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: Integrated Waste Management Facility

MANITOBA SUSTAINABLE DEVELOPMENT
ENVIRONMENTAL APPROVALS BRANCH
APR 26 2021
RECEIVED

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) 694-7615 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: (905) 567-4444	Mailing address:
Fax:	100-6925 Century Avenue, Mississauga, ON L5N 7K2

Email address: fabiano_gondim@golder.com

Short Description of Alteration *(max 90 characters):*
Height adjustment for the landfill component as per attached report.

Alteration fee attached: Yes: ☑ No: ☐

If No, please explain:

Date:	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")

GOLDER

FINAL REPORT

Prairie Green Integrated Waste Management Facility

Landfill Height Adjustment

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

+1 905 567 4444

20396341 Rev. 0

January 27, 2021

Distribution List

2 Hard Copies and One e-Copy - Waste Connections of Canada

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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. (formerly known as Progressive Waste Solutions Canada Inc. or BFI Canada Inc.) under Environment Act License No. 2177 E R5 issued on June 28, 1996 and revised on June 28, 2000, April 24, 2002, October 16, 2012, July 18, 2013 and 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 2020, Cells 1 to 15 of Phase I of the Landfill have been developed and Cell 16 of Phase I is under construction.

1.2 Purpose

This report was prepared to support an application to approve the proposed height adjustment of the Landfill. 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 current Landfill design, proposed Landfill height adjustment and geotechnical analyses completed for Phase I.

No geotechnical analyses were completed for Phase II as limited subsurface conditions and no base grade design are currently available.

2.0 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 I is approved with a perimeter berm, 6(H):1(V) waste fill perimeter side slopes to a crest elevation at approximately 257 metres above sea level (masl) and 2% top slopes with a top of final cover peak elevation at 260.4 masl (Figure 2). Phase II is approved with requirements similar to Phase I (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). As shown in Figure 4, each cell of Phase I was designed with a central valley. A leachate collection trench located at the central valley of each cell, sloped at 0.7%, 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 8). The sump forms the low point of each cell. Leachate is pumped from each individual sump into tanker trucks and hauled for treatment at the City of Winnipeg North End Wastewater Treatment Plant.

The original design of the composite base liner system for the floor and side slopes of Cells 1 to 13 of Phase I 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 Cells 14 to 17 of Phase I and 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 I includes a 300 mm thick sand filter layer, a nonwoven geotextile filter and a 300 mm thick clear stone drainage layer. This LCS design was modified and approved for some of the previous cells of Phase I to replace the 300 mm thick clear stone drainage layer with a tire shred layer outside the trench and sump areas. 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 Cells 15 to 17 of Phase I and all cells of Phase II.

The perforated leachate collection pipe located along the bottom of the central leachate collection trench was specified for Cells 1 to 10 of Phase I as high density polyethylene (HDPE) pipe with a ratio of the pipe outside diameter to the pipe minimum wall thickness (Dimension Ratio or DR) of 13.5. The perforated pipe along the trench of Cells 11 to 15 of Phase I was specified as DR11 HDPE. The perforated pipe along the trench of Cells 16 and 17 of Phase I was specified as DR17 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 8. It is noted that Section C of Figure 8 is located at the centre of a typical leachate collection trench, and Section D of Figure 8 is located outside of a typical leachate collection trench.

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.

3.0 LANDFILL HEIGHT ADJUSTMENT

The following height adjustments are proposed for Phases I and II.

For Phase I, the proposed height adjustment involves extending the existing 6(H):1(V) perimeter side slopes at a grade of 5(H):1(V) from elevation 256 masl to 286 masl, as shown in Figures 5 and 6. The top slopes are proposed at 5% from elevation 286 masl to the peak elevation (top of final cover) of 287.58 masl. This height adjustment would increase the peak of Phase I from the approved peak elevation of 260.4 masl to 287.58 masl. The maximum height above the surrounding ground surface (average elevation of 233 masl) would increase from approximately 28 metres above ground surface (mags) to approximately 55 mags. This represents a 27 m net height increase.

For Phase II, it is proposed to modify the perimeter 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 7. 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 28 mags to approximately 37 mags. This represents a 9 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 5 m higher than the proposed peak of Phase I and 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 21 m higher than the proposed peak of Phase I and 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.

4.0 GEOTECHNICAL ANALYSES FOR PHASE I HEIGHT ADJUSTMENT

4.1 Differential Settlement Analysis Along the Leachate Collection System Pipe

As additional waste is placed in the Landfill with the proposed height adjustment, the Landfill base will undergo additional 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 I and decrease towards the perimeter. Hence, the central part of the Landfill will undergo the largest amount of settlement of the base grades whereas 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 4, 5 and 6) located along the LCS pipe in the central trench of Cell 11. Detailed one-dimensional settlement calculations are provided in Appendix A. The consolidation test results reported by Golder (1995b) for the natural clay layer beneath the Landfill were used for the settlement calculations. The settlement calculations were carried out for the existing condition (Landfill height as of May 30, 2020 survey) and 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 A-1 (Appendix A). Four locations along the base grades were selected for the differential settlement calculations i.e., base grade locations at the sump location which is at 24 m from the south limit of the waste fill, at the currently approved crest of the 6(H):1(V) slope located at 119 m from south limit of the waste fill, at the crest of the proposed 5(H):1(V) slope located at 276 m from south limit of waste and at the proposed top of Landfill located at 296 m from south limit of waste.

The initial design slope of the base grade at the location of the LCS pipe along cross-section B-B' was 0.7% draining towards the sump. The thickness of the natural clay deposit beneath the base grades of Cell 11 ranges from approximately 5.9 m near the sump area to approximately 7.8 m near the central part of the Landfill.

The calculated subgrade settlements from the start of landfilling to the existing condition are as much as 0.39 m at the central area of the Landfill where the existing waste thickness is approximately 25 m to 0.023 m at the sump area where the existing waste thickness is approximately 11 m. The base grade slopes decrease from the initial value of 0.7% to as low as 0.33% near the central area of the Landfill. As shown on Cross-Section B-B', the existing waste elevations are well below the currently approved maximum waste elevations.

The calculated total subgrade settlements for the proposed height adjustment are as much as 1.1 m at the central area of the landfill where the maximum proposed waste thickness is approximately 57 m to 0.025 m at the sump area where the waste thickness is approximately 11 m. The base grade slopes decrease from the initial value of 0.7% to as low as 0.25% between the location of the currently approved crest of the 6(H):1(V) slope and the crest of the proposed 5(H):1(V) slope and 0.53% between the crest of the proposed 5(H):1(V) slope and the proposed top of the Landfill. 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.

4.2 Structural Stability of Leachate Collection System Pipe

Structural stability calculations were carried out for the 200 mm nominal diameter SDR 11 and 13.5 (Designation Code PE3408) HDPE leachate collection system pipes. SDR 11 pipe was installed in the central LCS trench of Cells 11 to 15 and SDR 13.5 pipe was installed in the central LCS trench of Cells 1 to 10.

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°C. [The temperature of 38°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 13.5 pipe are chemically resistant to municipal solid waste at the temperature of 38°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 B. Table 1 presents the resulting Factor of Safety values for the above failure mechanisms at the maximum applied vertical static pressure of 766 kPa (57 m of waste fill) acting on the DR11 and DR13.5 pipes in the central area of the cells.

Table 1: Factor of Safety for Different Pipe Failure Mechanisms

Failure Mechanism	Factor of Safety for 200 mm Nominal Diameter, DR11, PE3408 HDPE Pipe Installed in Cells 11 to 15	Factor of Safety for 200 mm Nominal Diameter, DR13.5, PE3408 HDPE Pipe Installed in Cells 1 to 10	Minimum Required Factor of Safety
Pipe Wall Crushing	1.7	1.5	1.0

Failure Mechanism	Factor of Safety for 200 mm Nominal Diameter, DR11, PE3408 HDPE Pipe Installed in Cells 11 to 15	Factor of Safety for 200 mm Nominal Diameter, DR13.5, PE3408 HDPE Pipe Installed in Cells 1 to 10	Minimum Required Factor of Safety
Reversal of Curvature (Ring Deflection)	1.4	1.3	1.0
Pipe Wall Buckling	4.4	3.5	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 13.5 (Designation Code PE3408) HDPE pipes with the proposed height adjustment.

4.3 Slope Stability Analyses

Slope stability analyses were carried out using the computer model Slide 2018 (Rocscience, 2018) for the Cross-section B-B' shown in Figures 4, 5 and 6 and typical details shown in Figure 8 (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 2018 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 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
Clay Berm Fill	18	NA	0	19	Estimated based on experience
Smooth Geomembrane	15	NA	0	11	Koerner and Narejo (2005)

Material	Unit Weight (kN/m^3)	Undrained Shear Strength (S_u) (kPa)	Effective Stress Parameters		Reference
			Cohesion (c') (kPa)	Friction Angle (degrees)	
and Clay Interface					
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)
Grey Clay	16.5	52 to 22[b]	0	19	Golder (1995b)

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 C-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 clay beneath the Landfill was assumed to be at ground surface elevation 233.0 masl, based on the bedrock piezometric level at ground surface. The leachate level in the Landfill was conservatively assumed to be at the same elevation as the piezometric level in the clay beneath the Landfill (corresponds to 3.0 m of leachate head 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 = 592 m

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

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

The results of the stability analyses are shown in Figures C-2, C-3, C-4, C-5, C-6 and C-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	2.5 (Figure C-2)
Clay foundation failure	Effective stress (drained) analysis	3.1 (Figure C-3)
Smooth geomembrane and clay liner interface failure at normal operating condition	Effective stress (drained) analysis	2.6 (Figure C-4)
Smooth geomembrane and clay interface failure with leachate mounding	Effective stress (drained) analysis	2.0 (Figure C-5)
Waste slope failure at normal operating condition	Effective stress (drained) analysis	4.4 (Figure C-6)
Waste slope failure with leachate mounding	Effective stress (drained) analysis	2.4 (Figure C-7)

5.0 CONCLUSIONS AND RECOMMENDATIONS

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 I of the Landfill, and indicate that the desired performance for slope stability and the leachate collection system would continue to be achieved.

Although the geotechnical analyses presented in this report are for the Phase I area, a height adjustment is also proposed for the Phase II area. To support the height adjustment for Phase II, subsurface investigation and similar analyses will need to be undertaken as part of the design for the first cell.

Signature Page

Golder Associates Ltd.

[redacted]

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FRG/SR/FSB/DEB/ml

https://golderassociates.sharepoint com/sites/136138/project files/5 technical work/height adjustment report/final/20396341-r-rev0 - height adjustment final report 2021jan27 docx

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Figures

LEGEND

- PROPERTY LIMITS
- APPROVED SITE BOUNDART
- APPROVED L MITS OF WASTE
- CELL DIV DE
- EXISTING GRAVEL ROAD
- EXISTING PAVED ROAD
- EXISTING RAILWAY (CPR)
- EXISTING FENC NG
- EXISTING DRAINAGE DITCH
- EXISTING WATER BODY
- EXISTING TREE L NE
- EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
- EXISTING GEODETIC CONTROL PO NTS
- 240.0 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1 0 masl)
- EL. 232.541 EXISTING GROUND SURFACE SPOT ELEVATION (masl)
- FUTURE ROAD

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPL NG DISTANCE, DATED MAY 30, 2020 BY THE BASE MAPP NG CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY L MITS FROM FIGURE 2 - 2018 FISCAL PLANN NG MODEL PREPARED BY DILLON CONSULTING.

0 200 400
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
SITE PLAN (MAY 30, 2020)

CONSULTANT

GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
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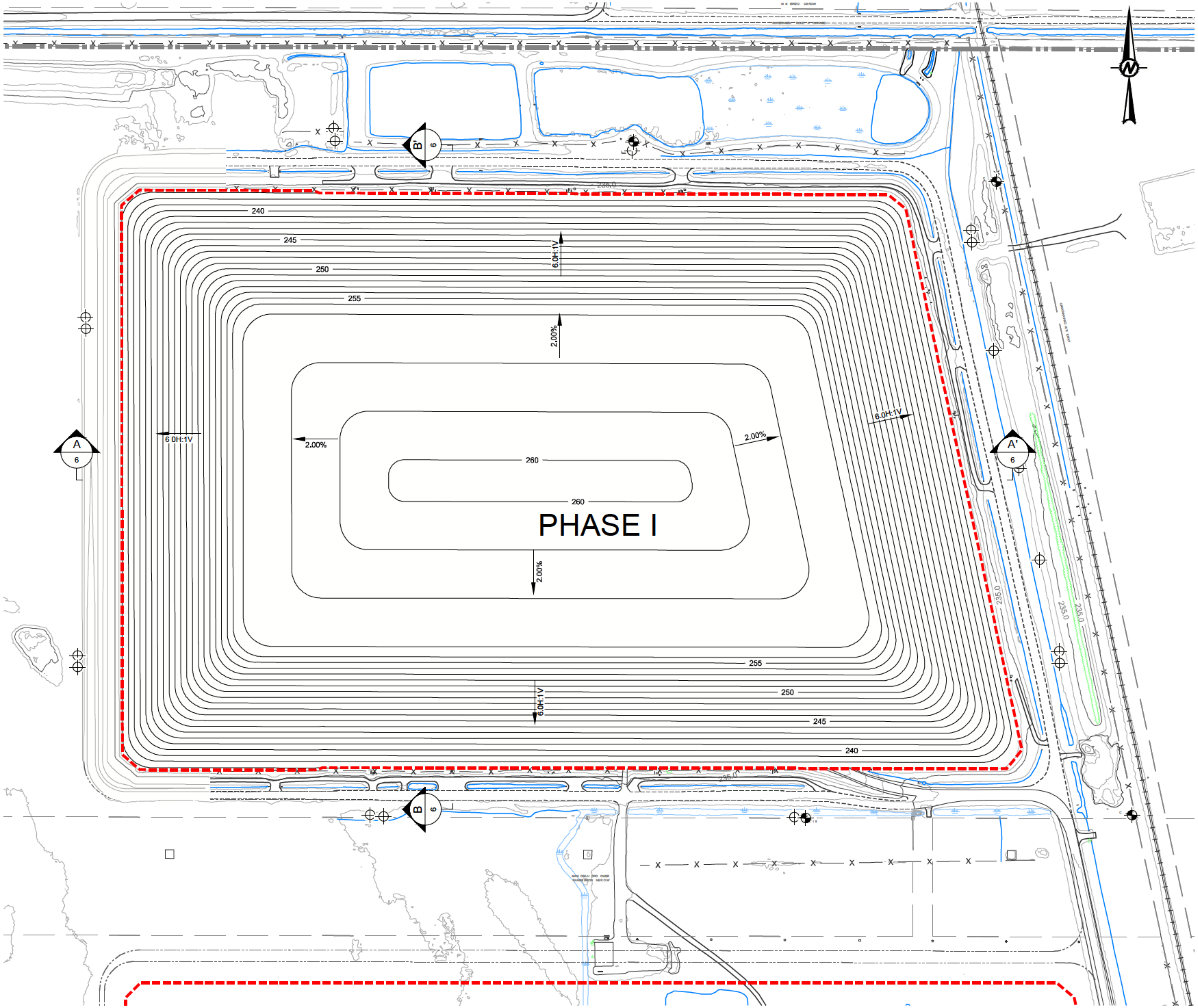

LEGEND

PROPERTY LIMITS
APPROVED SITE BOUNDART
APPROVED L MITS OF WASTE
EXISTING GRAVEL ROAD
EXISTING PAVED ROAD
EXISTING RAILWAY (CPR)
EXISTING FENC NG
EXISTING DRAINAGE DITCH
EXISTING WATER BODY
EXISTING TREE L NE
235.0 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1 0 masl)
EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
EXISTING GEODETIC CONTROL PO NTS
250 APPROVED TOP OF FINAL COVER CONTOUR (NTERVAL 1.0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

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2. APPROVED WASTE LIMITS AND PROPERTY L MITS FROM FIGURE 2 - 2018 FISCAL PLANN NG MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

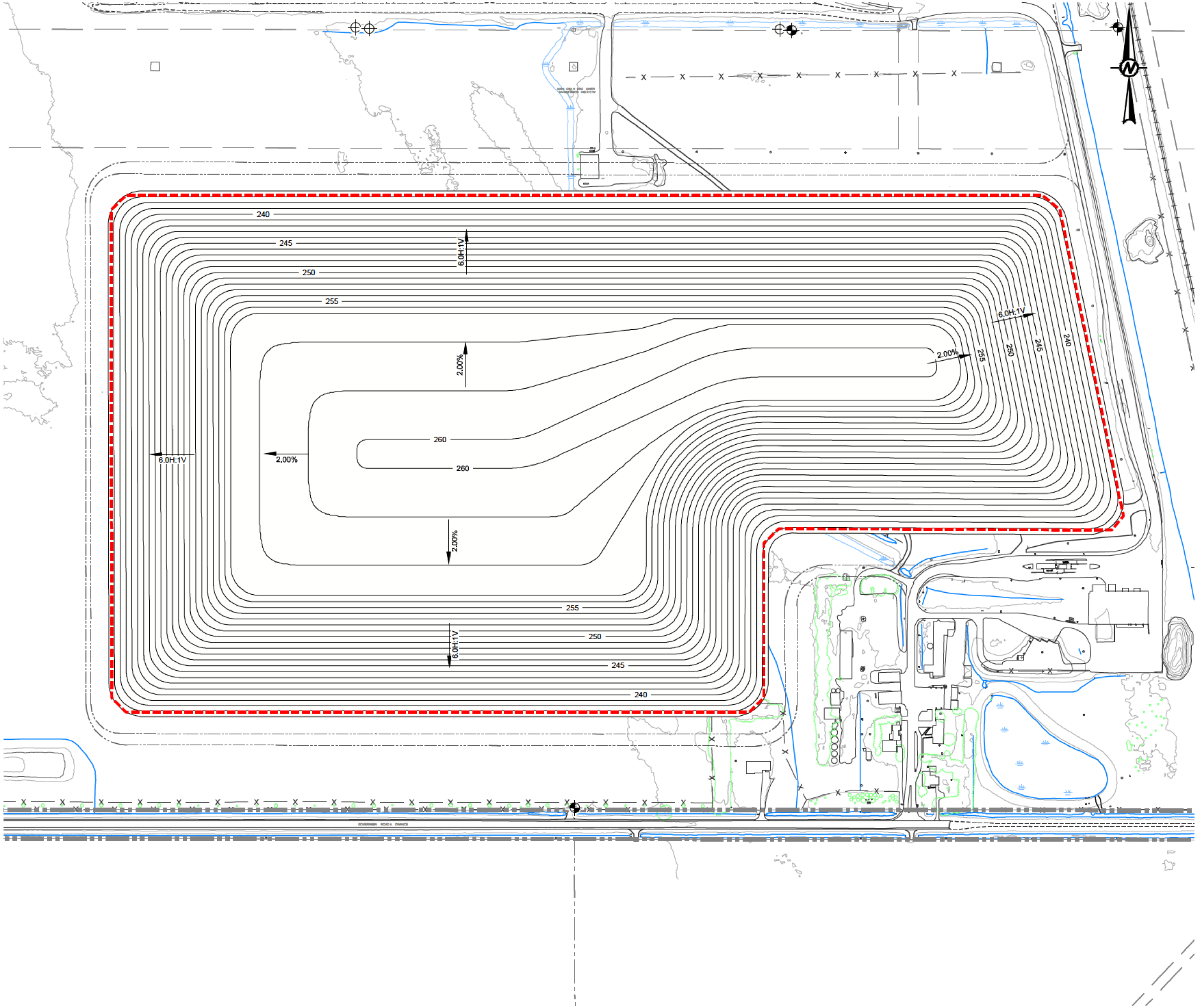
PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
APPROVED TOP OF FINAL COVER CONTOURS - PHASE I

CONSULTANT
GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	2



LEGEND

	PROPERTY LIMITS
	APPROVED SITE BOUNDART
	APPROVED L MITS OF WASTE
	EXISTING GRAVEL ROAD
	EXISTING PAVED ROAD
	EXISTING RAILWAY (CPR)
X — X	EXISTING FENC NG
	EXISTING DRAINAGE DITCH
	EXISTING WATER BODY
	EXISTING TREE L NE
235.0	EXISTING GROUND SURFACE CONTOUR (INTERVAL 1 0 masl)
	EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
	EXISTING GEODETIC CONTROL PO NTS
	FUTURE ROAD
250	APPROVED TOP OF FINAL COVER CONTOUR (NTERVAL 1.0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

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0 100 200
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

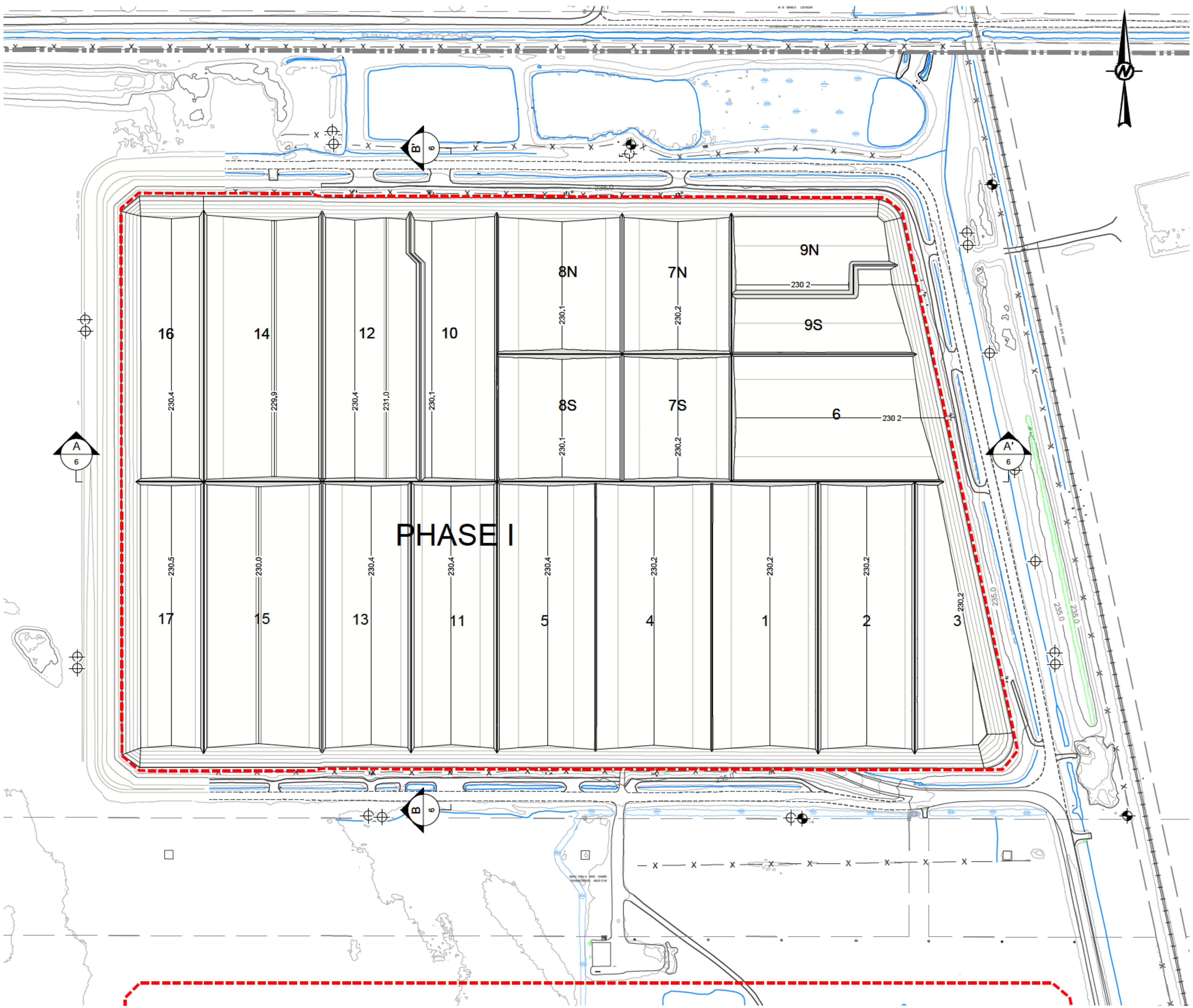
TITLE
APPROVED TOP OF FINAL COVER CONTOURS - PHASE II

CONSULTANT

GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	3



LEGEND

- PROPERTY LIMITS
- APPROVED SITE BOUNDART
- APPROVED L MITS OF WASTE
- EXISTING GRAVEL ROAD
- EXISTING PAVED ROAD
- EXISTING RAILWAY (CPR)
- EXISTING FENC NG
- EXISTING DRAINAGE DITCH
- EXISTING WATER BODY
- EXISTING TREE L NE
- 235,0 EXISTING GROUND SURFACE CONTOUR (INTERVAL 0 5 masl)
- EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
- EXISTING GEODETIC CONTROL PO NTS
- TOP LEACHATE COLLECTION SYSTEM CONTOUR (INTERVAL 1.0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPL NG DISTANCE, DATED MAY 30, 2020 BY THE BASE MAPP NG CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY L MITS FROM FIGURE 2 - 2018 FISCAL PLANN NG MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

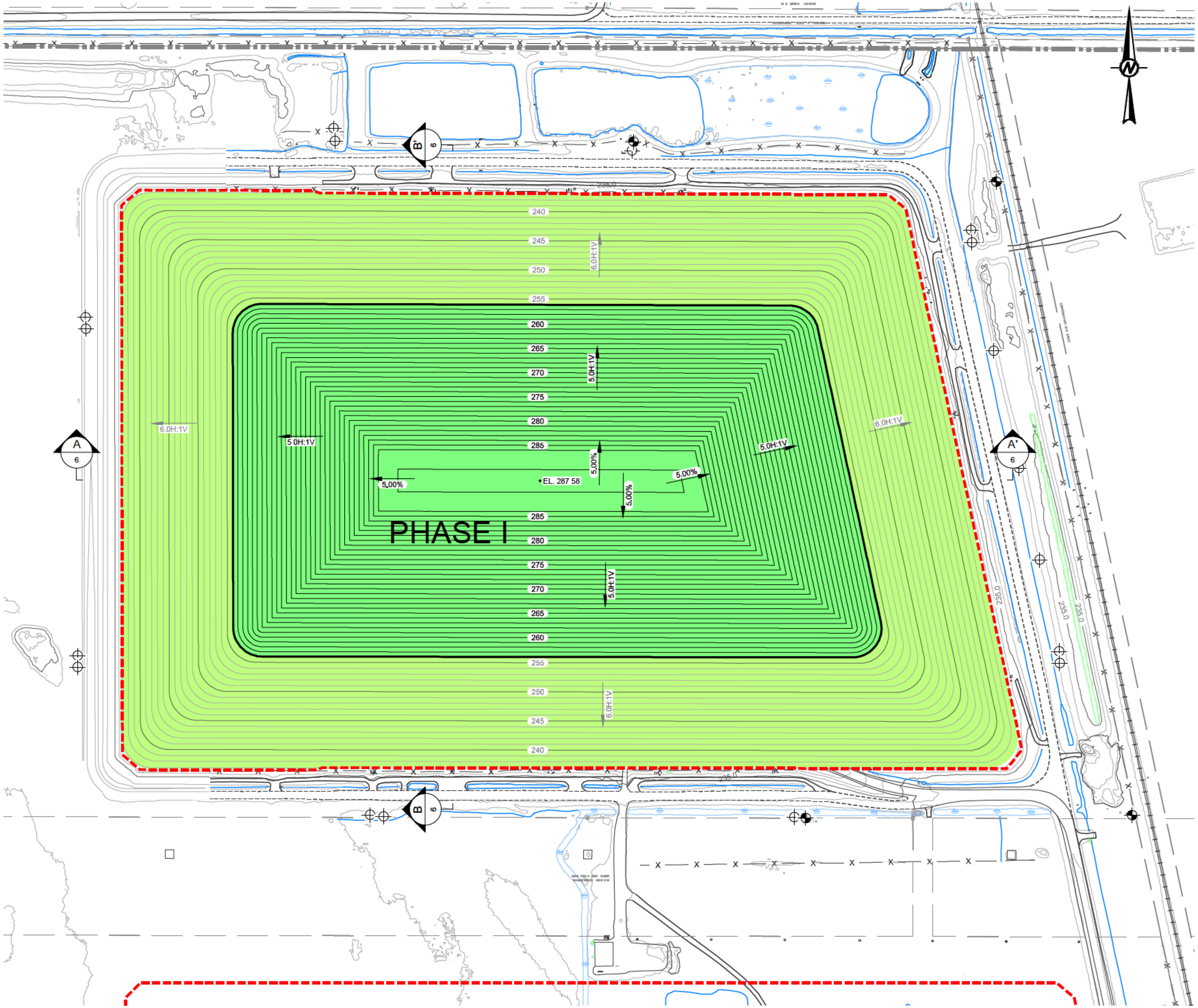
TITLE
APPROVED TOP OF LEACHATE COLLECTION SYSTEM - PHASE I

CONSULTANT

GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	4



LEGEND

- PROPERTY LIMITS
- APPROVED SITE BOUNDART
- APPROVED L MITS OF WASTE
- EXISTING GRAVEL ROAD
- EXISTING PAVED ROAD
- EXISTING RAILWAY (CPR)
- EXISTING FENC NG
- EXISTING DRAINAGE DITCH
- EXISTING WATER BODY
- EXISTING TREE L NE
- 235.0 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1 0 masl)
- EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
- EXISTING GEODETIC CONTROL PO NTS
- 250 APPROVED TOP OF FINAL COVER CONTOUR (NTERVAL 1.0 masl)
- 280 PROPOSED HEIGHT ADJUSTMENT TOP OF F NAL COVER CONTOUR (NTERVAL 1 0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.
2. TOTAL ADDITIONAL AIRSPACE QUANTITY ~ 2,828,100 m³.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPL NG DISTANCE, DATED MAY 30, 2020 BY THE BASE MAPP NG CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY L MITS FROM FIGURE 2 - 2018 FISCAL PLANN NG MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

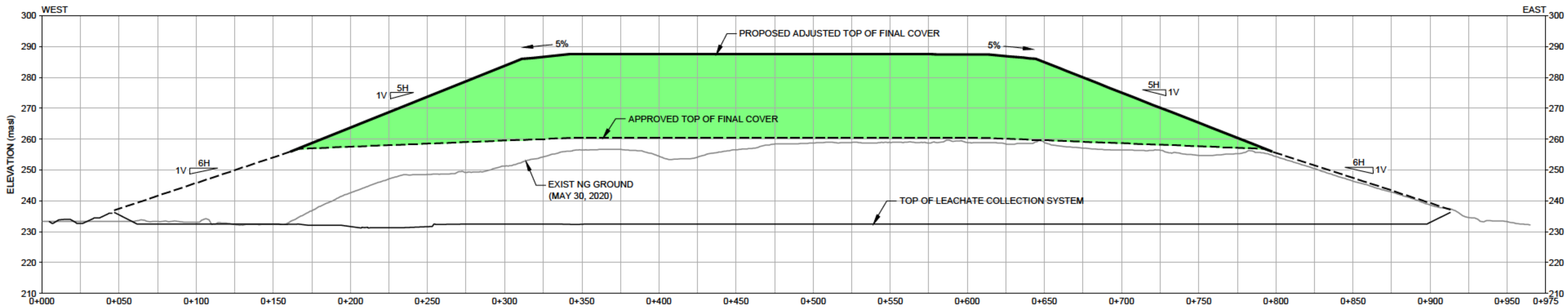
PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
PROPOSED ADJUSTED TOP OF FINAL COVER CONTOURS - PHASE I

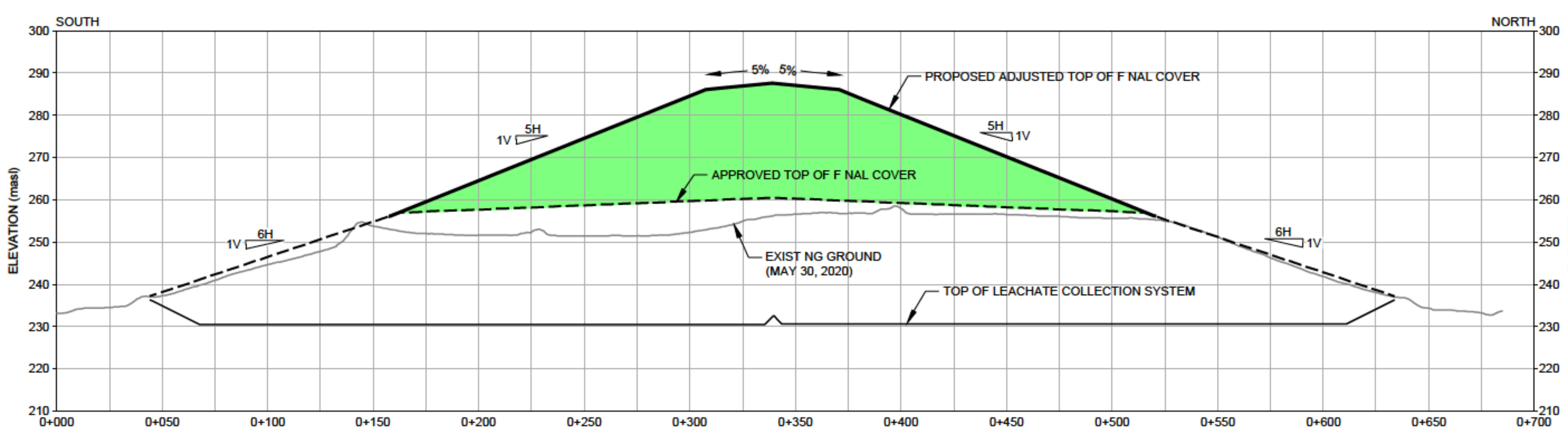
CONSULTANT
GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	5



V.E. = 2X A 5 CROSS-SECTION A-A'



V.E. = 2X B 5 CROSS-SECTION B-B'

NOTE(S)

1. TOTAL ADDITIONAL AIRSPACE QUANTITY ~ 2,286,578 m³.

REFERENCE(S)

1. EXISTING GROUND SURFACE IS BASED ON TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPLING DISTANCE, DATED MAY 30, 2020 BY THE BASE MAPPING CO. LTD.

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

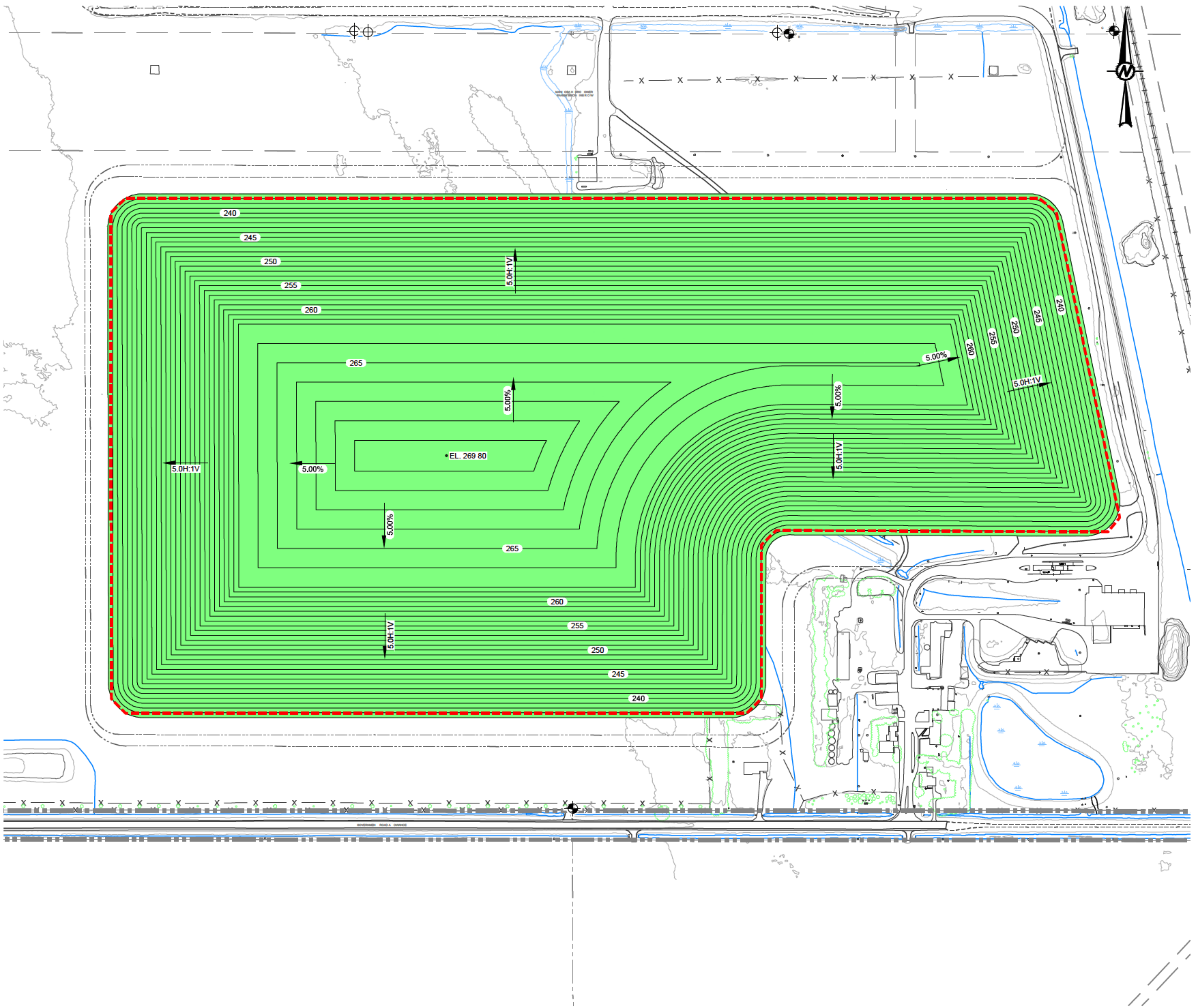
PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

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

CONSULTANT
GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REVIEWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	6



LEGEND

- PROPERTY LIMITS
- APPROVED SITE BOUNDART
- APPROVED L MITS OF WASTE
- EXISTING GRAVEL ROAD
- EXISTING PAVED ROAD
- EXISTING RAILWAY (CPR)
- EXISTING FENC NG
- EXISTING DRAINAGE DITCH
- EXISTING WATER BODY
- EXISTING TREE L NE
- 235,0 EXISTING GROUND SURFACE CONTOUR (INTERVAL 1 0 masl)
- EXISTING MONITOR NG WELL LOCATION (GOLDER ASSOCIATES, 1994)
- EXISTING GEODETIC CONTROL PO NTS
- FUTURE ROAD
- 265 PROPOSED HEIGHT ADJUSTMENT TOP OF F NAL COVER CONTOUR (NTERVAL 1 0 masl)

NOTE(S)

1. PROJECTION IS LOCAL SITE COORDINATE SYSTEM.
2. TOTAL ADDITIONAL AIRSPACE QUANTITY ~ 1,680,370 m³.

REFERENCE(S)

1. TOPOGRAPHIC BASE PLAN FROM 9 cm GROUND SAMPL NG DISTANCE, DATED MAY 30, 2020 BY THE BASE MAPP NG CO. LTD.
2. APPROVED WASTE LIMITS AND PROPERTY L MITS FROM FIGURE 2 - 2018 FISCAL PLANN NG MODEL PREPARED BY DILLON CONSULTING.

0 100 200
METRES

FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
PROPOSED ADJUSTED TOP OF FINAL COVER CONTOURS - PHASE II

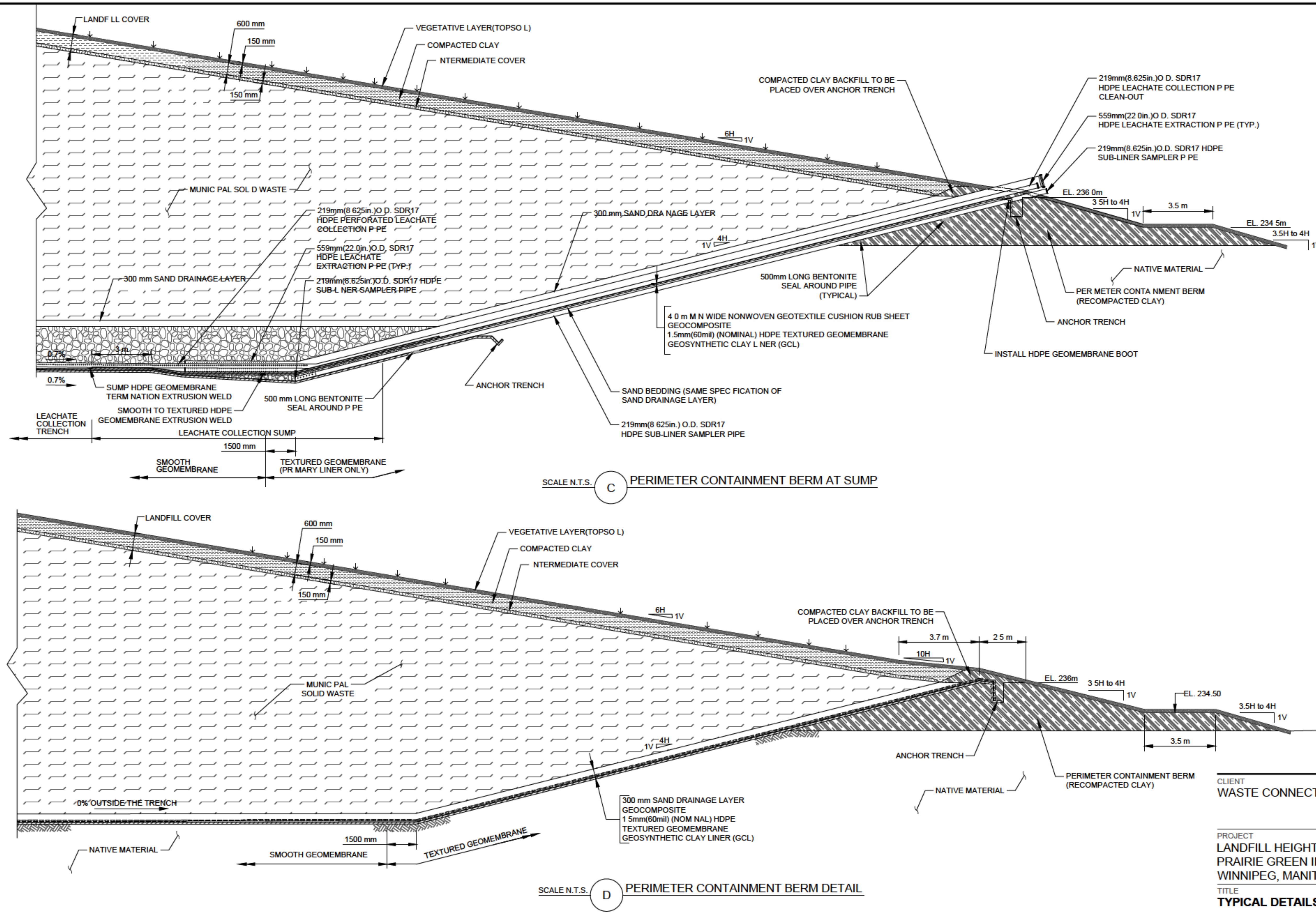
CONSULTANT

GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	7

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



FINAL

CLIENT
WASTE CONNECTIONS OF CANADA INC.

PROJECT
LANDFILL HEIGHT ADJUSTMENT
PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

TITLE
TYPICAL DETAILS

CONSULTANT

GOLDER

YYYY-MM-DD	2020-12-21
DESIGNED	FRG
PREPARED	FC
REV EWED	FRG
APPROVED	FSB

PROJECT NO.	CONTROL	REV.	FIGURE
20396341	0001	B	8

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

APPENDIX A

Settlement Analyses

Project Number: 20396341
Settlement Calculations - Prairie Green Landfill - Cell 11 - Cross Section B-B'
Exisiting Settlement (as of May 30, 2020)

	Interior-Toe	Appoved - Crest	New - Crest	New - Top	
Distance from South Edge of Waste (m)	**24**	**119**	**276**	**296**	
Top of Existing Waste and Interim Cover (May 30, 2020) (masl)	239.40	252 50	254 00	256.00	
Base Grade (masl)	227.90	228 56	229.66	229.80	
Bottom of Clay (masl)	222.00	222 00	222 00	222.00	
Ground Level Prior to Construction (masl)	233.00	233 00	233 00	233.00	
Middle of Lower Clay (masl)	224 9	225.3	225.8	225 9	
Top of Leachate Collection System (masl)	228 5	229.2	230.3	230.4	Unit Weight (kN/m^3)
Existing Waste Thickness (m)	10.6	23.0	23.4	25 3	13
Total Clay Thickness above Middle of Lower Clay (m)	2.95	3 28	3 83	3.90	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
Current Cover Thickness (m)	0.30	0 30	0 30	0.30	18

LOWER CLAY

Initial (Prior To Construction)					
Initial Total Stress at the Middle of Lower Clay (kPa)	132 9	127.4	118.3	117 2	
Water Level Elevation in Lower Clay (m)	233 0	233.0	233.0	233 0	(based on bedrock piezometric level at ground surface)
Initial Porewater Pressure (KPa)	79 0	75.7	70.3	69.7	
Initial Effective Stress (σ'_i (kPa))	53 9	51.6	48.0	47 5	
Final (Existing May 30, 2020 Waste Elevation)					
Final Total Stress at the Middle of Lower Clay (KPa)	202.4	369.5	383.8	409 2	
Final Porewater Pressure (KPa)	79 0	75.7	70.3	69.7	
Final Effective Stress (σ'_f (kPa))	123.4	293.8	313.5	339 5	
we have for Lower Clay Layer,					
Recompression Index (C_r)	0.03				
Initial Void Ratio (e_o)	1 8				
Preconsolidation Pressure (σ'_p (kPa))	230				
Compression Index (C_c)	0.7				
Thickness of Lower Clay Layer (H_o (m))	5 9	6.6	7.7	7 8	
Is final effective stress greater than preconsolidation pressure?	NO	YES	YES	YES	
Settlement of Lower Clay (m)	0.023	0.220	0.313	0.387	
Settlement of Lower Clay (cm)	**2.3**	**22.0**	**31.3**	**38.7**	

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

Project Number: 20396341
Settlement Calculations - Prairie Green Landfill - Cell 11 - Cross Section B-B'
Proposed Height Adjustment

	Interior-Toe/Sump A	Appoved - Crest	New - Crest	New - Top		Unit Weight (kN/m^3)
Distance from South Edge of Waste (m)	**24**	**119**	**276**	**296**		
Proposed Adjusted Top of Final Cover (masl)	240.00	255 83	287.23	288 23		
Base Grade (masl)	227.90	228 56	229.66	229 80		
Bottom of Clay (masl)	222.00	222 00	222.00	222 00		
Ground Level Prior to Construction (masl)	233.00	233 00	233.00	233 00		
Middle of Lower Clay (masl)	224 9	225.3	225 8	225.9		
Top of Leachate Collection System (masl)	228 5	229.2	230 3	230.4		
Total Clay Thickness above Middle of Lower Clay (m)	2.95	3 28	3.83	3 90		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
Final Cover Thickness (m)	0.90	0 90	0.90	0 90		18
Proposed Adjusted Final Waste Thickness (m)	10.6	25.77	56.07	56 93		13

<u>LOWER CLAY</u>

Initial (Prior To Construction)					
Initial Total Stress at the Middle of Lower Clay (kPa)	132 9	127.4	118 3	117.2	
Water Level Elevation in Lower Clay (m)	233 0	233.0	233 0	233.0	(based on bedrock piezometric level at ground surface)
Initial Porewater Pressure (KPa)	79 0	75.7	70 3	69.7	
Initial Effective Stress (σ'_i (kPa))	53 9	51.6	48 0	47.5	
Final (Proposed Adjusted Waste Elevation)					
Final Total Stress at the Middle of Lower Clay (KPa)	213 2	415.9	818 8	831.2	
Final Porewater Pressure (KPa)	79 0	75.7	70 3	69.7	
Final Effective Stress (σ'_f (kPa))	134 2	340.1	748 5	761.5	
we have for Lower Clay Layer,					
Recompression Index (C_r)	0.03				
Initial Void Ratio (e_o)	1 8				
Preconsolidation Pressure (σ'_p (kPa))	230				
Compression Index (C_c)	0.7				
Thickness of Lower Clay Layer (H_o (m))	5 9	6.6	7.7	7.8	
Is final effective stress greater than preconsolidation pressure?	NO	YES	YES	YES	
Settlement of Lower Clay (m)	0 025	0.324	1 037	1.071	
Settlement of Lower Clay (cm)	**2.5**	**32.4**	**103.7**	**107.1**	

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

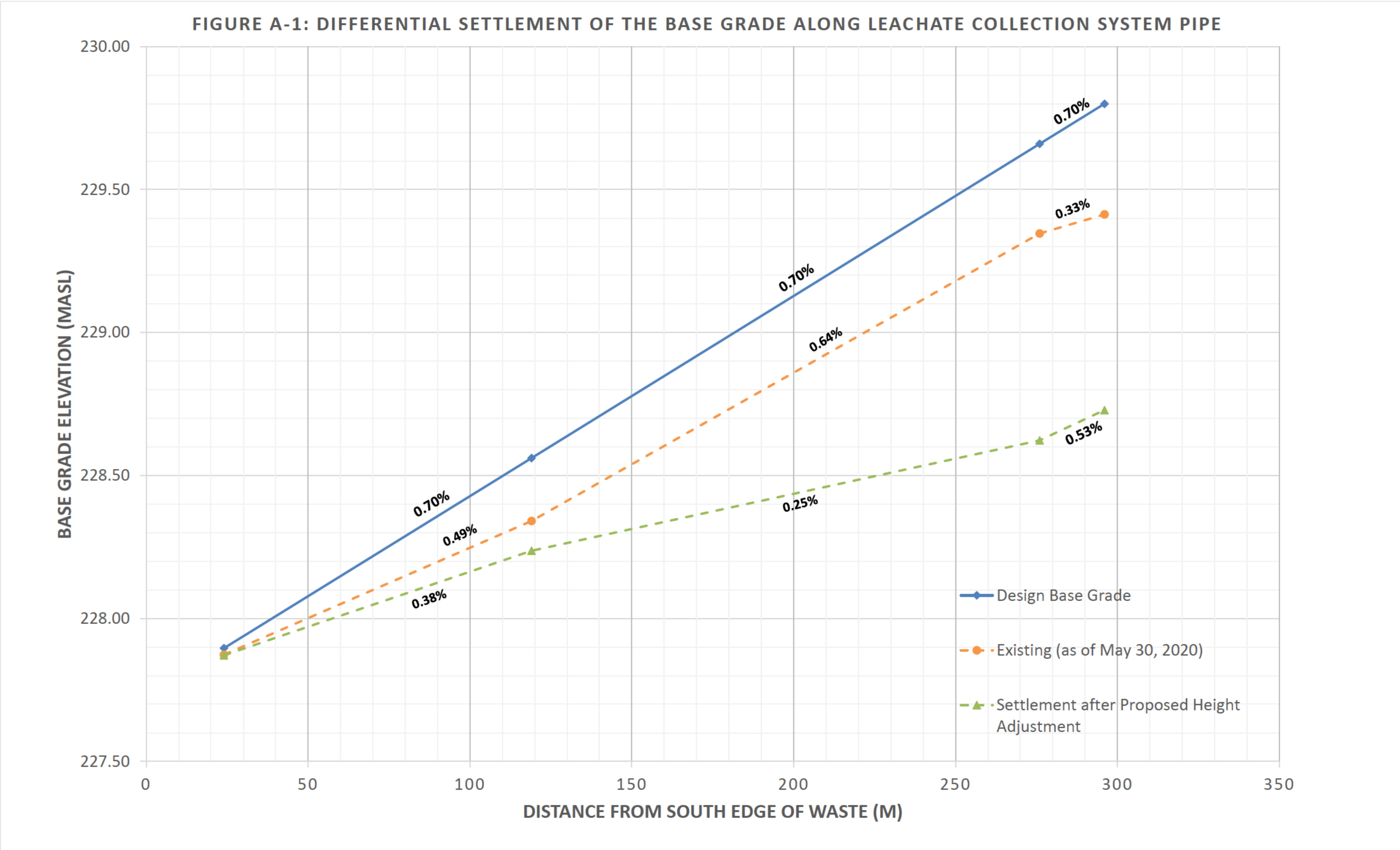


FIGURE A-1: DIFFERENTIAL SETTLEMENT OF THE BASE GRADE ALONG LEACHATE COLLECTION SYSTEM PIPE
BASE GRADE ELEVATION (MASL)
230.00
229.50
229.00
228.50
228.00
227.50
0
50
100
150
200
250
300
350
DISTANCE FROM SOUTH EDGE OF WASTE (M)
0.70%
0.70%
0.70%
0.33%
0.64%
0.49%
0.53%
0.25%
0.38%
Design Base Grade
Existing (as of May 30, 2020)
Settlement after Proposed Height Adjustment

APPENDIX B

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: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 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} = 56 9 m (max)
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 = 766 kPa
= 16006 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: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 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	=	16006	psf	766	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}	=	11939	psf	572	kPa	
S	=	456	psi	3146	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)

Factor of Safety = $\frac{S_{allow}}{S} = \frac{780}{456} =$ 1 7 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: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 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	=	16006	psf	766	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	=	2 3%		2 3%		
$\Delta x/D_M$	=	3 5%		3 5%		(Percent Ring Deflection)

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

Factor of Safety = $\frac{\text{Allowable ring def}}{\Delta x/D_M} = \frac{5\%}{3\ 5\%} =$ 1 4 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: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 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	=	16006	psf	766	kPa
P_B	=	111 2	psi	766	kPa

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

= 3372 kPa

Factor of Safety = $\frac{P_{CR}}{P_B}$ = $\frac{489}{111}$ = 4 4 Okay [Typical Recommended F S = 2 0 Ref 2]

Leachate Collection System Pipe Structural Stability Calculations, 8" DR13.5 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba		
Project Number: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 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} = 56 9 m (max)

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 = 766 kPa

= 16006 psf

8" HDPE Pipe, DR = 13 5, 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" DR13.5 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba	
Project Number: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 2021

		English Units		SI Units		
D_o	=	8 63	in	0 219	m	(for 8 in DR = 13 5 Sclairpipe PE3408)
t	=	0 639	in	0 016	m	
r_{CENT}	=	3 996	in	0 102	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	=	16006	psf	766	kPa	- Table B 1 1, adjusted using compensating multiplier of 0 73 at 38°C, Table B 1 2)
S_A	=	2 27	[-]	2 27	[-]	
VAF	=	0 691	[-]	0 691	[-]	
P_{RD}	=	11063	psf	530	kPa	
S	=	519	psi	3577	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)

$$\text{Factor of Safety} = \frac{S_{allow}}{S} = \frac{780}{519} = 1\ 5$$

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" DR13.5 HDPE Pipe, Prairie Green Integrated Waste Management Facility, R.M. of Rosser, Manitoba		
Project Number: 20396341	Prepared by: S. Rimal Reviewed by: F. Gondim / F. Barone	Date: January 2021

		English Units		SI Units		
E	=	19710	psi	135900 5	kPa	
D_o	=	8 63	in	0 219	m	(for 8 in DR = 13 5 Sclairpipe PE3408)
t	=	0 639	in	0 016	m	
D_M	=	7 991	in	0 203	m	
σ_v	=	16006	psf	766	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	=	5631	[-]	5631	[-]	
D_F	=	1 7	[-]	1 7	[-]	(deformation factor from Watkins-Gaube Graph, Ref 1)
ε_S	=	2 3%		2 3%		
$\Delta x/D_M$	=	4 0%		4 0%		(Percent Ring Deflection)

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

Factor of Safety = $\frac{\text{Allowable ring def}}{\Delta x/D_M}$ = $\frac{5\%}{4\ 0\%}$ = 1 3 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	=	7 991	in	0 203	m	
E	=	19710	psi	135900 5	kPa	
t	=	0 639	in	0 016	m	
I	=	0 0217	in^3	3 56E-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}	=	391	psi	2699	kPa	

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	=	16006	psf	766	kPa
P_B	=	111 2	psi	766	kPa

P_{CR} = critical constrained buckling pressure = 391 psi

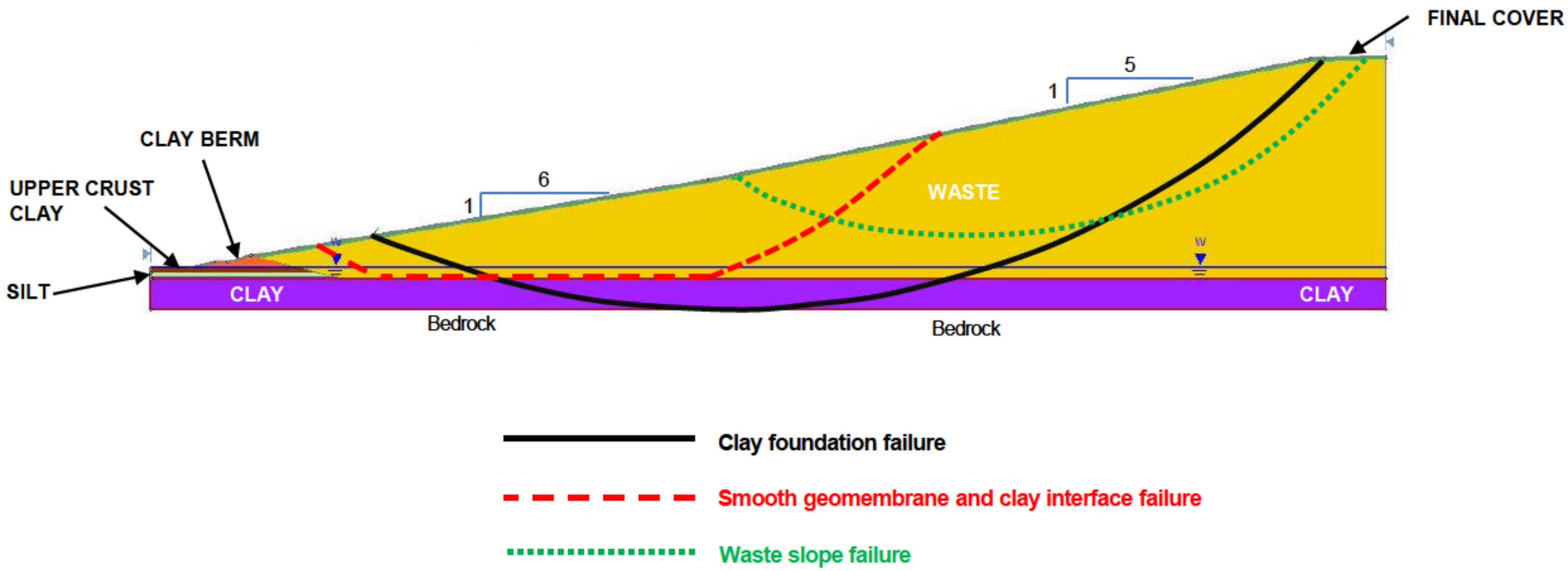
= 2699 kPa

$$\text{Factor of Safety} = \frac{P_{CR}}{P_B} = \frac{391}{111} = 3\ 5$$

Okay [Typical Recommended F S = 2 0 Ref 2]

APPENDIX C

Slope Stability Analyses



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PRAIRIE GREEN INTEGRATED WASTE MANAGEMENT
WINNIPEG, MANITOBA

CONSULTANT

GOLDER

YYYY-MM-DD	2021-01-19
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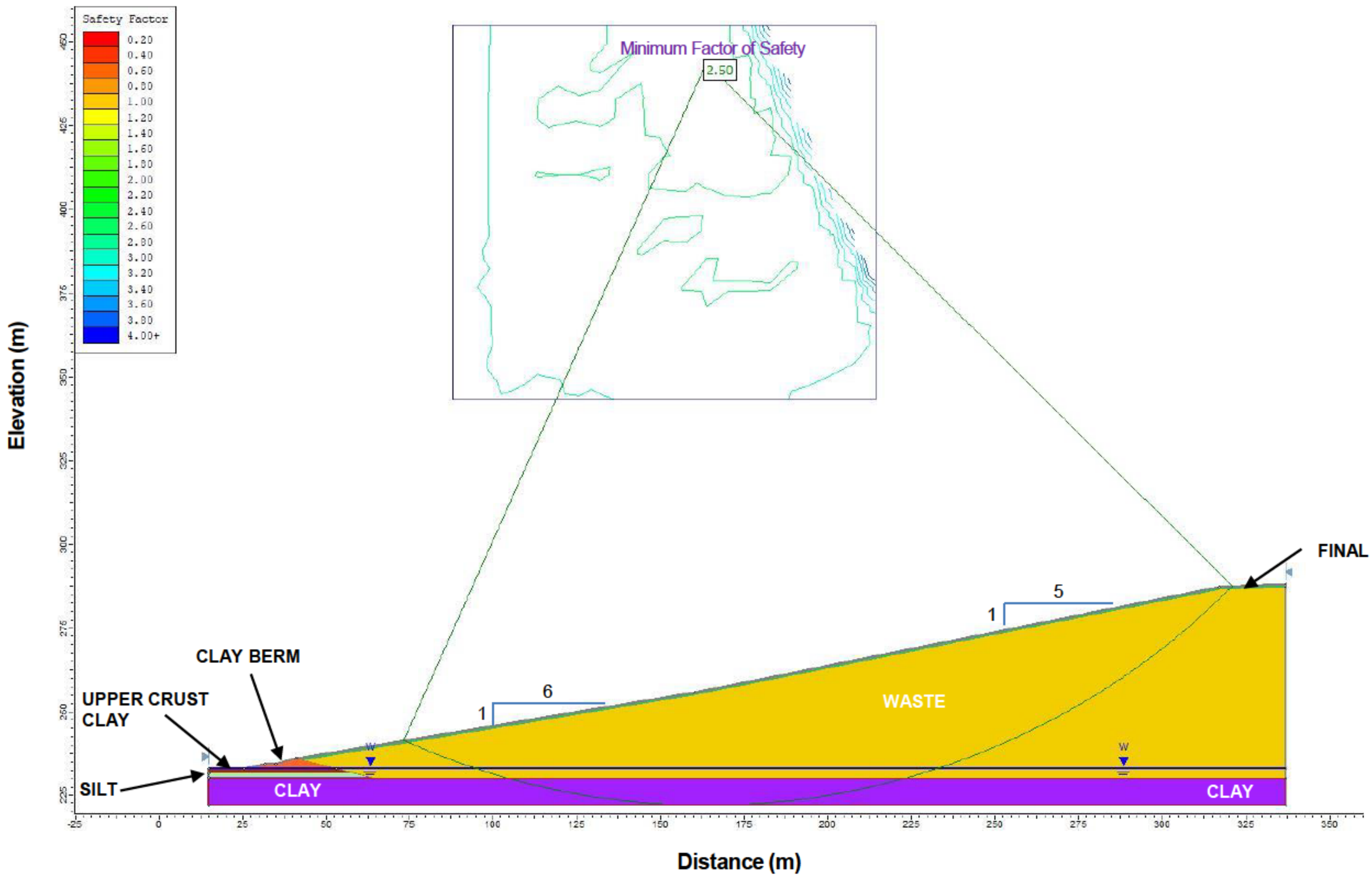
DESIGNED	SR
REVIEWED	FSB
APPROVED	FSB

TITLE
SCHEMATIC OF DIFFERENT FAILURE MODES

PROJECT NO.	CONTROL	REV.	
20396341	1000	A	C-1



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

PROJECT NO.	CONTROL	REV.	
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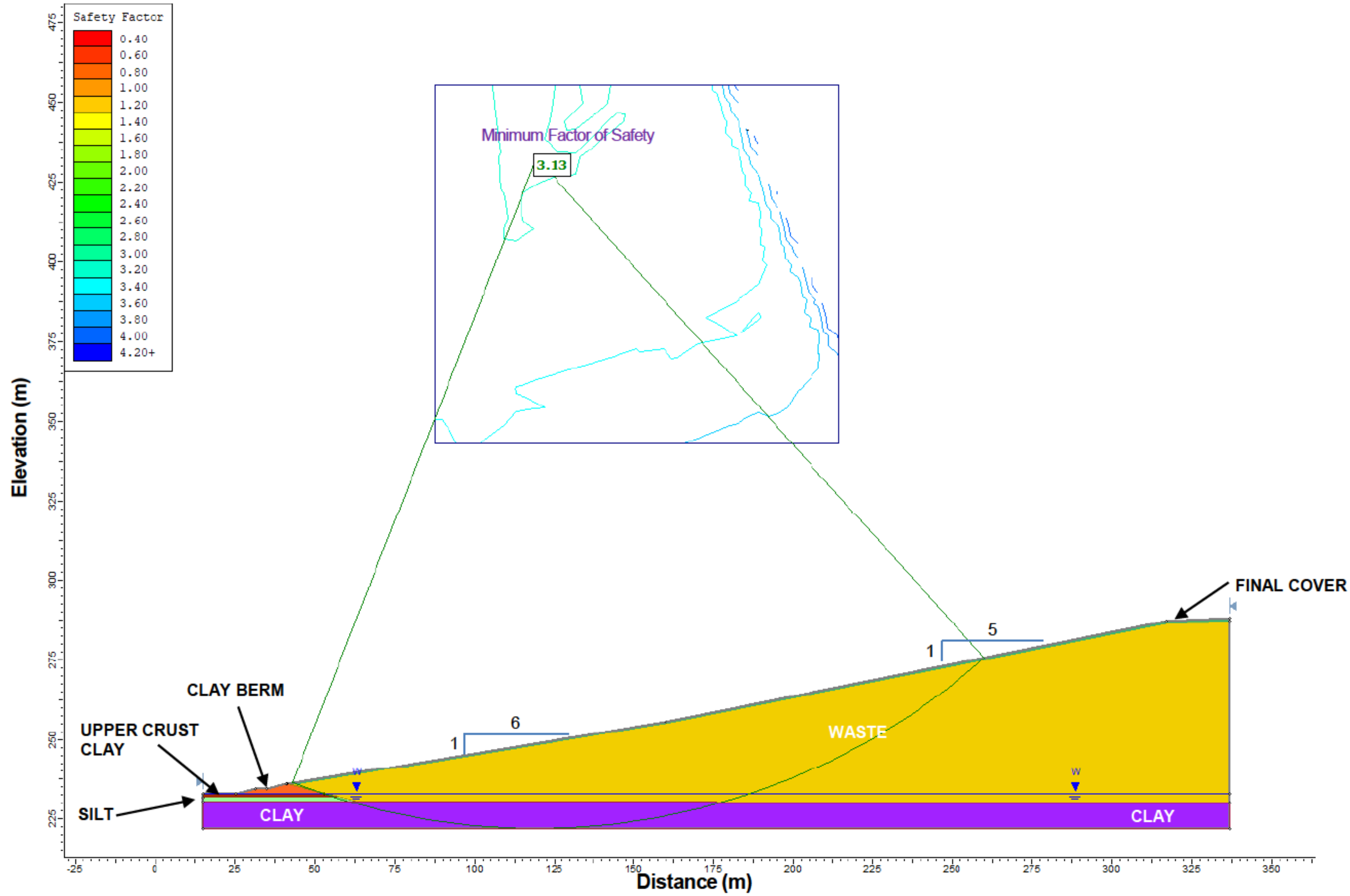

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SIDESLOPE STABILITY ANALYSES (SECTION B-B')
CLAY FOUNDATION FAILURE (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
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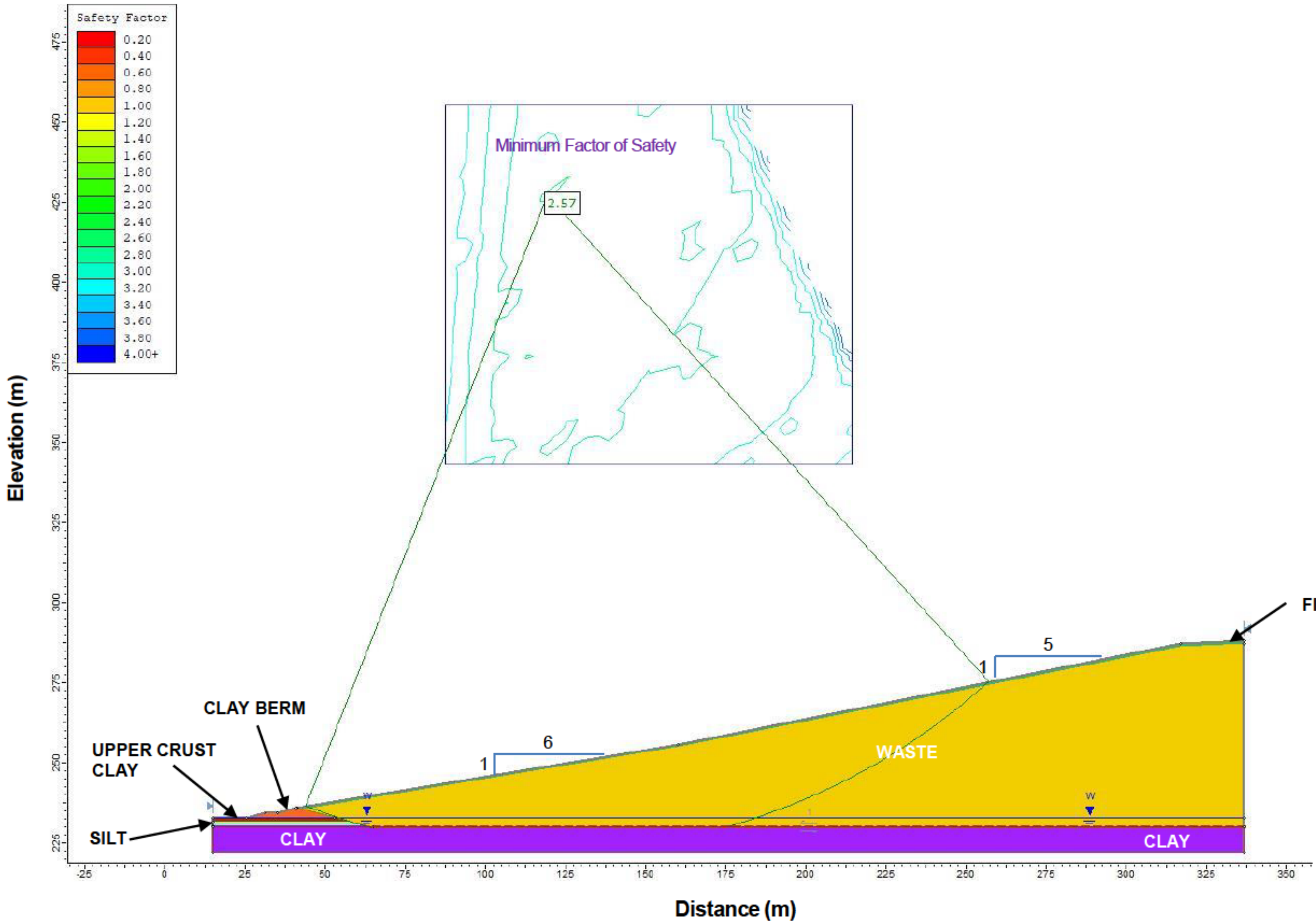

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TITLE
SIDESLOPE STABILITY ANALYSES (SECTION B-B') SMOOTH GEOMEMBRANE AND CLAY INTERFACE FAILURE AT NORMAL OPERATING CONDITION (DRAINED ANALYSIS)

PROJECT NO.	CONTROL	REV.	
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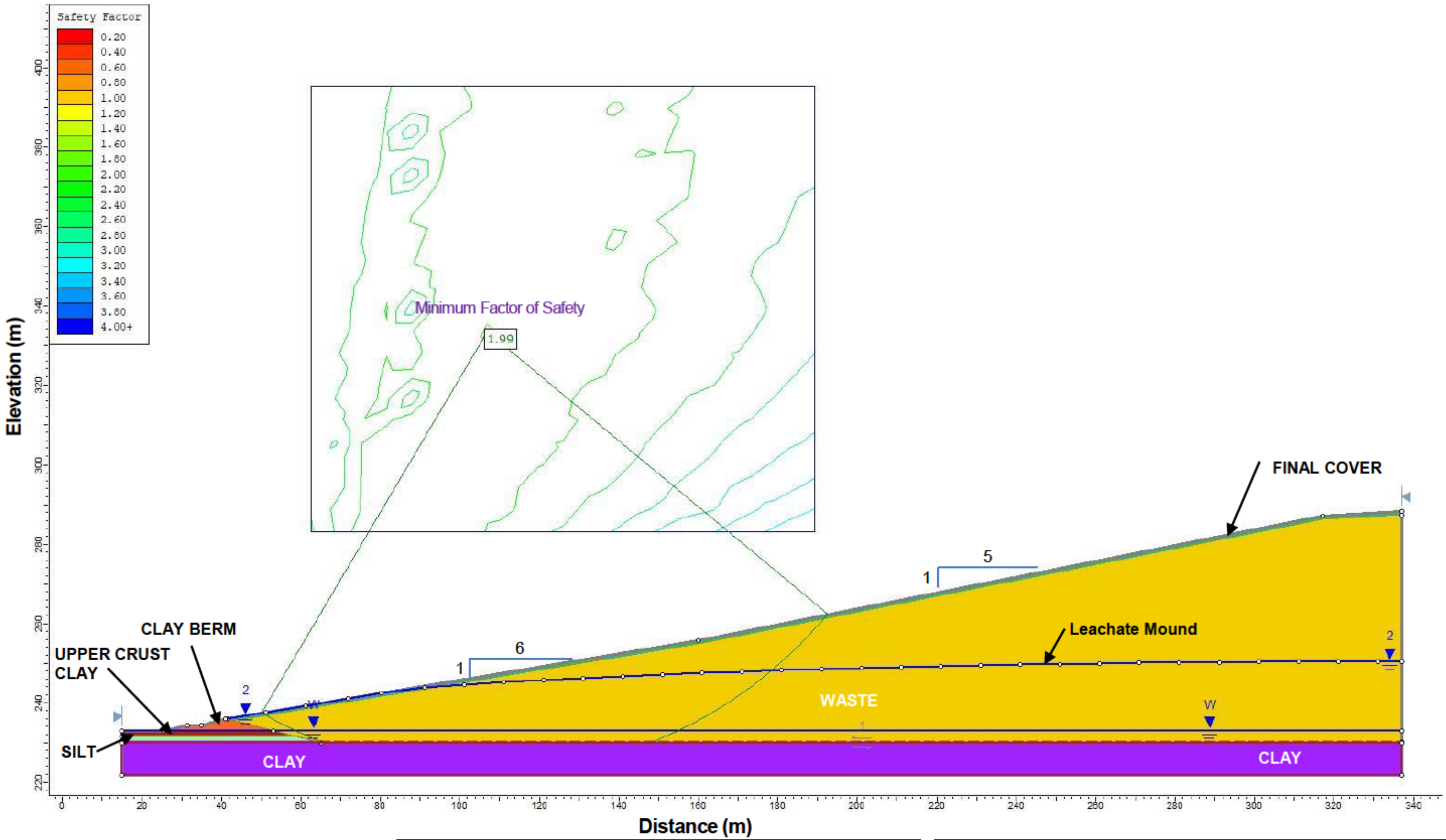

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SIDESLOPE STABILITY ANALYSES (SECTION B-B') SMOOTH GEOMEMBRANE AND CLAY INTERFACE FAILURE WITH LEACHATE MOUNDING (DRAINED ANALYSIS)

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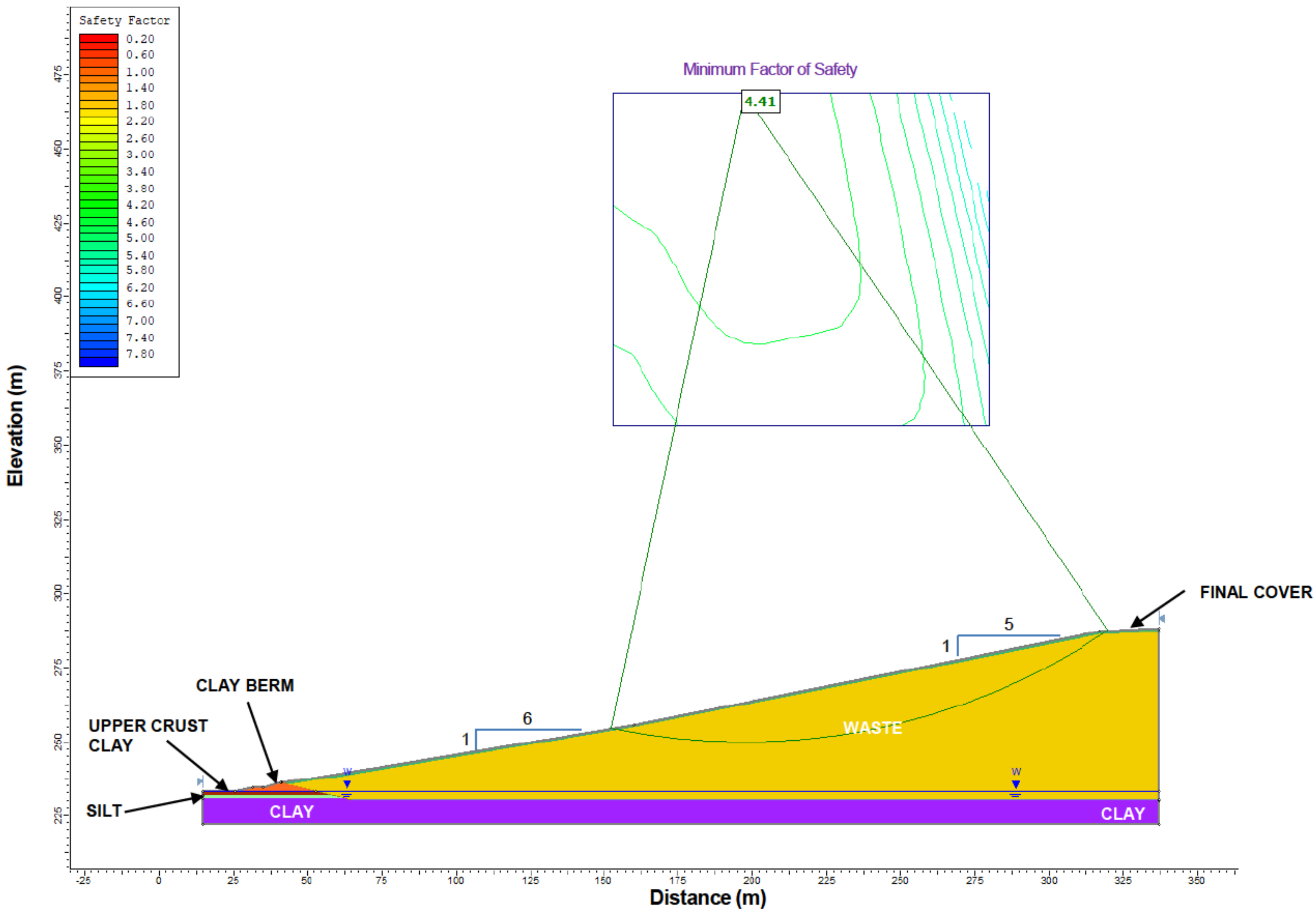
20396341	1000	A	C-5



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

PROJECT NO.	CONTROL	REV.	
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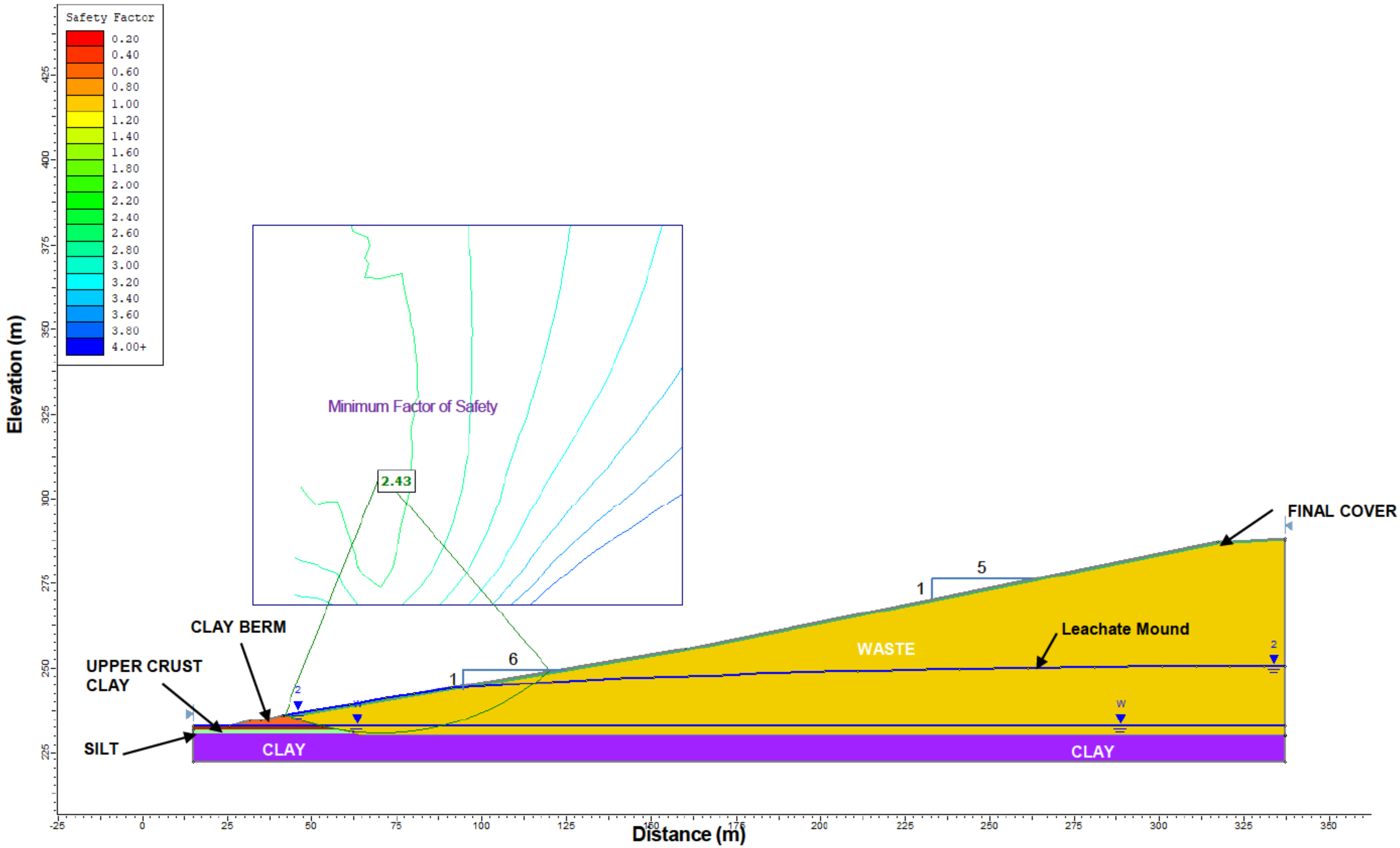

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SIDESLOPE STABILITY ANALYSES (SECTION B-B') WASTE SLOPE FAILURE WITH LEACHATE MOUNDING (DRAINED ANALYSIS)

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