APPENDIX C

Geotechnical Report

MANITOBA WATER SERVICES BOARD

GEOTECHNICAL INVESTIGATION

OAK BLUFF LAGOON STUDY

OAK BLUFF, MB

MAY 2022

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WSP PROJECT NO. 221-01415-00

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The report is intended to be used in its entirety. No excerpts may be taken to be representative of the findings in the assessment.

The conclusions presented in this report are based on work performed by trained, professional and technical staff, in accordance with their reasonable interpretation of current and accepted engineering and scientific practices at the time the work was performed.

The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation, using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by WSP and other engineering/scientific practitioners working under similar conditions, and subject to the same time, financial and physical constraints applicable to this project.

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Benchmark and elevations used in this report are primarily to establish relative elevation differences between the specific testing and/or sampling locations and should not be used for other purposes, such as grading, excavating, construction, planning, development, etc.

Design recommendations given in this report are applicable only to the project and areas as described in the text and then only if constructed in accordance with the details stated in this report. The comments made in this report on potential construction issues and possible methods are intended only for the guidance of the designer. The number of testing and/or sampling locations may not be sufficient to determine all the factors that may affect construction methods and costs. We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.

Overall conditions can only be extrapolated to an undefined limited area around these testing and sampling locations. The conditions that WSP interprets to exist between testing and sampling points may differ from those that actually exist. The accuracy of any extrapolation and interpretation beyond the sampling locations will depend on natural conditions, the history of Site development and changes through construction and other activities. In addition, analysis has been carried out for the identified chemical and physical parameters only, and it should not be inferred that other chemical species or physical conditions are not present. WSP cannot warrant against undiscovered environmental liabilities or adverse impacts off-Site.

This limitations statement is considered an integral part of this report.

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TABLES

APPENDICES

1 INTRODUCTION

WSP Canada Inc. (WSP) was retained by Manitoba Water Services Board to complete a geotechnical investigation for a proposed expansion to the existing Oak Bluff Lagoon located in NW & SW 17-9-2E in the community of Oak Bluff, Manitoba.

The scope of work for the geotechnical investigation included the following:

- Review of existing subsurface geotechnical report at the site
- Three geotechnical test holes
- Laboratory testing
- Geotechnical report

The objective of this geotechnical investigation was to review and verify the existing subsurface conditions provided from the previous geotechnical report and/or soil logs in order to identify any missing geotechnical information/soil testing to assist the preliminary design of the proposed lagoon expansion at the subject property.

The following report summarizes the field and laboratory testing programs, outlines the subsurface soil conditions encountered at the test hole locations, and provides geotechnical considerations and slope stability assessment for the proposed expansion based on the soil conditions encountered on site.

The use of this report is subject to the Certification of Works in Appendix A.

2 SITE AND PROJECT DESCRIPTION

The site is located at the existing wastewater treatment facility to the southeast of the community of Oak Bluff, MB, approximately 2.4 km south of the intersection between the Perimeter Highway and Red Coat Trail. The existing lagoon currently consists of two cells and has nearly reached its capacities due to the community's development. Based on the discussion with WSP Water & Waste Water Group, it was understood that the preliminary design for the proposed expansion works might consider the following two options,

- Option 1: Expand the lagoon to the south for both storage and treatment capacity by constructing three (3) new cells of 2.5 m depth from ground level to the floor, and then construct a 2.5 m berm from ground level so that the total operating depth for the constructed new cells will be approximately 5.0 m; the side slope angle for the new cells will be 4H:1V (Horizontal to Vertical)
- Option 2: Modify the existing primary cell by sub-excavation of two (2) new deep aerated primary cells within the footprint of the existing cell, followed by raising the existing lagoon berms by 0.6 m in order to achieve a total operating depth of 5.0 m; the side slope angle for the modified cells will be 5H:1V

At the time of this report writing, the preliminary design was not finalized yet for review. WSP understands that the exact footprint of the proposed pond expansion may be subject to change. If the proposed locations or sizes of the expansion change after the timeframe of this geotechnical study, additional geotechnical test holes may be required. The site for the proposed lagoon expansion is generally flat and is currently being covered with previous crop stubble and some snow at the time of field drilling.

3 REVIEW OF PAST GEOTECHNICAL INFORMATION

3.1 Existing Information

Prior to the site investigation, WSP completed a review of the existing geotechnical report (Project No: WE08 127 00 WE) completed by Genivar (former WSP) in 2009 for the proposed WWSP at RM of MacDonald, Oak Bluff, Manitoba. A total of sixteen (16) test holes were carried out during the site investigation as outlined in Figure 1 in Appendix B.

In general, the site consisted of 75 mm to 305 mm of topsoil, followed by native clay to the depth explored, except for TH14, where a 600 mm thick sand was observed in the clay layer. More detailed information related to the subsurface conditions at the site can be accessed from the previous geotechnical report.

3.2 Published Geological Information

Based on a review of available surficial geology mapping (Matile and Keller, 2004), offshore glaciolacustrine sediments are present on site. The sediments are estimated to be up to 20 m thick consisting of clay, silt and minor sand with low relief massive and laminated deposits.

4 METHODOLOGY

4.1 Field Investigation

Prior to the field investigation, WSP completed a Manitoba One-Call and obtained clearances from public utility providers (i.e., MB Hydro, MTS, the RM, etc.) for all drilling locations.

WSP oversaw the drilling of three (3) geotechnical test holes (TH22-01, 05 and 06) that were completed on April 8, 2022. It is worth to note that WSP initially planned a total of eight test holes within the footprint of the proposed lagoon area. However, due to the encountered ponding water and/or muddy site conditions, the rest five test holes near the south of the expansion boundary could not be conducted. Considering the similar soil conditions observed during site drilling and the existing soil logs provided from the previous geotechnical report, WSP suggested that the site had adequate test holes and/or soil information in order to provide the geotechnical recommendations for the preliminary design. As such, the subsurface conditions observed from the previous site investigation will also be referenced in this report.

All three completed test holes were drilled using a track mounted MP5 drill rig equipped with 125 mm diameter solid stem augers and a Standard Penetration Test (SPT) auto hammer, owned and operated by Paddock Drilling Ltd. All three test holes were backfilled to grade using the auger cuttings and bentonite upon completion of drilling. Test hole details are provided in Table 1. Figure 1 in Appendix B shows the completed test holes compared to the initially planned test hole locations, including the test holes previously completed by Genivar in 2009.

Table 1 Testhole Details

Test Hole #	Completion Date	Depth (mbgs)	*Northing	*Easting
TH22-01	Apr 08/22	6.7	5511672	622589
TH22-05	Apr 08/22	5.1	5511639	623132
TH22-06	Apr 08/22	5.1	5511682	622870

Note: mbgs – metres below ground surface

*UTM Coordinates are in NAD 83 Zone 14U

WSP field personnel visually classified the observed soils according to the modified Unified Soil Classification System (USCS) during site drilling. Disturbed soil samples were retrieved from auger flight at a continuous depth in all test holes. A pocket penetrometer reading was also taken on the cohesive auger samples. In addition, SPTs were performed, split-spoon samples were collected at the selected depths using the auto hammer of weight 624 N and drop height 760 mm as per ASTM D1586. The collected samples were labelled with the project name and number, test hole number, date of sampling, sample number and depth of the sample and submitted to the Laboratory for soil testing.

4.2 Laboratory Testing

The following laboratory tests were completed on soil samples collected on site:

- Moisture content tests for all collected samples (23)
- 3 Atterberg limits tests
- 3 Grain size analysis tests (sieve and hydrometer)
- 1 Hydraulic conductivity test

The laboratory test results are discussed in Section 5. The test results are shown on the test hole logs in Appendix C, and the laboratory test sheets are included in Appendix D.

5 SUBSURFACE CONDITIONS

The soil profile encountered at the test hole locations generally consisted of 250 mm to 300 mm topsoil followed by native clay to the depth explored. The frost depth encountered at the test hole locations was typically 1.83 m below grade. A description of the subsurface soil strata is provided in the following sub-sections.

5.1 Topsoil

Topsoil was encountered in all test hole locations and ranged from 250 mm to 300 mm thick. The topsoil was described as organic rich, black to brown with roots, and contained trace gravel.

5.2 Native Clay

Native clay was encountered below the topsoil and extended to the depths explored (5.1 m to 6.7 mbgs). The native clay was generally described as highly plastic, brown to dark grey, moist, and contained trace sand, trace to some silt. The frost depth encountered at the test hole locations was approximately 1.83 mbgs, then stiff to firm to depth 3.0 mbgs and firm to soft after 3.0 m depth.

Atterberg limits test and particle size analysis (hydrometer) were conducted at selected samples in TH22-01, TH22-05 and TH22-06. The results are summarized in Table 2.

Table 2 Laboratory Test Results for Native Clay

Test Hole #	Sample Depth (mbgs)	Atterberg Limits			Sieve and Hydrometer			
		Plastic Limit (%)	Liquid Limit (%)	Plasticity Symbol	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
TH22-01	0.8	30	77	CH	0.0	3.9	26.6	69.5
TH22-05	1.2	29	83	CH	0.0	0.9	17.7	81.4
TH22-06	0.9	29	82	CH	0.0	2.6	24.8	72.6

Notes: CH – highly plastic clay

In addition, a hydraulic conductivity test was also conducted from one of the selected Shelby tubes obtained in TH22-01 at depths from 0.9 to 1.5 m and 1.5 m to 2.1 m to estimate the hydraulic conductivity of the native clay material at the site. The result is summarized in Table 3.

Table 3 Hydraulic Conductivity Results

Testhole #	Depth (mbgs)	Material	Hydraulic Conductivity (m/sec)
TH22-01	0.9 to 1.5	Native Clay	6.5×10^{-11}
TH22-01	1.5 to 2.1	Native Clay	Non-testable due to the short received material

5.3 Groundwater and Sloughing Observations

No water seepage or sloughing was observed in all test holes upon completion of drilling. However, groundwater levels are prone to fluctuations and may be affected by seasonal fluctuations, recent rainfall, surface drainage, and infiltration, etc. Detailed descriptions of the subsurface soil strata are provided in the test hole logs in Appendix B.

6 GEOTECHNICAL RECOMMENDATIONS

6.1 Recommendations and Considerations

6.1.1 Earth Liner and Construction

As required by the Manitoba Sustainable Development (2017), the earthen lagoon construction must place a pond liner (base and interior) having a minimum of 1.0 m impervious high plastic clay soil with hydraulic conductivity values no greater than 1 x 10^{-9} m/s within the expansion cells. Based on the subsurface conditions encountered during drilling and the laboratory testing results, the native clay within the footprint of the pond expansion is considered as high plastic clay having an average value of Liquid Limit, Plastic Limit and Plasticity Index of 81%, 29 and 51%, respectively. The particle size analysis shows the native clay has well over 50% clay with silt contents between 18% and 26%. In addition, a hydraulic conductivity value of 6.5 x 10^{-11} m/s was obtained for one of the Shelby tube samples collected during drilling as outlined in Table 3. As such, it is suggested that the native clay on site could be used as the clay liner for the construction of the lagoon expansion.

It was understood that the proposed pond liner (base and interior) at the site should be constructed with a clay core within the proposed dykes. This would involve excavating a 2.0 m wide trench around the inside perimeter of the bottom of the pond and keying into the underlying impervious high plastic clay at depths ranging from 1.5 m to 2.1 mbgs.

During earthen cell construction, the backfill material used for the liner and key should be high plastic impervious clay and placed in layers not to exceed 200 mm non-compacted thickness at moisture content within 0 and +2 percent of the optimum moisture content and compacted at least 95% of Standard Proctor Maximum Dry Density (SPMDD). If any pockets or seams of unsuitable material are encountered during the pond construction, the unsuitable material must be removed and replaced with suitable high plastic clay soils.

6.1.2 Slope Stability and Erosion Control

Slope Stability Analysis & Results

A slope stability analysis is required in order to ensure the stability of the new proposed cells and/or modified cells meets the design criteria. The slope stability assessment was completed using the computer program SLOPE/W, a limit-equilibrium slope stability model developed by Geoslope International Ltd. This analysis method compared forces resisting instability against those driving instability and expressed this as a ratio referred to as Factor of Safety (FS). The values of FS above 1.0 were considered stable, and those below were unstable. In general, a factor of safety (FS) value of 1.5 is considered adequate for any lagoon slopes under normal conditions, and an FS of 1.3 is required under extreme conditions.

Based on the discussions with the RM public works, it was understood that the lagoon is typically discharged once a year in the fall immediately west of the lagoon to the Atchison Drain, which flows southeast to the La Salle River. In this regard, a steady-state analysis was used to present the normal condition at the site and had the cell water levels vary between the normal high (i.e., 1 m below the top berm) and the normal low (i.e., 1 m above the cell base). For extreme condition, a transient analysis was used to evaluate the effect that changing cell water level (i.e., rapid drawdown) would have on the berm stability during cell discharge. This is considered critical as the water level in the cell goes back to the normal low, the toe loading to resist movement decreases while the piezometric level in the upper embankment is still high, which will provide the extreme condition for the berm

stability. For first time slides, the post-peak shear strength values (c' = 5 kPa, ϕ' = 15°) were used for insitu stiff clay in the analysis. The bulk density of all the soil layers was evaluated based on typical density values that we experienced in the slope stability assessment. All soil shear strength parameter values in the model are outlined in Table 4 below.

Table 4 Soil Parameters Used in SLOPE/W Analysis

Soil Layers	Depth (m)	Unit Weight (kN/m^3)	Cohesion C' (kPa)	Friction ϕ' (Degree)	Hydraulic Conductivity (m/s)
Clay Fill	2.0 to 2.5 m above ground	18	2	23	$1x10^{-9}$
Native Clay	2.5 to 3.0 m below grade	18	5	15	$1x10^{-9}$

The slope stability results are summarized in Table 5.

Table 5 Slope Stability Results

Slope Configuration	Critical Factor of Safety (FS)			
	Normal Condition		Extreme Condition (Rapid Drawdown)	
	Normal High	Normal Low	2.0 m Drop	3.0 m Drop
4H:1V (New Cells; Option 1)	2.21 (Fig.2)	1.42 (Fig.3)	1.09 (Fig.4)	0.84 (Fig.5)
5H:1V (Modified Cells; Option 2)	2.62 (Fig.6)	1.60 (Fig.7)	1.30 (Fig.8)	1.04 (Fig.9)
Design Criteria (Min. FS Requirement)	**1.50**		**1.30**	

Note: 2.0 m Drop – Normal High to 2.0 m above the cell base; 3.0 m Drop – Normal High to 1.0 m above the cell base

The normal condition was conducted under steady-state analysis consisting of both seepage and slope stability analysis; the seepage analysis was completed using SEEP/W to estimate the piezometric line through the berm based on the soil parameters and boundary conditions mentioned above. The results were then used in the SLOPE/W to estimate the potential slip surface (PSS) critical FS values. The extreme condition was based on the rapid drawdown scenario and used to evaluate how changing cell water levels would impact the berm stability. The rapid drawdown scenario assumed cell water levels change from the normal high to 2 m and/or 1 m above the cell base (i.e., 3 m drop and/or 2 m drop) over seven (7) days.

As shown in Table 5, the FS values under the normal condition are near and/or above the minimum FS requirement. However, it is worth to note that potential failures could be expected if water levels in the cell dropped rapidly from the normal high to 1.0 m above the cell base (i.e., 3.0 m drop) as the FS values obtained were near and/or lower than the unity (FS = 1.0); it is recommended that the cell water should be discharged gradually and have the water levels kept at least 2.0 m above the cell base in order to reduce the impact of the changing cell water levels would have on the berm stability. In addition, potential failures may be expected if Option 1 is preferred during the preliminary design; an FS value of 1.09 was obtained for PSS that initiated from the top cell to the cell base. Any changes due to groundwater levels, cell water levels, additional loading at the top cell, cell base erosion and/or the combination of the above could contribute to berm failures. As such, a new cell construction with a side slope of 5H:1V (i.e., Option 2) is strongly recommended for the preliminary design.

The computer modelling output is outlined in Figures 2 to 9 in Appendix B.

It was understood that the preliminary design for the lagoon expansion is subject to change. If the proposed design configuration is significantly different from the final design, the slope stability should be reviewed and modified as necessary.

Erosion Control

A layer of riprap should be placed on the interior slope to protect any impacts resulting from wave action, rainfalls and any other erosion actions, whereas the exterior slope face can be protected using vegetated roll or seeding application.

6.2 Additional Consideration

WSP has the following additional considerations as outlined below:

- The excavated topsoil at depths between 250 mm and 300 mm should be stockpiled during construction and can be reused later for the outer slopes and top of the dykes.
- A well-developed and maintained grass cover above the riprap should add integrity to the dykes.
- The riprap blanket should start slightly from normal water high and extend into the cell base with an average thickness of 300 mm. The riprap will have a slightly positive impact on the embankment, although its intended use is for erosion control.
- The entire completed pond system should be fenced to keep people away from the pond. All gates should be locked to prevent access.

7 REFERENCES

Matile, G.L.D. and Keller, G.R. 2004: Surficial geology of the Winnipeg map sheet (NTS 62H), Manitoba; Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, Surficial Geology Compilation Map Series, SG-62H, scale 1:250000.

APPENDIX

A CERTIFICATION OF WORKS

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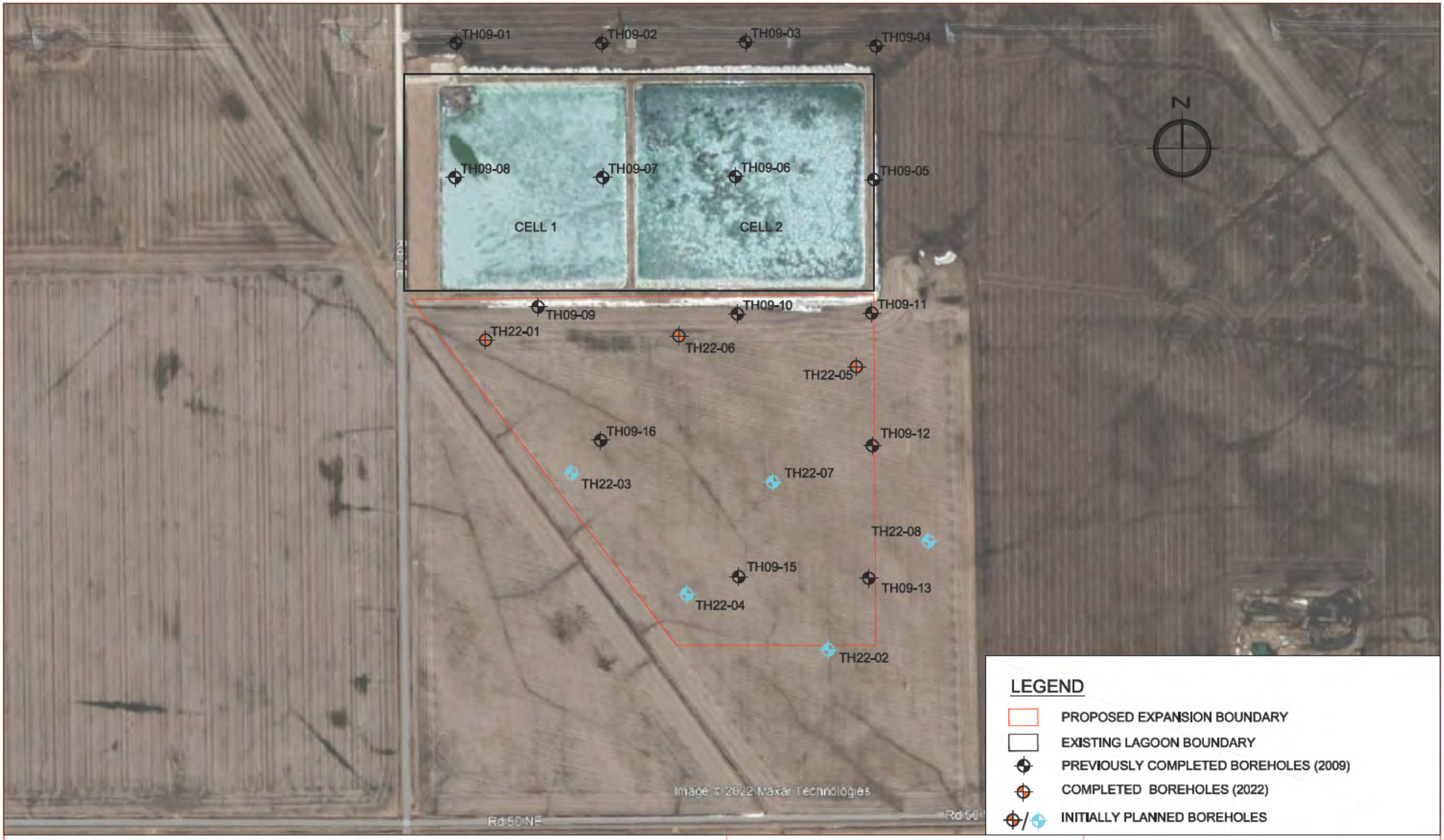
APPENDIX

B SITE PLAN AND COMPUTER MODELLING OUTPUT



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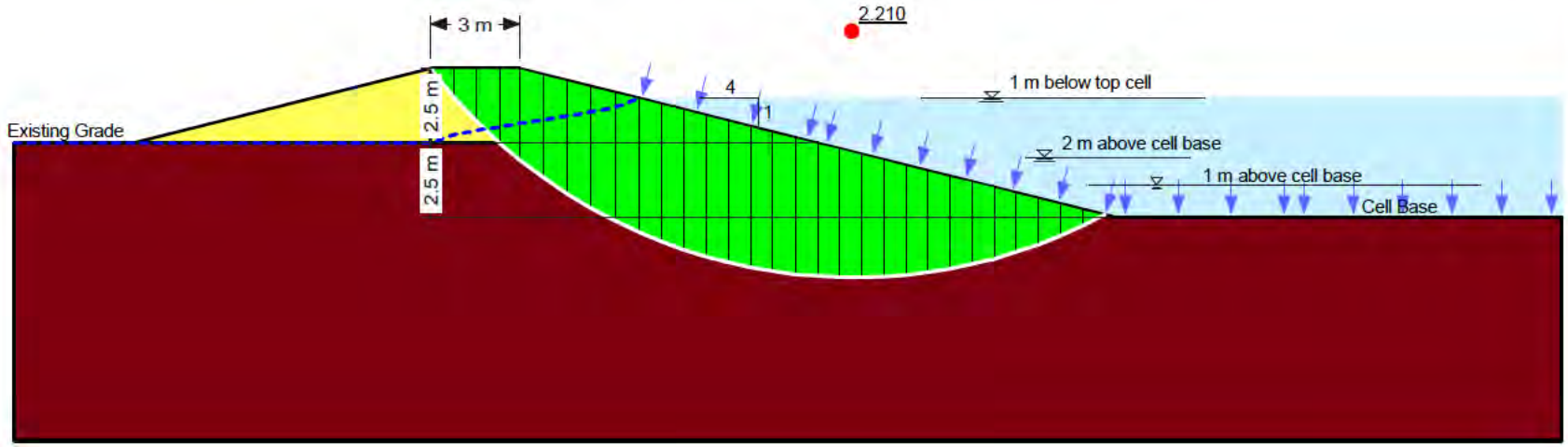
GEOTECHNICAL INVESTIGATION
PROPOSED LAGOON EXPANSION - OAK BLUFF, MB
TESTHOLE LOCATIONS PLAN

SCALE:	DATE:	DWG. No.
NTS	22 APRIL, 2022	FIG. 1

Apr 25, 2022 – 12:41pm
C:\Users\CAWG072851\OneDrive – WSP O365\Documents\WSP Work Folder–Computer\10–Projects Folder\2–Current Projects\221–01415–00 Oak Bluff Lagoon Study\Figure\Figure 1 – Testhole Locations Plan.dwg –tab: WSP_Red_Layout

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay Fill (Berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

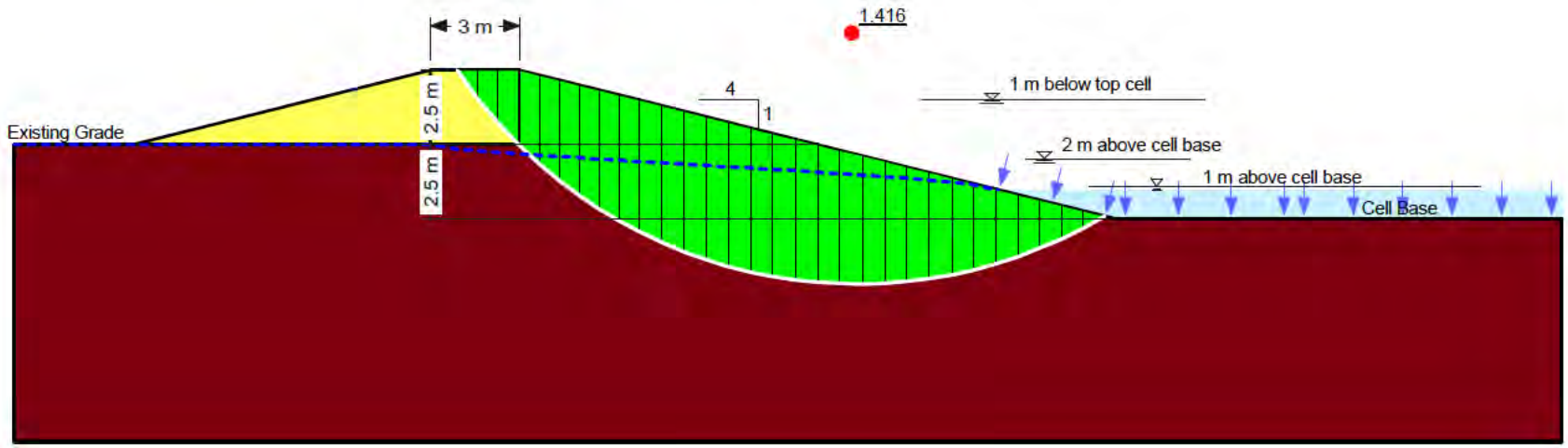


Option 1 (4H:1V) - Normal High

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 2

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay Fill (Berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

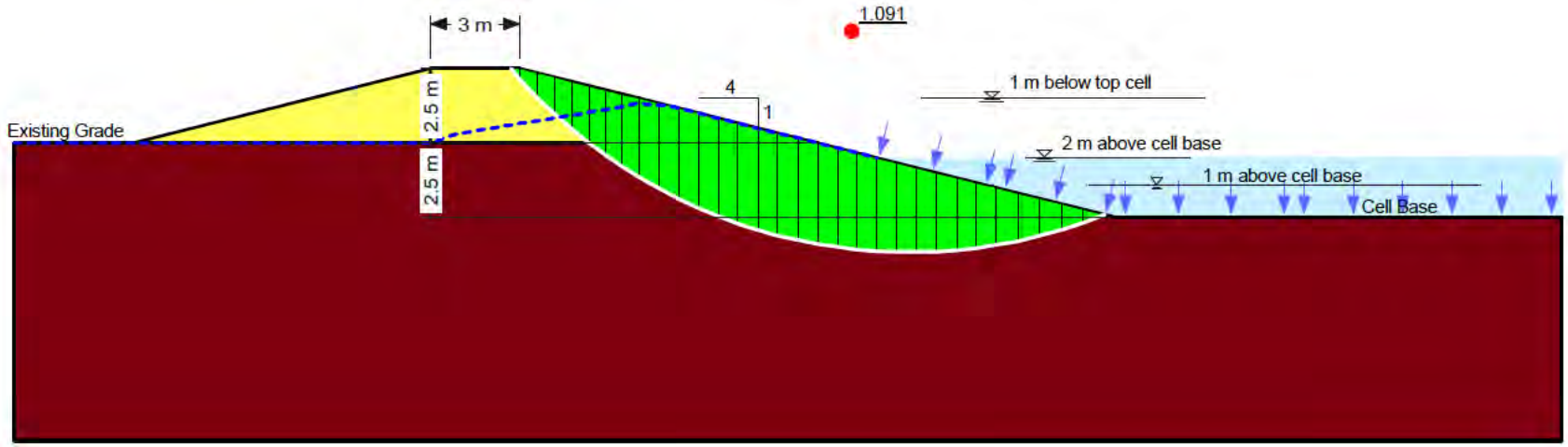


Option 1 (4H:1V) - Normal Low

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 3

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay Fill (Berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

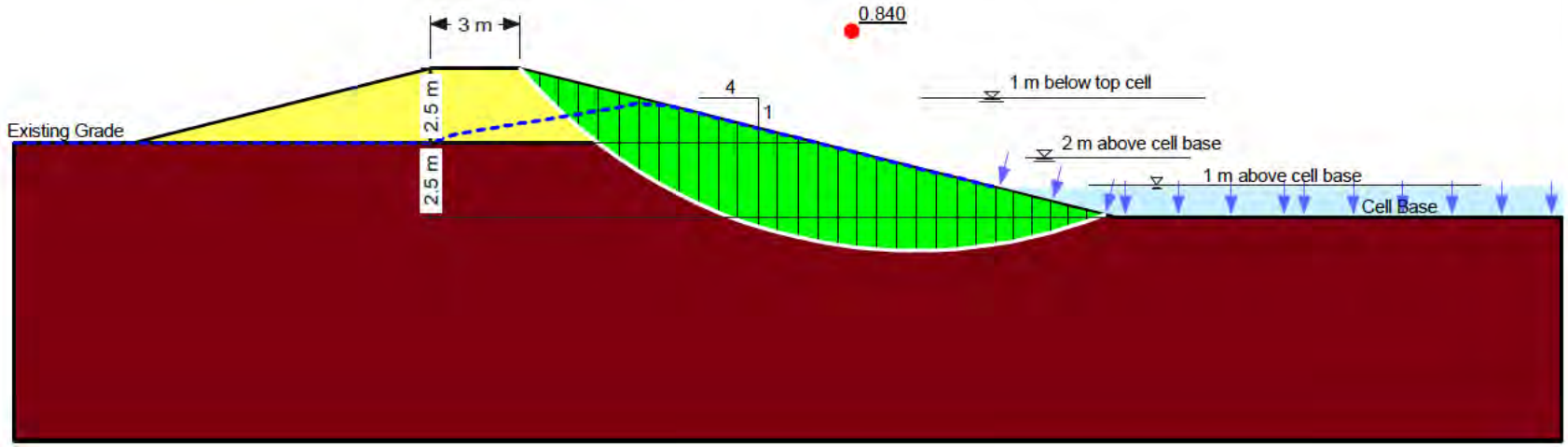


Option 1 (4H:1V) - Extreme (2 m drop)

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 4

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay Fill (Berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

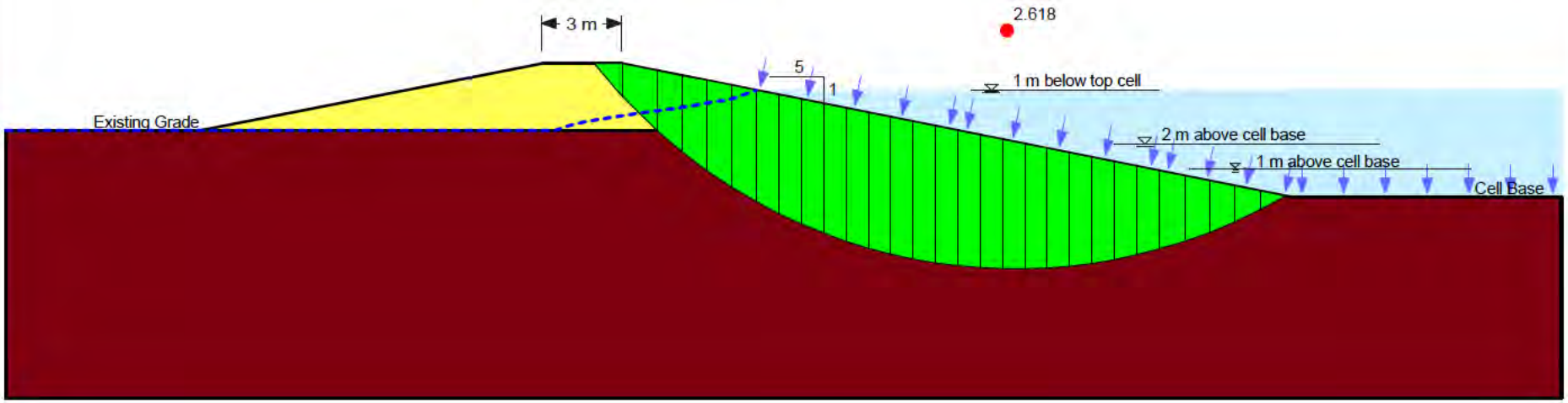


Option 1 (4H:1V) - Extreme (3 m drop)

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 5

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay fill (berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

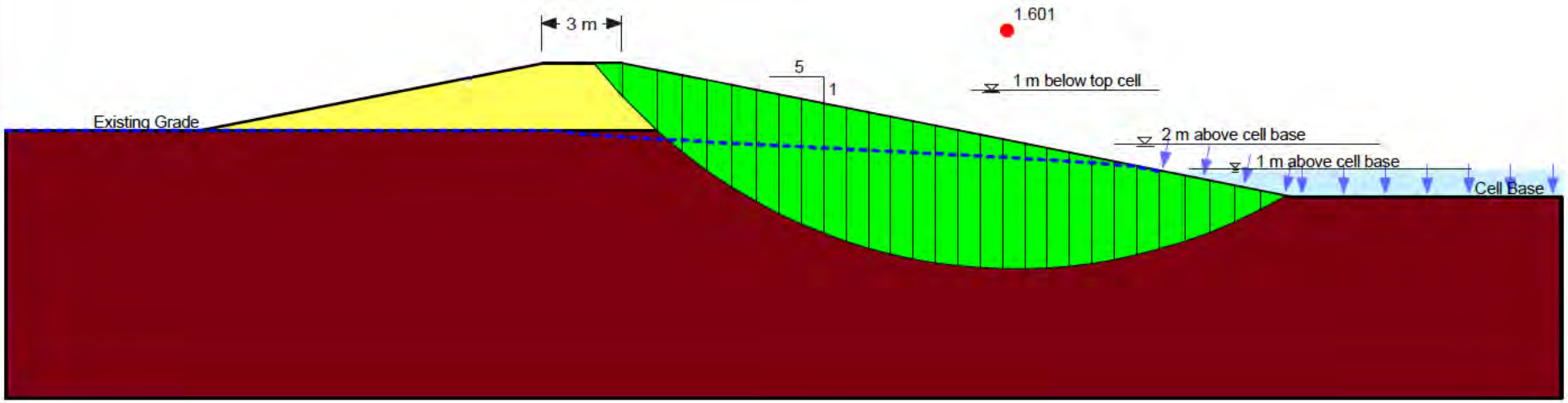


Option 2 (5H:1V) - Normal High

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 6

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay fill (berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

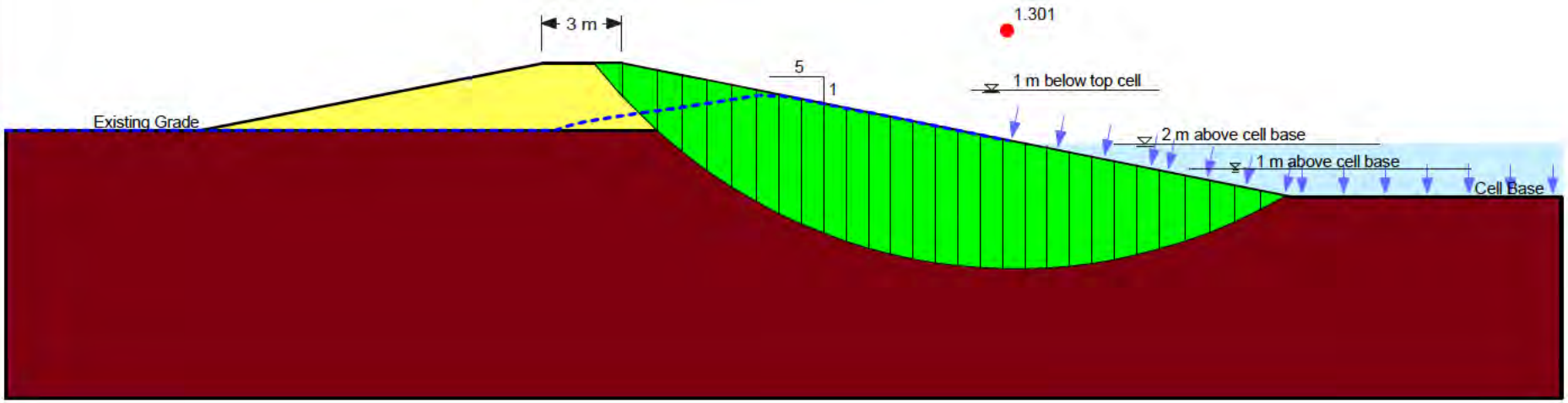


Option 2 (5H:1V) - Normal Low

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 7

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay fill (berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15

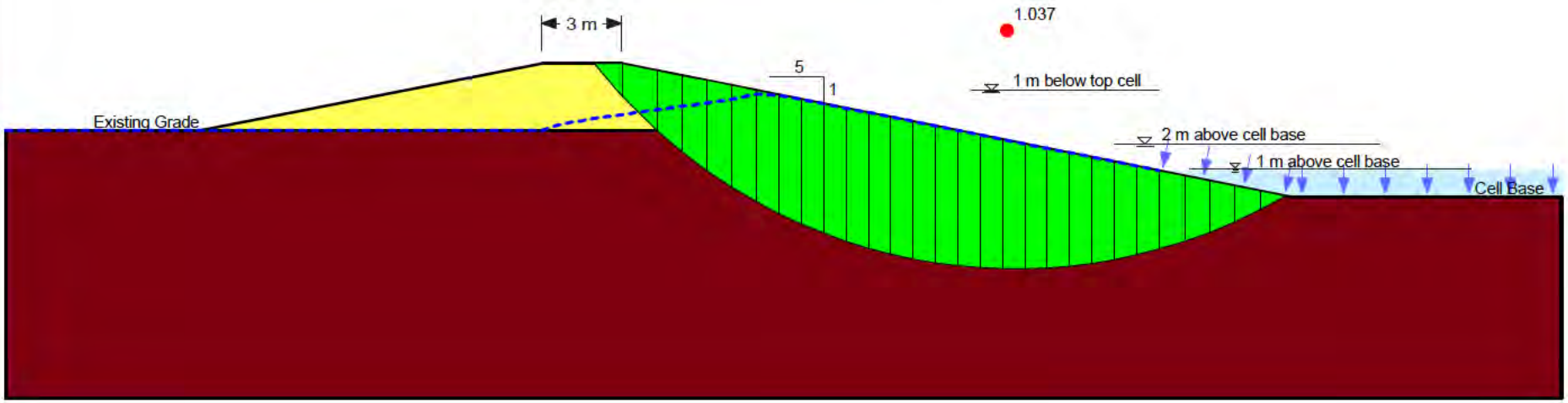


Option 2 (5H:1V) - Extreme (2 m drop)

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 8

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay fill (berm)	Mohr-Coulomb	18	2	23
	Native Clay	Mohr-Coulomb	18	5	15



Option 2 (5H:1V) - Extreme (3 m drop)

Oak Bluff Lagoon Expansion Study

221-01415-00 Figure 9

APPENDIX

C TEST HOLE LOGS

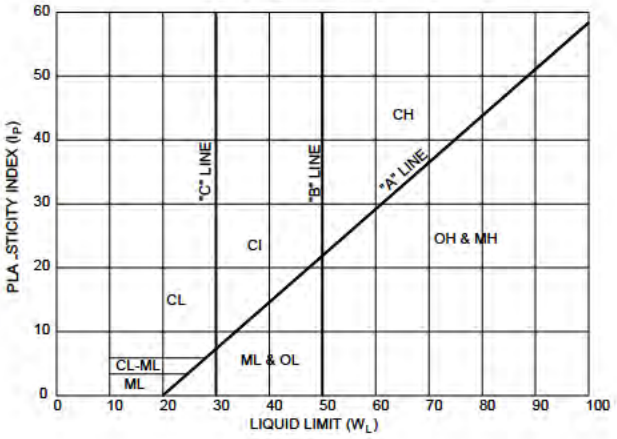
SOIL DESCRIPTION CHART

MODIFIED UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than half of material is retained in No.200 Sieve (0.075 mm)	GRAVELS (More than half of coarse fraction is larger than No. 4 sieve size (4.75 mm)	CLEAN GRAVELS (<5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES (> 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (More than half of coarse fraction is smaller than No. 4 sieve size (4.75	CLEAN SANDS (< 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		DIRTY SANDS (>12% fines)	SM	Silty Sands; sand-silt mixtures
			SC	Clayey sands; sand-clay mixtures
FINE GRAINED SOILS (More than half of material pass the No. 200 sieve size (0.075 mm)	CLAYS (Above "A" Line on PLASTICITY CHART: negligible organic content	W_L<30%	CL	Inorganic cla gravelly clay clays
		30<W_L <50%	CI	Inorganic clays gravelly clay
		W_L>50%	CH	Inorganic clays
	SILTS (Below "A" Line; negligible organic content)	W_L<50%	ML	Inorganic silts silty or clayey fi with sl
		W_L>50%	MH	Inorganic silt diatomaceou soils,
	ORGANIC SILTS AND CLAYS (Below "A" Line)	W_L<50%	OL	Organic silts a of lo
		W_L>50%	OH	Organic clay plasticit
	HIGHLY ORGANIC SOILS		Pt	Peat and othe

LABORATORY CLASSIFICATION CRITERIA		
termine amount of sand and gravel from grained size curve spending on percent of fines (fraction smaller than No. 200 sieve size), arse-grained soils are classified as follows: 5%.....GW, GP, SW, SP 12%.....GM, GC, SM, SC -12%.....Borderline cases requiring dual symbols**	$C_u = D_{60}/D_{10}$: $C_u \geq 4$ $C_c = (D_{30})^2/(D_{10}xD_{60})$: $1 < C_c > 3$	
	Not meeting all gradations requirements for GW	
	Atterberg Limits below "A" Line or P.I. < 4	Above "A" Line with P.I. Between 4 and 7 are borderline cases requiring use of dual symbols
	Atterberg Limits above "A" Line with P.I. > 7	
	$C_u = D_{60}/D_{10}$: $C_u \geq 6$ $C_c = (D_{30})^2/(D_{10}xD_{60})$: $1 < Cc > 3$	
	Not meeting all gradations requirements for SW	
	Atterberg Limits below "A" Line or P.I. < 4	Limits plotting in hatched zone with P.I. Between 4 and 7 are borderline cases requiring use of dual symbols
	Atterberg Limits above "A" Line	

PLASTICITY CHART



SOIL COMPONENTS

Fraction	U.S. Standard Sieve Size		Percentage (by weight)	Description
	Passing	Retained		
Gravel				
Coarse	76 mm	19 mm	35-50	AND
Fine	19 mm	4.75 mm		
Sand			20-35	Y
Coarse	4.75 mm	2.00 mm		
Medium	2.00 mm	0.425 mm	10-20	SOME
Fine	0.425 mm	0.075 mm		
Fines (Silt or Clay)	0.075 mm or less		0-10	TRACE
Oversize Material	Cobbles	76 mm to 300 mm		
	Boulders	> 300 mm		

Cohesionless Soils		Cohesive Soils	
Relative Density	SPT (N) Value	Consistency	Undrained Shear Strength (kPa)
Very Loose	0-4	Very Soft	<12
Loose	4-10	Soft	12-25
Compact	10-30	Firm	25-50
Dense	30-50	Stiff	50-100
Very Dense	>50	Very Stiff	100-200
		Hard	>200

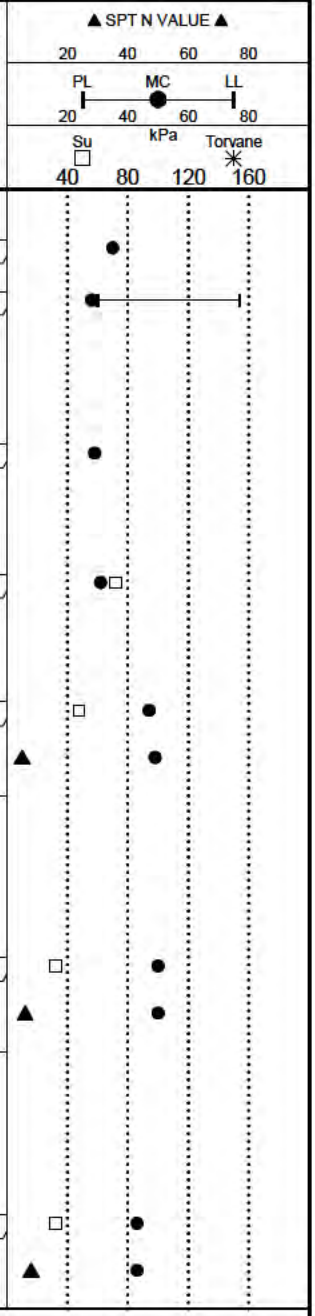
Updated - January 2022

WSP Canada Inc

TH22-01

CLIENT Manitoba Water Services Board
PROJECT NAME Oak Bluff Lagoon - Geotechnical Investigation
PROJECT NUMBER 221-01415-00
PROJECT LOCATION Oak Bluff, Manitoba
DATE STARTED 4/8/22 **COMPLETED** 4/8/22
GROUND ELEVATION 235.69 m **HOLE SIZE** 125 mm
DRILLING CONTRACTOR Paddock Drilling Ltd.
GROUND WATER LEVELS:
DRILLING METHOD Solid Stem Auger - MP-5 Track Rig
AT TIME OF DRILLING ---
LOGGED BY Jeremiah Kevin **CHECKED BY** Wei Gao
AT END OF DRILLING ---
NOTES 5511672 N; 622589 E
AFTER DRILLING ---

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	Shear Strength Su (kPa)	MOISTURE CONTENT (%)
	235.44	**TOPSOIL (250 mm)** - Organic rich, black-brown with roots, trace gravel, frozen				
		CLAY (CH) - Dark grey, trace silt, trace medium size sand, trace rootlets frozen to 1.83 mbgs,	GB S1			35
			GB S2			28
1		- PSA obtained on S2 at 0.7 mbgs: Gravel (0.0%); Sand (3.9%); Silt (26.6%); Clay (69.5%)	ST S2A			
			GB S3			29
2			ST S3A			
		- At depth of 2.29 mbgs, brown-grey, mottled, stiff, high plastic, moist, trace silt pocket	GB S4		72	31
3						
		- At depth of 3.05, some silt, firm to stiff	GB S5		48	47
			SPT S5A	1-2-3 (5)		49
4						
			GB S6		32	50
5		- At depth of 4.57 mbgs, firm to soft, some to with silt	SPT S6A	2-3-3 (6)		50
6						
			GB S7		32	43
	229.03		SPT S7A	3-4-4 (8)		43



END OF TESTHOLE
- Testhole ended at 6.7 mbgs
- No water seepage or sloughing was observed during and after the testhole drilling
- Testhole backfilled with auger cuttings and topped with bentonite chips

WSP Canada Inc

TH22-05

CLIENT Manitoba Water Services Board
PROJECT NAME Oak Bluff Lagoon - Geotechnical Investigation
PROJECT NUMBER 221-01415-00
PROJECT LOCATION Oak Bluff, Manitoba
DATE STARTED 4/8/22 **COMPLETED** 4/8/22
GROUND ELEVATION 236.44 m **HOLE SIZE** 125 mm
DRILLING CONTRACTOR Paddock Drilling Ltd.
GROUND WATER LEVELS:
DRILLING METHOD Solid Stem Auger - MP-5 Track Rig
AT TIME OF DRILLING ---
LOGGED BY Jeremiah Kevin **CHECKED BY** Wei Gao
AT END OF DRILLING ---
NOTES 5511639 N; 623132 E
AFTER DRILLING ---

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	Shear Strength Su (kPa)	TORVANE (kPa)	MOISTURE CONTENT (%)
	236.14	**TOPSOIL (300 mm)** - Organic rich, black-brown with roots, trace gravel, disturbed					
1		**CLAY (CH)** - Dark grey, trace silt, trace medium size sand, trace rootlets, frozen to 1.83 mbgs,	GB S1				38
			GB S2				33
			GB S3				29
		- PSA obtained on S4 at 1.2 mbgs: Gravel (0.0%); Sand (0.9%); Silt (17.7%); Clay (81.4%)	GB S4				29
			GB S5				31
2		- At depth of 1.52 mbgs, brown-grey, trace silt pocket	SPT S5A	4-4-6 (10)			36
		- At depth of 2.29 mbgs, firm to stiff, moist, mottled, high plastic	GB S6		48		39
3			GB S7		48		52
		- At depth of 3.51 mbgs, some silt	SPT S7A	2-3-4 (7)			44
4							
			GB S8		48		44
5	231.31		SPT S8A	3-3-4 (7)			43

END OF TESTHOLE
- Testhole ended at 5.1 mbgs
- No water seepage or sloughing was observed during and after the testhole drilling
- Testhole backfilled with auger cuttings and topped with bentonite chips

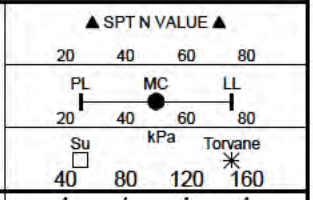
GENERAL BH PLOTS - WSP 221-01415-00 SOIL LOGS.GPJ GEO_TEMP WITH WELLS.GDT 4/28/22

WSP Canada Inc

TH22-06

CLIENT Manitoba Water Services Board
PROJECT NAME Oak Bluff Lagoon - Geotechnical Investigation
PROJECT NUMBER 221-01415-00
PROJECT LOCATION Oak Bluff, Manitoba
DATE STARTED 4/8/22 **COMPLETED** 4/8/22
GROUND ELEVATION 236.86 m **HOLE SIZE** 125 mm
DRILLING CONTRACTOR Paddock Drilling Ltd.
GROUND WATER LEVELS:
DRILLING METHOD Solid Stem Auger - MP-5 Track Rig
AT TIME OF DRILLING ---
LOGGED BY Jeremiah Kevin **CHECKED BY** Wei Gao
AT END OF DRILLING ---
NOTES 5511682 N; 622870 E
AFTER DRILLING ---

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	Shear Strength Su (kPa)	MOISTURE CONTENT (%)
	236.61	**TOPSOIL (250 mm)** - Organic rich, black-brown with roots, trace gravel, frozen				
		CLAY (CH) - Dark grey, trace silt, trace medium size sand, trace rootlets, frozen to 1.83 mbgs,	GB S1			27
			GB S2			28
1			GB S3			30
		- PSA obtained on S3 at 0.9 mbgs: Gravel (0.0%); Sand (2.6%); Silt (24.8%); Clay (72.6%)	GB S4			32
		- At depth of 1.52 mbgs, brown-grey, mottled, trace silt pocket	GB S5			36
2			SPT S5A	3-4-5 (9)		35
		- At depth of 2.29 mbgs, stiff, moist, high plastic, trace oxidation	GB S6		72	37
3		- At depth of 3.05 mbgs, some silt, firm to soft	GB S7		36	45
			SPT S7A	2-3-3 (6)		52
4						
			GB S8		36	49
5	231.73		SPT S8A	2-3-4 (7)		53
		END OF TESTHOLE - Testhole ended at 5.1 mbgs - No water seepage or sloughing was observed during and after the testhole drilling - Testhole backfilled with auger cuttings and topped with bentonite chips				



APPENDIX

D LABORATORY TEST RESULTS

MOISTURE CONTENT OF SOIL AND ROCK
(ASTM D2216)

Client:	WSP Canada Inc.	**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study	**Project No.:**	221-01415-00
Site Location:	Project Site	**Report Date:**	Apr 21, 2022
Date Sampled:	Apr 08, 2022	**Date Tested:**	Apr 12, 2022
Sampled By:	JK	**Tested By:**	PD

Test Hole No.	Sample No.	Depth (ft)	Moisture Content (%)
TH01	S1	1.0	34.9
TH01	S2	2.5	27.8
TH01	S3	5.0	28.9
TH01	S4	7.5	30.6
TH01	S5	10.0	47.3
TH01	S5A	10-11.5	49.5
TH01	S6	15.0	50.2
TH01	S6A	15-16.5	50.2
TH01	S7	20.0	42.7
TH01	S7A	20-21.5	42.5
TH05	S1	1.0	38.4
TH05	S2	2.0	32.7
TH05	S3	3.0	29.0
TH05	S4	4.0	28.8
TH05	S5	5.0	31.0
TH05	S5A	5-6.5	36.4
TH05	S6	7.5	38.5
TH05	S7	10.0	51.5
TH05	S7A	10-11.5	44.2
TH05	S8	15.0	44.1
TH05	S8A	15-16.5	42.7
TH06	S1	1.0	26.6
TH06	S2	2.0	27.8
TH06	S3	3.0	30.2
TH06	S4	4.0	32.0
TH06	S5	5.0	35.9
TH06	S5A	5-6.5	35.4
TH06	S6	7.5	37.1
TH06	S7	10.0	45.0
TH06	S7A	10-11.5	52.2

Test Hole No.	Sample No.	Depth (ft)	Moisture Content (%)
TH06	S8	15.0	48.8
TH06	S8A	15-16.5	52.5

Reviewed by: [redacted]

Bryan Hiebert, CET

Notice: The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

ATTERBERG LIMITS
(ASTM D4318)

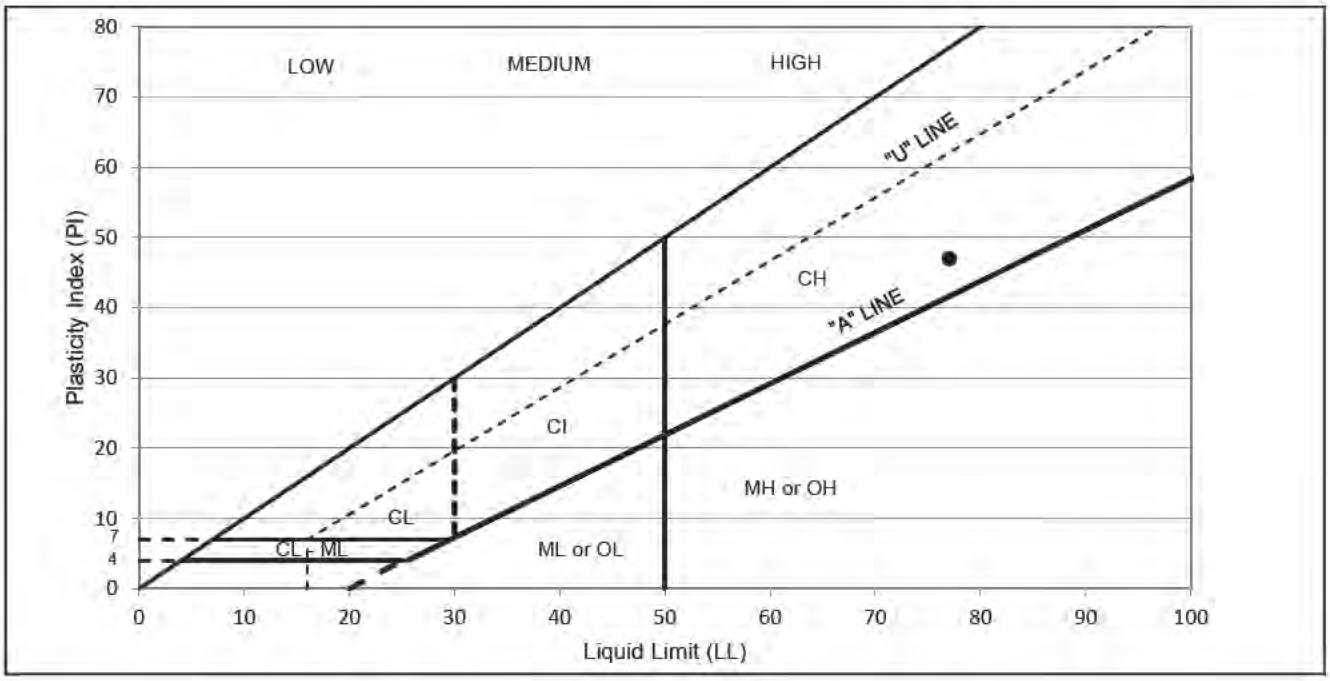
Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Site Location:	Project Site			**Report Date:**	Apr 21, 2022
Date Sampled:	Apr 08, 2022			**Date Tested:**	Apr 19, 2022
Sampled By:	JK	**Date Received:**	Apr 08, 2022	**Tested By:**	PD/BMH
Test Hole No.:	TH01	**Sample No.:**	S2	**Depth (ft):**	2.5 ft
Drying Method:	Oven	**Method:**	Multi-Point		

Liquid Limit Test (Manual, Plastic Grooving tool)

Trial	A	B	C
No. of Blows	22	25	29
Moisture Content (%)	76.8	76.7	76.1

Plastic Limit Test (Hand rolled)

Trial	A	B
Moisture Content (%)	30.6	30.4



USCS Symbol: CH

Soil Description: High Plastic Clay

LL, Liquid Limit (%): 77

PL, Plastic Limit (%): 30

PI, Plasticity Index: 47

Reviewed by: [redacted]
Bryan Hiebert, CET

Comment: As received moisture content is 27.8%.

ATTERBERG LIMITS
(ASTM D4318)

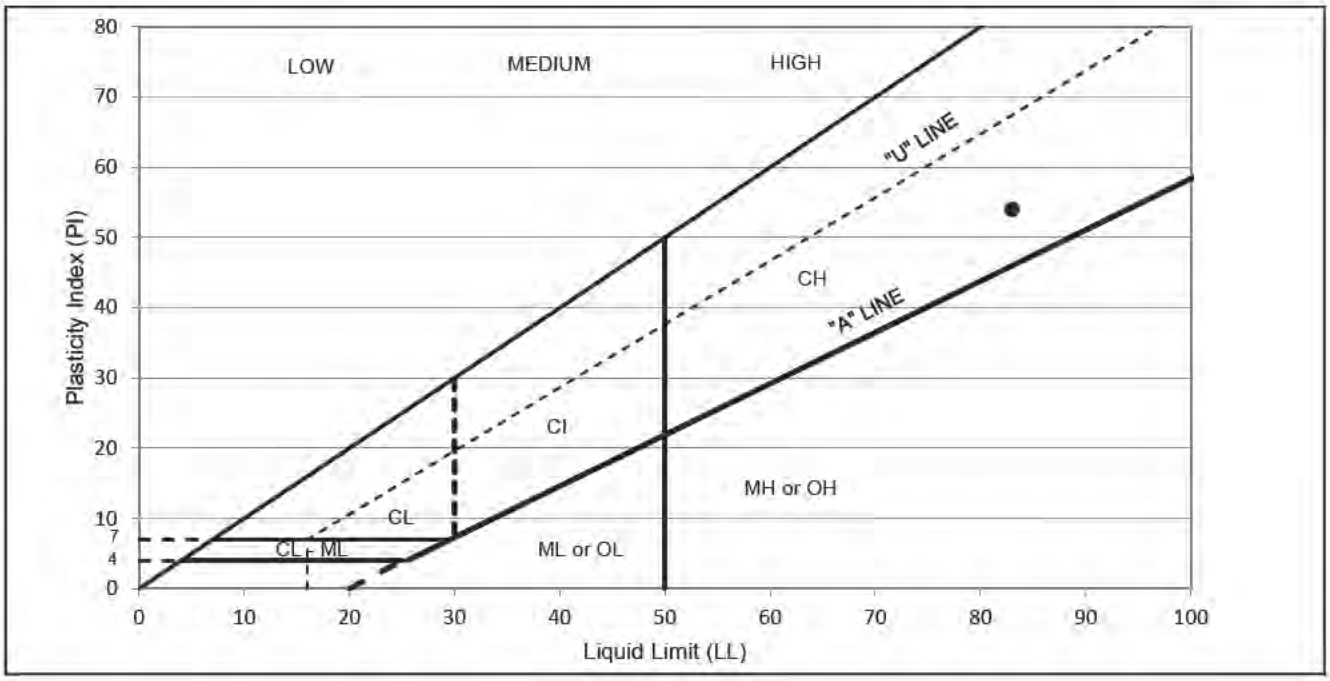
Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Site Location:	Project Site			**Report Date:**	Apr 21, 2022
Date Sampled:	Apr 08, 2022			**Date Tested:**	Apr 19, 2022
Sampled By:	JK	**Date Received:**	Apr 08, 2022	**Tested By:**	PD/BMH
Test Hole No.:	TH05	**Sample No.:**	S4	**Depth (ft):**	4.0 ft
Drying Method:	Oven	**Method:**	Multi-Point		

Liquid Limit Test (Manual, Plastic Grooving tool)

Trial	A	B	C
No. of Blows	17	25	28
Moisture Content (%)	85.2	83.1	82.9

Plastic Limit Test (Hand rolled)

Trial	A	B
Moisture Content (%)	29.3	29.3



USCS Symbol: CH

Soil Description: High Plastic Clay

LL, Liquid Limit (%): 83

PL, Plastic Limit (%): 29

PI, Plasticity Index: 54

Reviewed by: [redacted]

Bryan Hiebert, CET

Comment: As received moisture content is 28.8%.

ATTERBERG LIMITS
(ASTM D4318)

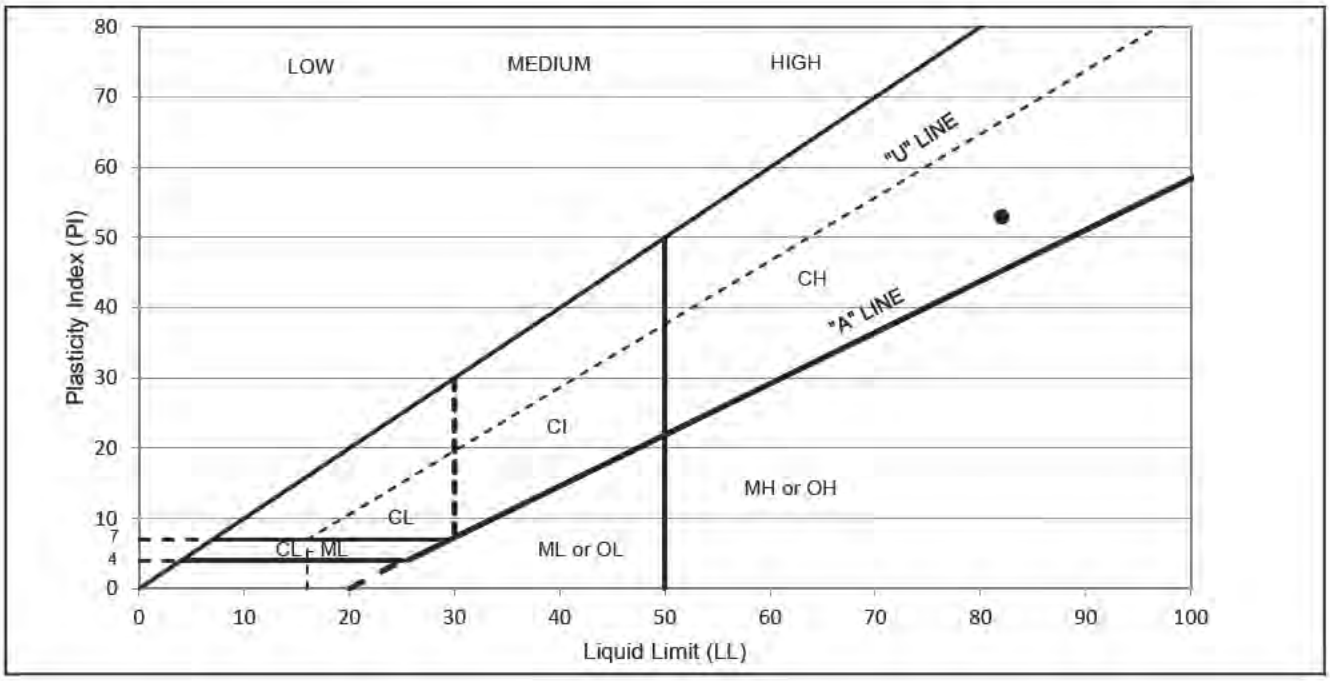
Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Site Location:	Project Site			**Report Date:**	Apr 21, 2022
Date Sampled:	Apr 08, 2022			**Date Tested:**	Apr 20, 2022
Sampled By:	JK	**Date Received:**	Apr 08, 2022	**Tested By:**	PD/BMH
Test Hole No.:	TH06	**Sample No.:**	S3	**Depth (ft):**	3.0 ft
Drying Method:	Oven	**Method:**	Multi-Point		

Liquid Limit Test (Manual, Plastic Grooving tool)

Trial	A	B	C
No. of Blows	21	30	35
Moisture Content (%)	83.3	80.6	79.2

Plastic Limit Test (Hand rolled)

Trial	A	B
Moisture Content (%)	29.0	29.0



USCS Symbol: CH

Soil Description: High Plastic Clay

LL, Liquid Limit (%): 82

PL, Plastic Limit (%): 29

PI, Plasticity Index: 53

Reviewed by: [redacted]
Bryan Hiebert, CET

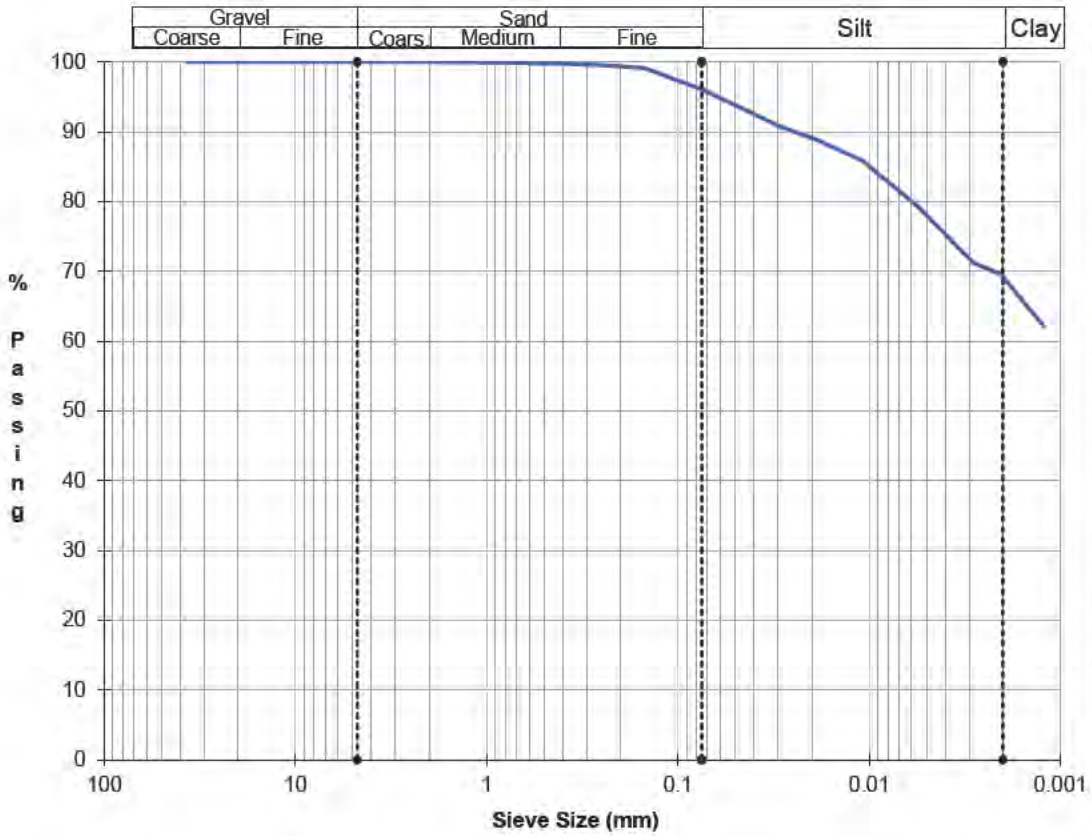
Comment: As received moisture content is 30.2%.

The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS (AASHTO T88)

Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Borehole No.:	TH01	**Sampled by:**	JK	**Sample Source:**	Project Site
Sample No.:	S2	**Date Sampled:**	Apr 08, 2022	**Date Received:**	Apr 08, 2022
Depth (ft):	2.5	**Sampling Method:**	Grab	**Tested By:**	PD/BMH

Dispersion Method: Stirring **Dispersion Period (min):** 1 **S.G. (assumed):** 2.65



Sieve Size (mm)	Percent Passing (%)
37.5	100.0
25.0	100.0
19.0	100.0
16.0	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.850	99.9
0.425	99.8
0.250	99.5
0.150	99.1
0.075	96.1
0.029	90.7
0.018	88.8
0.011	85.8
0.008	82.6
0.006	79.3
0.0028	71.2
0.0021	69.6
0.001	62.1

Percent of: Gravel = 0.0% Sand = 3.9% Silt = 26.6% Clay = 69.5%

Sample Description: Silty clay, trace sand.

Remarks: Separation made on No 10 sieve (2.0 mm).

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

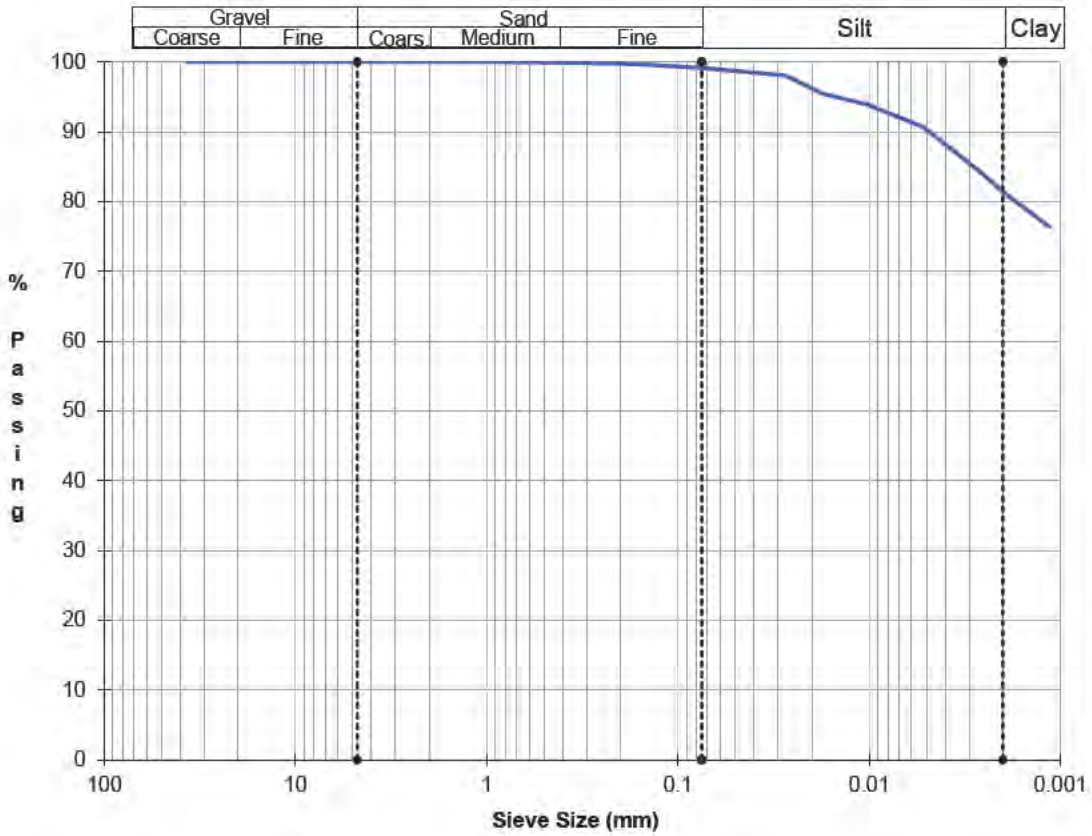
Reviewed by: [redacted]
Bryan Hiebert, CET

The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS (AASHTO T88)

Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Borehole No.:	TH05	**Sampled by:**	JK	**Sample Source:**	Project Site
Sample No.:	S4	**Date Sampled:**	Apr 08, 2022	**Date Received:**	Apr 08, 2022
Depth (ft):	4.0	**Sampling Method:**	Grab	**Tested By:**	PD/BMH

Dispersion Method: Stirring **Dispersion Period (min):** 1 **S.G. (assumed):** 2.7



Sieve Size (mm)	Percent Passing (%)
37.5	100.0
25.0	100.0
19.0	100.0
16.0	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.850	100.0
0.425	99.9
0.250	99.8
0.150	99.7
0.075	99.1
0.027	98.1
0.018	95.5
0.010	93.9
0.007	92.3
0.005	90.7
0.0026	84.3
0.0019	81.1
0.001	76.3

Percent of: Gravel = 0.0% Sand = 0.9% Silt = 17.7% Clay = 81.4%

Sample Description: Clay, some silt, trace sand.

Remarks: Separation made on No 10 sieve (2.0 mm).

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

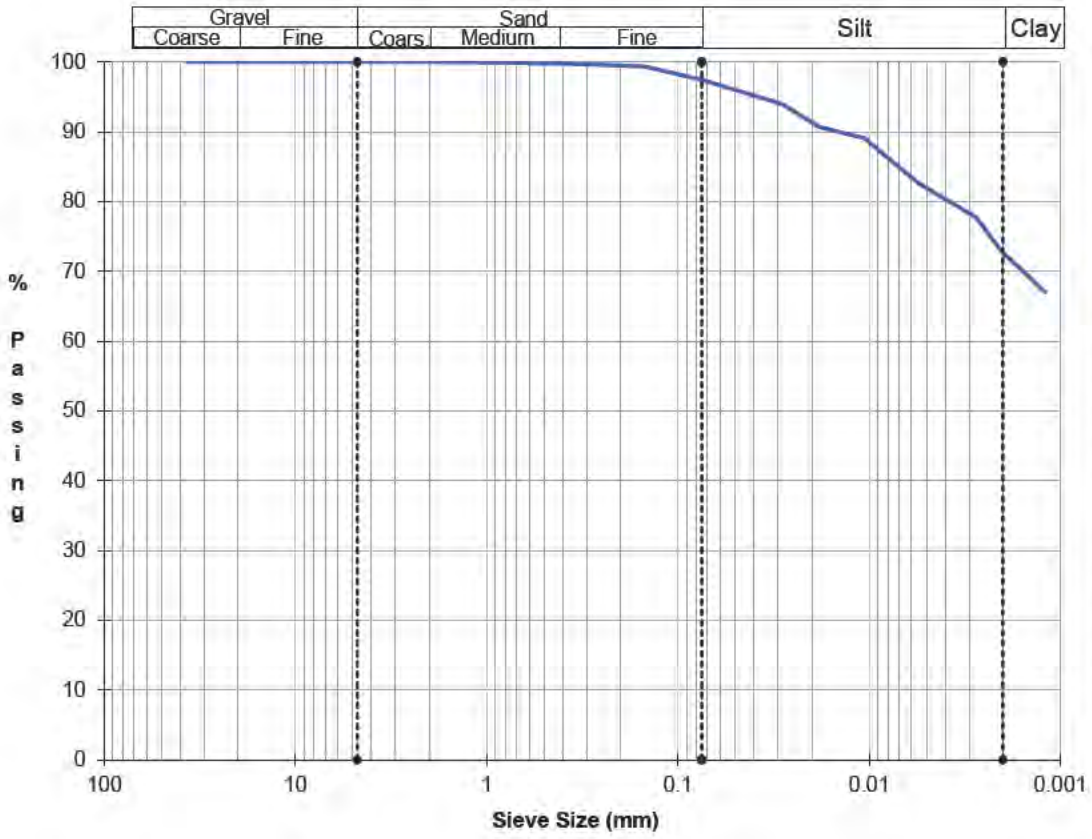
Reviewed by: [redacted]
Bryan Hiebert, CET

The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS (AASHTO T88)

Client:	WSP Canada Inc.			**Lab No.:**	22-001-007-S139
Project:	Oak Bluff Lagoon Study			**Project No.:**	221-01415-00
Borehole No.:	TH06	**Sampled by:**	JK	**Sample Source:**	Project Site
Sample No.:	S3	**Date Sampled:**	Apr 08, 2022	**Date Received:**	Apr 08, 2022
Depth (ft):	3.0	**Sampling Method:**	Grab	**Tested By:**	PD/BMH

Dispersion Method: Stirring **Dispersion Period (min):** 1 **S.G. (assumed):** 2.65



Sieve Size (mm)	Percent Passing (%)
37.5	100.0
25.0	100.0
19.0	100.0
16.0	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.850	99.9
0.425	99.8
0.250	99.6
0.150	99.3
0.075	97.4
0.028	94.0
0.018	90.7
0.011	89.1
0.008	85.8
0.005	82.6
0.0028	77.7
0.0020	72.8
0.001	67.0

Percent of: Gravel = 0.0% Sand = 2.6% Silt = 24.8% Clay = 72.6%

Sample Description: Silty clay, trace sand.

Remarks: Separation made on No 10 sieve (2.0 mm).

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Reviewed by: [redacted]

Bryan Hiebert, CET

420 Turenne Street Winnipeg, Manitoba R2J 3W8
Phone: (204) 233-1694 Fax: (204) 235-1579
E-mail: engtech@mymts.net
www.eng-tech.ca

April 29, 2022

Project No. 22-035-01

WSP Canada Group Ltd.
1600 Buffalo Place
Winnipeg, MB R3T 6B8

ATTENTION: Wei Gao, P.Eng.

RE: Hydraulic Conductivity Test Results, Oak Bluff Lagoon
(WSP Project No. 221-01415-00)

ENG-TECH Consulting Limited (ENG-TECH) was provided two (2) Shelby tube samples from the above project that were collected by WSP Canada Group Inc. and received by ENG-TECH on April 11, 2022. The Shelby tube samples were extracted on April 11, 2022 at the ENG-TECH laboratory. The soil sample was prepared for testing in accordance with ASTM D5084-16a, *Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials using a Flexible Wall Permeameter*.

One (1) hydraulic conductivity test was performed on the sample from TH1 3'-5'. The final hydraulic conductivity value (k_{20}) of this sample was 6.0×10^{-9} cm/sec. The hydraulic conductivity test data is summarized in Table 1, while the graphical representation of the hydraulic conductivity versus elapsed time is shown in Charts 1. Photographs of the sample are attached.

ENG-TECH trusts this is all the information you require. If you have any questions or require additional information, please contact the undersigned.

Sincerely,
ENG-TECH Consulting Limited

[redacted]

Walter Holowka, C.E.T., N.C.S.O.
Senior Geoenvironmental Technologist

[redacted]

Clark Hryhoruk, M.Sc., P.Eng.
Principal

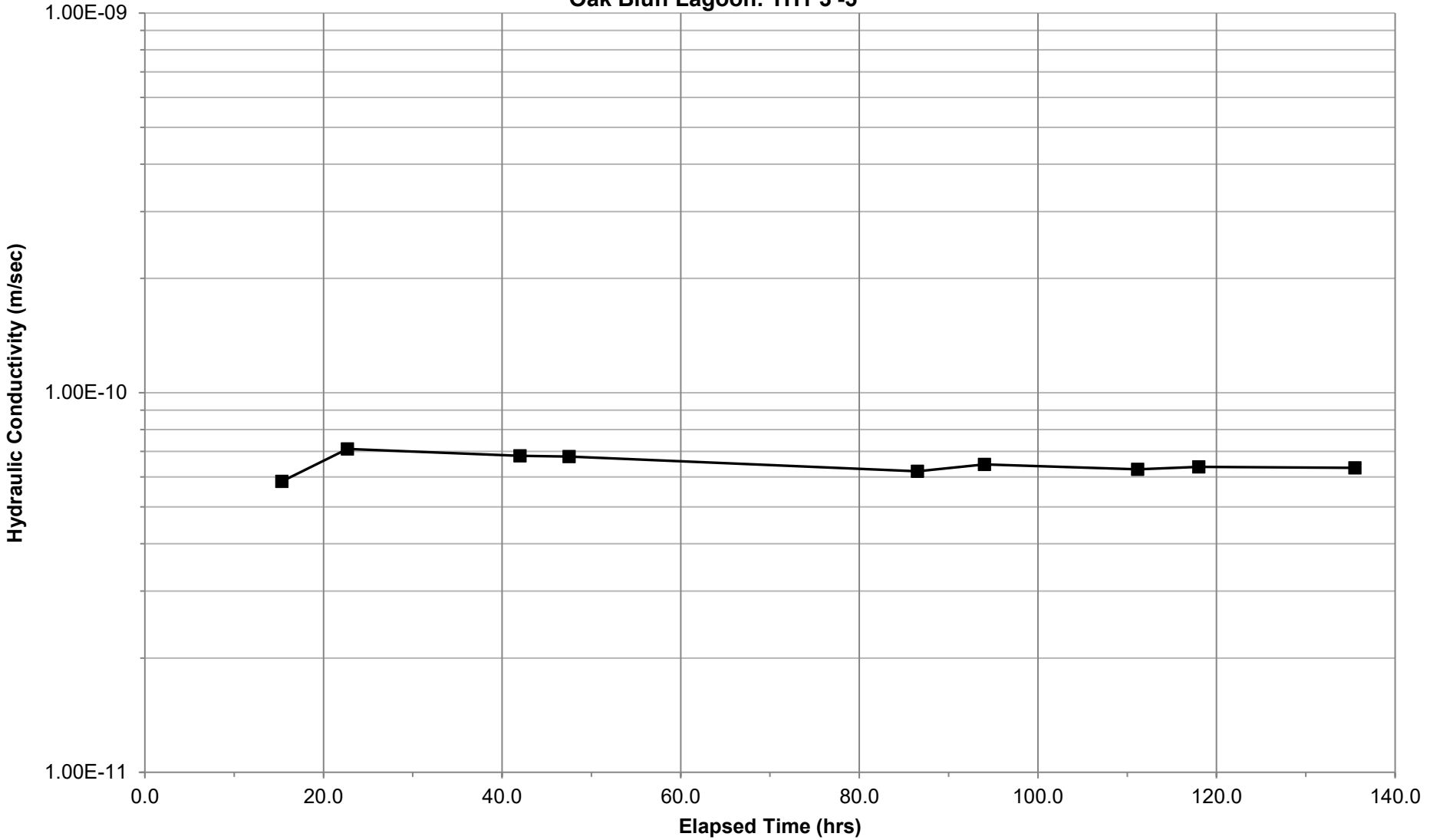
CDH/wgh

Attachments
Table 1 – Hydraulic Conductivity Test Data Oak Bluff Lagoon
Chart 1 – Hydraulic Conductivity versus Elapsed Time Oak Bluff Lagoon: TH1, 3'-5'
Photographs (1)

TABLE 1 HYDRAULIC CONDUCTIVITY TEST DATA OAK BLUFF LAGOON	
SAMPLE ID	**TH1 3'-5'**
INITIAL VALUES	
ENG-TECH Reference No.	22-35-1-6
Length of Sample in Tube (cm)	~60
Length (cm)	6.01
Diameter (cm)	7.18
Area (cm^2)	40.5
Volume (cm^3)	243.2
Water Content (%)	28.8
Bulk Dry Density (kg/m^3)	1,482
Specific Gravity (G_s) (assumed)	2.7
Void Ratio	0.821
Degree of Saturation (%)	94.7
FINAL VALUES	
Length (cm)	6.13
Diameter (cm)	7.34
Area (cm^2)	42.3
Volume (cm^3)	259.3
Water Content (%)	34.0
Bulk Dry Density (kg/m^3)	1,387
Specific Gravity (G_s) (assumed)	2.7
Void Ratio	0.947
Degree of Saturation (%)	~100
CONSOLIDATION PHASE	
Confining Pressure (kPa)	103.4
Pore Water Pressure (kPa)	82.7
Effective Stress (kPa)	20.7
PERMEATION PHASE	
Confining Pressure (kPa)	103.4
Pore Water Pressure (kPa)	82.7
Effective Stress (kPa)	20.7
Hydraulic Gradient	15.4
Permeant Fluid	Potable Tap Water
HYDRAULIC CONDUCTIVITY AT TEST TEMPERATURE: 22°C (cm/sec)	6.3×10^{-9}
HYDRAULIC CONDUCTIVITY CORRECTED TO: 20°C (cm/sec)	6.0×10^{-9}

ENG-TECH CONSULTING LIMITED

Chart 1: Hydraulic Conductivity Versus Elapsed Time
Oak Bluff Lagoon: TH1 3'-5'



ENG-TECH CONSULTING LIMITED

PHOTOGRAPH #1: TH, 3'-5' after hydraulic conductivity testing.

GEOTECHNICAL REPORT
PROPOSED WWSP FOR RM OF MACDONALD
OAK BLUFF, MANITOBA

Prepared for:

RM of Macdonald

Project No: WE 08 127 00 WE
January, 2009

GENIVAR

600 – 5 DONALD STREET

WINNIPEG, MB R3L 2T4

ENGINEERS, SCIENTISTS & PROJECT MANAGERS

TABLE OF CONTENTS

1.0 INTRODUCTION

The Rural Municipality of Macdonald is located in south central Manitoba and is situated adjacent to the southwestern boundary of Winnipeg, Manitoba's capital city. As part of future development for RM of Macdonald, a geotechnical investigation of the proposed wastewater lagoon expansion site located at sec 17-9-2 EPM was conducted.

This report deals with the site selection of the future wastewater lagoon based on the soil conditions with respect to the recent Environmental Act passed in 1988. Manitoba Conservation's Environmental guidelines now require that the dykes and the bottom of any lagoon be provided with a layer consisting of at least one metre of soil having a permeability of $1x10^{-7}$ cm/s or less or equivalence, i.e. the used of plastic liner.

2.0 BACKGROUND

At present, the RM of Macdonald has an existing wastewater storage pond comprised of one primary cell and one secondary cell located at sec 18-9-2 EPM.

3.0 TOPOGRAPHY

The proposed site is located on an area known as the Red River Plain sub-area. The Red River Plain sub-area is a clay basin, with local flood plains and river levees, which occupies the flat areas in the lower-lying part of the Lake Agassiz basin. The area consists of lacustrine clay and alluvial deposits which range from a few metre to 18m or more in thickness. Limestone bedrock below thick clay and till layers (see the attached nearest well logs of 9-2E and 11-9-2E) underlies much of the surficial deposits between 19.5m and 27m below grade.

4.0 FIELD METHODOLOGY AND TESTING

The subsoils encountered were visually classified to the full extent in the testhole and representative soil samples were recovered at regular depth intervals and some samples were submitted for moisture content, particle size analysis and Atterberg limit tests. Pocket penetrometer tests were conducted on the cohesive soil to determine the approximate unconfined compressive strength and relative density respectively. In addition, two shelby tube soil samples were obtained and tested for hydraulic conductivity test. Any groundwater seepage and sloughing encountered in the testholes were noted.

The field investigation was undertaken on October 22, 2008. A tracked-drill rig was used to drill sixteen testholes between 4.6 and 7.6m depths below grade. The testhole locations are shown on the site plan in Appendix A. Detailed descriptions of the soil profiles in each testhole are shown on the attached logs, TH1 to TH16 in Appendix B. Laboratory test results for moisture contents, Atterberg limit, particle size analysis and hydraulic conductivity are attached in Appendix C.

5.0 SUBSURFACE CONDITIONS

5.1 SOIL PROFILE/GROUNDWATER

The general soil profile reveals a topsoil layer of about 75mm to 300mm followed by a thick clay layer, which extended to the bottom of the testholes at 7.6m below grade. The exception to this soil profile is at TH14 where a silty sand layer was encountered at 0.3 to 1m below grade.

No seepage and caving conditions were observed from the testholes. Detailed description of testholes, TH1 to TH16 are shown in Appendix B, Testhole Logs.

Groundwater

At present, there is a preliminary groundwater report prepared by the Planning Branch of the Water Resources Division on this area. Groundwater is readily available and fresh in

the area east of the Red and Rat Rivers. The main aquifer in the area is the carbonate bedrock (limestone and dolostone) that underlies the whole area but bears freshwater only in the area east of the Red and Rat Rivers; our proposed site is located above the main aquifer area. The depth to the carbonate bedrock ranges from 12m to 40m. Minor shallow sand aquifers were found along the La Salle River meander belt and along one of its tributaries near Starbuck. The well yields of the main aquifer are adequate for moderate industrial and municipal requirements and groundwater quality ranges from fair to excellent.

A review of the Groundwater Pollution Hazard Map shows that the property is located outside a groundwater pollution hazard area.

Based on the drainage map of the area, groundwater flow at the site is immediately towards the south and eventually heading to La Salle River.

5.2 LABORATORY TESTING

In the laboratory, selected samples as shown in Appendix C were submitted for moisture contents, Atterberg limit and hydrometer test for classification and hydraulic conductivity. The test results are shown in Appendix C.

As classified during our field investigation, the clay layer encountered at the site is heavily fractured beneath the topsoil layer down to at least 2m below grade; the average depth of the clay with less fracture is about 1.5m below grade. Due to these reasons, hydraulic conductivity of the in-situ clay at about 1.5m was tested.

With the exception of TH14, the clay material of the upper 1.5m depths is a CH material based on Atterberg limit and particle size analysis tests. The estimated hydraulic conductivity of this material should range between 10^{-8} to 10^{-9} cm/sec.

The hydraulic conductivity of the in-situ clay obtained at 1.5m-2.1m depth for TH3 and TH8 were 5.6 $x10^{-9}$ and 6.2 x 10^{-9} cm/sec, respectively.

6.0 DESIGN CONSIDERATIONS

Design guidelines for a wastewater stabilization pond are shown below in Table 1.

TABLE 1: Minimum Requirements

WWSP Facility	Minimum Requirements	Design Compliance
Center of Population	450 metres	yes
Individual Residences	300 metres	yes
Organic Loading	56 kg/hectare/day	yes
Hydraulic Loading	Nov.1 to June 15	yes
Surface Runoff	some	Perimeter Ditching to be installed
Liner Material	1 metre thick of clay liner	In-situ clay is available; "Testing will be required after construction"
Zoning Requirements	Proximity to Property Lines: 30m	yes

For detailed comparisons, the proposed WWSP will be designed in accordance with the Province of Manitoba Design Objectives for Standard Sewage Lagoons (1985).

The proposed cells will contain a liquid depth of 1.5m and 1m freeboard to minimize the effects of wave action and provide stability. The inside and outside side slopes of the dykes will be 4:1. The top of the dykes will be designed to be 3m wide to permit vehicles to be driven on the dyke crest.

For lagoon construction, Manitoba Conservation's Environmental guidelines require that the proposed dykes and bottom of the proposed cells be provided with a layer consisting of at least one metre of soil having a permeability of less than $1x10^{-7}$ cm/s. The proposed pond site consists mainly of an area where clay is present.

The selected area, unfortunately, consists mainly of upper CH clay with fracture structure, which may not meet the specified hydraulic conductivity of 1x10-7 cm/s. Beneath the

fractured clay is high plasticity clay down to 7.6m below grade and which achieved a hydraulic conductivity test result of less than $1.0x10^{-7}$ cm/s, thus meeting the guidelines.

Based on our field investigation, well logs from Manitoba Water Well reports and laboratory analysis, the proposed pond liner (base and interior) for this site should be constructed with a clay core within the proposed dykes. This would involve excavating a trench approximately two metres wide (minimum) around the inside perimeter of the bottom of the proposed pond and keying into the underlying impervious high plastic clay to an approximate depth between 1.5 and 2.1m below ground surface. The trench will be backfilled with impervious clay in 150mm lifts compacted to at least eight passes with a sheepsfoot roller.

During construction of the proposed cells, the following steps should be followed.

1. The entire area for the proposed pond should be stripped of vegetation, topsoil and organic material; the depth of stripping is approximately 75 to 300mm. The stripped materials should be stockpiled and reused later for the outer slopes and top of the dykes.

2. Layout the proposed pond to the dimensions indicated in the design drawings.

3. For the proposed bottom and interior dykes, the liner and the key should be compacted to 95% standard Proctor density at ±2 to 3% of optimum moisture content with a sheepsfoot roller. Any unsuitable material such as sand or high percentage silt materials should be removed and replaced with the recommended liner and compacted to 95% standard Proctor density. Ensure that the inside liner consists of at least one metre width of impervious clay compacted to at least a minimum of 95% standard Proctor maximum density in 150 to 200mm lifts. A shrinkage factor of about 25% should be used in calculating volumes of material to be used.

4. The unsuitable material can be used as backfill on the outside face of the dykes. The embankment material should be placed in 150mm lifts compacted with at least eight passes with a sheepsfoot roller having a foot pressure of no less than 700 kPa.

Due to large size of the cells, further erosion control against wind and rain action should be provided by riprap placement on the dykes immediately after construction. A well-developed and maintained grass cover below the riprap should add integrity to the dykes.

The entire completed pond system should be fenced to keep people, children in particular away from the pond. All gates should be locked to prevent access.

Appropriate warning signs should be provided on the fence around the pond, to designate the nature of the facility, and advise against trespassing.

We recommend that a minimum distance of 5 meters be maintained between the outside toe of the embankment and the fence.

7.0 ADDITIONAL CONSIDERATIONS

On the basis of the soil conditions encountered during drilling (i.e. mainly a brown clay subgrade), the recommended road pavement construction at this site should be as follows:

Pavement Thicknesses

	Truck Route	% Compaction
Base Coarse	150 mm	100% Std Proctor
Subbase	225 mm	100% Std Proctor

The above pavement sections should be constructed on a prepared stiff clay subgrade, which should be free of any fibrous organics, softened and disturbed soils. The average depth of site stripping is about 75 to 300mm below ground surface. The prepared

subgrade should be proof rolled with a heavy sheepsfoot roller (min. 20 passes) which translates to at least 95% Std Proctor and inspected by a qualified geotechnical engineer prior to the placement of the overlying granular fill.

The granular base course and subbase materials should include organic-free, non-frozen, aggregate conforming to the Manitoba Highway gradation limits.

Where soft spots are encountered at the subgrade level, construction traffic should be restricted. Soft spots should be excavated with a large backhoe fitted with a smooth bucket, to at least 300mm below the underside of the subbase and replaced with a 300mm thick layer of 100mm down crushed aggregate/limestone. In this regard, the total granular fill thickness would be 675mm for truck access.

Sieve analysis and compaction testing of the granular base and subbase materials should be conducted by qualified geotechnical personnel to ensure that the materials supplied and percent compactions are in accordance with design specifications.

8.0 STANDARD LIMITATIONS

The factual data, interpretations and recommendations contained in this report pertain to the specific project as described in this report and are not applicable to any other project, site location or party. The comments given in this report are intended only for the guidance of the design engineer. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual test data, as to how subsurface conditions may affect their work.

Soil descriptions in this report are based on commonly accepted methods of classification and identification employed in professional geotechnical practice. Classification and identification of soil involves judgement and GENIVAR does not guarantee descriptions as exact, but infers accuracy only to the extent that is common in current geotechnical practice.

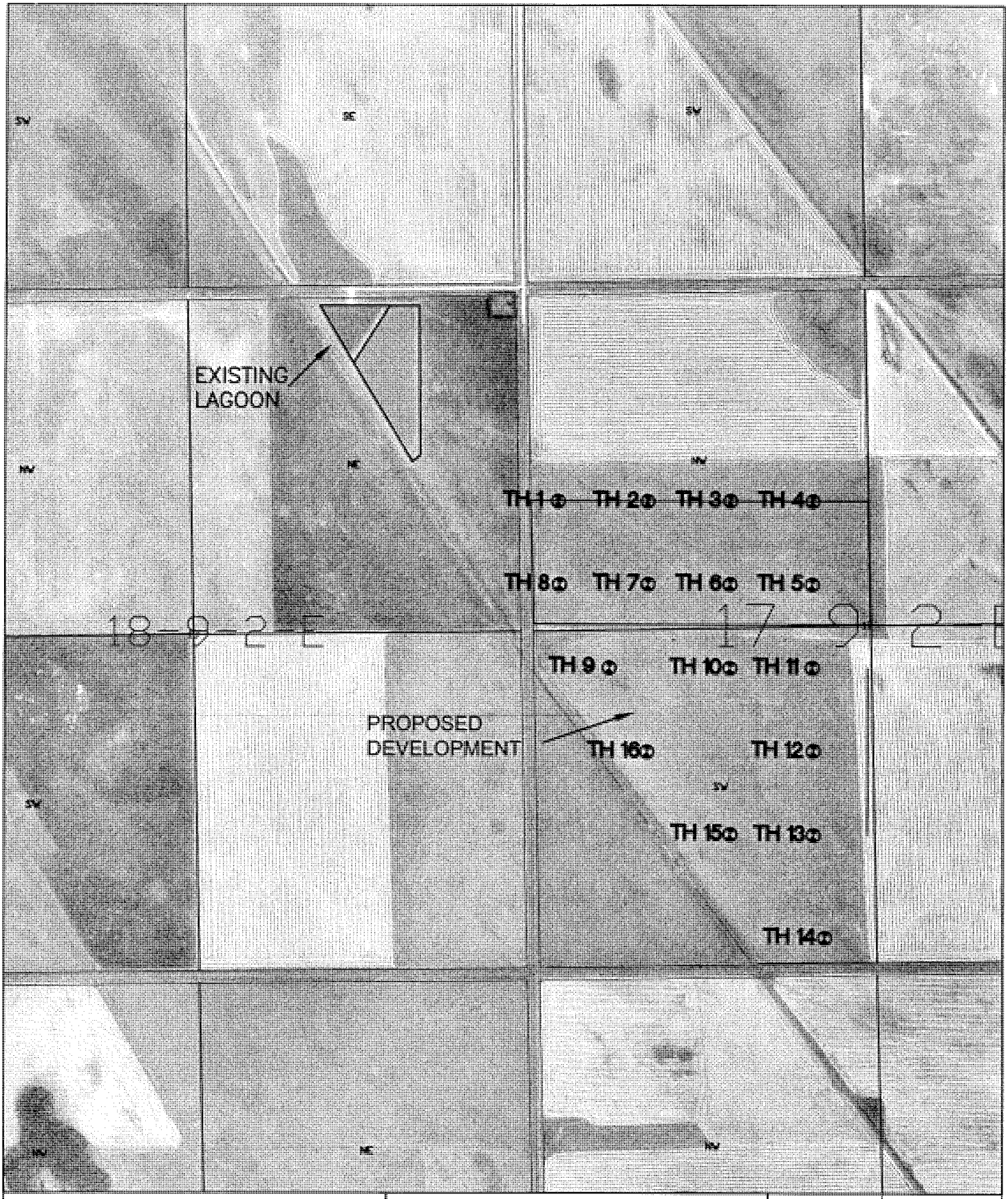
Soil formations are variable to a greater or lesser extent. The testpit logs indicate the approximate subsurface conditions only at the locations of the testpit. Boundaries between zones on the logs are often not distinct, but rather transitional, and have been interpreted. Subsurface conditions between test holes are inferred and may vary significantly from conditions encountered at the testpit.

Where conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the use, or reliance by the client, of this report that GENIVAR is notified of the changes and provided with an opportunity to review the recommendations of this report.

Prepared by: S.S. Urbano Jr., P. Eng.
Reviewed by: Ross Webster, P.Eng.

APPENDIX A

SITE PLAN



GENIVAR
600 - 5 DONALD STREET
WINNIPEG, MB R3L 2T4
Tel: (204)477-6650
Fax: (204)474-2864

OAK BLUFF LAGOON

TESTHOLE LOCATION PLAN

DATE: (YYMMDD)	08/12/19
APPROVED:	
DRAWN BY:	LC
PROJ. NO. WED912700	DWG. NO.

ACAD No. 0812700

APPENDIX B

TESTHOLE LOGS and WELL LOGS

GENIVAR

Project No: WE-08-127-00-WE

TH1

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 100 mm thick, loose, grey-black			
		CLAY grey-black, stiff, fissured; brown at 0.8m, trace of sulphate inclusions; fractured at 0.8m to 1m; cohesive clay beyond 1m; trace of fine gravel below 3.4m, grey-brown			150
10 / 3					75
15 / 4			95.4		50
		End of Testhole			

50 100 150 200 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH2

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 178mm thick, loose, grey-black, trace of rootlets	99.8		
		CLAY grey-black, stiff, fissured; brown at 0.5m, fractured down to 1.2m, stiff, fissured; trace of silt and sulphate inclusions below 1.5m			150
					75
			95.4		50
15 / 4		End of Testhole			

50 100 150 200 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH3

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 125mm thick, loose, grey-black, trace of rootlets			
		CLAY grey-black, stiff, fissured, fractured down to 1.4m; brown at 0.9m, stiff, fissured; trace of silt inclusions below 1.5m; TESTHOLE WAS DRY AFTER COMPLETION OF DRILLING			150
					75
			95.4		50
15 / 4		End of Testhole			

50 100 150 200 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH4

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL	99.8		
		152mm thick, loose, grey-black, trace of rootlets			
		CLAY grey-black to 0.6m, fractured down to 1.5m, stiff; fissured; brown at 0.6m; trace of silt inclusions and sulphate below 1.8m			200
					85
			95.4		75
15 / 4		End of Testhole			

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH5

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 100mm thick, loose, grey-black, trace of rootlets			
		CLAY grey-black, fractured down to 1.2m, stiff; brown at 64mm, stiff, fissured; trace of sulphate at 2.3m to 3.8m			
15 / 4.6			95.4		
		End of Testhole			

Pocket Penetrometer/ Field Vane (kPa): 50 100 150 200 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH6

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 250mm thick, loose, grey-black, trace of rootlets	99.7		
		CLAY brown, stiff, fissured, fractured down to 0.9m; trace of silt inclusions below 3m; TESTHOLE WAS DRY AFTER COMPLETION OF DRILLING			150 at 2.5m; 150 at 5m; 100 at 10m; 75 at 15m
15 / 4.6			95.4		
		End of Testhole			

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH7

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
ft / m		Ground Surface	100		50 100 150 200 250
0 / 0		*TOPSOIL* 100mm thick, loose, grey-black, trace of rootlets			
7 / 2		*CLAY* stiff, fractured down to 1.5m; grey-black; brown at 0.8m; trace of silt inclusions at 2.3m; trace of sulphate inclusions below 3m			
15 / 4		End of Testhole	95.4		

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH8

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 150mm thick, loose, grey-black, trace of rootlets			
		CLAY grey-black, stiff, fissured, fractured down to 1.5m; brown at 0.8m; trace of silt and sulphate inclusions below 1.5m; grey at 7m; TESTHOLE SQUEEZED IN AT 7M AND DRY AFTER COMPLETION OF DRILLING			250 at 1.5m; 75 at 3m; 50 at 4.5m; 50 at 6m
25 / 7.6		End of Testhole	92.4		50 at 7.6m

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH9

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 75mm thick, loose, grey-black, trace of rootlets			
		CLAY olive-grey, stiff, fissured, fractured down to 1.4m; brown at 1.4m; trace of sulphate and silt inclusions at 1.8m; TESTHOLE WAS DRY AFTER COMPLETION OF DRILLING			
15 / 4			95.4		
		End of Testhole			

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

100

75

100

150

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH10

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 305mm thick, loose, grey-black, trace of rootlets	99.7		
		CLAY olive-grey, stiff, fractured down to 1.8m; brown at 0.8m; trace of sulphates below 3m			85
			95.4		75
15		End of Testhole			

50 100 150 200 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH11

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 203mm thick, loose, grey-black, trace of rootlets	99.8		
		CLAY grey-black to 0.9m, stiff, fissured; fractured down to 1.4m; brown at 1m; trace of silt and sulphate inclusion below 2.3m			
15 / 4		End of Testhole	95.4		

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

150

225

75

65

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH12

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth ft	Depth m	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa) 50 100 150 200 250
0	0		Ground Surface	100		
			TOPSOIL 127mm thick, loose, grey-black, trace of rootlets			
1						
2						
3	1					
4						
5						
6						
7	2		*CLAY* grey-black to 0.9m, stiff, fissured; fractured down to 1.8m; brown at 0.9m; trace of sulphates below 1.5m			
8						
9						
10	3					
11						
12						
13	4					
14						
15				95.4		
			End of Testhole			
16						

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH13

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 230mm thick, loose, grey-black, trace of rootlets			
		CLAY grey-black, stiff, fissured, fractured down to 1.5m; brown at 0.8m; trace of sulphates between 3m to 4.6m; grey at 7.3m; TESTHOLE SQUEEZED IN AT 7.3M AND DRY AFTER COMPLETION OF DRILLING.			
25 / 7.6		End of Testhole	92.4		

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

200
150
100
75
75
50

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH14

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth (ft / m)	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0 / 0		Ground Surface	100		
		TOPSOIL 127mm thick, loose, grey-black, trace of rootlets	99.7		
1		*CLAY* grey-black to 0.3m, stiff, fissured			
2		*SAND* silty, fine grained, tan-brown, dry	98.9		
3 / 1					
4					
5					200
6					
2					
7					
8					
9		*CLAY* stiff, brown, fissured; NOT FRACTURED			
10 / 3					100
11					
12					
13 / 4					
14					
15			95.4		100
		End of Testhole			
16					

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH15

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth ft	Depth m	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
0	0		Ground Surface	100		
			TOPSOIL			
			229mm thick, loose, grey-black, trace of rootlets	99.8		
1						
2						
3	1					
4						
5						
6						
7	2		*CLAY*			
8			olive-grey, stiff, fractured down to 2m; trace of sulphate at 0.6m to 1.2m; brown at 1.2m			
9						
10	3					75
11						
12						
13	4					
14						
15				95.4		75
			End of Testhole			
16						

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

GENIVAR

Project No: WE-08-127-00-WE

TH16

Project: RM of Macdonald WWSP Expansion

Client: RM of Macdonald

Logged: AO

Location: Oak Bluff

Engineer: S.S.U

Depth	Symbol	Description	Elevation(m)	SPT(blows/0.3m)	Pocket Penetrometer/ Field Vane (kPa)
ft / m		Ground Surface	100		
0 / 0		*TOPSOIL* 203mm thick, loose, grey-black, trace of rootlets	99.8		
		CLAY olive-grey, stiff, fissured; fractured from 1m to 1.37m; brown at 0.9m; trace of silt inclusions			
			95.4		
		End of Testhole			

Pocket Penetrometer/ Field Vane (kPa): 50, 100, 150, 200, 250

125

125

100

100

Drill Method: Truck Mounted Auger

Drill Date: 10/22/08

Hole Size: 125 mm

GENIVAR
#600-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

Elevation: Assumed 100m

Checked by: S.S.U.

LOCATION: 9-2E

Owner: C MUYS
Driller: MONDOR, L. E.
Well Name:
Well Use: PRODUCTION
Water Use: Domestic
Date Completed: 1971 Oct 09

WELL LOG

From (ft.)	To (ft.)	Log
0	29.0	CLAY
29.0	51.0	HARDPAN
51.0	64.0	SAND
64.0	103.9	LIMESTONE, SALTY WATER

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	64.0	casing	5.00			
64.0	103.9	open hole				

Top of Casing: ft. below ground

PUMPING TEST

Date: 1971 Oct 09
Pumping Rate: 12.0 Imp. gallons/minute
Water level before pumping: 37.0 ft. below ground
Pumping level at end of test: 39.0 ft. below ground
Test duration: 1 hours, 30 minutes
Water temperature: ?? degrees F

REMARKS

500 FT W OF LA SALLE RD, S OF HWY #100, N OF HWYS #2 + 3

LOCATION: SW11-9-2E

Owner: R GOUSSEAU
Driller: Paul Slusarchuk Well Drilling LTd.
Well Name:
Well Use: PRODUCTION
Water Use: Livestock
Date Completed: 1981 Jul 15

WELL LOG

From (ft.)	To (ft.)	Log
0	35.0	CLAY
35.0	88.9	TILL
88.9	90.9	BROKEN LIMESTONE

90.9 144.9 LIMESTONE SALT WATER

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	90.9	casing	5.00			T & C GALVANIZED
90.9	144.9	open hole	4.90			

Top of Casing: 1.5 ft. above ground

PUMPING TEST

Date: 1981 Jul 15
Pumping Rate: 30.0 Imp. gallons/minute
Water level before pumping: 26.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: 1 hours, 15 minutes
Water temperature: ?? degrees F

LOCATION: 20-9-2E

Owner: WM WASTLE
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: PRODUCTION
Water Use: Domestic
Date Completed: 1911 May 20

WELL LOG

From (ft.)	To (ft.)	Log
0	20.0	CLAY
20.0	41.0	CLAY AND HARDPAN
41.0	52.0	GRAVEL, WATER

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	50.0	casing	6.00			

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: Imp. gallons/minute
Water level before pumping: 25.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

GROUND LEVEL ELEV EST 775 FT

LOCATION: NW20-9-2E

Owner: G P WASTLE
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: TEST WELL
Water Use:
Date Completed: 1911 Jun 08

WELL LOG

From (ft.)	To (ft.)	Log
0	10.0	CLAY
10.0	45.0	SAND
45.0	203.9	ROCK, POOR WATER

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	87.9	casing	6.00			
87.9	203.9	open hole				

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: Imp. gallons/minute
Water level before pumping: 100.9 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: hours, minutes
Water temperature: ?? degrees F

REMARKS

GROUND LEVEL ELEV EST 775 FT

LOCATION: 21-9-2E

Owner: UNKNOWN
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: PRODUCTION
Water Use: Domestic
Date Completed: 1903 Apr 28

WELL LOG

From	To	Log

From (ft.)	To (ft.)	Log
0	24.0	CLAY
24.0	45.0	HARDPAN
45.0	56.0	ROCK, LIMESTONE, WATER

No construction data for this well.

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: Imp. gallons/minute
Water level before pumping: 24.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

WELL DRILLED BETWEEN 1903-1920, GROUND LEVEL ELEV EST 775 FT

LOCATION: 21-9-2E

Owner: C MATTHEWS
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: TEST WELL
Water Use:
Date Completed: 1911 May 08

WELL LOG

From (ft.)	To (ft.)	Log
0	25.0	CLAY
25.0	50.0	CLAY AND SAND
50.0	109.9	SAND, POOR WATER

No construction data for this well.

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: Imp. gallons/minute
Water level before pumping: 56.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

GROUND LEVEL ELEV EST 775 FT

LOCATION: 22-9-2E

Owner: GREATER WPG GAS CO
Driller: APEX WELL DRILLING LTD.
Well Name:
Well Use: PRODUCTION
Water Use: Industrial
Date Completed: 1974 Jun 28

WELL LOG

From (ft.)	To (ft.)	Log
0	28.0	CLAY
28.0	34.0	CLAY AND PEBBLES
34.0	64.0	CLAY AND GRAVEL TILL
64.0	71.5	WEATHERED ROCK FORMATION
71.5	170.4	ROCK FORMATION- CAVING CONDITIONS WATER SALTY CLAY LAYERS BETWEEN 102 AND 103.5 FEET AND 113 AND 114 FEET

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type	Material
0	71.5	casing	12.00			T & C	BLACK IRON
71.5	170.4	open hole	12.00				

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: 33.2 Imp. gallons/minute
Water level before pumping: 18.0 ft. below ground
Pumping level at end of test: 65.0 ft. below ground
Test duration: 54 hours, 40 minutes
Water temperature: ?? degrees F

LOCATION: SE23-9-2E

Owner: NICK ROEBUCK
Driller: Ford Drilling Ltd.
Well Name:
Well Use: PRODUCTION
Water Use: Domestic
Date Completed: 1999 Sep 28

WELL LOG

From (ft.)	To (ft.)	Log
0	6.0	CLAY
6.0	118.0	TILL
118.0	127.0	LIMESTONE WITH BROKEN LAYERS AND SAND
127.0	185.0	LIMESTONE

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	129.0	CASING	5.25			GALVANIZED
129.0	185.0	OPEN HOLE		4.50		

Top of Casing: 2.0 ft. above ground

PUMPING TEST

Date: 1999 Sep 28
Pumping Rate: 20.0 Imp. gallons/minute
Water level before pumping: 87.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

NORTH OF HOTEL IN FRASERWOOD.

88.9 101.9 SANDSTONE, SAND, WATER

No construction data for this well.

Top of Casing: ft. below ground

PUMPING TEST

Date:
Pumping Rate: Imp. gallons/minute
Water level before pumping: 37.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

GROUND LEVEL ELEV EST 780 FT

LOCATION: 32-9-2E

Owner: A STEPHENSTON
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: TEST WELL
Water Use:
Date Completed: 1903 Oct 23

WELL LOG

From (ft.)	To (ft.)	Log
0	15.0	CLAY
15.0	25.0	CLAY AND LIMESTONE
25.0	55.0	LIMESTONE

No construction data for this well.

Top of Casing: ft. below ground

No pump test data for this well.

REMARKS

GROUND LEVEL ELEV EST 780 FT

LOCATION: NE32-9-2E

Owner: BOSSUYT BROS
Driller: Friesen Drillers Ltd.
Well Name:
Well Use: PRODUCTION
Water Use: Domestic,Livestock
Date Completed: 1980 Aug 11

LOCATION: SE30-9-2E

Owner: WRB
Driller: PRUDEN DRILLING CO. LTD.
Well Name: G05OG003 M0-5
Well Use: OBSERVATION
Water Use:
Date Completed: 1966 Feb 05

WELL LOG

From (ft.)	To (ft.)	Log
0	24.0	CLAY
24.0	82.9	TILL
82.9	95.9	SHALE
95.9	145.9	BEDROCK

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type Material
0	96.9	casing	5.00			IRON
96.9	145.9	open hole	5.00			

Top of Casing: 1.0 ft. above ground

PUMPING TEST

Date:
Pumping Rate: ?? Imp. gallons/minute
Water level before pumping: 30.0 ft. below ground
Pumping level at end of test: ?? ft. below ground
Test duration: ??? hours, ?? minutes
Water temperature: ?? degrees F

REMARKS

109 FT W OF N/S RD, 52 FT N OF FRONTAGE RD, S OF HWY 100 CHEMICAL ANALYSIS, GROUND LEVEL ELEV MEASURED 236.906 M

LOCATION: 32-9-2E

Owner: A STEPHENSON
Driller: MANITOBA GOVERNMENT
Well Name:
Well Use: PRODUCTION
Water Use: Domestic
Date Completed: 1903 Oct 28

WELL LOG

From (ft.)	To (ft.)	Log
0	30.0	CLAY
30.0	45.0	CLAY AND LIMESTONE
45.0	88.9	LIMESTONE

WELL LOG

From (ft.)	To (ft.)	Log
0	15.0	CLAY
15.0	45.0	TILL, BROWN
45.0	99.9	SANDY TILL
99.9	133.9	BROWN TILL
133.9	189.9	LIMESTONE, SLIGHTLY SALTY

WELL CONSTRUCTION

From (ft.)	To (ft.)	Casing Type	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type	Material
0	134.9	casing	5.25	5.50		INSERT	BLACK IRON
134.9	189.9	open hole		5.00			

Top of Casing: 2.0 ft. below ground

PUMPING TEST

Date: 1980 Aug 11
Pumping Rate: 30.0 Imp. gallons/minute
Water level before pumping: 35.0 ft. below ground
Pumping level at end of test: 50.0 ft. below ground
Test duration: 2 hours, minutes
Water temperature: ?? degrees F

APPENDIX C

LABORATORY TEST RESULTS

THE
NATIONAL
TESTING
LABORATORIES
LIMITED
Established in 1923

199 Henlow Bay
Winnipeg, MB R3Y 1G4
Phone (204) 488-6999
Fax (204) 488-6947
Email info@nationaltestlabs.com
www.nationaltestlabs.com

GENIVAR
600 - 5 Donald Street
Winnipeg, Manitoba
R3L 2T4

November 24, 2008

Project: RM of Macdonald
WWSP Expansion

Attention: Silvestre Urbano

Soil samples were submitted to our laboratory on October 23, 2008. The following tests were conducted on selected soil samples:

- liquid limit (one-point), plastic limit, and plasticity index (ASTM D4318)
- particle size analysis (ASTM D422)
- water content (ASTM D2216)
- hydraulic conductivity (ASTM D5084)

The test results are provided in the following tables and on the attached Particle Size Analysis and Hydraulic Conductivity reports.

We appreciate the opportunity to assist you in this project. Please call me if you have any questions regarding this report.

[redacted]

Kurtis Kulchyski
Senior Geotechnical Technologist

TABLE 1
RM OF MACDONALD WWSP EXPANSION
PLASTICITY INDEX TEST DATA

Sample Identification	Liquid Limit	Plastic Limit	Plasticity Index	% Retained on 0.425 mm Sieve
TH8 @ 1'	94	23	71	<1%
TH3 @ 2.5'-5' (mixture)	91	25	66	<1%

Notes
1. Test conducted in accordance with ASTM D4318 Method B (one-point liquid limit)
2. The soil samples were air-dried during sample preparation

TABLE 2
RM OF MACDONALD WWSP EXPANSION
PARTICLE SIZE ANALYSIS TEST DATA

Sample Identification	Gravel, % 75 to 4.75 mm	Sand, %			Silt, % <0.075 to 0.005 mm	Clay, % <0.005 mm	Colloids,% <0.001 mm
		Coarse <4.75 to 2.0 mm	Medium <2.0 to 0.425 mm	Fine <0.425 to 0.075 mm			
TH8 @ 5'	0.0	0.0	0.3	0.3	7.0	92.4	76.2

Notes:
1. A high speed stirring device was used for 1 minute to disperse the test sample.
2. Sample was air-dried during preparation.
3. The percentage of colloids is also included in the clay size fraction.

TABLE 3
RM OF MACDONALD WWSP EXPANSION
WATER CONTENT TEST DATA

Sample Identification	Water Content, %	Sample Identification	Water Content, %	Sample Identification	Water Content, %	Sample Identification	Water Content, %
TH3- 2.5'	28.6	TH8-1'	30.7	TH8-20'	54.0	TH13-10'	47.4
TH3-5'	36.9	TH8-5'	35.3	TH8-25'	55.8	TH13-15'	42.0
TH3-10'	49.0	TH8-10'	55.7	TH13-2.5'	33.9	TH13-20'	36.7
TH3-15'	49.5	TH8-15'	54.7	TH13-5'	33.5	TH15-25'	44.9

TABLE 4
RM OF MACDONALD WWSP EXPANSION
HYDRAULIC CONDUCTIVITY TEST DATA

Sample ID	Hydraulic Conductivity "k_{20}"
TH3 @ 5'-7'	5.6×10^{-9} cm/s
TH8 @ 5'-7'	6.2×10^{-9} cm/s

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923

PARTICLE SIZE ANALYSIS
ASTM D422

GENIVAR
#600 - 5 Donald Street.
Winnipeg, Manitoba
R3L 2T4

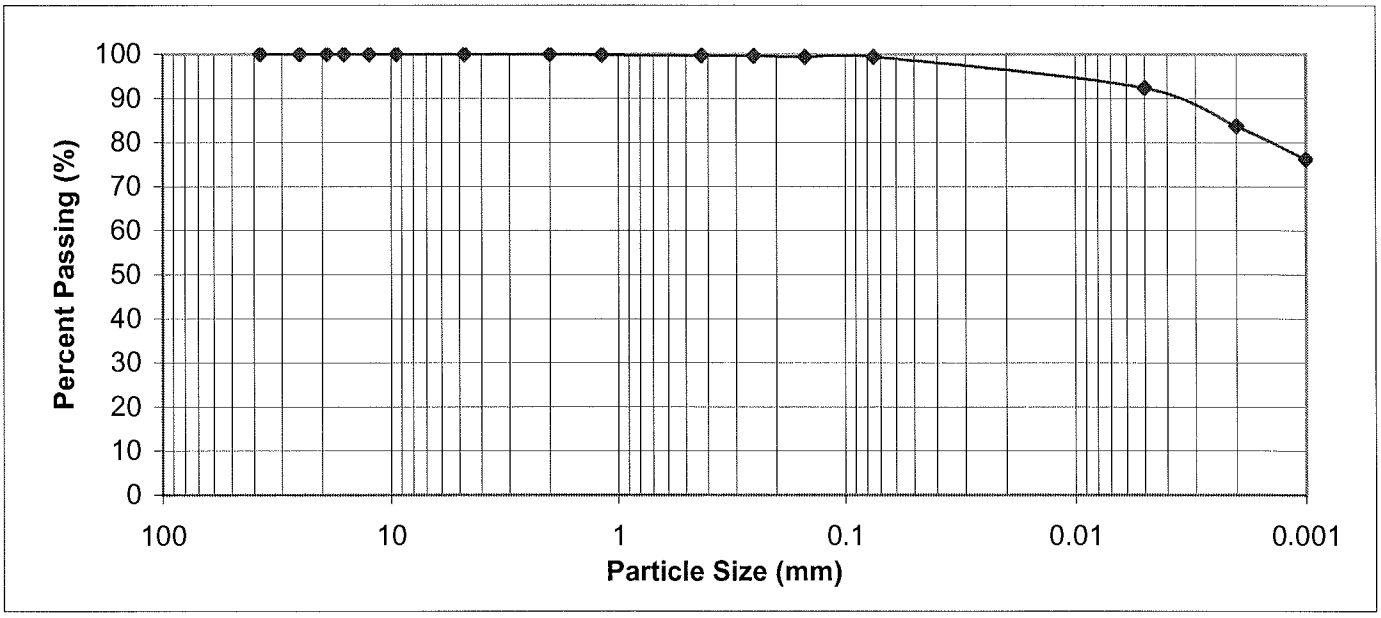
PROJECT: RM of Macdonald
WWSP Expansion

Attention: Silvestre Urbano

PROJECT NO.: GEN-831

SAMPLED BY: Client
SAMPLE ID: TH8 @ 5'

DATE RECEIVED: October 23, 2008
TESTED BY: Kurtis Kulchyski



PARTICLE SIZE	PERCENT PASSING
37.50 mm	100.0
25.00 mm	100.0
19.00 mm	100.0
16.00 mm	100.0
12.50 mm	100.0
9.50 mm	100.0
4.75 mm	100.0
2.00 mm	100.0

PARTICLE SIZE	PERCENT PASSING
1.18 mm	99.9
0.425 mm	99.7
0.250 mm	99.6
0.150 mm	99.4
0.075 mm	99.4
0.005 mm	92.4
0.002 mm	83.7
0.001 mm	76.2

Gravel, % 75 to 4.75 mm	Sand, %			Silt, % <0.075 to 0.005 mm	Clay, % <0.005 mm	Colloids, % < 0.001 mm
	Coarse <4.75 to 2.0 mm	Medium <2.0 to 0.425 mm	Fine <0.425 to 0.075 mm			
0.0	0.0	0.3	0.3	7.0	92.4	76.2

November 19, 2008

REVIEWED BY: Kurtis Kulchyski

199 Henlow Bay, Winnipeg, Manitoba R3Y 1G4 Phone (204) 488-6999 Fax (204) 488-6947 Email info@nationaltestlabs.com

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923

HYDRAULIC CONDUCTIVITY
ASTM D5084

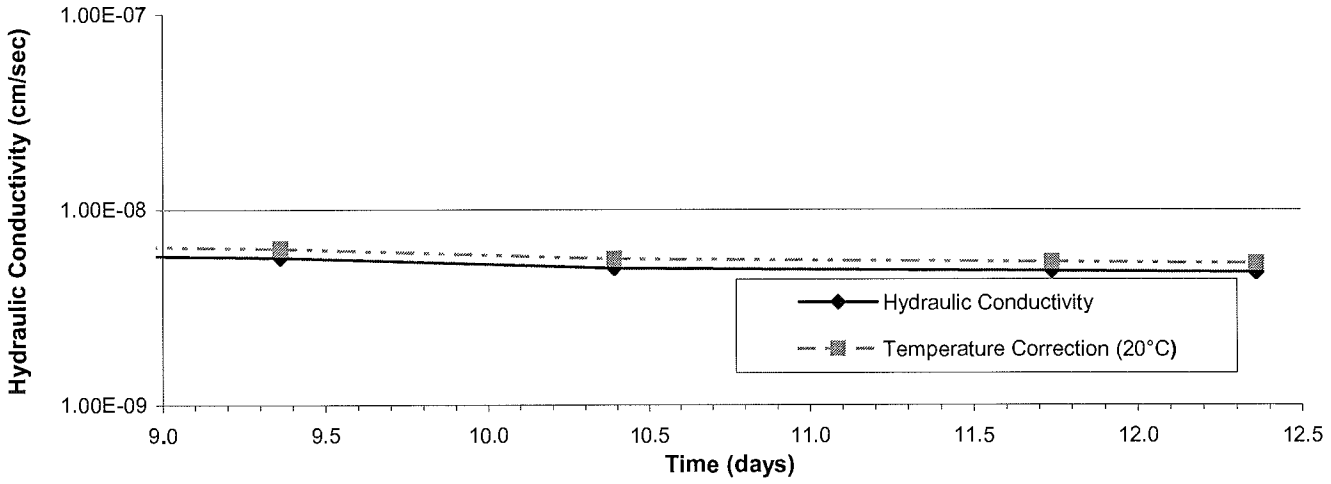
GENIVAR
#600 - 5 Donald St.
Winnipeg, MB
R3L 2T4

PROJECT: RM of Macdonald WWSP Expansion

Attention: Silvestre Urbano

SAMPLE I.D.:	**TH3 5-7'**
SOIL TYPE:	Brown, stiff, moist, high plastic clay, with fine gravel and gypsum inclusions
DATE TESTED:	October 29th to November 10th, 2008
CONFINING PRESSURE (kPa):	137.9
EFFECTIVE SATURATION STRESS (kPa):	34.5
HYDRAULIC GRADIENT:	18.5
TYPE OF PERMEANT LIQUID:	De-aired Water
HYDRAULIC CONDUCTIVITY, "k" (cm/s):	5.1E-09
HYDRAULIC CONDUCTIVITY, "k_{20}" (cm/s):	**5.6E-09**

	Height (mm)	Diameter (mm)	Wet Mass (gm)	Dry Density (gm/cm^3)	Water Content (%)	Saturation (%)
Initial Reading	77.9	71.8	560.2	1.268	40.3	94.7
Final Reading	80.2	72.4	576.5	1.195	46.1	97.4



November 19, 2008

REVIEWED BY: Kurtis Kulchyski

199 Henlow Bay, Winnipeg, Manitoba R3Y 1G4 Phone (204) 488-6999 Fax (204) 488-6947 Email info@nationaltestlabs.com

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923

HYDRAULIC CONDUCTIVITY
ASTM D5084

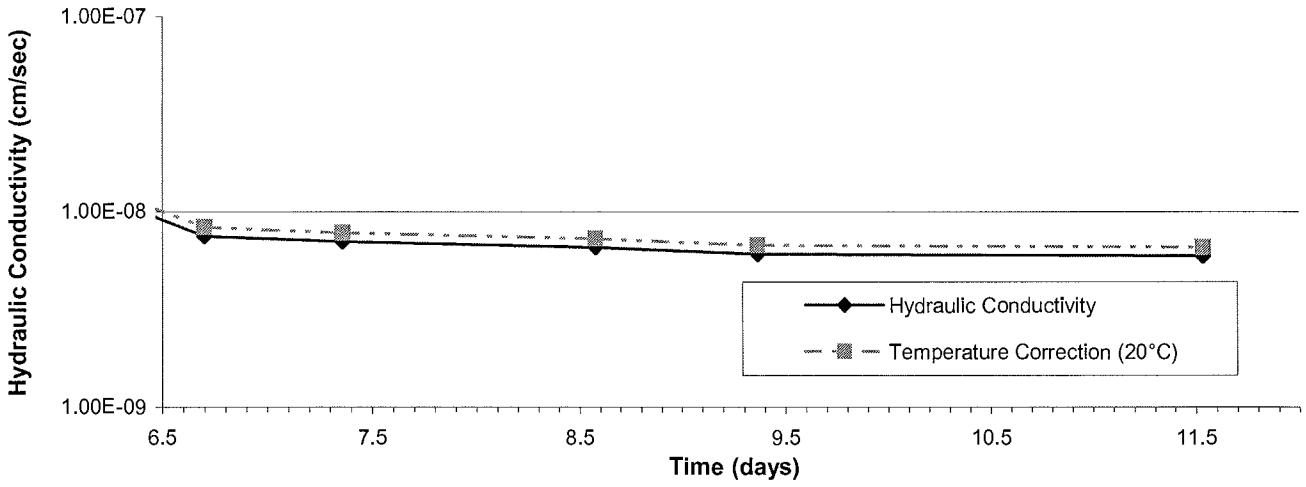
GENIVAR
#600 - 5 Donald St.
Winnipeg, MB
R3L 2T4

PROJECT: RM of Macdonald WWSP Expansion

Attention: Silvestre Urbano

SAMPLE I.D.:	**TH8 5-7'**
SOIL TYPE:	Brown, soft, moist, high plastic clay, with fine gravel and gypsum inclusions
DATE TESTED:	October 29th to November 10th, 2008
CONFINING PRESSURE (kPa):	137.9
EFFECTIVE SATURATION STRESS (kPa):	34.5
HYDRAULIC GRADIENT:	19.8
TYPE OF PERMEANT LIQUID:	De-aired Water
HYDRAULIC CONDUCTIVITY, "k" (cm/s):	5.6E-09
HYDRAULIC CONDUCTIVITY, "k_{20}" (cm/s):	**6.2E-09**

	Height (mm)	Diameter (mm)	Wet Mass (gm)	Dry Density (gm/cm^3)	Water Content (%)	Saturation (%)
Initial Reading	72.8	71.8	523.3	1.227	44.5	98.6
Final Reading	74.8	72.8	540.3	1.173	48.2	98.6



November 19, 2008

REVIEWED BY: Kurtis Kulchyski

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