(Addendum) Stability Risk Assessment

MEECE LANDFILL
SWYNNERETON
STAFFORDSHIRE
ST15 0QN

For : Swan Environmental Services

Report Ref: 3009 / R02 Rev1

Dated: 11th August 2023

Director : D I Grant BSc (Hons) PhD

Geotechnical & Geoenvironmental Consultants

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Report No 3009 / R02 Rev1

Rev 1	11 08 2023	Review comments addressed
Rev 0	01 03 2023	1st Issue

Prepared for Swan Environmental Services

Filename: Consultancy/3009 Meece SRA/Reports/Rep3009_R02 Rev1 Meece SRA Final.docx

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1. INTRODUCTION

This Addendum Stability Risk Assessment (SRA) is for the Biffa Waste Services Ltd (Biffa) Meece Landfill, Swynnerton, Staffordshire.

It refers to a request from the Environment Agency (EA) to '*confirm if a review to the SRA has been undertaken for the additional restoration material*' as requested in EPR Compliance Assessment Report Ref: BV4967IW/0426870 dated 16 June 2022. This document has been revised in line with comments received from the Environment Agency via email (from Roger Pee 24 April 2023 at 16:02) and a subsequent online meeting held on the 23 June 2023.

This addendum report is limited to a consideration of restoration material only. It is in addition to a set of previous SRA documents carried out by others (see Section 2.5).

This addendum SRA has been carried out in general accordance with the latest Environment Agency 2022 advice 'How to do a stability risk assessment: landfill sites for hazardous and non-hazardous waste' (*Ref 1*). It relies on information from other SRA's which may have been written to previous guidance. In line with the EA Guidance the report layout includes an entry in each section of that Guidance even if only confirm that a specific feature is not relevant to this site.

2. CONTACT DETAILS AND REPORT CONTEXT

2.1 Site Location

The site is located at grid reference SJ 850 341 approximately 1.5km south of the village of Swynnerton Staffordshire (Figures 2-1 & 2-2). The landfill site covers some 36 hectares.

A previous report by Golder Associates (*Ref 3*) notes that the site lies on gently undulating ground with a general fall towards the south. The site is located on a former MoD training ground. The existing MoD training ground is present along the southern boundary of the site. Land to north, east and west is mainly agricultural.

Survey drawings for the area of concern are enclosed as **Appendix A**.

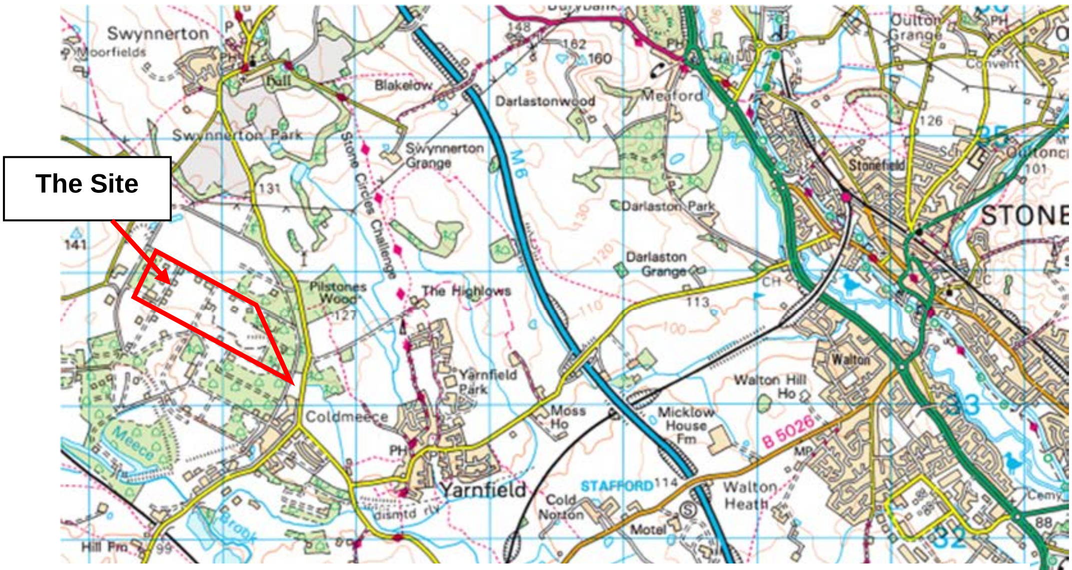


Figure 2-1: Site Location

Figure 2-2: Aerial image (© Google 2022)

2.2 Site Operator

The site operator is Biffa Waste Services Limited.

Site Name: Meece Landfill Site,
Yarnfield Road,
Swynnerton,
Cold Meece

ST15 0QN

2.3 Agent who completed SRA

Report compiled by
Dr David Grant of Dig-Geotech Ltd as subconsultant to Swan Environmental Ltd

Address : Dig-Geotech Ltd **,** 2 Easthams Road, Crewkerne**,** Somerset TA18 7AQ.

2.4 Site Setting

Historically the site operated as a hazardous co-disposal landfill until July 2004 when it started operating as a non-hazardous site accepting mainly municipal waste. The site was originally developed in and around 1939 as part of a munitions filling depot and was subsequently operated by the Ministry of Defence (MoD) as a munition depot prior to its development into a landfill site. The southern boundary of the site still abuts a MoD training ground which is where the majority of the munition plant was located. The land to the west, north and east of the site is mainly agricultural. Waste disposal began on site in the late 1980s.

2.5 Conceptual Model

A stability risk assessment was prepared by Golder Associates on behalf of Biffa Waste Services Limited in September 2003 (*Golder Associates 2003*).

Section 1.2 of that report related to a Conceptual Stability Site Model.

This is an addendum SRA report. The Conceptual Site Model has not changed from that other than for part of the capping system & restoration soils as referred to below at Section 3.8.

3. STABILITY CONCEPTUAL SITE MODEL

3.1 Primary components

As referred to in previous SRA - see Section 2.5.

3.2 Pore fluid pressures

As referred to in previous SRA - see Section 2.5

3.3 Settlement and strains

The previous SRA (*Golder Associates 2003*) noted that

> **2.1.7 Capping system screening**
>
> The approved cap design comprises of a clay cap with no geosynthetics. The capping slopes are relatively flat, being in the order of 2 to 8 degrees. If the final waste profile is stable, the cap will therefore also be stable.

No further assessment of settlement or strains was given at that time.

The capping was subsequently altered to include in parts a geosynthetic clay liner (GCL) as shown at Section 3.8, Figure 3-1. The GCL incorporated into the works was Bentofix NSP 4300, a needle-punched reinforced sodium bentonite product manufactured by Naue Gmbh & Co. The GCL cap was installed on a 150mm thick bedding layer and covered by a 300mm thick protection layer as soon as possible following installation of the GCL.

All seaming was carried out according to the CQA Plan and manufacturer's installation instructions, with edge overlaps of 300mm (minimum) and end overlaps of 1000mm (minimum). All tie-ins to existing GCL were completed according to the CQA Method Statement. The existing GCL was cleared of all soils to expose at least 1m width of GCL using a combination of hydraulic excavator, shovels and brushes; accessory bentonite was then placed at a rate of at least 0.5 kg per linear metre to form a competent seal before the tie-in GCL panel was finally placed.

The 300mm protection layer was placed directly above the GCL by excavator and graded using a tracked dozer.

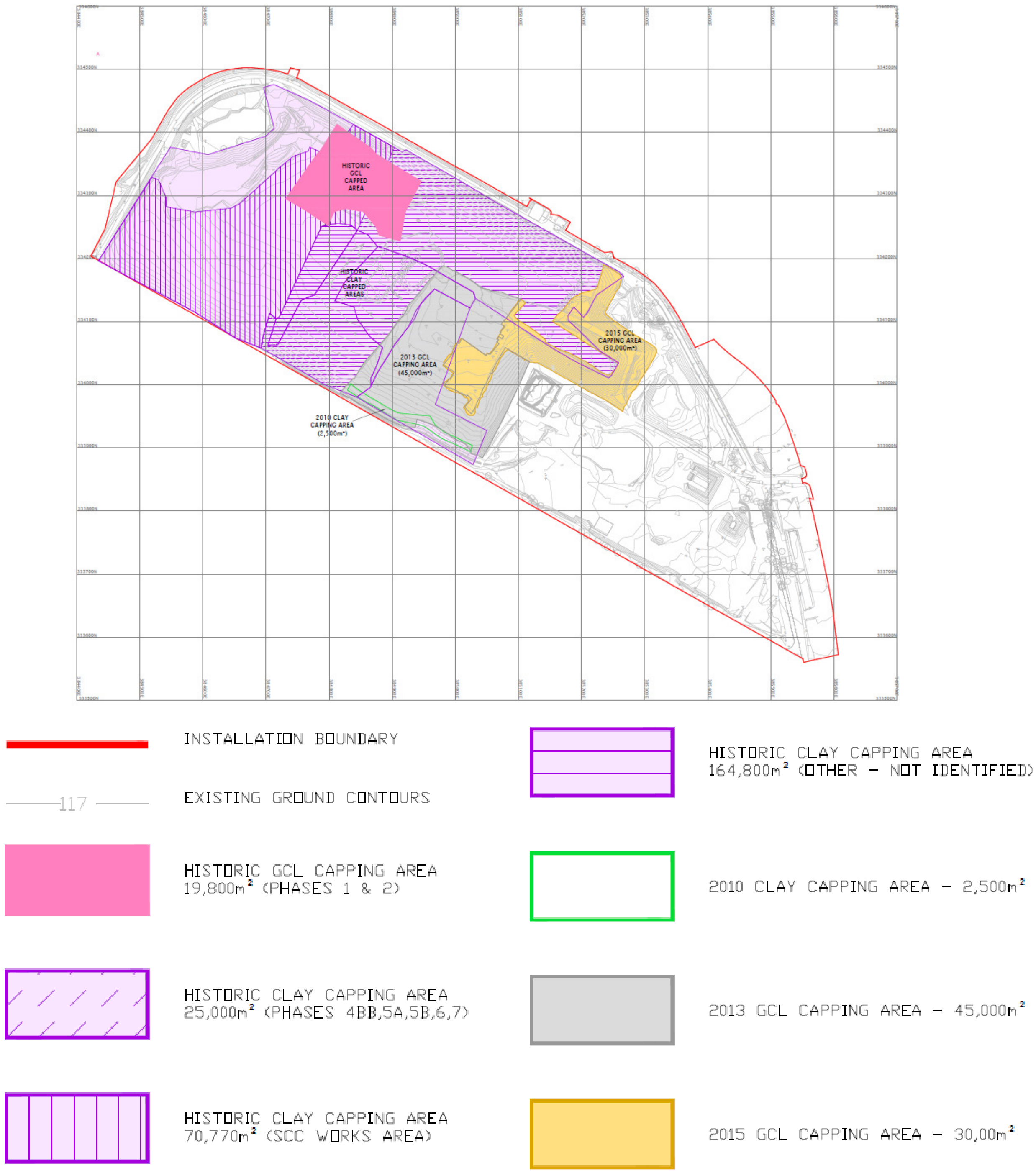


Figure 3-1 : Capping areas

Subsequently additional restoration soils have been placed above the GCL at depths disused later in this report, but generally at between 1m and 8m depths. Biffa report having placed extra restoration soils above those originally placed to address areas of settlement and improve surface water management at the site. Following this in 2022 the EA have expressed concerns that the additional load above the GCL may have caused unacceptable strains.

Reference to the GCL manufacturers specification shows that the GCL is suitable for up to 15% strain. Limit equilibrium analysis presented later in this report for slope stability, have shown that the additional restoration soil depths do not cause failure of the capping or the underlying waste. No numerical analysis of the likely deformation profiles have been carried out. Measurements based on site surveys have been inconclusive due to earth working activities and movement of restoration soils between survey dates. It is generally noted however that the final levels above the GCL change over a wide area with no rapid changes in depth. As such it is concluded that the GCL will have settled due to the application of additional surcharge load in direct reaction to the settlement of the waste mass below the CGL. As the settlements are over a wide area and largely one-dimensional, it is not expected that significant strains shall have been formed within the individual GCL sheets. At junctions between panels, the process of placing gave a 1m longitudinal overlap, and a lateral 0.3m overlap. As such it is not expected that the mostly vertical deformation shall have allowed significant lateral or longitudinal strains to occur at junctions between panels.

3.4 Basal sub-grade

As referred to in previous SRA - see Section 2.5

3.5 Side slope sub-grade

As referred to in previous SRA - see Section 2.5

3.6 Basal lining system

As referred to in previous SRA - see Section 2.5

3.7 Waste mass

As referred to in previous SRA - see Section 2.5

3.8 Capping system

The 2003 Golder Associate’s Report Section 1.2.6 noted that :

1.2.6 Capping system model

The sealing layer for the cells will comprise a 1.0 m thick compacted clay possessing a permeability of at least 1 x 10^{-9} m/s.

The sealing liner will be protected from the underlying waste by placement of a 300 mm thick blinding layer comprising sand, silt or similar inert material.

The capping material will comprise a 1 m thick clay layer. Restoration cover soils will be placed over the clay layer to achieve a minimum total thickness above the waste of 2.0 m. The cover soils will comprise soil forming materials and soil conditioners, including compost, in order to achieve the standard required for restoration to agriculture. The proposed after use of the site will comprise agriculture and some shrubs, hedgerows and tree planting.

Capping works conducted to Phase 1 and Phase 2 in 1999 utilised a geosynthetic clay liner (GCL). However the next phase of capping was conducted using clay and it was expected at the time that Golder Associates undertook the original SRA works that clay capping would be used for the remainder of the site.

However, capping placed in 2013 used GCL. The use of this material was agreed with the Environment Agency by acceptance of the CQA Plan for the 2013 capping works.

Proposed restoration levels and profiles have also been altered, in particular a greater depth of restoration soils is now proposed. **Appendix B** presents a set of sections showing the proposed restoration profiles. The sections also show the level of the capping and an indication of current leachate levels. The revised stability risk assessments are based on these profiles as detailed in the following report sections.

4. STABILITY RISK ASSESSMENT

The stability risk assessments for

- basal sub-grade
- side slope sub-grade
- basal lining system
- side slope lining system
- waste mass

were detailed in the Golder Associates SRA (See Section 2.5). Details have not changed.

This addendum Stability Risk Assessment is for the capping system only. The revisions relate to both changed profiles and elevations for the restoration soils and capping, and also to the type of materials used.

5. LIFECYCLE PHASES

You must identify the critical phases during the development of the landfill.

This report cover the stability of the restoration soils as all other elements of the site remain as per the original SRA produced by Golder Associates (*Ref 3*).

6. DATA SUMMARY

The site is currently mothballed and is only accepting waste for restoration. It is understood that future development of the site is proposed at some point in the future.

7. JUSTIFICATION FOR MODELLING APPROACH & SOFTWARE

Slope stability analyses have been carried out using the commercial slope stability programme Geo5-Slope Stability (2022 Revision) produced by Fine Software Ltd and supported by spreadsheet hand calculation.

The Geo5-Slope Stability analyses method used was a Limit Equilibrium method whereby the resistance due to a soil strength is balanced against destabilising forces due to soil weight, fluids and any additional construction loading. The specific analytical methodologies used were those due to Bishop or Spencer with variably inclined interslice forces.

Environment Agency suggested requirements for a capping system on sloped ground are typically for the calculated factor of safety, F, to be F > 1.3 (*Environment Agency 2003*) for a global factor of safety approach. Golder Associates (2003) based their analyses on global stability needing to achieve F > 1.3.

The UK adoption of BS EN1997-1 Eurocode 7: *Geotechnical Design* has moved away from the use of a global factor of safety. It is now the practice to apply a set of partial factors to both the soils strengths and any applied loads, and then to show that the available factored resistance exceeds the factored load applied. The original design in 2003 was prior to the introduction of Eurocodes, and hence the relevant factor of safety is generally for a global F > 1.3. However to also asses the slopes to current standards, the analyses presented here also considered a Eurocode 7 approach. Where partial factors are used, the Geo5 programme refers to a Utilisation Factor that must be less than 100% for a safe design.

The Eurocode partial factors to be applied in the UK are defined in the National Annex to BS EN 1997-1. The UK have adopted Design Approach 1 (DA1). Within design approach DA1 are a number of load combinations that must be considered. Each combination considers a different method of failure and applies partial factors in a different way. To show a safe design all design combinations must be satisfied. Load combinations DA1-1 and DA1-2 have been considered. In simple terms DA1-1 applies partial factors to the loads and DA1-2 applies factors to material properties (i.e the soil strengths). In this case it would be expected that DA1-2 give the critical design combination.

Sections have been considered as shown on the plans enclosed at **Annex B**. Inspection of the sections shows that the worst cases that combined the thickest case of restoration fill and steepest, longest slope angles are for sections 1, 2 & 3. Detailed Slope stability analysis have hence been carried out for those sections only. Section 1 consider the north slope only which was a clay capping. Section 2 considered the north and south slopes with clay capping for the north slope and a GCL at the south Section 3 was for a clay capping

Soils strength parameters were selected to be compatible with previous analysis for the site. No new Intrusive ground investigation or laboratory work to assess soil strengths has been undertaken. The soil paraments used for the analyses are summarised at Section 8.

8. JUSTIFICATION FOR GEOTECHNCIAL PARAMETERS SELECTED FOR ANALYSIS

8.1 Geology & ground conditions

No new ground investigation specifically related to this area has been undertaken as part of this assessment. Geological and ground conditions are taken from previous stability risk assessments (SRA) reports provided by the Client, namely:

- Golder Associates (2003). Section C stability risk assessment. Meece 1 Landfill. 03523484.502. For Biffa Waste Services Limited.

The known geology of the area is Mercia Mudstone Group Sedimentary bedrock formed between 252.2 and 201.3 million years ago during the Triassic period. The Mercia Mudstone is described as a red marl with thin sandstones, rock salt and gypsum.

A BGS geological cross section shows the Mercia Mudstone forming a basin with a general dip and thickening towards the east. The Swynnerton fault cuts across the northwestern corner of the site bringing the Sherwood Sandstone Pebble Beds to the surface. The thickness of the Mercia Mudstone stone is unknown at this site due to the absence of deep boreholes. A thickness of approximately 130 metres is reported nearby. Faulting near to this site may however have impacted thickness. The Golder Associates report noted that landfill cells would be constructed into Mercia Mudstone.

8.2 Soils Parameters

The Golder Associates report reviewed previous ground investigation records to derive parameters suitable for slope stability and other engineering analysis. Table 8-1 summarises the soil parameters.

Table 8-1: Soil parameters derived from previous reports

Stratum	Material	Bulk Unit Weight	Shear strength parameters		
In situ (MMG)		kN/m³	Undrained Cohesion Cu (kPa)	Cohesion c' (kPa)	Angle of Shearing Resistance Φ' (degrees)
1.	In situ weathered Mercia mudstone	18.6	n/a	5 selected for analysis (Range of 2 - 7.2)	28 selected for analysis (Range of 25 – 32)
Engineered Fill					
2.	weathered Mercia mudstone	18.6	50 to 70	2.0 selected for analysis (Range of 2 - 7.2)	25 selected for analysis (Range of 25 – 32)
3.	Cap Material	18.6		2	25
Other					
4.	Textured geomembrane / clay liner interface			25	10
5.	Waste	12		5	25

The Golder Associates reports did not consider the restoration soils. Biffa has noted that the restoration soil is a locally derived stoney Clay. No specific shear strength testing is available for the restoration soils. The selected shear strength parameters are hence conservative values based on experience of similar materials. Table 8-2 gives the parameters used full analysis related to the restoration soils.

Table 8-2: Soil parameters derived for restoration soils

Stratum	Material	Bulk Unit Weight	Shear strength parameters		
		kN/m^3	Undrained Cohesion Cu (kPa)	Cohesion c' (kPa)	Angle of Shearing Resistance Φ' (degrees)
Engineered Fill					
6.	Restoration Soils	18.6	40	0.05	22

8.3 Interface shear angles (GCL)

The GCL used was a Bentofic NSP 4300 or similar. Published interface shear angles of GCL geotextile components against geosynthetics or soils are given in Table 8-3

Table 8-3: Typical Capping analysis parameters

adjacent geo-synthetic or soil	range of friction angle woven	nonwoven
smooth geomembrane	8° to 12°	8° to 12°
textured geomembrane	10° to 25°	18° to 35°
top soil	18° to 28°	21° to 32°
sand	21° to 28°	24° to 32°
sandy gravel	23° to 28°	25° to 34°

Source : Slope design with Bentofix Bentofix® GCLs. NAUE GmbH & Co. KG, Espelkamp-Fiestel, Germany · All rights reserved. · No. 27 · Status 02/2008

Geosynthetic clay liners use needle punched non-woven geomembranes intended to allow shear stress to transfer across the liner. Analyses presented here have assumed an angle of shearing resistance of 21 degrees as a typical lower bound shear strength to a cover soil above.

The GCL is placed with a bedding layer below and a protection layer above. For the slope stability analysis, the capping has been modelled as a single entity with the unit weight equivalent to the soil above and below that made the majority of the thickness i.e in this case assumed at 18.6kN/m^3 (Table 8-2).

8.4 Groundwater / leachate levels

Groundwater levels for the analysis either used a phreatic water level or a pore water pressure (r_u).

The phreatic water levels were derived from Swan Environmental interpretation of winter 2022 / 23 leachate monitoring data as shown of the sections at Appendix B. The modelled water levels were the phreatic water levels plus a 1.0m excess head. Swan Environmental note that the winter 2022 / 23 leachate elevations are above those intended longer term and hence the analysis is conservative.

Using a phreatic surface does not help model shallower surfaces above the chosen water line. To also investigate risks related to potential shallower depth slips, assuming a pull or to pressure ratio. The chosen pore water pressure ratio (r_u) was r_u = 0.1 to represent inundation by eg rainfall.

9. SELECT APPROPRIATE FACTORS OF SAFETY

Environment Agency suggested requirements for a capping system on sloped ground are typically for the calculated factor of safety, F, to be F > 1.3 (*Environment Agency 2003*) using a global factor of safety approach. Golder Associates (2003) based their analyses on global stability needing to achieve F > 1.3.

The UK adoption of BS EN1997-1 Eurocode 7: *Geotechnical Design* has moved away from the use of a global factor of safety. It is now the practice to apply a set of partial factors to both the soils strengths and any applied loads, and then to show that the available factored resistance exceeds the factored applied loads. The original design in 2003 was prior to the introduction of Eurocodes, and hence the relevant factor of safety is generally for a global F > 1.3. However to also asses the slopes to current standards, the analyses presented here also considered a Eurocode 7 approach. Where partial factors are used, the Geo5 programme refers to a Utilisation Factor that must be less than 100% for a safe design.

10. SENSITIVITY ANALYSES

Section not used.

11. ASSESSMENT

11.1 Section 1-1 North – clay capping

Section 1-1 was for a clay capping with restoration soils above. The results of the analyses are summarised as Table 11-1. Geo5 analysis output is within **Appendix C**.

Table 11-1: Section1-1 Summary of Geo5-Slope Stability Analyses

Run ID	Stage	Input details	FoS DA1-1	DA1-2	Global factor Unfactored	Output Comments
			Target <100%		Target F>1.3	
Section 1-1						
MeeceS1Run201 (Section1 North)	Stage 1	Restoration Profile. North slope	98.9%	90.60%	1.38	Unfactored approach gives different critical slip surface. FoS on same slip as EC7 is F =1.52.
MeeceS1Run201 (Section1 North)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	86.40%	101.60%	1.23	shallow slump in restoration soils

Analysis MeeceS1Run201 Stage 1 was for the more critical north slope and assumed a leachate level 1.0m above current recorded levels. The stability was shown as sufficient for permanent works to both an EC7 approach and a global factor of F>1.3 (Figure 11-1).

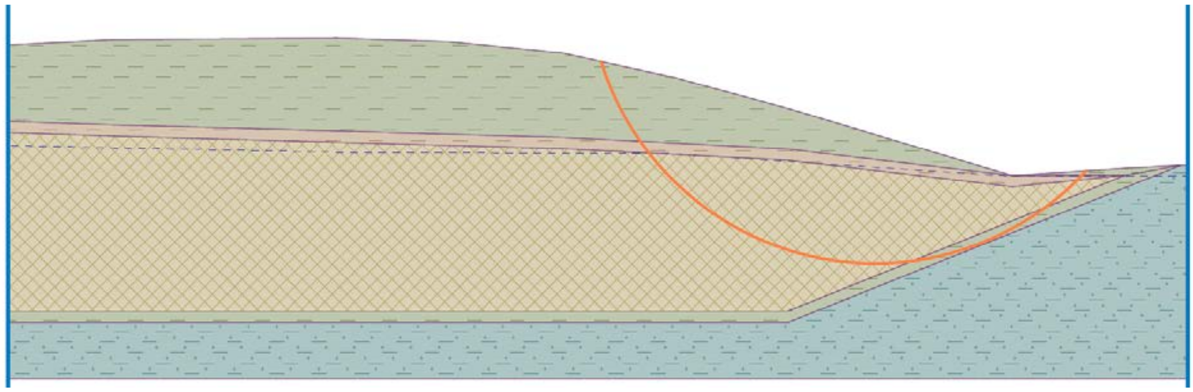


Figure 11-1 : Section 1-1.

Analysis MeeceS1Run202 Stage 2 was also for the north slope but assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient for a short term risk although marginally dropped below levels required for permanent works. The risk related to a shallow slump in the near surface restoration soil (Figure 11-2). The analysis assumed the August 2022 topographical levels, which are slightly above the proposed restoration levels. If the restoration soils were to be regraded to meet the proposed restoration profiles, then the slope shall be suitable under all conditions'

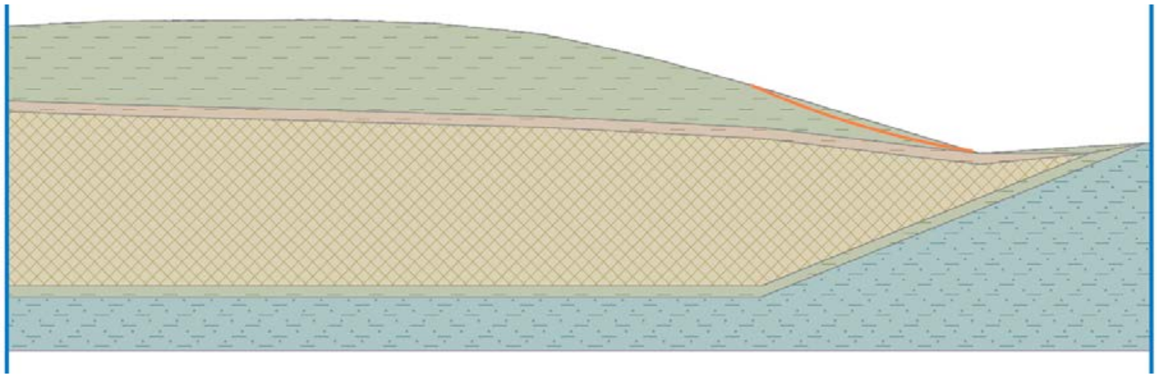


Figure 11-2 : Section 1-1, r_u=0.1, shallow slump

11.2 Section 2-2 North – clay capping

Section 2-2 north was for a clay capping with restoration soils. The results of the analyses are summarised as Table 11-2. Geo5 analysis output is within Appendix C.

Table 11-2: Section 2-2 North, Summary of Geo5-Slope Stability Analyses

Run ID	Stage	Input details	FoS DA1-1	DA1-2	Global factor Unfactored	Output Comments
			Must be <100%			
Section 2-2						
MeeceS2Run201 (Section2 North)	Stage 1	Restoration Profile. North slope	65.10%	53.10%	2.35	
MeeceS2Run201 (Section2 North)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	45.60%	53.40%	2.34	

Analysis MeeceS2Run201 Stage 1 assumed a leachate level 1.0m above current recorded levels. The stability was shown as sufficient for permanent works to both an EC7 approach and a global factor of F>1.3 (Figure 11-3)

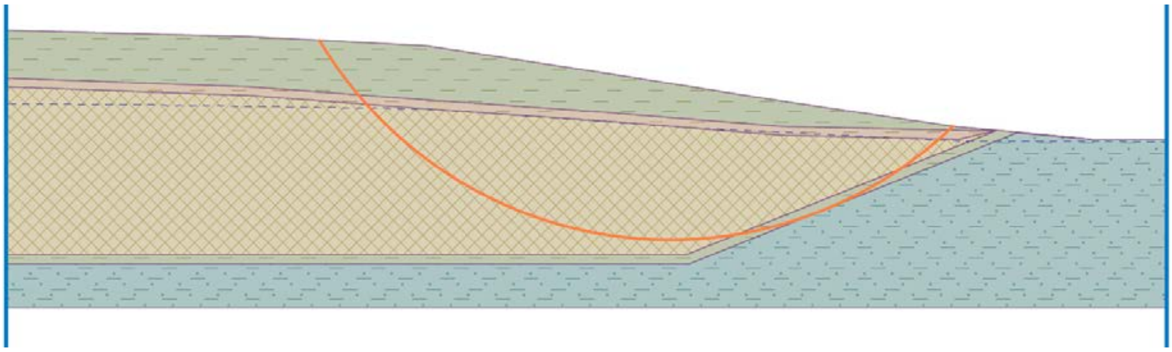


Figure 11-3 : Section 2-2 North.

Analysis MeeceS2Run202 Stage 2 (Figure 11-4) was also for the north slope but assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient.

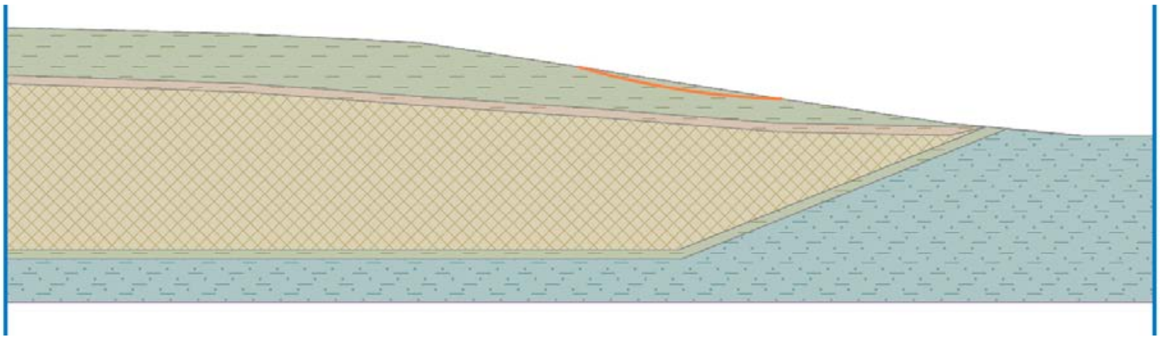


Figure 11-4 : Section 2-2, r_u=0.1, shallow slump

11.3 Section 2-2 South – Geosynthetic Clay Liner (circular slip)

Section 2-2 south was for a geosynthetic clay liner with restoration soils. The results of the analyses are summarised as Table 11-3. Geo5 analysis output is within Appendix C.

Analysis MeeceS2Run205 Stage 1 assumed a leachate level 1.0m above current recorded levels. The stability was shown as sufficient for permanent works to both an EC7 approach and a global factor of F>1.3 (Figure 11-5)

Analysis MeeceS2Run205 Stage 2 (Figure 11-6) was also for the south slope but assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient.

Table 11-3: Section 2-2 South, Summary of Geo5-Slope Stability Analyses

			FoS		Global factor	Output
Run ID	**Stage**	**Input details**	**DA1-1**	**DA1-2**	**Unfactored**	**Comments**
			Must be <100%			
Section 2-2						
MeeceS2Run205 (Section2 South)	Stage 1	Restoration Profile. South slope. GCL capping	51.80%	58.30%	2.14	
MeeceS2Run205 (Section2 South)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	55.60%	65.00%	1.92	shallow slump in restoration soils

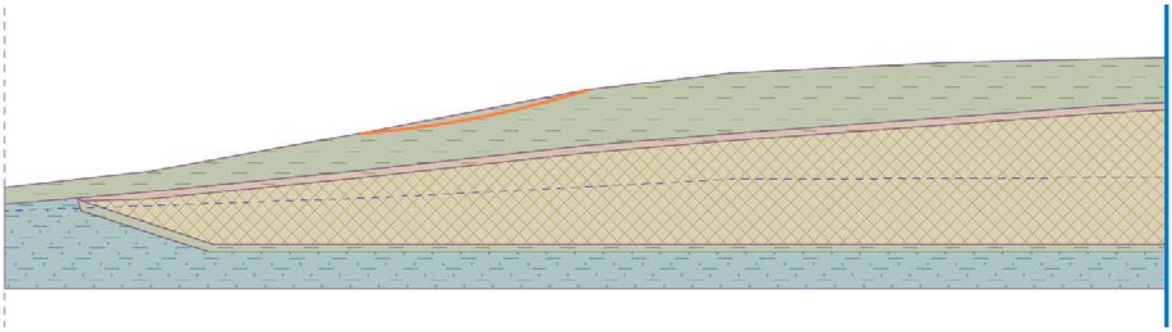


Figure 11-5 : Section 2-2 South.

Analysis MeeceS2Run205 (Figure 11-6) was also for the south slope but assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient.

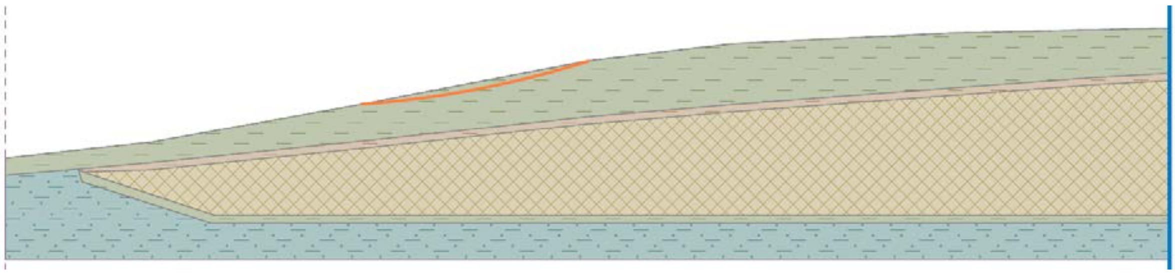


Figure 11-6 : Section 2-2 South, r_u=0.1, shallow slump

11.4 Section 2-2 South – Geosynthetic Clay Liner (Non - circular)

Section 2-2 south was for a geosynthetic clay liner with restoration soils. Section 11-3 considered circular slips that could transverse the GCL. A set of analysis is presented in this section with the GCL acting as a stress concentrator and forming a non circular slip surface. The results of the analyses are summarised as Table 11-4. Geo5 analysis output is within Appendix C.

Table 11-4: Section 2-2 South, Summary of Geo5-Slope Stability Analyses (Non circular)

			FoS		Non partial factor	Output
Run ID	**Stage**	**Input details**	**DA1-1**	**DA1-2**	**SLS**	**Comments**
			Must be <100%			
Section 2-2						
MeeceS2Run215 (Section2 South) NON CIRCULAR	Stage 1	Restoration Profile. South slope. GCL capping	48.50%	53.70%	2.33	Non circular slip through GCL
MeeceS2Run215 (Section2 South) NON CIRCULAR	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	56.00%	60.10%	2.08	Non circular slip through GCL

Analysis MeeceS2Run215 Stage 1 assumed a leachate level 1.0m above current recorded levels. The stability was shown as sufficient for permanent works to both an EC7 approach and a global factor of F>1.3 (Figure 11-7)

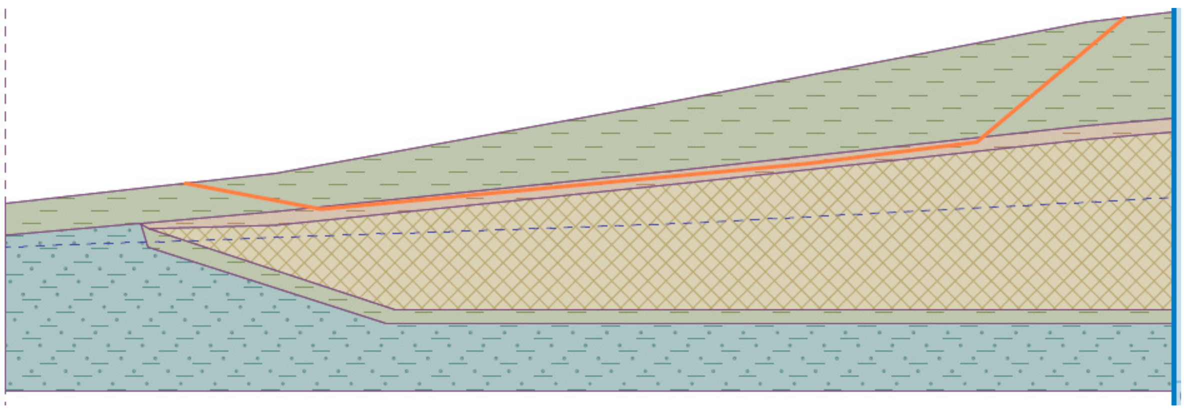


Figure 11-7 : Section 2-2 South, non circular

Analysis MeeceS2Run205 (Figure 11-8) was also for the south slope but assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient.

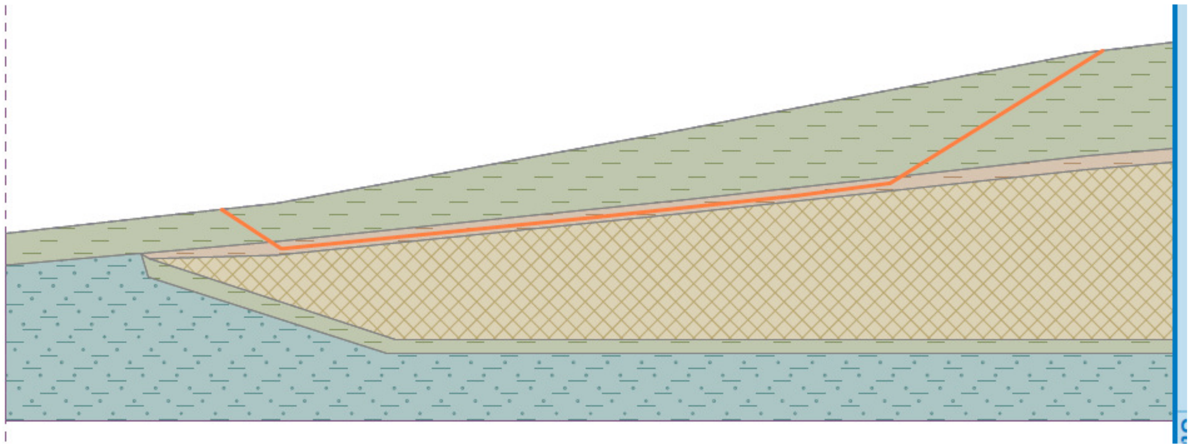


Figure 11-8 : Section 2-2 South, r_u=0.1, non circular

11.5 Section 3-3 South – clay capping

Section 3-3 south was for a clay capping with restoration soils. The results of the analyses are summarised as Table 11-5. Geo5 analysis output is within Appendix C.

Table 11-5: Section 3-3 South, Summary of Geo5-Slope Stability Analyses

			FoS		**Global factor**	**Output**
Run ID	**Stage**	**Input details**	**DA1-1**	**DA1-2**	**Unfactored**	**Comments**
			Target <100%		Target F>1.3	
Section 3-3						
MeeceS3Run201 (Section3 South)	Stage 1	Restoration Profile. South slope	46.80%	39.40%	3.18	
MeeceS3Run201 (Section3 South)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	40.50%	47.20%	2.65	

Analysis MeeceS3Run201 Stage 1 assumed a leachate level 1.0m above current recorded levels. The stability was shown as sufficient for permanent works to both an EC7 approach and a global factor of F>1.3 (Figure 11-9).

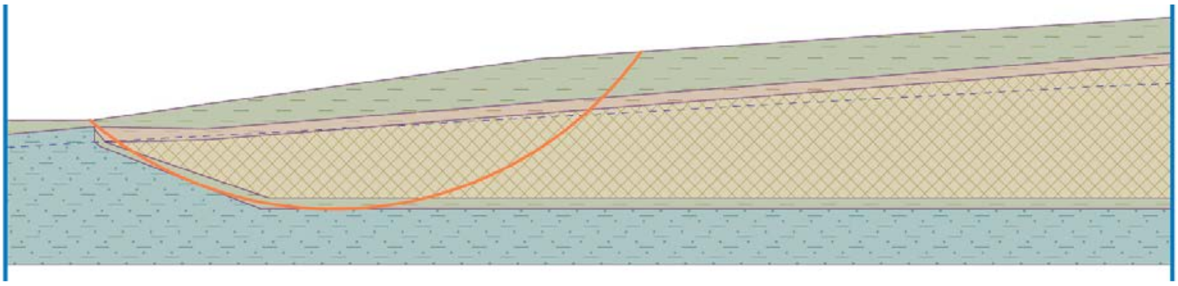


Figure 11-9 : Section 3-3 South

Analysis MeeceS3Run201 Stage 2 (Figure 11-10) assumed a pre pressure ratio of r_u = 0.1 to represent porewater pressures within the fill and restoration soil under conditions of heavy rainfall. The stability was shown as sufficient.

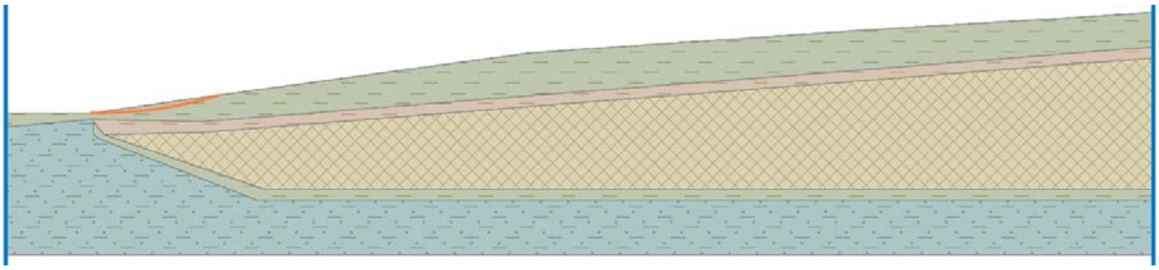


Figure 11-10 : Section 2-2, r_u=0.1, shallow slump

12. MONITORING

Section not used.

13. CONCLUSION

This addendum SRA referred to revised restoration soil levels only. Slope stability analyses have shown that the restoration soils when placed to the proposed slope angles and with either a clay cap or a GCL cap the soils are stable in both the long and short term.

14. TABLES

Tables are embedded within the relevant sections.

15. DRAWINGS

Drawings presented in Appendix A and Appendix B.

16. APPENDICES

Attached to this report.

References :

1. Environment Agency (2003) Environment Agency R&D Technical Report P1-385/ TR1 and TR2, 'Stability of Landfill Lining Systems', February 2003.

2. Environment Agency (2023). Landfill operators: environmental permits - How to do a stability risk assessment: landfill sites for hazardous and non-hazardous waste - Guidance - GOV.UK (www.gov.uk) Last accessed 2023.02.17

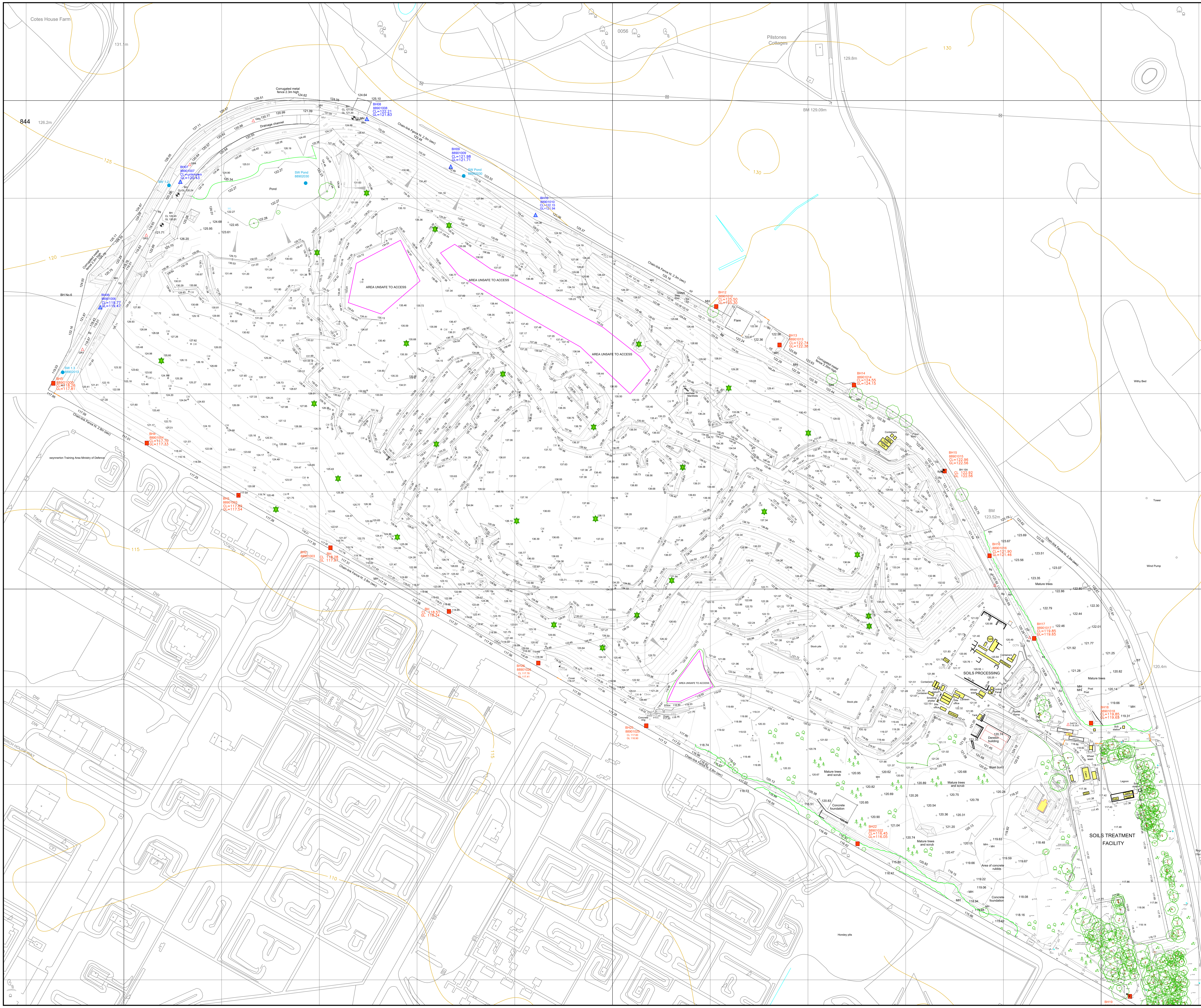
3. Golder Associates (2003). Section C. Meece 1 Landfill. stability risk assessment 03523484.502. For Biffa Waste Services Limited.

4. Jones, D.R.V. & Dixon (2001a) N, 'The stability of geosynthetic landfill lining systems' Geotechnical Engineering of Landfills, Thomas Telford, London, 1998.

5. Jones, D.R.V. & Pine, R.J., (2001b) 'Design of inclined geosynthetic lining systems for vertical landfill expansion' Proc. 8th Int. waste Management and Landfill Symposium, 2001.

Appendices

Appendix A : Drawings



Station Coordinates

No	Eastings	Northings	Level
GR1	384457.692	334245.424	118.623
GR3	384522.976	334362.296	119.910
GR4	384567.382	334434.563	120.546
GR5	384632.376	334479.438	120.916
0407A	385466.173	333861.455	119.001
LG1	385391.273	334003.986	121.054
LG2	385426.879	333950.564	120.330

REV.	DATE	DRAWN	DESCRIPTION

Biffa Waste Services Ltd
Poplars Landfill Site
Lichfield Road
Cannock
WS11 8NQ
Tel: 01543 577890
Mob: 07834092155
e-mail michelle.saunders@biffa.co.uk

PROJECT	Operational Site Survey	DRAWN	LB
LOCATION	Meece Landfill Site	DATE	09.02.22
DRAWING TITLE	Survey as at 9th August 2022	SCALE(S)	1:1250
DRAWING No.	COMPUTER REF.		

Appendix B : Proposed Restoration Sections

NOTES

1. TOPO SURVEY PROVIDED BY BIFFA WASTE SERVICES REF: 3D DATA as at 9th August 2022
2. CAPPING LEVELS ARE FROM esid05 - 5220594r2 restoration DATED 10.09.2003 MINUS 1m
3. LEACHATE LEVELS ARE FROM MONITORING WELLS LW1 TO LW23 PLUS PHASE 6 AND 7. RECORDED 11.10.2022

LEGEND (PLAN)

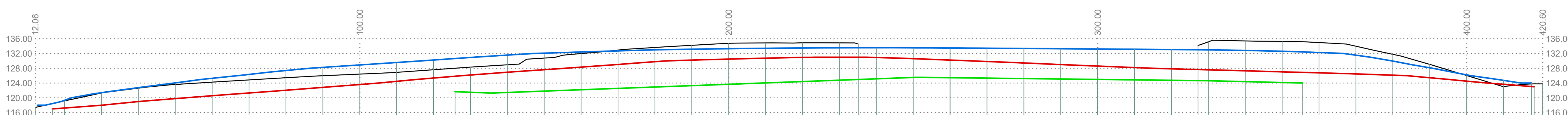
- 137.5 — EXISTING GROUND CONTOURS
- 132.0 — CAPPING LEVEL (TOP OF WASTE) CONTOURS
- 132.0 — FINAL RESTORATION CONTOURS

LEGEND (SECTIONS)

- EXISTING GROUND PROFILE
- CAPPING LEVEL (TOP OF WASTE) PROFILE
- FINAL RESTORATION PROFILE
- LEACHATE LEVELS PROFILE

SECTION 1

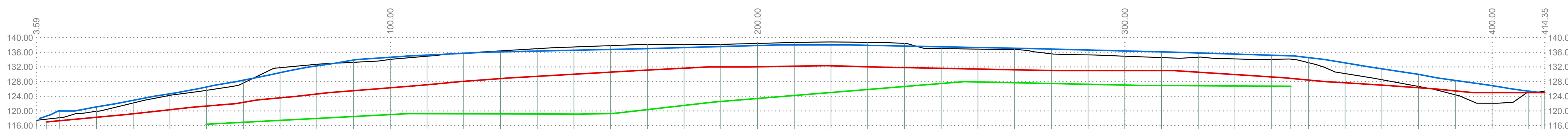
Horiz. 1:1000
Vert. 1:1000



CHAINAGE	RESTORATION	CAPPING	TOPO	LEACHATE
12.055	118.000		117.393	
16.711		117.000		
20.000	119.323	117.247	119.184	
30.000	121.389	117.994	121.315	
40.000	122.760	118.989	122.618	
50.000	124.042	119.787	123.611	
60.000	125.292	120.566	124.247	
70.000	126.344	121.310	124.854	
80.000	127.394	122.056	125.449	
90.000	128.244	122.836	125.990	
100.000	128.907	123.606	126.430	
110.000	129.566	124.465	126.896	
120.000	130.235	125.363	127.604	
125.823				121.666
130.000	130.936	126.177	128.311	121.508
140.000	131.570	126.934	128.941	121.454
150.000	132.094	127.619	130.766	121.822
160.000	132.409	128.315	131.987	122.191
170.000	132.708	129.033	132.934	122.561
180.000	132.998	129.782	133.639	122.930
190.000	133.171	130.221	134.224	123.300
200.000	133.307	130.486	134.758	123.669
210.000	133.415	130.739	134.866	124.039
220.000	133.498	130.956	134.898	124.408
230.000	133.543	131.000	134.886	124.778
235.122			134.549	
240.000	133.556	130.926		125.147
250.000	133.532	130.602		125.517
260.000	133.484	130.224		125.451
270.000	133.434	129.838		125.334
280.000	133.367	129.439		125.218
290.000	133.294	129.006		125.102
300.000	133.222	128.598		124.985
310.000	133.152	128.196		124.869
320.000	133.075	127.856		124.752
327.201			134.192	
330.000	132.987	127.588	135.163	124.631
340.000	132.829	127.317	135.403	124.387
350.000	132.604	127.035	135.287	124.143
355.567				124.007
360.000	132.270	126.773	134.965	
370.000	131.550	126.470	133.976	
380.000	129.956	126.132	131.781	
390.000	128.135	125.442	129.056	
400.000	126.218	124.525	126.036	
410.000	124.729	123.667	123.066	
418.306	124.000	123.000		
420.597			123.794	

SECTION 2

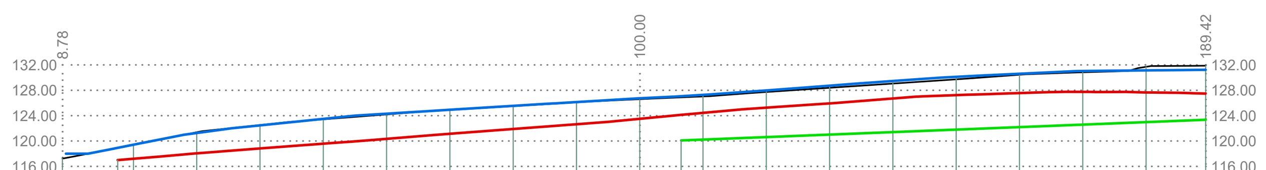
Horiz. 1:1000
Vert. 1:1000



CHAINAGE	RESTORATION	CAPPING	TOPO	LEACHATE
3.592	118.000		117.451	
6.327		117.000		
10.000	120.000	117.339	118.168	
20.000	121.108	118.273	119.896	
30.000	122.905	119.240	122.170	
40.000	124.677	120.335	124.253	
50.000	126.542	121.337	125.624	116.389
60.000	128.387	122.348	127.626	116.913
70.000	130.440	123.576	131.792	117.436
80.000	132.294	124.623	132.716	117.960
90.000	133.877	125.524	133.267	118.484
100.000	134.638	126.320	134.041	119.008
110.000	135.231	127.143	134.923	119.255
120.000	135.727	128.074	135.780	119.227
130.000	136.100	128.826	136.382	119.199
140.000	136.324	129.441	136.984	119.172
150.000	136.548	130.013	137.444	119.144
160.000	136.771	130.589	137.807	119.304
170.000	136.993	131.147	138.137	120.370
180.000	137.276	131.661	138.158	121.507
190.000	137.560	132.000	138.160	122.585
200.000	137.838	132.040	138.410	123.401
210.000	138.000	132.203	138.672	124.218
220.000	138.000	132.309	138.802	125.034
230.000	137.895	132.029	138.700	125.851
240.000	137.695	131.827	138.432	126.667
250.000	137.495	131.626	137.014	127.484
260.000	137.296	131.425	136.860	127.912
270.000	137.097	131.224	136.809	127.697
280.000	136.870	131.023	135.575	127.482
290.000	136.614	131.000	135.290	127.268
300.000	136.357	131.000	134.921	127.053
310.000	136.099	131.000	134.553	126.929
320.000	135.811	130.569	134.647	126.873
330.000	135.503	129.923	134.188	126.817
340.000	135.192	129.265	134.064	126.761
345.213				126.732
350.000	134.547	128.428	133.169	
360.000	133.108	127.676	130.191	
370.000	131.486	127.045	128.521	
380.000	129.981	126.332	126.676	
390.000	128.318	125.462	124.412	
400.000	126.903	125.000	122.099	
410.000	125.403	125.000	125.085	
414.353	125.000		125.420	

SECTION 3

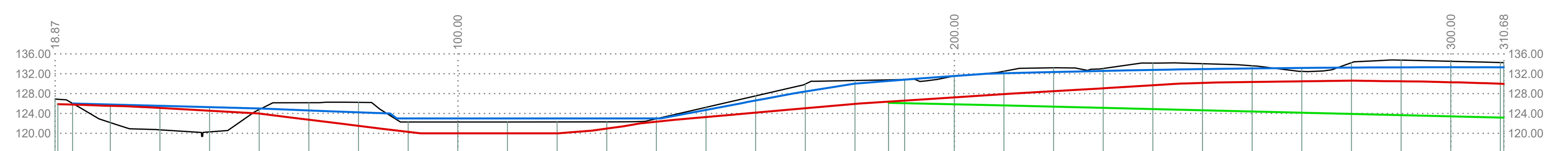
Horiz. 1:1000
Vert. 1:1000



CHAINAGE	RESTORATION	CAPPING	TOPO	LEACHATE
10.000	118.000		117.459	
17.516		117.000		
20.000	119.421	117.204	119.421	
30.000	121.263	118.053	121.382	
40.000	122.461	118.828	122.521	
50.000	123.492	119.578	123.423	
60.000	124.312	120.341	124.195	
70.000	124.929	121.142	124.896	
80.000	125.541	121.900	125.494	
90.000	126.142	122.645	126.090	
100.000	126.737	123.503	126.592	
106.533				120.091
110.000	127.271	124.434	127.030	120.227
120.000	127.977	125.257	127.726	120.620
130.000	128.720	125.933	128.393	121.014
140.000	129.460	126.706	129.059	121.407
150.000	130.119	127.235	129.726	121.801
160.000	130.601	127.555	130.446	122.194
170.000	131.034	127.744	130.832	122.587
180.000	131.129	127.657	131.690	122.981
189.421	131.219	127.472	131.874	123.351

SECTION 4

Horiz. 1:1000
Vert. 1:1000



CHAINAGE	RESTORATION	CAPPING	TOPO	LEACHATE
19.436	126.000	125.859	126.813	
30.000	125.799	125.536	122.162	
40.000	125.533	125.113	120.702	
50.000	125.270	124.553	120.289	
60.000	125.008	123.980	124.784	
70.000	124.605	122.737	126.162	
80.000	124.229	121.502	126.235	
90.000	123.000	120.289	122.271	
100.000	123.000	120.000	122.271	
110.000	123.000	120.000	122.272	
120.000	123.000	120.000	122.290	
130.000	123.000	120.950	122.308	
140.000	123.000	122.337	122.932	
150.000	124.711	123.279	125.237	
160.000	126.617	124.170	127.542	
170.000	128.426	125.055	129.928	
180.000	130.009	125.923	130.636	
186.757				126.139
190.000	130.812	126.592	130.877	126.067
200.000	131.546	127.239	131.484	125.845
210.000	132.093	127.895	132.501	125.617
220.000	132.341	128.486	133.198	125.373
230.000	132.568	129.068	133.062	125.128
240.000	132.769	129.681	134.146	124.883
250.000	132.943	130.156	134.024	124.639
260.000	133.071	130.344	133.608	124.394
270.000	133.170	130.477	132.473	124.150
280.000	133.243	130.608	134.224	123.905
290.000	133.291	130.478	134.747	123.661
300.000	133.310	130.276	134.514	123.416
310.000 / 310.681	[illegible]	[illegible]	[illegible]	123.171 / [illegible]

REV	FIRST ISSUE	DRAWN	CHKD
0		SW	PC

Biffa Waste Services Ltd
Poplars Landfill Site
Lichfield Road
Cannock
WS11 8NQ
Tel: 01543 577890
Mob: 07834092155
e-mail michelle.saunders@biffa.co.uk

SITE: MEECE LANDFILL SITE

PROJECT: RESTORATION

TITLE: CAPPING LEVELS, FINAL RESTORATION AND LEACHATE LEVELS

SCALE: 1:2000@A1 (PLAN)

DATE: 16.02.2023

NUMBER: 001

DRAWN	CH'KED	REV
SW	PC	0

Swan Environmental
Offices 24/25 • The Rear Walled Garden • The Nostell Estate Yard
Nostell • Wakefield • WF4 1AB swanenvironmental.co.uk

16-02-2023 15:02 ML23_RESTC_001 rest sects_0.dwg

Appendix C : Geo5 Slope Stability Summary Sheets

SLOPE : Summary of Analyses Runs   Job No: 3009   Project: Meece Landfill

last update 18/07/2023

Run ID	Stage	Input details	FoS DA1-1	DA1-2	Non partial factor SLS	Output Comments
			Target <100%		Target F>1.3	
Section 1-1						
MeeceS1Run201 (Section1 North)	Stage 1	Restoration Profile. North slope	98.90%	90.60%	1.38	sls gives different critical slip surface. FoS on same slip as EC7 is F =1.52.
MeeceS1Run201 (Section1 North)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	86.40%	101.60%	1.23	shallow slump in restoration soils

Run ID	Stage	Input details	FoS DA1-1	DA1-2	Non partial factor SLS	Output Comments
			Must be <100%			
Section 2-2						
MeeceS2Run201 (Section2 North)	Stage 1	Restoration Profile. North slope	65.10%	53.10%	2.35	
MeeceS2Run201 (Section2 North)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	45.60%	53.40%	2.34	shallow slump in restoration soils
MeeceS2Run205 (Section2 South)	Stage 1	Restoration Profile. South slope. GCL capping	51.80%	58.30%	2.14	
MeeceS2Run205 (Section2 South)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	55.60%	65.00%	1.92	shallow slump in restoration soils

MeeceS2Run215 (Section2 South) NON CIRCULAR	Stage 1	Restoration Profile. South slope. GCL capping	48.50%	53.70%	2.33	Non circular slip through GCL

MeeceS2Run215 (Section2 South) NON CIRCULAR	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	56.00%	60.10%	2.08	Non circular slip through GCL

			FoS		Non partial factor	Output
Run ID	**Stage**	**Input details**	**DA1-1**	**DA1-2**	**SLS**	**Comments**
			Target <100%		Target F>1.3	
Section 3-3						
MeeceS3Run201 (Section3 South)	Stage 1	Restoration Profile. South slope	46.80%	39.40%	3.18	
MeeceS3Run201 (Section3 South)	Stage 2	Ru = 0.1 applied as rainfall event to restoration soils	40.50%	47.20%	2.65	

Slope stability analysis

Input data

Project

Task :	Meece Landfill
Part :	Section 1 North
Description :	Aug 2022 Profile (note this locally higher than 2021 restoration levels - worst case analysed)
Customer :	Swan Environmental /Biffa
Author :	DG
Date :	17/07/2023
Project ID :	Meece Ladfill. Addendum SRA
Project number :	DG3009

Settings

United Kingdom - EN 1997

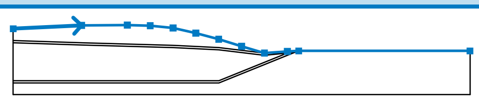
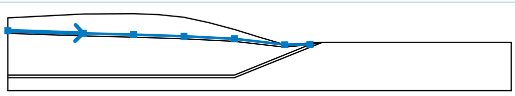
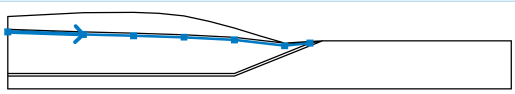
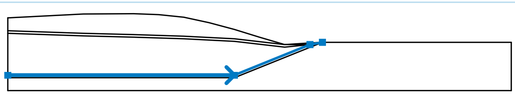
Stability analysis

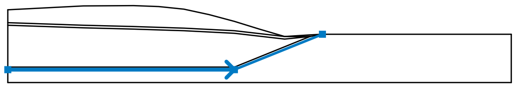
Verification methodology :	according to EN 1997
Earthquake analysis :	Standard
Design approach :	1 - reduction of actions and soil parameters

Partial factors on actions (A)									
Permanent design situation									
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.35	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

Partial factors for soil parameters (M)					
Permanent design situation					
		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		300.00	133.66	330.00	135.16	350.00	135.29
		360.00	134.97	370.00	133.98	380.00	131.78
		390.00	129.06	400.00	126.04	410.00	123.07
		420.00	123.74	425.00	124.00	500.00	124.00
2		300.00	128.60	330.00	127.59	350.00	127.03
		370.00	126.47	390.00	125.44	410.00	123.07
		420.00	123.10				
3		300.00	127.60	330.00	126.59	350.00	126.03
		370.00	125.47	390.00	124.44	410.00	122.07
		420.00	123.10				
4		300.00	111.00	390.00	111.00	420.00	123.10
		425.00	124.00				

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
5		300.00	110.00	390.00	110.00	425.00	124.00

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Waste		25.00	5.00	12.00
2	In situ Weathered MMG (CLAY)		28.00	5.00	18.60
3	Engineered CLAY (MMG derived)		25.00	2.00	18.60
4	Capping (Clay)		25.00	2.00	18.60
5	Restoration Soil (above capping)		22.00	0.05	18.60

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Waste		12.00		
2	In situ Weathered MMG (CLAY)		18.60		
3	Engineered CLAY (MMG derived)		18.60		
4	Capping (Clay)		18.60		
5	Restoration Soil (above capping)		18.60		

Soil parameters

Waste

Unit weight : γ = 12.00 kN/m³

Stress-state : effective

Angle of internal friction :	φ_{ef}	=	25.00 °
Cohesion of soil :	c_{ef}	=	5.00 kPa
Saturated unit weight :	γ_{sat}	=	12.00 kN/m^3

In situ Weathered MMG (CLAY)

Unit weight :	γ	=	18.60 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	28.00 °
Cohesion of soil :	c_{ef}	=	5.00 kPa
Saturated unit weight :	γ_{sat}	=	18.60 kN/m^3

Engineered CLAY (MMG derived)

Unit weight :	γ	=	18.60 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	25.00 °
Cohesion of soil :	c_{ef}	=	2.00 kPa
Saturated unit weight :	γ_{sat}	=	18.60 kN/m^3

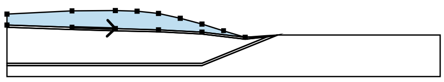
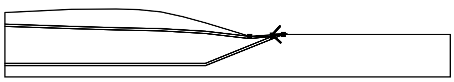
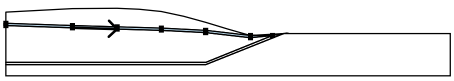
Capping (Clay)

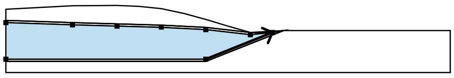
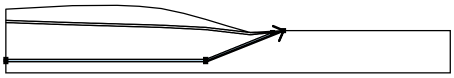
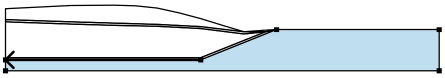
Unit weight :	γ	=	18.60 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	25.00 °
Cohesion of soil :	c_{ef}	=	2.00 kPa
Saturated unit weight :	γ_{sat}	=	18.60 kN/m^3

Restoration Soil (above capping)

Unit weight :	γ	=	18.60 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	22.00 °
Cohesion of soil :	c_{ef}	=	0.05 kPa
Saturated unit weight :	γ_{sat}	=	18.60 kN/m^3

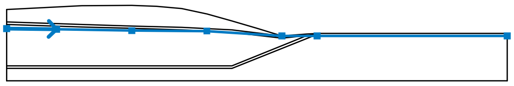
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		330.00	127.59	350.00	127.03	Restoration Soil (above capping)
		370.00	126.47	390.00	125.44	
		410.00	123.07	400.00	126.04	
		390.00	129.06	380.00	131.78	
		370.00	133.98	360.00	134.97	
		350.00	135.29	330.00	135.16	
		300.00	133.66	300.00	128.60	
2		425.00	124.00	420.00	123.74	Restoration Soil (above capping)
		410.00	123.07	420.00	123.10	
3		330.00	126.59	350.00	126.03	Capping (Clay)
		370.00	125.47	390.00	124.44	
		410.00	122.07	420.00	123.10	
		410.00	123.07	390.00	125.44	
		370.00	126.47	350.00	127.03	
		330.00	127.59	300.00	128.60	
		300.00	127.60			

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
4		390.00	111.00	420.00	123.10	Waste
		410.00	122.07	390.00	124.44	
		370.00	125.47	350.00	126.03	
		330.00	126.59	300.00	127.60	
		300.00	111.00			
5		390.00	110.00	425.00	124.00	Engineered CLAY (MMG derived)
		420.00	123.10	390.00	111.00	
		300.00	111.00	300.00	110.00	
6		390.00	110.00	300.00	110.00	In situ Weathered MMG (CLAY)
		300.00	105.00	500.00	105.00	
		500.00	124.00	425.00	124.00	

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		300.00	126.00	320.00	125.75	350.00	125.14
		380.00	125.00	410.00	123.00	424.00	123.00
		500.00	123.00				

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1 (stage 1)

Circular slip surface

Slip surface parameters								
Center :	x =	397.78	[m]	Angles :	α_1 =	-72.83	[°]
	z =	140.75	[m]		α_2 =	47.44	[°]
Radius :	R =	25.49	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 1551.28 kN/m
Sum of passive forces : F_p = 1567.78 kN/m

Sliding moment : M_a = 39542.24 kNm/m

Resisting moment : M_p = 39962.73 kNm/m
Utilization : 98.9 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 53.10 kN/m
Sum of passive forces : F_p = 58.58 kN/m

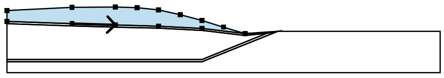
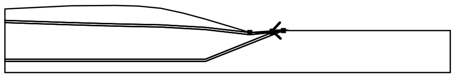
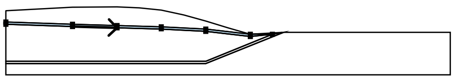
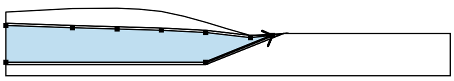
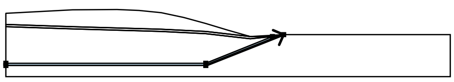
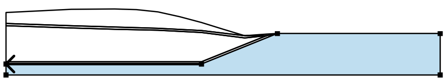
Sliding moment : M_a = 3934.10 kNm/m
Resisting moment : M_p = 4340.26 kNm/m
Utilization : 90.6 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

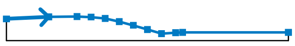
Input data (Stage of construction 2)

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		330.00	127.59	350.00	127.03	Restoration Soil (above capping)
		370.00	126.47	390.00	125.44	
		410.00	123.07	400.00	126.04	
		390.00	129.06	380.00	131.78	
		370.00	133.98	360.00	134.97	
		350.00	135.29	330.00	135.16	
		300.00	133.66	300.00	128.60	
2		425.00	124.00	420.00	123.74	Restoration Soil (above capping)
		410.00	123.07	420.00	123.10	
3		330.00	126.59	350.00	126.03	Capping (Clay)
		370.00	125.47	390.00	124.44	
		410.00	122.07	420.00	123.10	
		410.00	123.07	390.00	125.44	
		370.00	126.47	350.00	127.03	
		330.00	127.59	300.00	128.60	
		300.00	127.60			
4		390.00	111.00	420.00	123.10	Waste
		410.00	122.07	390.00	124.44	
		370.00	125.47	350.00	126.03	
		330.00	126.59	300.00	127.60	
		300.00	111.00			
5		390.00	110.00	425.00	124.00	Engineered CLAY (MMG derived)
		420.00	123.10	390.00	111.00	
		300.00	111.00	300.00	110.00	
6		390.00	110.00	300.00	110.00	In situ Weathered MMG (CLAY)
		300.00	105.00	500.00	105.00	
		500.00	124.00	425.00	124.00	

Water

Water type : Coefficient Ru

No.	Interface Ru location	Coordinates of interface Ru points [m] x	z	x	z	x	z	Coeff. Ru [–]
1		300.00	133.66	330.00	135.16	350.00	135.29	0.100
		360.00	134.97	370.00	133.98	380.00	131.78	
		390.00	129.06	400.00	126.04	410.00	123.07	
		420.00	123.74	425.00	124.00	500.00	124.00	

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 2)

Analysis 1 (stage 2)

Circular slip surface

Slip surface parameters									
Center :	x =	421.91	[m]	Angles :	α_1 =	-24.21	[°]
	z =	202.37	[m]		α_2 =	-9.01	[°]
Radius :	R =	80.10	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 36.64 kN/m
Sum of passive forces : F_p = 42.42 kN/m

Sliding moment : M_a = 663.57 kNm/m
Resisting moment : M_p = 768.20 kNm/m
Utilization : 86.4 %

Slope stability ACCEPTABLE

Combination 2

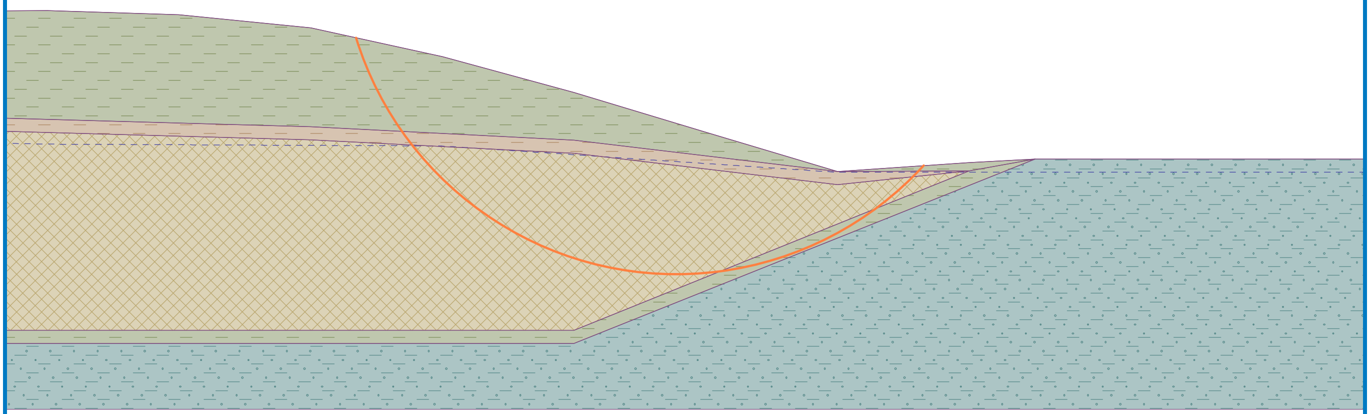
Sum of active forces : F_a = 52.64 kN/m
Sum of passive forces : F_p = 51.83 kN/m

Sliding moment : M_a = 4216.85 kNm/m
Resisting moment : M_p = 4151.52 kNm/m
Utilization : 101.6 %

Slope stability NOT ACCEPTABLE

Optimized slip surface for : Combination 2

Name :	Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 1551.28 kN/m

Sum of passive forces : F_p = 1567.78 kN/m

Sliding moment : M_a = 39542.24 kNm/m

Resisting moment : M_p = 39962.73 kNm/m

Utilization : 98.9 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 53.10 kN/m

Sum of passive forces : F_p = 58.58 kN/m

Sliding moment : M_a = 3934.10 kNm/m

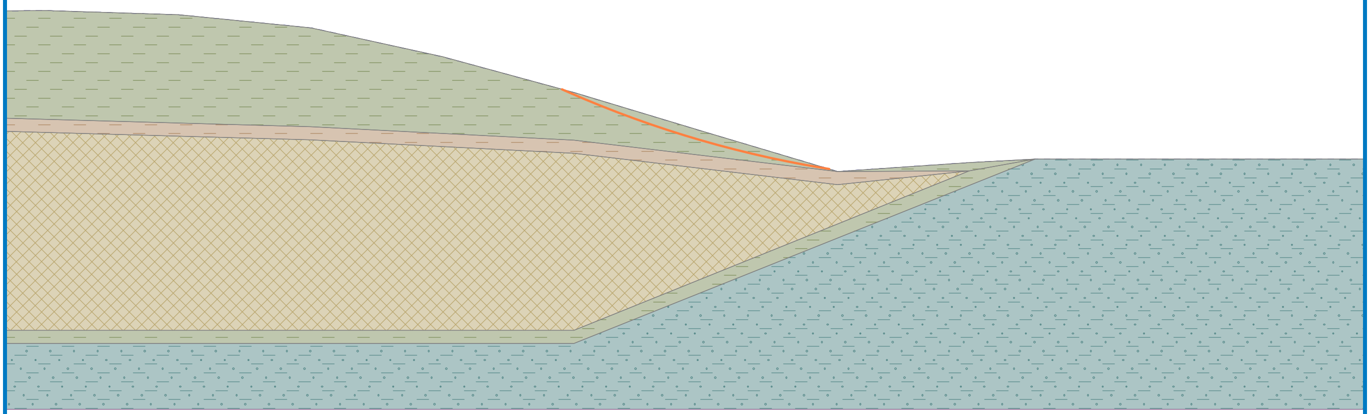
Resisting moment : M_p = 4340.26 kNm/m

Utilization : 90.6 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

Name : **Stage - analysis : 2 - 1**



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 36.64 kN/m
Sum of passive forces : F_p = 42.42 kN/m

Sliding moment : M_a = 663.57 kNm/m
Resisting moment : M_p = 768.20 kNm/m
Utilization : 86.4 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 52.64 kN/m
Sum of passive forces : F_p = 51.83 kN/m

Sliding moment : M_a = 4216.85 kNm/m
Resisting moment : M_p = 4151.52 kNm/m
Utilization : 101.6 %

Slope stability NOT ACCEPTABLE

Optimized slip surface for : Combination 2

Slope stability analysis

Input data

Project

Task : Meece Landfill
Part : Section 2 North
Description : Proposed (2021, 138m) restoration levels (Note this generally higher than than Aug 2022 survey)
Customer : Swan Environmental / Biffa
Author : DG
Date : 17/07/2023
Project ID : Meece Landfill Addendum SRA
Project number : DG3009

Settings

United Kingdom - EN 1997

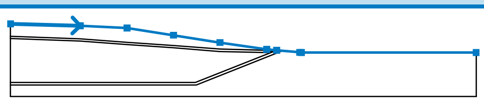
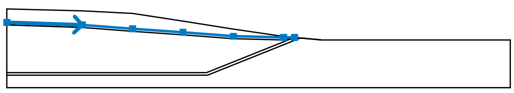
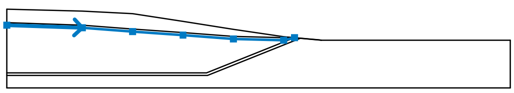
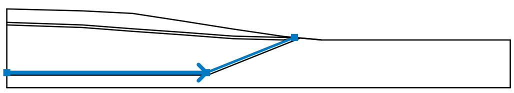
Stability analysis

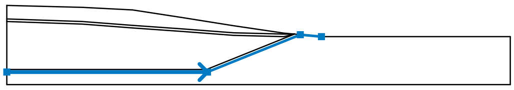
Verification methodology : according to EN 1997
Earthquake analysis : Standard
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)									
Permanent design situation									
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.35	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

Partial factors for soil parameters (M)					
Permanent design situation					
		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		300.00	136.36	330.00	135.60	350.00	134.55
		370.00	131.49	390.00	128.32	410.00	125.40
		414.35	125.00	424.20	124.08	425.00	124.00
		500.00	124.00				
2		300.00	131.00	330.00	129.92	350.00	128.43
		370.00	127.05	390.00	125.46	410.00	125.00
		414.35	125.00				
3		300.00	130.00	330.00	128.92	350.00	127.43
		370.00	126.05	390.00	124.46	410.00	124.00
		414.35	125.00				
4		300.00	111.00	379.35	111.00	414.35	125.00

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
5		300.00	110.00	379.72	110.00	416.60	124.75
		425.00	124.00				

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Waste		25.00	5.00	12.00
2	In situ Weathered MMG (CLAY)		28.00	5.00	18.60
3	Engineered CLAY (MMG derived)		25.00	2.00	18.60
4	Capping (Clay)		25.00	2.00	18.60
5	Restoration Soil (above capping)		22.00	0.05	18.60

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Waste		12.00		
2	In situ Weathered MMG (CLAY)		18.60		
3	Engineered CLAY (MMG derived)		18.60		
4	Capping (Clay)		18.60		
5	Restoration Soil (above capping)		18.60		

Soil parameters

Waste

Unit weight : γ = 12.00 kN/m³

Stress-state : effective

Angle of internal friction : φ_{ef} = 25.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Saturated unit weight : γ_{sat} = 12.00 kN/m3

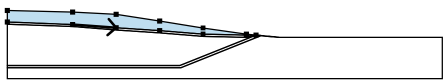
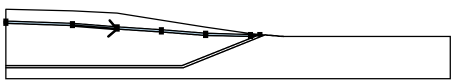
In situ Weathered MMG (CLAY)
Unit weight : γ = 18.60 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 28.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m3

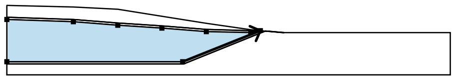
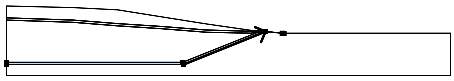
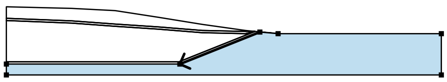
Engineered CLAY (MMG derived)
Unit weight : γ = 18.60 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 25.00 °
Cohesion of soil : c_{ef} = 2.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m3

Capping (Clay)
Unit weight : γ = 18.60 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 25.00 °
Cohesion of soil : c_{ef} = 2.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m3

Restoration Soil (above capping)
Unit weight : γ = 18.60 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 22.00 °
Cohesion of soil : c_{ef} = 0.05 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m3

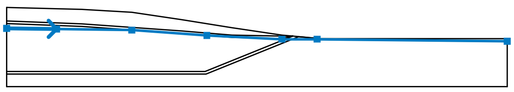
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		330.00	129.92	350.00	128.43	Restoration Soil (above capping)
		370.00	127.05	390.00	125.46	
		410.00	125.00	414.35	125.00	
		410.00	125.40	390.00	128.32	
		370.00	131.49	350.00	134.55	
		330.00	135.60	300.00	136.36	
		300.00	131.00			
2		330.00	128.92	350.00	127.43	Capping (Clay)
		370.00	126.05	390.00	124.46	
		410.00	124.00	414.35	125.00	
		410.00	125.00	390.00	125.46	
		370.00	127.05	350.00	128.43	
		330.00	129.92	300.00	131.00	
		300.00	130.00			

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
3		379.35	111.00	414.35	125.00	Waste
		410.00	124.00	390.00	124.46	
		370.00	126.05	350.00	127.43	
		330.00	128.92	300.00	130.00	
		300.00	111.00			
4		379.72	110.00	416.60	124.75	Engineered CLAY (MMG derived)
		425.00	124.00	424.20	124.08	
		414.35	125.00	379.35	111.00	
		300.00	111.00	300.00	110.00	
5		416.60	124.75	379.72	110.00	In situ Weathered MMG (CLAY)
		300.00	110.00	300.00	105.00	
		500.00	105.00	500.00	124.00	
		425.00	124.00			

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		300.00	128.05	320.00	127.87	350.00	127.40
		380.00	125.30	410.00	123.80	424.00	123.80
		500.00	123.00				

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1 (stage 1)

Circular slip surface

Slip surface parameters								
Center :	x =	377.47	[m]	Angles :	α_1 =	-59.23	[°]
	z =	158.78	[m]		α_2 =	43.79	[°]
Radius :	R =	46.12	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 2359.21 kN/m
Sum of passive forces : F_p = 3624.20 kN/m

Sliding moment : M_a = 108806.94 kNm/m

Resisting moment : M_p = 167147.95 kNm/m
Utilization : 65.1 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 1394.71 kN/m
Sum of passive forces : F_p = 2627.45 kN/m

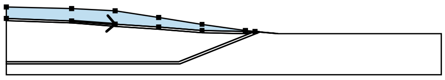
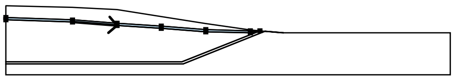
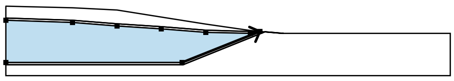
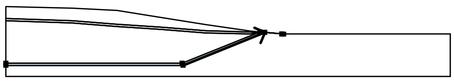
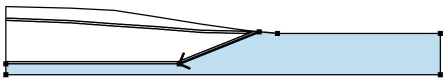
Sliding moment : M_a = 73975.66 kNm/m
Resisting moment : M_p = 139360.18 kNm/m
Utilization : 53.1 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

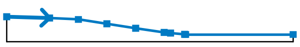
Input data (Stage of construction 2)

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		330.00	129.92	350.00	128.43	Restoration Soil (above capping)
		370.00	127.05	390.00	125.46	
		410.00	125.00	414.35	125.00	
		410.00	125.40	390.00	128.32	
		370.00	131.49	350.00	134.55	
		330.00	135.60	300.00	136.36	
		300.00	131.00			
2		330.00	128.92	350.00	127.43	Capping (Clay)
		370.00	126.05	390.00	124.46	
		410.00	124.00	414.35	125.00	
		410.00	125.00	390.00	125.46	
		370.00	127.05	350.00	128.43	
		330.00	129.92	300.00	131.00	
		300.00	130.00			
3		379.35	111.00	414.35	125.00	Waste
		410.00	124.00	390.00	124.46	
		370.00	126.05	350.00	127.43	
		330.00	128.92	300.00	130.00	
		300.00	111.00			
4		379.72	110.00	416.60	124.75	Engineered CLAY (MMG derived)
		425.00	124.00	424.20	124.08	
		414.35	125.00	379.35	111.00	
		300.00	111.00	300.00	110.00	
5		416.60	124.75	379.72	110.00	In situ Weathered MMG (CLAY)
		300.00	110.00	300.00	105.00	
		500.00	105.00	500.00	124.00	
		425.00	124.00			

Water

Water type : Coefficient Ru

No.	Interface Ru location	Coordinates of interface Ru points [m]						Coeff. Ru [–]
		x	z	x	z	x	z	
1		300.00	136.36	330.00	135.60	350.00	134.55	0.100
		370.00	131.49	390.00	128.32	410.00	125.40	
		414.35	125.00	424.20	124.08	425.00	124.00	
		500.00	124.00					

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 2)

Analysis 1 (stage 2)

Circular slip surface

Slip surface parameters							
Center :	x =	393.89	[m]	Angles :	α_1 =	-16.13	[°]
	z =	222.07	[m]		α_2 =	-1.77	[°]
Radius :	R =	93.94	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 227.90 kN/m
Sum of passive forces : F_p = 500.13 kN/m

Sliding moment : M_a = 7980.97 kNm/m
Resisting moment : M_p = 17514.51 kNm/m
Utilization : 45.6 %

Slope stability ACCEPTABLE

Combination 2

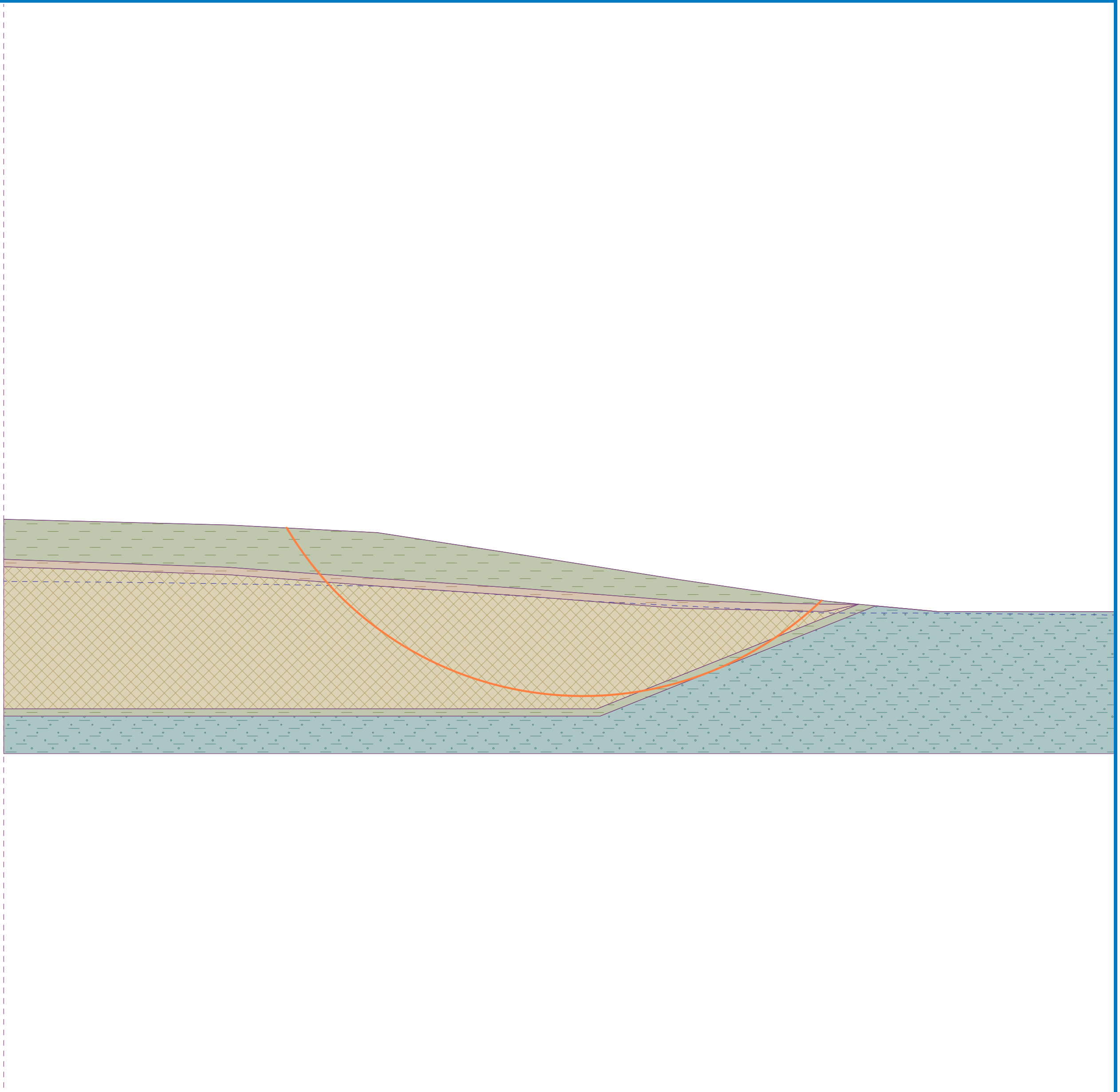
Sum of active forces : F_a = 33.24 kN/m
Sum of passive forces : F_p = 62.22 kN/m

Sliding moment : M_a = 3122.12 kNm/m
Resisting moment : M_p = 5844.81 kNm/m
Utilization : 53.4 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

Name : | **Stage - analysis : 1 - 1**



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 2359.21 kN/m
Sum of passive forces : F_p = 3624.20 kN/m
Sliding moment : M_a = 108806.94 kNm/m
Resisting moment : M_p = 167147.95 kNm/m
Utilization : 65.1 %

Slope stability ACCEPTABLE

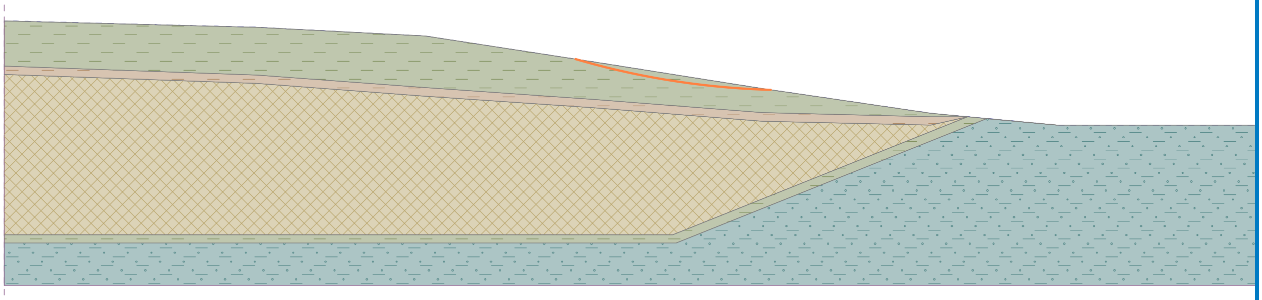
Combination 2

Sum of active forces : F_a = 1394.71 kN/m
Sum of passive forces : F_p = 2627.45 kN/m
Sliding moment : M_a = 73975.66 kNm/m
Resisting moment : M_p = 139360.18 kNm/m
Utilization : 53.1 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

Name :	Stage - analysis : 2 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 227.90 kN/m
Sum of passive forces : F_p = 500.13 kN/m

Sliding moment : M_a = 7980.97 kNm/m
Resisting moment : M_p = 17514.51 kNm/m
Utilization : 45.6 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 33.24 kN/m
Sum of passive forces : F_p = 62.22 kN/m

Sliding moment : M_a = 3122.12 kNm/m
Resisting moment : M_p = 5844.81 kNm/m
Utilization : 53.4 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

Slope stability analysis

Input data

Project

Task : Meece Landfill
Part : Section 2 South
Description : Proposed (2021, 138m) restoration levels (Note this generally higher than than Aug 2022 survey)
Customer : Swan Environmental / Biffa
Author : DG
Date : 17/07/2023
Project ID : Meece Landfill Addendum SRA
Project number : DG3009

Settings

United Kingdom - EN 1997

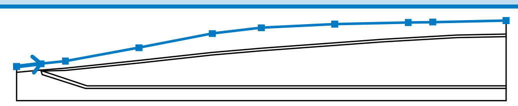
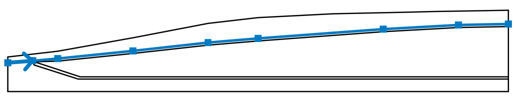
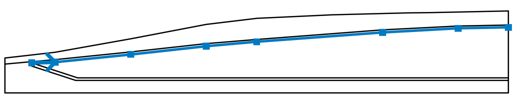
Stability analysis

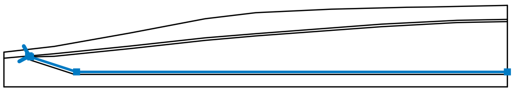
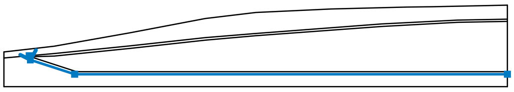
Verification methodology : according to EN 1997
Earthquake analysis : Standard
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)										
Permanent design situation										
		Combination 1				Combination 2				
		Unfavourable		Favourable		Unfavourable		Favourable		
Permanent actions :	γ_G =	1.35	[–]	1.00	[–]	1.00	[–]	1.00	[–]	
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]	
Water load :	γ_w =	1.35	[–]			1.00	[–]			

Partial factors for soil parameters (M)					
Permanent design situation					
		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		0.00	118.89	10.00	120.00	20.00	121.11
		50.00	126.54	80.00	132.29	100.00	134.64
		130.00	136.10	160.00	136.77	170.00	136.99
		200.00	137.60				
2		0.00	116.53	9.83	117.39	9.84	117.39
		10.00	117.40	20.00	118.27	50.00	121.34
		80.00	124.62	100.00	126.32	150.00	130.01
		180.00	131.66	200.00	132.04		
3		10.60	117.00	20.00	117.27	50.00	120.34
		80.00	123.62	100.00	125.32	150.00	129.01
		180.00	130.66	200.00	131.04		

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
4		9.83	117.39	10.00	117.34	10.60	117.00
		28.85	111.00	200.00	111.00		
5		10.00	117.34	10.50	115.65	28.12	110.00
		200.00	110.00				

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]
1	Waste		25.00	5.00	12.00
2	In situ Weathered MMG (CLAY)		28.00	5.00	18.60
3	Engineered CLAY (MMG derived)		25.00	2.00	18.60
4	Capping (GCL)		21.00	0.00	18.60
5	Restoration Soil (above capping)		22.00	0.05	18.60

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m^3]	γ_s [kN/m^3]	n [–]
1	Waste		12.00		
2	In situ Weathered MMG (CLAY)		18.60		
3	Engineered CLAY (MMG derived)		18.60		
4	Capping (GCL)		18.60		
5	Restoration Soil (above capping)		18.60		

Soil parameters

Waste

Unit weight :	γ = 12.00 kN/m^3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 25.00 °
Cohesion of soil :	c_{ef} = 5.00 kPa
Saturated unit weight :	γ_{sat} = 12.00 kN/m^3

In situ Weathered MMG (CLAY)

Unit weight :	γ = 18.60 kN/m^3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 28.00 °
Cohesion of soil :	c_{ef} = 5.00 kPa
Saturated unit weight :	γ_{sat} = 18.60 kN/m^3

Engineered CLAY (MMG derived)

Unit weight :	γ = 18.60 kN/m^3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 25.00 °
Cohesion of soil :	c_{ef} = 2.00 kPa
Saturated unit weight :	γ_{sat} = 18.60 kN/m^3

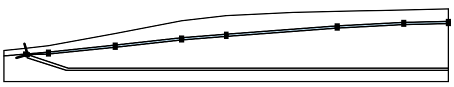
Capping (GCL)

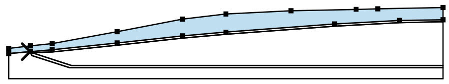
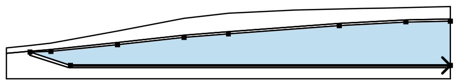
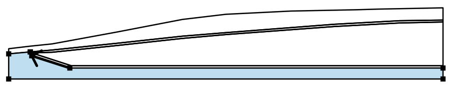
Unit weight :	γ = 18.60 kN/m^3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 21.00 °
Cohesion of soil :	c_{ef} = 0.00 kPa
Saturated unit weight :	γ_{sat} = 18.60 kN/m^3

Restoration Soil (above capping)

Unit weight :	γ = 18.60 kN/m^3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 22.00 °
Cohesion of soil :	c_{ef} = 0.05 kPa
Saturated unit weight :	γ_{sat} = 18.60 kN/m^3

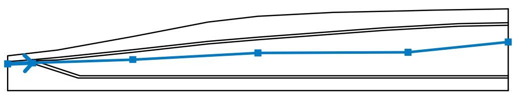
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		10.00	117.34	10.60	117.00	Capping (GCL)
		20.00	117.27	50.00	120.34	
		80.00	123.62	100.00	125.32	
		150.00	129.01	180.00	130.66	
		200.00	131.04	200.00	132.04	
		180.00	131.66	150.00	130.01	
		100.00	126.32	80.00	124.62	
		50.00	121.34	20.00	118.27	
		10.00	117.40	9.84	117.39	
		9.83	117.39			

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
2		9.83	117.39	9.84	117.39	Restoration Soil (above capping)
		10.00	117.40	20.00	118.27	
		50.00	121.34	80.00	124.62	
		100.00	126.32	150.00	130.01	
		180.00	131.66	200.00	132.04	
		200.00	137.60	170.00	136.99	
		160.00	136.77	130.00	136.10	
		100.00	134.64	80.00	132.29	
		50.00	126.54	20.00	121.11	
		10.00	120.00	0.00	118.89	
		0.00	116.53			
3		28.85	111.00	200.00	111.00	Waste
		200.00	131.04	180.00	130.66	
		150.00	129.01	100.00	125.32	
		80.00	123.62	50.00	120.34	
		20.00	117.27	10.60	117.00	
4		10.50	115.65	28.12	110.00	Engineered CLAY (MMG derived)
		200.00	110.00	200.00	111.00	
		28.85	111.00	10.60	117.00	
		10.00	117.34			
5		28.12	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	117.34	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		0.00	115.65	10.00	116.00	50.00	117.39
		100.00	120.01	160.00	120.30	200.00	124.40

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1 (stage 1)

Circular slip surface

Slip surface parameters								
Center :	x =	38.39	[m]	Angles :	α_1 =	4.34	[°]
	z =	268.31	[m]		α_2 =	17.20	[°]
Radius :	R =	142.33	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 2748.54 kN/m
Sum of passive forces : F_p = 5310.18 kN/m

Sliding moment : M_a = 160074.87 kNm/m
Resisting moment : M_p = 309265.03 kNm/m
Utilization : 51.8 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 67.59 kN/m
Sum of passive forces : F_p = 115.87 kN/m

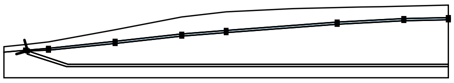
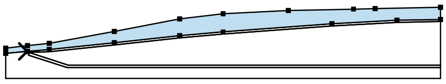
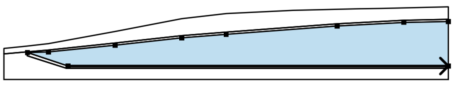
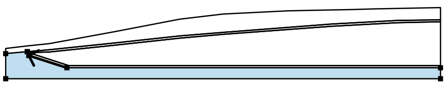
Sliding moment : M_a = 9619.62 kNm/m
Resisting moment : M_p = 16491.92 kNm/m
Utilization : 58.3 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

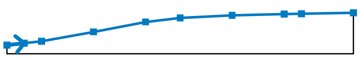
Input data (Stage of construction 2)

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		10.00	117.34	10.60	117.00	Capping (GCL)
		20.00	117.27	50.00	120.34	
		80.00	123.62	100.00	125.32	
		150.00	129.01	180.00	130.66	
		200.00	131.04	200.00	132.04	
		180.00	131.66	150.00	130.01	
		100.00	126.32	80.00	124.62	
		50.00	121.34	20.00	118.27	
		10.00	117.40	9.84	117.39	
		9.83	117.39			
2		9.83	117.39	9.84	117.39	Restoration Soil (above capping)
		10.00	117.40	20.00	118.27	
		50.00	121.34	80.00	124.62	
		100.00	126.32	150.00	130.01	
		180.00	131.66	200.00	132.04	
		200.00	137.60	170.00	136.99	
		160.00	136.77	130.00	136.10	
		100.00	134.64	80.00	132.29	
		50.00	126.54	20.00	121.11	
		10.00	120.00	0.00	118.89	
		0.00	116.53			
3		28.85	111.00	200.00	111.00	Waste
		200.00	131.04	180.00	130.66	
		150.00	129.01	100.00	125.32	
		80.00	123.62	50.00	120.34	
		20.00	117.27	10.60	117.00	
4		10.50	115.65	28.12	110.00	Engineered CLAY (MMG derived)
		200.00	110.00	200.00	111.00	
		28.85	111.00	10.60	117.00	
		10.00	117.34			
5		28.12	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	117.34	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : Coefficient Ru

No.	Interface Ru location	Coordinates of interface Ru points [m]						Coeff. Ru [–]
		x	z	x	z	x	z	
1		0.00	118.89	10.00	120.00	20.00	121.11	0.100
		50.00	126.54	80.00	132.29	100.00	134.64	
		130.00	136.10	160.00	136.77	170.00	136.99	
		200.00	137.60					

Tensile crack
Tensile crack not input.

Earthquake
Earthquake not included.

Settings of the stage of construction
Design situation : permanent

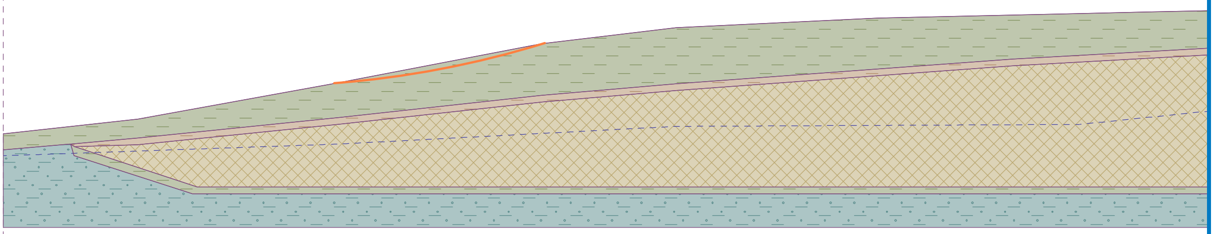
Results (Stage of construction 2)

Analysis 1 (stage 2)
Circular slip surface

Slip surface parameters							
Center :	x =	39.77	[m]	Angles :	α_1 =	3.95	[°]
	z =	259.99	[m]		α_2 =	17.63	[°]
Radius :	R =	133.95	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1
Sum of active forces : F_a = 871.37 kN/m
Sum of passive forces : F_p = 1567.11 kN/m
Sliding moment : M_a = 45703.56 kNm/m
Resisting moment : M_p = 82195.10 kNm/m
Utilization : 55.6 %
Slope stability ACCEPTABLE
Combination 2
Sum of active forces : F_a = 71.16 kN/m
Sum of passive forces : F_p = 109.43 kN/m
Sliding moment : M_a = 9531.96 kNm/m
Resisting moment : M_p = 14657.90 kNm/m
Utilization : 65.0 %
Slope stability ACCEPTABLE
Optimized slip surface for : Combination 2

Name :	Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 2748.54 kN/m
Sum of passive forces : F_p = 5310.18 kN/m
Sliding moment : M_a = 160074.87 kNm/m
Resisting moment : M_p = 309265.03 kNm/m
Utilization : 51.8 %

Slope stability ACCEPTABLE

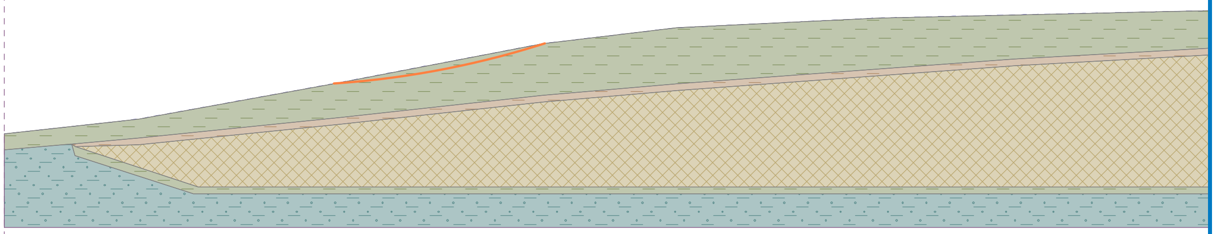
Combination 2

Sum of active forces : F_a = 67.59 kN/m
Sum of passive forces : F_p = 115.87 kN/m
Sliding moment : M_a = 9619.62 kNm/m
Resisting moment : M_p = 16491.92 kNm/m
Utilization : 58.3 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

Name :	Stage - analysis : 2 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 871.37 kN/m
Sum of passive forces : F_p = 1567.11 kN/m

Sliding moment : M_a = 45703.56 kNm/m
Resisting moment : M_p = 82195.10 kNm/m
Utilization : 55.6 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 71.16 kN/m
Sum of passive forces : F_p = 109.43 kN/m

Sliding moment : M_a = 9531.96 kNm/m
Resisting moment : M_p = 14657.90 kNm/m
Utilization : 65.0 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

Slope stability analysis

Input data

Project

Task : Meece Landfill
Part : Section 2 South
Description : Proposed (2021, 138m) restoration levels (Note this generally higher than than Aug 2022 survey)
Customer : Swan Environmental / Biffa
Author : DG
Date : 18/07/2023
Project ID : Meece Landfill Addendum SRA
Project number : DG3009

Settings

United Kingdom - EN 1997

Stability analysis

Verification methodology : according to EN 1997
Earthquake analysis : Standard
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)

Permanent design situation

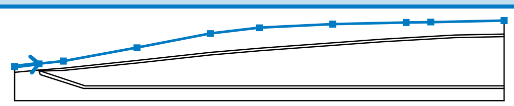
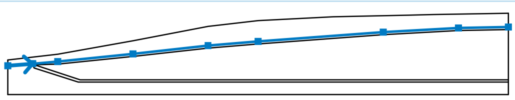
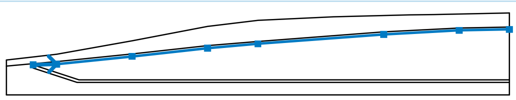
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.35	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

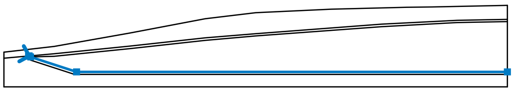
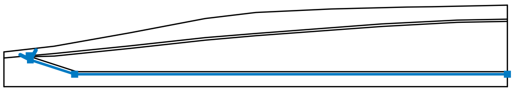
Partial factors for soil parameters (M)

Permanent design situation

		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		0.00	118.89	10.00	120.00	20.00	121.11
		50.00	126.54	80.00	132.29	100.00	134.64
		130.00	136.10	160.00	136.77	170.00	136.99
		200.00	137.60				
2		0.00	116.53	9.83	117.39	9.84	117.39
		10.00	117.40	20.00	118.27	50.00	121.34
		80.00	124.62	100.00	126.32	150.00	130.01
		180.00	131.66	200.00	132.04		
3		10.60	117.00	20.00	117.27	50.00	120.34
		80.00	123.62	100.00	125.32	150.00	129.01
		180.00	130.66	200.00	131.04		

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
4		9.83	117.39	10.00	117.34	10.60	117.00
		28.85	111.00	200.00	111.00		
5		10.00	117.34	10.50	115.65	28.12	110.00
		200.00	110.00				

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]
1	Waste		25.00	5.00	12.00
2	In situ Weathered MMG (CLAY)		28.00	5.00	18.60
3	Engineered CLAY (MMG derived)		25.00	2.00	18.60
4	Capping (GCL)		21.00	0.00	18.60
5	Restoration Soil (above capping)		22.00	0.05	18.60

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m^3]	γ_s [kN/m^3]	n [–]
1	Waste		12.00		
2	In situ Weathered MMG (CLAY)		18.60		
3	Engineered CLAY (MMG derived)		18.60		
4	Capping (GCL)		18.60		
5	Restoration Soil (above capping)		18.60		

Soil parameters

Waste

Unit weight : γ = 12.00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 25.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Saturated unit weight : γ_{sat} = 12.00 kN/m^3

In situ Weathered MMG (CLAY)

Unit weight : γ = 18.60 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 28.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m^3

Engineered CLAY (MMG derived)

Unit weight : γ = 18.60 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 25.00 °
Cohesion of soil : c_{ef} = 2.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m^3

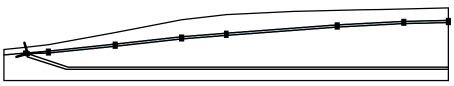
Capping (GCL)

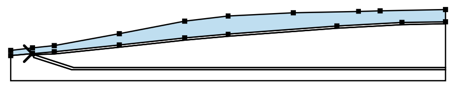
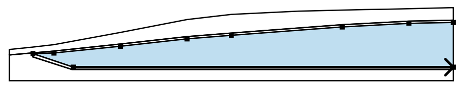
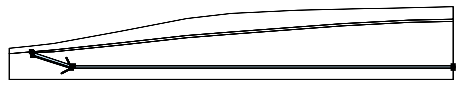
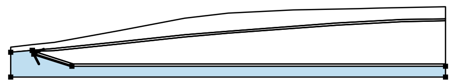
Unit weight : γ = 18.60 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 21.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m^3

Restoration Soil (above capping)

Unit weight : γ = 18.60 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 22.00 °
Cohesion of soil : c_{ef} = 0.05 kPa
Saturated unit weight : γ_{sat} = 18.60 kN/m^3

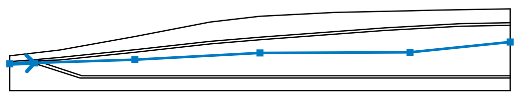
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		10.00	117.34	10.60	117.00	Capping (GCL)
		20.00	117.27	50.00	120.34	
		80.00	123.62	100.00	125.32	
		150.00	129.01	180.00	130.66	
		200.00	131.04	200.00	132.04	
		180.00	131.66	150.00	130.01	
		100.00	126.32	80.00	124.62	
		50.00	121.34	20.00	118.27	
		10.00	117.40	9.84	117.39	
		9.83	117.39			

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
2		9.83	117.39	9.84	117.39	Restoration Soil (above capping)
		10.00	117.40	20.00	118.27	
		50.00	121.34	80.00	124.62	
		100.00	126.32	150.00	130.01	
		180.00	131.66	200.00	132.04	
		200.00	137.60	170.00	136.99	
		160.00	136.77	130.00	136.10	
		100.00	134.64	80.00	132.29	
		50.00	126.54	20.00	121.11	
		10.00	120.00	0.00	118.89	
		0.00	116.53			
3		28.85	111.00	200.00	111.00	Waste
		200.00	131.04	180.00	130.66	
		150.00	129.01	100.00	125.32	
		80.00	123.62	50.00	120.34	
		20.00	117.27	10.60	117.00	
4		10.50	115.65	28.12	110.00	Engineered CLAY (MMG derived)
		200.00	110.00	200.00	111.00	
		28.85	111.00	10.60	117.00	
		10.00	117.34			
5		28.12	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	117.34	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		0.00	115.65	10.00	116.00	50.00	117.39
		100.00	120.01	160.00	120.30	200.00	124.40

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1 (stage 1)

Polygonal slip surface

Coordinates of slip surface points [m]									
x	z	x	z	x	z	x	z	x	z
13.26	120.36	23.33	118.44	59.33	121.82	71.90	123.42	82.84	132.62
Analysis of the slip surface without optimization.									

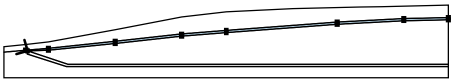
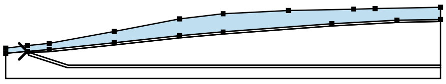
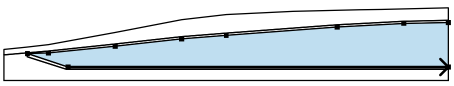
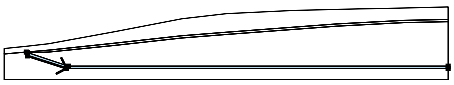
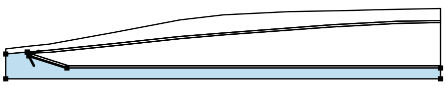
Slope stability verification (Sarma)
Combination 1
Utilization : 48.5 %

Slope stability ACCEPTABLE
Combination 2
Utilization : 53.7 %

Slope stability ACCEPTABLE

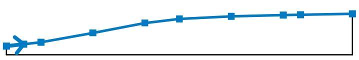
Input data (Stage of construction 2)

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		10.00	117.34	10.60	117.00	Capping (GCL)
		20.00	117.27	50.00	120.34	
		80.00	123.62	100.00	125.32	
		150.00	129.01	180.00	130.66	
		200.00	131.04	200.00	132.04	
		180.00	131.66	150.00	130.01	
		100.00	126.32	80.00	124.62	
		50.00	121.34	20.00	118.27	
		10.00	117.40	9.84	117.39	
		9.83	117.39			
2		9.83	117.39	9.84	117.39	Restoration Soil (above capping)
		10.00	117.40	20.00	118.27	
		50.00	121.34	80.00	124.62	
		100.00	126.32	150.00	130.01	
		180.00	131.66	200.00	132.04	
		200.00	137.60	170.00	136.99	
		160.00	136.77	130.00	136.10	
		100.00	134.64	80.00	132.29	
		50.00	126.54	20.00	121.11	
		10.00	120.00	0.00	118.89	
		0.00	116.53			
3		28.85	111.00	200.00	111.00	Waste
		200.00	131.04	180.00	130.66	
		150.00	129.01	100.00	125.32	
		80.00	123.62	50.00	120.34	
		20.00	117.27	10.60	117.00	
4		10.50	115.65	28.12	110.00	Engineered CLAY (MMG derived)
		200.00	110.00	200.00	111.00	
		28.85	111.00	10.60	117.00	
		10.00	117.34			
5		28.12	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	117.34	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : Coefficient Ru

No.	Interface Ru location	Coordinates of interface Ru points [m] x	z	x	z	x	z	Coeff. Ru [–]
1		0.00	118.89	10.00	120.00	20.00	121.11	0.100
		50.00	126.54	80.00	132.29	100.00	134.64	
		130.00	136.10	160.00	136.77	170.00	136.99	
		200.00	137.60					

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 2)

Analysis 1 (stage 2)

Polygonal slip surface

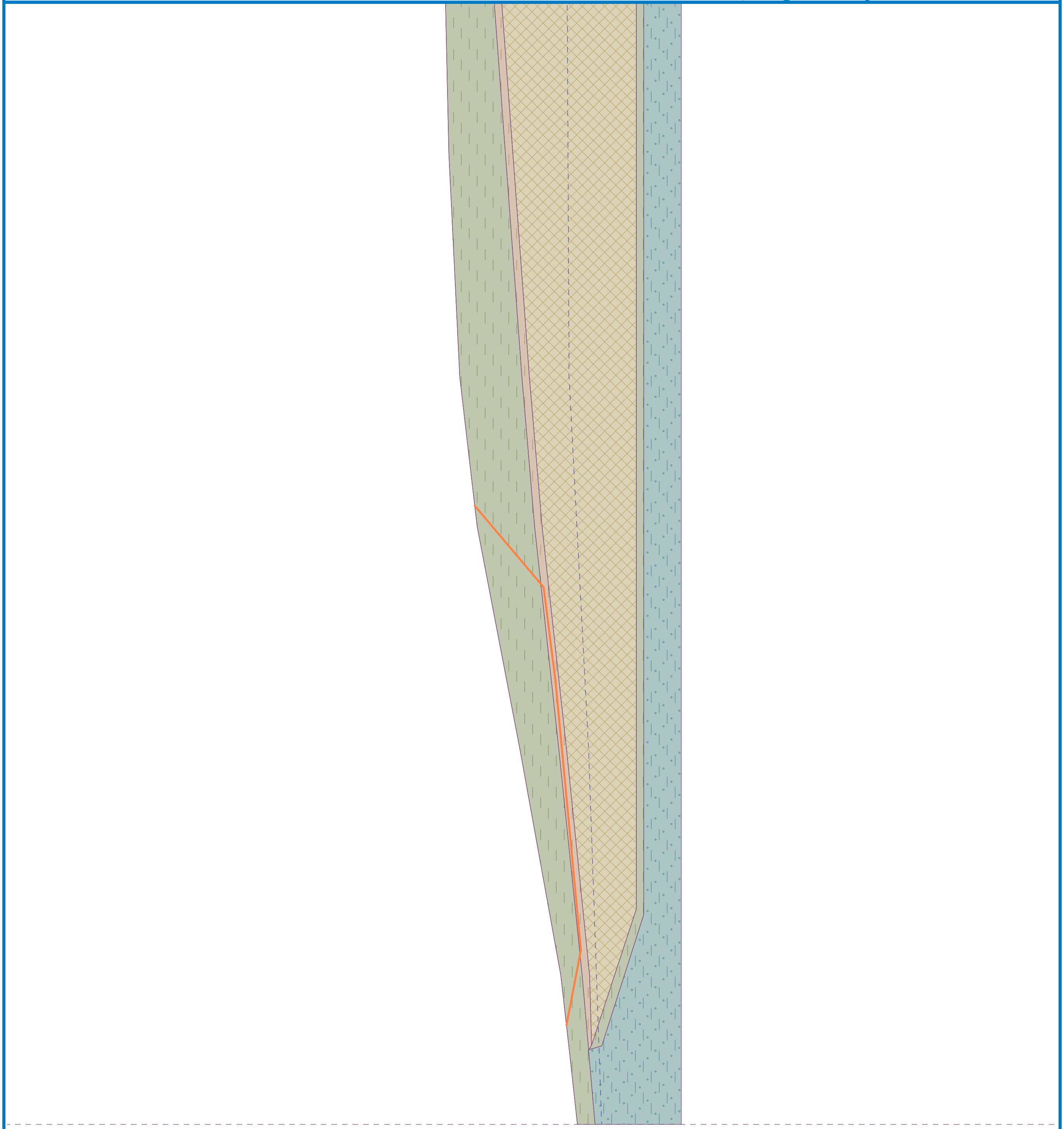
Coordinates of slip surface points [m]									
x	z	x	z	x	z	x	z	x	z
15.91	120.66	15.99	120.60	20.36	117.74	43.57	120.06	58.62	121.68
65.42	122.60	81.16	132.43						
Analysis of the slip surface without optimization.									

Slope stability verification (Sarma)
Combination 1
Utilization : 56.0 %

Slope stability ACCEPTABLE
Combination 2
Utilization : 60.1 %

Slope stability ACCEPTABLE

Name :	Stage - analysis : 1 - 1



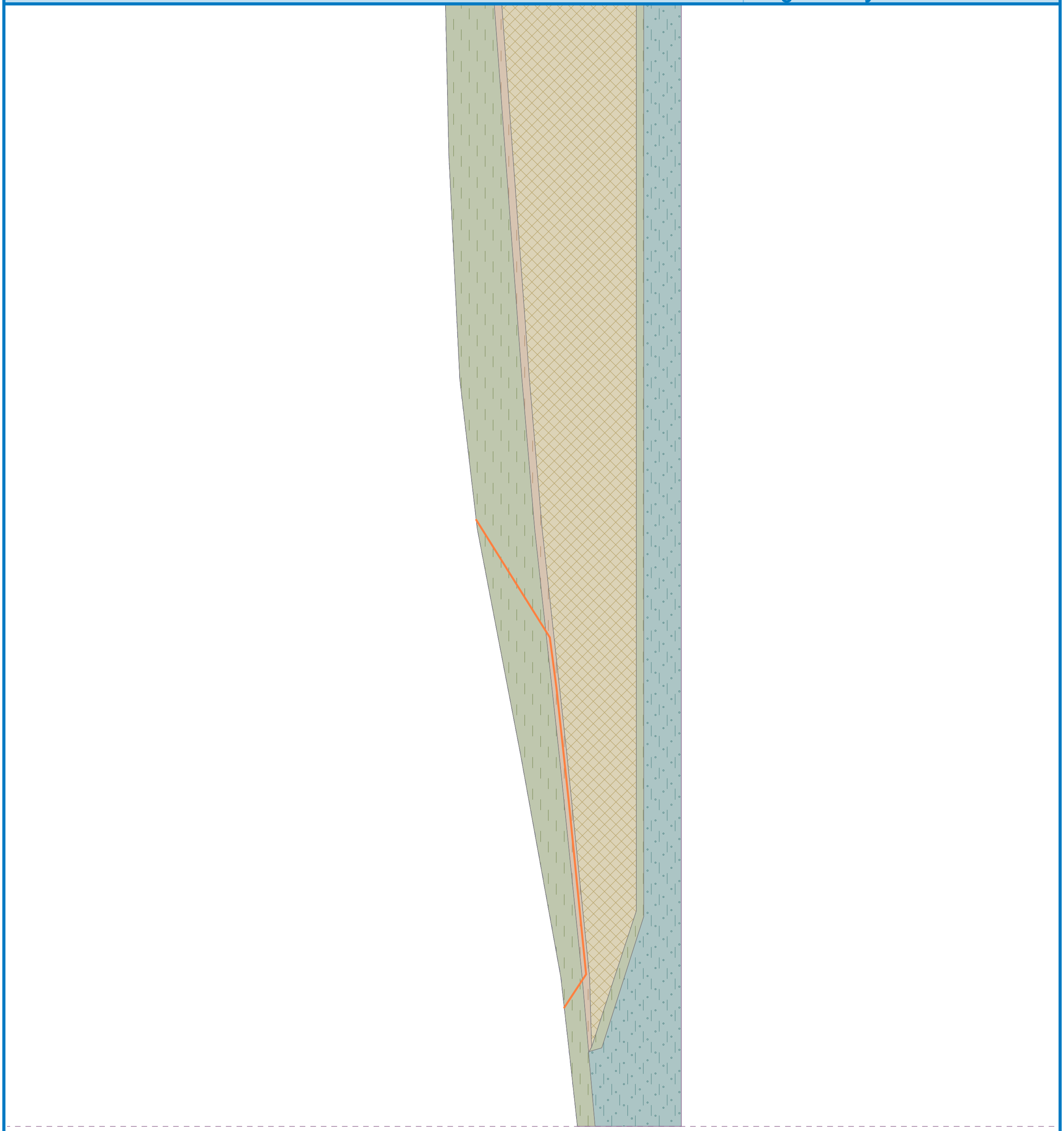
Analysis of the slip surface without optimization.

Slope stability verification (Sarma)
Combination 1
Utilization : 48.5 %

Slope stability ACCEPTABLE
Combination 2
Utilization : 53.7 %

Slope stability ACCEPTABLE

Name :	Stage - analysis : 2 - 1



Analysis of the slip surface without optimization.

Slope stability verification (Sarma)
Combination 1
Utilization : 56.0 %

Slope stability ACCEPTABLE
Combination 2
Utilization : 60.1 %

Slope stability ACCEPTABLE

Slope stability analysis

Input data

Project

Task :	Meece Landfill
Part :	Section 3 South
Description :	Proposed (2021, 138m) restoration levels (Note this generally higher than than Aug 2022 survey)
Customer :	Swan Environmental / Biffa
Author :	DG
Date :	18/07/2023
Project ID :	Meece Landfill Addendum SRA
Project number :	DG3009

Settings

United Kingdom - EN 1997

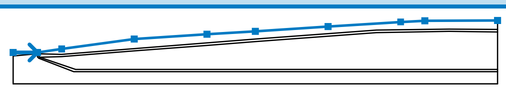
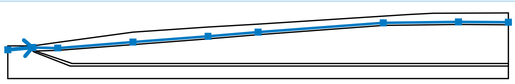
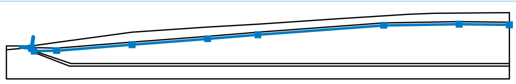
Stability analysis

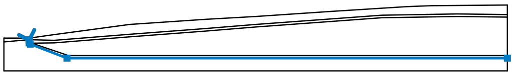
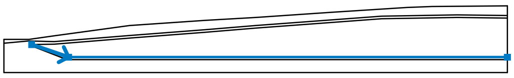
Verification methodology :	according to EN 1997
Earthquake analysis :	Standard
Design approach :	1 - reduction of actions and soil parameters

Partial factors on actions (A)					
Permanent design situation					
		Combination 1		Combination 2	
		Unfavourable	Favourable	Unfavourable	Favourable
Permanent actions :	$\gamma_G =$	1.35 [–]	1.00 [–]	1.00 [–]	1.00 [–]
Variable actions :	$\gamma_Q =$	1.50 [–]	0.00 [–]	1.30 [–]	0.00 [–]
Water load :	$\gamma_w =$	1.35 [–]		1.00 [–]	

Partial factors for soil parameters (M)			
Permanent design situation			
		Combination 1	Combination 2
Partial factor on internal friction :	$\gamma_\phi =$	1.00 [–]	1.25 [–]
Partial factor on effective cohesion :	$\gamma_c =$	1.00 [–]	1.25 [–]
Partial factor on undrained shear strength :	$\gamma_{cu} =$	1.00 [–]	1.40 [–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		0.00	118.00	10.00	118.00	20.00	119.42
		50.00	123.49	80.00	125.54	100.00	126.74
		130.00	128.72	160.00	130.60	170.00	131.03
		200.00	131.22				
2		0.00	116.53	9.83	117.39	9.98	117.40
		10.00	117.40	20.00	117.20	50.00	119.58
		80.00	121.90	100.00	123.50	150.00	127.23
		180.00	127.66	200.00	127.47		
3		10.00	117.21	10.07	117.12	10.13	117.04
		11.00	116.00	20.00	116.20	50.00	118.58
		80.00	120.90	100.00	122.50	150.00	126.23
		180.00	126.66	200.00	126.47		

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
4		9.98	117.40	10.00	117.34	10.00	117.21
		10.00	117.12	10.00	116.06	10.50	115.65
		25.00	110.00	200.00	110.00		
5		11.00	116.00	25.73	111.00	200.00	111.00

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]
1	Waste		25.00	5.00	12.00
2	In situ Weathered MMG (CLAY)		28.00	5.00	18.60
3	Engineered CLAY (MMG derived)		25.00	2.00	18.60
4	Capping (Clay)		25.00	2.00	18.60
5	Restoration Soil (above capping)		22.00	0.05	18.60

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m^3]	γ_s [kN/m^3]	n [–]
1	Waste		12.00		
2	In situ Weathered MMG (CLAY)		18.60		
3	Engineered CLAY (MMG derived)		18.60		
4	Capping (Clay)		18.60		
5	Restoration Soil (above capping)		18.60		

Soil parameters

Waste

Unit weight :	γ =	12.00 kN/m3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	25.00 °
Cohesion of soil :	c_{ef} =	5.00 kPa
Saturated unit weight :	γ_{sat} =	12.00 kN/m3

In situ Weathered MMG (CLAY)

Unit weight :	γ =	18.60 kN/m3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	28.00 °
Cohesion of soil :	c_{ef} =	5.00 kPa
Saturated unit weight :	γ_{sat} =	18.60 kN/m3

Engineered CLAY (MMG derived)

Unit weight :	γ =	18.60 kN/m3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	25.00 °
Cohesion of soil :	c_{ef} =	2.00 kPa
Saturated unit weight :	γ_{sat} =	18.60 kN/m3

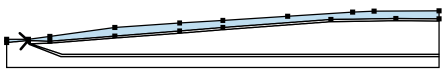
Capping (Clay)

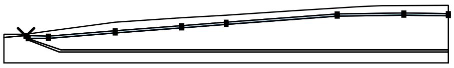
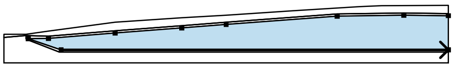
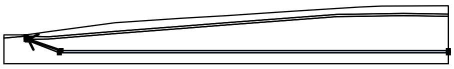
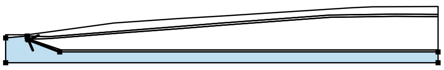
Unit weight :	γ =	18.60 kN/m3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	25.00 °
Cohesion of soil :	c_{ef} =	2.00 kPa
Saturated unit weight :	γ_{sat} =	18.60 kN/m3

Restoration Soil (above capping)

Unit weight :	γ =	18.60 kN/m3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	22.00 °
Cohesion of soil :	c_{ef} =	0.05 kPa
Saturated unit weight :	γ_{sat} =	18.60 kN/m3

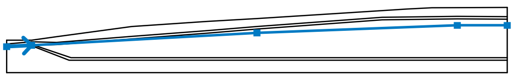
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		9.83	117.39	9.98	117.40	Restoration Soil (above capping)
		10.00	117.40	20.00	117.20	
		50.00	119.58	80.00	121.90	
		100.00	123.50	150.00	127.23	
		180.00	127.66	200.00	127.47	
		200.00	131.22	170.00	131.03	
		160.00	130.60	130.00	128.72	
		100.00	126.74	80.00	125.54	
		50.00	123.49	20.00	119.42	
		10.00	118.00	0.00	118.00	
		0.00	116.53			

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
2		10.00	117.34	10.00	117.21	Capping (Clay)
		10.07	117.12	10.13	117.04	
		11.00	116.00	20.00	116.20	
		50.00	118.58	80.00	120.90	
		100.00	122.50	150.00	126.23	
		180.00	126.66	200.00	126.47	
		200.00	127.47	180.00	127.66	
		150.00	127.23	100.00	123.50	
		80.00	121.90	50.00	119.58	
		20.00	117.20	10.00	117.40	
		9.98	117.40			
3		25.73	111.00	200.00	111.00	Waste
		200.00	126.47	180.00	126.66	
		150.00	126.23	100.00	122.50	
		80.00	120.90	50.00	118.58	
		20.00	116.20	11.00	116.00	
4		25.73	111.00	11.00	116.00	Engineered CLAY (MMG derived)
		10.13	117.04	10.07	117.12	
		10.00	117.21	10.00	117.12	
		10.00	116.06	10.50	115.65	
		25.00	110.00	200.00	110.00	
		200.00	111.00			
5		25.00	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	116.06	10.00	117.12	
		10.00	117.21	10.00	117.34	
		9.98	117.40	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		0.00	115.44	10.00	116.00	100.00	121.00
		180.00	124.00	200.00	124.00		

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1 (stage 1)

Circular slip surface

Slip surface parameters							
Center :	x =	30.62	[m]	Angles :	α_1 =	-42.39	[°]
	z =	140.31	[m]		α_2 =	57.01	[°]
Radius :	R =	30.15	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)
Combination 1

Sum of active forces : F_a = 852.62 kN/m
Sum of passive forces : F_p = 1821.67 kN/m

Sliding moment : M_a = 25706.37 kNm/m
Resisting moment : M_p = 54923.26 kNm/m
Utilization : 46.8 %

Slope stability ACCEPTABLE
Combination 2

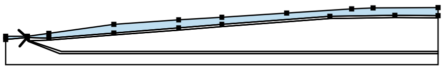
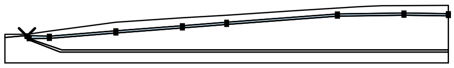
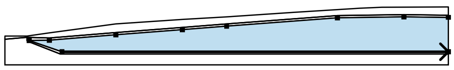
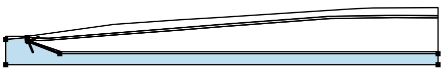
Sum of active forces : F_a = 653.16 kN/m
Sum of passive forces : F_p = 1659.58 kN/m

Sliding moment : M_a = 24826.62 kNm/m
Resisting moment : M_p = 63080.51 kNm/m
Utilization : 39.4 %

Slope stability ACCEPTABLE
Optimized slip surface for : Combination 1

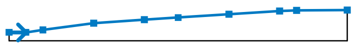
Input data (Stage of construction 2)

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		9.83	117.39	9.98	117.40	Restoration Soil (above capping)
		10.00	117.40	20.00	117.20	
		50.00	119.58	80.00	121.90	
		100.00	123.50	150.00	127.23	
		180.00	127.66	200.00	127.47	
		200.00	131.22	170.00	131.03	
		160.00	130.60	130.00	128.72	
		100.00	126.74	80.00	125.54	
		50.00	123.49	20.00	119.42	
		10.00	118.00	0.00	118.00	
		0.00	116.53			
2		10.00	117.34	10.00	117.21	Capping (Clay)
		10.07	117.12	10.13	117.04	
		11.00	116.00	20.00	116.20	
		50.00	118.58	80.00	120.90	
		100.00	122.50	150.00	126.23	
		180.00	126.66	200.00	126.47	
		200.00	127.47	180.00	127.66	
		150.00	127.23	100.00	123.50	
		80.00	121.90	50.00	119.58	
		20.00	117.20	10.00	117.40	
		9.98	117.40			
3		25.73	111.00	200.00	111.00	Waste
		200.00	126.47	180.00	126.66	
		150.00	126.23	100.00	122.50	
		80.00	120.90	50.00	118.58	
		20.00	116.20	11.00	116.00	
4		25.73	111.00	11.00	116.00	Engineered CLAY (MMG derived)
		10.13	117.04	10.07	117.12	
		10.00	117.21	10.00	117.12	
		10.00	116.06	10.50	115.65	
		25.00	110.00	200.00	110.00	
		200.00	111.00			
5		25.00	110.00	10.50	115.65	In situ Weathered MMG (CLAY)
		10.00	116.06	10.00	117.12	
		10.00	117.21	10.00	117.34	
		9.98	117.40	9.83	117.39	
		0.00	116.53	0.00	105.00	
		200.00	105.00	200.00	110.00	

Water

Water type : Coefficient Ru

No.	Interface Ru location	Coordinates of interface Ru points [m]						Coeff. Ru
		x	z	x	z	x	z	[–]
1		0.00	118.00	10.00	118.00	20.00	119.42	0.100
		50.00	123.49	80.00	125.54	100.00	126.74	
		130.00	128.72	160.00	130.60	170.00	131.03	
		200.00	131.22					

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 2)

Analysis 1 (stage 2)

Circular slip surface

Slip surface parameters								
Center :	x =	10.63	[m]	Angles :	α_1 =	-1.33	[°]
	z =	155.01	[m]		α_2 =	17.09	[°]
Radius :	R =	37.02	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 52.94 kN/m
Sum of passive forces : F_p = 130.57 kN/m

Sliding moment : M_a = 849.75 kNm/m
Resisting moment : M_p = 2095.59 kNm/m
Utilization : 40.5 %

Slope stability ACCEPTABLE

Combination 2

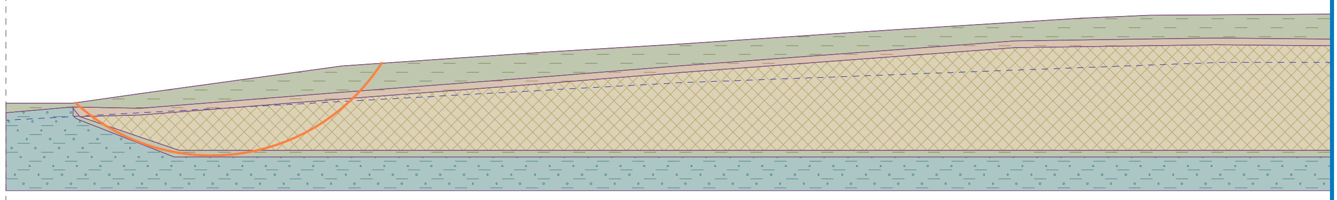
Sum of active forces : F_a = 9.36 kN/m
Sum of passive forces : F_p = 19.83 kN/m

Sliding moment : M_a = 346.55 kNm/m
Resisting moment : M_p = 734.11 kNm/m
Utilization : 47.2 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

Name :	Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 852.62 kN/m
Sum of passive forces : F_p = 1821.67 kN/m

Sliding moment : M_a = 25706.37 kNm/m
Resisting moment : M_p = 54923.26 kNm/m
Utilization : 46.8 %

Slope stability ACCEPTABLE

Combination 2

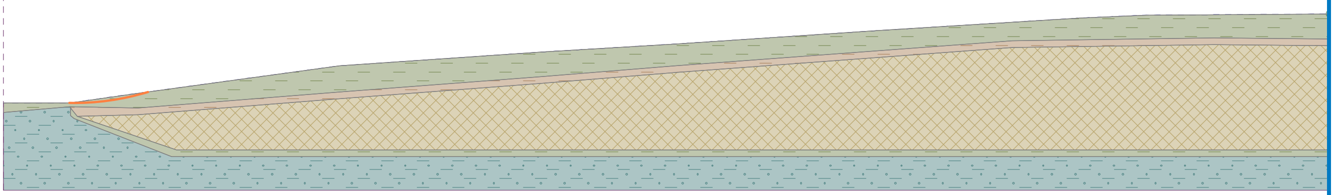
Sum of active forces : F_a = 653.16 kN/m
Sum of passive forces : F_p = 1659.58 kN/m

Sliding moment : M_a = 24826.62 kNm/m
Resisting moment : M_p = 63080.51 kNm/m
Utilization : 39.4 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 1

Name :	Stage - analysis : 2 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : F_a = 52.94 kN/m
Sum of passive forces : F_p = 130.57 kN/m

Sliding moment : M_a = 849.75 kNm/m
Resisting moment : M_p = 2095.59 kNm/m
Utilization : 40.5 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : F_a = 9.36 kN/m
Sum of passive forces : F_p = 19.83 kN/m

Sliding moment : M_a = 346.55 kNm/m
Resisting moment : M_p = 734.11 kNm/m
Utilization : 47.2 %

Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

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