enc TESTING INC.

#270, 120 Pembina Road
Sherwood Park, Alberta
T8H 0M2
Phone: (780) 467-1334
Fax: (780) 467-1336

ENC Project: 16-1051 ENC File: 901-0

September 20, 2016

McElhanney Consulting Services Ltd.
500, 999 – 8th Street SW
Calgary, Alberta
T2R 1J5

Phone: (403) 262-5042; Cell: (587) 774-9386; Email: ngrimson@mcelhanney.com

Attention: Mr. Nathan Grimson, BDES, MLA, Landscape Architect Intern

Geotechnical Investigation
Proposed Living Waters Boardwalk
Elk Island National Park, Alberta

As requested, ENC Testing Inc. has completed a geotechnical investigation at the above noted site. Please find enclosed our report with respect to the above noted investigation. In brief, this report presents the geotechnical recommendations for design and construction aspects of this project.

We hereby give assurance that this geotechnical investigation enclosed was prepared by or under the direct supervision of this registered Professional, complying with the Alberta Building Code.

We trust this report meets your engineering design requirements. If you should have any questions or comments, please feel free to contact ENC Testing Inc.

Respectfully,
ENC Testing Inc.

R. Wilhelm

Ralph Wilhelm, M. Eng., P. Eng., MCSCE

Geotechnical Investigation
Proposed Living Waters Boardwalk
Elk Island National Park, Alberta

Prepared For:

McElhanney Consulting Services Ltd.
500, 999 – 8th Street SW
Calgary, Alberta
T2R 1J5

Date of Report:
September 2016

Materials Testing by:
ENC Testing Inc.
Sherwood Park, Alberta

Geotechnical Investigation
Proposed Living Waters Boardwalk
Elk Island National Park, Alberta

TABLE OF CONTENTS

List of Pictures

Preliminary Geotechnical Investigation

Project: Proposed Living Waters Boardwalk

Location: Elk Island National Park, Alberta

Client: McElhanney Consulting Services Ltd.

Attention: Mr. Nathan Grimson

1. INTRODUCTION

As requested, ENC Testing Inc. has completed a geotechnical investigation made on the above noted site. In brief, this report presents the geotechnical recommendations for design and construction aspects of this project. The purpose of the investigation is to provide general soils information, foundation parameters and address any site specific issues that may be encountered during construction.

The project will consist of the removal and replacement of the current timber boardwalk located by Astotin Lake near the Astotin Theatre, located in Elk Island National Park, Alberta. Should these conditions change, the undersigned should be contacted so that additional recommendations may be supplied.

Written authorization signed by Mr. Nathan Grimson was received via email on August 12, 2016. Fieldwork was completed on September 1, 2016. This geotechnical investigation was conducted as outlined in revised proposal S16-1051 dated July 22, 2016, and is subject to the terms and conditions contained therein.

Previous land utilization, environmental concerns, buried objects unless encountered, or other geotechnical issues not specifically noted are beyond the scope of this report. All recommendations are based on the soils encountered in the testholes. Should different soils be encountered between the testholes, additional recommendations may be provided. The recommendations provided apply only to the outlined structure. Other forms may require alternative recommendations.

2. SITE DESCRIPTION

The proposed structure is located by Astotin Lake near the Astotin Theatre in Elk Island National Park. The site is shown in Picture 1.

Utilities checked included water, sewer, power, communication and gas service lines. Underground utilities found on site were avoided during testhole probing.

Picture 1: Aerial View of Site

3. FIELD INVESTIGATION

The soil investigation, of limited scope because access was limited by water and unsafe conditions, was conducted using a truck mounted Geoprobe rig owned and operated by ENC Testing Inc. of Sherwood Park, Alberta. Two testholes were advanced: 1 by MacroCore and 1 by Cone Penetration (CPT) in 1.2-metre increments. These are all recorded on the testhole logs and site plan in the Appendix. A continuous visual description was recorded on site, which included the soil types, depths, moisture, and other pertinent observations. Slightly disturbed samples were removed at intervals of 0.6 metres from the testholes for further testing at the laboratory. Following the probing, a piezometric standpipe was installed in Testhole E1. Elevations were levelled by others.

4. LABORATORY TESTING

All samples returned to the laboratory were tested for moisture content. Two representative samples were further tested to determine the liquid and plastic limits of the Atterberg Limit series. A sample was also tested for sulphates. The results of all laboratory and field testing are provided on the attached testhole logs in the Appendix.

5. SUBSURFACE SOIL CONDITIONS

A detailed description of the soils encountered is found on the attached testhole logs in the Appendix. In general, the subsurface soil profile at this site may be described as topsoil, clay / sand fill, sand, clay and clay till.

5.1 Topsoil

A-horizon, damp, black-brown to black organic topsoil was found in all testholes to 0.2–1.4 metre depths.

5.2 Clay / Sand Fill

Silty, coarse grained, poorly graded, damp to moist, sand fill with medium brown-grey clay fill layers were found in all testholes to 1.4 metre depth. Its moisture content varied 4.0–18.7% and averaged 11.3%.

5.3 Sand

Silty, fine grained, poorly graded, moist to wet, light brown sand with intermittent high plastic clay layers were found or inferred from CPT in all testholes below topsoil to 6.7–6.9 metres depths. It became medium to dark grey, with coal inclusions, below 3.0 metres depth. Its moisture content varied 14.3–31.0% and averaged 20.7%.

5.4 Clay

Silty, medium to high plastic, firm to stiff, moist to wet, light brown-grey clay was found and inferred from CPT in all testholes under sand to 9.6–10.4 metres depths. Its moisture content varied 25.1–34.9% and averaged 31.9%. Atterberg test series in Testhole E1 at 7.3 metres depth showed a plastic limit of 16.5%, liquid limit of 40.6% and plasticity index of 24.1%.

5.5 Clay Till

Sandy, medium plastic, stiff to very stiff, moist, medium grey clay till with coal, and pebble inclusions was found and inferred from CPT in all testholes under clay to 9.8–11.7 metres termination depths. Its moisture content was 21.4%. Atterberg test series in Testhole E1 at 9.6 metres depth showed a plastic limit of 14.5%, liquid limit of 34.6% and plasticity index of 20.1%.

6. GROUNDWATER CONDITIONS

Following drilling, a piezometric standpipe was installed in Testhole E1. The water level was measured after 11 days as shown in the results tabulated below:

Testhole number	Ground Elev.	Date Probed	Below Ground Surface at End of Drilling (metres)		Below Ground Surface September 12, 2016 (metres)	
	(m)		**Depth**	**Elev.**	**Depth**	**Elev.**
E 1	712.38	1-Sep	7.20	705.18	4.72	707.66

It should be noted that groundwater level may fluctuate on a seasonal or yearly basis, after periods of heavy rainfall or extended dry weather and between the testhole locations.

7. RECOMMENDATIONS

7.1 General Construction

1. Water was found on the site at 4.72 metres deep on September 12, 2016. Ground water may impact excavation. The single location of investigation does not provide data that extrapolates over the whole site – **see the Closure statement.**

Picture 2: Looking SSW along trail

7.2 Cast-in-Place Piles

1. A cast-in-place concrete pile foundation system is considered geotechnically satisfactory at the investigation location. The structure may be founded on an adequately reinforced grade beam or pile cap supported by bored, cast-in-place, concrete friction piles. The design capacity can be calculated on the basis of an allowable skin friction value.

2. The allowable skin friction values that may be used are as follows:

Soil Stratum metres depth below grade in sand, clay or clay till	**Skin Friction Value (kPa)**		
	SLS	Resistance Factor (ϕ)	Factored ULS
0.0 – 1.5	0		0
1.5 – 11.7	24	0.4	30

3. Considering the effects of frost and seasonal moisture changes, the friction value for the first 1.5 metres of pile should not be considered in design for unheated or isolated piles.

4. Down-drag is load placed on the pile by settlement of added fill. It can be reduced

to -5 kPa by placing a double polyethylene wrapped sonotube through the fill. This provides a smooth low friction surface to reduce the down-drag. Alternatively, without this treatment, down drag of -20kPa will occur and must be supported in the design. This applies wherever fill in excess of 1.5 metres is found at a pile location.

5. The recommended minimum skin friction pile depths at this site, to prevent frost uplift, are 4.5 metres in a continuously heated structure and 5.0 metres in a non-continuously heated structure. Reinforcing should have similar minimum lengths. The minimum pile diameter for all piles should be 400 millimetres, with a minimum skin friction pile spacing of 3.0 pile diameters on center.

6. The mixing of piles, pile types, or footings within one structural element is not recommended as differential movements may occur.

7. The allowable end-bearing values that may be used, with casing required through sand, are as follows:

Soil Stratum metres below grade in clay or clay till	**End-Bearing Value (kPa)**		
	SLS	Resistance Factor (ϕ)	Factored ULS
7.5 – 9.6	240	0.4	300
9.6 – 11.7	380	0.4	500

8. These values are based on an estimated movement of 25 millimetres to full load. Skin friction should not be included in the design of end-bearing piles. Note that end-bearing piles have a maximum bell to shaft ratio of 3:1. Cover of 2.0 bell diameters has been assumed in the calculation of the capacity of the belled piles bearing value. For partial bells, the belling tool must be the same size as the shaft diameter. In order to keep the bell open, the bell must be entirely formed in the clay or clay till.

9. All pile holes must be clean and dry during and prior to placement of concrete. The pile concrete should be placed as soon as possible after the pile has been bored to minimize the potential of sloughing or ingressing groundwater.

10. The piling contractor should make its own determination as to the need for casing and ability to provide a clean pile. It is noted that different piling equipment requires different conditions to maintain clean and open pile holes.

11. All pile holes should be carefully inspected to ensure that no water or slough material is present prior to concrete placement. Full time inspection by ENC Testing Inc. is recommended for all piles and is required should the client require ABC schedules.

12. Provisions should be made for the possible swelling of the subsoil and the effects of frost action by providing a suitable 100 millimetre void form beneath the grade beams.

13. It is recommended that all piles be adequately reinforced. Concrete for all piles should be adequately compacted.

7.3 Continuous Flight Auger (CFA) Piles

1. A CFA concrete pile foundation system is considered geotechnically satisfactory for the investigation location. The structure may be founded on an adequately reinforced grade beam or pile cap supported by CFA bored, tremie concreted piles. The CFA Pile capacity typically falls between a drilled and driven pile.
2. The allowable skin friction values that may be used for design are as for cast in place piles above.

7.4 Screw Piles

1. A Screw Pile system is considered to be possible for the investigation location. The structure may be founded on an adequately reinforced grade beam or pile cap supported by torque installed screw piles.
2. For a helix spacing/diameter (S/D) ratio of 1.0 to 1.5, the design capacity can be calculated on the basis of an allowable cylinder shear from the top to bottom helixes and end-bearing of the bottom helix.
3. For an S/D ratio greater than 3.0 the design capacity may be calculated by treating each helix as an individual bearing plate. However, movement may be considerably larger with screw piles of this nature due to the re-worked nature of the materials during screw pile installation. The bearing area must be taken only as the size of the bearing plates, excluding the shaft area in all cases.
4. The allowable cylinder shears, from the top to the bottom helix, that may be used for a S/D of 1.0 to 1.5 are as follows:

Soil Stratum	**Soil Cylinder Shear Value (kPa)**		
metres below present grade in sand, clay or clay till	SLS	Resistance Factor (ϕ)	Factored ULS
1.5 – 11.7	24	0.4	30

5. The shaft adhesion should only be used for a length = H – D, where H is the distance from the ground elevation to the top of the first helix and D is the diameter of the top helix. Considering the effects of frost and seasonal moisture changes, the friction value for the first 1.5 metres of pile, below existing grade, should not be considered in design. The shaft adhesion must only be considered with true helix piles.
6. The allowable shaft adhesion values that may be used for design are as follows:

Soil Stratum	**Shaft Adhesion Value (kPa)**		
metres below present grade in sand, clay or clay till	SLS	Resistance Factor (ϕ)	Factored ULS
1.5 – 11.7	12	0.4	15

7. The allowable end-bearing values that may be used for design are as follows:

Soil Stratum	**End-Bearing Value (kPa)**		
metres below present grade in sand, clay or clay till	SLS	Resistance Factor (ϕ)	Factored ULS
7.5 – 9.6	250	0.4	320
9.6 – 11.7	400	0.4	530

8. End-bearing should be used for the bottom helix only if the S/D ratio is less than 3.0. End-bearing can be computed for each helix if the S/D ratio is larger than 3.0.

9. To control movement, any contractor supplied torque based criteria must utilize a factor of safety of at least 3.0, and provide certified calibration to be supported by ENC Testing Inc.

10. Adjustment to compensate for any fill or site excavation must be made. Please note that these depths are from existing grade, and the pile length, as measured from below the grade beam will be shorter.

11. The minimum recommended pile helix diameter for all piles is 400 millimetres, with a minimum pile spacing of 3.0 pile diameters on center. It is anticipated that the shaft diameter will be about 200 millimetres. It is assumed that the screw piles will be long, and have multiple helixes.

12. Some provisions should be made for the possible swelling of the subsoil beneath the grade beams and the effects of frost action. This can be done by providing a suitable 100 millimetre void.

13. Adjustment to compensate for any fill or site excavation must be made. Please note that these depths are from existing grade.

14. It is recommended that the piles be poured full of concrete after cut off and dowels set to provided connection to the grade of pile caps.

15. It is recommended that pile installation be monitored by ENC Testing Inc. on a full time basis and is required if ABC schedules are needed for the project. Screw piles can otherwise be torque installed with the contractor's proprietary method of determining the capacity. This method is then outside ENC's responsibility.

7.5 Trench Excavation and Backfill

1. The water table on the site was found at 4.72 metres deep on September 12, 2016. Ground water may impact excavation.

2. The trench location was not defined, but the subsurface soil conditions encountered in the test holes are considered to be fair to poor for the installation of pipes and/or control structures using Alberta Occupational Health and Safety (OHS) or better trenching and backfilling standards.

3. Actual cutback angles should be determined in the field during construction. The Occupational Health and Safety Act, General Safety Regulation should be strictly

followed, except were superseded by this report. Please note that OH&S permits a vertical portion at the bottom of the trench, and this is not recommended in sands and silts.

4. To minimize pipe loading, trench widths should be minimal but compatible with safe construction operations. The trench width must be wide enough to accommodate pipe bedding and compaction equipment.

5. Long open trenches are not recommended as the sidewalls will fail over time. Protection for the workers is recommended for extended time excavations.

6. The moisture content of **sand and clay** in the testholes ranged from **14.3 to 34.9%.** This variable condition will cause a corresponding variability in the utility trench pipe bedding and backfill conditions. Mixing or drying may be required to achieve optimum moisture content for best compaction.

7. To overcome utility installation difficulties, it is recommended that a washed or screened rock and geotextile separator be utilized for the pipe bedding in areas of poor pipe bedding conditions. The washed rock and geotextile should surround the entire pipe with the exact dimensions determined in the field during construction. It is recommended that soft un-compactable material be replaced by washed rock to a minimum depth of 150 millimetres below the pipe. Depending upon the conditions of soil at the pipe base, additional rock may be required.

8. Pipe bedding should adhere to nearby municipal specifications or better standard. The backfill material beneath and up to the middle of the pipe should be an approved bedding sand material where conditions allow. This material should be hand placed and hand tamped with care taken to fill the underside of the pipe.

9. Minimum trench compaction recommendations are 98% of the corresponding Standard Proctor Density. A 150 millimetre maximum lift thickness should be used throughout. This degree of compaction should be readily achievable with some of the subsurface soils encountered in the testholes; however, drying or mixing may be required.

10. Bedding first lifts will require lighter and smaller compaction equipment to avoid damage to the pipe installed. Ideally, each lift should be tested, the thickness determined and approval received before additional material is placed.

11. It should be noted that the ultimate performance of the trench backfill is directly related to the consistency and uniformity of the backfill compaction, as well as the underground contractor’s construction procedures. In order to achieve this uniformity, the lift thickness and compaction criterion should be strictly enforced, including near the pipe zone. Sand, utilized to protect fragile pipe must also be compacted.

12. Temporary surcharge loads, such as spill piles, should not be allowed to within 2.0 metres of an unsupported excavation face while mobile vehicles should be kept back at least 1.0 metre. All excavations should be checked regularly for signs of sloughing or failures, especially after rainfall periods.

7.6 Concrete

A test on a selected soil sample from Testhole E1 at 7.3 metres below grade indicated a severe potential for sulphate attack. Therefore, C.S.A. Type HS cement should be used for concrete. The minimum strength should be 32 MPa. Concrete should be air entrained where freeze-thaw will occur.

7.7 Seismic Analysis

Elk Island Park is located in the seismic zone S_a (0.2) = 0.12; this site is classified as a Class C site according to the Alberta Building Code (ABC) Table 4.1.8.4.A.

8. CLOSURE

This geotechnical investigation report was prepared for the exclusive and confidential use of McElhanney Consulting Services Ltd. and its agents, and applies only to the subject project. The recommendations given are based on the subsurface soil conditions encountered during testhole boring, current construction techniques, and generally accepted engineering practices. **Soil conditions are known only at the test boring locations.**

Due to the geological randomness of many soil formations, no interpolation of soil conditions between or away from the testholes has been made or implied. No other warranty, expressed or implied, is made. Should other soils be encountered during construction or other information pertinent to the structures become available, the recommendations may be altered or modified in writing by the undersigned.

We trust this information is satisfactory for your current needs. If you should have any further questions, please contact our office.

Respectfully yours,
ENC Testing Inc.

PROFESSIONAL ENGINEER
R.R.W. WILHELM
ALBERTA

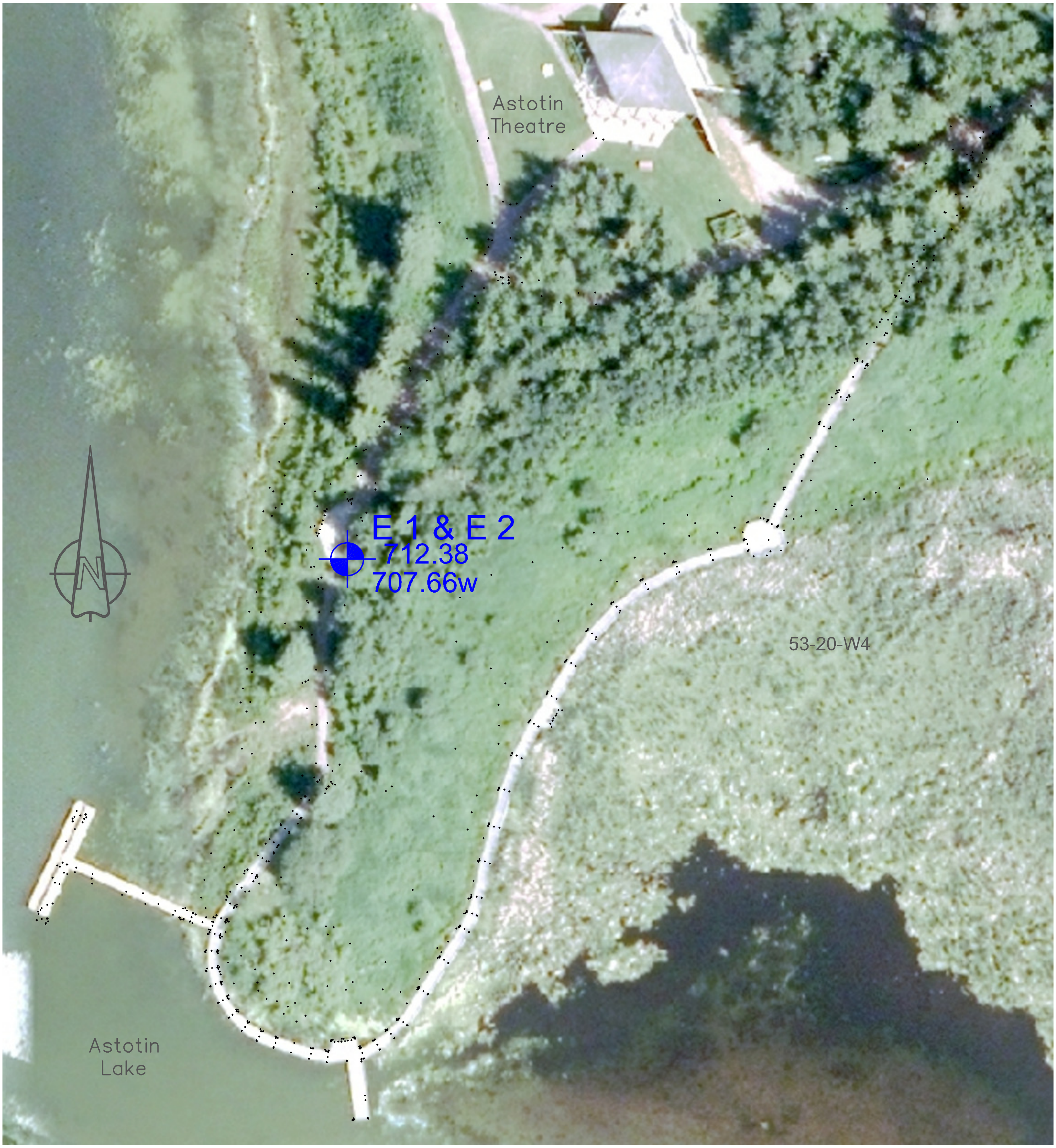
PERMIT TO PRACTICE
ENC TESTING INC.
2016 September 20
PERMIT NUMBER P07111
The Association of Professional Engineers and Geoscientists of Alberta

Ralph Wilhelm, M. Eng., P. Eng., MCSCE

A P P E N D I X

LIST OF CONTENTS

T16-1051 McElhanney Elk Island Boardwalk.dwg



LEGEND PROPERTY BUILDING TESTHOLE SURVEY POINT

EXISTING

Testhole Number
Elevation
Water Elevation

PROPOSED

Site Plan Showing Testhole Locations

Client: **McElhanney Consulting Services Ltd.** Date: **September 12, 2016**

Project: **Living Waters Boardwalk, Elk Island Park, Alberta**

Drawn by: **JH** Checked by: **KR** Scale: **NTS** Figure: **A1**

enc
TESTING INC

ENC Testing Inc.
#270, 120 Pembina Road
Sherwood Park, Alberta T8H 0M2
Telephone: 780-467-1334
Fax: 780-467-1336

TESTHOLE E1

CLIENT McElhanney Consulting Services Ltd.
DATE DRILLED 01-Sep-16
PROJECT NAME Living Waters Boardwalk, Elk Island National Park
GROUND ELEVATION 712.38
PROJECT LOCATION Elk Island, Alberta
GROUND WATER LEVELS:
PROJECT NUMBER T16-1051
AT END OF DRILLING 7.20 m / Elev 705.18 m
DRILLING METHOD Macro Core
AFTER DRILLING ON 12-Sep-16
LOGGED BY KR **REVIEWED BY** RW
THE WATER LEVEL IS 4.72 m / Elev 707.66 m
TESTHOLE LOCATION 8.6m S of S corner of E handrail, 2.2m E of SE corner of boardwalk

LEGEND **SAMPLE TYPE:** MACROCORE
SULPHATE: SEVERE
WELL BACKFILL: SAND BENTONITE SLOTTED PIPE Slough

U.S.C.S.	ELEVATION (m)	DEPTH (m)	MATERIAL DESCRIPTION
TSOIL	712.2	0.2	(TSOIL) TOPSOIL, A horizon organic, damp, black-brown
FILL			(FILL) CLAY / SAND FILL layers, silty, coarse grained, poorly graded, damp to moist, medium brown-grey
TSOIL	711.0	1.4	(TSOIL) TOPSOIL, (25mm) A horizon organic, damp, black
SM	711.0	1.4	(SM) SAND, silty, fine grained, poorly graded, moist to wet, light brown -- medium to dark grey from 3.0m -- intermittent high plastic silty clay layers and coal inclusions from 3.4m
CH	705.5	6.9	(CH) CLAY, silty, medium to high plastic, stiff to very stiff, moist to wet, light brown-grey
CI	702.8	9.6	(CI) CLAY TILL, sandy, medium plastic, stiff, moist, medium grey, inclusions of coal and pebbles
	702.6	9.8	End of testhole at 9.8m No slough Standpipe Installed Water at 7.20m after drilling Water at 4.72m on 12-Sep-16 at 11 days

SULPHATE	SAMPLE TYPE	POCKET PEN. (kPa)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	MACROCORE	100	18.7			
	MACROCORE		10.4			
	MACROCORE		20.4			
	MACROCORE		18.2			
	MACROCORE		21.3			
	MACROCORE		31.0			
	MACROCORE		20.9			
	MACROCORE		17.2			
	MACROCORE		16.9			
	MACROCORE		19.9			
	MACROCORE		29.0			
SEVERE	MACROCORE	250	25.1	40.6	16.5	24.1
	MACROCORE	200	33.2			
	MACROCORE	200	34.9			
	MACROCORE	200	34.4			
	MACROCORE	150	21.4	34.6	14.5	20.1

DEPTH (m): 0 1 2 3 4 5 6 7 8 9 10 11 12

ENC Testing Inc.
#270, 120 Pembina Road
Sherwood Park, Alberta T8H 0M2
Telephone: 780-467-1334
Fax: 780-467-1336

TESTHOLE E2

CLIENT McElhanney Consulting Services Ltd.

DATE DRILLED 01-Sep-16

PROJECT NAME Living Waters Boardwalk, Elk Island National Park

GROUND ELEVATION 712.38

PROJECT LOCATION Elk Island, Alberta

GROUND WATER LEVELS:

PROJECT NUMBER T16-1051

AT END OF DRILLING ---

DRILLING METHOD Macro Core / Cone Penetration

AFTER DRILLING ON

LOGGED BY KR **REVIEWED BY** RW

THE WATER LEVEL IS ---

TESTHOLE LOCATION 8.6m S of S corner of E handrail, 2.7m E of SE corner of boardwalk

LEGEND **SAMPLE TYPE:** ◯ MACROCORE

SULPHATE:

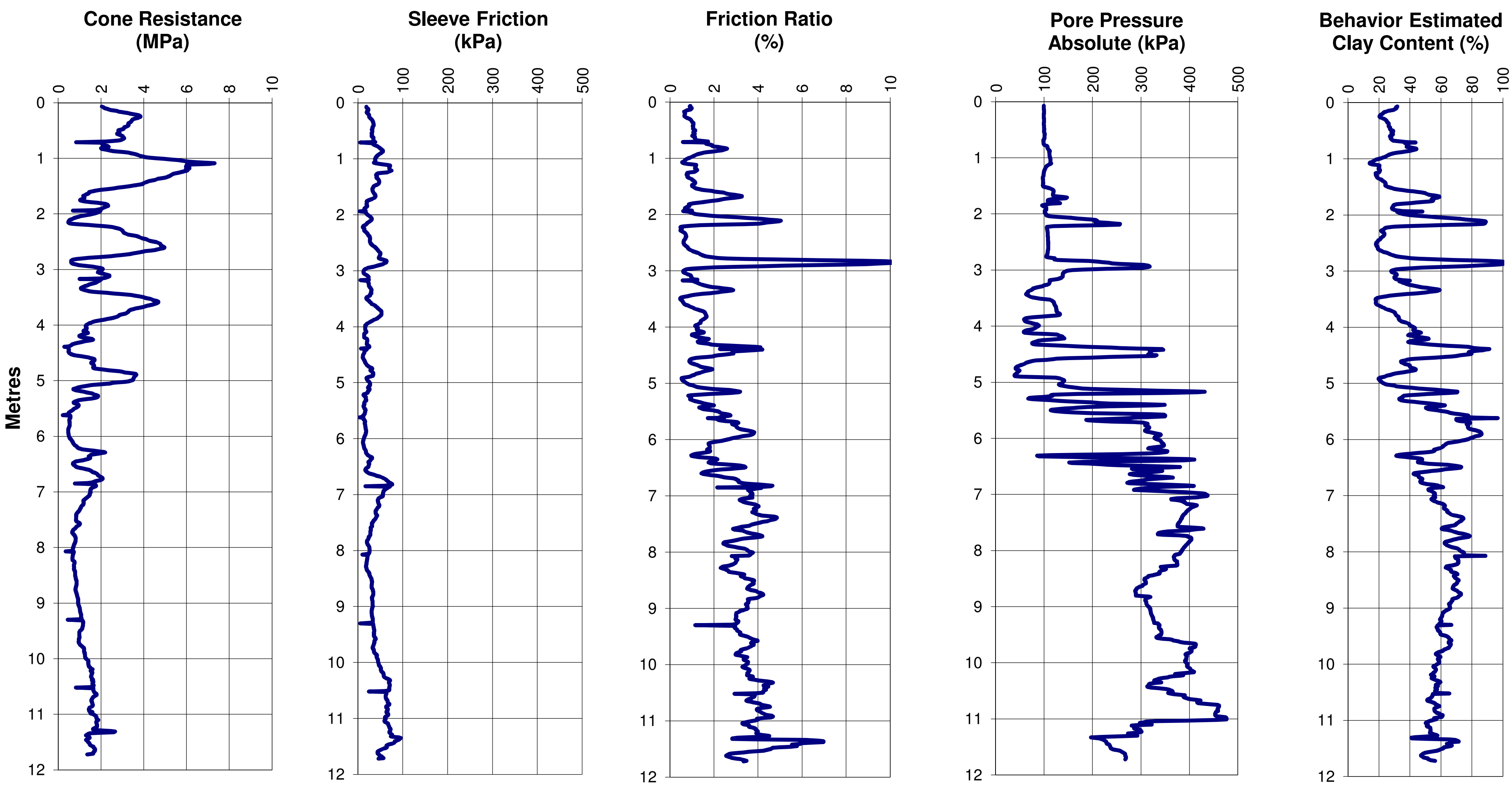
WELL BACKFILL:

U.S.C.S.	ELEVATION (m)	DEPTH (m)	MATERIAL DESCRIPTION	SULPHATE	SAMPLE TYPE	POCKET PEN. (kPa)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
TSOIL	712.2	0.2	(TSOIL) TOPSOIL, A horizon organic, damp, black-brown							
FILL			(FILL) CLAY / SAND FILL layers, silty, coarse grained, poorly graded, damp to moist, medium brown-grey		◯		4.0			
					◯		12.0			
TSOIL	711.0	1.4	(TSOIL) TOPSOIL, (25mm) A horizon organic, damp, black							
SM	711.0	1.4	(SM) SAND, silty, fine grained, poorly graded, moist to wet, light brown 2.4m, End of probing, cone penetration and implied classification below, SAND with intermittent high plastic clay layers continues		◯		14.3			
					◯		18.7			
CH	705.7	6.7	(CH) CLAY, silty, medium to high plastic, firm to stiff							
CI	702.0	10.4	(CI) CLAY TILL, sandy, stiff to very stiff							
	700.7	11.7	End of cone penetration at 11.72m							

ENC Testing Inc.

Cone Penetration Test Results

Project:	Living Waters Boardwalk, Elk Island National Park	Project No:	16-1051	Figure Number:	A 4
Client:	McElhanney Consulting Services Ltd.	Test No:	E 2	Tested By:	KR
Location:	2.7m E of SE boardwalk corner, 8.6m S of E handrail's S corner	Date:	September 1, 2016	Reviewed By:	RW
3TM:	Easting: Northing: Zone:	Elevation:			



End at 11.72 m

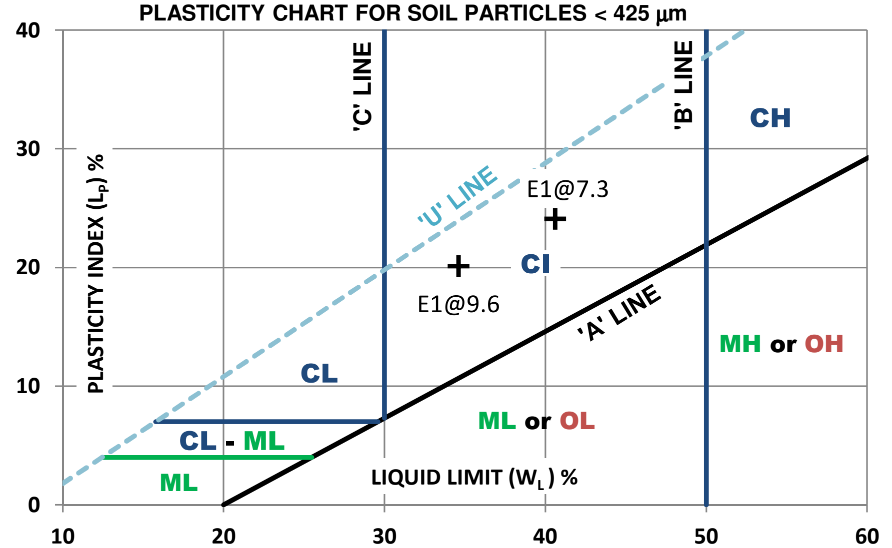
C:\Users\R.Wilhelm.ENCTESTING.000\Documents\Client Files 2016\T16-1051 McElhanney Living Waters Boardwalk Elk Island Park\Cone\Cone e2 CALC

MODIFIED (BY PFRA, 1985) **UNIFIED CLASSIFICATION SYSTEM** FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	ENC SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75 μm)	GRAVELS > 50% > 4.75 mm	CLEAN GRAVELS WITH FEW OR NO FINES	GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	Determine percentages of gravel and sand from grain size curve. Depending on percentages of fines (fraction smaller than 75 μm) coarse grained soils are classified as follows: Less than 5% GW, GP, SW, SP; More than 12% GM, GC, SM, SC 5% to 12% Borderline cases requiring the use of dual symbols	$C_U = \frac{D_{60}}{D_{10}} > 4; C_C = \frac{(D_{30})^2}{(D_{10})(D_{60})} = 1 - 3$	
			GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES		NOT MEETING ALL GRADATION REQUIREMENTS FOR GW	
		GRAVELS WITH SIGNIFICANT AMOUNT OF FINES	GM		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES		ATTERBERG LIMITS BELOW 'A' LINE, Ip < 4	ABOVE 'A' LINE 4 < Ip < 7, ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
			GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE 'A' LINE, Ip > 7	
	SANDS ≥ 50% < 4.75 mm	CLEAN SANDS WITH FEW OR NO FINES	SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		$C_U = \frac{D_{60}}{D_{10}} > 6; C_C = \frac{(D_{30})^2}{(D_{10})(D_{60})} = 1 - 3$	
			SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		NOT MEETING ALL GRADATION REQUIREMENTS FOR SW	
		SANDS WITH SIGNIFICANT AMOUNT OF FINES	SM		SILTY SANDS, SAND-SILT MIXTURES		ATTERBERG LIMITS BELOW 'A' LINE, Ip < 4	ABOVE 'A' LINE 4 < Ip < 7, ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
			SC		CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE 'A' LINE, Ip > 7	
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75 μm)	SILTS (BELOW 'A' LINE - NEGLIGIBLE ORGANIC CONTENT)	$W_L < 50\%$	ML		INORGANIC SILTS & VERY FINE SANDS, ROCK FLOUR, SILTY / CLAYEY FINE SANDS, CLAYEY SILTS WITH SLIGHT PLASTICITY	CLASSIFICATION IS BASED ON PLASTICITY CHART (SEE BELOW)		
		$W_L > 50\%$	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS			
	CLAYS (ABOVE 'A' LINE - NEGLIGIBLE ORGANIC CONTENT)	$W_L < 30\%$	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS			
		$30\% < W_L < 50\%$	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS			
		$W_L > 50\%$	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS			
	ORGANIC CLAYS & SILTS (BELOW 'A' LINE)	$W_L < 50\%$	OL		INORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW AND MEDIUM PLASTICITY			
		$W_L > 50\%$	OH		ORGANIC CLAYS OF HIGH PLASTICITY, ORGANIC SILTS			
HIGHLY ORGANIC SOILS			OR		PEAT OR OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, OFTEN FIBROUS TEXTURE		

enc TESTING INC.
#270, 120 Pembina Road
Sherwood Park, AB
T8H 0M2

PLASTICITY CHART FOR SOIL PARTICLES < 425 μm



ADDITIONAL DESCRIPTORS

FRACTION	SIEVE SIZE PASSES	SIEVE SIZE RETAINS	RANGES, ADJECTIVES
BOULDER COBBLE	900 mm 300 mm	300 mm 75 mm	
GRAVEL COARSE FINE	75 mm 19 mm	19 mm 4.75 mm	> 35 % and 21 – 35 % ~ y* 10 – 20 % some >0 – 10 % trace
SAND COARSE MEDIUM FINE	4.75 mm 2.0 mm 425 mm	2.0 mm 425 mm 75 mm	
SILT / CLAY	75 mm	* GRAVELLY, SANDY, SILTY, CLAYEY ADJECTIVES AS ABOVE	