Stability Assessment of Proposed Stabilisation Buttress

Saxon Pit

East Midlands Waste Management

Prepared by:

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Revision Record

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0	25 August 2023	SL	TD	TD
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4	22 July 2024			

Basis of Report

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Tables in Text

Drawings and Appendices

1.0 Introduction

East Midlands Waste Management Limited (EMWM) has retained SLR Consulting Limited (SLR) to prepare a geotechnical stability assessment of the proposed stabilisation buttress of the southern slope at Saxon Pit, Whittlesey. This report describes the manner in which the assessment has been carried out and presents the overall findings of the work.

1.1 Proposed Development

SLR understands that there have been ongoing stability issues with the Site, resulting in an over-steepened slope along the southern boundary. Historically, SLR designed and monitored the existing buttress that is being constructed to stabilise the northern and north-eastern slopes on Site. It is now required for the southern slope to be stabilised due to multiple shallow failures being recorded along the slope adjacent to the railway.

It is proposed to construct a buttress to increase the overall stability of the slope. Due to the presence of third-party land to the south, the crest of the existing slope cannot be cut back to reduce the gradient. A buttress is therefore considered to be the only effective solution.

It is understood that no cut/fill exercise will be carried out on site and therefore all material will need to be imported for the construction of the buttress.

1.1.1 Slope Monitoring

Visual inspections indicate that the failures have been shallow and contained within the uppermost soils of the slope, typically within the weathered zone of the Oxford Clay and sections containing peat. However, to determine whether the ground deformation is also occurring at greater depth, two (2No.) tube-way inclinometers were installed to a maximum depth of 20.0m bgl during the 2017 ground investigation[1]. This allowed for subsequent monitoring to be carried out to establish rates of ground movement and position of ground deformation.

Since 2017, inclinometer monitoring has been carried out at a minimum frequency of once a month at the two locations at the crest of the southern slope. The monitoring results show maximum displacements of up to 59mm in the upper 2.0m of soils.

Drawing 001 contains historical slope sections showing a comparison between a survey carried out c. 2004 and the 2019 topographic survey. This further confirms that the crest of the southern slope is migrating.

[1] SLR Consulting Ltd. ‘Factual Ground Investigation Report – Saxon Pit, Whittlesey.’ December 2017. Ref: 403.07764.00001.

2.0 Ground Model

2.1 Geotechnical Laboratory Testing

It is understood that the buttress will be constructed using imported inert fill. Geotechnical laboratory testing has been conducted on typical material anticipated to be used within the filling operations . A summary of the results is presented below.

2.1.1 2017 Results

Undisturbed, disturbed and bulk disturbed samples collected during the 2017 ground investigation[1] were sent to a UKAS accredited laboratory for the following analyses:

- Moisture content;
- Atterberg limits;
- Particle size distribution; and,
- Quick undrained triaxial.

The results indicated undrained shear strengths ranging from 59kPa to 140kPa for the weathered and in-situ Oxford Clay.

2.2 Groundwater

2No. groundwater monitoring wells were installed during the 2017 ground investigation. BH03 is in close proximity to the slope and has been previously monitored on an approximate monthly basis. Monitoring indicated water levels of between 3.22 and 3.53m bgl (metres below ground level), contained within the weathered Oxford Clay. It is understood that BH03 has been lost and has not been monitored since May 2021 (approximate). The groundwater levels used for this assessment have been estimated using previous data so may not be representative of the current conditions.

3.0 Stability Assessment

SLR understands that that the buttress-forming material will be placed to an earthworks specification and will following existing placement methods.

3.1 Justification for Modelling Approach and Software

The analytical method used in this assessment involves the use of limit equilibrium stability analyses for the derivation of factors of safety for the stabilisation buttress. The limit equilibrium analyses have been undertaken using the package SLOPE/W Version 11.2 (Geo-Slope International). The Bishop[2] slip-circle and Morgenstern-Price[3] non-circular methods of analysis have been used.

3.2 Justification of Geotechnical Parameters Selected for Analysis

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component in Table 3-1. The geotechnical parameters for limit equilibrium analysis include the shear strength and unit

[2] Bishop, A.W., (1965), 'The use of the slip-circle in the stability analysis of slopes' Geotechnique.

[3] Morgenstern, N.R and Price, V.E. (1965), 'The analysis of stability of general slip surfaces' Geotechnique.

weight of each material within the model. The parameters detailed below are taken from the existing laboratory testing results and previous SLR experience, where laboratory data is not available. The analysis has assumed that the pore water pressures within the fill will be represented by a porewater pressure ratio (r_u) of 0.2 to allow for pore fluid pressures to build up within the buttress.

Table 3-1: Geotechnical Design Parameters

Material	Bulk Unit Weight, γ (kN/m³)	Undrained Shear Strength (kPa)	Drained Parameters	
			Effective cohesion, c' (kPa)	Angle of shearing resistance, ϕ' (°)
Made Ground	18.00	-	0	28
Peat	18.00	-	6	25
Weathered Oxford Clay	17.95	45	-	-
Oxford Clay	17.95	140	-	-
Inert Fill	18.00	-	2 (peak) 0 (residual)	29 (peak) 23 (residual)

3.3 Selection of Appropriate Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action, which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses).

Prior to determining appropriate factors of safety for the model, it is necessary to identify key 'receptors' and evaluate the consequences in the event of a failure (relating to both stability and integrity). Consideration of the following receptors is required:

- groundwater;
- property - relating to site infrastructure, third party property; and
- human beings (i.e. direct risk).

A factor of safety (FOS) of 1.3 is considered appropriate for this scenario for the peak levels and a FOS of 1.0 is considered appropriate for the residual levels, however the slope analysed is in proximity to Network Rail assets and therefore a higher FOS may be required.

3.4 Topographic Survey

A topographic survey[4] was provided by EMWM for the purpose of this assessment, Drawing 001 contains the drawing and the cross-sections produced to derive the slope profile. The slope forming the majority of the buttress along the south-western edge of the site has been modelled, as well as the slope adjacent to the existing site buildings. The geometries shall be used throughout the analyses and are solely based on the information provided.

[4] HD Surveying. September 2019. 'Topographic Survey – Saxon Pit.' Drawing Ref: 0903_001_T-0.

It should be noted that the proposed design[5] at the position of Section C indicates the geometry of the western edge of the buttress to be 1V:3H (full slope height), whilst the geometry of the buttress directly adjacent to the existing site buildings is to be modelled at 1V:1.6H and 1V:1.7H. The width of the crest of the buttress is proposed at 5.0m.

3.5 Limit Equilibrium Analyses

Limit Equilibrium analyses have been carried out on the bund in the submerged peak (short-term) and residual (long term) condition. The parameters used within the submerged condition have been taken from the laboratory testing, as well as site observations and experience on site.

3.5.1 1V:3H Proposed Buttress Slopes

Analyses were carried out on the current proposed design for the majority of the buttress, with a slope gradient of 1V:3H, using anticipated parameters for the inert fill at peak and residual values.

Table 3-2 presents the results which indicate an acceptable FOS, outputs are included within Appendix A.

Table 3-2: Proposed Buttress Profile Results for Slope 1V:3H

Material	Gradient	Factor of Safety	Comments
Imported fill	1V:3H	1.61 (Peak)	Acceptable
		1.10 (Residual)	

3.5.2 Localised Proposed Buttress Slopes

Subsequent analyses were carried out on the slope adjacent to the existing site buildings. This section of the buttress has been proposed to be steeper than the rest of the buttress, to reduce the lateral extent of the buttress at the toe of the slope to allow the existing buildings to remain in-situ. Table 3-3 presents a summary of the FOS generated for a range of slope geometries, with highlighted cells indicating an acceptable FOS. It can be seen from the results that a geometry of 1V:2.5H is the steepest slope (and therefore minimum material) that produces an acceptable FOS. In this scenario, the buttress extends approximately 59.0m out from the crest (69.0m from the natural slope crest) which will encroach on the footprint of the buildings. Outputs for the 1V:2.5H slope only are presented in Appendix B.

Table 3-3: Summary of FOS for Slope Gradients

Gradient	Inert Fill Peak	Inert Fill Residual
1V:1.6H	0.71	0.48
1V:1.65H	0.75	0.50
1V:1.7H	0.80	0.55
1V:1.75H	0.81	0.58
1V:1.8H	0.91	0.60
1V:1.85H	0.93	0.62

[5] SBRice. January 2018. ‘Saxon Pit – Existing and Proposed Sections.’ Drawing Ref: EMWM.SP-1-4-001.

Gradient	Inert Fill Peak	Inert Fill Residual
1V:1.9H	0.95	0.64
1V:2H	1.26	0.85
1V:2.5H	1.30	1.06
1V:3H	1.61	1.10

3.5.2.1 Recommendation Option

The analyses have shown that in order to achieve an acceptable FOS, the gradient of the slope needs to be at least 1V:2.5H. For the existing site buildings to remain in-situ, it may be possible to install a retaining wall, such as a gabion wall, at the toe. Based on preliminary calculations, any retaining wall would need to be approximately 47.0m from the crest of the buttress, retaining an approximate height of 5.0m along a length of 120m (Drawing 002). Initial stability analyses have been assessed which produce an acceptable FOS, however it should be noted that any retaining wall would need to be considered further at detailed design stage, including stability of the wall itself.

4.0 Recommendations and Conclusions

Based on the results of the stability analyses, an acceptable FOS for the 1V:3H gradient proposed for the majority of the buttress has been determined through the stability assessment.

The assessment demonstrates that an acceptable gradient for the slope adjacent to the existing site buildings is 1V:2.5H. It is anticipated that the toe of the buttress, when formed at this inclination, would need to be retained at an approximate lateral distance of 47.0m from the crest to enable the site buildings to remain in-situ. The retained height at this distance is estimated at 5.0m, extending an approximately 140m laterally. Further consideration of any potential retaining solution is required and would need to go through detailed design, including stability checks of the solution itself.

To ensure ongoing stability of the buttress, a specific earthworks specification will need to be adopted as well as regular topographic surveys and reporting of progress.

An indicative volumetric calculation has been undertaken using the geometries determined from the limit equilibrium stability modelling has estimated approximately 217,000m^3 of imported material will be required to buttress and stabilise the slope in the long term.

Drawing 001 Historical Slope Sections

Stability Assessment of Proposed Stabilisation Buttress

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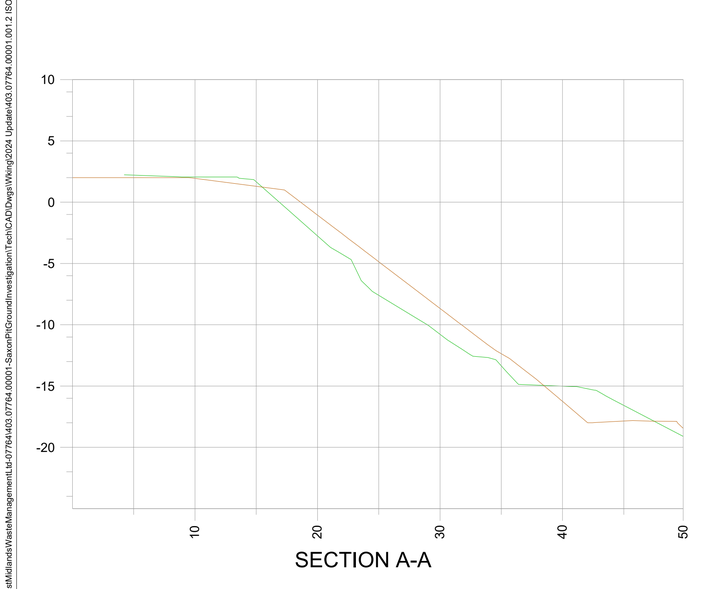
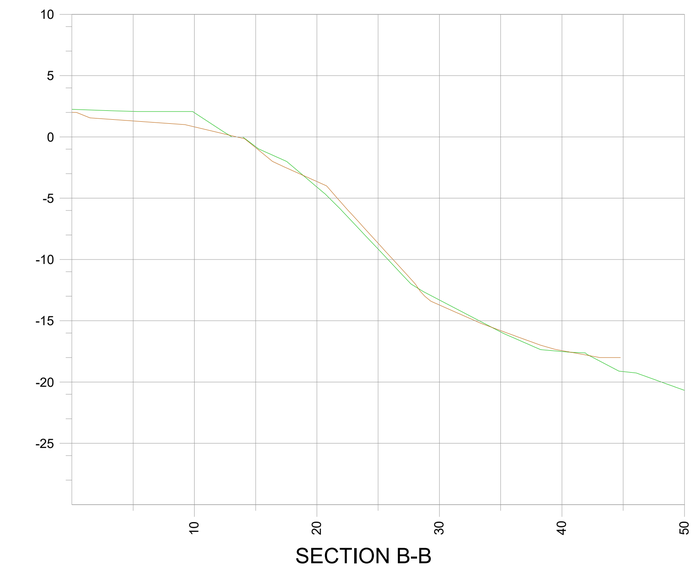


SECTION A-A



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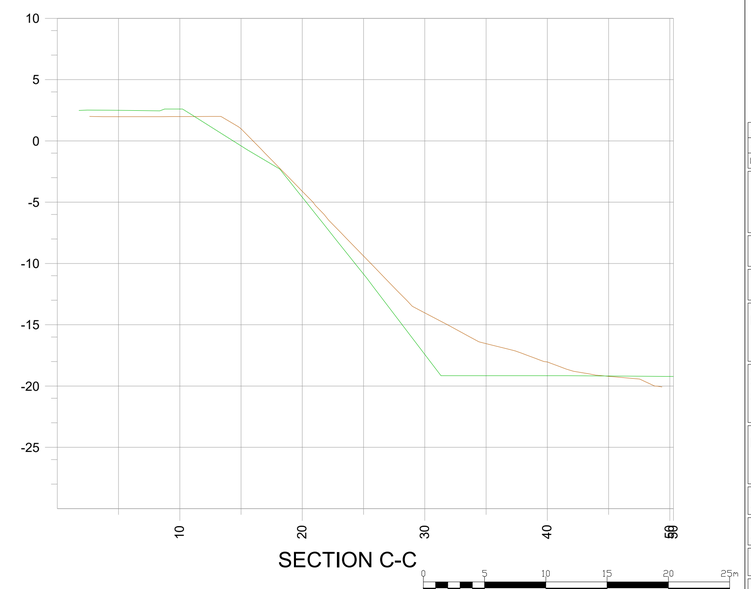

SECTION C-C

Notes:

1.

Legend:

-12.00- EXISTING CONTOURS SURFACE (2019)

Legend Sections:

ORIGINAL SURFACE (2005)

EXISTING SURFACE (12-02-2019)

Rev	Amendments	Date	By	Chk	Auth
2	updated title	09.07.24	AB	T	TD
1	Isopachyte rendering replaced with contours	05.07.24	AB	T	TD

SLR

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Drawing Status & Suitability Code

Client: EAST MIDLANDS WASTE MANAGEMENT

Project: STABILITY ASSESSMENT OF PROPOSED STABILISATION BUTTRESS

Drawing Title: HISTORICAL SLOPE SECTIONS / PROFILES

Scale	SLR Project No.
AS SHOWN @ A1	403.07764.00001

Designed	Drawn	Checked	Authorised
AB	AB	SL	TD
Date 09.23	Date 09.23	Date 09.23	Date 09.23

Drawing Number: 001 Rev: 2

N:\EastMidlandsWasteManagementLtd-07764\403.07764.00001-SaxonPitGroundInvestigation\Tech\CAD\Dwgs\Wking\2024 Update\403.07764.00001.001.2 ISOPACHYTE SECTIONS.dwg 09/07/2024 Alex Betts

Drawing 002 Proposed Buttress and Gabion Wall

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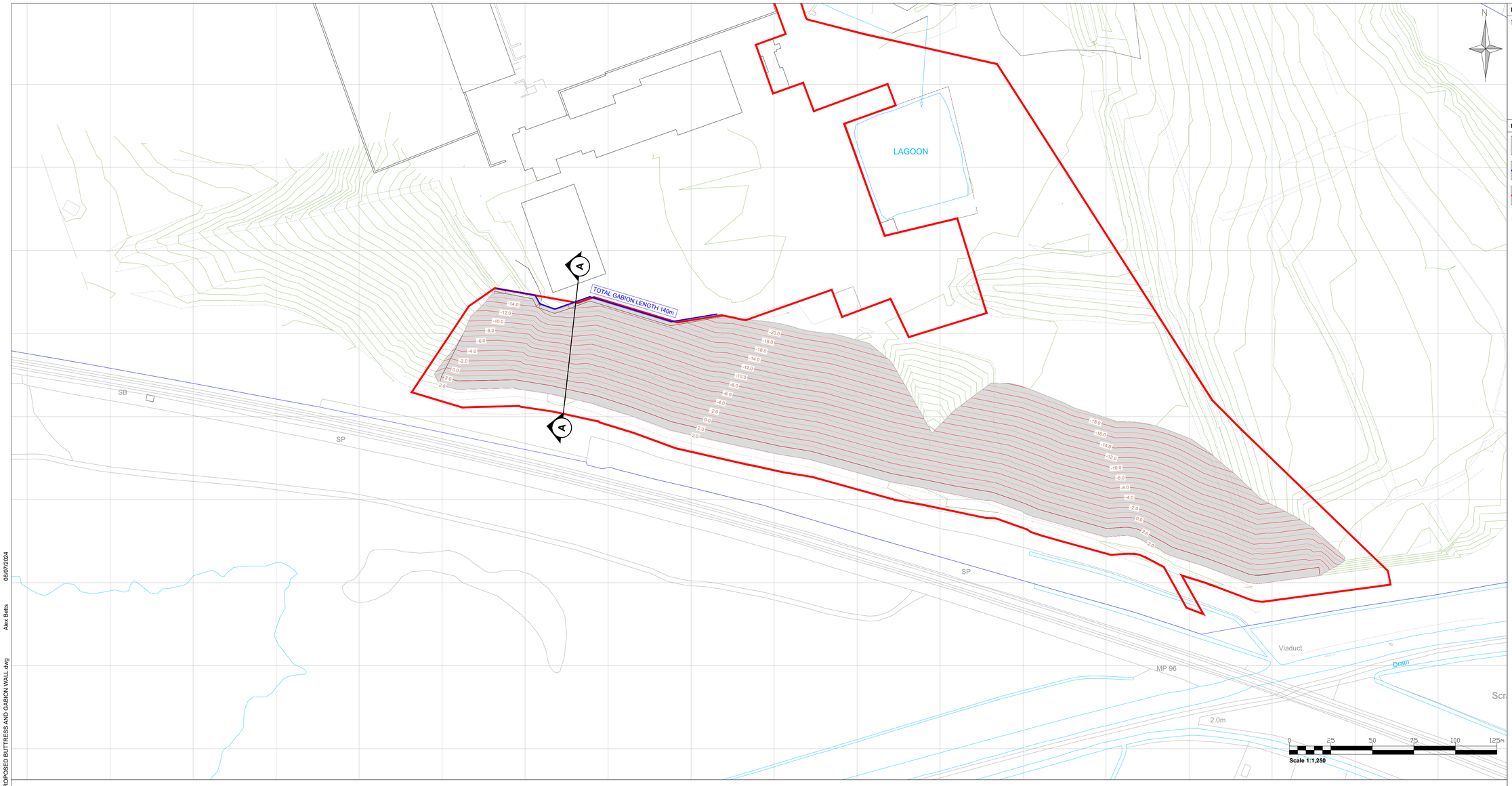

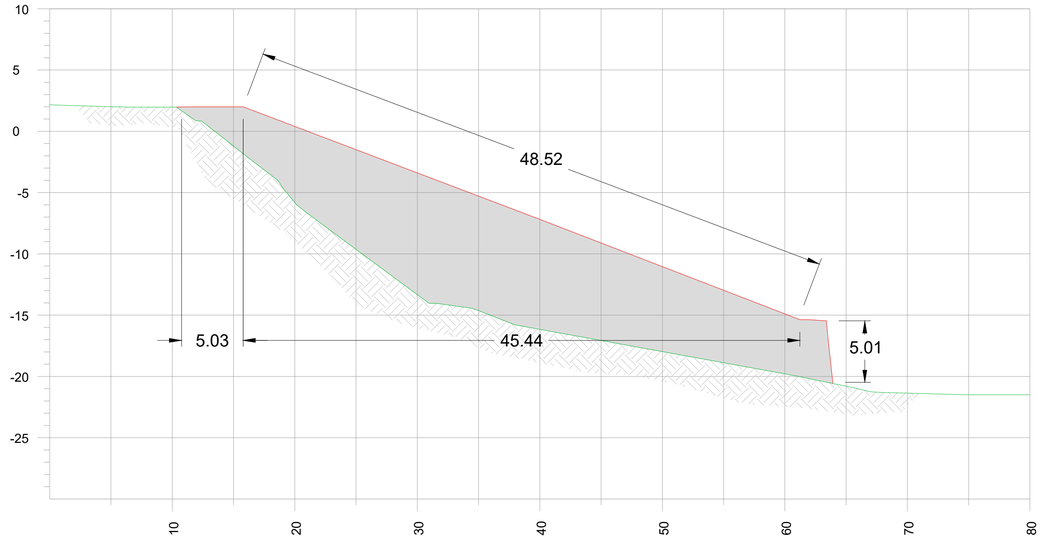

0 5 10 15 20 25m

Scale 1:250

Notes:

1.

Legend:

- SURVEY 12-02-19
- BUTTRESS AND GABIONS
- PROPOSED PHASE 2 BUTTRESS MAY 2024

Rev	Amendments	Date	By	Chk	Auth
4	red line, legend, section updated	05/07/24	AB	TD	TD
3	Base map, legend amended	18/06/24	AB	TD	TD
2	design amended	05/06/24	AB	TD	TD
1		29/05/24	AB	TD	TD

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Drawing Status & Suitability Code

Client: EAST MIDLANDS WASTE MANAGEMENT

Project: STABILITY ASSESSMENT OF PROPOSED STABILISATION BUTTRESS

Drawing Title: PROPOSED BUTTRESS AND GABION WALL

Scale	SLR Project No.
AS SHOWN @ A1	403.07764.00001

Designed	Drawn	Checked	Authorised
AB	AB	SL	TD
Date 09.23	Date 09.23	Date 09.23	Date 09.23

Drawing Number: **002** Rev. **4**

08/07/2024 Alex Betts

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Appendix A 1V:3H Slope Stability Assessment Outputs

Stability Assessment of Proposed Stabilisation Buttress

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Appendix A

Figure A-1: Fill, Peak Parameters

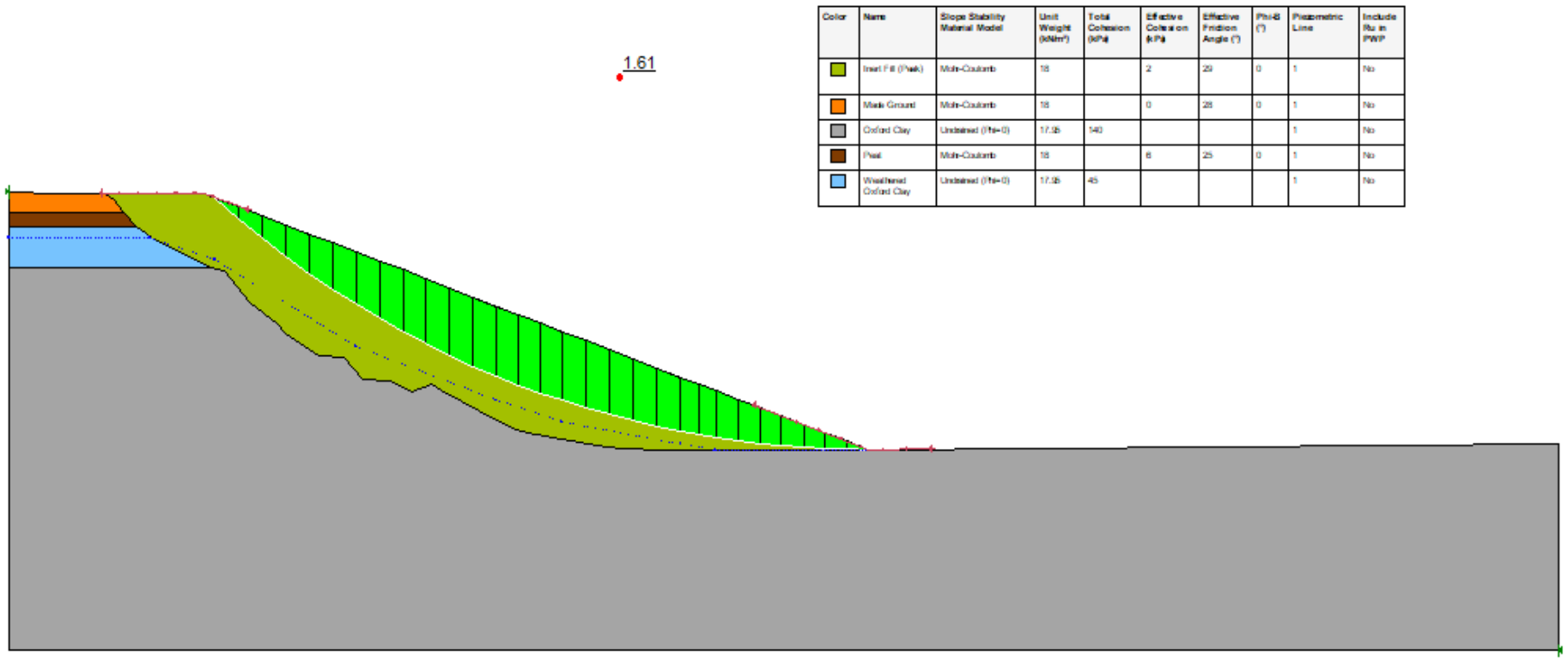
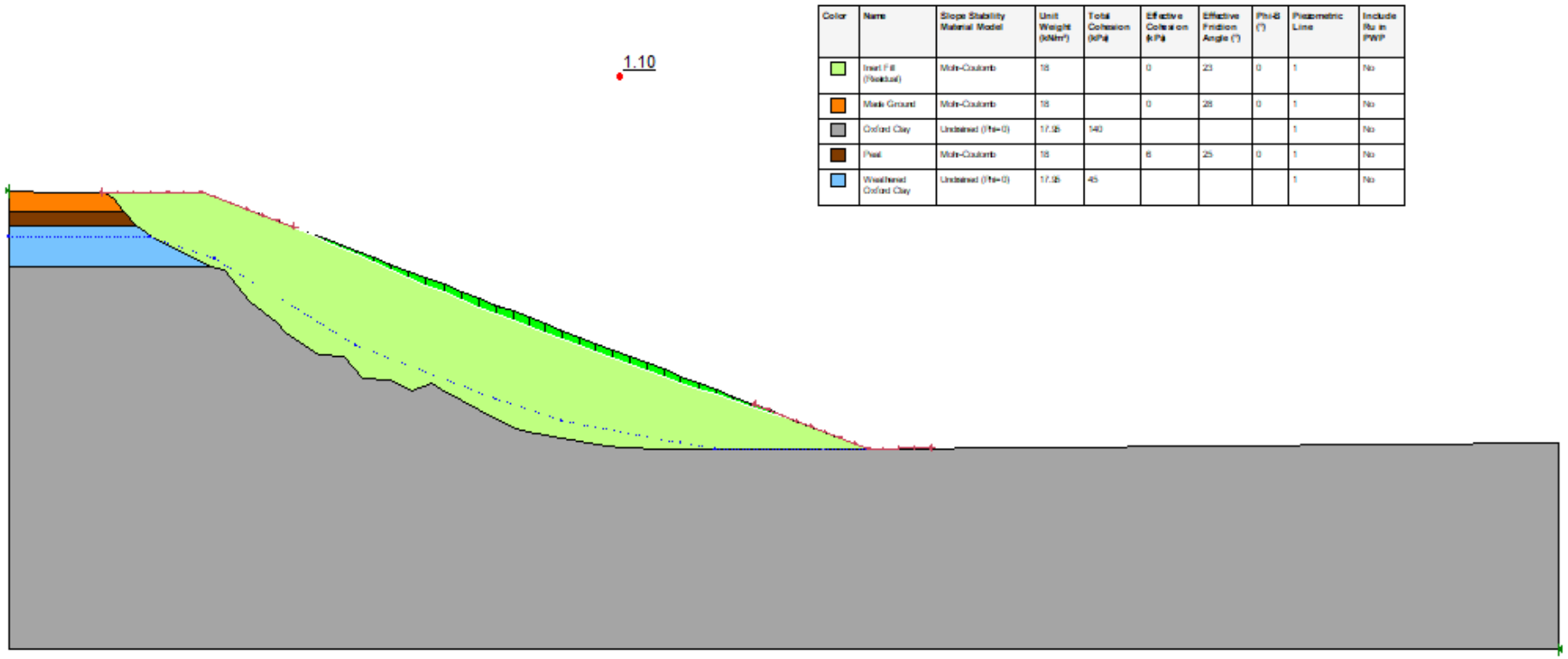


Figure A-2: Fill, Residual Parameters



Appendix B Localised Slope Stability Assessment Outputs

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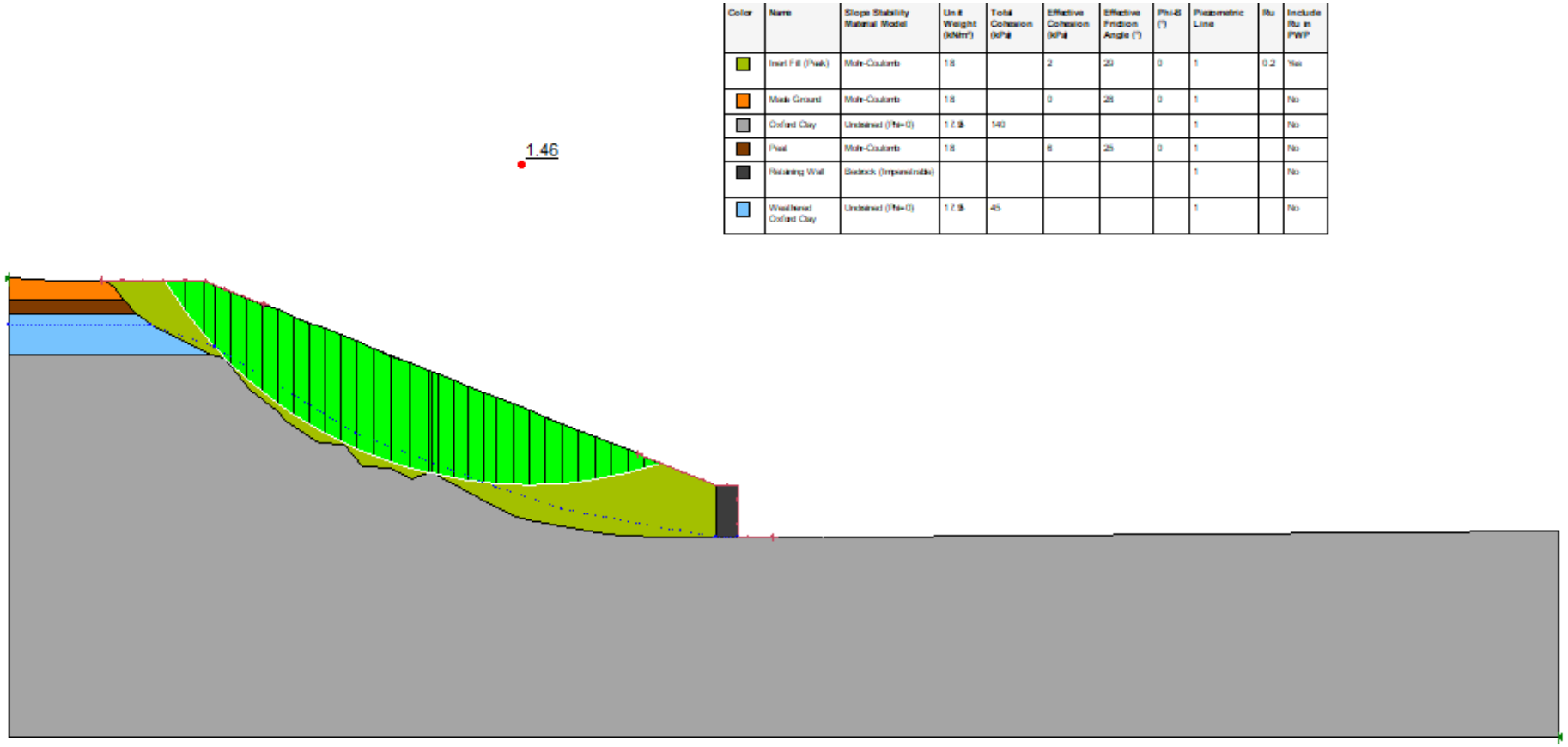
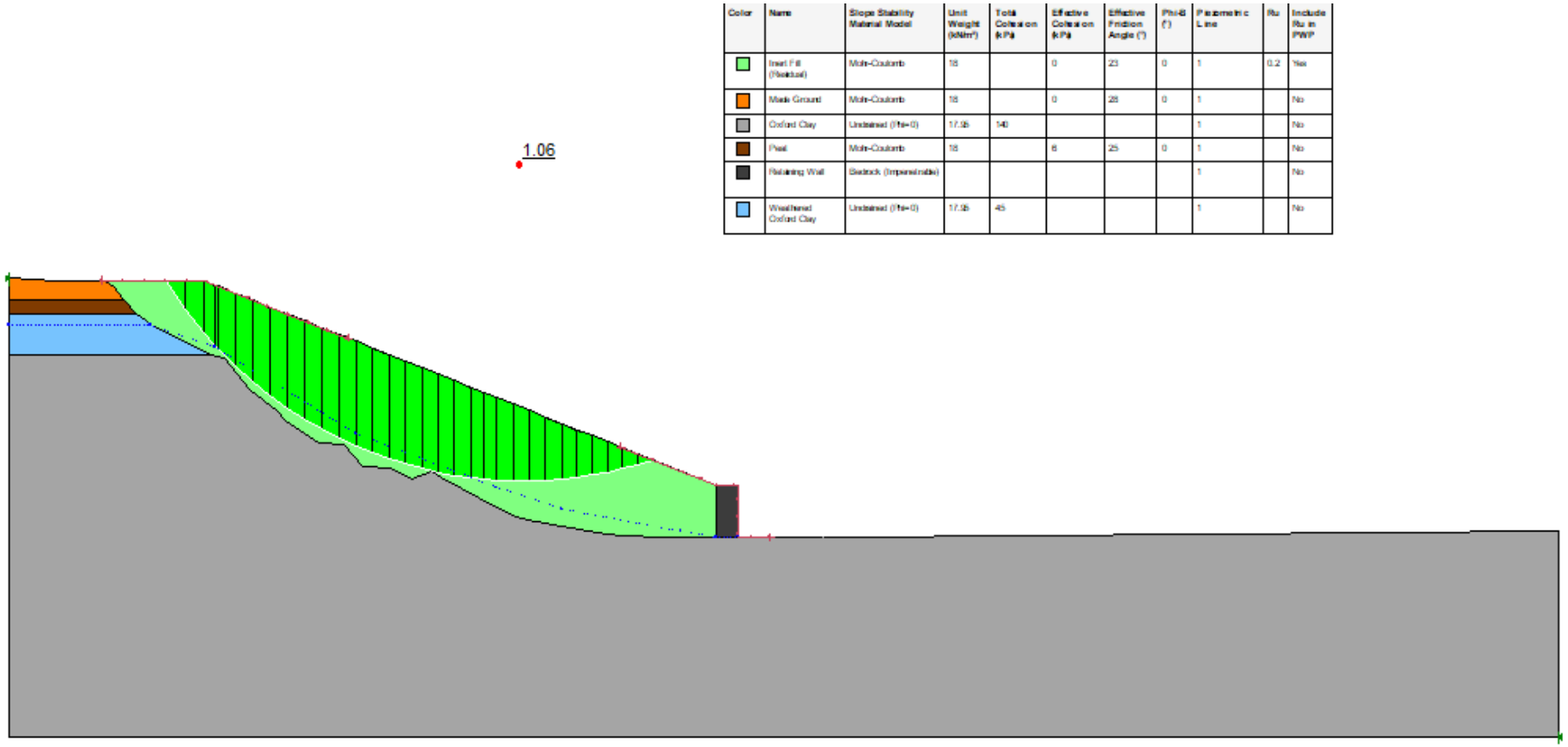
Appendix B

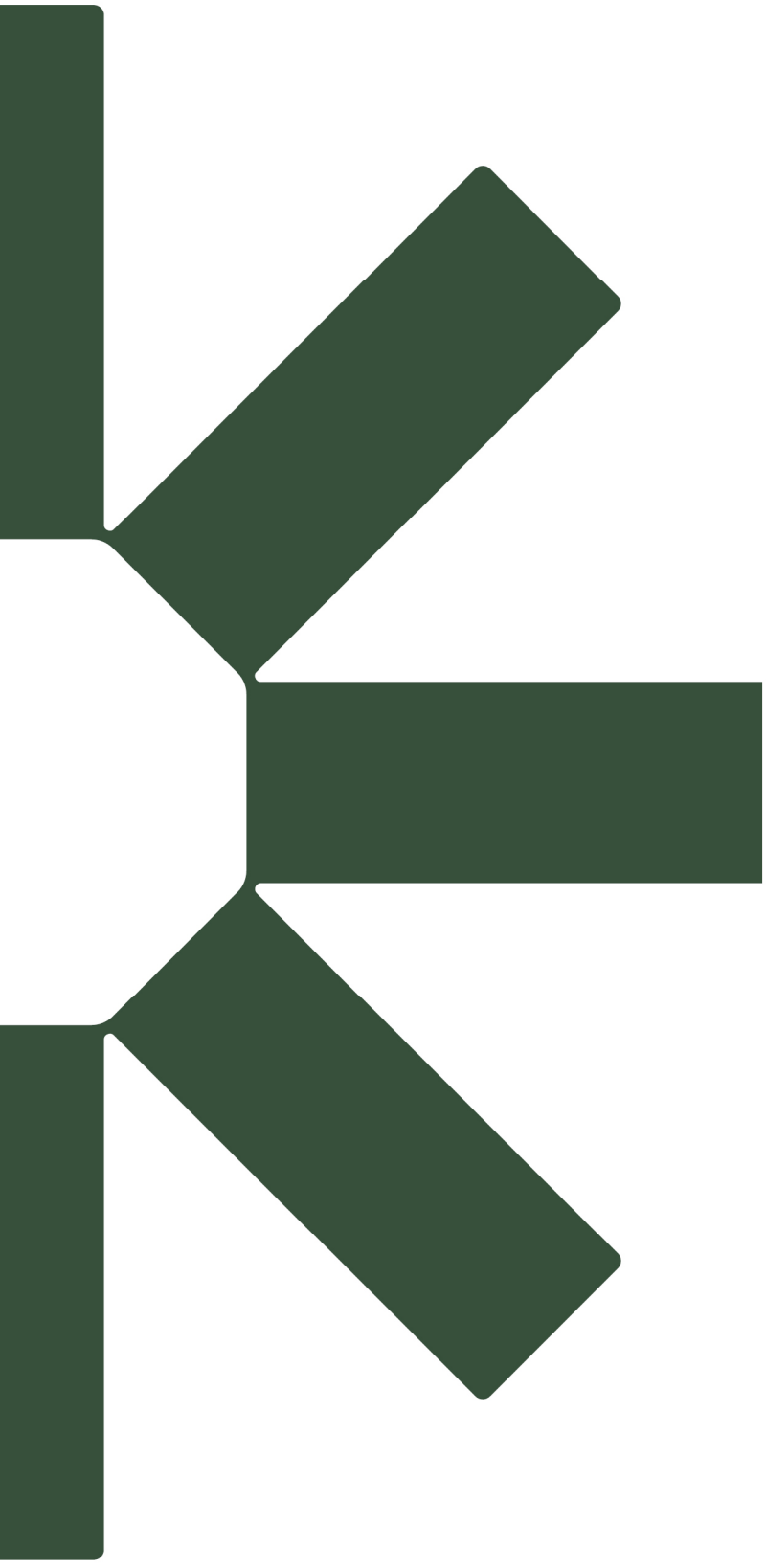
Figure B-1: Fill, Peak Parameters, Retained Toe



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Line	Ru	Include Ru in PWP
	Inert Fill (Peak)	Mohr-Coulomb	18		2	29	0	1	0.2	Yes
	Made Ground	Mohr-Coulomb	18		0	28	0	1		No
	Oxford Clay	Undrained (Phi=0)	17.5	140				1		No
	Peat	Mohr-Coulomb	18		6	25	0	1		No
	Retaining Wall	Bedrock (Impenetrable)						1		No
	Weathered Oxford Clay	Undrained (Phi=0)	17.5	45				1		No

Figure B-2: Fill, Residual Parameters, Retained Toe





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