Notice of Alteration Form

Manitoba
Sustainable Development

Client File No.: 3851.00

Environment Act Licence No.: 2177 E R5

Legal name of the Licencee: Waste Connections of Canada Inc.

Name of the development: Prairie Green Integrated Waste Management Facility

Category and Type of development per Classes of Development Regulation:

Waste Treatment and Storage | Class 1 Waste Disposal Grounds

Licencee Contact Person: Barry Blue
Mailing address of the Licencee: Box 19 Grp 245 RR2
City: Winnipeg   Province: MB   Postal Code: R3C 2E6
Phone Number: (204) 792-3389   Fax: Email: barry.blue@wasteconnections.com

Name of proponent contact person for purposes of the environmental assessment (e.g. consultant):
Fabiano Gondim, P.Eng.

Phone: (647) 355-7484
Fax:

Mailing address:
100-6925 Century Avenue, Mississauga, ON L5N 7K2

Email address: fabiano_gondim@golder.com

Short Description of Alteration *(max 90 characters)*:
Design and height adjustment for Phase II of the landfill as per attached report.

Alteration fee attached: Yes: ☑ No: ☐

If No, please explain:

Date: 2022-03-28

Signature: [redacted]

Printed name: Barry Blue

A complete Notice of Alteration **(NoA)** consists of the following components:

- ☑ **Cover letter**
- ☑ **Notice of Alteration Form**
- ☑ **2 hard copies and 1 electronic copy of the NoA detailed report** (see "Information Bulletin - Alteration to Developments with Environment Act Licences")
- ☑ **$500 Application fee, if applicable** (Cheque, payable to the Minister of Finance)

Submit the complete NoA to:

Director
Environmental Approvals Branch
Manitoba Sustainable Development
1007 Century Street
Winnipeg, Manitoba R3H 0W4

For more information:

Phone: (204) 945-8321
Fax: (204) 945-5229
http://www.gov.mb.ca/sd/eal

Note: Per Section 14(3) of the Environment Act, Major Notices of Alteration must be filed through submission of an Environment Act Proposal Form (see "Information Bulletin – Environment Act Proposal Report Guidelines")

WASTE
CONNECTIONS
OF
CANADA

March 31, 2022

James Capotosto
Director, Environmental Compliance and Enforcement Branch
Environmental Approvals Branch
Manitoba Environment, Climate and Parks
1007 Century Street
Winnipeg, MB
R3H 0W4

Re: WASTE CONNECTIONS OF CANADA INC.
PRAIRE GREEN INTEGRATED WASTE MANAGEMENT FACILITY
PHASE II WASTE FILL HEIGHT ADJUSTMENT

Dear Mr Capotosto,

The purpose of this letter is to request approval from Manitoba Environment, Climate and Parks (MECP) to adjust the height of the approved waste fill area known as Phase II, at the Prairie Green Integrated Waste Management Facility (Facility). The Facility is owned and operated by Waste Connections of Canada Inc. (Waste Connections) under Environmental Act License No. 2177 E R5.

In January 2021, Waste Connections submitted an application to MECP to adjust the heights of the Landfill Phases I and II. MECP approved the height adjustment for Phase I on May 26, 2021, and informed Waste Connections that a separate submission including similar level of geotechnical analysis and details would be required for Phase II. Waste Connections retained Golder Associates Ltd. (Golder) to prepare a report to support the application to approve the proposed height adjustment of the Phase II fill area. This is the only change being proposed, and no changes are proposed to the approved setbacks, waste fill area, liner system design, leachate collection system design and final cover of the Landfill. The report to support the proposed height adjustment is attached to this letter and provides a description of the current landfill design, proposed height adjustment and geotechnical analysis completed.

We trust the above meets with your approval. If you should have any questions please do not hesitate to contact the undersigned.

Sincerely,

[redacted]

Barry Blue
District Manager

Attachments: Notice of Alteration Form, Manitoba Sustainable Development
PGIWMF Phase II Height Adjustment Design Report, prepared by Golder Associates Ltd.

cc. Sonja Bridges – Manitoba Environment, Climate and Parks

Nada Suresh – Manitoba Environment, Climate and Parks
Chris Visser – Region Engineering Manager, Waste Connections of Canada

REPORT

Prairie Green Integrated Waste Management Facility

Phase II Base and Height Adjustment Design

Submitted to:

Waste Connections of Canada Inc.
375 Oak Point Highway
Winnipeg, Manitoba

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada

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March 2022

Distribution List

1 Hard Copy and One e-Copy - Waste Connections of Canada

2 Hard Copies and One e-Copy - Manitoba Conservation and Climate

1 e-Copy: Golder Associates Ltd.

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1.0 INTRODUCTION

1.1 Background

The Prairie Green Integrated Waste Management Facility (Prairie Green IWMF) is owned and operated by Waste Connections of Canada Inc. under Environment Act License No. 2177 E R5 issued on June 28, 1996 and mostly recently revised on November 13, 2015.

The Prairie Green IWMF opened in 1996 and is located on Section 14 and the north half of Section 11 of Township 12, Range 2 East in the Rural Municipality of Rosser, Manitoba, approximately 16 km north of the City of Winnipeg.

The Prairie Green IWMF has a landfill component (Landfill), a recycling facility, a materials recovery facility, a composting facility, and a petroleum contaminated soil treatment facility. The Landfill was designed to accept municipal solid non-hazardous waste, which includes residential, industrial, commercial, and institutional wastes.

The Landfill was approved with two separate waste fill areas, known as Phase I and Phase II. Each Phase consists of 17 cells, for a total of 34 cells (see Figure 1). Golder Associates Ltd. (Golder) prepared the two key documents that served as the basis for the Landfill original approval, i.e., the Design & Development Report (Golder, 1995a) and the Geotechnical Assessment Report (Golder, 1995b). As of December 2021, Cells 1 to 16 of Phase I of the Landfill have been developed.

In January 2021, Waste Connections of Canada Inc. (Waste Connections) submitted an application to Manitoba Conservation and Climate to adjust the heights of the Landfill Phases I and II. The application included a report prepared by Golder entitled Prairie Green Integrated Waste Management Facility, Landfill Height Adjustment dated January 27, 2021 and a Technical Memorandum prepared by Golder entitled Prairie Green Integrated Waste Management Facility, Addendum 1 to the Landfill Height Adjustment Report, Location of Existing and Future Recycling/Composting and Soil Remediation Operations dated February 26, 2021. Manitoba Conservation and Climate approved the height adjustment for Phase I on May 26, 2021, and informed Waste Connections that a separate submission including similar level of geotechnical analysis and details would be required for Phase II.

1.2 Purpose

This report was prepared to support an application to approve the proposed height adjustment of the Landfill Phase II. This is the only change being proposed, i.e., no changes are proposed to the approved setbacks, waste fill area, liner system design, leachate collection system design and final cover of the Landfill.

The following sections describe the geotechnical investigations and laboratory testing results, current Phase II design, proposed Phase II height adjustment design and supporting geotechnical analyses.

2.0 GEOTECHNICAL INVESTIGATIONS AND LABORATORY TESTING PROGRAM

2.1 Work Program

Golder designed a geotechnical investigation and laboratory testing program to supplement the geotechnical reports available for the Site and to support the specific geotechnical analyses and design for the proposed Phase II height adjustment design.

Golder engaged the Winnipeg geotechnical team of the engineering firm WSP to locally support the project. The WSP geotechnical team retained and supervised Maple Leaf Drilling Ltd. for the advancement of four boreholes and installation of four monitoring wells identified as P-12 Deep (Bedrock), P-12 Shallow (Clay), P-13 Deep (Bedrock) and P-13 Shallow (Clay) at the locations shown in Figure 1. The deep boreholes were advanced to bedrock surface, (approximately 12.1 m to 15.6 m depth below existing ground surface) using a B54X track-mounted drill rig equipped with solid stem auger. Split spoon samples, Standard Penetration Test (SPT) blow counts and in-situ (vane) shear strength measurements were obtained at each deep borehole. In addition, Shelby Tube samples were obtained from each deep borehole for laboratory shear strength and consolidation testing. Shallow boreholes were advanced to medium brown clay (approximately 3.1 m depth below existing ground surface). No samples were collected from the shallow boreholes.

Two shallow groundwater monitoring wells P-12 Shallow (Clay) and P-13 Shallow (Clay) were installed using 50 mm diameter Schedule 40 PVC pipe on August 4, 2021 with screen sections within the brown clay unit just below the silt unit (Appendix A). Two deep monitoring wells P-12 Deep (Bedrock) and P-13 Deep (Bedrock) were installed on August 4, 2021 with screen sections straddling the dolomite limestone unit or entirely within the dolomite limestone unit, respectively (Appendix A).

WSP geotechnical team logged the boreholes, collected soil samples, obtained coordinates and elevations for the boreholes and monitoring wells, completed groundwater level measurements and used the WSP geotechnical laboratory in Winnipeg to perform particle size analysis, moisture content and Atterberg Limits tests. The specialized tests, i.e., triaxial shear strength and consolidation tests were carried out at Golder's laboratory in Saskatoon.

2.2 Soil Description and Laboratory Testing Results

Borehole Records from the geotechnical field investigation are provided in Appendix A. The Borehole Records contain soil descriptions, SPT blow counts, in-situ (vane) shear strengths, undrained shear strength, water contents, Atterberg Limits and piezometer installation details. Moisture content, Atterberg Limits, grain size analyses consolidation and triaxial testing results are presented in Appendix B.

Description of the soil types encountered, including the results of testing are summarized below.

Topsoil

- encountered in all four boreholes
- 0.15 m thick

Upper Clay

- encountered in all four boreholes underlying the topsoil layer
- approximately 1 m thick
- water content of 27% to 33%
- very stiff consistency
- high plasticity
- contains trace to some sand and silt

Silt

- encountered in all four boreholes separating the upper and lower clay layers
- approximately 1.1 m to 1.4 m thick
- water content of 21% to 23%
- silt content of 75% to 83%
- contains some clay and trace sand

- soft consistency

Lower Clay

- encountered in all four boreholes underlying the silt layer
- transitions from brown to grey at approximately 4.5 m
- top of layer at Elevation 230 m (approx.)
- approximately 7.5 m to 8.8 m thick
- clay size content of 83% to 87%
- water content of 31% to 72%
- plastic limit of 25% to 27%
- liquid limit of 84% to 94%
- plasticity index of 59% to 67%
- consistency stiff to firm (below 3.0 m depth from ground surface), firm to soft (below 5.0 m depth), very soft (below 8.4m depth) in borehole P-12 Deep (Bedrock)
- consistency stiff to firm (below 3.3 m depth from ground surface), firm to soft (below 6.1 m depth), very soft (below 7.5 m depth) in borehole P-13 Deep (Bedrock)
- undrained shear strength measured using field vane linearly decreases with depth from approximately 20 kPa to 15 kPa
- contains trace sand and some silt
- consolidation parameters for the lower clay are summarized in Table B.1 in Appendix B. Note that the pre-consolidation pressure of 135 kPa obtained from the consolidation test for Shelby tube sample S7A taken at depth of 7.6 m to 8.4 m below ground surface at borehole P-12 Deep (Bedrock) is indicative of very soft consistency. The pre-consolidation pressure of 265 kPa obtained from the consolidation test for Shelby tube sample S5A taken at depth of 4.6 m to 5.3 m below ground surface at borehole P-13 Deep (Bedrock) is indicative of firm consistency.
- Consolidated undrained triaxial test results for the lower clay are summarized in Table B.2 in Appendix B. The effective friction angle and cohesion for the Shelby tube sample S7A taken at depth of 7.6 m to 8.4 m below ground surface at borehole P-12 Deep (Bedrock) are 16.9° and 0 kPa respectively. For Shelby tube sample S5A taken at depth of 4.6 m to 5.3 m below ground surface at borehole P-13 (Bedrock), the effective friction angle and cohesion are 16.0° and 4.6 kPa respectively.

Till

- silty till encountered in two deep boreholes overlying bedrock at depths of 9.8 m and 11.4 below ground surface at boreholes P-12 Deep and P-13 Deep, respectively
- approximately 0.7 m thickness in borehole P-12 Deep to 5.9 m thickness in borehole P-13 Deep
- water content of 10% to 12.5%
- dense to very dense consistency
- contains trace gravel, some sand

Bedrock

- dolomitic limestone encountered at depths of 15.6 m and 12.1 m below ground surface at boreholes P-12 Deep and P-13 Deep, respectively

2.3 Groundwater Levels

Groundwater levels at the monitoring wells were measured following completion of the well installation and then again on several dates within about two months of installation. The groundwater level readings are provided in Table A.1 in Appendix A.

Groundwater levels measured in shallow monitoring well P-13 Shallow (Clay) were between Elevation 230.6 m and 231.2 m. Groundwater levels measured in deep monitoring wells P-12 Deep (Bedrock) and P-13 Deep (Bedrock) were between Elevation 230.3 and 230.9 m. Comparison of the groundwater levels obtained on the same date between piezometer P-13 Shallow (Clay) (Mid Screen Elev. 229.7 m) and piezometer P-13 Deep (Bedrock) (Mid Screen Elev. 219.8 m) indicates a downward hydraulic gradient of approximately 0.02 to 0.03.

3.0 CURRENT LANDFILL DESIGN

As mentioned above, the Landfill was approved with two separate waste fill areas, known as Phase I and Phase II. Each Phase will be developed with 17 cells, for a total of 34 cells (see Figure 1). Phase II is approved with a perimeter berm, 6(H):1(V) waste fill perimeter side slopes with a crest elevation (top of final cover) at approximately 257 metres above sea level (masl) and 2% top slopes with a peak elevation (top of final cover) at 260.3 masl (Figure 3).

The Landfill was designed and approved with a composite base liner system, a leachate collection system (LCS), and a leak detection system as described in the Design & Development Report (Golder, 1995a).

The original design of the composite base liner system for the floor and sideslopes of the cells consists of a 0.6 m thick recompacted clay liner, overlain by a 1.5 mm (60 mil) High Density Polyethylene (HDPE) geomembrane. This design was modified and approved on September 14, 2015 for all cells of Phase II to replace the 0.6 m thick recompacted clay liner with a geosynthetic clay liner (GCL).

The original design of the LCS of Phase II includes a 300 mm thick sand filter layer, a nonwoven geotextile filter and a 300 mm thick clear stone drainage layer. The LCS design was also modified and approved on August 27, 2014 to replace the 300 mm thick clear stone drainage layer with a geocomposite for all cells of Phase II.

The final cover design consists of a 0.75 m thick compacted clayey soil layer covered with a 0.15 m thick topsoil layer, for a total final cover thickness of 0.9 m. The final cover is seeded with a grass seed mix following placement of topsoil.

4.0 PROPOSED LANDFILL DESIGN

The proposed base design for Phase II is shown in Figure 2. The Phase II base design is generally consistent with the Phase I base design. Each of the 17 cells proposed for Phase II will have perimeter berms to allow independent leachate drainage for each cell. The floor of each cell has a 2% crossfall sloped to the central valley of each cell. A leachate collection trench located at the central valley of each cell, sloped at 1%, collects leachate from a continuous drainage layer and drains leachate by gravity to a sump located at the toe of the cell excavation side slope adjacent to the perimeter road (see Figure 6). The sump forms the low point of each cell. Leachate is pumped from each individual sump into tanker trucks and hauled to on-Site leachate evaporation ponds or for treatment at the City of Winnipeg North End Wastewater Treatment Plant.

The perforated leachate collection pipe located along the bottom of the central leachate collection trench was specified for Cells 1, 2, 3 and 14 to 17 as high density polyethylene (HDPE) pipe with a ratio of the pipe outside diameter to the pipe minimum wall thickness (Standard Dimension Ratio or SDR) of 17. The perforated pipe along the trench of Cells 4 to 13 was specified as DR11 HDPE. For all cells, the perforated pipe along the trench is surrounded by 50 mm diameter clear stone as shown in Section C of Figure 6. It is noted that Section C of Figure 6 is located at the centre of a typical leachate collection trench, and Section D of Figure 6 is located outside of a typical leachate collection trench.

For Phase II, it is proposed to modify the perimeter above ground side slopes from 6(H):1(V) to 5(H):1(V) from the toe of the side slopes to a crest elevation (top of final cover) of 263 masl as shown in Figure 4. The top slopes are proposed at 5% from elevation 263 masl to the peak elevation of the final cover of 269.8 masl. This height adjustment would increase the peak of Phase II from the approved peak (top of final cover) elevation of 260.3 masl to 269.8 masl. The maximum height above the surrounding ground surface (average elevation of 233 masl) would increase from approximately 27 mags to approximately 37 mags. This represents about 10 m net height increase.

For context, Waste Connections provided the information that the existing electricity transmission towers located between Phases I and II of the Landfill have a height of 60 m above ground surface, which is 23 m higher than the proposed peak of Phase II. In addition, Waste Connections provided the information that the grain elevator located about 800 m north of Phase I has a height of about 76 mags, which is 39 m higher than the proposed peak of Phase II.

As mentioned above, no changes are proposed to the approved setbacks, waste fill area, and the design of the liner, leachate collection and final cover systems.

5.0 GEOTECHNICAL ANALYSES FOR THE PROPOSED DESIGN

5.1 Differential Settlement Analysis Along the Leachate Collection System Pipe

As waste is placed in the Landfill, the Landfill base will undergo settlement due to compression of the subgrade soils under the weight of the waste fill. The final overall waste deposit thickness will be greatest in the central areas of Phase II and decrease towards the perimeter. Hence, the central part of the Landfill will undergo the largest amount of settlement of the base grades and the perimeter will undergo the least amount of settlement, causing differential settlement of the perforated pipe along the central leachate collection trench of each cell.

A differential settlement analysis was carried out for the proposed waste height adjustment along Cross-Section B-B’ (shown in Figures 2, 4 and 5) located along the LCS pipe in the central trench of Cell 11. Detailed one-dimensional settlement calculations are provided in Appendix C. The consolidation test results for the natural clay layer beneath the Landfill were used for the settlement calculations. The settlement calculations were carried out for the proposed height adjustment shown on Cross-Section B-B’. The calculated (post-settlement) slopes along the LCS pipe are shown graphically in Figure C-1 (Appendix C). Four locations along the base grades were selected for the differential settlement calculations i.e., base grade locations at the sump location (Chainage 69.9 m), middle of 5(H):1(V) slope (Chainage 123.1 m), crest of 5(H):1(V) slope (Chainage 176.3 m) and top of the landfill (Chainage 312.3 m).

The design slope of the base grade at the location of the LCS pipe along cross-section B-B' is 1% draining towards the sump. The thickness of the natural clay deposit beneath the base grades of Cell 11 ranges from approximately 6.3 m near the sump area to approximately 8.7 m near the central part of the Landfill.

The calculated subgrade settlements for the proposed height adjustment are as much as 1.1 m at the central area of the Landfill where the waste thickness is approximately 39 m to 0.11 m at the sump area where the waste thickness is approximately 13 m. The base grade slopes decrease from the initial value of 1% to as low as 0.21% near the sump area. These final (post-settlement) base grade slopes indicate that overall positive leachate drainage to the sump would occur along the leachate collection pipe with the proposed height adjustment.

5.2 Structural Stability of Leachate Collection System Pipe

Structural stability calculations were carried out for the 200 mm nominal diameter SDR 11 and 17 (Designation Code PE3408) HDPE leachate collection system pipes. DR 11 pipe is proposed to be installed in the central LCS trench of Cells 4 to 13 and DR 17 pipe is proposed to be installed in the central LCS trench of Cells 1 to 3 and Cells 14 to 17.

The calculations involve the equations presented in the Handbook of Polyethylene Pipe by the Plastic Pipe Institute (PPI, 2008). Specifically, the Factor of Safety was calculated for the failure mechanisms listed below:

- **Pipe Wall Crushing** occurs when the external pressure applied to the pipe induces compressive stresses that exceed the allowable pipe wall compressive strength (yield strength) of HDPE pipe. The Factor of Safety against pipe wall crushing is calculated as the allowable wall compressive strength (yield strength) of HDPE pipe divided by the actual pipe wall compressive stress. A Factor of Safety of greater than 1.0 is recommended by the PPI for this failure mechanism. Of note is that the calculation of allowable compressive strength and applied compressive stress incorporate reduction factors for Modulus of Elasticity of the HDPE pipe to account for long-term sustained loading (100 years) and elevated temperature of 38^{o}C. [The temperature of 38^{o}C is based on Golder's data base of temperatures at the base of municipal solid waste landfills with leachate collection systems in place]. Furthermore, HDPE DR11 and DR17 pipes are chemically resistant to municipal solid waste at the temperature of 38^{o}C and hence no reduction factor is applied to compressive strength in relation to chemical attack.

- **Ring Deflection** occurs when the external pressure applied to the pipe causes excessive distortion / deflection along the pipe circumference (i.e., excessive ring deflection). Plastic Pipe Institute (2008) recommends an allowable ring deflection of 5% for non-pressure pipe applications but allow spot deflection of up to 7.5% during field inspection. The maximum allowable ring deflection is the vertical deflection of the pipe crown divided by the outer diameter of the pipe. The Factor of Safety against ring deflection is calculated as the maximum allowable ring deflection divided by the predicted ring deflection under the actual applied loading. A Factor of Safety greater than 1.0 is recommended by the PPI for this failure mechanism. The same reduction factors applied to the Modulus of Elasticity for the pipe wall crushing failure mode are applied to the ring deflection analysis.

- **Wall Buckling** occurs when the external pressure applied to the pipe causes buckling along the pipe circumference. The Factor of Safety against wall buckling is calculated as the critical buckling pressure at the top of the pipe divided by the applied vertical pressure under the waste loading. A Factor of Safety greater than 2.0 is recommended by the PPI. The same reduction factors applied to the Modulus of Elasticity for the pipe wall crushing failure mode are applied to the wall buckling analysis.

Detailed calculations are presented in Appendix D. Table 1 presents the resulting Factor of Safety values for the above failure mechanisms at the maximum applied vertical static pressure of 530 kPa acting on the DR11 and 450 kPa acting on DR17 pipes.

Table 1: Factor of Safety for Different Pipe Failure Mechanisms

Failure Mechanism	Factor of Safety for 200 mm Nominal Diameter, DR11, PE3408 HDPE Pipe to be Installed in Cells 4 to 13	Factor of Safety for 200 mm Nominal Diameter, DR17, PE3408 HDPE Pipe to be Installed in Cells 1 to 3 and 14 to 17.	Minimum Required Factor of Safety
Pipe Wall Crushing	2.5	2.2	1.0
Reversal of Curvature (Ring Deflection)	2.1	1.8	1.0
Pipe Wall Buckling	6.4	4.7	2.0

All of the above calculated Factor of Safety values are acceptable and support the structural integrity of the 200 mm nominal diameter SDR 11 and 17 (Designation Code PE3408) HDPE pipes with the proposed height adjustment.

5.3 Slope Stability Analyses

Slope stability analyses were carried out using the computer model Slide 2 (Rocscience, 2020) for the Cross-section B-B' shown in Figures 2, 4 and 5 and typical details shown in Figure 6 (Detail D). This location was selected for the slope stability analyses because it reflects the maximum potential waste loading for the proposed height adjustment. Slide 2 uses a limit equilibrium method of analysis as described by Morgenstern and Price (1965). The program utilizes numerous trial "failure" circular and non-circular surfaces to compute the minimum Factors of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. Theoretically, a Factor of Safety greater than 1.0 is stable, however, for static stability analysis of municipal solid waste landfill slopes, a minimum Factor of Safety of 1.4 is commonly used for design purposes (Daniel and Koerner, 1997).

Soil and waste input parameters for the stability analyses, including unit weight, effective friction angle, effective cohesion, and undrained shear strength of the clay, are presented in Table 2.

Table 2: Soil and Waste Properties Used for Slope Stability Analyses

Material	Unit Weight (kN/m^3)	Undrained Shear Strength (S_u) (kPa)	Effective Stress Parameters		Reference
			Cohesion (c') (kPa)	Friction Angle (degrees)	
Waste	13[a]	NA	15	36	Bray et. al (2009)
Final Cover	18	NA	0	18	Estimated based on experience

Material	Unit Weight (kN/m^3)	Undrained Shear Strength (S_u) (kPa)	Effective Stress Parameters		Reference
			Cohesion (c') (kPa)	Friction Angle (degrees)	
Clay Berm Fill	18	NA	0	19	Estimated based on experience
Smooth Geomembrane and Clay Interface	15	NA	0	11	Koerner and Narejo (2005)
Textured Geomembrane and Clay Interface	15	NA	0	16	Koerner and Narejo (2005)
Silt	17	NA	0	30	Carter and Bentley (2016)
Upper Weathered Clay	16.5	52	0	19	Golder (1995b)
Lower Clay	17.0	20 to 15[b]	2.3	16.5	Vane test results for undrained shear strength on lower clay, Golder (1995b) and triaxial consolidated undrained triaxial test (with pore pressure measurement) for effective stress parameters. All tests performed as part of this assignment.

Notes:

a – Unit weight of 13 KN/m^3 for waste is based on 80% MSW (12 kN/m^3) to 20% soil (20 kN/m^3) ratio by weight.

b – Decreases linearly with depth.

The examined modes of slope failure are shown schematically in Figure E-1 and include clay foundation failure, failure along interface of the smooth geomembrane and underlying clay liner and failure confined to the waste fill. For the clay foundation failure mode, a total stress (undrained) analysis was carried out for the filling period and an effective stress (drained) analysis was carried out for the long-term post closure period. For the other failure modes, only effective stress analyses were carried out as the failure mode involves layers that are relatively permeable and hence do not build up excess porewater pressures during loading. For the effective stress analyses, the piezometric level in the middle of clay layer beneath the Landfill was assumed to be at elevation 230.5 masl, based on the average of shallow (clay) and deep (bedrock) piezometric levels measured in October 2021 at monitoring well nests

P-12 and P-13. The leachate level in the Landfill was conservatively assumed to be at 3.0 m above the basal geomembrane liner. An effective stress analysis was also carried out for each mode of failure assuming no leachate collection and a fully developed leachate mound calculated using the Harr Equation (Rowe et. al. 2004) as shown in Figure C-3, i.e.,

$$h = \sqrt{\frac{q_{net}}{k_w}(L - x)\,x}$$

where,

h = mound height above the toe of the Landfill perimeter slope (m)

q_{net} = infiltration rate through the Landfill final cover = 0.076 m per year, based on HELP Model (Cornerstone, 2013)

L = Landfill width = 545 m

x = distance from toe of Landfill perimeter slope (m)

k_w = hydraulic conductivity of waste = 1×10^{-6} m/s (estimated based on experience)

The results of the stability analyses are shown in Figures E-2, E-3, E-4, E-5, E-6 and E-7. The minimum Factors of Safety values for each failure mode are provided in Table 3. The calculated minimum Factor of Safety values are greater than the minimum required Factor of Safety of 1.4 for municipal solid waste landfill design (Daniel and Koerner, 1997) and are therefore considered acceptable.

Table 3: Minimum Factor of Safety Values for Slope Stability Analyses

Failure Mode	Analysis Type	Calculated Minimum Factor of Safety
Clay foundation failure	Total stress (undrained) analysis	1.6 (Figure E-2)
Clay foundation failure	Effective stress (drained) analysis	2.8 (Figure E-3)
Smooth geomembrane and clay liner interface failure at normal operating condition	Effective stress (drained) analysis	2.6 (Figure E-4)
Smooth geomembrane and clay interface failure with leachate mounding	Effective stress (drained) analysis	2.0 (Figure E-5)
Waste slope failure at normal operating condition	Effective stress (drained) analysis	4.5 (Figure E-6)
Waste slope failure with leachate mounding	Effective stress (drained) analysis	2.5 (Figure E-7)

6.0 CONCLUSIONS AND RECOMMENDATIONS

To support the proposed design and height adjustment for Phase II, a subsurface investigation and geotechnical analyses were completed for Phase II.

The geotechnical and pipe structural analyses and results presented in this report meet industry standards design criteria in terms of Factor of Safety. The results support the feasibility of the proposed height adjustment for Phase II of the Landfill and indicate that the desired performance for slope stability and the leachate collection system will be achieved.

Signature Page

Golder Associates Ltd.

[redacted]

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Senior Waste Engineer/Project Manager

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Frank Barone, Ph.D., P.Eng.
Principal, Geo-Environmental Engineer

FRG/SR/FSB/ml

https://golderassociates.sharepoint.com/sites/148589/project files/5 technical work/report/final report/21473621-r-reva - phase ii - design -final report-2022march11.docx

APEGM
Certificate of Authorization
Golder Associates Ltd.
No. 2997 Date: March 30, 2022

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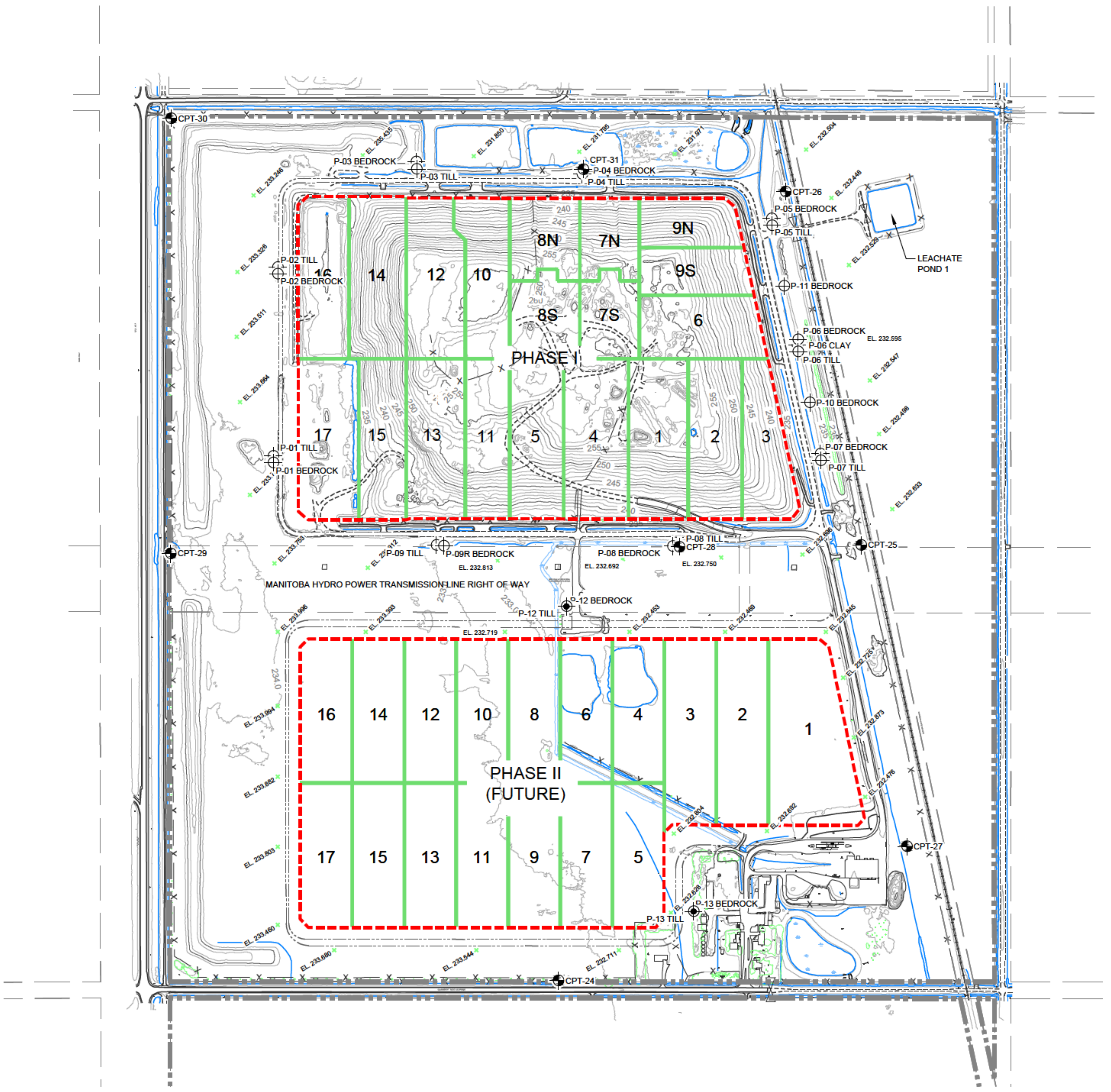
Figures



LEGEND

— —	PROPERTY LIMITS
▬ ▪ ▪ ▬	APPROVED SITE BOUNDARY
🟥 🟥 🟥	APPROVED LIMITS OF WASTE
🟩	CELL DIVIDE
- - - - -	EXISTING GRAVEL ROAD
═══	EXISTING PAVED ROAD
┼┼┼┼	EXISTING RAILWAY (CPR)
– X —— X –	EXISTING FENCING
——	EXISTING DRAINAGE DITCH
◯	EXISTING WATER BODY
——	EXISTING TREE LINE
⊕ P-11	EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 1994)
◉ CPT-26	EXISTING GEODETIC CONTROL POINTS
⊙ P-12	EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 2021)
240	EXISTING GROUND SURFACE CONTOUR (INTERVAL 1.0 masl)
-·-·-	FUTURE ROAD

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 08, 2021 BY THE BASE MAPPING CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY LIMITS FROM FIGURE 2 - 2018 FISCAL PLANNING MODEL PREPARED BY DILLON CONSULTING.

0 200 400
1:8,000 METRES

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

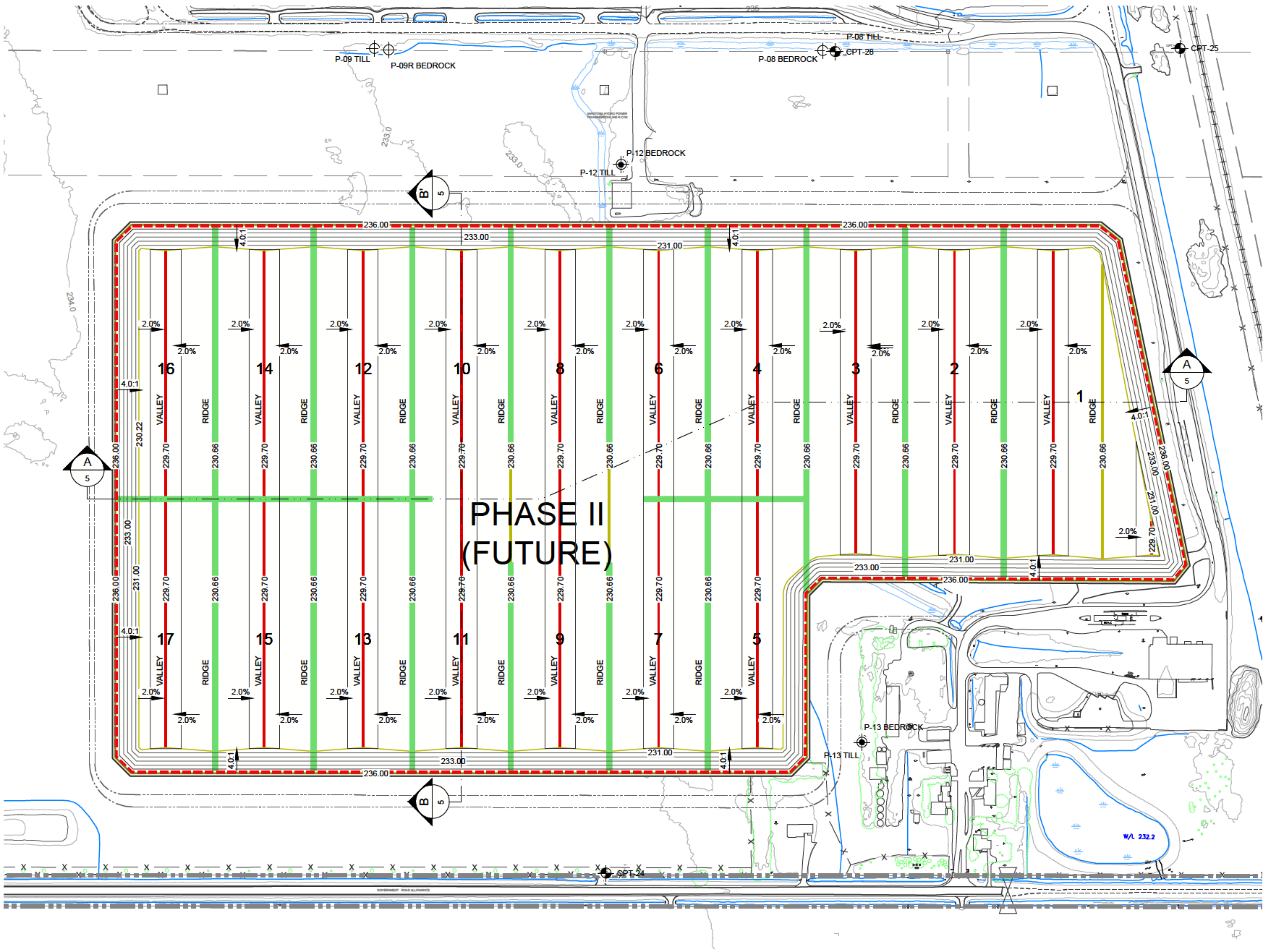
TITLE
SITE PLAN (MAY 8, 2021) AND MONITORING WELLS

CONSULTANT
wsp GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
0 50 mm



LEGEND

PROPERTY LIMITS
APPROVED SITE BOUNDARY
APPROVED LIMITS OF WASTE
EXISTING GRAVEL ROAD
EXISTING PAVED ROAD
EXISTING RAILWAY (CPR)
EXISTING FENCING
EXISTING DRAINAGE DITCH
EXISTING WATER BODY
EXISTING TREE LINE
235 EXISTING GROUND SURFACE CONTOUR (INTERVAL 0.5 masl)
EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 1994)
EXISTING GEODETIC CONTROL POINTS
EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 2021)
FUTURE ROAD
231.00 FUTURE PHASE II BASE CONTOURS (INTERVAL 1.0 masl)
🟩 FUTURE PHASE II CELL DIVIDE

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 08, 2021 BY THE BASE MAPPING CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY LIMITS FROM FIGURE 2 - 2018 FISCAL PLANNING MODEL PREPARED BY DILLON CONSULTING.

0 100 200
1:4,000 METRES

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

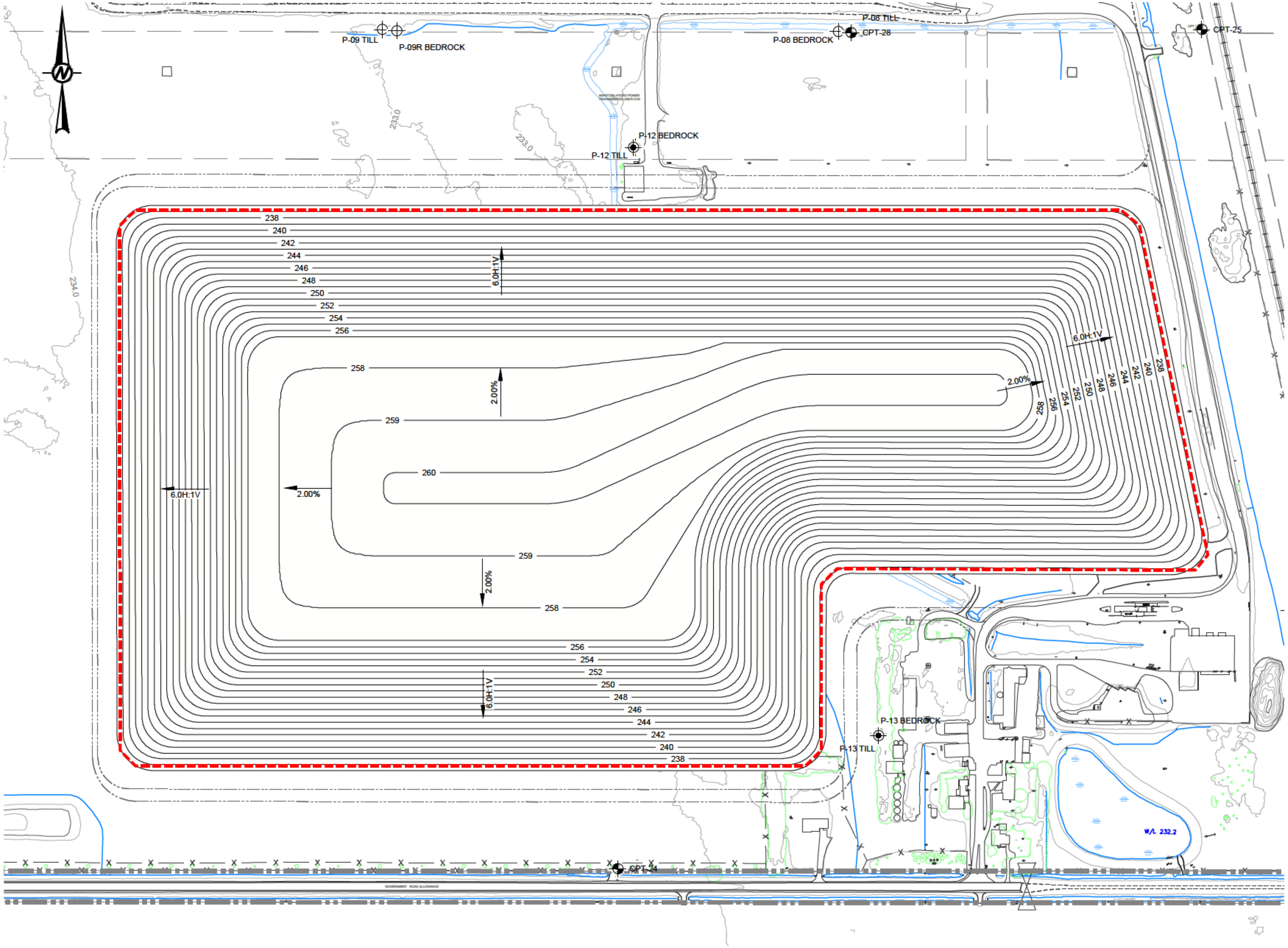
PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
PHASE II BASE GRADES

CONSULTANT
wsp GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	2



LEGEND

- PROPERTY LIMITS
- APPROVED SITE BOUNDARY
- APPROVED LIMITS OF WASTE
- EXISTING GRAVEL ROAD
- EXISTING PAVED ROAD
- EXISTING RAILWAY (CPR)
- X —— X —— EXISTING FENCING
- EXISTING DRAINAGE DITCH
- EXISTING WATER BODY
- EXISTING TREE LINE
- 235 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1.0 masl)
- EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 1994)
- EXISTING GEODETIC CONTROL POINTS
- EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 2021)
- FUTURE ROAD
- 250 APPROVED TOP OF FINAL COVER CONTOUR (INTERVAL 1.0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 8, 2021 BY THE BASE MAPPING CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY LIMITS FROM FIGURE 2 - 2018 FISCAL PLANNING MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
APPROVED TOP OF FINAL COVER CONTOURS - PHASE II

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	3

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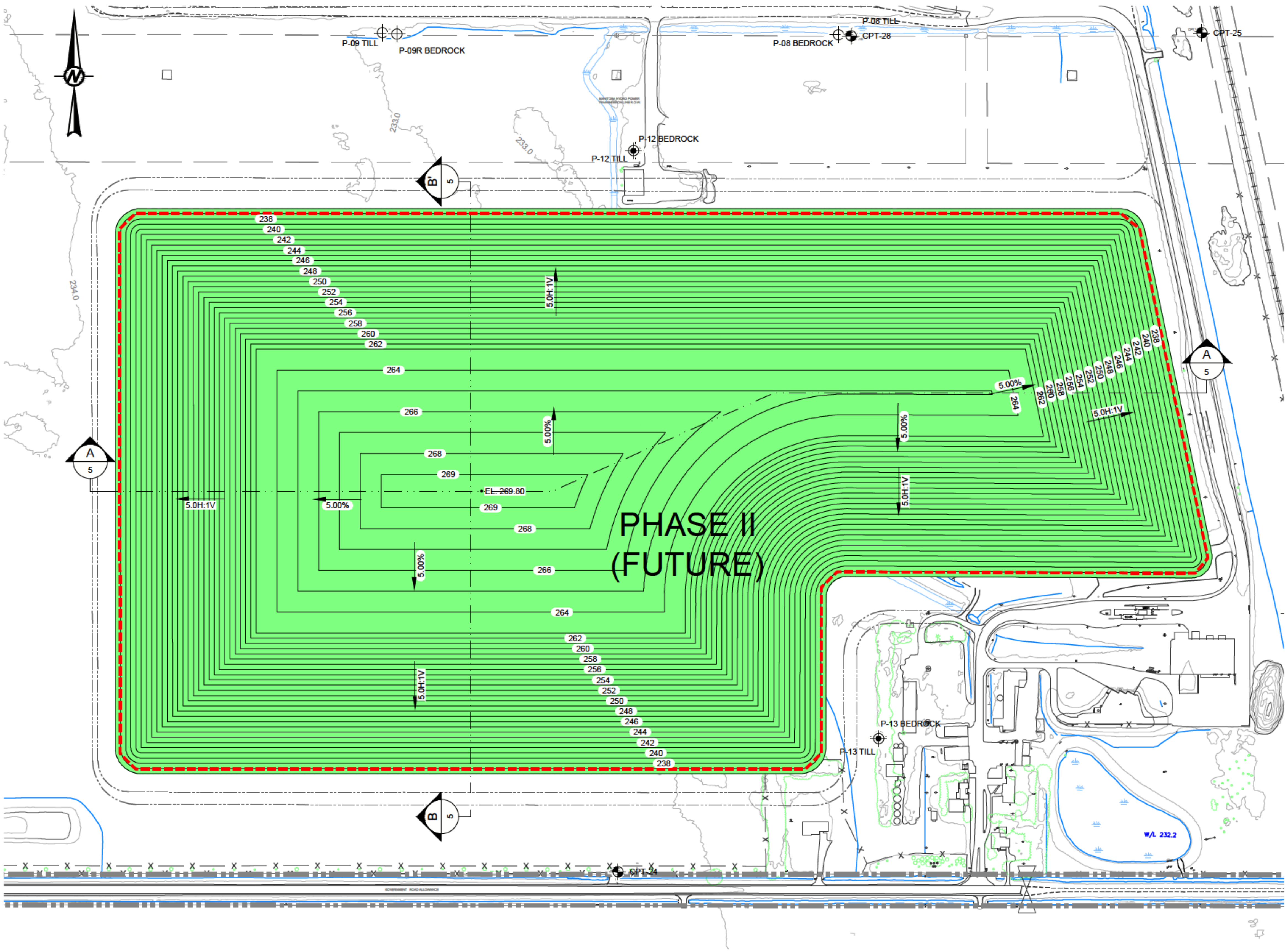
0 50 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

PROPERTY LIMITS
APPROVED SITE BOUNDARY
APPROVED LIMITS OF WASTE
EXISTING GRAVEL ROAD
EXISTING PAVED ROAD
EXISTING RAILWAY (CPR)
EXISTING FENCING
EXISTING DRAINAGE DITCH
EXISTING WATER BODY
EXISTING TREE LINE
235 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1.0 masl)
EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 1994)
EXISTING GEODETIC CONTROL POINTS
EXISTING MONITORING WELL LOCATION (GOLDER ASSOCIATES, 2021)
FUTURE ROAD
🟩 PROPOSED HEIGHT ADJUSTMENT TOP OF FINAL COVER CONTOUR (INTERVAL 1.0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.
2. NET INCREASE WITH VERTICAL EXPANSION AND BASE GRADES DESIGN TO BE APPROVED IN 2022 VOLUME = 1,362,554 m³.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 8, 2021 BY THE BASE MAPPING CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY LIMITS FROM FIGURE 2 - 2018 FISCAL PLANNING MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE

PROPOSED ADJUSTED TOP OF FINAL COVER CONTOURS - PHASE II

CONSULTANT
wsp GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	4

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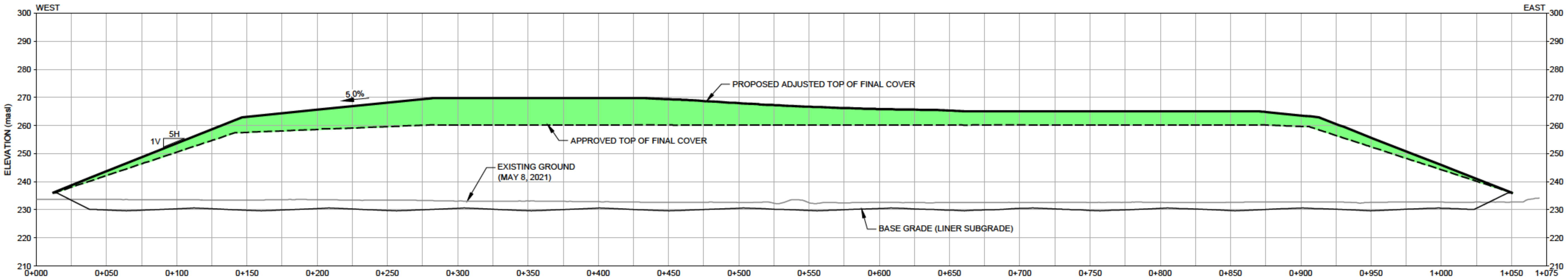
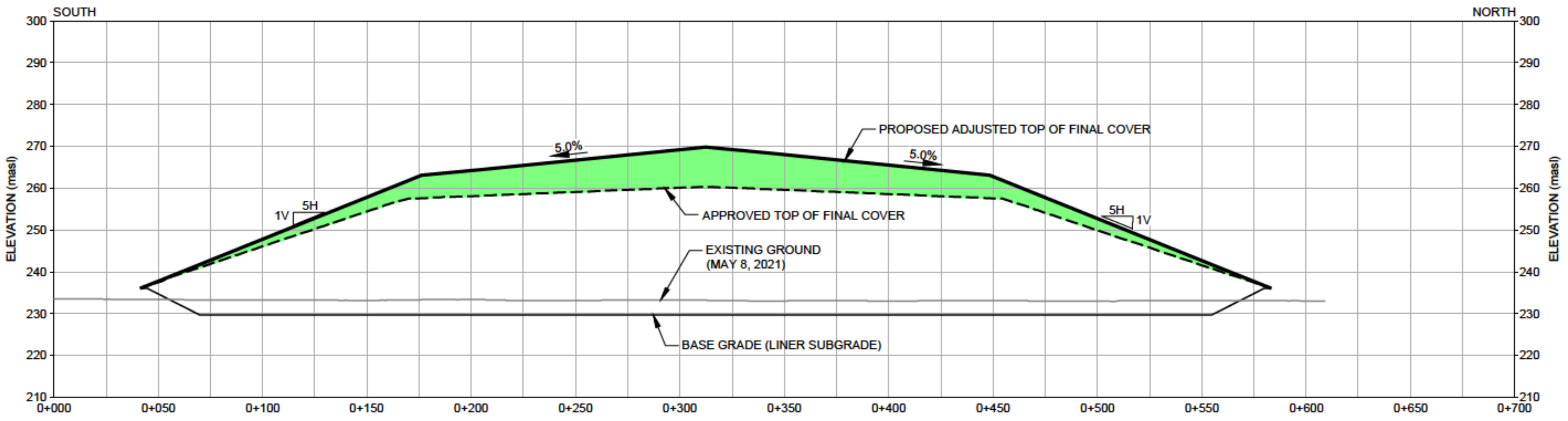


SCALE 1:1,500 m A CROSS-SECTION A-A'
V.E.=2X 3 4



SCALE 1:1,500 m B CROSS-SECTION B-B'
V.E.=2X 3 4

NOTE(S)

1. NET INCREASE WITH VERTICAL EXPANSION AND BASE GRADES DESIGN TO BE APPROVED IN 2022 VOLUME = 1,362,554 m³.

REFERENCE(S)

1. EXISTING GROUND SURFACE IS BASED ON TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 8, 2021 BY THE BASE MAPPING CO. LTD.

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

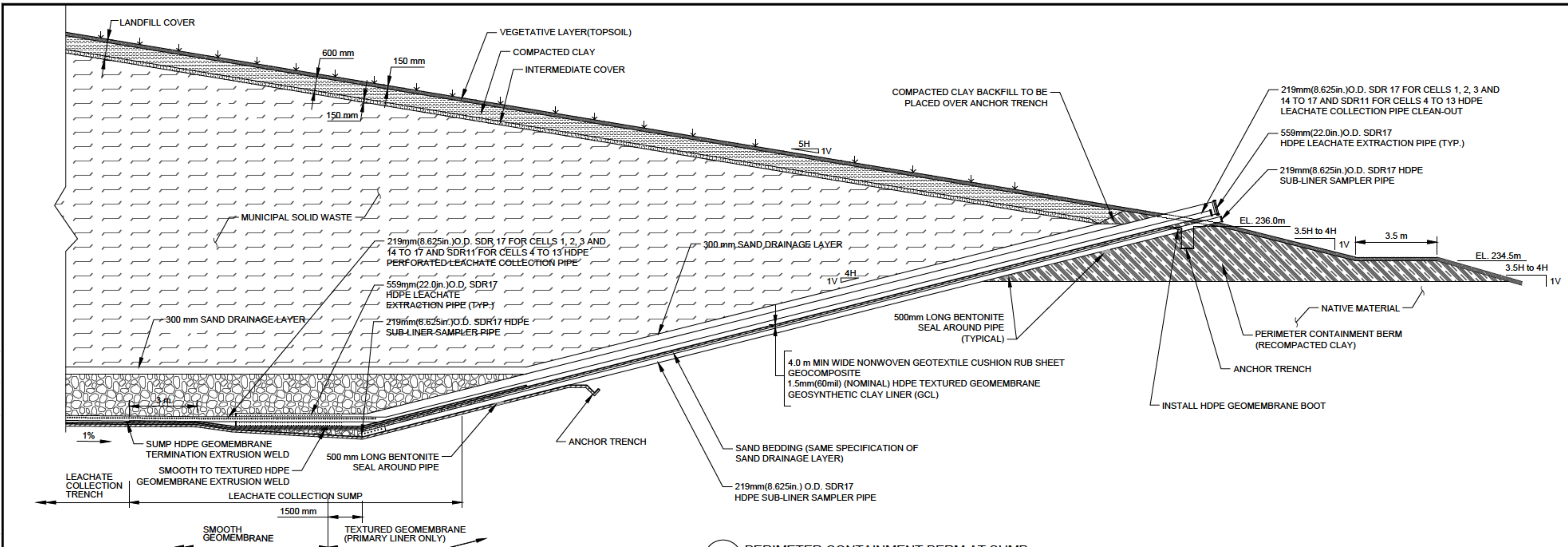
PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
CROSS-SECTIONS A-A' AND B-B'

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	5



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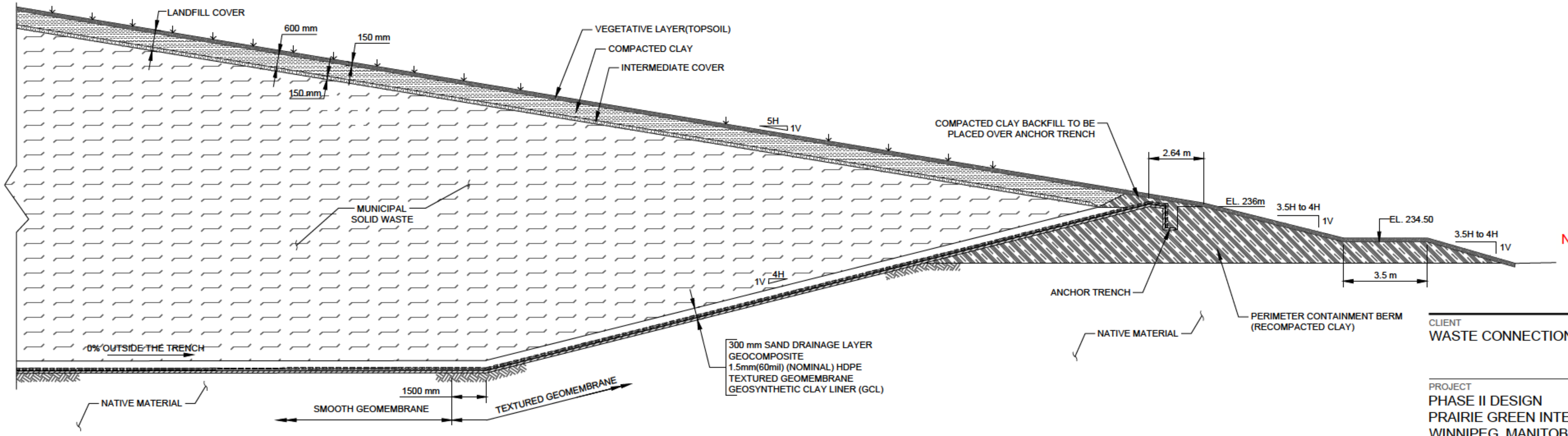

SCALE N.T.S. (D) PERIMETER CONTAINMENT BERM DETAIL

NOT FOR CONSTRUCTION

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
PHASE II DESIGN
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
TYPICAL DETAILS

CONSTULTANT

WSP GOLDER

YYYY-MM-DD	2021-12-15
DESIGNED	FRG
PREPARED	AZ
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	0001	A	6

APPENDIX A

Borehole Logs and Groundwater Levels

Table A.1 - Groundwater Levels

ID	Installation Elevation (m)	Ground Elevation (m)	Stick-up Length (m)	Elevation at Top Cap (m)	Date (mm/dd/yyyy)	Depth of Water Below Top Cap (m)	Groundwater Elevation (m)
P-13 Deep (Bedrock)	218.88	232.48	0.86	233.34	August 9, 2021	3.03	230.31
					August 17, 2021	2.90	230.45
					August 24, 2021	2.48	230.86
					October 4, 2021	2.49	230.85
P-13 Shallow (Clay)	229.34	232.44	0.94	233.38	August 9, 2021	2.81	230.57
					August 17, 2021	2.76	230.62
					August 24, 2021	2.21	231.17
					October 4, 2021	2.19	231.20
P-12 Deep (Bedrock)	216.12	232.72	1.02	233.74	August 9, 2021	3.42	230.32
					August 17, 2021	3.30	230.44
					August 24, 2021	3.32	230.42
					October 4, 2021	3.31	230.43
P-12 Shallow (Clay)	229.61	232.71	0.91	233.62	August 9, 2021	--	--
					August 17, 2021	--	--
					August 24, 2021	--	--
					October 4, 2021	--	--

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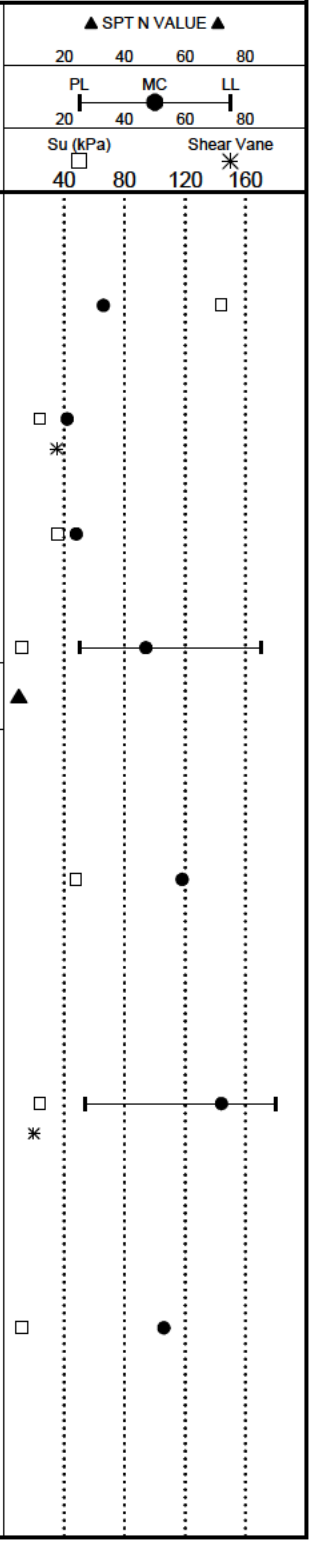
P-12 Deep (Bedrock)

CLIENT Golder Associates Ltd.
PROJECT NAME Prairie Green Landfill - Geotech Assmt.
PROJECT NUMBER 211-08078-00
PROJECT LOCATION Stony Mountain, MB
DATE STARTED 21/8/4 **COMPLETED** 21/8/4
GROUND ELEVATION 232.72 m **HOLE SIZE** 125 mm
DRILLING CONTRACTOR Maple Leaf Drilling
GROUND WATER LEVELS:
DRILLING METHOD Solid Stem Auger - B54X Track Rig
AT TIME OF DRILLING ---
LOGGED BY Wei Gao **CHECKED BY** Fabiano Gondim
AT END OF DRILLING ---
NOTES 12189.255 N, 11863.026 E
AFTER DRILLING ---

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)
0.15	232.57	**TOPSOIL (150 mm)** - Black, moist, organic rich with grass covered		
1	231.35	**CLAY (CH)** - Black to dark brown, moist, high plastic, very stiff, trace organics, trace to some silt	GB S1	
2	230.43	**SILT (ML)** - Tan-brown, moist, low plastic, soft, some clay, trace sand - Particle size analysis obtained on S2 - Gravel (0.0%), Sand (1.3%), Silt (83.3%), Clay (15.3%)	GB S2 VA S2A	
3		**CLAY (CH)** - Medium brown, moist, stiff, high plastic, trace sand, some silt - Below 3.0 m, stiff to firm - Particle size analysis obtained on S4 - Gravel (0.0%), Sand (0.4%), Silt (16.9%), Clay (82.7%)	GB S3 GB S4 SPT S4A	 1-3-2 (5)
4		- At depth of 4.2 m, medium brown to grey, stiff to firm	GB S5	
5		- Below 5.0 m, firm to soft	ST S5A	
6		- Particle size analysis obtained on S6 - Gravel (0.0%), Sand (0.8%), Silt (14.2%), Clay (85.0%)	GB S6 VA S6A	
7			GB S7	
8		- Below 8.4 m, very soft, trace to some gravel	ST S7A	
9				



(Continued Next Page)

P-12 Deep (Bedrock)

PAGE 2 OF 2

wsp canada group

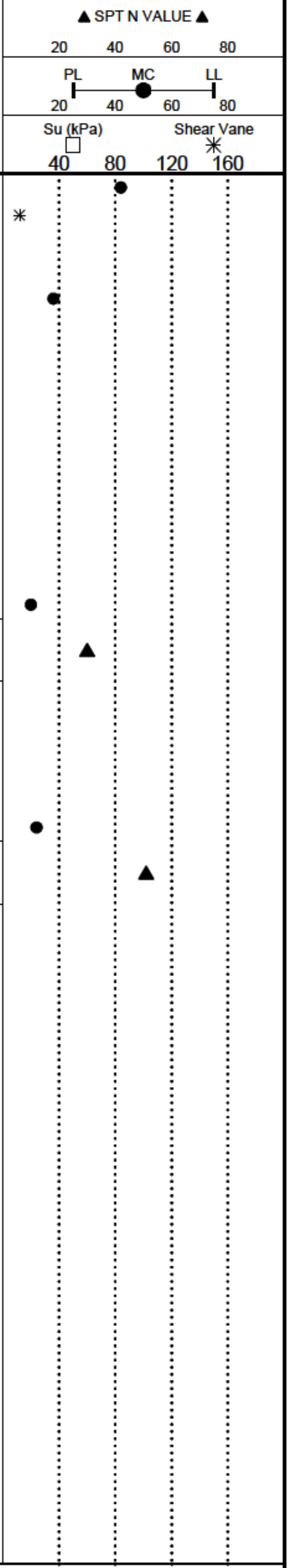
CLIENT Golder Associates Ltd.

PROJECT NUMBER 211-08078-00

PROJECT NAME Prairie Green Landfill - Geotech Assmt.

PROJECT LOCATION Stony Mountain, MB

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)
			GB S8 VA S8A	
	222.97			
10		**TILL (SILTY)** - Silt till with trace gravel, some sand, beige brown, moist, dense	GB S9	
11				
12			GB S10	
			SPT S10A	5-12-18 (30)
13		- Very dense at 13.6 m depth, trace cobbles		
			GB S11	
14			SPT S11A	10-23-28 (51)
15		- At depth of 15.1 m, trace to some boulders		
	217.12	**DOLOMITE LIMESTONE** - Beige to tan, mottled, rough undulating fractures, broken limestone at upper 0.53 m from bedrock surface, some rocks - Competent after 0.53 m below bedrock surface, with point fractures.		
16				
	216.12	**END OF TESTHOLE** - Testhole drilled using solid stem auger to refusal at 15.1 mbg, then switched to HQ coring and ended in dolomite limestone at 16.6 mbg. - Slough observed at 2.4 mbgs in the silt layer upon completion of drilling. - No water seepage observed during and after drilling. - A monitoring well was installed using 50 mm dia. PVC SCH40 pipe upon completion of testhole drilling.		
17				
18				
19				



P-12 Shallow (Clay)

wsp canada group

CLIENT Golder Associates Ltd.

PROJECT NAME Prairie Green Landfill - Geotech Assmt.

PROJECT NUMBER 211-08078-00

PROJECT LOCATION Stony Mountain, MB

DATE STARTED 21/8/4 **COMPLETED** 21/8/4

GROUND ELEVATION 232.71 m **HOLE SIZE** 125 mm

DRILLING CONTRACTOR Maple Leaf Drilling

GROUND WATER LEVELS:

DRILLING METHOD Solid Stem Auger - B54X Track Rig

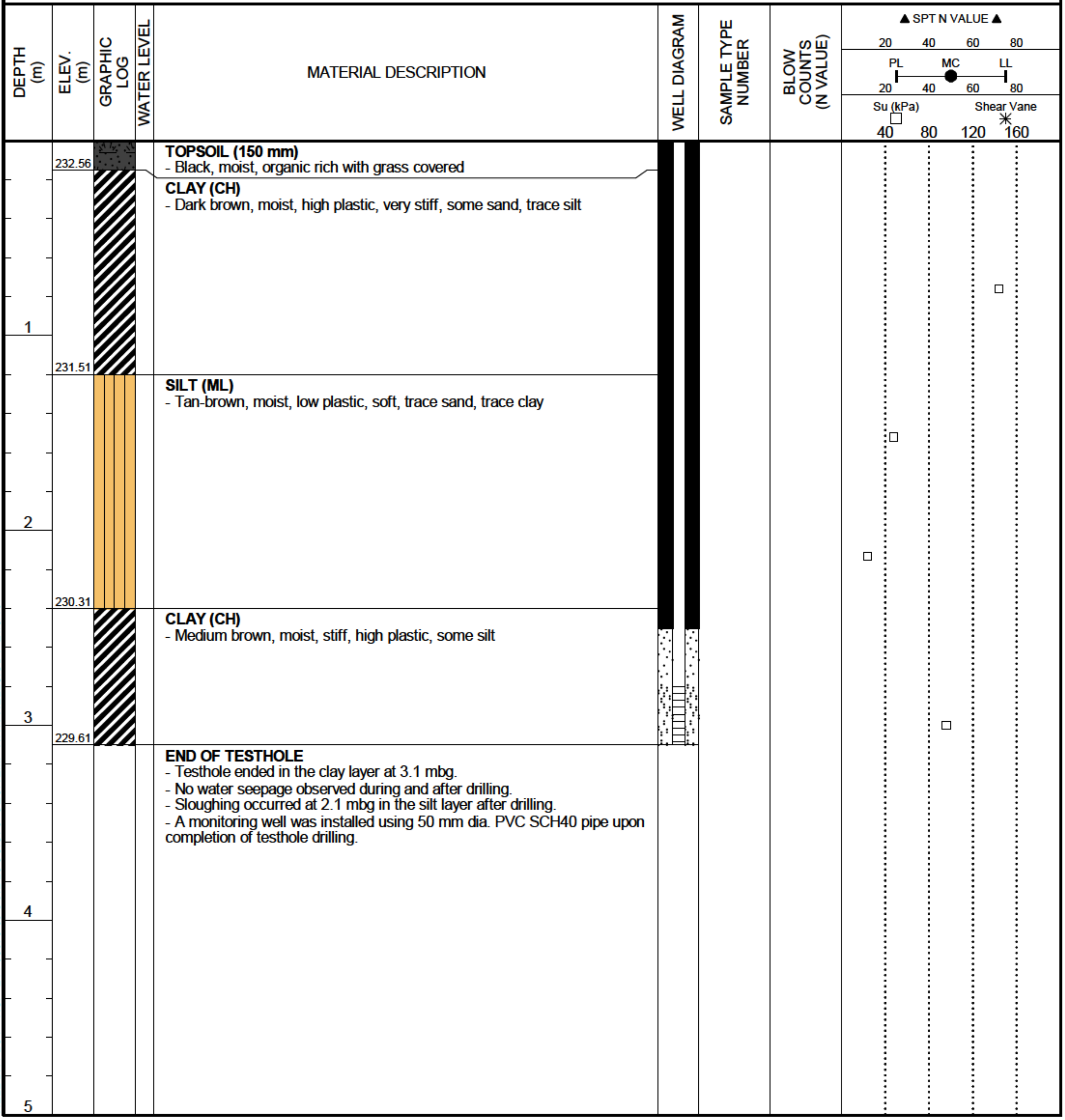
AT TIME OF DRILLING ---

LOGGED BY Wei Gao **CHECKED BY** Fabiano Gondim

AT END OF DRILLING ---

NOTES 12188.995 N, 11861.281 E

AFTER DRILLING ---



TOPSOIL (150 mm)
- Black, moist, organic rich with grass covered

CLAY (CH)
- Dark brown, moist, high plastic, very stiff, some sand, trace silt

SILT (ML)
- Tan-brown, moist, low plastic, soft, trace sand, trace clay

CLAY (CH)
- Medium brown, moist, stiff, high plastic, some silt

END OF TESTHOLE
- Testhole ended in the clay layer at 3.1 mbg.
- No water seepage observed during and after drilling.
- Sloughing occurred at 2.1 mbg in the silt layer after drilling.
- A monitoring well was installed using 50 mm dia. PVC SCH40 pipe upon completion of testhole drilling.

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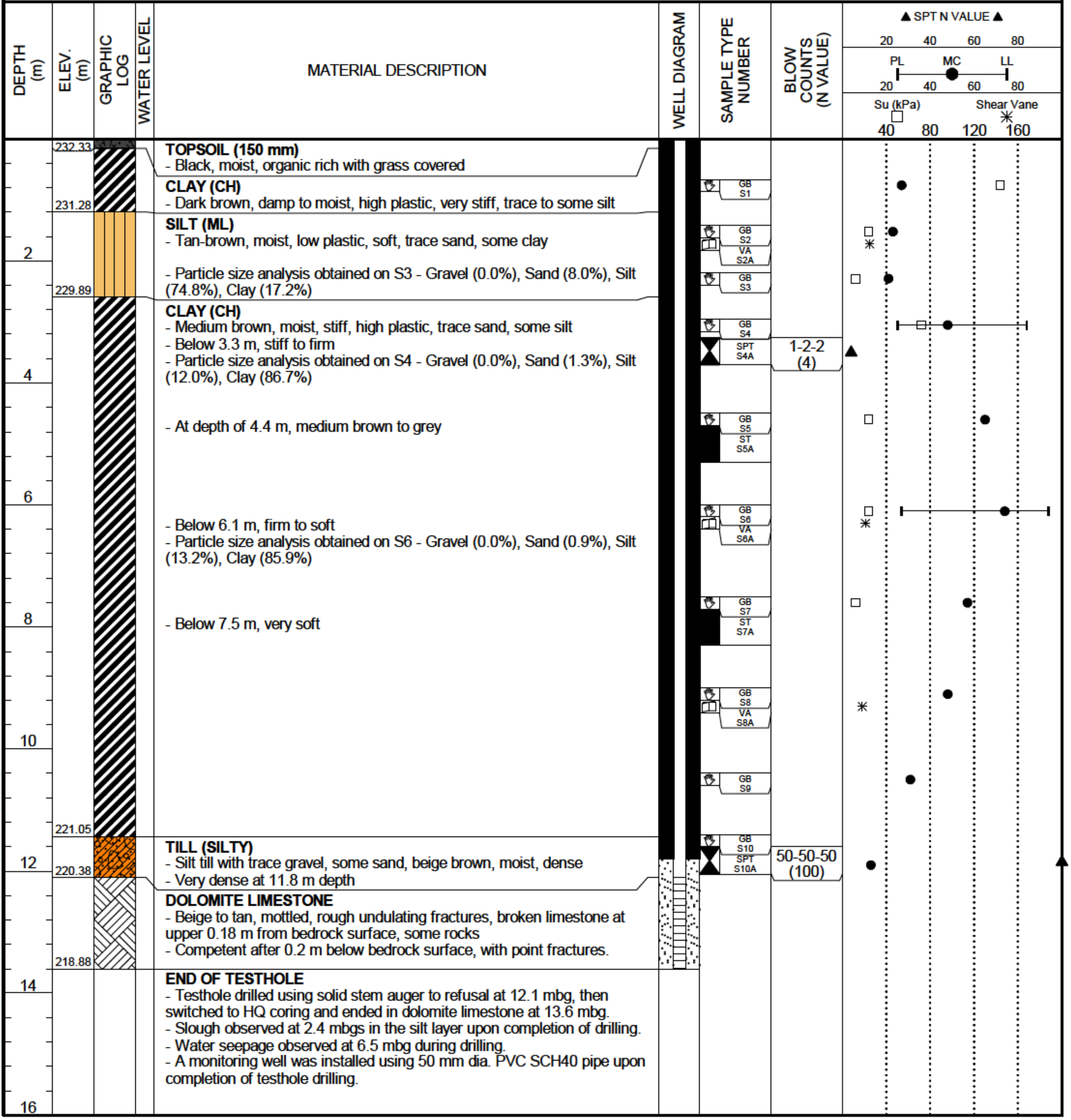
P- 13 Deep (Bedrock)

PAGE 1 OF 1

CLIENT Golder Associates Ltd.
PROJECT NAME Prairie Green Landfill - Geotech Assmt.
PROJECT NUMBER 211-08078-00
PROJECT LOCATION Stony Mountain, MB
DATE STARTED 21/8/4 **COMPLETED** 21/8/4
GROUND ELEVATION 232.48 m **HOLE SIZE** 125 mm
DRILLING CONTRACTOR Maple Leaf Drilling
GROUND WATER LEVELS:
DRILLING METHOD Solid Stem Auger - B54X Track Rig
AT TIME OF DRILLING ---
LOGGED BY Wei Gao **CHECKED BY** Fabiano Gondim
AT END OF DRILLING ---
NOTES 11627.228 N, 12096.346 E
AFTER DRILLING ---

ELEV. (m)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)
232.33	**TOPSOIL (150 mm)** - Black, moist, organic rich with grass covered		
231.28	**CLAY (CH)** - Dark brown, damp to moist, high plastic, very stiff, trace to some silt	GB S1	
229.89	**SILT (ML)** - Tan-brown, moist, low plastic, soft, trace sand, some clay - Particle size analysis obtained on S3 - Gravel (0.0%), Sand (8.0%), Silt (74.8%), Clay (17.2%)	GB S2 VA S2A GB S3	
221.05	**CLAY (CH)** - Medium brown, moist, stiff, high plastic, trace sand, some silt - Below 3.3 m, stiff to firm - Particle size analysis obtained on S4 - Gravel (0.0%), Sand (1.3%), Silt (12.0%), Clay (86.7%) - At depth of 4.4 m, medium brown to grey - Below 6.1 m, firm to soft - Particle size analysis obtained on S6 - Gravel (0.0%), Sand (0.9%), Silt (13.2%), Clay (85.9%) - Below 7.5 m, very soft	GB S4 SPT S4A GB S5 ST S5A GB S6 VA S6A GB S7 ST S7A GB S8 VA S8A GB S9	 1-2-2 (4)
220.38	**TILL (SILTY)** - Silt till with trace gravel, some sand, beige brown, moist, dense - Very dense at 11.8 m depth	GB S10 SPT S10A	 50-50-50 (100)
218.88	**DOLOMITE LIMESTONE** - Beige to tan, mottled, rough undulating fractures, broken limestone at upper 0.18 m from bedrock surface, some rocks - Competent after 0.2 m below bedrock surface, with point fractures.		
	END OF TESTHOLE - Testhole drilled using solid stem auger to refusal at 12.1 mbg, then switched to HQ coring and ended in dolomite limestone at 13.6 mbg. - Slough observed at 2.4 mbgs in the silt layer upon completion of drilling. - Water seepage observed at 6.5 mbg during drilling. - A monitoring well was installed using 50 mm dia. PVC SCH40 pipe upon completion of testhole drilling.		



wsp canada group

P-13 Shallow (Clay)

PAGE 1 OF 1

CLIENT Golder Associates Ltd.

PROJECT NAME Prairie Green Landfill - Geotech Assmt.

PROJECT NUMBER 211-08078-00

PROJECT LOCATION Stony Mountain, MB

DATE STARTED 21/8/4 **COMPLETED** 21/8/4

GROUND ELEVATION 232.44 m **HOLE SIZE** 125 mm

DRILLING CONTRACTOR Maple Leaf Drilling

GROUND WATER LEVELS:

DRILLING METHOD Solid Stem Auger - B54X Track Rig

AT TIME OF DRILLING ---

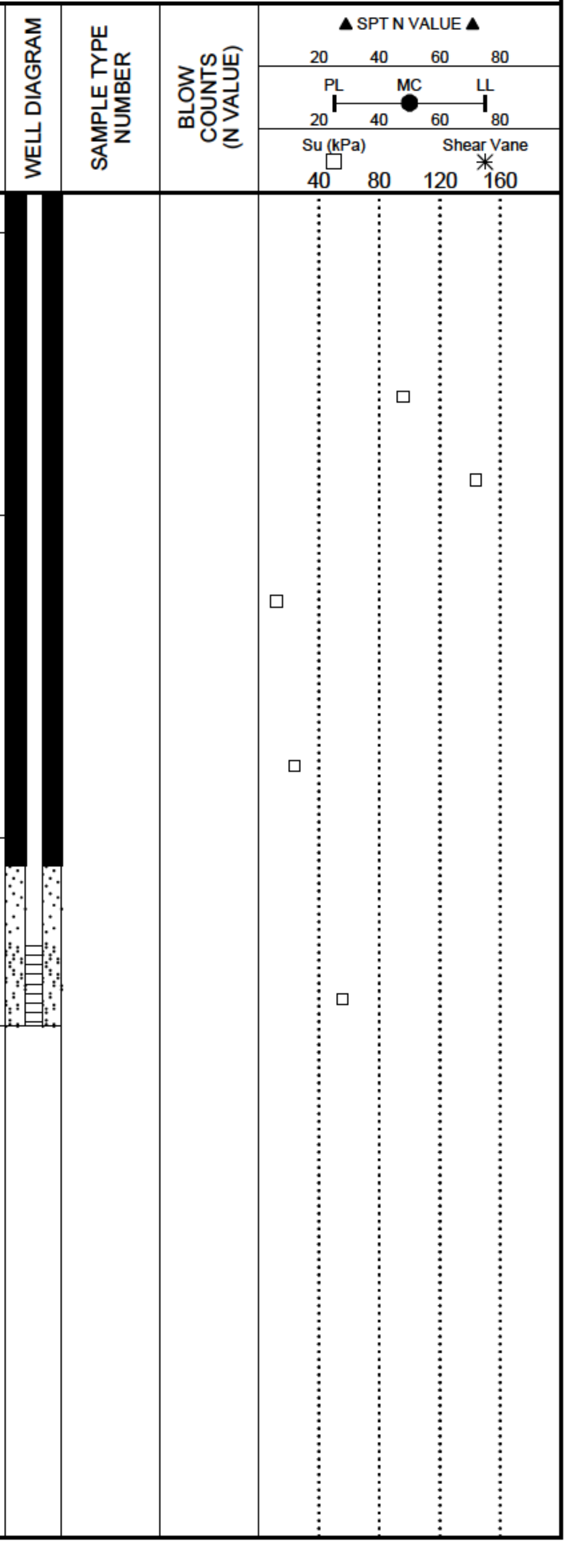
LOGGED BY Wei Gao **CHECKED BY** Fabiano Gondim

AT END OF DRILLING ---

NOTES 11625.449 N, 12096.274 E

AFTER DRILLING ---

DEPTH (m)	ELEV. (m)	MATERIAL DESCRIPTION
	232.29	**TOPSOIL (150 mm)** - Black, moist, organic rich with grass covered
1	231.24	**CLAY (CH)** - Medium brown, moist, high plastic, very stiff, some sand, trace silt
2	230.04	**SILT (ML)** - Tan-brown, moist, low plastic, soft, trace sand, trace clay
3	229.34	**CLAY (CH)** - Medium brown, moist, stiff, high plastic, trace sand, some silt
4 5		**END OF TESTHOLE** - Testhole ended in the clay layer at 3.1 mbg. - No water seepage observed during and after drilling. - Sloughing occurred at 1.8 mbg in the silt layer after drilling. - A monitoring well was installed using 50 mm dia. PVC SCH40 pipe upon completion of testhole drilling.



APPENDIX B

Laboratory Results

Table B.1: Summary of Consolidation Test Results for Lower Clay

Parameter	**Units**	**Sample S7A Borehole P-12 Deep (Bedrock)** **Sample Depth (7.62m - 8.38 m)**	**Sample S5A Borehole P-13 Deep (Bedrock)** **Sample Depth (4.57 m - 5.33 m)**
Initial Total Unit Weight	kN/m^3	17.7	15.7
Initial Water Content	%	47.4	61.4
Initial Void Ratio	-	1.24	1.77
Pre-consolidation Pressure, σ'_p	kPa	135	265
Recompression Index, C_r	-	0.07	0.19
Compression Index, C_c	-	0.6	0.8

Table B.2: Summary of Consolidated Undrained Triaxial Compression Test Results for Lower Clay

Parameter	**Units**	**Sample S7A Borehole P-12 Deep (Bedrock)** **Sample Depth (7.62m – 8.38 m)**	**Sample S5A Borehole P-13 Deep (Bedrock)** **Sample Depth (4.57 m – 5.33 m)**
Initial Total Unit Weight	kN/m^3	17.2	16.9
Initial Water Content	%	58.1	63.4
Initial Void Ratio	-	1.48	1.61
Effective Consolidation Pressure Range	kPa	100 to 400	100 to 400
Effective Friction Angle, ϕ’	Degrees	16.9	16.0
Effective Cohesion, c’	kPa	0	4.6

MOISTURE CONTENT OF SOIL AND ROCK
(ASTM D2216)

Client: Wei Gao (P.Eng), WSP Canada Inc.
Project: Prairie Green Landfill - Soil Testing
Site Location: -
Date Tested: 2021-08-09

Lab No.: 21-001-005-1
Project No.: 211-08078-00
Report Date: 2021-08-11
Tested By: BMH/PD

	Test Hole No.	Sample No.	Depth (ft)	Moisture Content (%)
P-13 Deep (Bedrock)	TH01	S1	2.5	26.9
	TH01	S2	5.0	22.7
	TH01	S3	7.5	21.4
	TH01	S4	10.0	47.9
	TH01	S5	15.0	64.9
	TH01	S6	20.0	73.5
	TH01	S7	25.0	56.9
	TH01	S8	30.0	48.2
	TH01	S9	35.0	31.2
	TH01	S10	40.0	12.6
P-12 Deep (Bedrock)	TH03	S1	2.5	33.3
	TH03	S2	5.0	20.9
	TH03	S3	7.5	24.0
	TH03	S4	10.0	47.4
	TH03	S5	15.0	59.4
	TH03	S6	20.0	71.8
	TH03	S7	25.0	53.3
	TH03	S8	30.0	41.5
	TH03	S9	33.0	17.5
	TH03	S10	40.0	10.3
	TH03	S11	45.0	11.5

Reviewed by: [redacted]

Bruno Marinelli, 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:	Wei Gao (P.Eng) - WSP Canada Inc.	**Lab No.:**	21-001-005-2
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00
Site Location:	-	**Report Date:**	2021-08-11
Date Sampled:	2021-08-05	**Date Tested:**	2021-08-10
Sampled By:	Wei Gao **Date Received:** 2021-08-06	**Tested By:**	PD/BMH

Bore Hole No.: TH01 **Sample No.:** S4 **Depth :** 10.0 ft

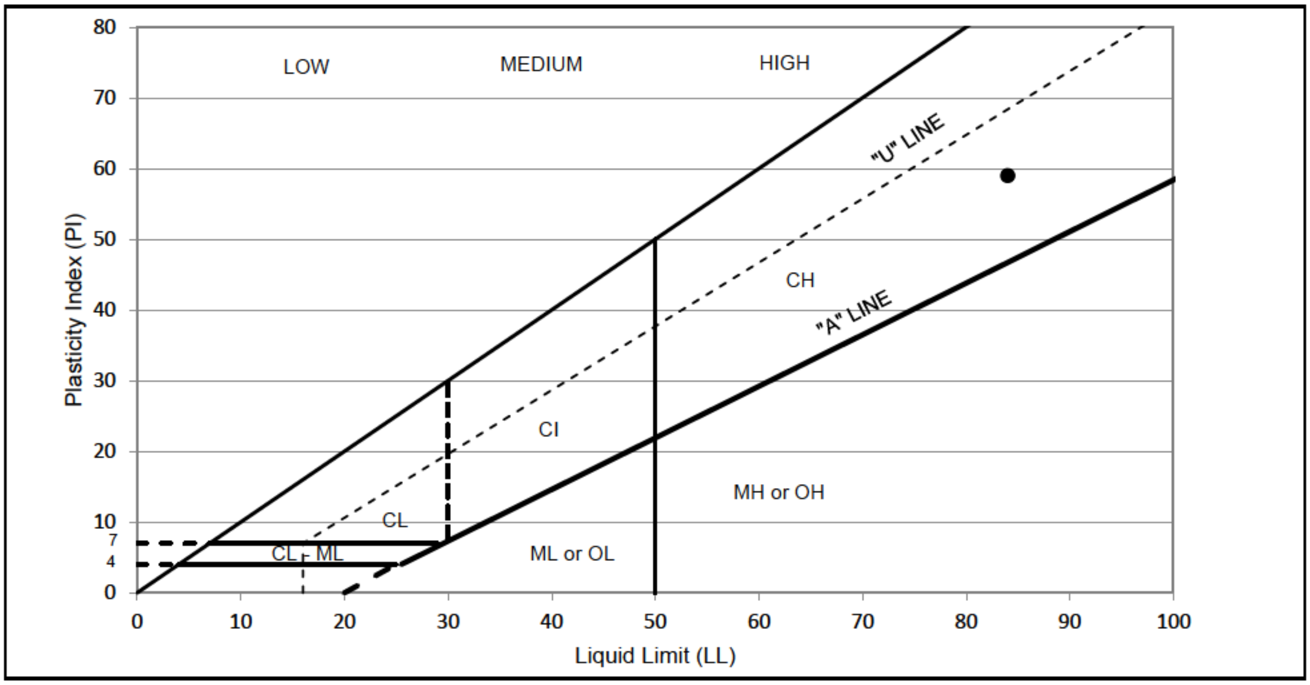
Drying Method: Oven **Method:** Multi-Point

Liquid Limit Test
(Manual, Plastic Grooving tool)

Trial	A	B	C
No. of Blows	20	26	31
Moisture Content (%)	84.7	84.2	83.7

Plastic Limit Test
(Hand rolled)

Trial	A	B
Moisture Content (%)	24.5	24.5



USCS Symbol CH

LL, Liquid Limit (%) 84

PL, Plastic Limit (%) 25

PI, Plasticity Index 59

Comment: As received moisture content is 47.9 %.

Soil Description: High Plastic Clay

Reviewed by: [redacted]

Bruno Marinelli, 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.

ATTERBERG LIMITS
(ASTM D4318)

Client:	Wei Gao (P.Eng) - WSP Canada Inc.	**Lab No.:**	21-001-005-3
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00
Site Location:	-	**Report Date:**	2021-08-11
Date Sampled:	2021-08-05	**Date Tested:**	2021-08-10
Sampled By:	Wei Gao **Date Received:** 2021-08-06	**Tested By:**	PD/BMH

Bore Hole No.: TH01 **Sample No.:** S6 **Depth :** 20.0 ft

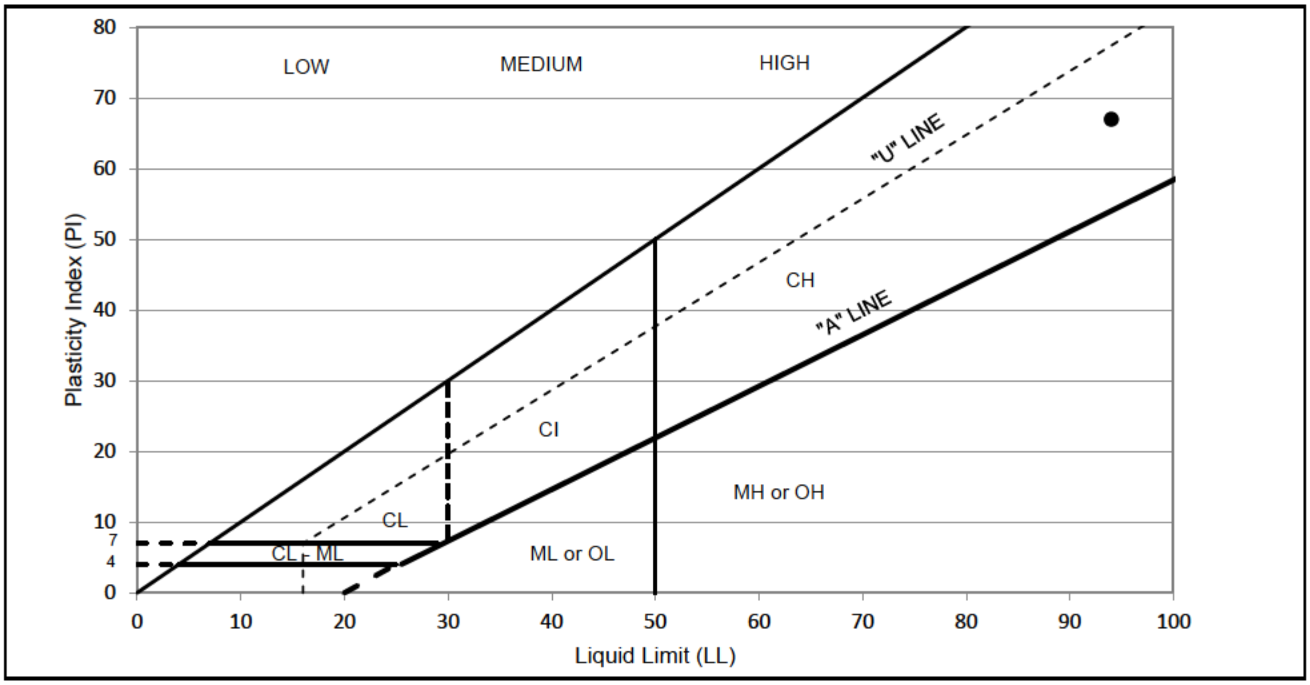
Drying Method: Oven **Method:** Multi-Point

Liquid Limit Test
(Manual, Plastic Grooving tool)

Trial	**A**	**B**	**C**
No. of Blows	20	27	30
Moisture Content (%)	94.5	93.2	92.6

Plastic Limit Test
(Hand rolled)

Trial	**A**	**B**
Moisture Content (%)	27.4	27.4



USCS Symbol CH

Soil Description: High Plastic Clay

LL, Liquid Limit (%) 94

PL, Plastic Limit (%) 27

Reviewed by: [redacted]

PI, Plasticity Index 67

Bruno Marinelli, CET

Comment: As received moisture content is 73.5 %.

ATTERBERG LIMITS
(ASTM D4318)

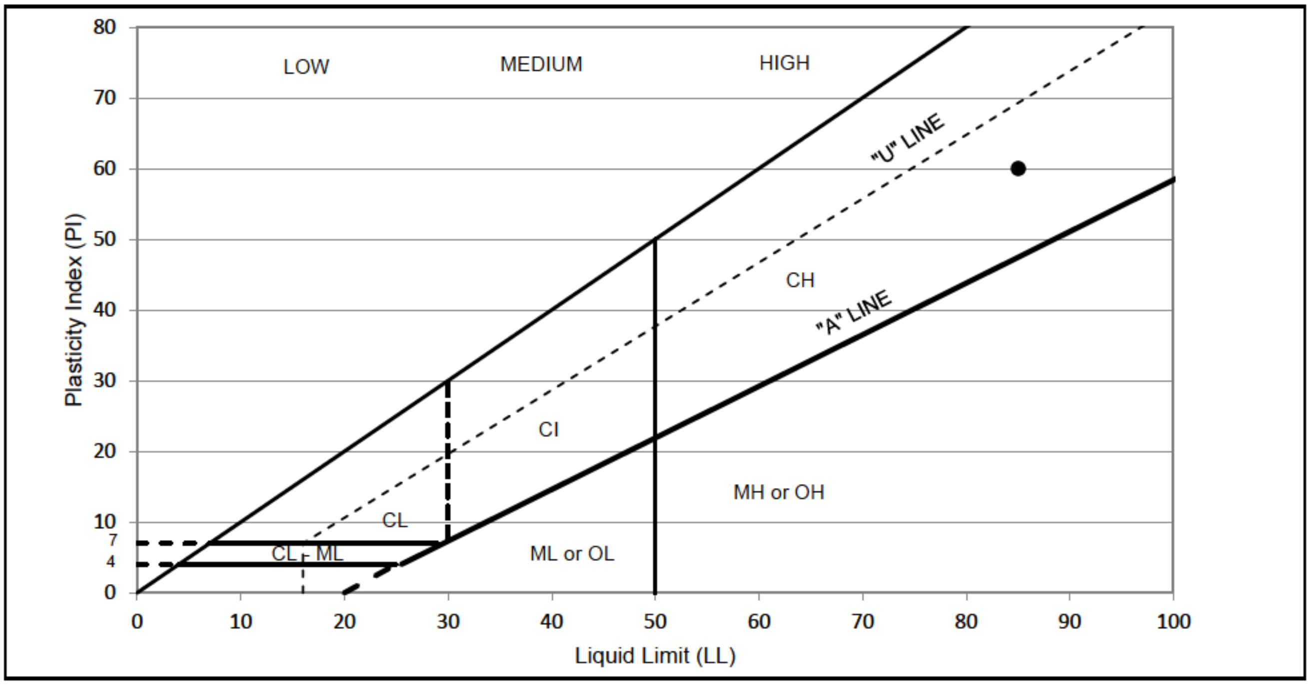
Client:	Wei Gao (P.Eng) - WSP Canada Inc.			**Lab No.:**	21-001-005-4
Project:	Prairie Green Landfill - Soil Testing			**Project No.:**	211-08078-00
Site Location:	-			**Report Date:**	2021-08-11
Date Sampled:	2021-08-05			**Date Tested:**	2021-08-10
Sampled By:	Wei Gao	**Date Received:**	2021-08-06	**Tested By:**	PD/BMH
Bore Hole No.:	TH03	**Sample No.:**	S4	**Depth :**	10.0 ft
Drying Method:	Oven	**Method:**	Multi-Point		

Liquid Limit Test
(Manual, Plastic Grooving tool)

Trial	**A**	**B**	**C**
No. of Blows	21	27	30
Moisture Content (%)	85.8	85.0	84.6

Plastic Limit Test
(Hand rolled)

Trial	**A**	**B**
Moisture Content (%)	24.4	24.8



USCS Symbol CH

Soil Description: High Plastic Clay

LL, Liquid Limit (%) 85

PL, Plastic Limit (%) 25

Reviewed by: [redacted]

Bruno Marinelli, CET

PI, Plasticity Index 60

Comment: As received moisture content is 47.4 %.

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:	Wei Gao (P.Eng) - WSP Canada Inc.	**Lab No.:**	21-001-005-5
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00
Site Location:	-	**Report Date:**	2021-08-11
Date Sampled:	2021-08-05	**Date Tested:**	2021-08-10
Sampled By:	Wei Gao **Date Received:** 2021-08-06	**Tested By:**	PD/BMH

Bore Hole No.: TH03 **Sample No.:** S6 **Depth :** 20.0 ft

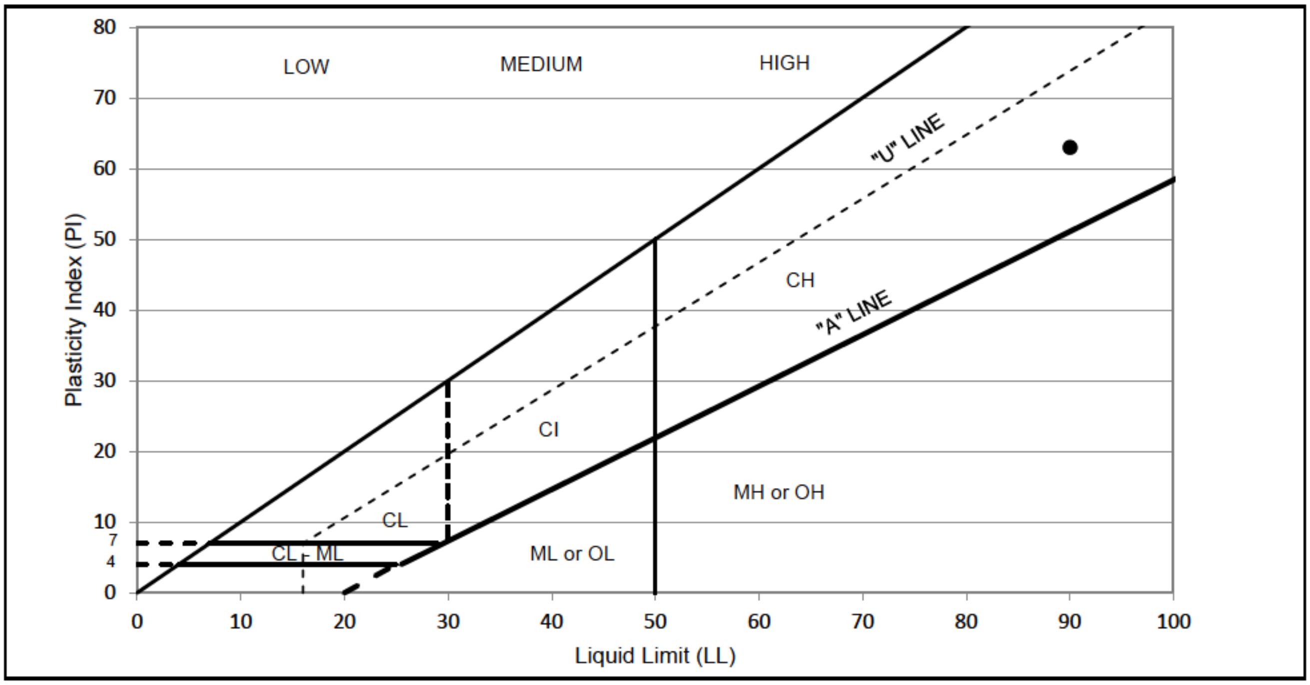
Drying Method: Oven **Method:** Multi-Point

Liquid Limit Test
(Manual, Plastic Grooving tool)

Trial	A	B	C
No. of Blows	19	25	29
Moisture Content (%)	91.7	90.2	89.2

Plastic Limit Test
(Hand rolled)

Trial	A	B
Moisture Content (%)	26.9	26.9



USCS Symbol CH

LL, Liquid Limit (%) 90

PL, Plastic Limit (%) 27

PI, Plasticity Index 63

Soil Description: High Plastic Clay

Reviewed by: [redacted]

Bruno Marinelli, CET

Comment: As received moisture content is 71.8 %.

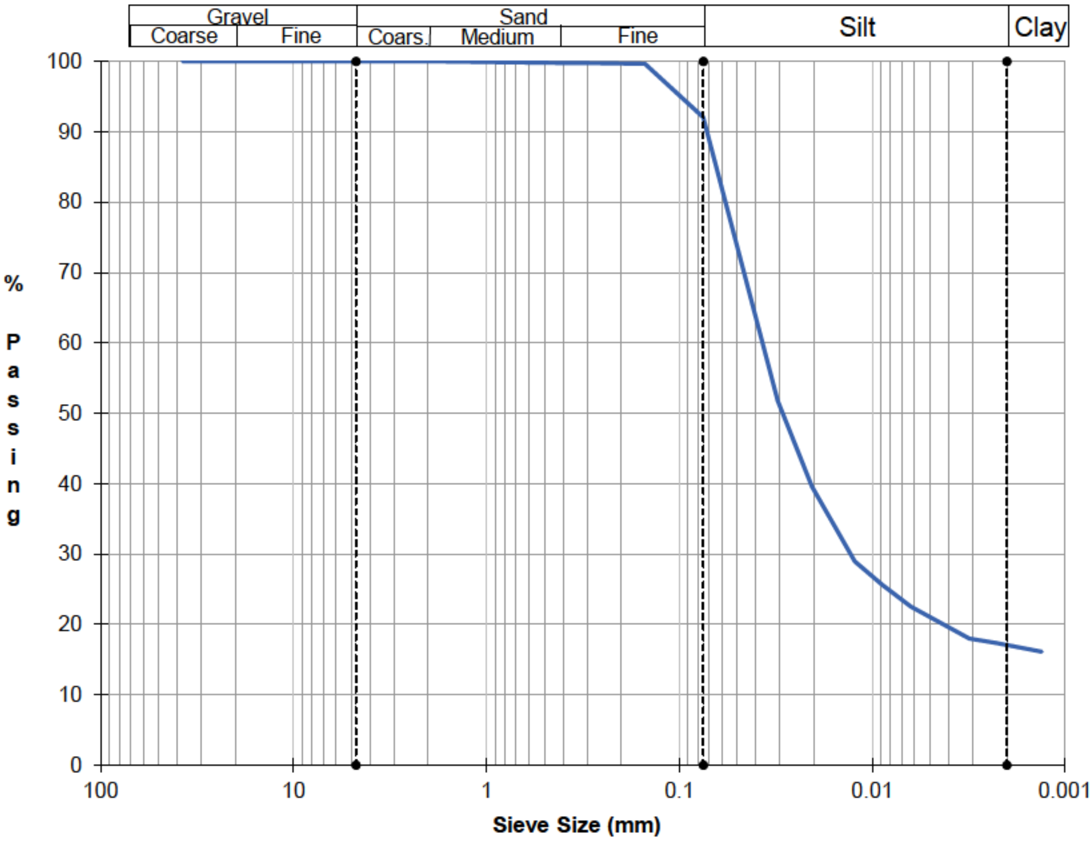
The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS
(ASTM D6913 & D7928)

Client:	Wei Gao (P.Eng), WSP Canada Inc.	**Lab No.:**	21-001-005-6
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00

Borehole No.:	TH01	**Sampled by:**	Wei Gao	**Sample Source:**	Project Site
Sample No.:	S3	**Date Sampled:**	2021-08-05	**Date Received:**	2021-08-06
Depth (ft):	7.5	**Sampling Method:**	Grab	**Tested By:**	BMH/PD

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	99.7
0.150	99.6
0.075	92.0
0.031	51.8
0.020	39.6
0.012	28.9
0.009	25.6
0.006	22.5
0.0031	18.0
0.0023	17.4
0.0013	16.1

Percent of: Gravel = 0.0% Sand = 8.0% Silt = 74.8% Clay = 17.2%

Sample Description: Silt, some clay, trace sand.
Remarks: Separation made on No 10 sieve (2.0 mm).

Reviewed by: [redacted]

Bruno Marinelli, CET

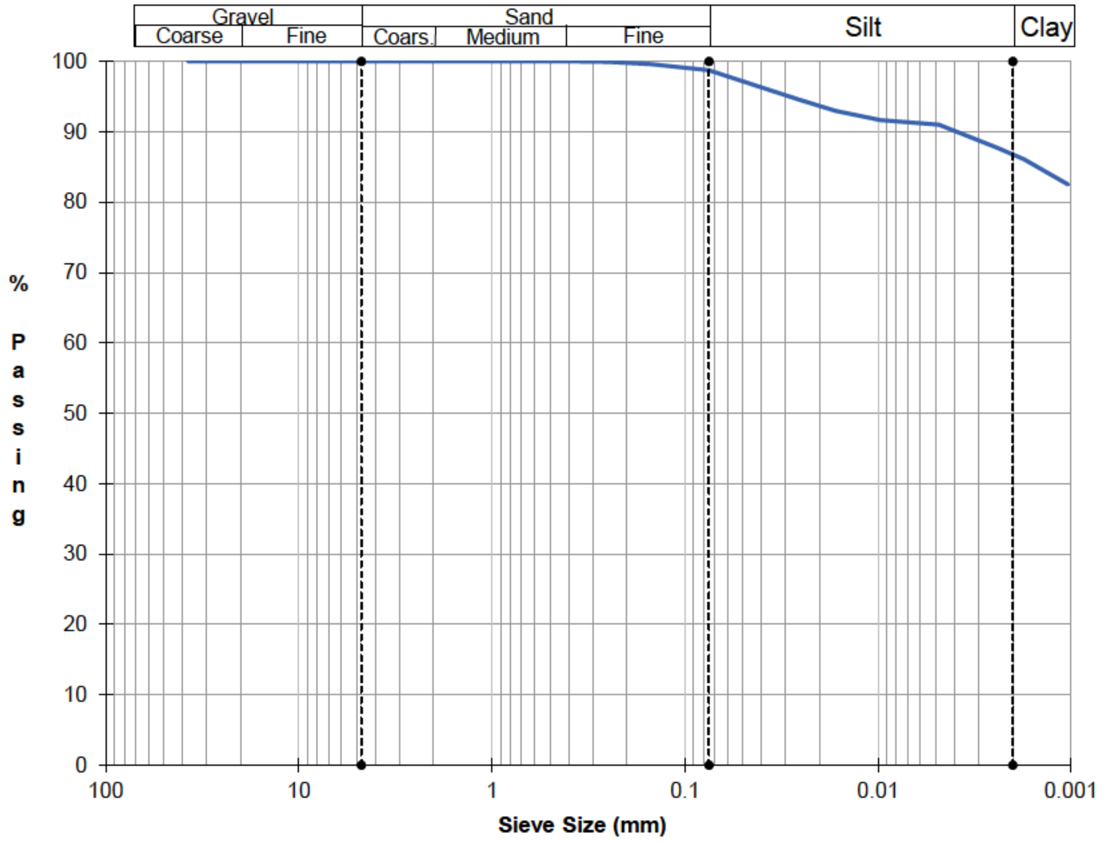
The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS
(ASTM D6913 & D7928)

Client:	Wei Gao (P.Eng), WSP Canada Inc.	**Lab No.:**	21-001-005-7
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00

Borehole No.:	TH01	**Sampled by:**	Wei Gao	**Sample Source:**	Project Site
Sample No.:	S4	**Date Sampled:**	2021-08-05	**Date Received:**	2021-08-06
Depth (ft):	10.0	**Sampling Method:**	Grab	**Tested By:**	BMH/PD

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	100.0
0.425	100.0
0.250	99.9
0.150	99.6
0.075	98.7
0.026	94.6
0.017	92.9
0.010	91.6
0.007	91.3
0.005	91.0
0.0024	87.7
0.0018	86.1
0.0010	82.5

Percent of: Gravel = 0.0% Sand = 1.3% Silt = 12.0% Clay = 86.7%

Sample Description: Clay, some silt, trace sand.

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

Reviewed by: [redacted]

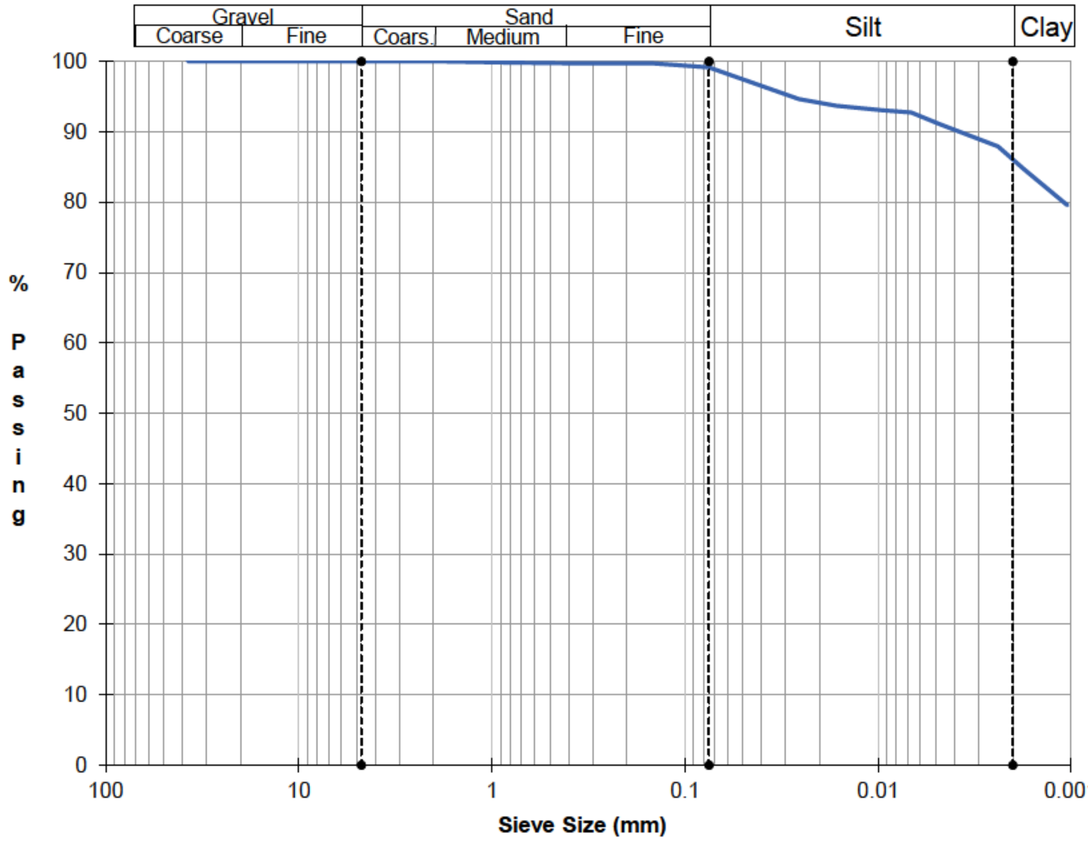
Bruno Marinelli, CET

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS (ASTM D6913 & D7928)

Client:	Wei Gao (P.Eng), WSP Canada Inc.	**Lab No.:**	21-001-005-8
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00

Borehole No.:	TH01	**Sampled by:**	Wei Gao	**Sample Source:**	Project Site
Sample No.:	S6	**Date Sampled:**	2021-08-05	**Date Received:**	2021-08-06
Depth (ft):	20.0	**Sampling Method:**	Grab	**Tested By:**	BMH/PD

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	99.8
0.425	99.7
0.250	99.7
0.150	99.7
0.075	99.1
0.026	94.6
0.016	93.7
0.009	93.0
0.007	92.7
0.005	91.1
0.0024	87.9
0.0018	84.7
0.0010	79.5

Percent of: Gravel = 0.0% Sand = 0.9% Silt = 13.2% Clay = 85.9%

Sample Description: Clay, some silt, trace sand.
Remarks: Separation made on No 10 sieve (2.0 mm).

Reviewed by: [redacted]

Bruno Marinelli, CET

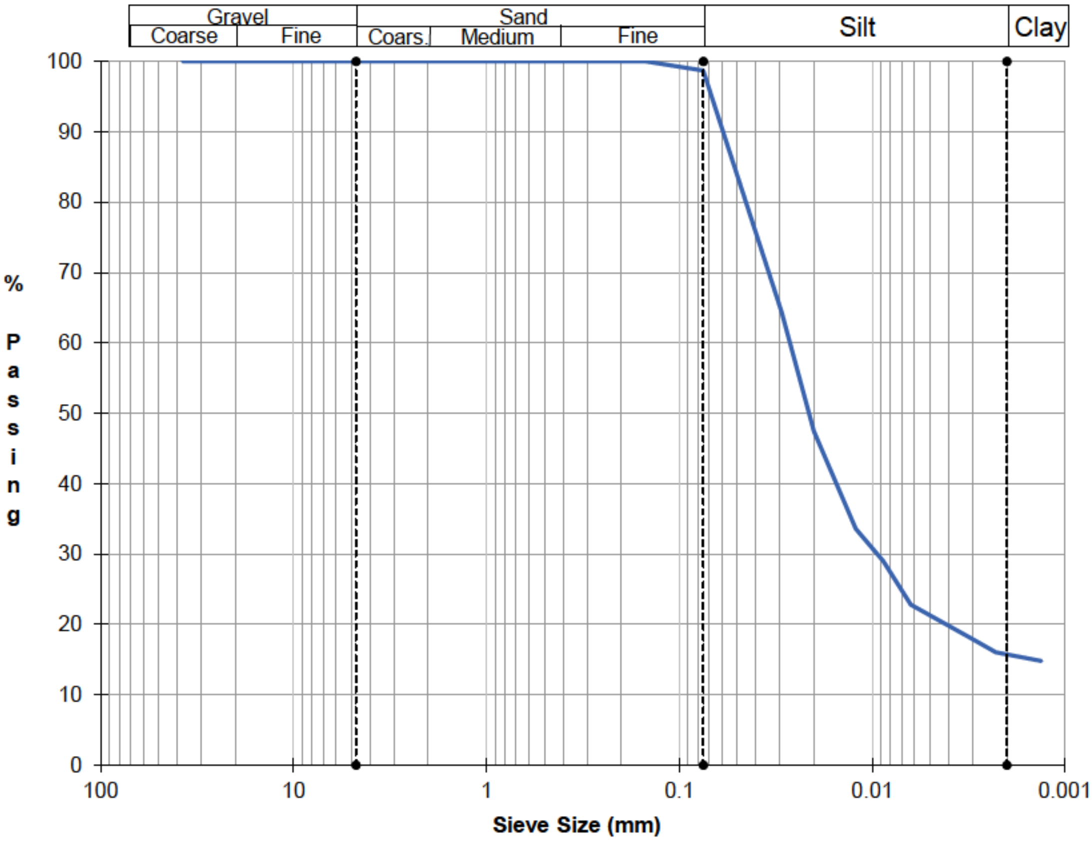
The test data given herein pertain to the sample provided. Reporting of these data constitutes a testing service. Engineering review and interpretation may be provided upon written request.

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS
(ASTM D6913 & D7928)

Client: Wei Gao (P.Eng), WSP Canada Inc.
Lab No.: 21-001-005-9
Project: Prairie Green Landfill - Soil Testing
Project No.: 211-08078-00

Borehole No.: TH03
Sampled by: Wei Gao
Sample Source: Project Site
Sample No.: S2
Date Sampled: 2021-08-05
Date Received: 2021-08-06
Depth (ft): 5.0
Sampling Method: Grab
Tested By: BMH/PD

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	100.0
0.425	100.0
0.250	100.0
0.150	100.0
0.075	98.7
0.029	64.4
0.020	47.4
0.012	33.6
0.009	29.0
0.006	22.8
0.0031	18.2
0.0023	16.0
0.0013	14.8

Percent of: Gravel = 0.0% Sand = 1.3% Silt = 83.3% Clay = 15.3%

Sample Description: Silt, some clay, trace sand.
Remarks: Separation made on No 10 sieve (2.0 mm).

Reviewed by: [redacted]
Bruno Marinelli, CET

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS
(ASTM D6913 & D7928)

Client: Wei Gao (P.Eng), WSP Canada Inc. **Lab No.:** 21-001-005-10

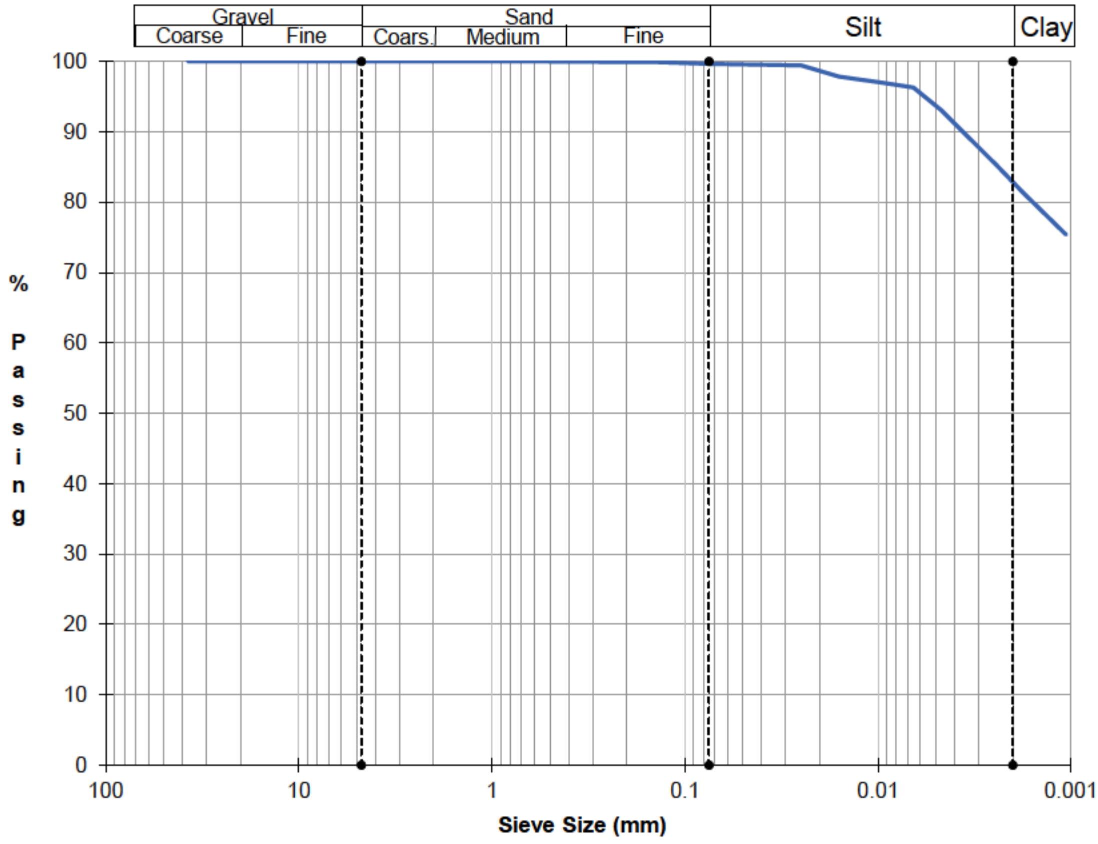
Project: Prairie Green Landfill - Soil Testing **Project No.:** 211-08078-00

Borehole No.: TH03 **Sampled by:** Wei Gao **Sample Source:** Project Site

Sample No.: S4 **Date Sampled:** 2021-08-05 **Date Received:** 2021-08-06

Depth (ft): 10.0 **Sampling Method:** Grab **Tested By:** BMH/PD

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	100.0
0.425	99.9
0.250	99.9
0.150	99.9
0.075	99.6
0.025	99.4
0.016	97.8
0.009	96.9
0.007	96.2
0.005	93.1
0.0024	85.2
0.0018	81.4
0.0011	75.3

Percent of: Gravel = 0.0% Sand = 0.4% Silt = 16.9% Clay = 82.7%

Sample Description: Clay, some silt, trace sand.

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

Reviewed by: [redacted]

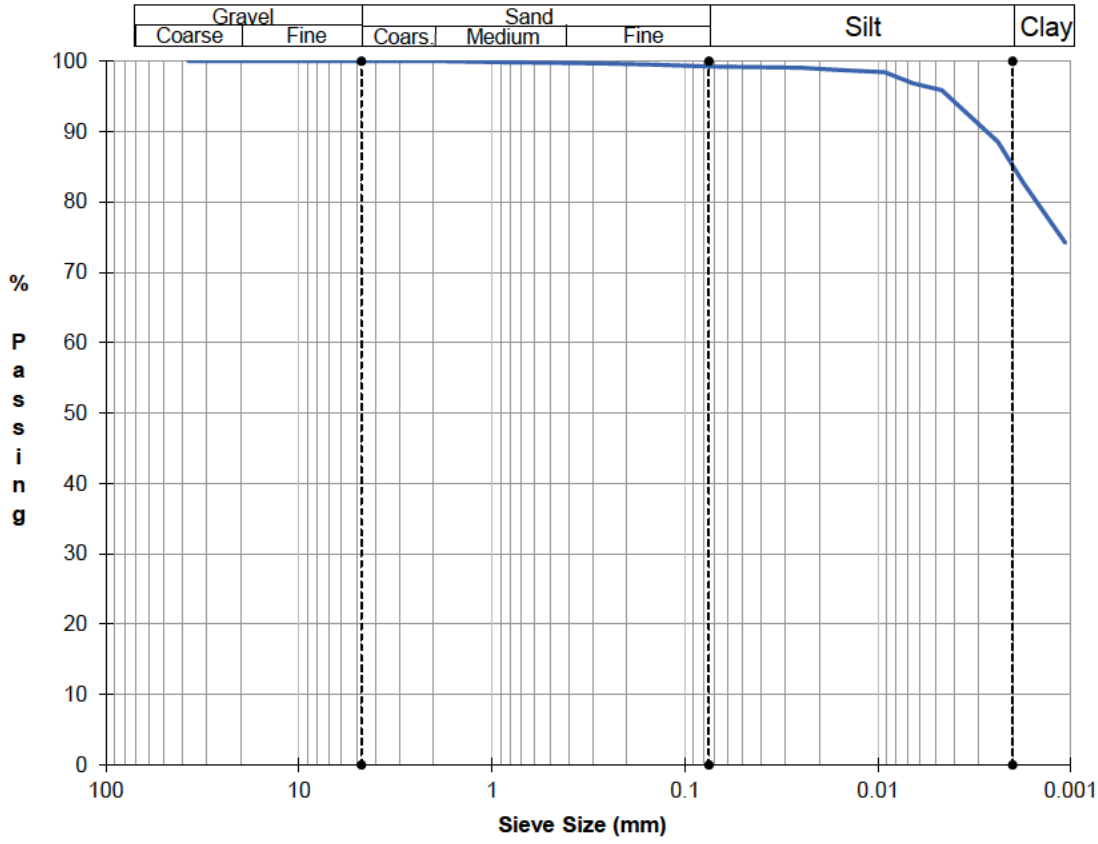
Bruno Marinelli, CET

PARTICLE-SIZE DISTRIBUTION OF SOILS USING SIEVE AND HYDROMETER ANALYSIS (ASTM D6913 & D7928)

Client:	Wei Gao (P.Eng), WSP Canada Inc.	**Lab No.:**	21-001-005-11
Project:	Prairie Green Landfill - Soil Testing	**Project No.:**	211-08078-00

Borehole No.:	TH03	**Sampled by:**	Wei Gao	**Sample Source:**	Project Site
Sample No.:	S6	**Date Sampled:**	2021-08-05	**Date Received:**	2021-08-06
Depth (ft):	20.0	**Sampling Method:**	Grab	**Tested By:**	BMH/PD

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	99.8
0.425	99.7
0.250	99.6
0.150	99.5
0.075	99.2
0.025	99.0
0.016	98.7
0.009	98.4
0.007	96.8
0.005	95.8
0.0024	88.5
0.0018	82.8
0.0011	74.2

Percent of: Gravel = 0.0% Sand = 0.8% Silt = 14.2% Clay = 85.0%

Sample Description: Clay, some silt, trace sand.

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

Reviewed by: [redacted]

Bruno Marinelli, 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.

GOLDER
MEMBER OF WSP

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. / B.K. / J.S. Date: December 14, 2021

Sample: P-12 S7A 7.62 - 8.38 m
Golder sample: SL7288-02

	Initial	Final
Sample height (mm):	25.3	22.2
Sample diameter (mm):	64.2	64.2
Sample area (cm^2):	32.4	32.4
Volume (cm^3)	82	72
Wet mass (g):	148.0	138.8
Dry mass (g):	100.4	100.4
Water content (%):	47.4	38.3
Solids content (%):	67.8	72.3
Wet density (kg/m^3):	1809	1931
Dry density (kg/m^3):	1227	1396
Void ratio:	1.24	0.98
Height of solids (mm):	11.3	11.3
Degree of saturation (%):	105	108

Specific gravity: 2.75 (assumed)

Load #	Stress (kPa)	Void ratio	Cummulative Work (kJ/m^3)	Average void ratio	Coefficient of consolidation, c_v (cm^2/s)
0	62	1.24	0.0		
1	112	1.23	1.4	1.23	4.0E-04
2	162	1.18	4.6	1.20	2.7E-04
3	296	1.00	23	1.09	2.2E-04
4	496	0.88	46	0.94	1.4E-04
5	958	0.71	112	0.80	2.2E-04
6	296	0.73			
7	112	0.77			
8	75	0.79			
9	3.4	0.98			

Comments:

Reviewed by: [redacted]

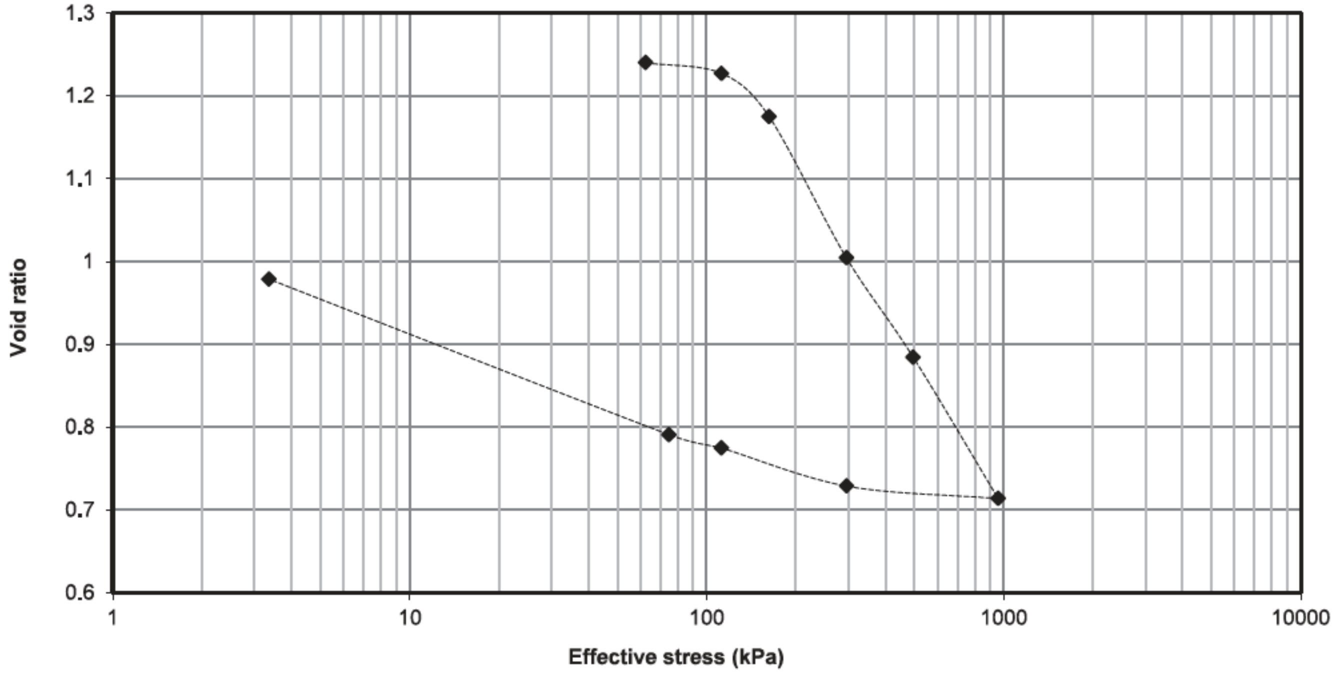
GOLDER
MEMBER OF WSP

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

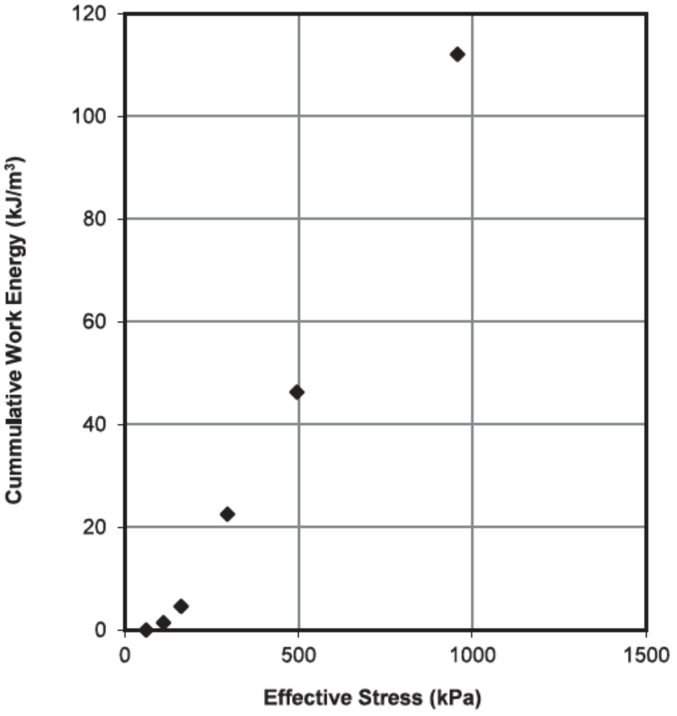
ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W. / B.K. / J.S.	Date: December 14, 2021
Sample:	P-12 S7A 7.62 - 8.38 m Golder sample: SL7288-02	

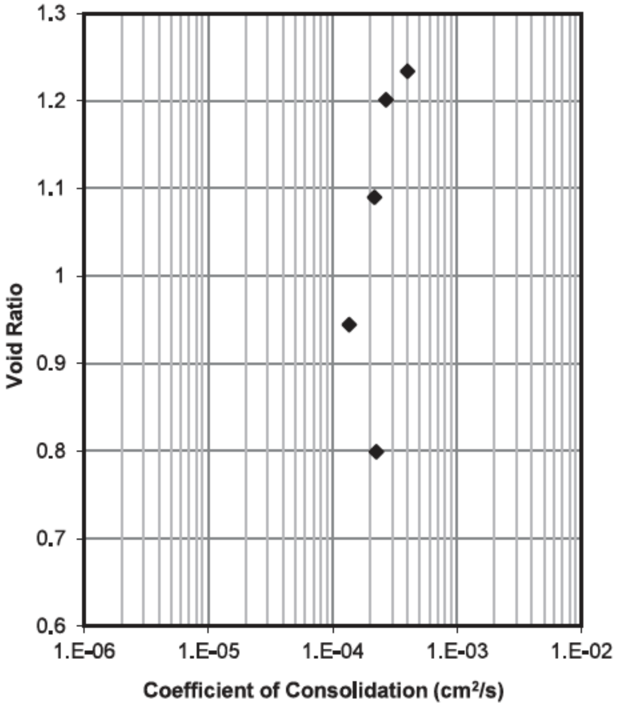
Void Ratio versus Effective Stress



Cummulative Work Energy versus Effective Stress



Coefficient of Consolidation versus Void Ratio



ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

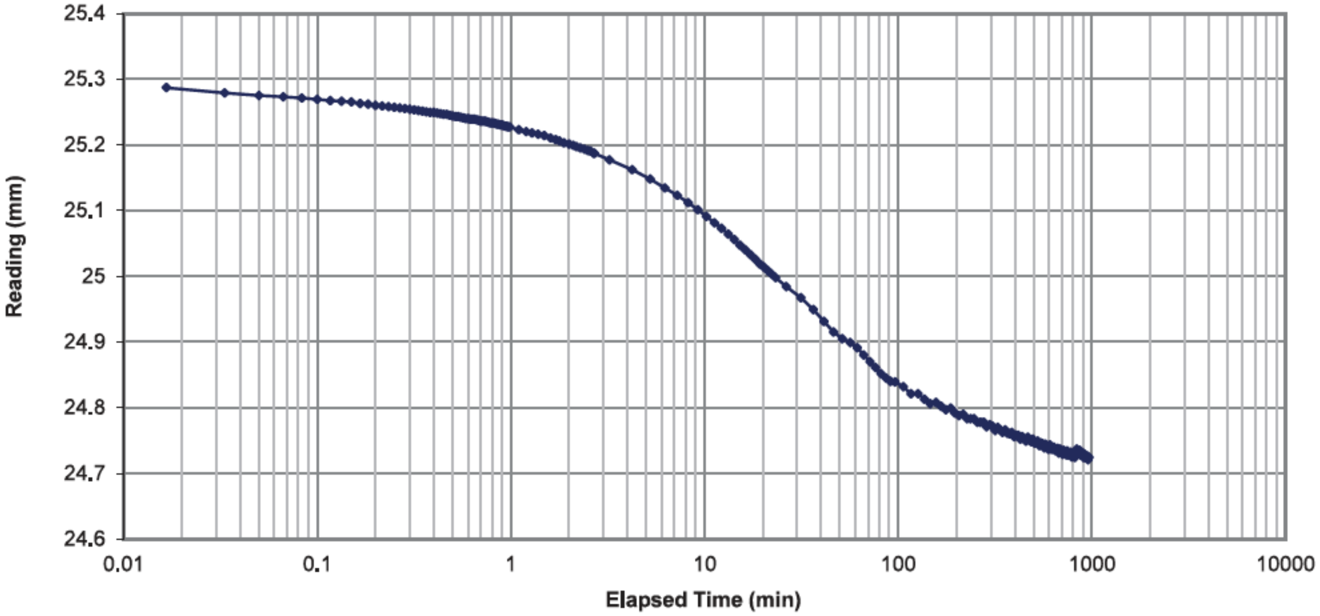
ASTM D2435

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. / B.K. / J.S. Date: December 14, 2021

Sample: P-12 S7A 7.62 - 8.38 m
Golder sample: SL7288-02

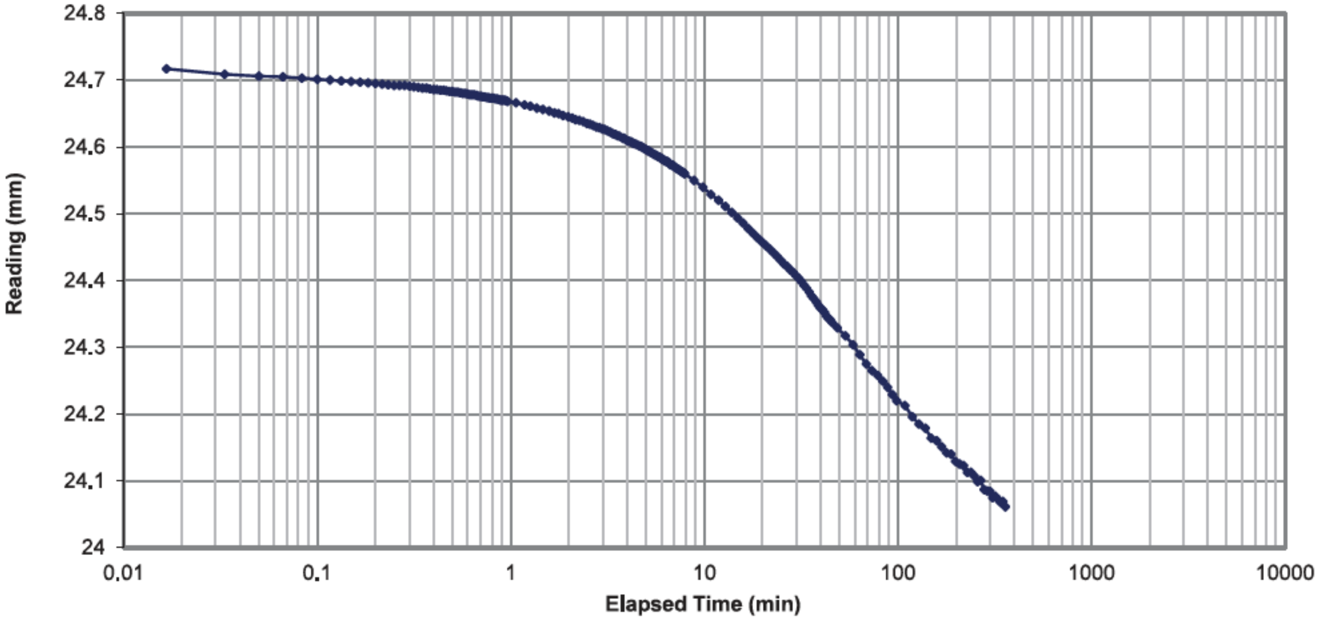
Load #: 1
Stress: 112 kPa

Dial Reading versus Elapsed Time



Load #: 2
Stress: 162 kPa

Dial Reading versus Elapsed Time

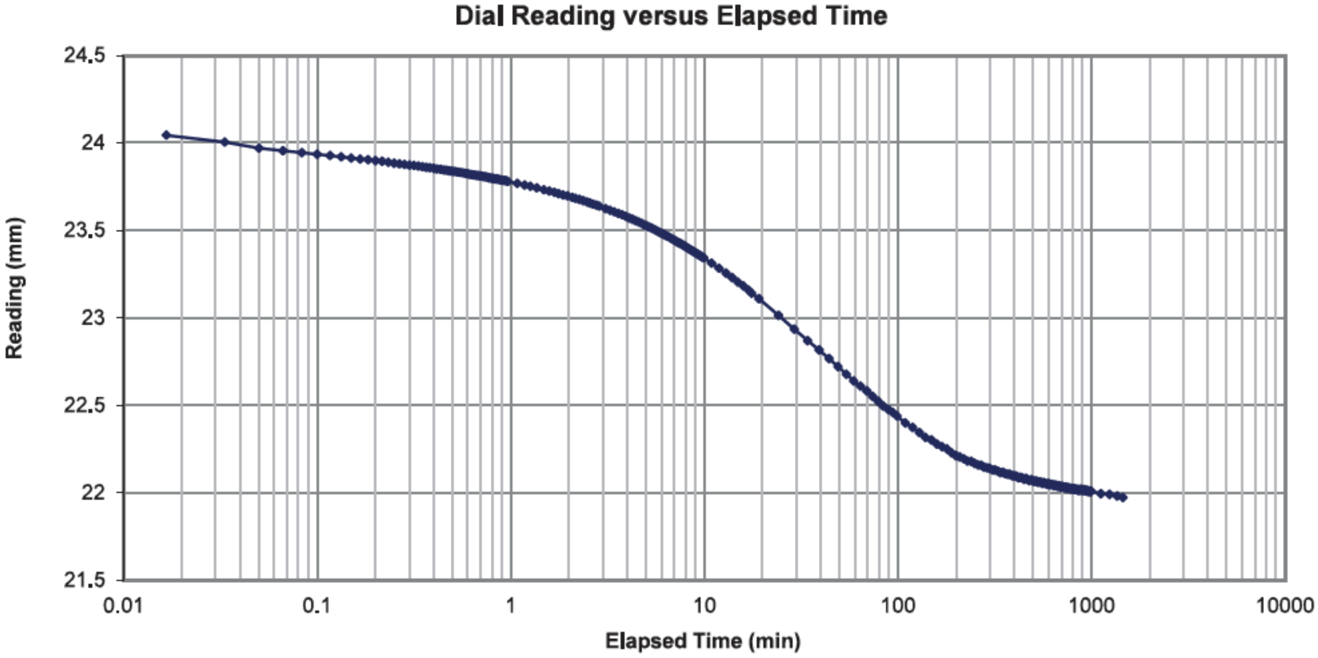


ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

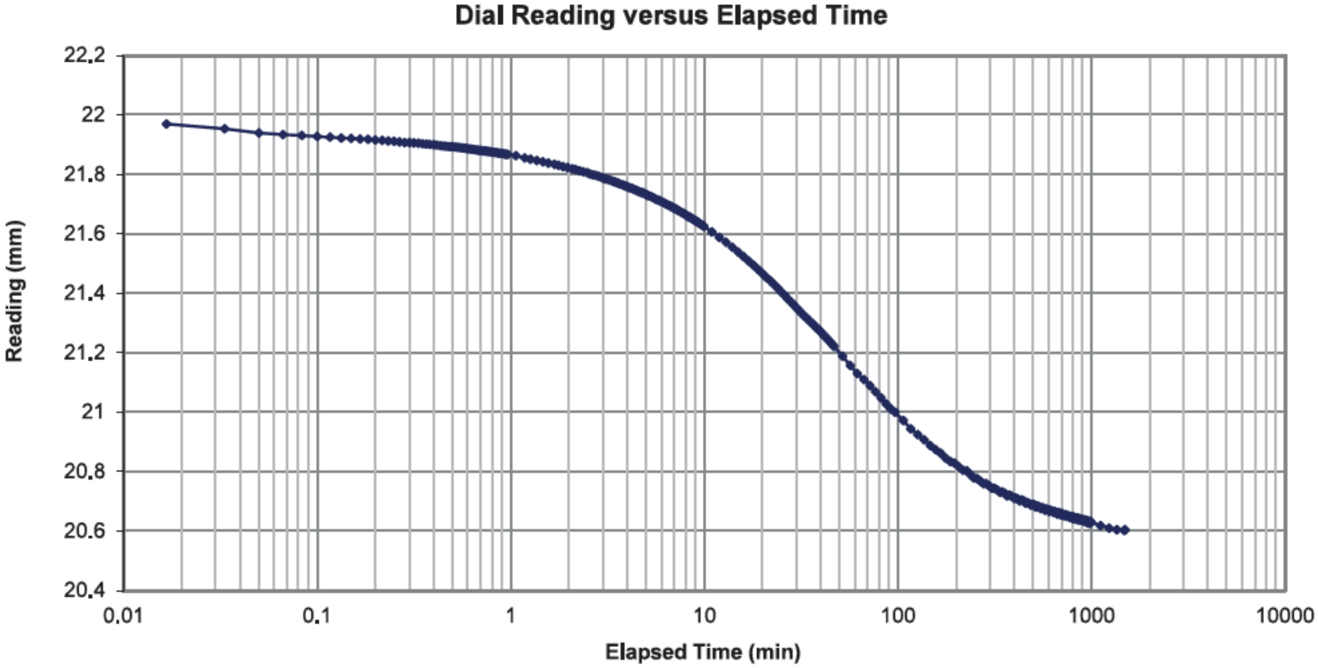
ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W. / B.K. / J.S.	Date: December 14, 2021
Sample:	P-12 S7A 7.62 - 8.38 m Golder sample: SL7288-02	

Load #: 3
Stress: 296 kPa



Load #: 4
Stress: 496 kPa

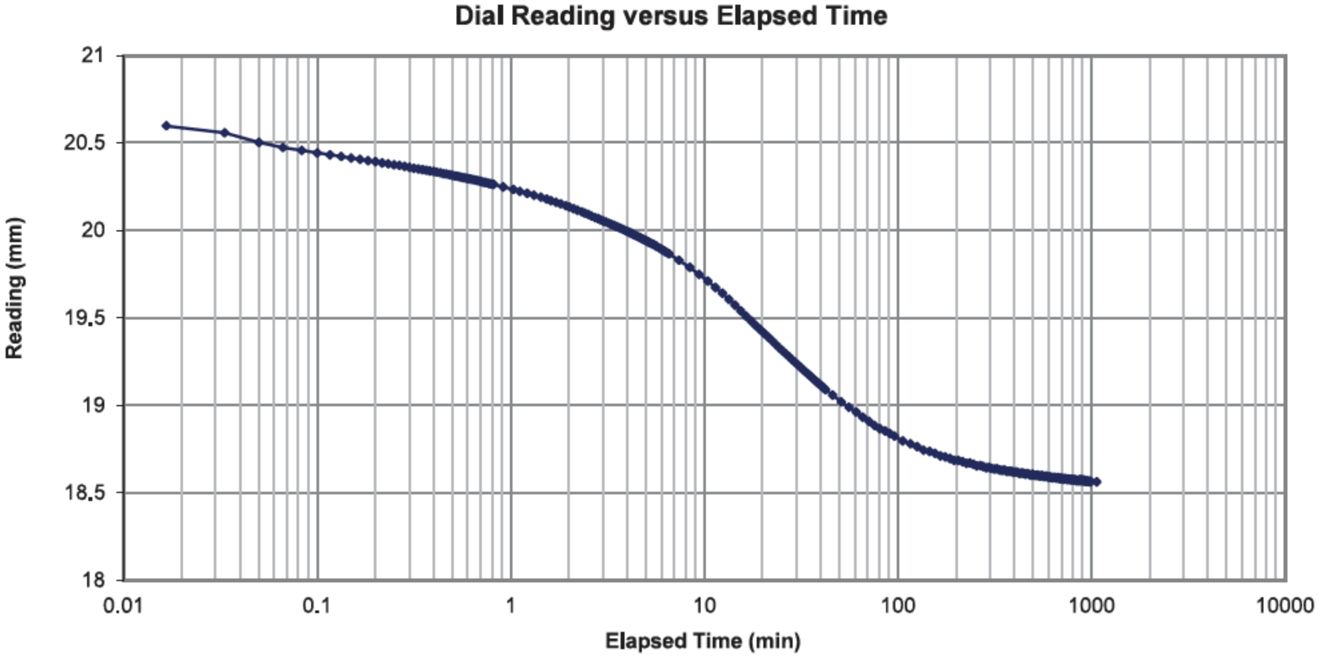


ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

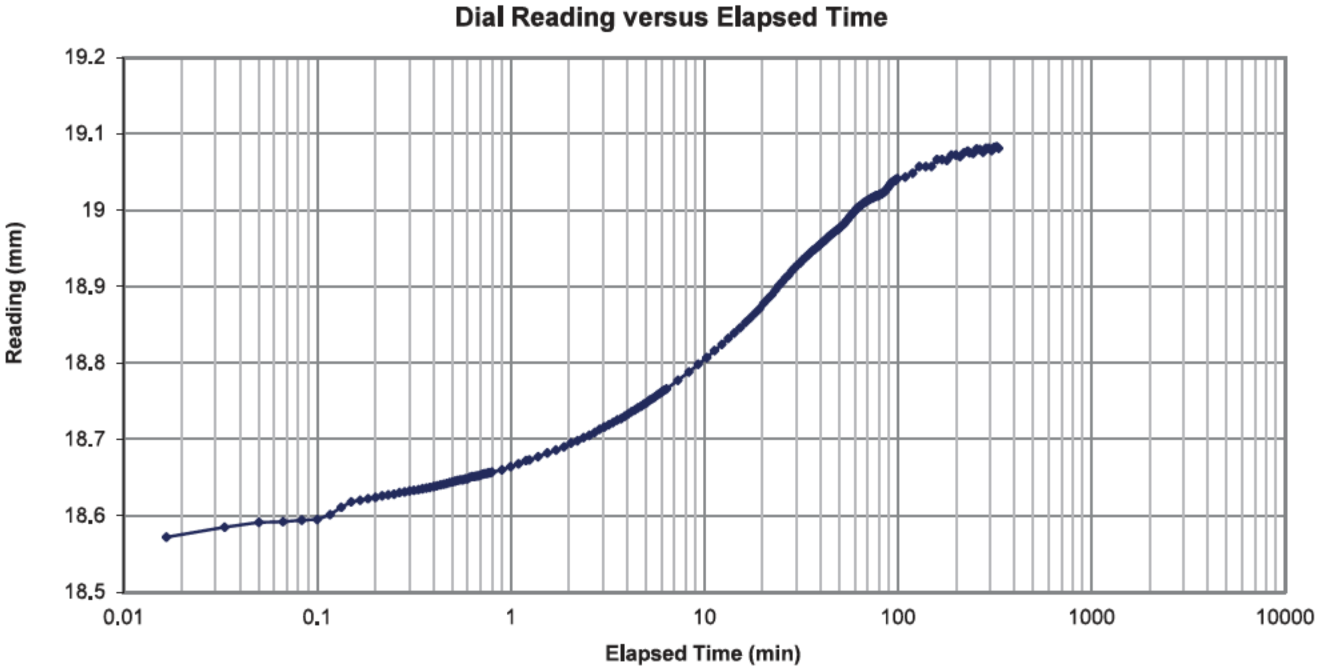
ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W. / B.K. / J.S.	Date: December 14, 2021
Sample:	P-12 S7A 7.62 - 8.38 m Golder sample: SL7288-02	

Load #: 5
Stress: 958 kPa



Load #: 6
Stress: 296 kPa



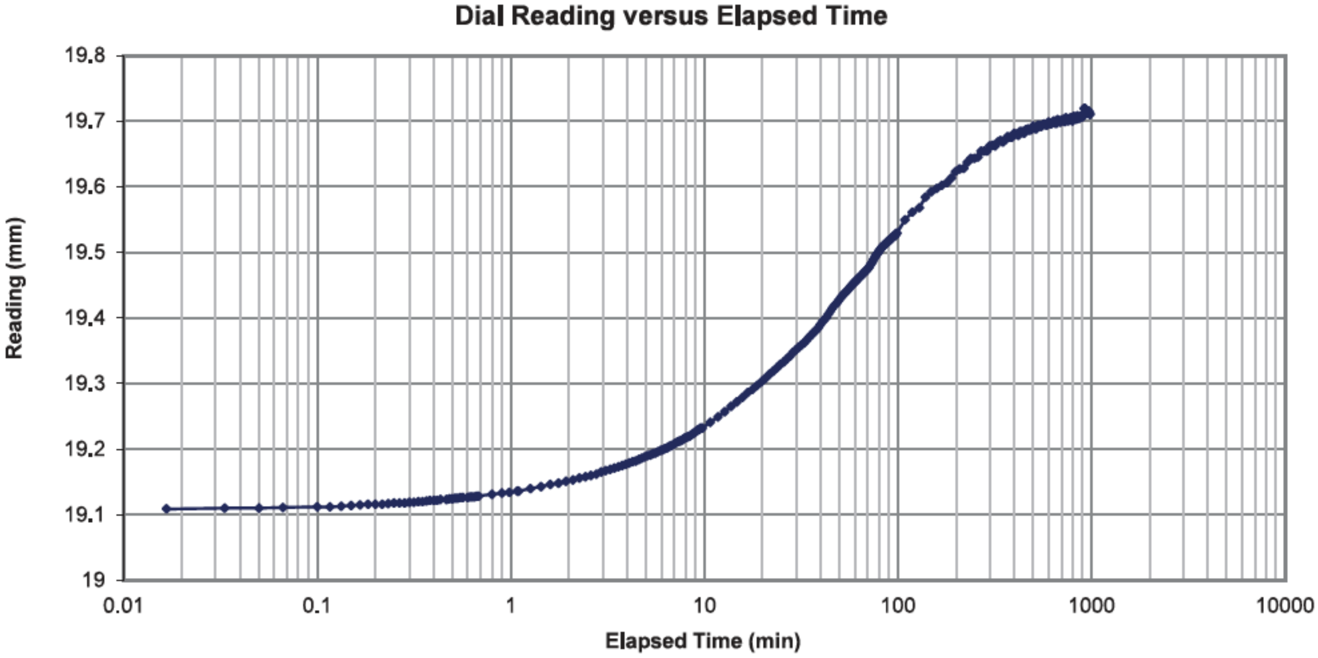
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

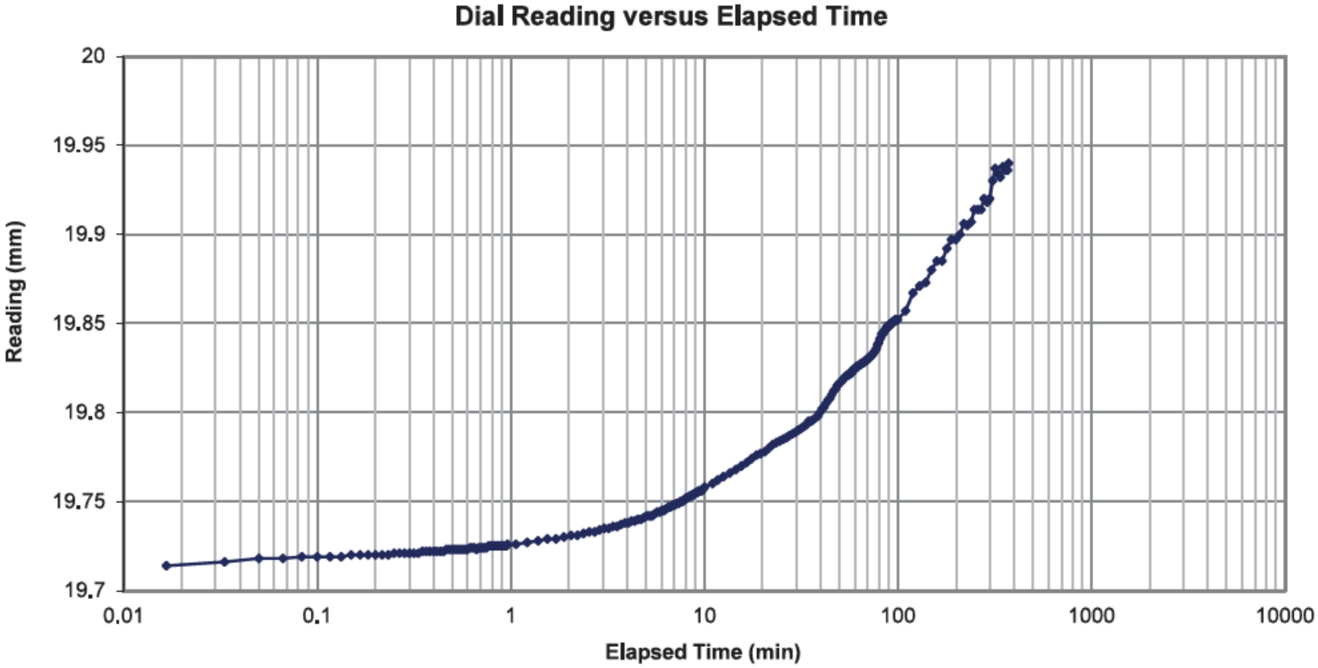
Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. / B.K. / J.S. Date: December 14, 2021

Sample: P-12 S7A 7.62 - 8.38 m
Golder sample: SL7288-02

Load #: 7
Stress: 112 kPa



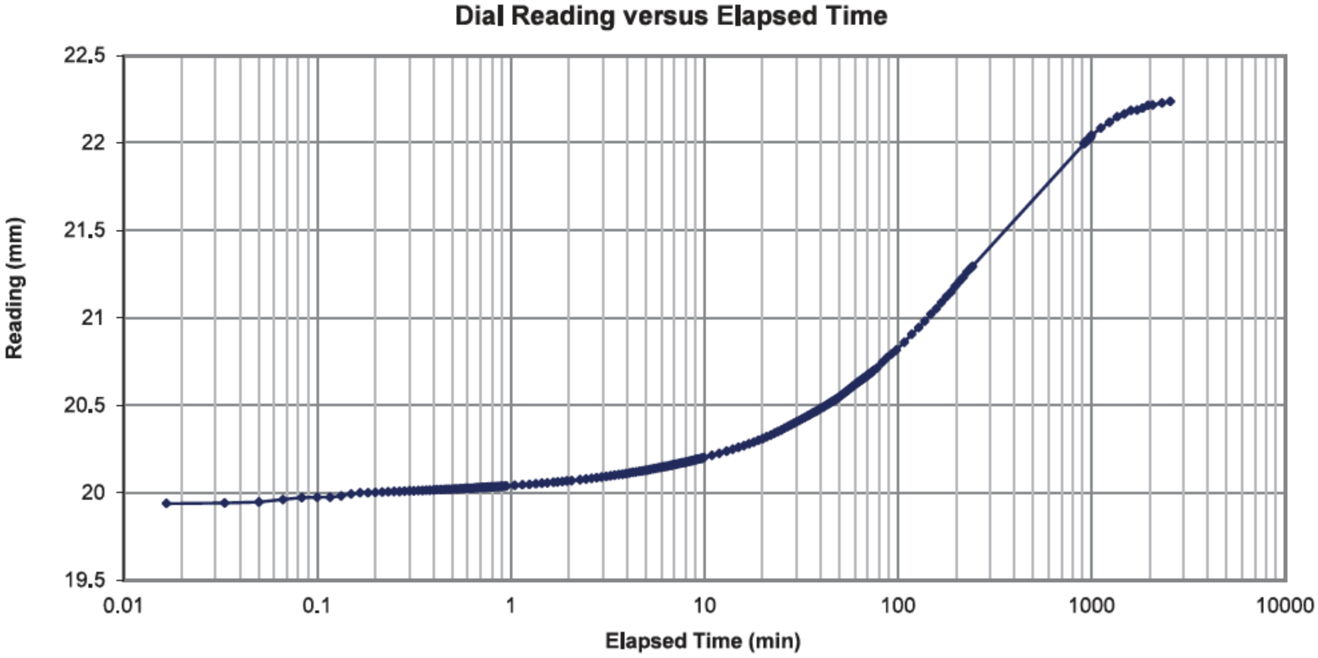
Load #: 8
Stress: 75 kPa



ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W. / B.K. / J.S.	Date: December 14, 2021
Sample:	P-12 S7A 7.62 - 8.38 m Golder sample: SL7288-02	
Load #:	9	
Stress:	3.4 kPa	



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ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

	Initial	Final			
Sample height (mm):	25.7	25.3	Specific gravity:	2.75	(assumed)
Sample diameter (mm):	64.2	64.2			
Sample area (cm^2):	32.4	32.4			
Volume (cm^3)	83	82			
Wet mass (g):	133.4	136.1			
Dry mass (g):	82.6	82.6			
Water content (%):	61.4	64.7			
Solids content (%):	62.0	60.7			
Wet density (kg/m^3):	1600	1660			
Dry density (kg/m^3):	991	1007			
Void ratio:	1.77	1.76			
Height of solids (mm):	9.3	9.3			
Degree of saturation (%):	95	101			

Load #	Stress (kPa)	Void ratio	Cummulative Work (kJ/m^3)	Average void ratio	Coefficient of consolidation, c_v (cm^2/s)
0	50	1.77	0.0		
1	100	1.72	2.2	1.75	2.1E-04
2	200	1.62	7.6	1.67	9.9E-05
3	400	1.47	25	1.54	7.7E-05
4	737	1.27	69	1.37	5.2E-05
5	1,200	1.10	144	1.19	2.8E-05
6	400	1.18			
7	100	1.31			
8	3.2	1.76			

Comments:

Reviewed by: [redacted]

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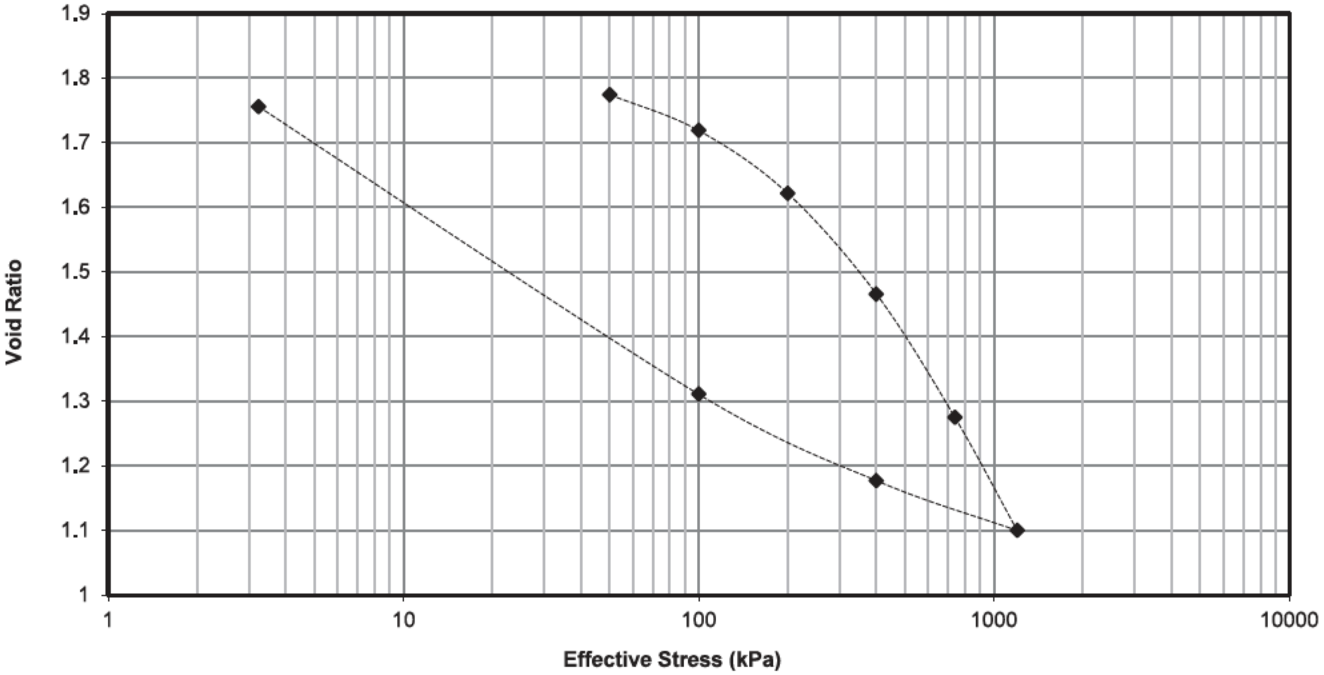
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

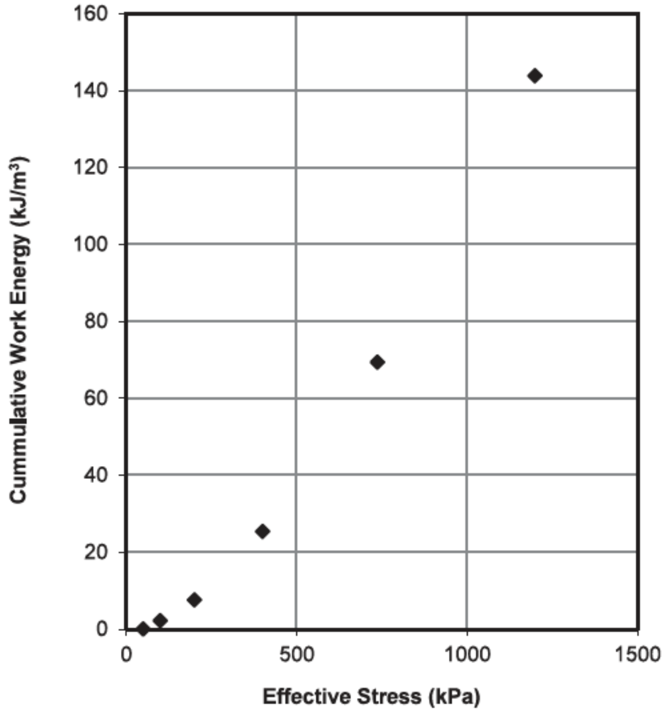
Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

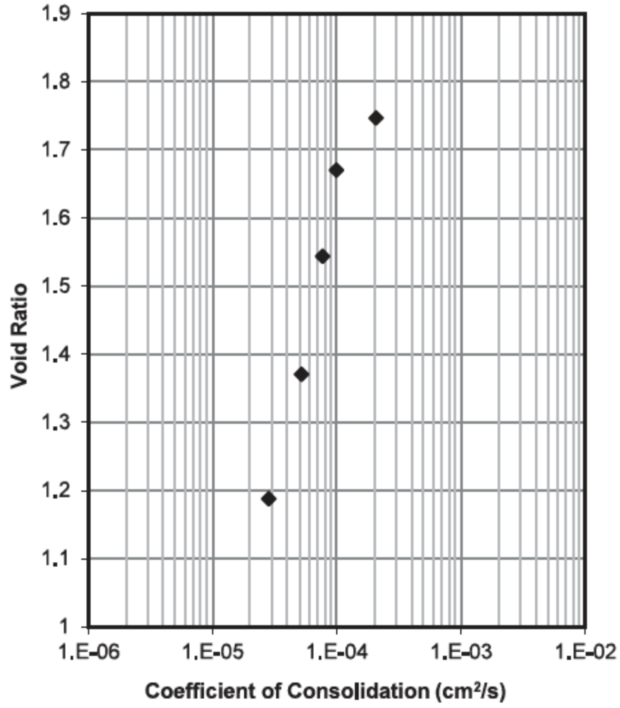
Void Ratio versus Effective Stress



Cummulative Work Energy versus Effective Stress



Coefficient of Consolidation versus Void Ratio



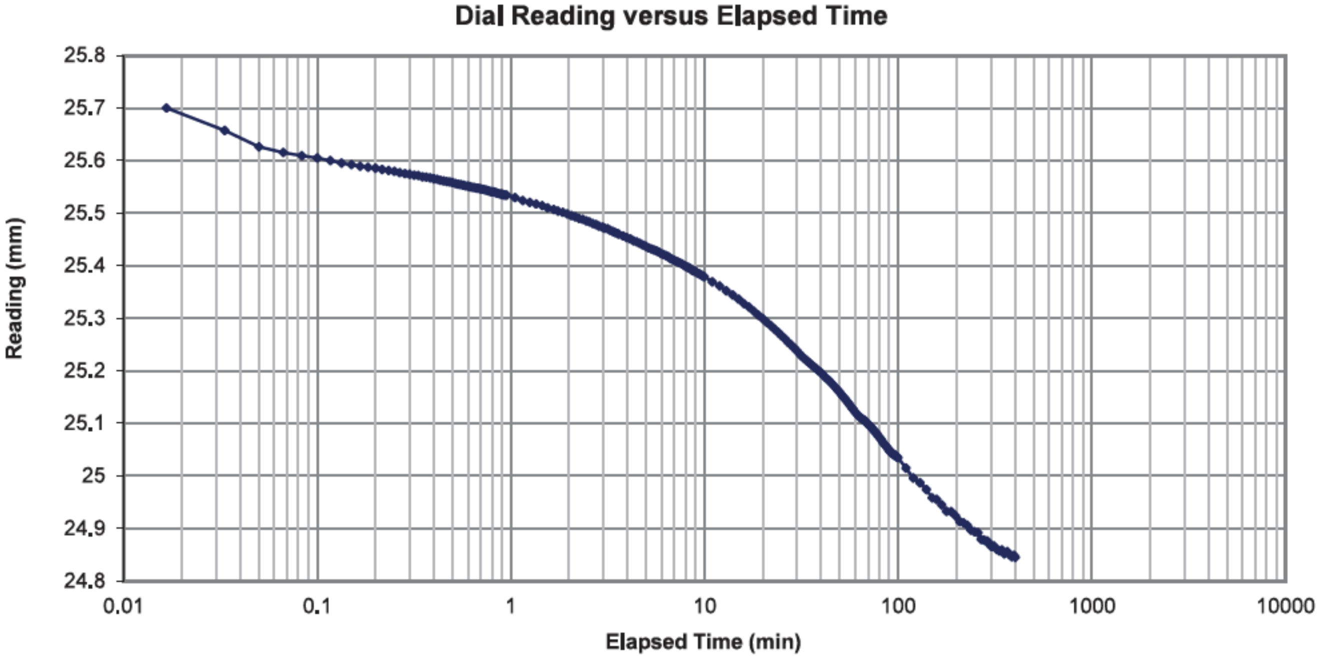
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

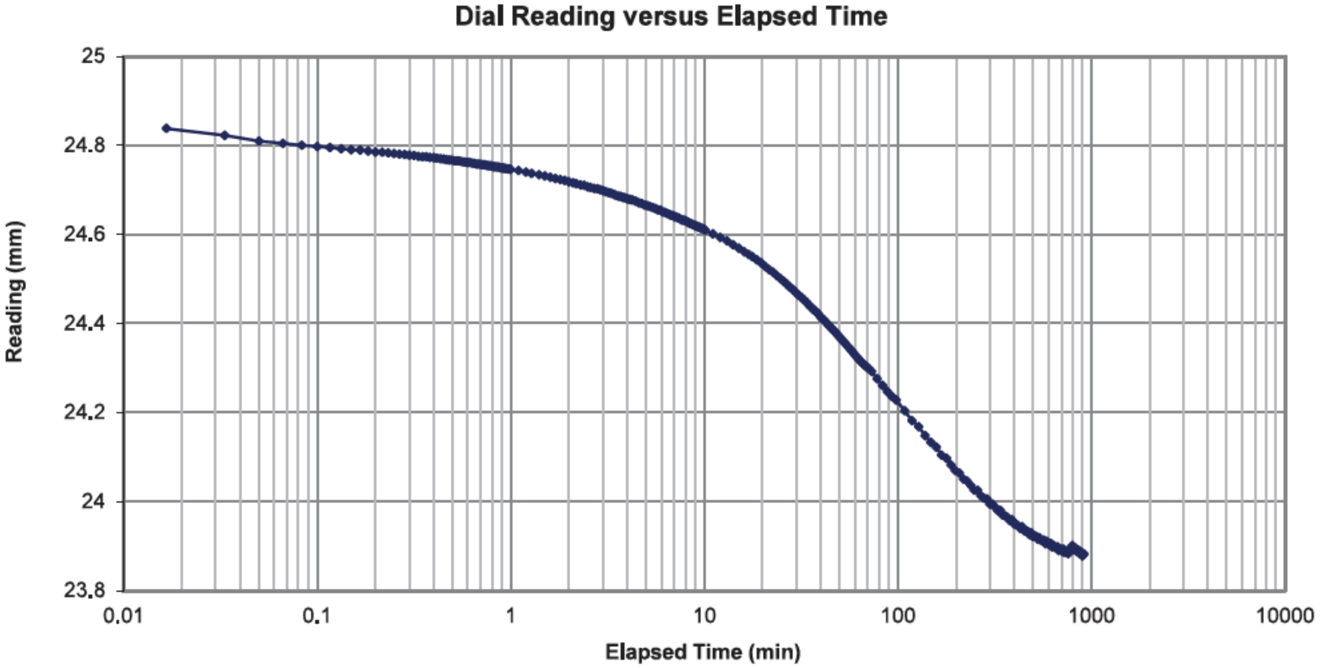
Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

Load #: 1
Stress: 100 kPa



Load #: 2
Stress: 200 kPa

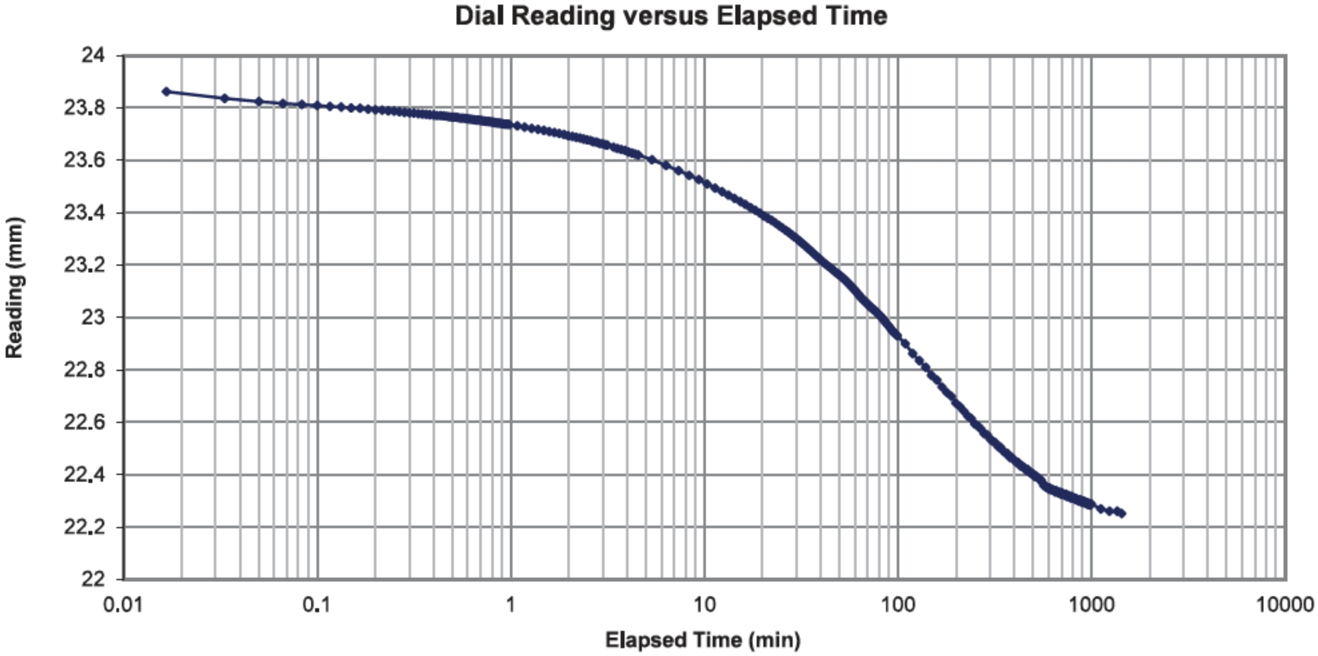


ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

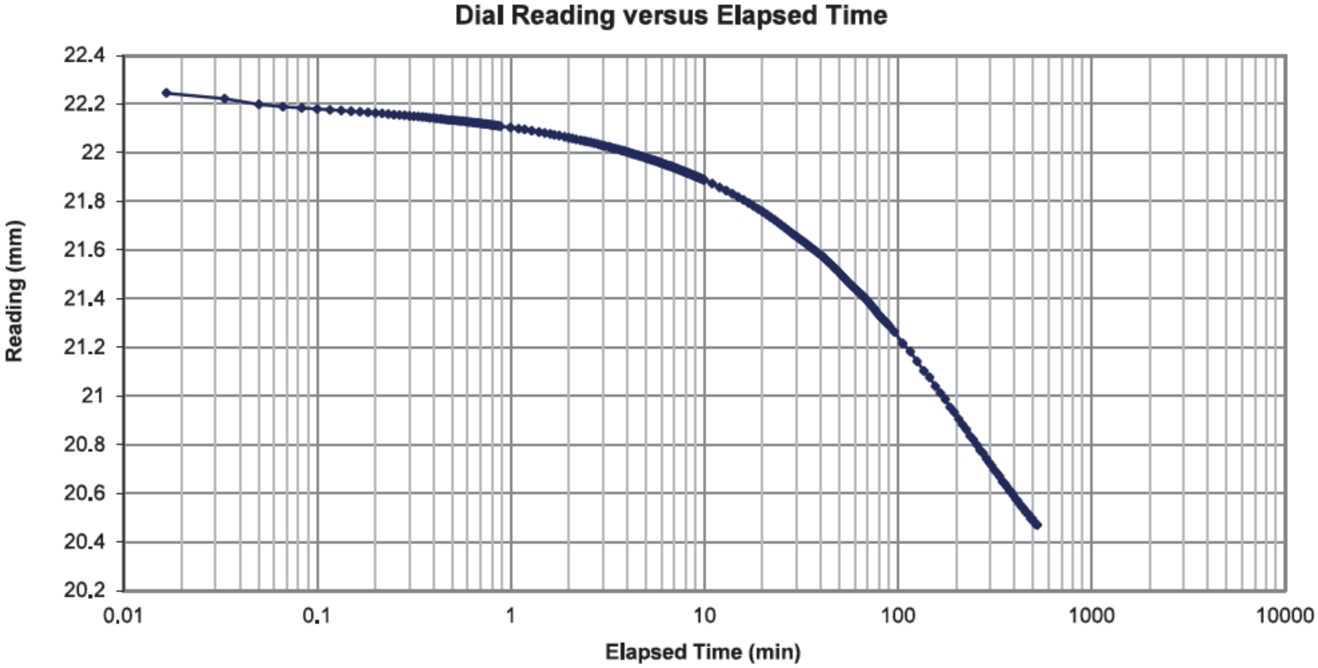
ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	B.K.	Date: December 10, 2021
Sample:	P-13 S5A 4.57-5.33 m depth Golder sample: SL7288-03	

Load #: 3
Stress: 400 kPa



Load #: 4
Stress: 737 kPa



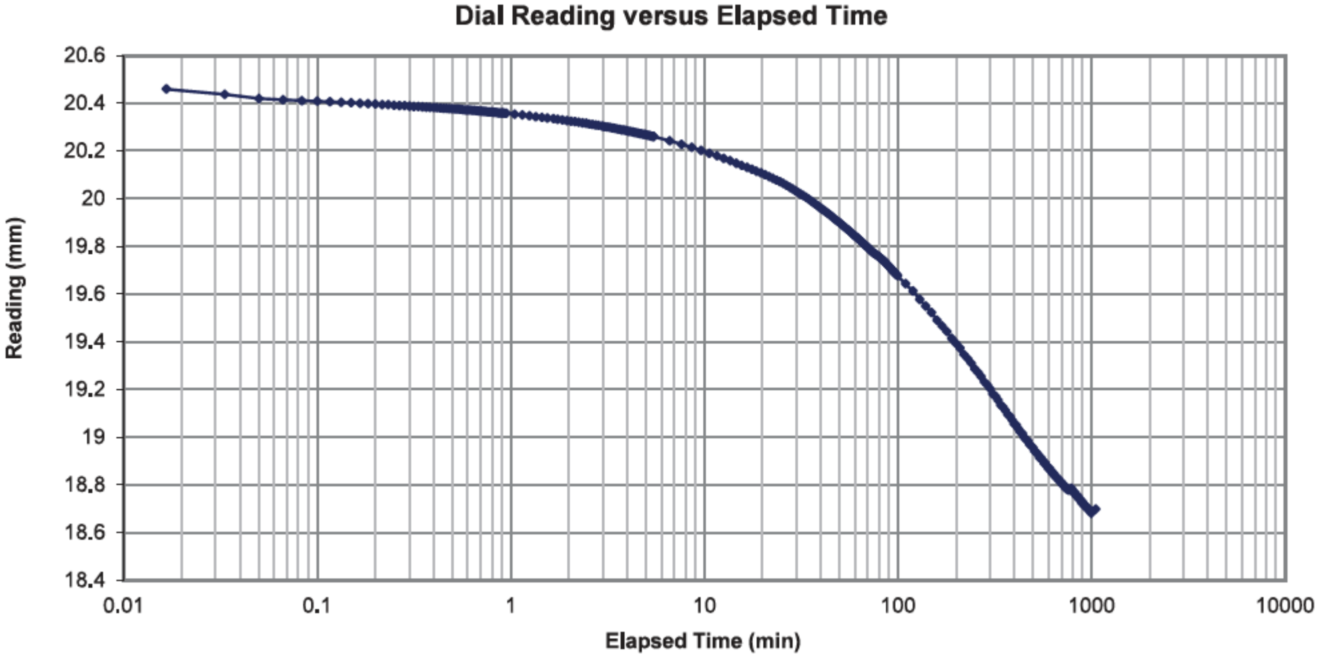
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

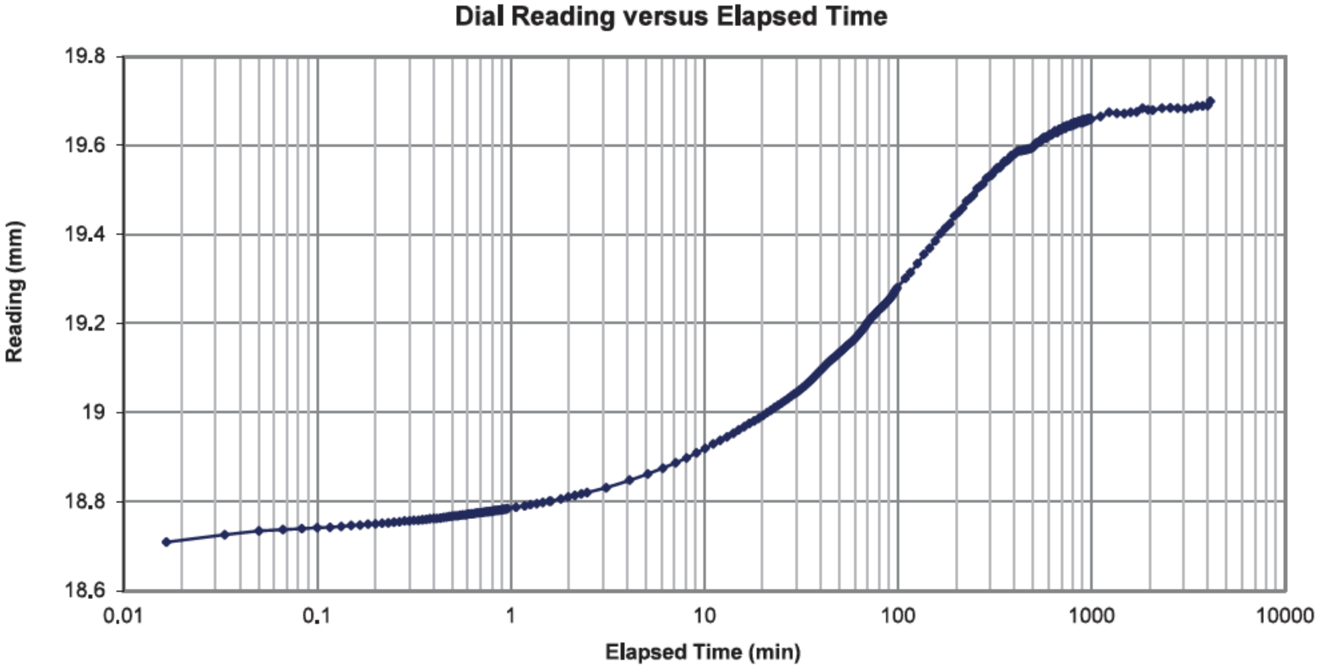
Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

Load #: 5
Stress: 1,200 kPa



Load #: 6
Stress: 400 kPa



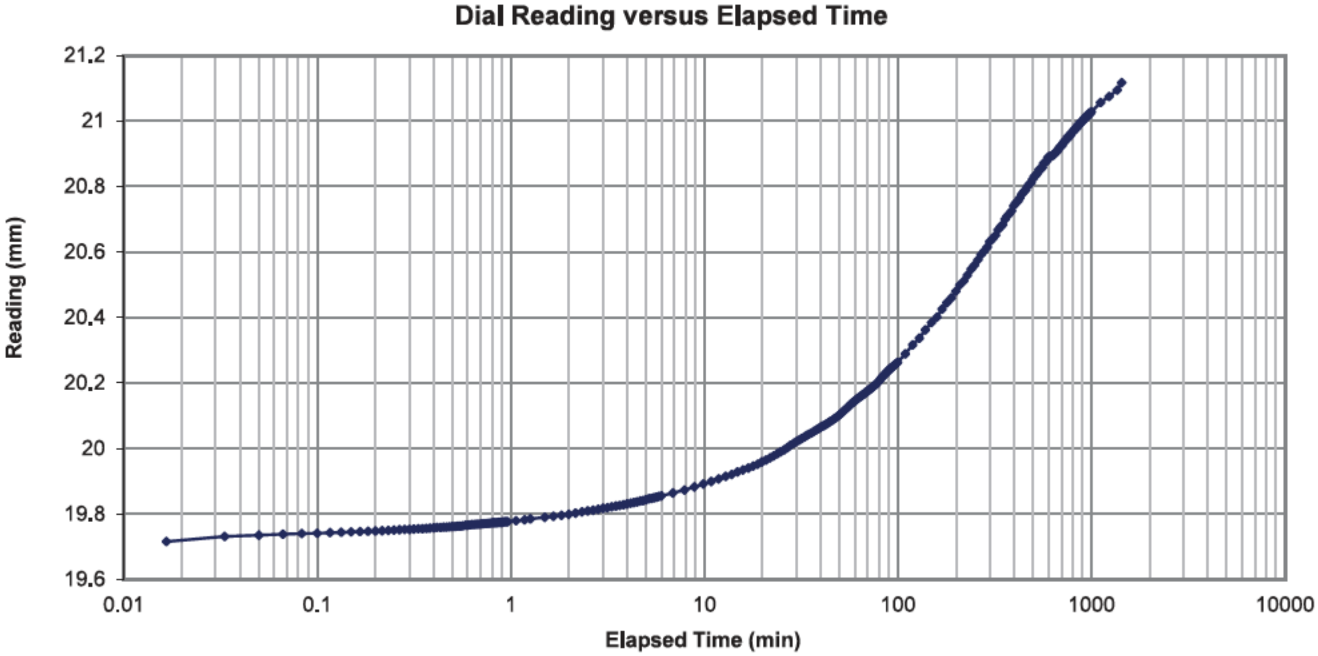
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

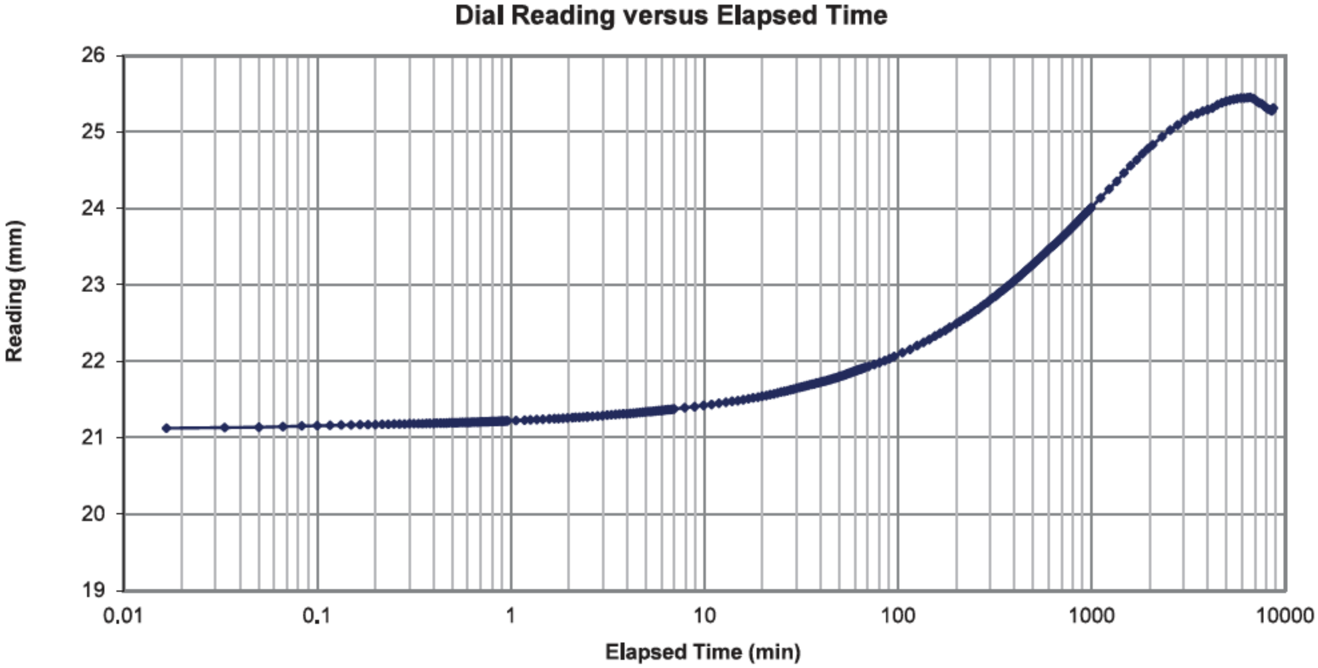
Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

Load #: 7
Stress: 100 kPa



Load #: 8
Stress: 3.2 kPa



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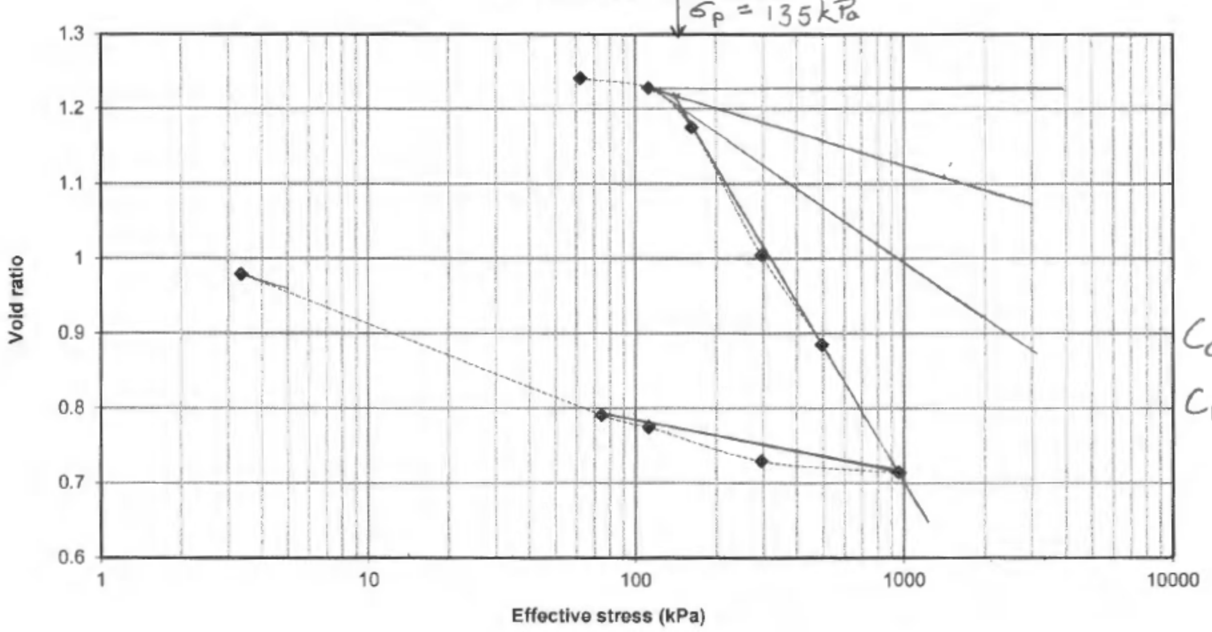
ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W. / B.K. / J.S.	Date: December 14, 2021
Sample:	P-12 S7A 7.62 - 8.38 m Golder sample: SL7288-02	

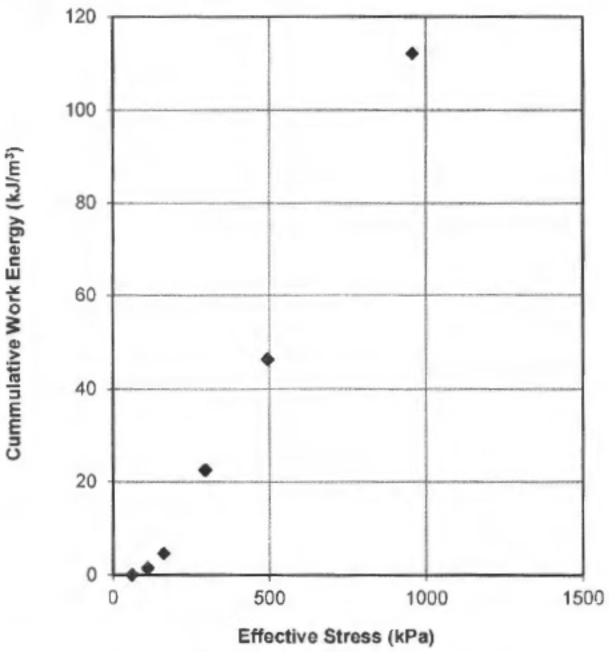
Void Ratio versus Effective Stress



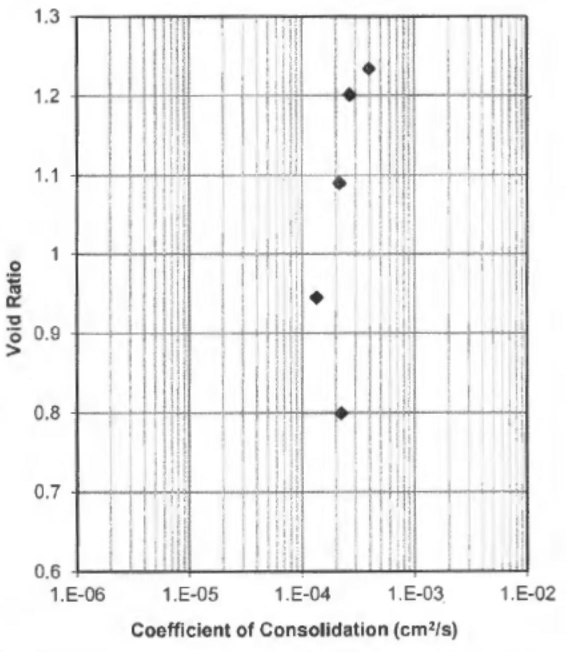
$C_c = 0.6$

$C_R = 0.07$

Cummulative Work Energy versus Effective Stress



Coefficient of Consolidation versus Void Ratio

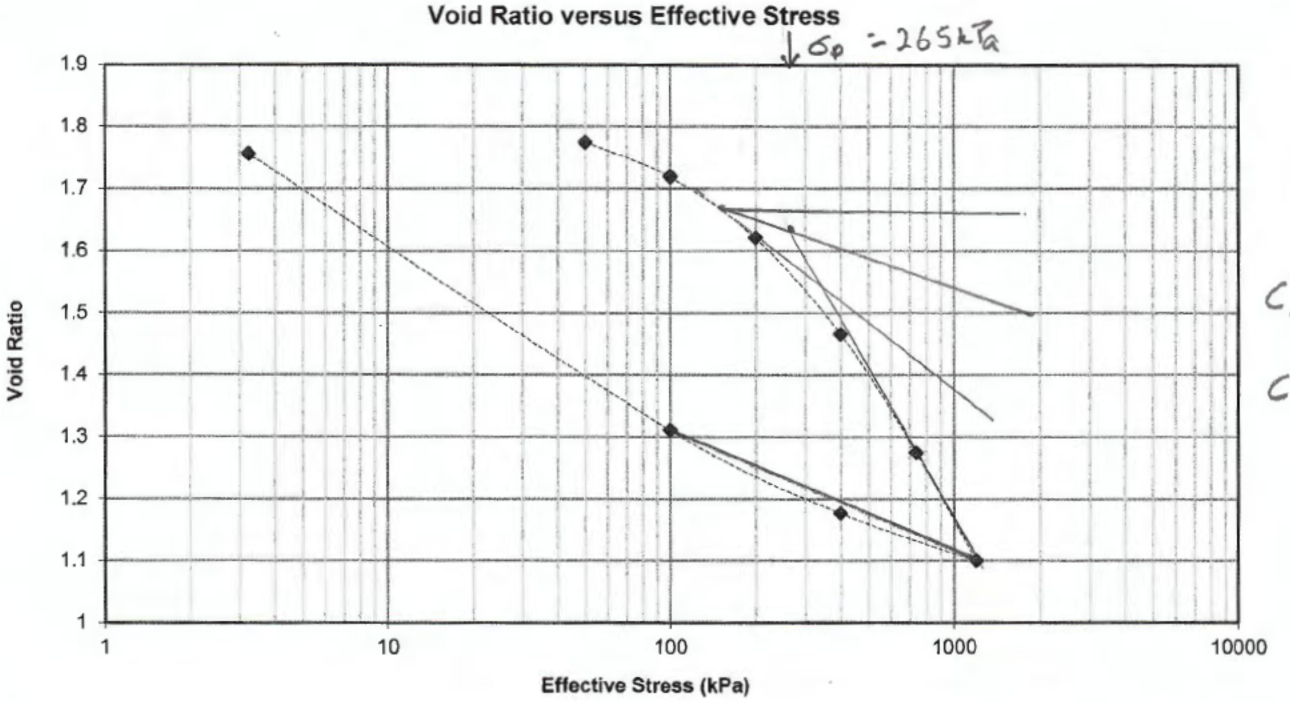


ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

ASTM D2435

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: B.K. Date: December 10, 2021
Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

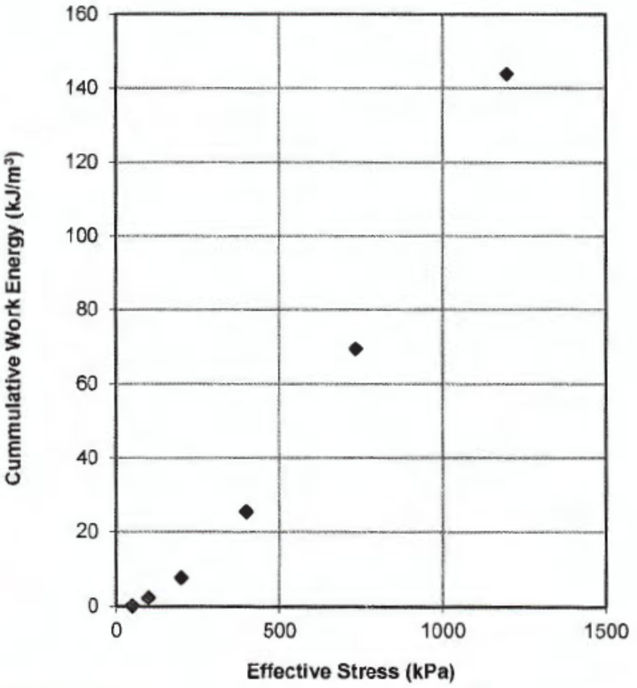
Void Ratio versus Effective Stress



$C_c = 0.8$

$C_R = 0.19$

Cummulative Work Energy versus Effective Stress



Coefficient of Consolidation versus Void Ratio

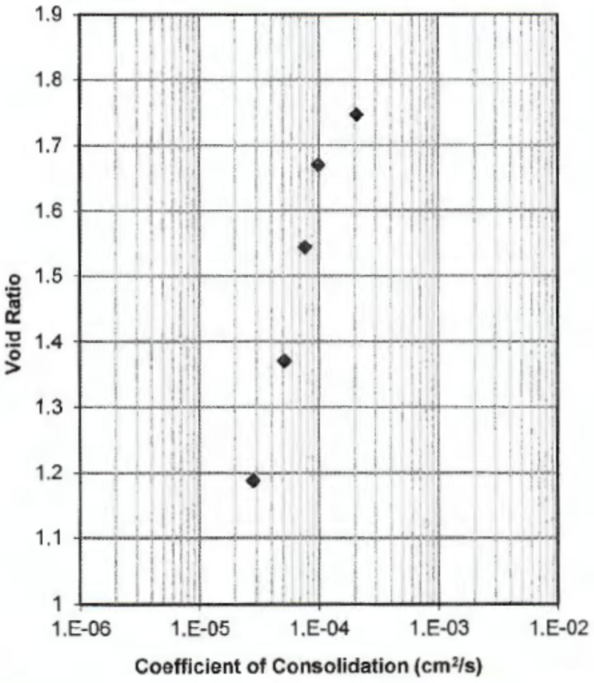


Table B.1: Summary of Consolidation Test Results for Lower Clay

Parameter	**Units**	**Sample S7A Borehole P-12 Deep (Bedrock)** **Sample Depth (7.62m - 8.38 m)**	**Sample S5A Borehole P-13 Deep (Bedrock)** **Sample Depth (4.57 m - 5.33 m)**
Initial Total Unit Weight	kN/m^3	17.7	15.7
Initial Water Content	%	47.4	61.4
Initial Void Ratio	-	1.24	1.77
Pre-consolidation Pressure, σ'_p	kPa	135	265
Recompression Index, C_r	-	0.07	0.19
Compression Index, C_c	-	0.6	0.8

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TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: February 28, 2022

Sample: P-12 S7A 7.62-8.38 m depth
Golder sample: SL7288-02

Initial Sample Parameters:

Sample #:	S7A
Lab #:	SL7288-02
Sample type:	Intact
Initial diameter (mm):	66.1
Initial height (mm):	133.4
Initial mass (g):	799.7
Initial water content (%):	58.1
Initial void ratio:	1.48
Wet density (kg/m^3):	1749
Dry density (kg/m^3):	1107

Test Parameters:

Cell pressure (kPa):	383	483	683
Pore pressure (kPa):	283	283	283
Effective stress (kPa):	100	200	400
"B" parameter:	0.97	-	-
Consolidation volume change (%):	5.4	10.0	14.5
Consolidated diameter (mm):	65.5	64.9	64.5
Consolidated height (mm):	128.3	124.5	119.6

Conditions at Failure: Failure criteria: maximum deviator stress

Axial strain:	1.2%	2.5%	8.2%
Deviator stress (kPa):	68	92	173
Effective minor principle stress, σ'_3 (kPa):	73	133	203
Effective major principle stress, σ'_1 (kPa):	141	224	377
Final water content (%):			42.6
Final void ratio:			1.12

(Deviator and principle stresses shown above for the 100 and 200 kPa points represent conditions when shearing was stopped, rather than actual maximum deviator stress if allowed to shear to 15% strain)

Comments:
- multi-stage triaxial compression test conducted on a single specimen
- final void ratios based on specific gravity = 2.75 (assumed)

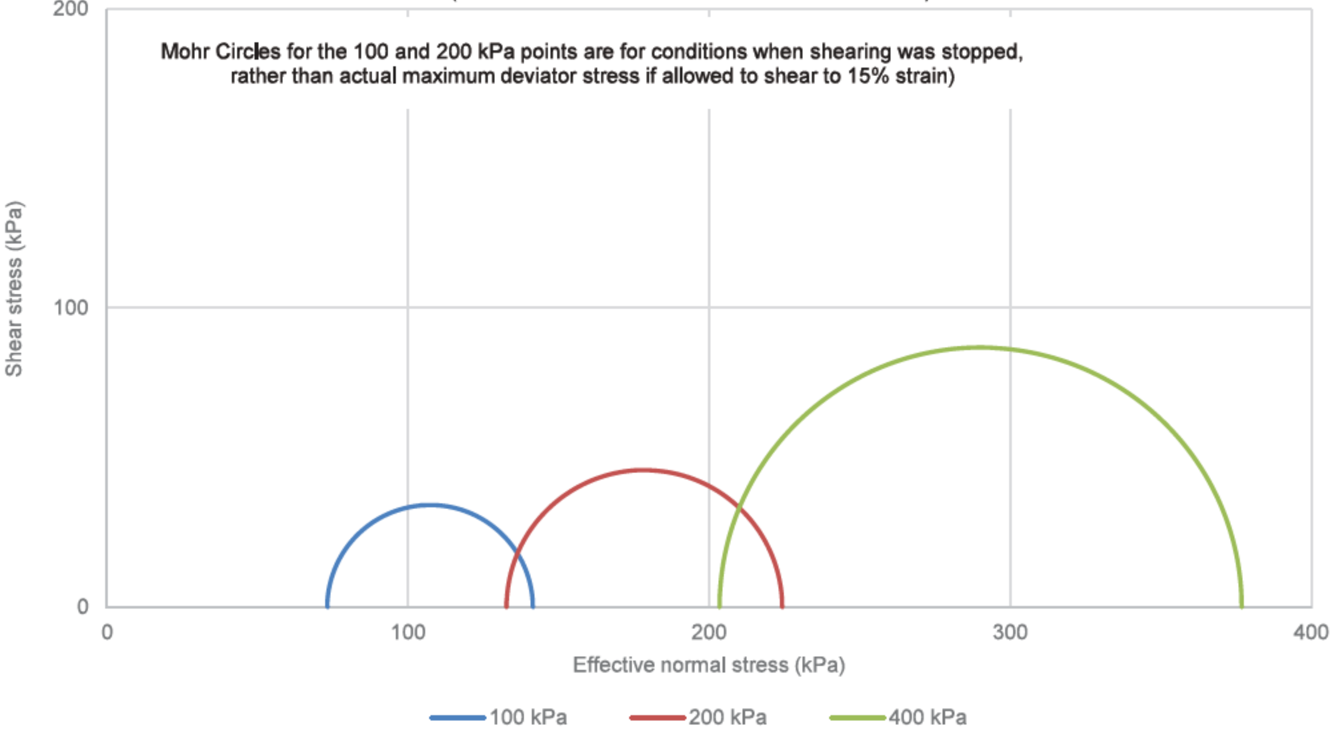
Reviewed by: [redacted]

TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

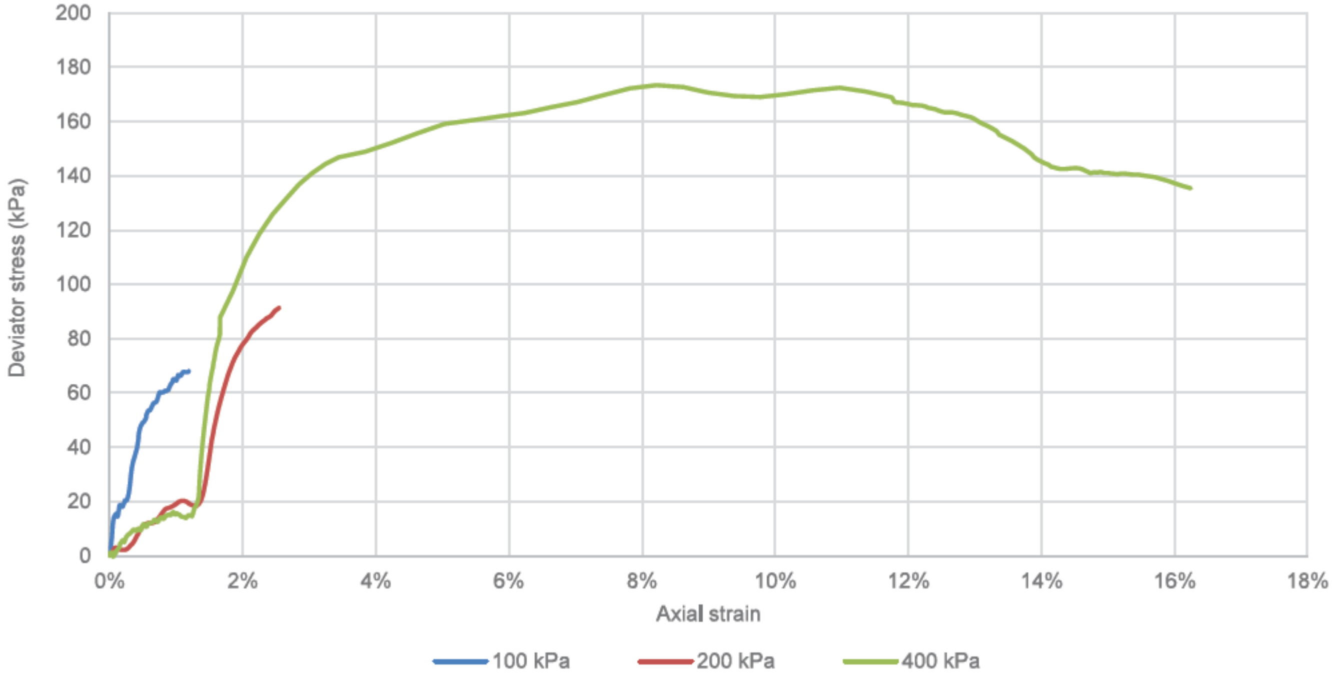
Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W.	Date: February 28, 2022
Sample:	P-12 S7A 7.62-8.38 m depth Golder sample: SL7288-02	

Mohr Circles

(based on maximum deviator stress failure criteria)



Axial Strain versus Deviator Stress

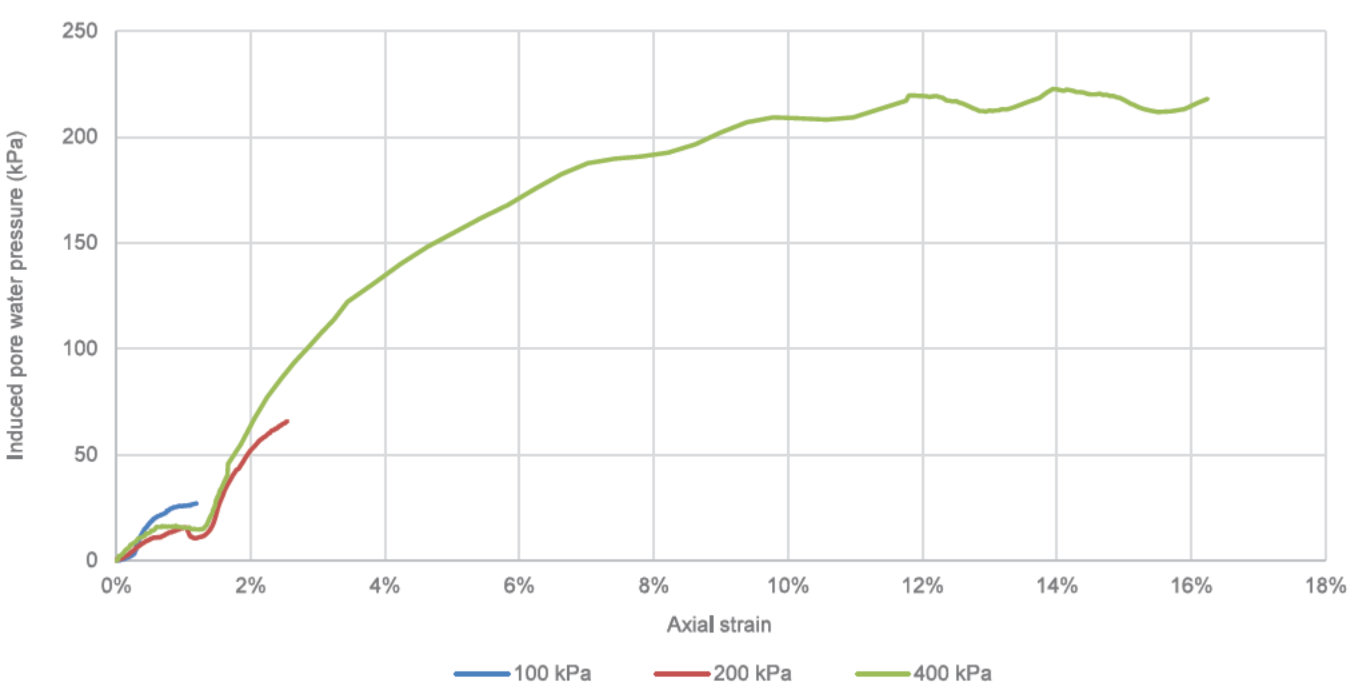


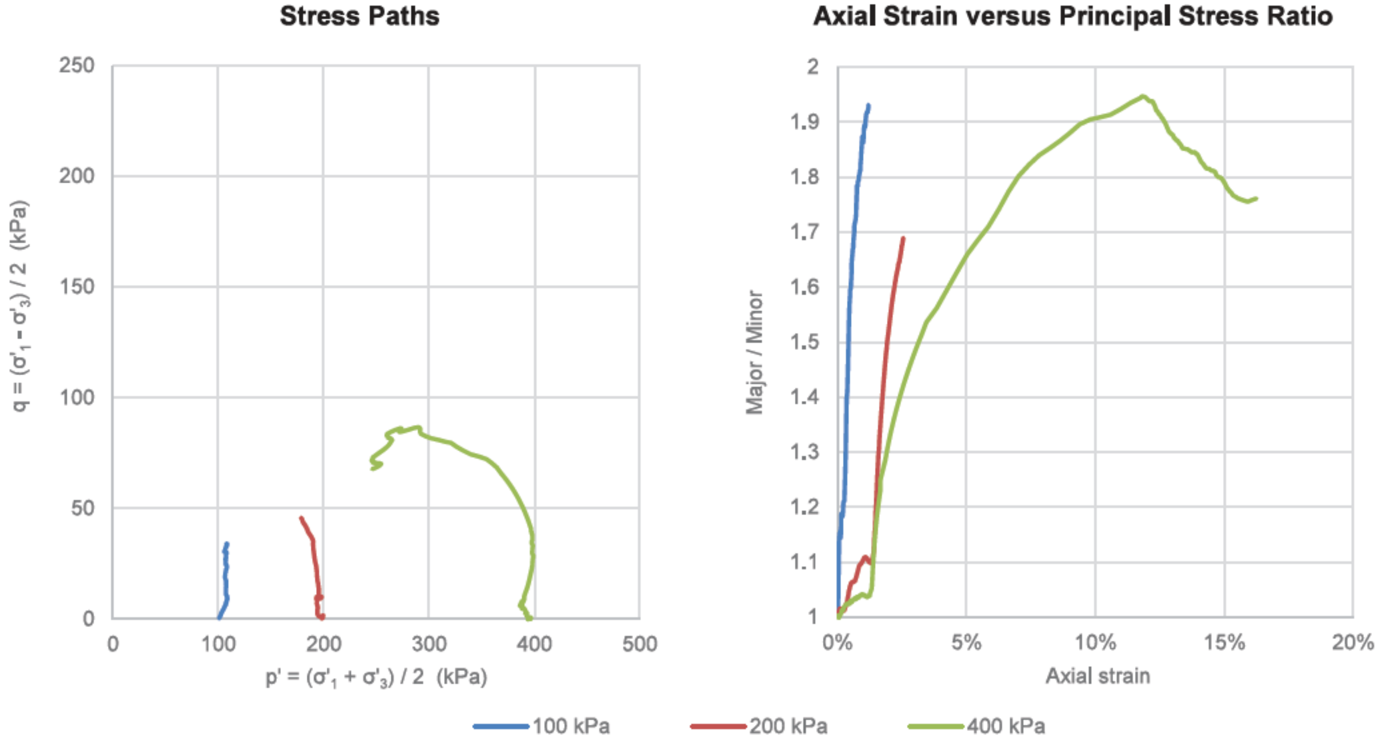
TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: February 28, 2022

Sample: P-12 S7A 7.62-8.38 m depth
Golder sample: SL7288-02

Axial Strain versus Induced Pore Water Pressure





TRIAXIAL COMPRESSION TEST-CONSOLIDATED UNDRAINED

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W.	Date: February 28, 2022
Sample:	P-12 S7A 7.62-8.38 m depth Golder sample: SL7288-02	

Photos:	**Pre-test**	**Post-test**
Sample #: S7A Lab #: SL7288-02 Effective stress: 100, 200 and 400 kPa		

Comments:

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TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: January 19, 2022

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

Initial Sample Parameters:

Sample #:	S5A
Lab #:	SL7288-03
Sample type:	Intact
Initial diameter (mm):	66.2
Initial height (mm):	126.1
Initial mass (g):	745.6
Initial water content (%):	63.4
Initial void ratio:	1.61
Wet density (kg/m^3):	1720
Dry density (kg/m^3):	1052

Test Parameters:

Cell pressure (kPa):	383	483	683
Pore pressure (kPa):	283	283	283
Effective stress (kPa):	100	200	400
"B" parameter:	0.97	-	-
Consolidation volume change (%):	1.3	4.4	9.8
Consolidated diameter (mm):	66.0	65.8	65.3
Consolidated height (mm):	125.0	122.1	116.7

Conditions at Failure: Failure criteria: maximum deviator stress

Axial strain:	1.3%	1.6%	3.7%
Deviator stress (kPa):	62	108	192
Effective minor principle stress, σ'_3 (kPa):	67	125	238
Effective major principle stress, σ'_1 (kPa):	129	233	430
Final water content (%):			56.0
Final void ratio:			1.36

(Deviator and principle stresses shown above for the 100 and 200 kPa points represent conditions when shearing was stopped, rather than actual maximum deviator stress if allowed to shear to 15% strain)

Comments:
- multi-stage triaxial compression test conducted on a single specimen
- void ratios based on specific gravity = 2.75 (assumed)

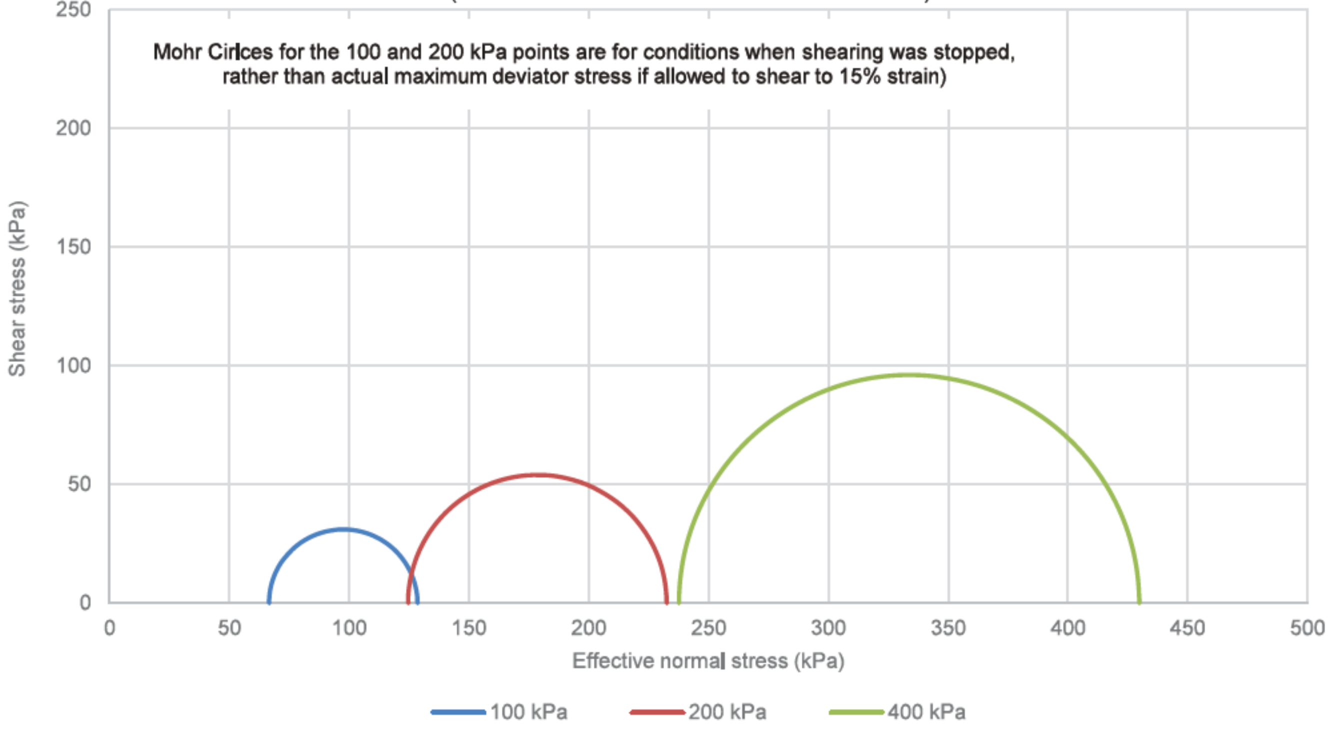
Reviewed by: [redacted]

TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

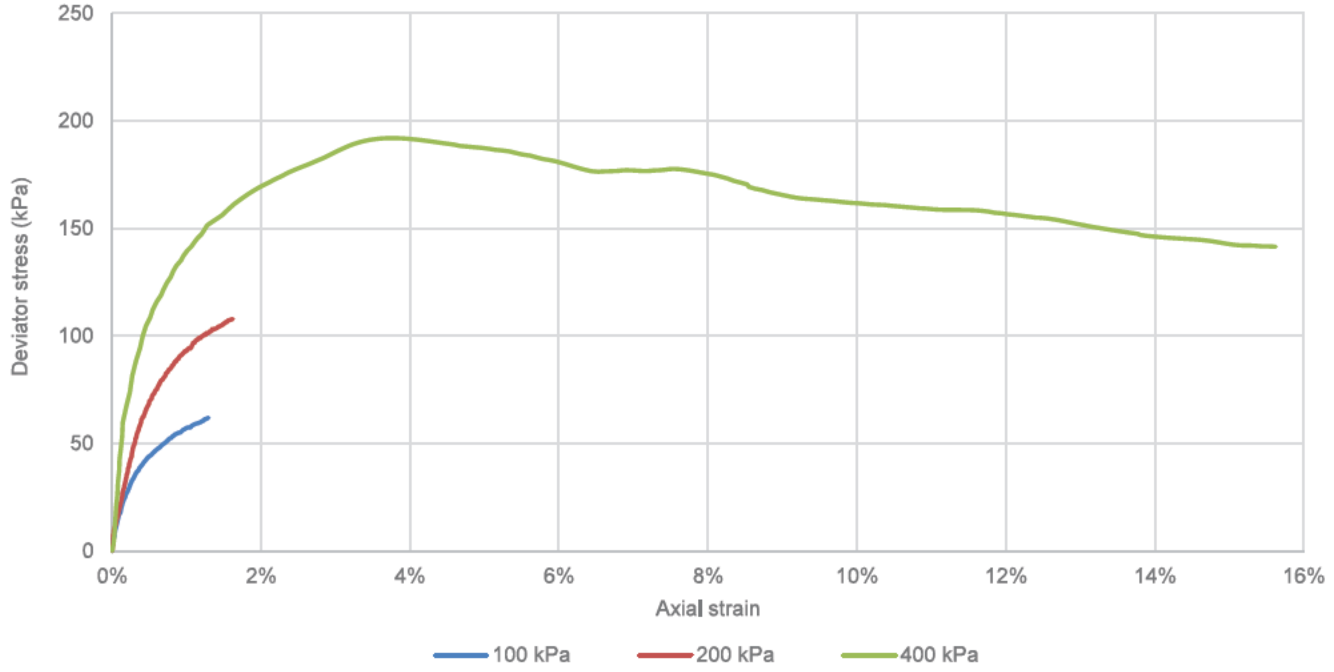
Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W.	Date: January 19, 2022
Sample:	P-13 S5A 4.57-5.33 m depth Golder sample: SL7288-03	

Mohr Circles

(based on maximum deviator stress failure criteria)



Axial Strain versus Deviator Stress

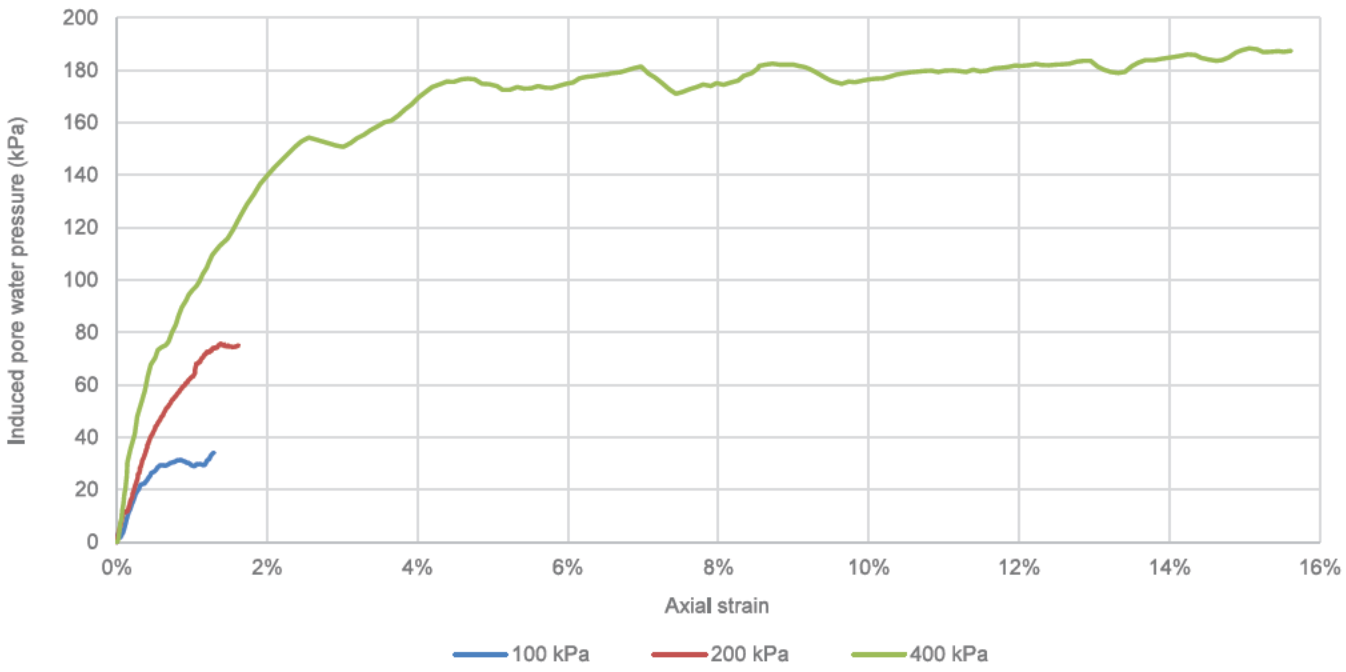


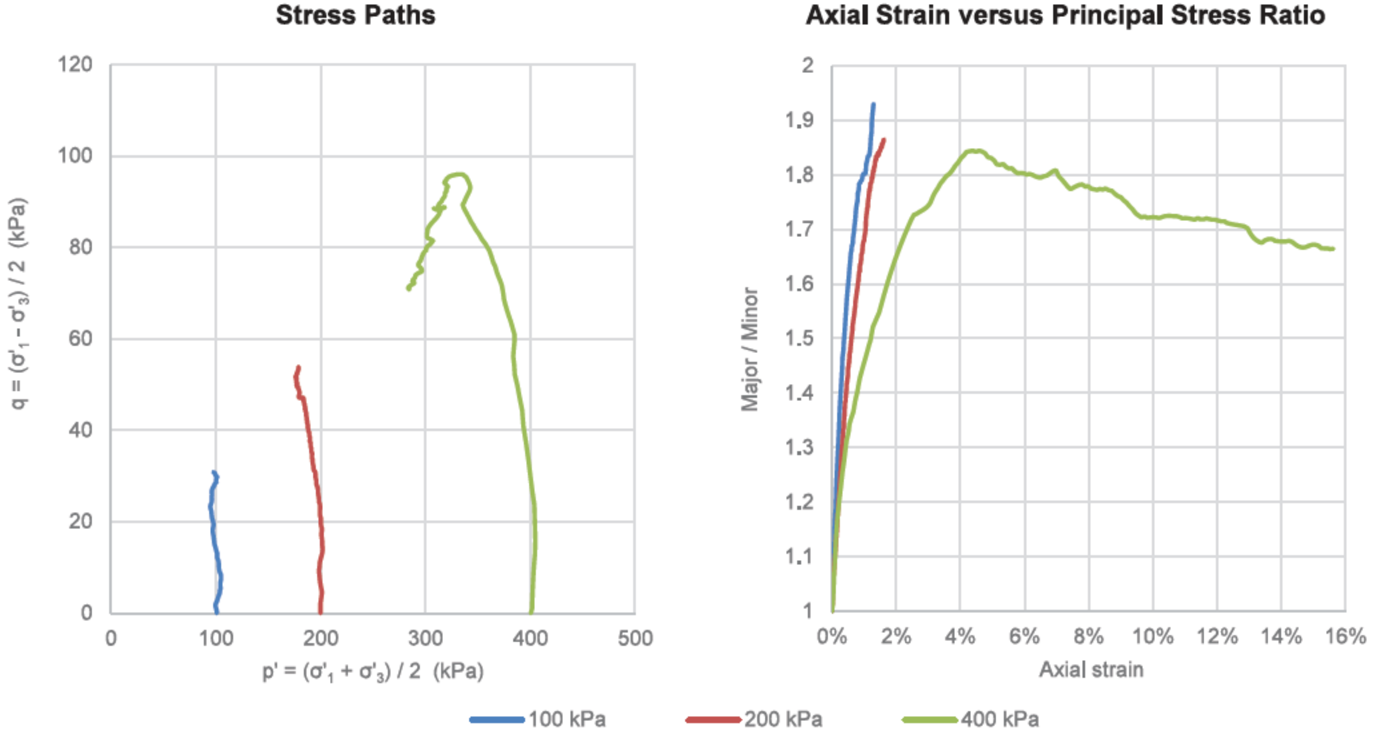
TRIAXIAL COMPRESSION TEST-CONSOLIDATED UNDRAINED

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: January 19, 2022

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

Axial Strain versus Induced Pore Water Pressure




Stress Paths

Axial Strain versus Principal Stress Ratio

TRIAXIAL COMPRESSION TEST-
CONSOLIDATED UNDRAINED

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: January 19, 2022

Sample: P-13 S5A 4.57-5.33 m depth
Golder sample: SL7288-03

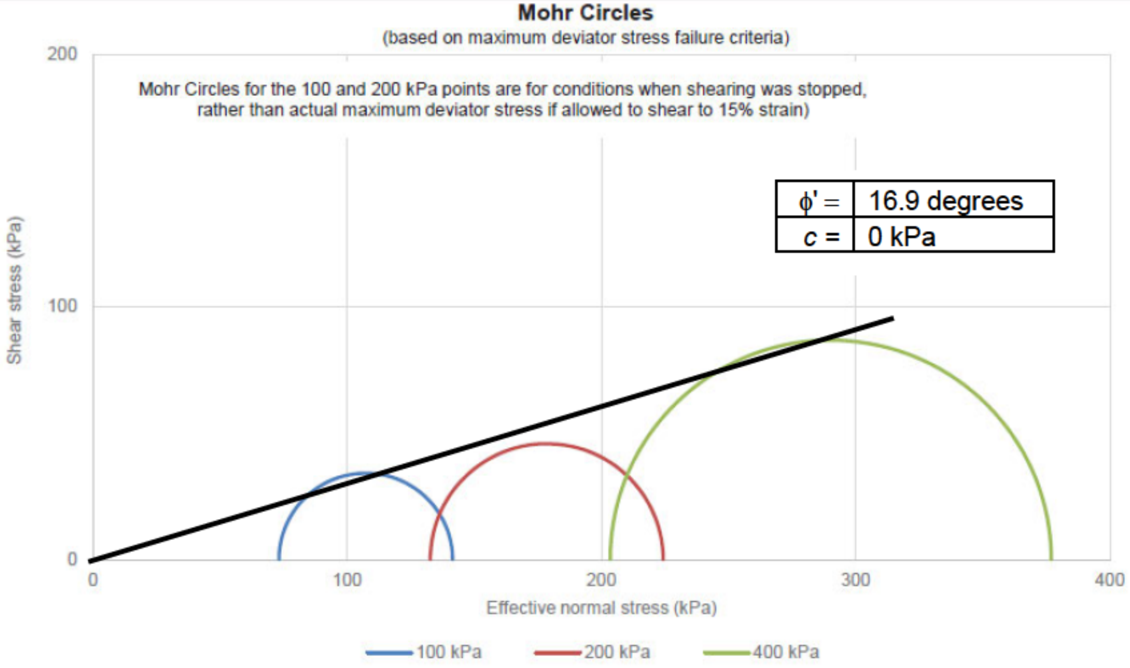
Photos:	**Pre-test**	**Post-test**
Sample #: S5A Lab #: SL7288-03 Effective stress: 100, 200 and 400 kPa		

Comments:

Effective Friction Angle and Cohesion

Project #: 21473621 Phase: 2000
Short Title: Waste Connections / Prairie Green Landfill Phase II Design / MB
Tested By: M.W. Date: February 28, 2022

Sample: P-12 S7A 7.62-8.38 m depth
Golder sample: SL7288-02



Mohr Circles

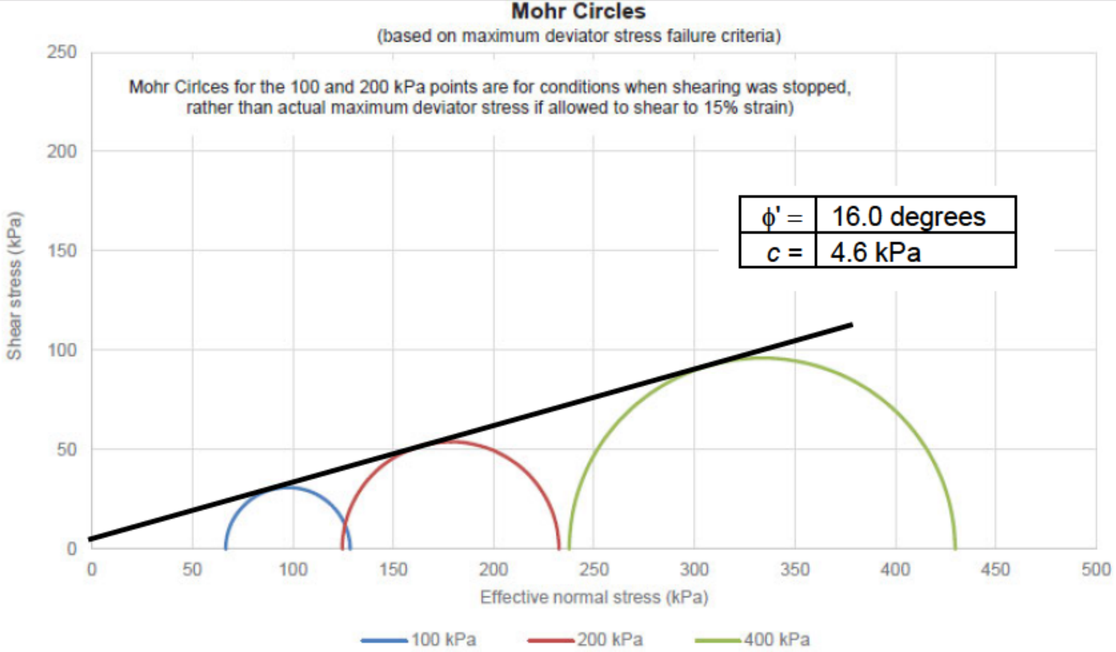
(based on maximum deviator stress failure criteria)

Mohr Circles for the 100 and 200 kPa points are for conditions when shearing was stopped, rather than actual maximum deviator stress if allowed to shear to 15% strain)

ϕ' =	16.9 degrees
c =	0 kPa

Effective Friction Angle and Cohesion

Project #:	21473621	Phase: 2000
Short Title:	Waste Connections / Prairie Green Landfill Phase II Design / MB	
Tested By:	M.W.	Date: January 19, 2022
Sample:	P-13 S5A 4.57-5.33 m depth Golder sample: SL7288-03	



APPENDIX C

Settlement Analyses

Project Number: 21473621
Settlement Calculations - Prairie Green Landfill - Phase 2 - Cross Section B-B'

	Interior-Toe	Mid Slope	Crest	Top	
Chainage (m)	**69.87**	**123.07**	**176.28**	**312.29**	
Top of Final Cover (masl)	241.72	252.36	263.00	269.80	
Base Grade (masl)	227.28	227.81	228.34	229.70	(One Percent)
Bottom of Clay (masl)	221.00	221.00	221.00	221.00	
Ground Level Prior to Construction (masl)	233.00	233.00	233.00	233.00	
Middle of Lower Clay (masl)	224.1	224.4	224.7	225.4	
Top of Leachate Collection System (masl)	227.9	228.4	228.9	230.3	Unit Weight (kN/m^3)
Waste Thickness (m)	12.9	23.1	33.2	38.6	13
Total Clay Thickness above Middle of Lower Clay (m)	3.14	3.40	3.67	4.35	16.5
Sand Filter Thickness (m)	0.30	0.30	0.30	0.30	18
Stone Drainage Layer Thickness (m)	0.30	0.30	0.30	0.30	17
Cover Thickness (m)	0.90	0.90	0.90	0.90	18

LOWER CLAY

Initial (Prior To Construction)					
Initial Total Stress at the Middle of Lower Clay (kPa)	146.2	141.8	137.4	126.2	
Water Level Elevation in Lower Clay (m)	230.5	230.5	230.5	230.5	(average of shallow and deep piezometric level
Initial Porewater Pressure (KPa)	62.4	59.8	57.2	50.5	at P-12 and P-13)
Initial Effective Stress (σ'_i (kPa))	83.8	82.0	80.3	75.7	
Final					
Final Total Stress at the Middle of Lower Clay (KPa)	246.7	382.5	518.3	600.3	
Final Porewater Pressure (KPa)	62.4	59.8	57.2	50.5	
Final Effective Stress (σ'_f (kPa))	184.3	322.7	461.1	549.8	
we have for Lower Clay Layer,					
Recompression Index (C_r)	0.13	0.13	0.19	0.19	
Initial Void Ratio (e_o)	1.51	1.51	1.77	1.77	
Preconsolidation Pressure (σ'_p (kPa))	200	200	265	265	
Compression Index (C_c)	0.7	0.7	0.8	0.8	
Thickness of Lower Clay Layer (H_o (m))	6.3	6.8	7.3	8.7	
Is final effective stress greater than preconsolidation pressure?	NO	YES	YES	YES	
Settlement of Lower Clay (m)	0.111	0.531	0.771	1.121	
Settlement of Lower Clay (cm)	**11.1**	**53.1**	**77.1**	**112.1**	

Notes:

Equations for settlement:

1. If final effective stress is less than the preconsolidation pressure:

$$S_c = \frac{C_r}{1+e_o} H_o \log \frac{\sigma'_f}{\sigma'_i}$$

2. If final effective stress is greater than the preconsolidation pressure:

$$S_c = \frac{C_r}{1+e_o} H_o \log \frac{\sigma'_p}{\sigma'_i} + \frac{C_c}{1+e_o} H_o \log \frac{\sigma'_f}{\sigma'_p}$$

Made by: S. Rimal
Reviewed by: F. Barone

Golder Associates

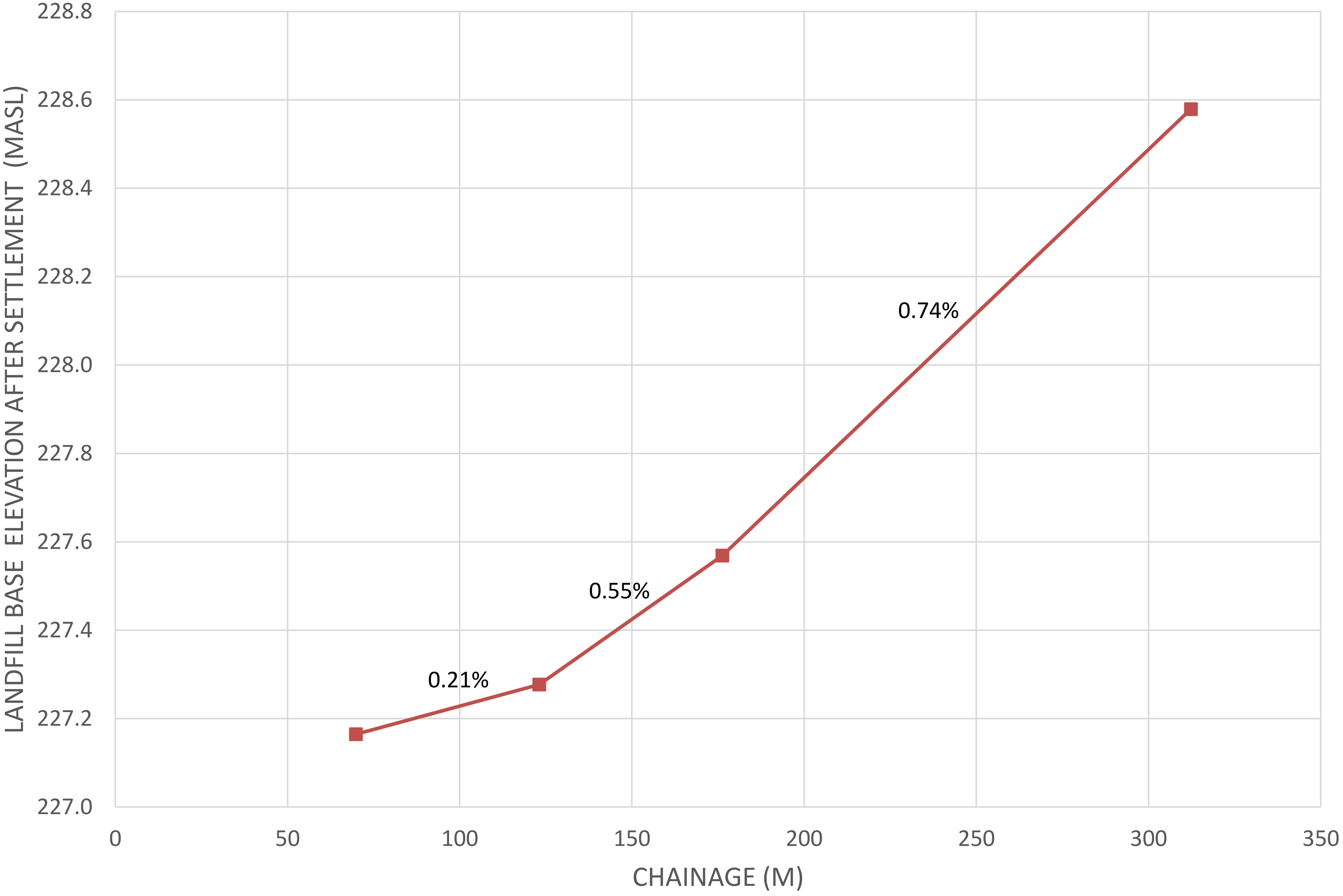


FIGURE C-1: DIFFERENTIAL SETTLEMENT OF THE BASE GRADE ALONG LEACHATE COLLECTION SYSTEM PIPE (CELL 11, CROSS-SECTION B-B')

APPENDIX D

HDPE Pipe Structural Stability Calculations

Leachate Collection System Pipe Structural Stability Calculations, 8" DR11 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba

Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

References:

Ref. 1 - Handbook of Polyethylene Pipe, Plastics Pipe Institute, Second Edition.
Ref. 2 - Large Scale Constrained Modulus Test, Final Report, Prepared by MCG Geotechnical Engineering, Morrison, CO for Plastics Pipe Institute (February 2010)
Ref. 3 - High Density Polyethylene Pipe, Systems Design, Sclairpipe, KWH Pipe.
Ref. 4 - PolyPipe Design and Engineering Guide for Polyethylene Piping (September 2008)

Thickness (H) of fills above the Leachate Collection System (LCS) Pipe

H_{cover} = 0.9 m
H_{waste} = 38.6 m (max.) (Use DR-11 for Cells 4 to 13)
H_{sand} = 0.3 m
H_{stone} = 0.3 m

Unit weights (γ)

γ_{cover} = 18 kN/m^3
γ_{waste} = 13 kN/m^3
γ_{sand} = 18 kN/m^3
γ_{Stone} = 17 kN/m^3

Applied vertical stress on the pipe (σ_v)

σ_v = 529 kPa
= 11038 psf

8" HDPE Pipe, DR = 11, Designation Code PE3408

(a) Check for pipe wall crushing

From Ref. 1 (page 229), the pipe wall compressive stress:

$$S = \frac{P_{RD} \times D_o}{288 \times t}$$

where,

S = pipe wall compressive stress [lb/in^2]
P_{RD} = radial directed earth pressure [lb/ft^2] = VAF x σ_v (Eq. 3-23 Ref. 1)
VAF = vertical arching factor [-] = 0.88 -0.71 x (S_A - 1)/(S_A + 2.5) (Eq. 3-21 Ref. 1)
S_A = hoop stress stiffness ratio [-] = (1.43 x M_s x r_{CENT})/ (E x t) (Eq. 3-22 Ref. 1)
r_{CENT} = radius to centroidal axis of pipe [in] = (D_o - t)/2
M_s = one-dimensional modulus of soil [psi]
E = apparent modulus of elasticity of pipe material [psi]
D_o = pipe outside diameter [in]
t = wall thickness [in]
σ_v = applied vertical stress on pipe (psf)

Leachate Collection System Pipe Structural Stability Calculations, 8" DR11 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba		
Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

		English Units		SI Units		
D_o	=	8.63	in	0.219	m	(for 8 in. DR = 11 Sclairpipe PE3408)
t	=	0.784	in	0.020	m	
r_{CENT}	=	3.923	in	0.100	m	
M_s	=	5000	psi	34475	kPa	(Table 2 - Ref. 2 for 1.5 inch granite with high compactive effort)
E	=	19710	psi	135900	kPa	(Long term apparent modulus of elasticity of 27,000 psi at 23°C, Ref. 1 - Chapter 3
σ_v	=	11038	psf	528	kPa	- Table B.1.1, adjusted using compensating multiplier of 0.73 at 38°C, Table B.1.2)
S_A	=	1.82	[-]	1.82	[-]	
VAF	=	0.746	[-]	0.746	[-]	
P_{RD}	=	8233	psf	394	kPa	
S	=	315	psi	2170	kPa	

S_{allow} = allowable pipe wall compressive stress = 780 psi
= 5378 kPa

(Allowable pipe wall compressive stress of 1000 psi at 23°C, Ref. 1 - Chapter 3 - Table C.1, for PE3408 pipe, adjusted using compensating multiplier of 0.78 at 38°C, Table A-2)

$$\text{Factor of Safety} = \frac{S_{allow}}{S} = \frac{780}{315} = 2.5$$

Okay [Typical Recommended F.S. = 1.0 Ref. 1]

(b) Check for ring deflection (Watkins - Gaube Graph)

From Ref. 1 (Eqn. 3-28), percent ring deflection is:

$$\left(\frac{\Delta x}{D_M}\right) \times 100 = D_F \times \varepsilon_S$$

where,

Δx = ring deflection [in]
D_M = mean diameter [in] (i.e. Do - t)
D_F = deformation factor (from Watkins - Gaube Graph)
ε_S = soil strain [%] = σ_v /(144 x E_s) (Eq. 3-27 Ref. 1)
σ_v = applied vertical stress on pipe (psf)
E_s = secant modulus of soil [psi] = M_s (1 + μ) (1-2μ) / (1 - μ) (Eq. 3-26 Ref. 1)
M_s = one dimensional soil modulus [psi]
μ = soil's Poisson ratio [-]

Ridgity factor, R_F for Watkins - Gaube Graph is:

$$R_F = \frac{12\, E_S\, (DR\ - 1)^3}{E}$$

DR = standard dimension ratio of pipe [-] i.e pipe outside diameter / wall thickness
E_s = secant modulus of soil [psi]
E = apparent modulus of elasticity of pipe material [psi]

Leachate Collection System Pipe Structural Stability Calculations, 8" DR11 HDPE Pipe,
Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba

Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

		English Units		SI Units		
E	=	19710	psi	135900.5	kPa	
D_o	=	8.63	in	0.219	m	(for 8 in. DR = 11 Sclairpipe PE3408)
t	=	0.784	in	0.020	m	
D_M	=	7.846	in	0.200	m	
σ_v	=	11038	psf	528	kPa	
μ	=	0.15	[-]	0.15	[-]	(Ref. 1 Table 3-13)
M_s	=	5000	psi	34475	kPa	
E_s	=	4735	psi	32650	kPa	
R_F	=	2883	[-]	2883	[-]	
D_F	=	1.5	[-]	1.5	[-]	(deformation factor from Watkins-Gaube Graph, Ref. 1)
ε_S	=	1.6%		1.6%		
$\Delta x/D_M$	=	2.4%		2.4%		(Percent Ring Deflection)

allowable ring deflection = 5% (Ref. 1 page 218)

Factor of Safety = $\frac{\text{Allowable ring def.}}{\Delta x/D_M}$ = $\frac{5\%}{2.4\%}$ = 2.1 Okay [Typical Recommended F.S. = 1.0 Ref. 1]

(c) Check for wall buckling

Moore-Selig Equation for critical buckling pressure:

$$P_{CR} = \frac{2.4\,\emptyset\,R_H}{D_M}\,(E\,I)^{\frac{1}{3}}\,(E_S^*)^{\frac{2}{3}}$$

where,

P_{CR} = critical constrained buckling pressure [psi]
Φ = calibration factor [-]
R_H = geometry factor [-]
D_M = mean diameter [in] (i.e. D_o - t)
E = apparent modulus of elasticity of pipe material [psi]
I = pipe wall moment of inertia [in^4/in] = (t^3/12, for a solid wall pipe)
E_s = secant modulus of soil [psi] = M_s (1 + μ) (1-2μ) / (1 - μ) (Eq. 3-26 Ref. 1)
E^*_s = E_s / (1-μ)
μ = soil's Poisson ratio [-]

		English Units		SI Units		
Φ	=	0.55	[-]	0.55	[-]	(Ref. 1 Page 233)
R_H	=	1	[-]	1	[-]	(Ref. 1 Page 233)
D_M	=	7.846	in	0.200	m	
E	=	19710	psi	135900.5	kPa	
t	=	0.784	in	0.020	m	
I	=	0.0402	in^3	6.58E-07	m	
E_s	=	4735	psi	32650	kPa	
μ	=	0.15	[-]	0.15	[-]	(Ref. 1 Table 3-13)
E^*_s	=	5571	psi	38412	kPa	
P_{CR}	=	489	psi	3372	kPa	

Leachate Collection System Pipe Structural Stability Calculations, 8" DR11 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba		
Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

Applied vertical pressure on the pipe:

$$P_B = \frac{\sigma_v}{144}$$

where,

P_B = applied verical pressure on the pipe (psi)

σ_v = applied vertical pressure on pipe (psf)

		English Units		SI Units	
σ_v	=	11038	psf	528	kPa
P_B	=	76.7	psi	529	kPa

P_{CR} = critical constrained buckling pressure = 489 psi

= 3372 kPa

$$\text{Factor of Safety} = \frac{P_{CR}}{P_B} = \frac{489}{76.7} = 6.4$$

Okay [Typical Recommended F.S. = 2.0 Ref. 2]

Leachate Collection System Pipe Structural Stability Calculations, 8" DR17 HDPE Pipe,
Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba

Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

References:
Ref. 1 - Handbook of Polyethylene Pipe, Plastics Pipe Institute, Second Edition.
Ref. 2 - Large Scale Constrained Modulus Test, Final Report, Prepared by MCG Geotechnical Engineering,
Morrison, CO for Plastics Pipe Institute (February 2010)
Ref. 3 - High Density Polyethylene Pipe, Systems Design, Sclairpipe, KWH Pipe.
Ref. 4 - PolyPipe Design and Engineering Guide for Polyethylene Piping (September 2008)

Thickness (H) of fills above the Leachate Collection System (LCS) Pipe

H_{cover} = 0.9 m
H_{waste} = 32.5 m (max.) (Use DR-17 for Cells 1 to 3 and 14 to 17)
H_{sand} = 0.3 m
H_{stone} = 0.3 m

Unit weights (γ)

γ_{cover} = 18 kN/m^3
γ_{waste} = 13 kN/m^3
γ_{sand} = 18 kN/m^3
γ_{Stone} = 17 kN/m^3

Applied vertical stress on the pipe (σ_v)

σ_v = 449 kPa
= 9382 psf

8" HDPE Pipe, DR = 17, Designation Code PE3408

(a) Check for pipe wall crushing

From Ref. 1 (page 229), the pipe wall compressive stress:

$$S = \frac{P_{RD} \times D_o}{288 \times t}$$

where,

S = pipe wall compressive stress [lb/in^2]
P_{RD} = radial directed earth pressure [lb/ft^2] = VAF x σ_v (Eq. 3-23 Ref. 1)
VAF = vertical arching factor [-] = 0.88 -0.71 x (S_A - 1)/(S_A + 2.5) (Eq. 3-21 Ref. 1)
S_A = hoop stress stiffness ratio [-] = (1.43 x M_s x r_{CENT})/ (E x t) (Eq. 3-22 Ref. 1)
r_{CENT} = radius to centroidal axis of pipe [in] = (D_o - t)/2
M_s = one-dimensional modulus of soil [psi]
E = apparent modulus of elasticity of pipe material [psi]
D_o = pipe outside diameter [in]
t = wall thickness [in]
σ_v = applied vertical stress on pipe (psf)

Leachate Collection System Pipe Structural Stability Calculations, 8" DR17 HDPE Pipe,
Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba

Project Number: 21473621
Prepared by: S. Rimal
Reviewed by: F. Gondim / F. Barone
Date: December 2021

		English Units		SI Units		
D_o	=	8.63	in	0.219	m	(for 8 in. DR = 17 Sclairpipe PE3408)
t	=	0.507	in	0.013	m	
r_{CENT}	=	4.062	in	0.103	m	
M_s	=	5000	psi	34475	kPa	(Table 2 - Ref. 2 for 1.5 inch granite with high compactive effort)
E	=	19710	psi	135900	kPa	(Long term apparent modulus of elasticity of 27,000 psi at 23°C, Ref. 1 - Chapter 3
σ_v	=	9382	psf	449	kPa	- Table B.1.1, adjusted using compensating multiplier of 0.73 at 38°C, Table B.1.2)
S_A	=	2.91	[-]	2.91	[-]	
VAF	=	0.630	[-]	0.630	[-]	
P_{RD}	=	5907	psf	283	kPa	
S	=	349	psi	2407	kPa	

S_{allow} = allowable pipe wall compressive stress = 780 psi
= 5378 kPa

(Allowable pipe wall compressive stress of 1000 psi at 23°C, Ref. 1 - Chapter 3 - Table C.1, for PE3408 pipe, adjusted using compensating multiplier of 0.78 at 38°C, Table A-2)

$$\text{Factor of Safety} = \frac{S_{allow}}{S} = \frac{780}{349} = 2.2$$

Okay [Typical Recommended F.S. = 1.0 Ref. 1]

(b) Check for ring deflection (Watkins - Gaube Graph)

From Ref. 1 (Eqn. 3-28), percent ring deflection is:

$$\left(\frac{\Delta x}{D_M}\right) \times 100 = D_F \times \varepsilon_S$$

where,

Δx = ring deflection [in]
D_M = mean diameter [in] (i.e. Do - t)
D_F = deformation factor (from Watkins - Gaube Graph)
ε_S = soil strain [%] = σ_v /(144 x E_s) (Eq. 3-27 Ref. 1)
σ_v = applied vertical stress on pipe (psf)
E_s = secant modulus of soil [psi] = M_s (1 + μ) (1-2μ) / (1 - μ) (Eq. 3-26 Ref. 1)
M_s = one dimensional soil modulus [psi]
μ = soil's Poisson ratio [-]

Ridgity factor, R_F for Watkins - Gaube Graph is:

$$R_F = \frac{12\,E_S\,(DR\;-1)^3}{E}$$

DR = standard dimension ratio of pipe [-] i.e pipe outside diameter / wall thickness
E_s = secant modulus of soil [psi]
E = apparent modulus of elasticity of pipe material [psi]

Leachate Collection System Pipe Structural Stability Calculations, 8" DR17 HDPE Pipe,
Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba

Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

		English Units		SI Units		
E	=	19710	psi	135900.5	kPa	
D_o	=	8.63	in	0.219	m	(for 8 in. DR = 17 Sclairpipe PE3408)
t	=	0.507	in	0.013	m	
D_M	=	8.123	in	0.207	m	
σ_v	=	9382	psf	449	kPa	
μ	=	0.15	[-]	0.15	[-]	(Ref. 1 Table 3-13)
M_s	=	5000	psi	34475	kPa	
E_s	=	4735	psi	32650	kPa	
R_F	=	11809	[-]	11809	[-]	
D_F	=	2	[-]	2	[-]	(deformation factor from Watkins-Gaube Graph, Ref. 1)
ε_S	=	1.4%		1.4%		
$\Delta x/D_M$	=	2.8%		2.8%		(Percent Ring Deflection)

allowable ring deflection = 5% (Ref. 1 page 218)

Factor of Safety = $\frac{\text{Allowable ring def.}}{\Delta x/D_M} = \frac{5\%}{2.8\%} =$ 1.8 Okay [Typical Recommended F.S. = 1.0 Ref. 1]

(c) Check for wall buckling

Moore-Selig Equation for critical buckling pressure:

$$P_{CR} = \frac{2.4\,\emptyset\,R_H}{D_M}(E\,I)^{\frac{1}{3}}\,(E_S^*)^{\frac{2}{3}}$$

where,

P_{CR} = critical constrained buckling pressure [psi]
Φ = calibration factor [-]
R_H = geometry factor [-]
D_M = mean diameter [in] (i.e. D_o - t)
E = apparent modulus of elasticity of pipe material [psi]
I = pipe wall moment of inertia [in^4/in] = (t^3/12, for a solid wall pipe)
E_s = secant modulus of soil [psi] = M_s (1 + μ) (1-2μ) / (1 - μ) (Eq. 3-26 Ref. 1)
E^*_s = E_s / (1-μ)
μ = soil's Poisson ratio [-]

		English Units		SI Units		
Φ	=	0.55	[-]	0.55	[-]	(Ref. 1 Page 233)
R_H	=	1	[-]	1	[-]	(Ref. 1 Page 233)
D_M	=	8.123	in	0.207	m	
E	=	19710	psi	135900.5	kPa	
t	=	0.507	in	0.013	m	
I	=	0.0109	in^3	1.78E-07	m	
E_s	=	4735	psi	32650	kPa	
μ	=	0.15	[-]	0.15	[-]	(Ref. 1 Table 3-13)
E^*_s	=	5571	psi	38412	kPa	
P_{CR}	=	305	psi	2106	kPa	

Leachate Collection System Pipe Structural Stability Calculations, 8" DR17 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba		
Project Number: 21473621	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: December 2021

Applied vertical pressure on the pipe:

$$P_B = \frac{\sigma_v}{144}$$

where,

P_B = applied verical pressure on the pipe (psi)

σ_v = applied vertical pressure on pipe (psf)

		English Units		SI Units	
σ_v	=	9382	psf	449	kPa
P_B	=	65.1	psi	449	kPa

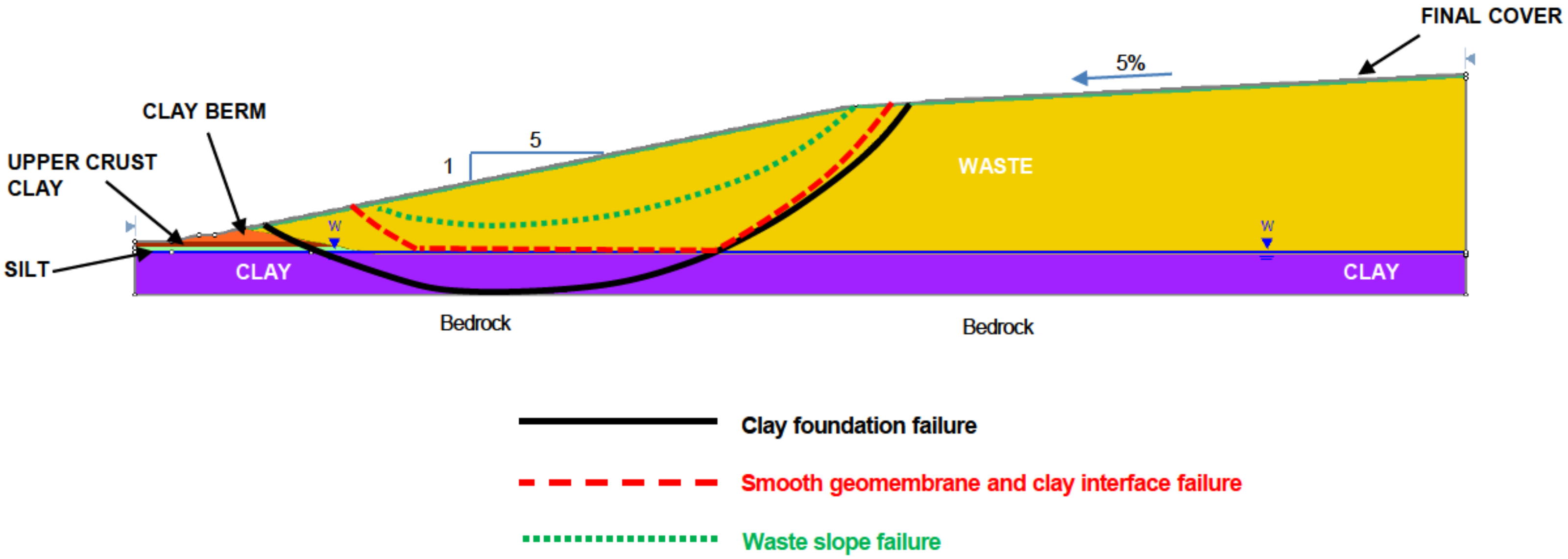
P_{CR} = critical constrained buckling pressure = 305 psi

= 2106 kPa

Factor of Safety = $\frac{P_{CR}}{P_B} = \frac{305}{65.1} =$ 4.7 Okay [Typical Recommended F.S. = 2.0 Ref. 2]

APPENDIX E

Slope Stability Analyses



CLIENT
WASTE CONNECTIONS OF CANADA INC.

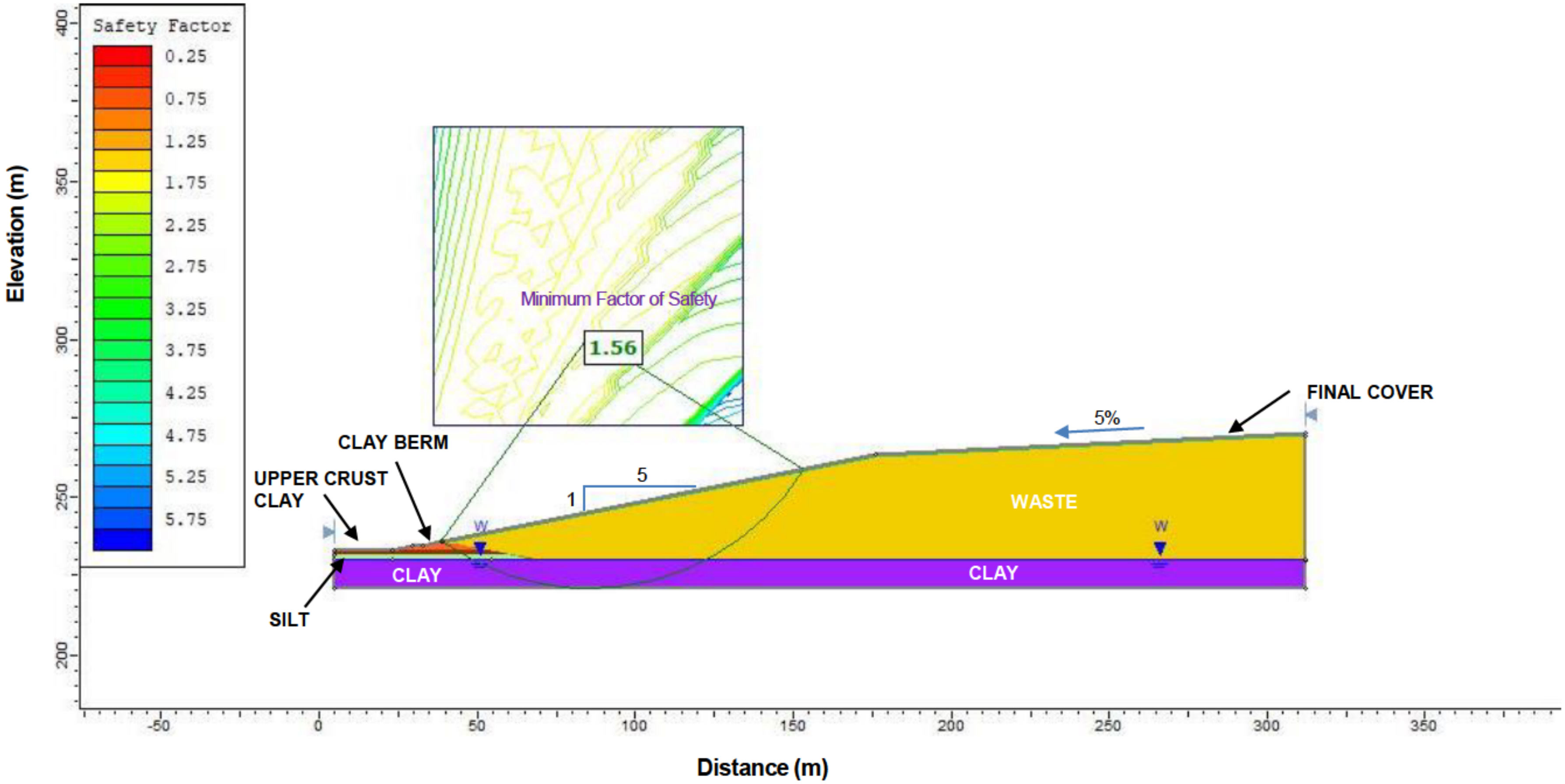
CONSULTANT
GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
SCHEMATIC OF DIFFERENT FAILURE MODES

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-1**



CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

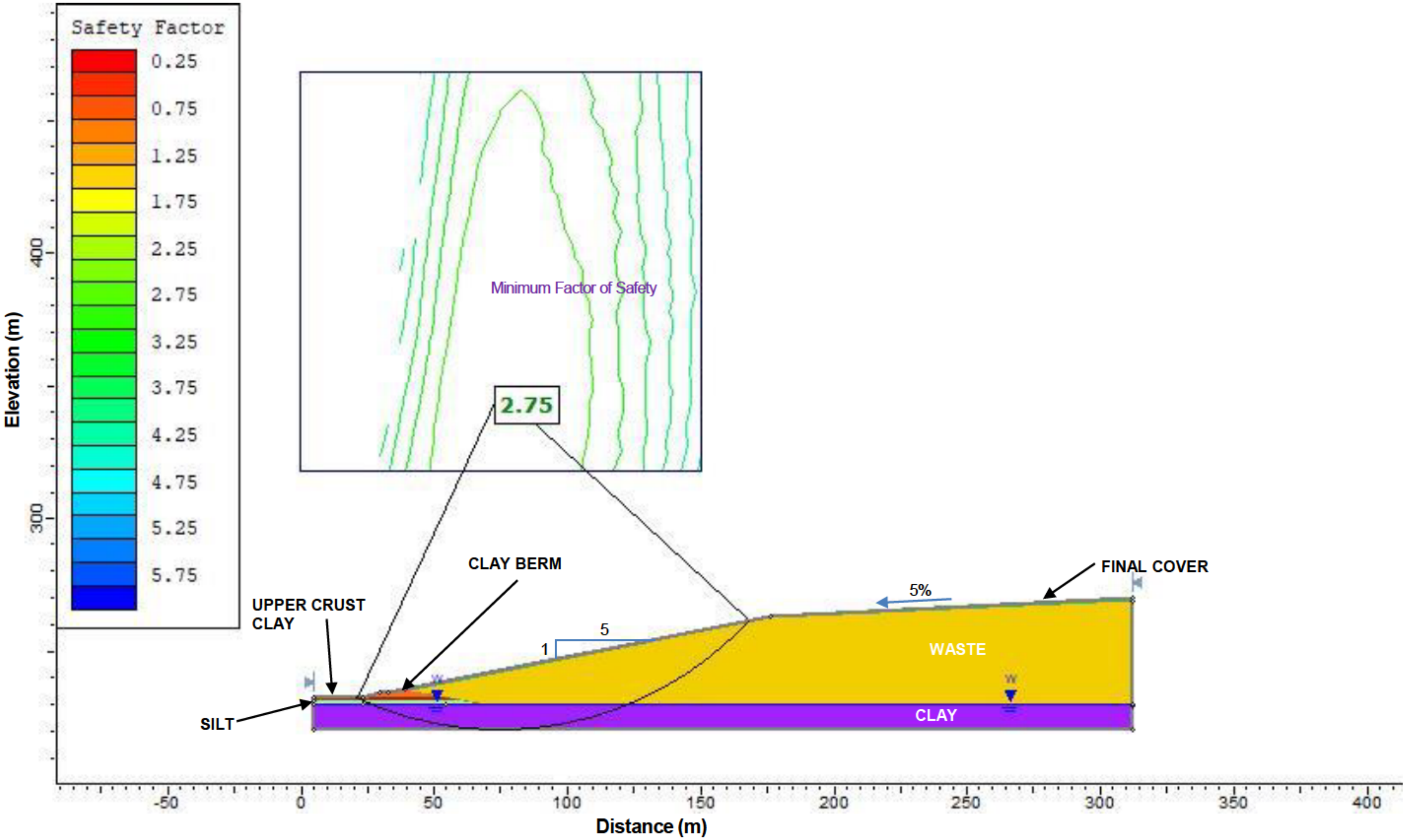
CONSULTANT

GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
CLAY FOUNDATION FAILURE (UNDRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-2**



CLIENT
WASTE CONNECTIONS OF CANADA INC.

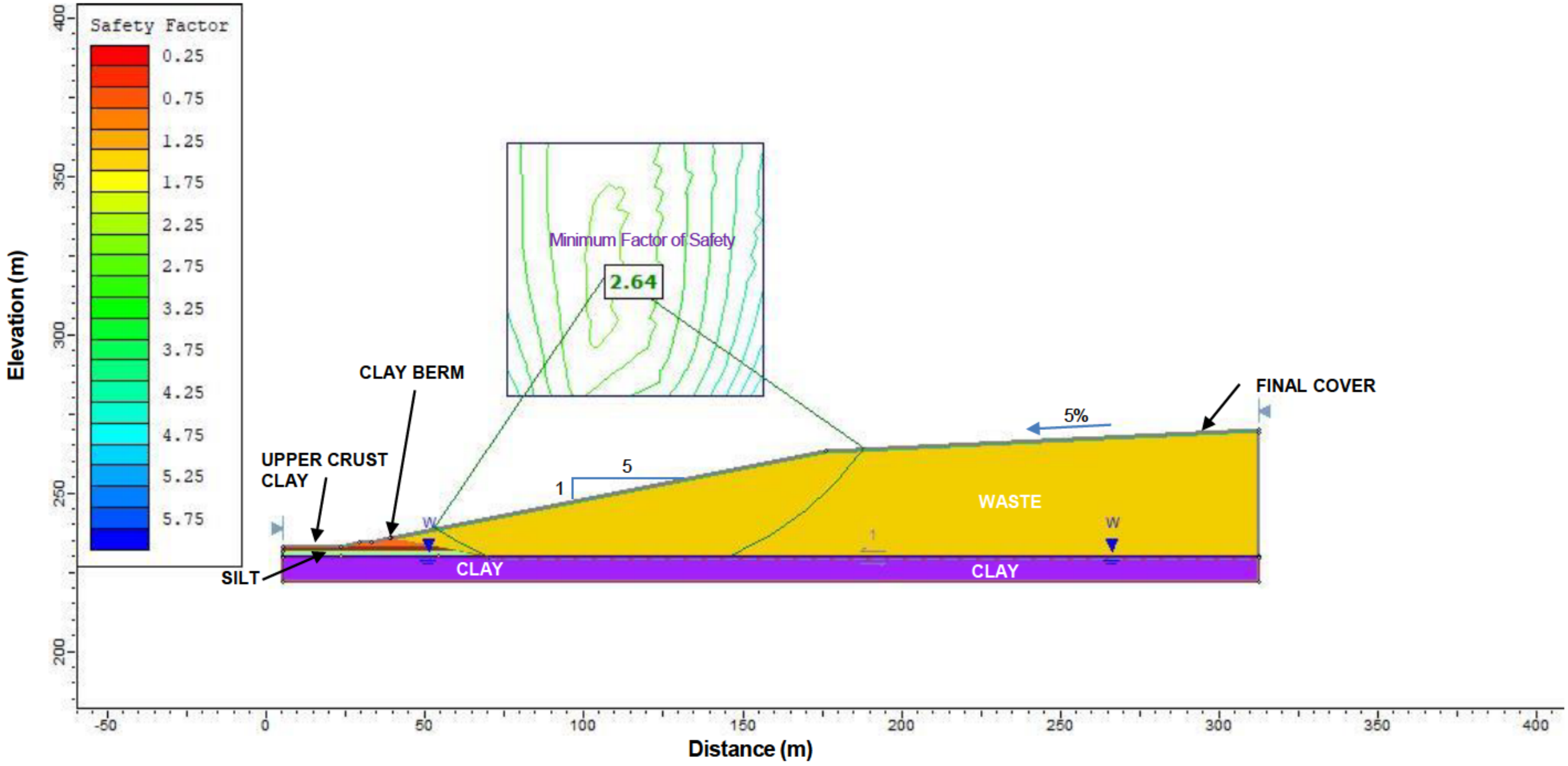
PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

CONSULTANT
GOLDER

YYYY-MM-DD	2022-03-25
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
CLAY FOUNDATION FAILURE (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-3**



CLIENT
WASTE CONNECTIONS OF CANADA INC.

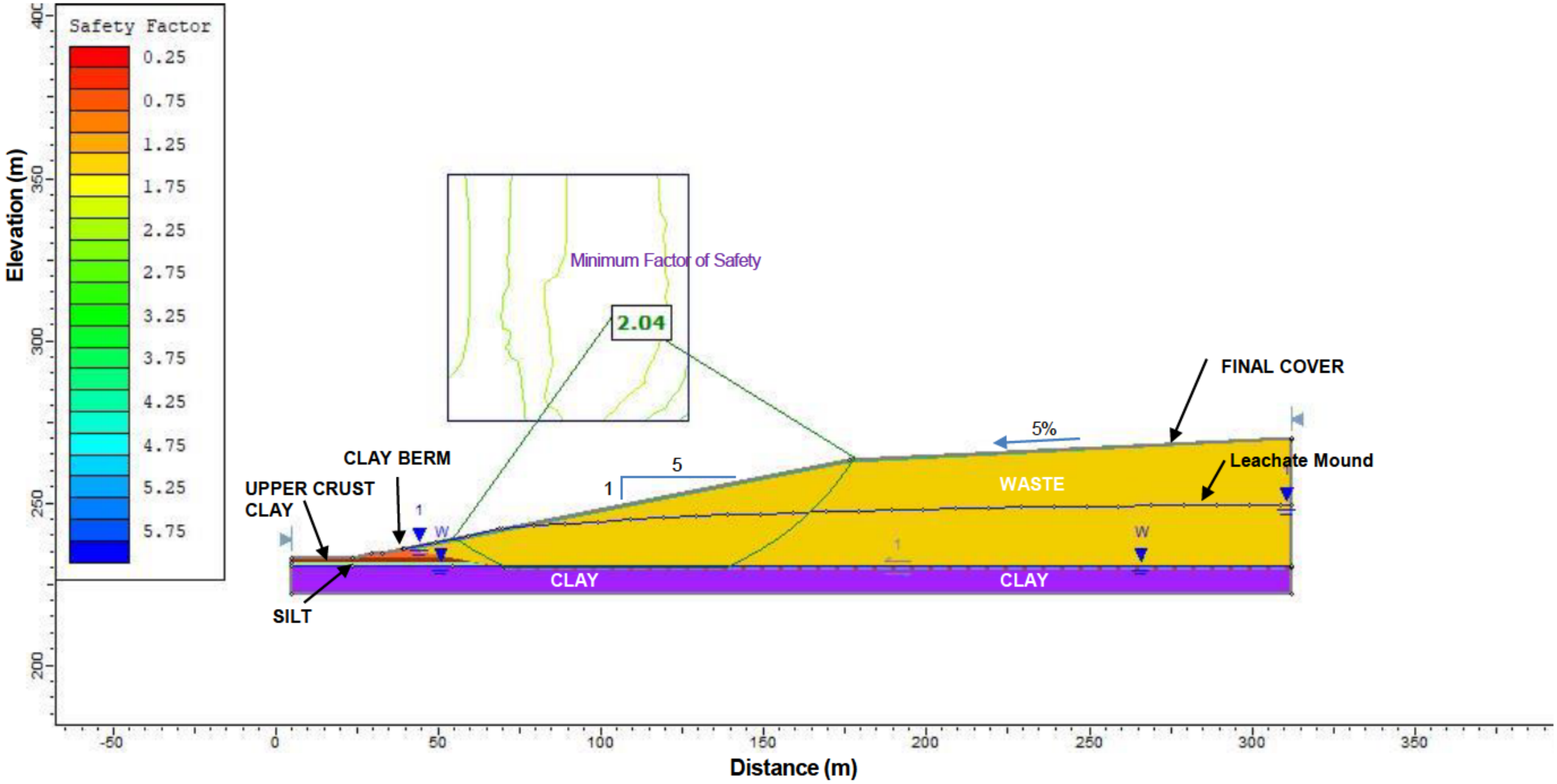
PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

CONSULTANT
GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
SMOOTH GEOMEMBRANE AND CLAY INTERFACE FAILURE
AT NORMAL OPERATING CONDITION (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-4**



CLIENT
WASTE CONNECTIONS OF CANADA INC.

CONSULTANT

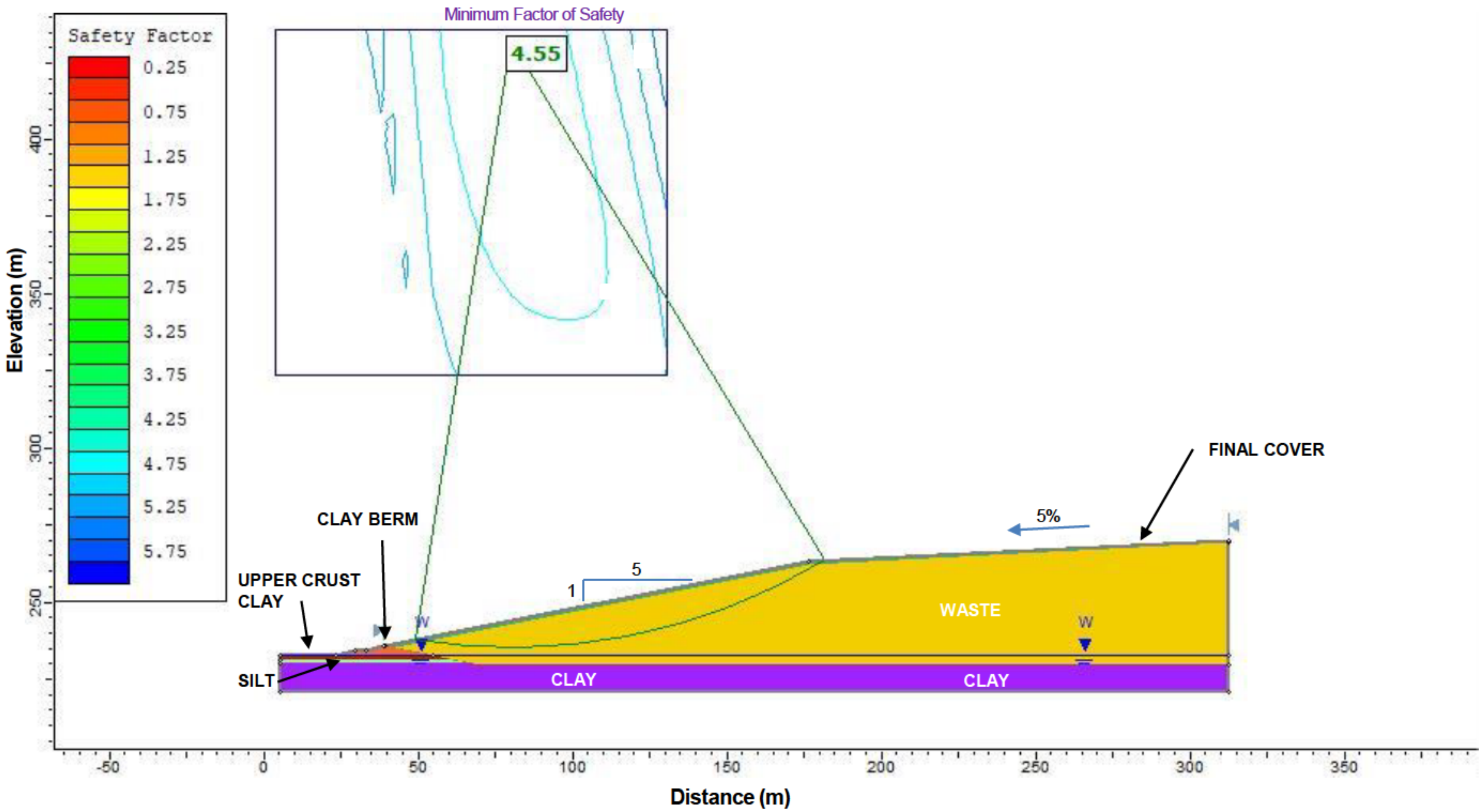
GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
SMOOTH GEOMEMBRANE AND CLAY INTERFACE FAILURE
WITH LEACHATE MOUNDING (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	FIGURE
21473621	1000	A	E-5



CLIENT
WASTE CONNECTIONS OF CANADA INC.

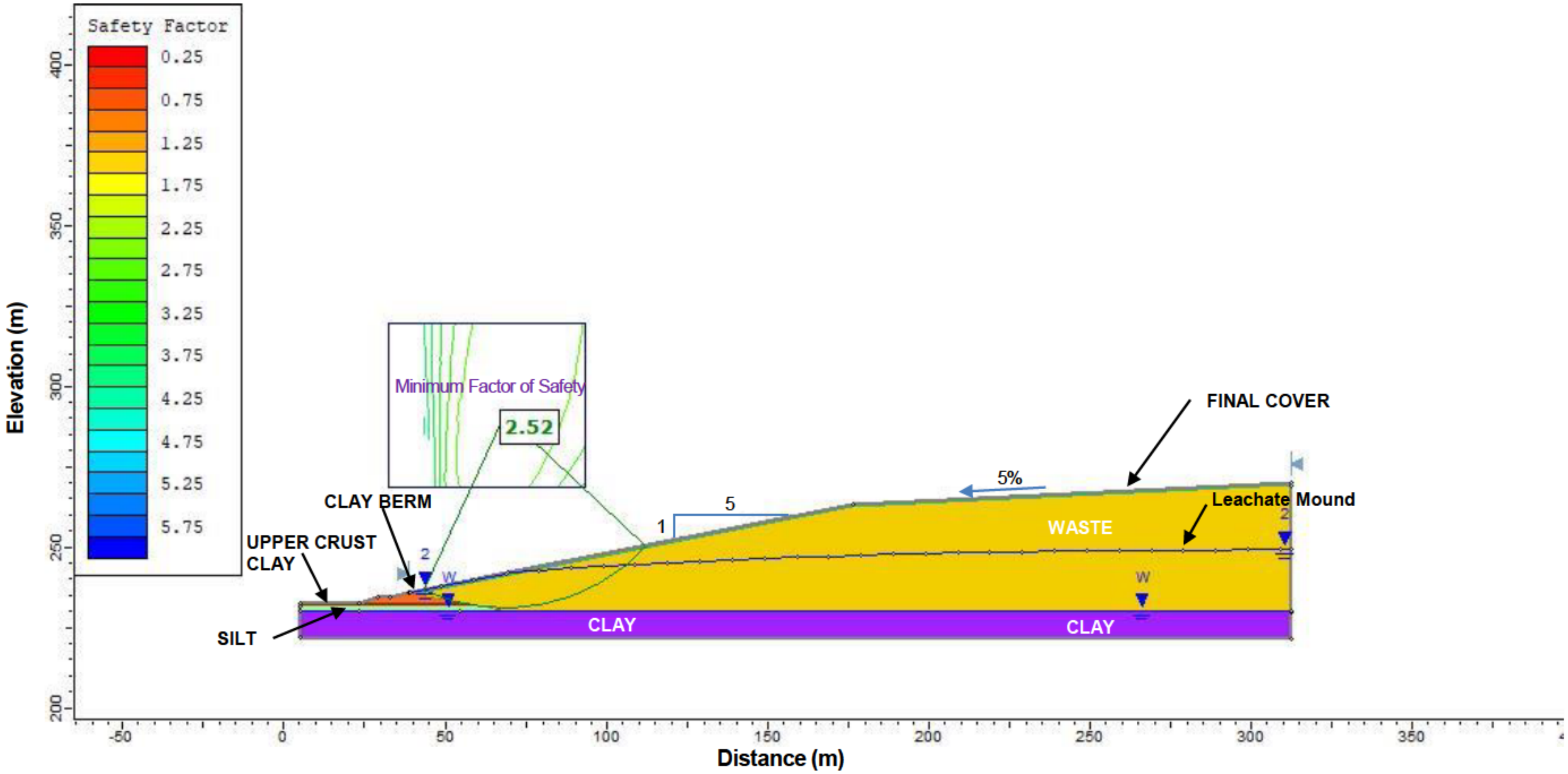
PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

CONSULTANT
GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
WASTE SLOPE FAILURE AT NORMAL OPERATING CONDITION (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-6**



CLIENT
WASTE CONNECTIONS OF CANADA INC.

CONSULTANT
GOLDER

YYYY-MM-DD	2021-12-21
PREPARED	TVJG
DESIGNED	TVJG
REVIEWED	SR
APPROVED	FSB

PROJECT
PHASE II DESIGN AND HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B')
WASTE SLOPE FAILURE WITH LEACHATE MOUNDING
(DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
21473621	1000	A	**E-7**

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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