 – 1050	firm
50 – 100	1050 – 2100	stiff
100 – 200	2100 – 4200	very stiff
200	4200	hard

The SPT - N of non-cohesive soil is related to compactness condition as follows:

N – Blows / 300 mm	COMPACTNESS
0 - 4	very loose
4 - 10	loose
10 - 30	compact
30 - 50	dense
50 +	very dense

References:

ASTM D2487 – Classification of Soils For Engineering Purposes (Unified Soil Classification System)

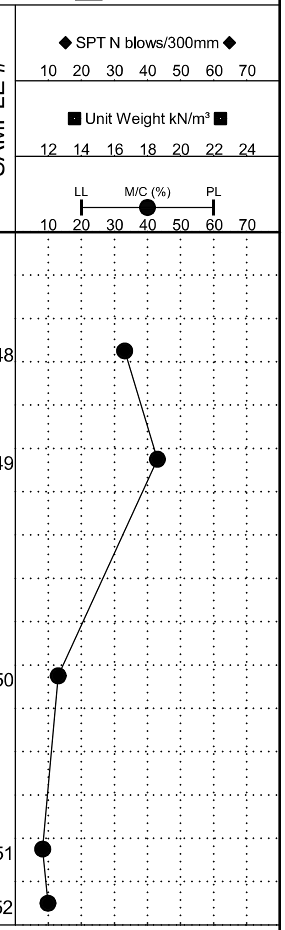
Canadian Foundation Engineering Manual, 4th Edition, Canadian Geotechnical Society, 2006

PROJECT: Ferry Road & Riverbend CSR Works	CLIENT: Tetra Tech WEI	TESTHOLE NO: **15-134**
LOCATION: Scott Park - UTM 5526467 N, 628689 E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: BRAT 22R - drill rig, 125 mm SS Augers	ELEVATION (m): 233.275

SAMPLE TYPE: GRAB | SHELBY TUBE | SPLIT SPOON | BULK | NO RECOVERY | CORE

BACKFILL TYPE: BENTONITE | GRAVEL | SLOUGH | GROUT | CUTTINGS | SAND

ELEVATION (m)	DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #
233 – 230	0 – 3.3	CLAY (silty) - brown - stiff, moist - high plasticity, trace silt inclusions - trace till inclusions below 1.5 m	GRAB GRAB GRAB	G48 G49 G50
230 – 228.4	3.3 – 4.9	SILT (Till) - trace sand, trace gravel - brown, compact, dry	GRAB SPLIT SPOON	G51 S52



END OF TEST HOLE AT 4.9 m IN SILT (TILL) (AUGER REFUSAL)

Notes:
1. Frost to 1.5 m.
2. No sloughing or seepage observed.
3. Test hole backfilled with auger cuttings and bentonite chips.

DYREGROV ROBINSON INC.
Consulting Geotechnical Engineers

LOGGED BY: WG	COMPLETION DEPTH: 4.88 m
REVIEWED BY: GR	COMPLETION DATE: 25/2/15
PROJECT ENGINEER: Gil Robinson	

Appendix C

Stability Modelling Results

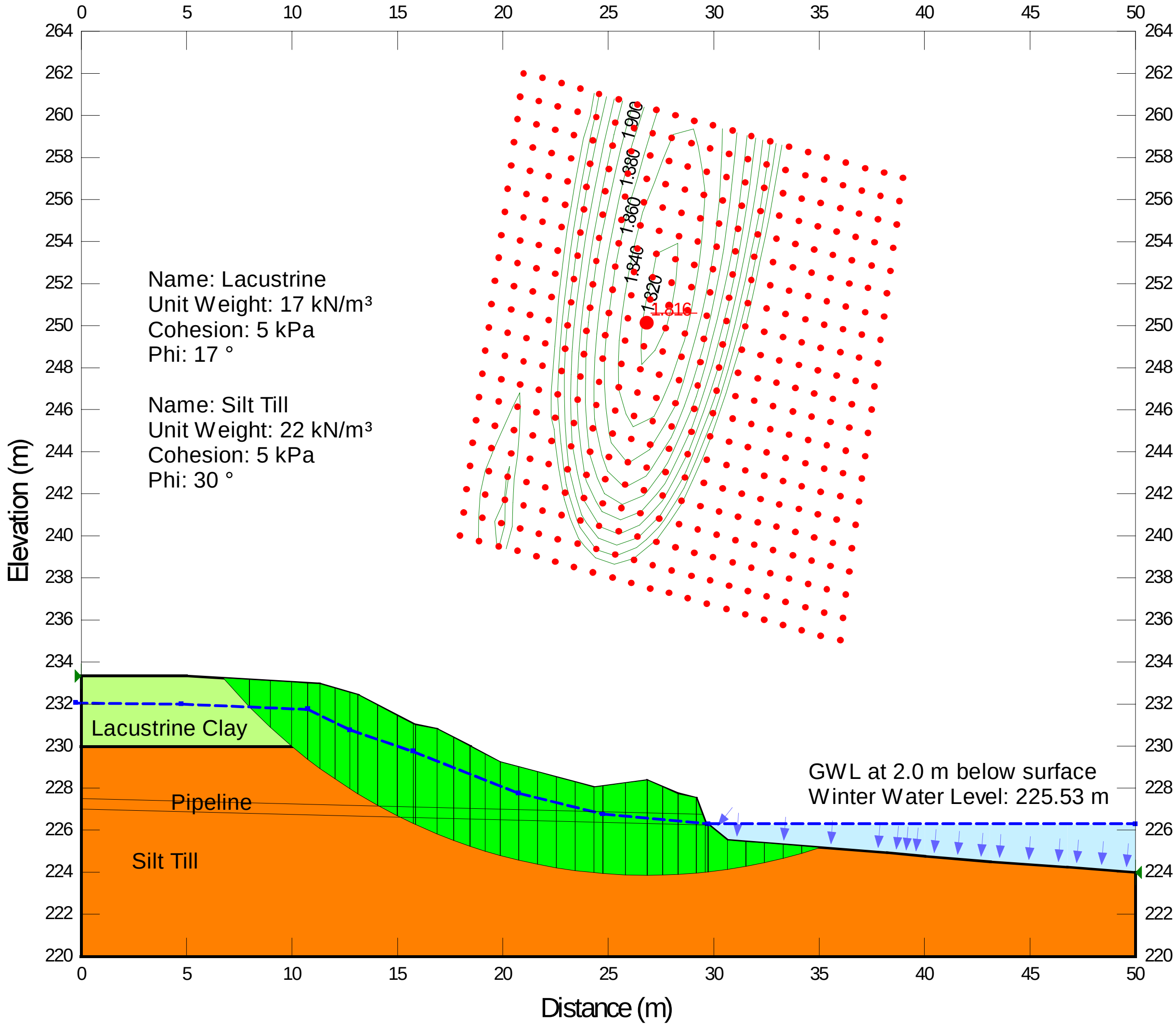


Figure C1 – Global Stability

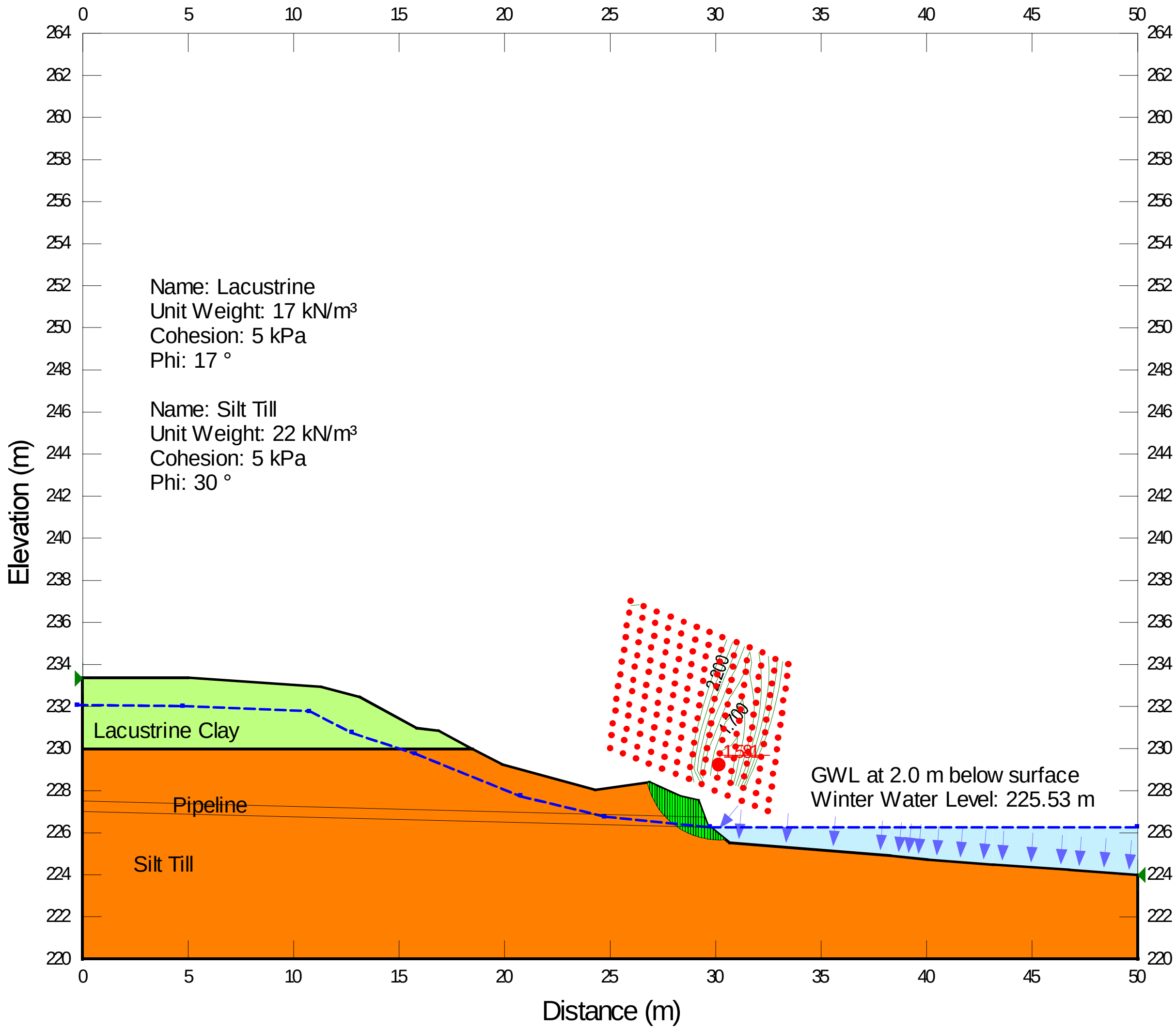


Figure C2 – Local Stability