Slope Stability Analysis Report
14 Mile Creek
Pigott Farm Land
Oakville, Ontario

Prepared for:

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BRM-00059627-C0

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1 Introduction

As requested by Mr. Sundar Premasiri, Ph. D., P. Eng., of MMM Group Limited **exp** Services Inc. (**exp**) performed stability analyses of an approximately 100 m long portion of 14 Mile Creek immediately north of Dundas Street West in Oakville, Ontario.

The majority of the site bordering the creek is currently used for agricultural purposes.

2 Procedure

The fieldwork for this study consisted of a site visit to visually inspect the conditions of the slopes and drilling four boreholes on the slopes.

The visual inspection was carried out on June 22, 2011, to record the general slope condition, including sign of instability, if any, vegetation cover, internal and surface erosion.

We were provided the drawing for the elevations of the slope at two cross-sections along the slope by MMM Group Limited.

The boreholes were drilled to a maximum depth of 6.0 m using CME 55 track mounted drill rig owned and operated by a specialist drilling subcontractor. Boreholes 1 and 3 were drilled near the top of slopes on the north and south sides of the creek, respectively. Boreholes 2 and 4 were drilled at the bottom of slopes, also on the north and south sides of the creek, respectively. The approximate borehole locations are shown on the attached Borehole Location Plan, Drawing 1.

A representative of **exp** was present throughout the drilling operations. In the borehole, samples were retrieved at regular intervals by following standard split spoon sampling procedure. The samples were logged in the field and returned to the **exp** laboratory for detailed examination by the project engineer. Results of the tests are summarized on the borehole logs, attached in Appendix 'A'.

Water Level observations were carried out in the open boreholes after completion of the drilling operations and in the monitoring wells installed in Boreholes 1 to 4.

3 Slope Conditions

The subject slopes form the north and south banks of 14 Mile Creek, located on the north side of Dundas Street West. The flow channel is approximately 2.5 to 4.0 m wide, and about 1.5 to 2.2 m below the existing grades. The creek flows from west to east across the property. A reinforced concrete wall with precast concrete panel facings has been constructed along the Dundas Street West. The concrete wall is approximately 30 m in length. The height of the wall is about 1.0 m and the channel is approximately 2.5 m wide. There was no visual sign of tilting or forward leaning of the wall, and the condition of the concrete wall was also generally good. No erosion was observed in the shale bedrock on which concrete wall is founded. The rest of the creek is unlined.

The slope is approximately 1.5 to 2.2 m high. The overall slope gradient varies 2:1 to 9:1 (H:V). At the time of our inspection on June 22, 2011, the slope was well vegetated with trees and grass, and there was no visual sign of instability.

Shale bedrock was identified at the bottom of the creek channel. The depth of the flow was about 0.3 m. There was no sign of active toe erosion at that time.

Photographs 1 to 4 attached in Appendix C show the general conditions of the creek bank and the concrete wall at the time of this study.

4 Subsurface Conditions

The general stratigraphy comprises fill overlying weathered shale/till complex. Below the weather shale till complex, shale bedrock was observed. Groundwater is at about 0.5 to 3.6 m below ground surface at the time of our study.

The detailed subsurface conditions at the borehole locations are presented in the borehole logs attached in Appendix A.

Based on the results of the boreholes, the soil parameters shown in Table 1 below have been estimated, and are used in the stability analyses.

5 Slope Stability Analysis

The stability analysis was performed for two slope sections, located at an approximate distance of 55 m from each other (Appendix A). The east slope (section B-B) is about 2.15 m high with gradients varying from 2H:1V to 6H:1V. The west slope (section A-A) has an approximate height of 1.5 m, with gradients in the range of 6.4H:1V to 9H:1V.

Stability analyses were carried out for Sections A-A and B-B, located as shown on Drawing 1, using the Slope/W software (GeoStudio 2004), the embankment geometry as provided by MMM Group Limited, and subsurface conditions revealed by the boreholes. The factor of safety (F.S.) against slope failure was evaluated based on the limit equilibrium analysis method proposed by Morgenstern and Price for circular sliding surfaces.

The soil parameters adopted in the analyses are summarized in Table 1. These parameters are estimated from the index properties of the soil units, and are considered to be realistic if slightly conservative.

Table 1: Soil Properties used in Analysis

Material	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Angle of Shearing Resistance
Fill	19	0	28°
Highly Weathered Shale/Till Complex	22	0	34°
Shale Bedrock	-	-	-

For each section, we analyzed under static and seismic conditions. Design ground acceleration for the project site was determined from the Earthquake Hazards Program Website by interpolating 2005 National Building Code of Canada Seismic Hazard values. The map indicates a peak horizontal ground acceleration (PHGA) value of approximately 0.26 g at the project site. The value is associated with an earthquake having 2 percent probability of exceedance in a 50-year period, (0.000404 per annum probability).

The results of the analyses are shown in Figures 1 to 4 in Appendix 'B', and are summarized in Table 2 below.

Table 2: Stability Analyses Results

Section	Minimum Safety Factors				Distance Between Physical Top of Slope and Stable Top of Slope*	Toe Erosion Allowance
	Static	Figure	Seismic	Figure		
Section A-A (Existing Condition)	3.27	1	1.24	2	0	0
Section B-B (Existing Condition)	1.31	3	0.73	4	1.25	0

*Stable Top of Bank is where the F.S. is 1.5 and 1.1 or higher for static and seismic condition, respectively.

6 Results of Stability Analyses

6.1 Section A-A (Figure 1 and 2)

The slope at this section is about 1.5 m high, and the slope gradient is about 6H:1V to 9H:1V. The minimum calculated values of F.S. for this section are 3.27 and 1.24 under static and seismic conditions, respectively. The weathered shale was visible at the bottom of creek. At this location, the physical top of the bank is the long term stable top of bank.

6.2 Section B-B (Figure 3 and 4)

This is the most critical slope within the study area. The slope at this section is about 2.5 m high, and the slope gradient is about 2H:1V to 6H:1V. The minimum calculated values of F.S. for this section are 1.31 and 0.73 (i.e., unstable) under static and seismic conditions. The sliding surfaces associated with F.S. 1.5 and 1.1 under static and seismic conditions daylight at about 0.5 and 1.25 m, respectively behind the physical top of slope. In accordance with Table 3 of the MNR Technical Guide entitled River & Stream Systems: Erosion Hazard Limit, a toe erosion allowance is not required. Therefore, at this section, the long term stable top of bank is located 1.25 m behind the physical top of bank.

7 General Comments

When design and specifications based on the results reported herein are required, **exp** should be retained for a general review to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, **exp** will assume no responsibility for interpretation of the recommendations in the report.

This report has been prepared for and is intended for the exclusive use of MMM Group Limited, TRCA and its clients and engineers. Any use which a third party makes of this report, or any part thereof, of any reliance on or decision to be made based on it, are the responsibility of such third parties. **Exp** accepts no responsibility for damages, if any, suffered by any third party as a result of decision made or actions based on this report. The contents of this report should not be relied upon by any other party without the express written consent of **exp**. The findings are relevant for the dates of our site visits and should not be relied upon to represent conditions at later dates.

We trust that this report is sufficient for your purposes. Should you have any questions regarding this report, please do not hesitate to contact the undersigned.

exp Services Inc.

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Geotechnical Division

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PROVINCE OF ONTARIO

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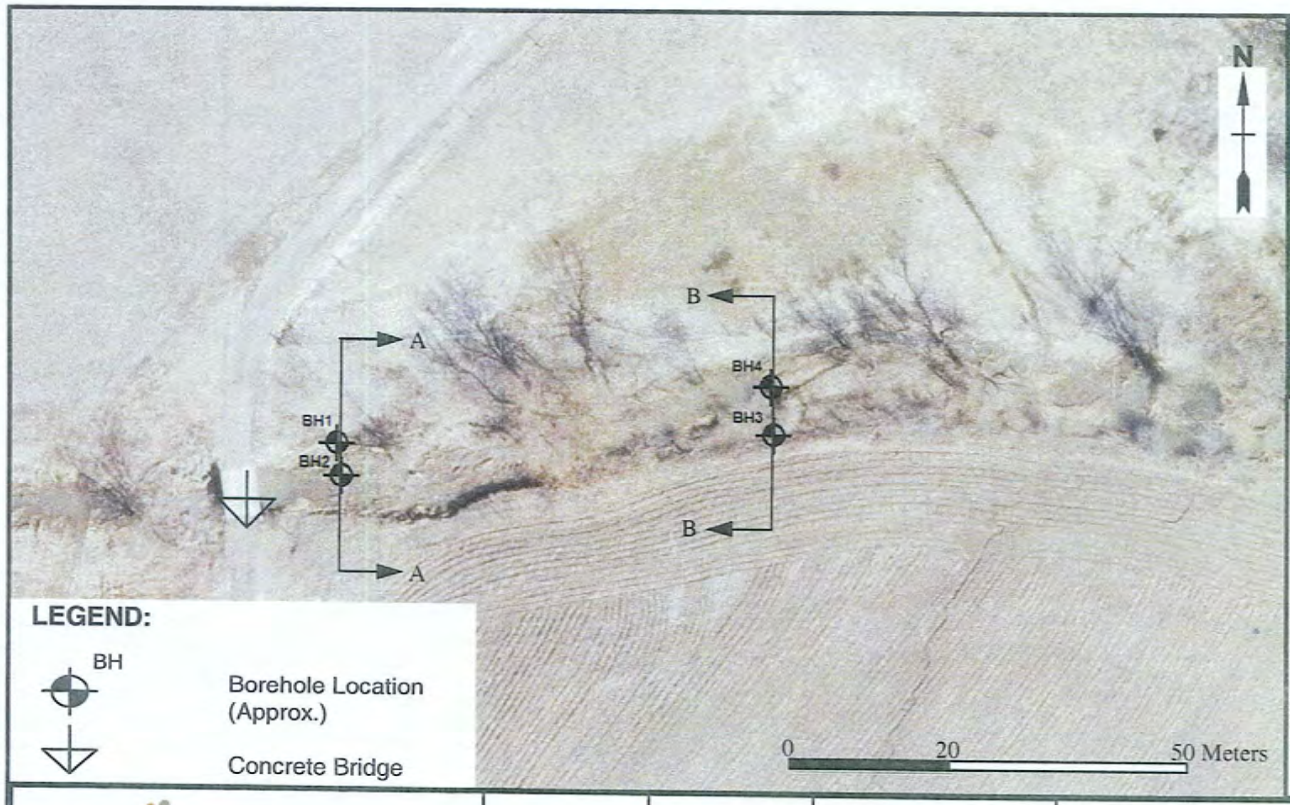
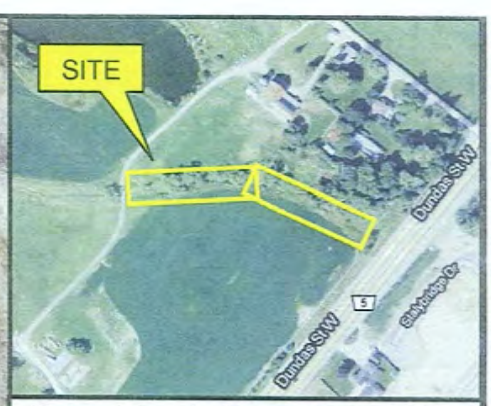
Appendix A:
Drawings – Borehole Location Plan; Notes on Sample Descriptions and Soil Types; Borehole Logs



LEGEND:

BH — Borehole Location (Approx.)

Concrete Bridge



- The boundaries and soil types have been established only at the borehole locations. Between boreholes the boundaries are assumed and may be subject to considerable error.
- Soil samples will be retained in storage for 3 months and then destroyed unless client advises otherwise.
- Topsoil quantities and/or volumes of unsuitable fill should not be established from the information provided at the borehole locations.
- Borehole elevations should not be used to design building(s), or floor slab(s), or parking lot(s) grades.
- This drawing to be read with subject report, project number as shown below.
- See report text for site datum.
- Test hole locations are approximate.
- Dimensions shown on this drawing are in metric units, unless otherwise noted.

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DRAWN: M.W
CHECKED: D.D
P.M.: D.D
SCALE: As shown

Borehole Location Plan
14 Mile Creek Geotechnical Investigation
Dundas Street West and Colonel William Parkway
Oakville, Ontario

Reference: BRM-00059637-C0

Drawing: 1

Notes on Sample Descriptions

Drawing 1A

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering (ISSMFE). Laboratory grain size analyses provided by **exp** also follow the same system. Others may use different classification systems; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002 0.006 0.02 0.06 0.2 0.6 2.0 6.0 20 60 200

EQUIVALENT GRAIN DIAMETER IN MILLIMETERS

CLAY (PLASTIC) TO	FINE	MEDIUM	CRS.	FINE	COARSE
SILT (NONPLASTIC	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should

be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Excerpt from "OHSA Regulations for Construction Projects," Part III, Section 226:

Soil Types

Type 1 Soil

a) is hard, very dense and only able to be penetrated with difficulty by a small sharp object;

b) has a low natural moisture content and a high degree of internal strength;

c) has no signs of water seepage; and

d) can be excavated only by mechanical equipment.

Type 2 Soil

a) is very stiff, dense and can be penetrated with moderate difficulty by a small sharp object;

b) has a low to medium natural moisture content and a medium degree of internal strength; and

c) has a damp appearance after it is excavated.

Type 3 Soil

a) is stiff to firm and compact to loose in consistency or is previously excavated soil;

b) exhibits signs of surface cracking;

c) exhibits signs of water seepage;

d) if it is dry, may run easily into a well-defined conical pile; and

e) has a low degree of internal strength.

Type 4 Soil

a) is soft to very soft and very loose in consistency, very sensitive and upon disturbance is significantly reduced in natural strength;

b) runs easily or flows, unless it is completely supported before excavating procedures;

c) has almost no internal strength;

d) is wet or muddy; and

e) exerts substantial fluid pressure on its supporting system.

O. Reg. 213/91, s. 226.

Log of Borehole 1

Project No. BRM00059627-C0

Drawing No. 2

Project: Geotechnical Investigation

Sheet No. 1 of 1

Location: 14 Mile Creek, Oakville, Ontario

Date Drilled: July 14, 2011

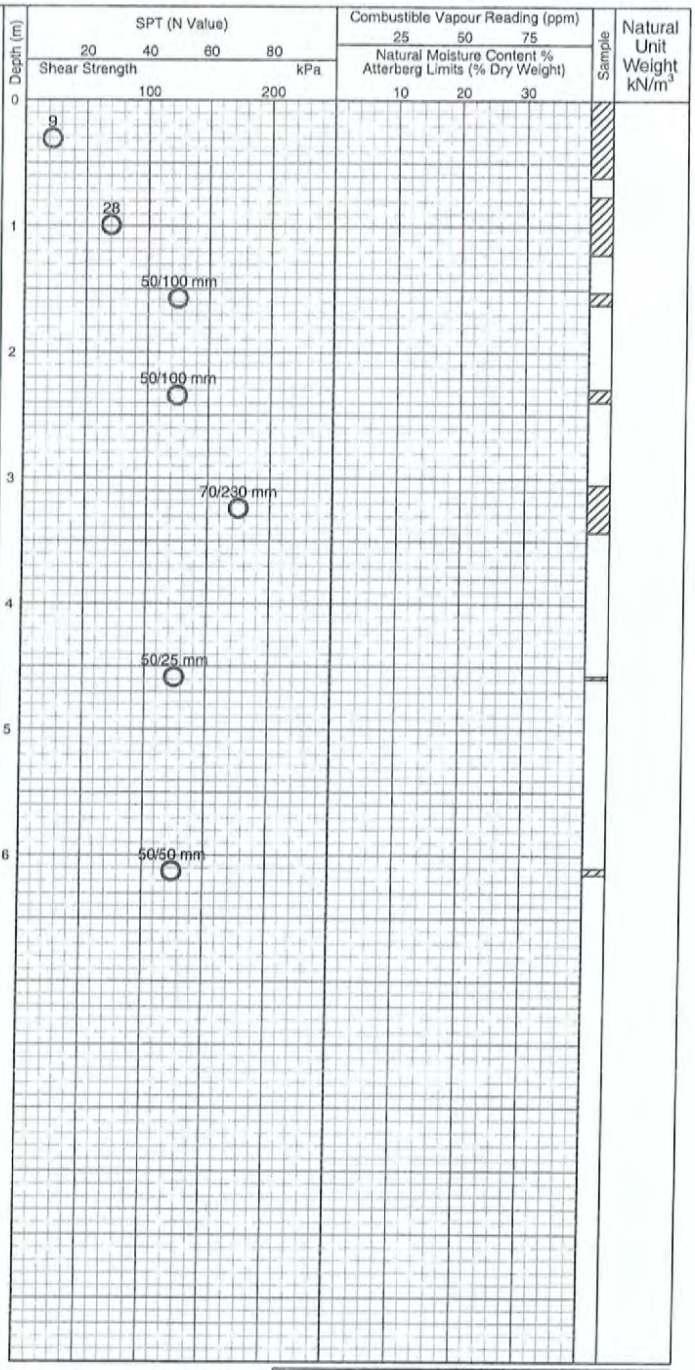
Drill Type: CME 55 - Trackmount

Datum: Geodetic

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

Groundwater	Soil/Rock Symbol	Soil Description	ELEV. m
		~400 mm topsoil over **FILL:** clayey silt, topsoil and shale fragment inclusions, trace rootlets, brown to reddish brown, moist	146.77
		SHALE: weathered, limestone layers, reddish brown, grey layers, moist (Queenston Formation)	~145.4
		-becoming wet	~140.6
		END OF BOREHOLE	



Notes:
1. Borehole advanced to completion at ~6.2 m depth by conventional soil sampling methods using a specialist drilling subcontractor. For borehole definitions, see notes prior to logs.
2. This drawing forms part of and must be read in conjunction with the subject report **(Ref. BRM00059627-C0);** borehole data requires interpretation assistance by **exp** professional staff before use by others.
3. Standpipe piezometer installed and borehole backfilled as shown on completion.

Elapsed Time	Water Level (m)	Hole Open to (m) SP = Standpipe
On completion	2.13	6.10
July 15, 2011	1.80	
July 27, 2011	1.32	

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Log of Borehole 2

Project No. BRM00059627-C0

Drawing No. 3

Project: Geotechnical Investigation

Sheet No. 1 of 1

Location: 14 Mile Creek, Oakville, Ontario

Date Drilled: July 13, 2011

Drill Type: CME 55 - Trackmount

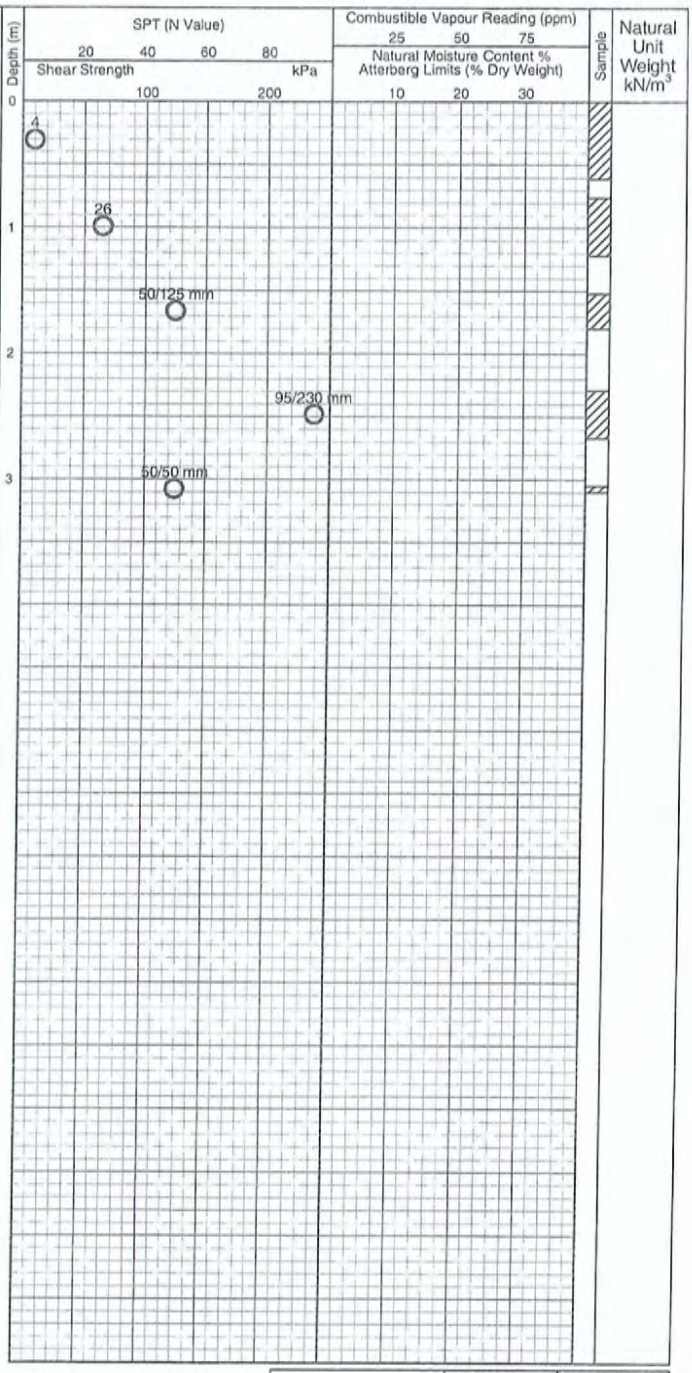
Datum: Geodetic

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

Groundwater	Soil/Rock Symbol	Soil Description	ELEV. m
		~700 mm topsoil over **WEATHER SHALE/TILL COMPLEX:** reddish brown with grey interlayers, moist, compact to dense	145.99
			~143.2
		SHALE: weathered, reddish brown with grey interlayers, moist (Queenston Foundation)	~142.9
		END OF BOREHOLE	

Notes:
1. Borehole advanced to completion at ~3.1 m depth by conventional soil sampling methods using a specialist drilling subcontractor. For borehole definitions, see notes prior to logs.
2. This drawing forms part of and must be read in conjunction with the subject report **(Ref. BRM00059627-C0);** borehole data requires interpretation assistance by **exp** professional staff before use by others.
3. Standpipe piezometer installed and borehole backfilled as shown on completion.



Elapsed Time	Water Level (m)	Hole Open to (m) SP = Standpipe
On completion	2.41	3.10
July 13, 2011 PM	0.22	
July 15, 2011	0.20	
July 27, 2011	0.53	

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Log of Borehole 3

Project No. BRM00059627-C0

Drawing No. 4

Project: Geotechnical Investigation

Sheet No. 1 of 1

Location: 14 Mile Creek, Oakville, Ontario

Date Drilled: July 13, 2011

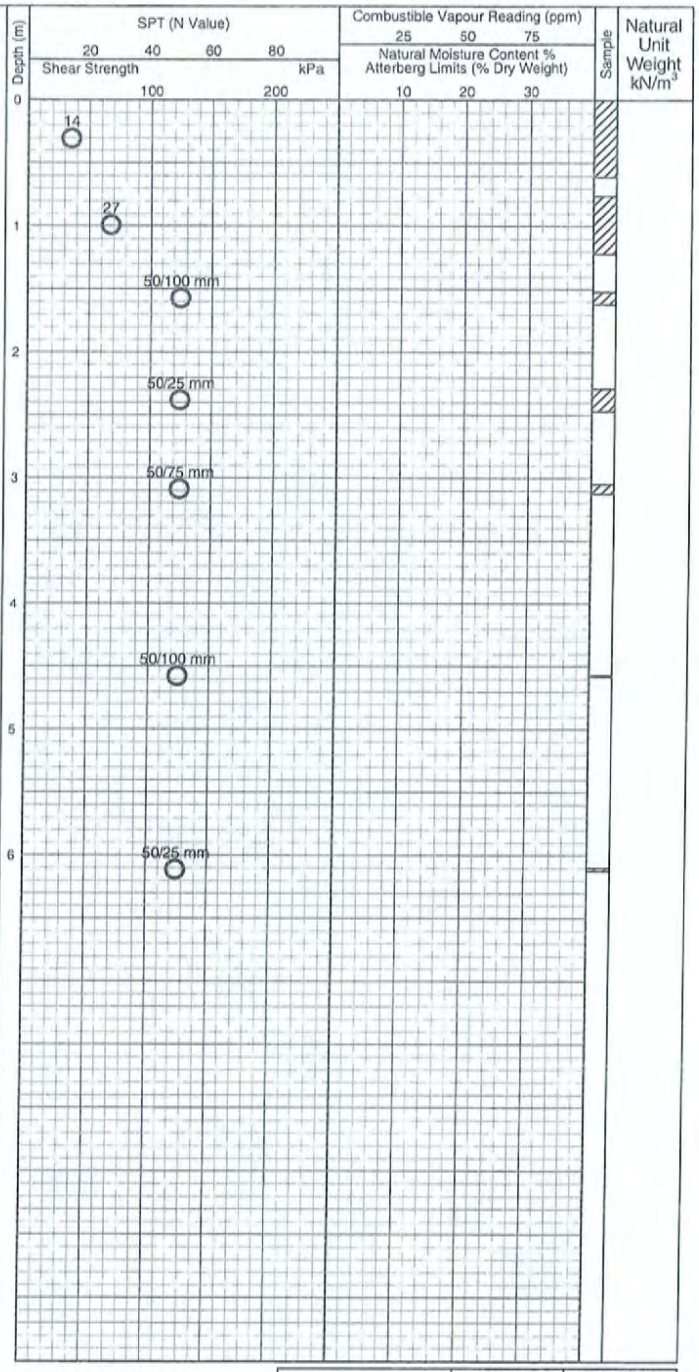
Drill Type: CME 55 - Trackmount

Datum: Geodetic

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

Groundwater	Soil/Rock Symbol	Soil Description	ELEV. m
		~450 mm topsoil over **FILL:** silt, trace clay, trace gravel, minor rootlets, brown, moist	147.78
		WEATHER SHALE/ TILL COMPLEX: reddish brown, moist, very dense	~146.8
		SHALE: weathered, limestone layers, reddish brown, grey interlayers, moist (Queenston Formation)	~146.4
		END OF BOREHOLE	~141.7



Notes:
1. Borehole advanced to completion at ~6.1 m depth by conventional soil sampling methods using a specialist drilling subcontractor. For borehole definitions, see notes prior to logs.
2. This drawing forms part of and must be read in conjunction with the subject report **(Ref. BRM00059627-C0);** borehole data requires interpretation assistance by **exp** professional staff before use by others.
3. Standpipe piezometer installed and borehole backfilled as shown on completion.

Elapsed Time	Water Level (m)	Hole Open to (m) SP = Standpipe
On completion	4.32	6.07
July 13, 2011 PM	3.14	
July 15, 2011	3.20	
July 27, 2011	3.56	

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Log of Borehole 4

Project No. BRM00059627-C0

Drawing No. 5

Project: Geotechnical Investigation

Sheet No. 1 of 1

Location: 14 Mile Creek, Oakville, Ontario

Date Drilled: July 15, 2011

Drill Type: Manual SPT

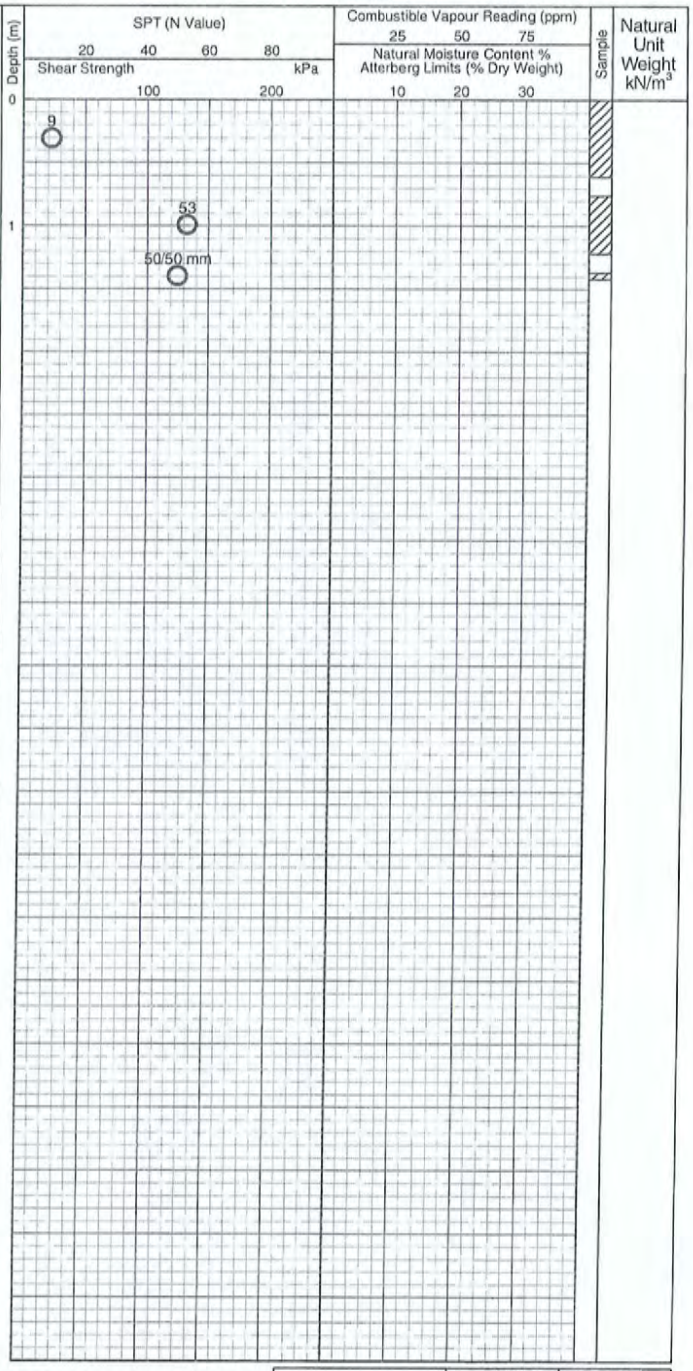
Datum: Geodetic

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test

Combustible Vapour Reading
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at % Strain at Failure
Penetrometer

Groundwater	Soil/Rock Symbol	Soil Description	ELEV. m
		~200mm topsoil over **WEATHER SHALE/TILL COMPLEX:** reddish brown, moist, compact	145.65
			~144.6
		SHALE: weathered, limestone layers, reddish brown, grey layers, moist (Queenston Formation)	~144.2
		END OF BOREHOLE	

Notes:
1. Borehole advanced to completion at ~1.4 m depth by conventional soil sampling methods using a specialist drilling subcontractor. For borehole definitions, see notes prior to logs.
2. This drawing forms part of and must be read in conjunction with the subject report **(Ref. BRM00059627-C0);** borehole data requires interpretation assistance by **exp** professional staff before use by others.
3. Standpipe piezometer installed and borehole backfilled as shown on completion.



Elapsed Time	Water Level (m)	Hole Open to (m) SP = Standpipe
On completion	0.85	1.43
July 27, 2011	1.32	

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Appendix B:
Slope Stability Analysis Results

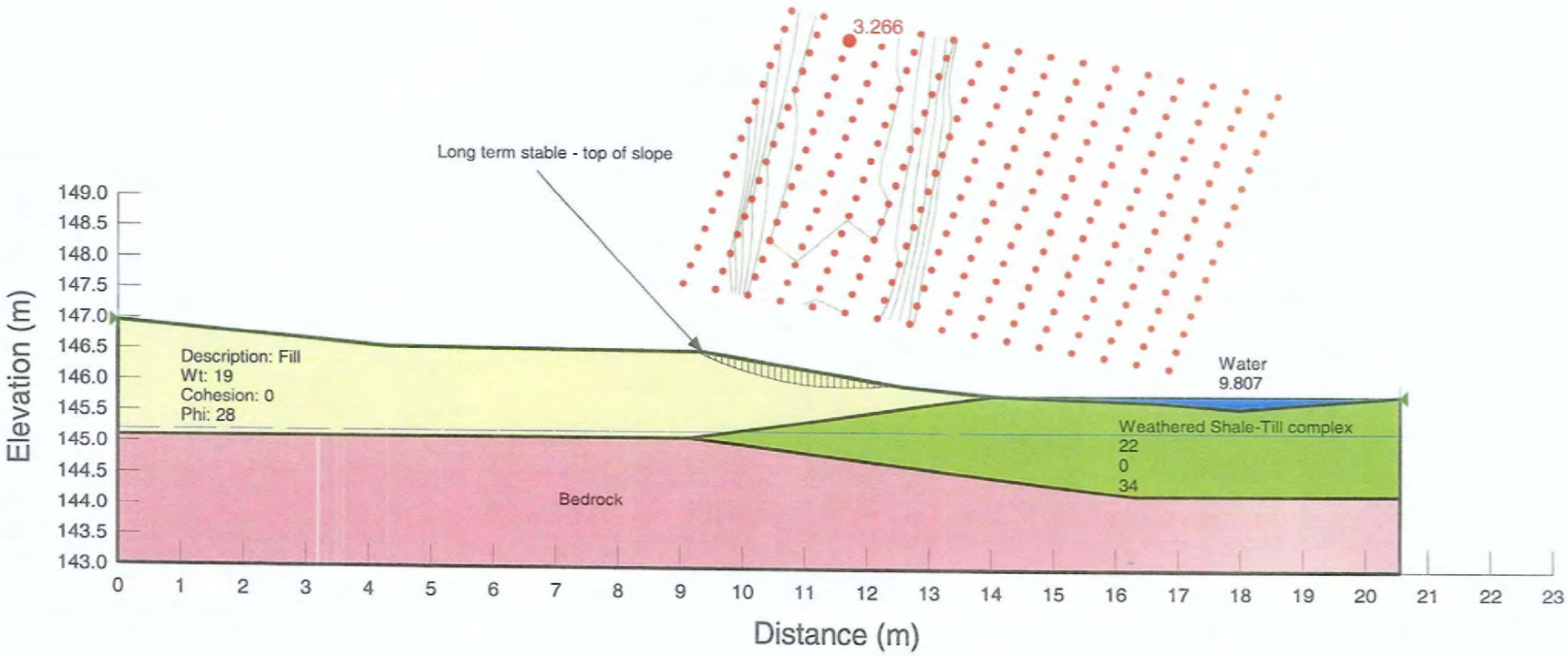

Figure 1 – Slope Stability Analysis
Section A-A (Static Condition)

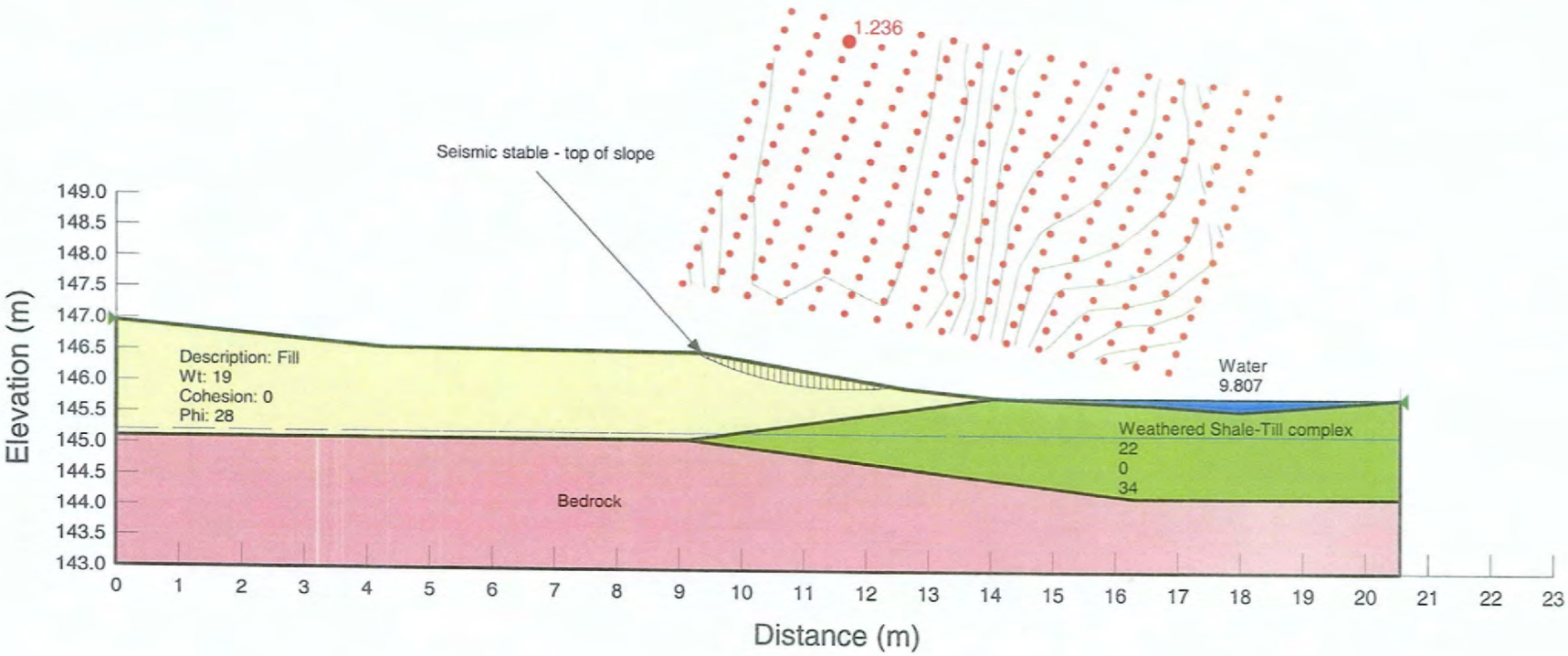

Figure 2 –Slope Stability Analysis
Section A-A (Seismic Condition)

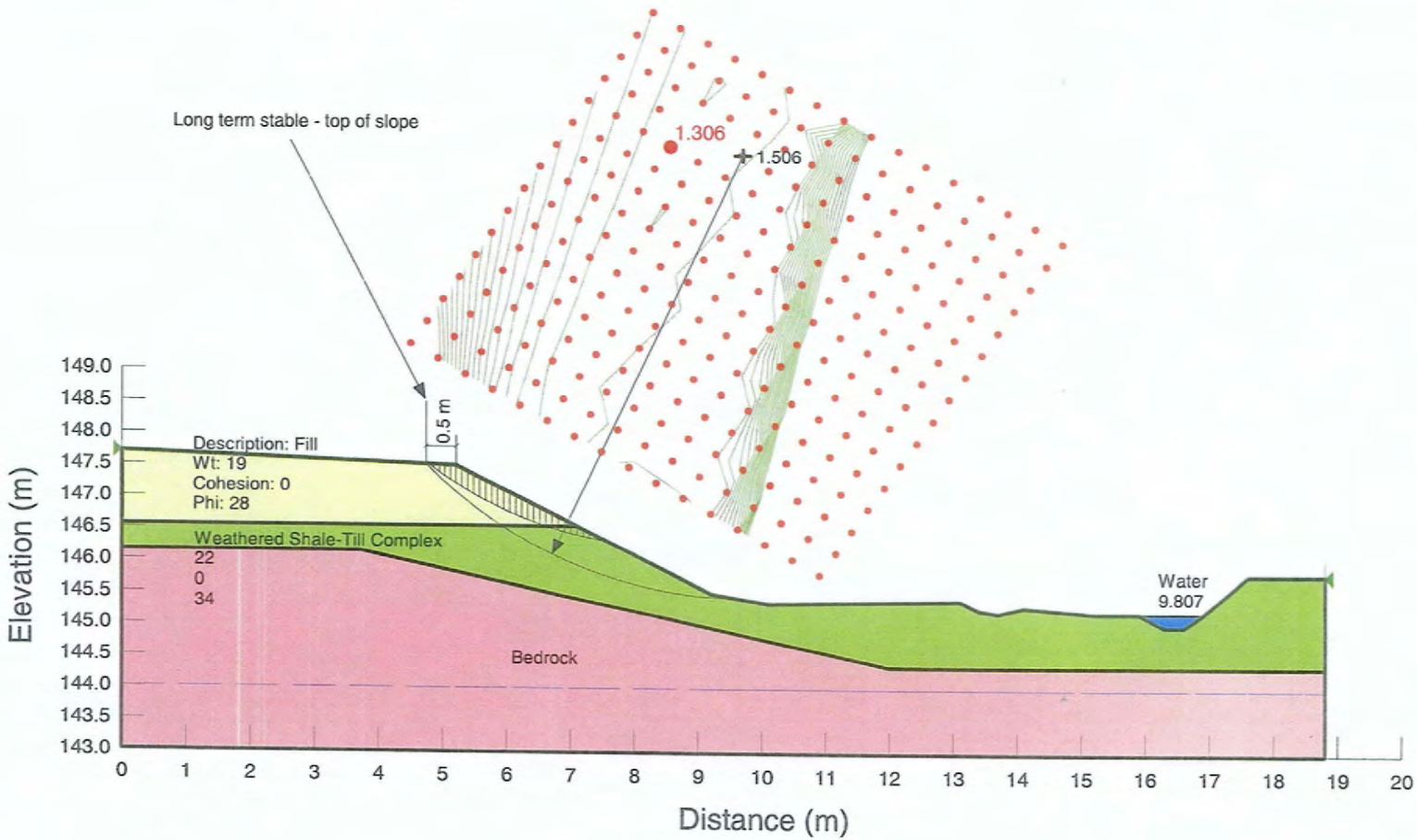

Figure 3 – Slope Stability Analysis
Section B-B (Static Condition)

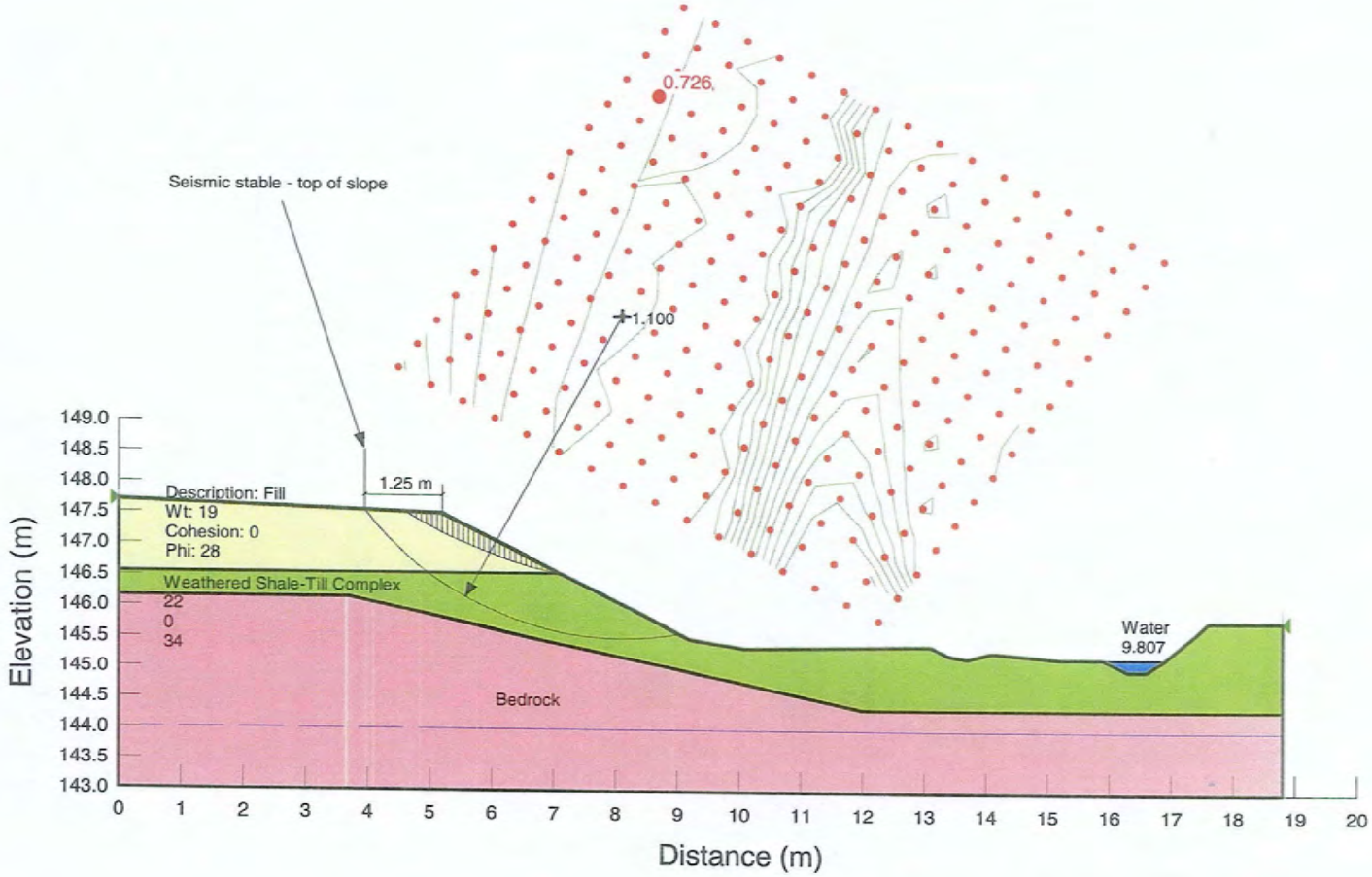

Figure 4 – Slope Stability Analysis
Section B-B (Seismic Condition)

Appendix C: Photographs

Photo 1 – General View of the slope Looking east

Photo 2 – General View of the Slope Looking East

Photo 3 – Concrete wall along the Dundas Street West

Photo 4 – Exposed Shale bedrock at the bottom of Creek