Retford Circular Economy Project Environmental Statement Addendum – Volume 3 Technical Appendices

Technical Appendix 9.5: RCEP PFA Lagoons – Bund Stability Analysis

January 2024

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RCEP PFA Lagoons

Bund Stability Analysis

Lound Hive Ltd

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Making Sustainability Happen

Revision Record

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Basis of Report

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1.0 Introduction

1.1 Instruction

SLR Consulting Limited (SLR) have been appointed by Lound Hive Limited (LHL) to undertake a stability assessment of the existing embankments at the Pulverised Fuel Ash (PFA) lagoons located to the north of Retford, DN22 8SB (the Site).

LHL has proposed to extract, process and export the PFA from the former ash disposal lagoons – the Amended Proposed Development. As part of the planning application to the Local Authority, Nottinghamshire County Council (NCC), a Flood Risk Assessment (FRA) was prepared by ERM.

In response to the planning application, the Environment Agency (EA) has requested that the FRA assesses the stability of the retained embankments in the event of flooding to demonstrate that they are structurally safe. Subsequently, this report details the stability assessments of the existing embankments onsite prior to, during and post flooding assuming a reasonable worst-case groundwater elevation, and conservative estimates of the geotechnical properties.

The following sections provide details of the assessment and subsequent conclusions.

1.2 Topographic Setting & Amended Proposed Development

The proposed area within the Site for extraction of PFA and subsequent restoration ('Area A') comprises predominantly pastureland. The Site comprises an area of topographically elevated land ('High Rise'), formed by tipped PFA retained by engineered sandstone bunds, and the remaining c. 1/3rd of lower ground ('Low Rise') in the northeast of the Site. The PFA was piped in slurry form into previously worked sand and gravel quarries. The topographic elevations around the Site lie around 8-10mAOD, and it is assumed that the ground levels prior to the original quarrying were similar to the surrounding areas. The High Rise has been built up 8-10m above the surrounding area, whereas the Low Rise is c.1-2m higher than the surrounding area. Drawing 017A & 017B illustrate the layout of the sandstone bunds in plan and cross section respectively.

The topographic data used in this assessment and all modelling work relating to site design and engineering comprises a combination of the DEFRA LiDAR 1m resolution DTM data and a site-specific GPS survey commissioned by the LHL.

The design of the Amended Proposed Development is such that there is no change to the present landform beyond the application boundary and, in areas that have the potential to interact with floodwater, the lower section of the bunds is left fully intact above the 1 in 100 year + 30% CC simulated flood level (with an allowance of 300mm freeboard). Drawing 017C shows the modelled level difference between the preexisting and proposed post extraction and restoration ground levels.

2.0 Stability Assessment

2.1 Conceptual Stability Site Model

The conceptual stability site model has been developed from information obtained from a ground investigation undertaken by SLR in June 2021[1]. The purpose of the investigation was to quantify the extent and volume of the emplaced PFA within the Site.

[1] SLR Consulting Ltd (2021) 210625_416.11943.00001 Lound PFA GI Report. Prepared for Lound Hive Ltd

The stability analyses are carried out on the existing embankments which will be retained, at an elevation above the predicted 1 in 100 year + 30% climate change peak flood level at two locations, shown in Plate 7 of the FRA, based on the flood extents predicted by the latest EA flood model.

The ground investigation comprised boreholes and trial pits which identified the PFA comprising soft to firm slightly sandy silt. This was underlain by the clearly defined underlying bedrock comprising red sandstone of the Chester Formation, part of the Sherwood Sandstone Group. As recorded on the British Geological Survey (BGS) records[2], the in-situ geology that overlies the sandstone, is the River Terrace Deposits comprising sand and gravel. Environment Agency (EA) documentation and anecdotal evidence from the landowner suggested sandstone bunds had been constructed across the Site to increase the capacity of the PFA lagoons above the original ground level. This was confirmed in the 2021 ground investigation which identified the bunds comprising Chester Formation, often blended with River Terrace Deposits.

Following discussions with ERM (the project's environmental consultant); a series of cross sections were generated, as shown in Appendix A. Sections B and D have been used in the stability analysis, where the crest of the embankment and PFA sits at 11.2m and 17.3m AOD. Flood levels have been assumed to reach a maximum of 9.60m AOD in both of the sections analysed.

The boreholes were monitored during the ground investigation and recorded groundwater levels across the Site at depths of between 4.93m and 11.87m above ordnance datum (AOD). Two borehole locations did not encounter groundwater. The groundwater levels from the boreholes have been applied in the stability models for the two sections; 8.85m in BH/21/06 for Section D, and 7.81m from BH/21/26 for Section B. Due to the permeability of the underlying strata, and the surface water levels surrounding the Site, it has been assumed that the groundwater level within the PFA backfill is in continuity with the surface water level around the perimeter of the Site.

Following extraction of the PFA, the slopes will be buttressed with Site-won sandstone; therefore, the stability of the extraction slopes have been screened out for the stability analyses.

2.2 Data Summary

The following data are required as input for the analyses undertaken for this Stability Risk Assessment

- Material unit weight; and,
- Drained and undrained shear strength of soils and waste.

The geotechnical parameters have been estimated for the borehole logs, any publicly available information and literature, and from relevant experience from within SLR in the same or similar materials.

2.3 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 by limit equilibrium slope stability analyses, which are the only type of analyses required for the current study.

[2] BGS GeoIndex Onshore: https://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 09/06/2023.

Prior to determining appropriate factors of safety for the various components of 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
- Human beings (i.e. direct risk)
- Ecological receptors

The Site comprises a former permitted landfill and as a result the methodology adopted for this Stability Risk Assessment generally follows the principles outlined in the Environment Agency R&D Technical Report P-385, volumes TR1 and TR2[3] (from here on referred to as the guidance). Where additional analytical techniques have been used, these are described within the text.

The factor of safety adopted is related to the consequences of a failure. The guidance makes allowance for use of either a global factor of safety approach (the traditional method) or partial factoring of input parameters to produce an Over Design Factor (ODF). This assessment applies the traditional method and a global factor of safety of 1.3 is considered appropriate when using conservative parameters.

2.4 Justification for Modelling Approach and Software

In order to perform a comprehensive stability assessment, the components of the development, must be considered not only individually but also in conjunction with one another where relevant. Any analytical techniques adopted for such an assessment should adequately represent all the considered scenarios, i.e. the different phases of the development, including temporary works. The methodology and the software should also achieve the desired output parameters for the assessment, e.g. determination of limit equilibrium factor of safety.

The analytical methods used in this stability assessment include limit equilibrium stability analyses for the derivation of factors of safety for the proposed excavation slope.

The limit equilibrium analyses have been undertaken using the package Slope/W 2021.3 version 11.2.2.23310 (Geo-Slope International). The Morgenstern-Price[4] non-circular methods of analysis have been used.

2.5 Justification of Geotechnical Parameters Selected for Analysis

The parameters used in the analysis have been:

- Adapted from similar work undertaken by SLR.
- Inferred from site specific data or other relevant published data.

It should be noted that the geotechnical parameters for limit equilibrium analysis include the shear strength and unit weight of each material within the model. Shear strength has been

[3] Environment Agency R&D Technical Report P1-385/ TR1 and TR2, 'Stability of Landfill Liner Systems', March 2003.

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

defined using total and effective shear strength parameters of cohesion, (c′), and the angle of shearing resistance, (ø′).

Conservative in-situ material parameters have been based on site observations and from previous experience. The values applied are considered to be at the lower bound of what would typically be expected for the materials present. The adopted parameters are presented in Table 2-1.

Table 2-1: Geotechnical Design Parameters

Material	Unit Weight, γ (kN/m^3)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (º)	Undrained Shear Strength (kPa)	Typical Description
Pulverised Fuel Ash (PFA)	16	-	-	45	Soft to firm slightly sandy silt.
Retaining Bund	21	1	35	-	Reworked Sherwood Sandstone and River Terrace Deposits
River Terrace Deposits	30	1	35	-	Sand and Gravel
Sherwood Sandstone	21	-	-	500	Silty medium Sandstone.

2.6 Analyses

Two analyses have been carried out for the Site. One analysis has been conducted for the slope along Section B located in the northeast of the Site; a second analysis has been conducted along Section D in the southwest of the site. Both analyses considered three situations:

- pre-flood with a piezometric line at the existing level;
- during flooding with the proposed and anticipated flood level; and
- post flooding.

In order to reflect a worst case, critical condition, the post flood scenario assumes groundwater remains high within the sandstone derived perimeter bunds. This results in effectively a “rapid Drawdown” scenario where elevated pore pressures within the bund material are acting to destabilise the soil mass.

An “entry and exit” analysis method has been used in all the analyses. A circular failure is considered across a number of predefined entry and exit points across the slope profile. Once a critical failure condition is identified and further optimisation process is undertaken. The slip surface is divided into a number of increments and the endpoints of each increment adjusted to evaluate the potential for a lower factor of safety. This process is repeated until the change in factor of safety falls below a specified tolerance. This process often results in a non-circular failure mode, more consistent with a natural failure process.

2.6.1 Section B Stability Analysis

Table 2-2 presents a summary of the results for Section B. All three scenarios, pre, during and post flooding, resulted in an acceptable factor of safety (>1.3). The analyses are presented in figures 1, 2, and 3 within Appendix B.

A reduced factor of safety is recorded in the post flood scenario, portrayed in Figure 03, due to the unconfined elevated groundwater within the perimeter bunds. However, the factor of safety remains above the acceptable minimum.

Table 2-2: Summary of Stability Analysis for Section B

Figure	Factor of Safety	Comments
01	2.186	Pre- Flood Level. Acceptable FOS >1.3
02	1.978	During Flooding. Acceptable FOS >1.3
03	1.380	Post-Flood Level. Acceptable FOS >1.3

2.6.2 Section D Stability Analysis

Table 2-3 presents a summary of the results for Section D. All three scenarios, pre, during and post flooding, resulted in an acceptable factor of safety (>1.3). The analyses are presented in figures 1, 2, and 3 within Appendix B.

Similar to Section B, a reduced factor of safety is observed in the post flood scenario, portrayed in Figure 06. This is again due to the unconfined elevated groundwater within the perimeter bunds. The factor of safety remains above the acceptable minimum and demonstrates flooding will not compromise the stability of the confining bunds.

Table 2-3: Summary of Stability Analysis for Section D

Figure	Factor of Safety	Comments
04	2.146	Pre- Flood Level. Acceptable FOS >1.3
05	2.124	During Flooding. Acceptable FOS >1.3
06	1.471	Post-Flood Level. Acceptable FOS >1.3

3.0 Conclusions

A stability assessment has been carried out to determine if the embankments will remain structurally safe following flooding which has been modelled with a 1 in 100 year + 30% for climate change (+300mm freeboard) scenario. Two sections have been modelled, Section B and D to consider their existing state pre-flooding, with the proposed flood level, and post flooding. Analyses showed that the slopes are currently stable with a factor of safety of 2.186 and 2.146. The values decrease slightly to 1.978 and 2.124 during flooding, and to 1.380 and 1.471 post flooding. This shows that in a reasonable worst-case scenario, following rapid drawdown from the anticipated flood level, would lower the factor of safety of the slopes. However, all scenarios recorded an acceptable factor of safety (>1.3) and will therefore, remain stable and structurally safe.

It should be noted that excavation works will be carried out in accordance with the Quarries Regulations 1999. These provide a framework for the design, operation, management and inspection of quarry operations in the UK. The Regulations require the operator to appoint competent persons to manage the quarry safely and a Geotechnical Specialist is appointed to undertake Geotechnical Assessments at appropriate intervals.

These measures will ensure the findings of this Assessment are confirmed during the operation of the Site and any deviations from these conclusions can be addressed throughout the life of the Site.

Appendix A Site Drawings

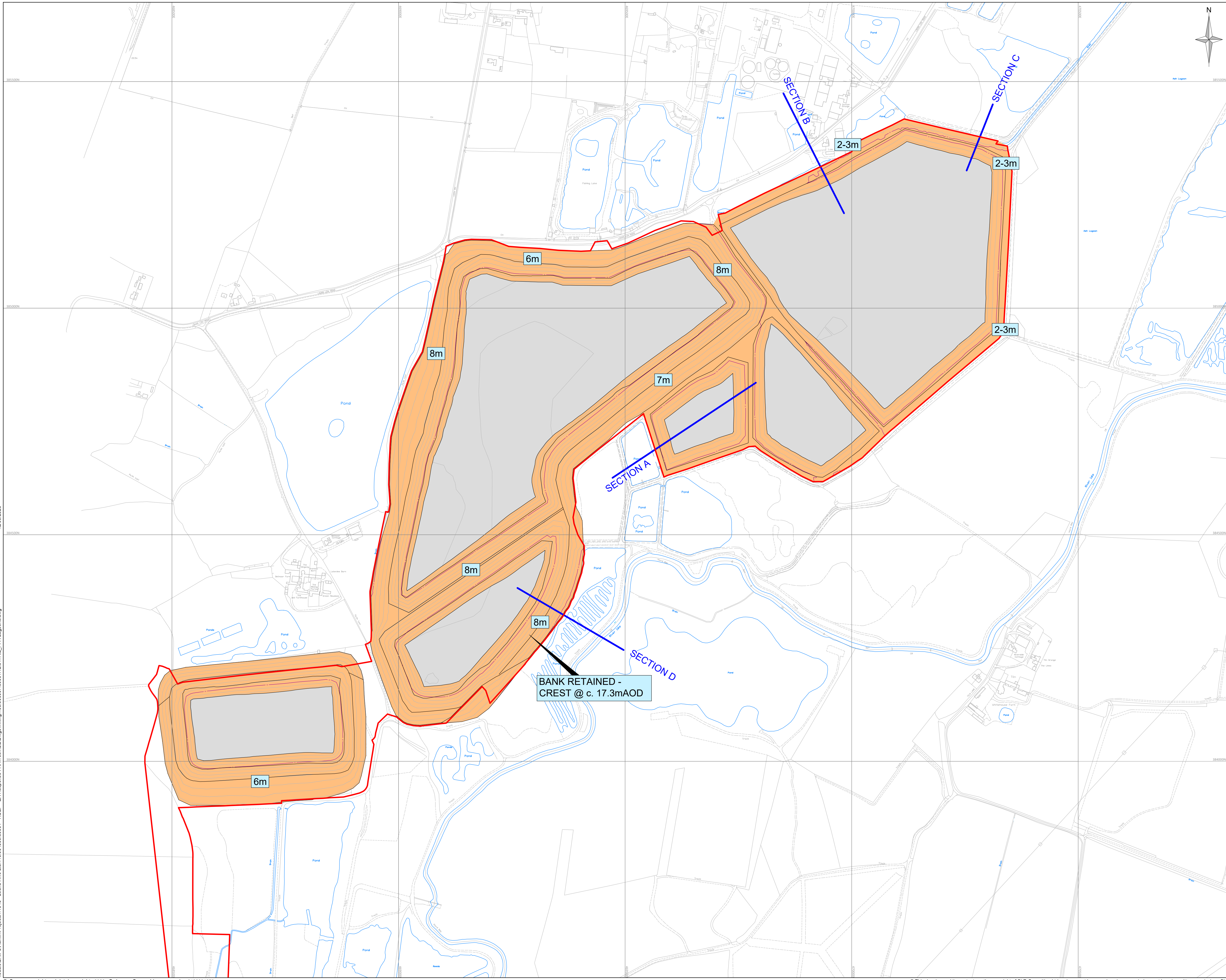
RCEP PFA Lagoons

Bund Stability Analysis

Lound Hive Ltd

SLR Project No.: 416.064860.00001

23 November 2023



Notes:

1.

Legend:

- TOPOGRAPHY CONTOURS - DERIVED FROM EA LIDAR
- APPLICATION SITE
- SANDSTONE BUND PROFILE
- PFA EXTRACTION AREA
- 11.2m APPROXIMATE HEIGHT OF BUND TO SURROUNDING GROUND LEVEL

Rev	Amendments	Date	By	Chk	Auth

SLR

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Drawing Status & Suitability Code

Client
HIVE AGGREGATES LTD

Project
RETFORD CIRCULAR ECONOMY PROJECT

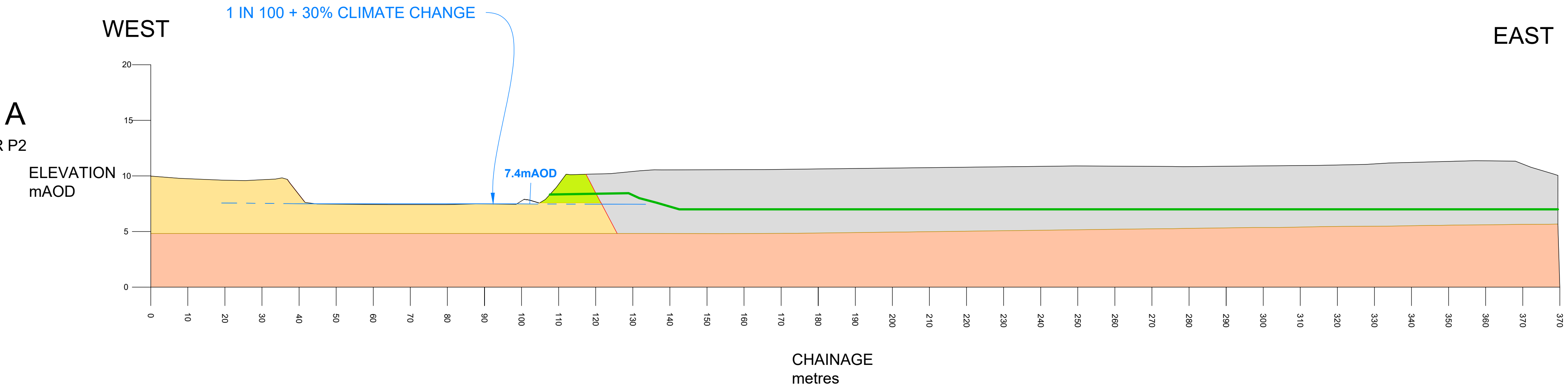
Drawing Title
SITE PLAN
SANDSTONE BUND PROFILES

Scale	SLR Project No.
1:7,500 @ A3	416.064377.00001

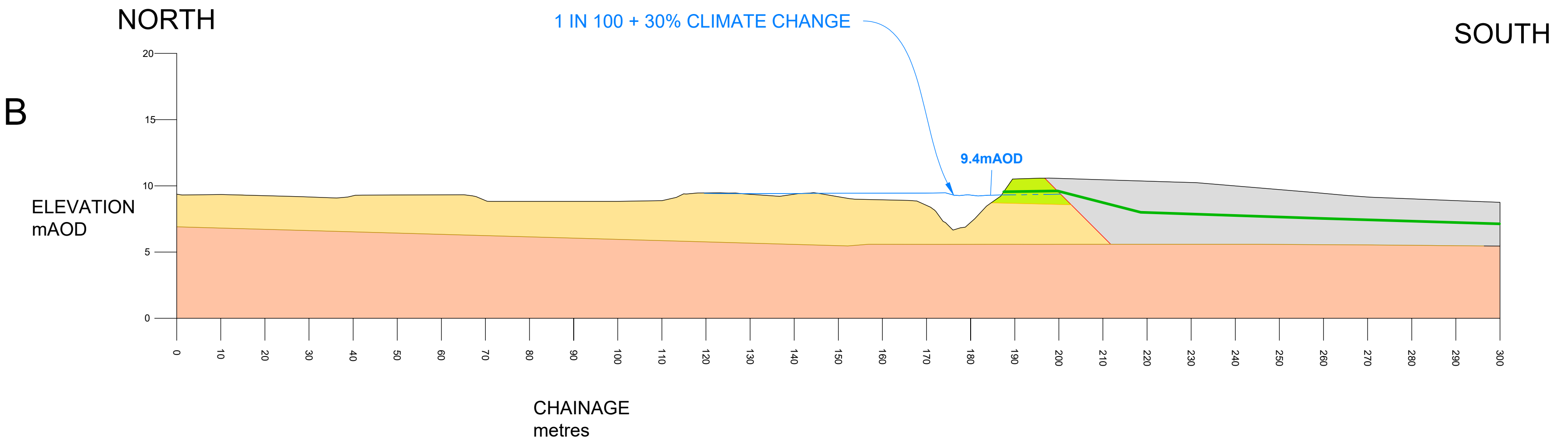
Designed	Drawn	Checked	Authorised
BM	BM	SH	SH
Date: JULY 23	Date: JULY 23	Date: JULY 23	Date: JULY 23

Drawing Number: **017A** Rev.

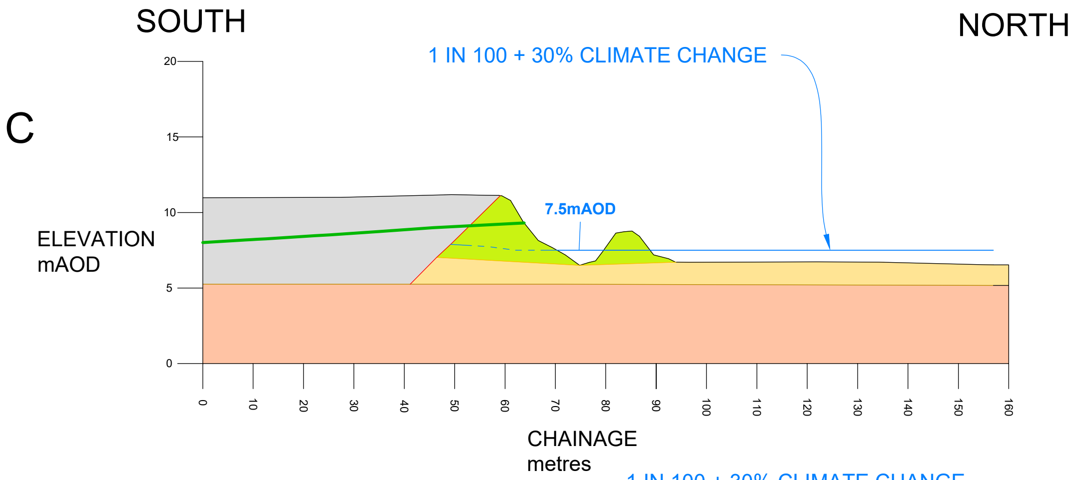
SECTION A
Through LR P1 & LR P2



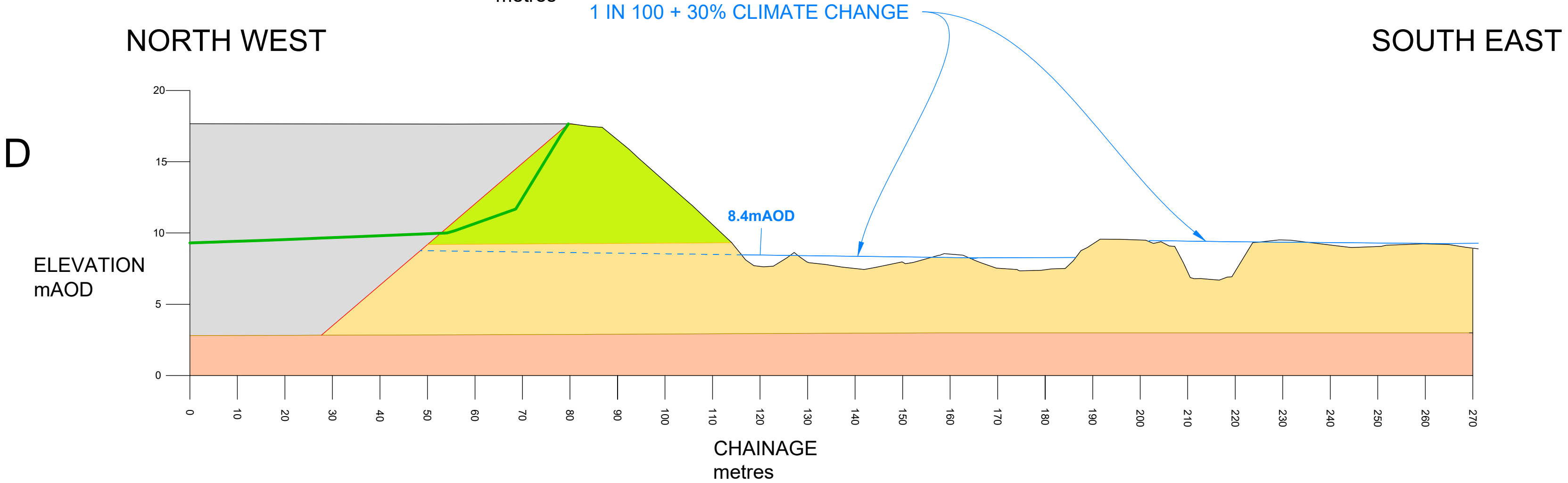
SECTION B
Through LR P5



SECTION C
Through LR P5



SECTION D
Through HR P2



3 X VERTICAL EXAGGERATION

N

Notes:

1.

Legend:

- EXTRACTION PROFILE
- PROPOSED RESTORATION LANDFORM
- TOPOGRAPHY (EA LIDAR DERIVED)
- 9.4mAOD — 1 IN 100 + 30% CLIMATE CHANGE FLOOD MODEL SURFACE - DERIVED SPOT LEVELS ADJACENT TO SITE BOUNDARY
- IN-SITU SHERWOOD SANDSTONE
- PFA
- IN-SITU RIVER TERRACE SAND AND GRAVEL
- RETAINING BUND (ESTIMATED PROFILE)

Rev	Amendments	Date	By	Chk	Auth

SLR

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Drawing Status & Suitability Code

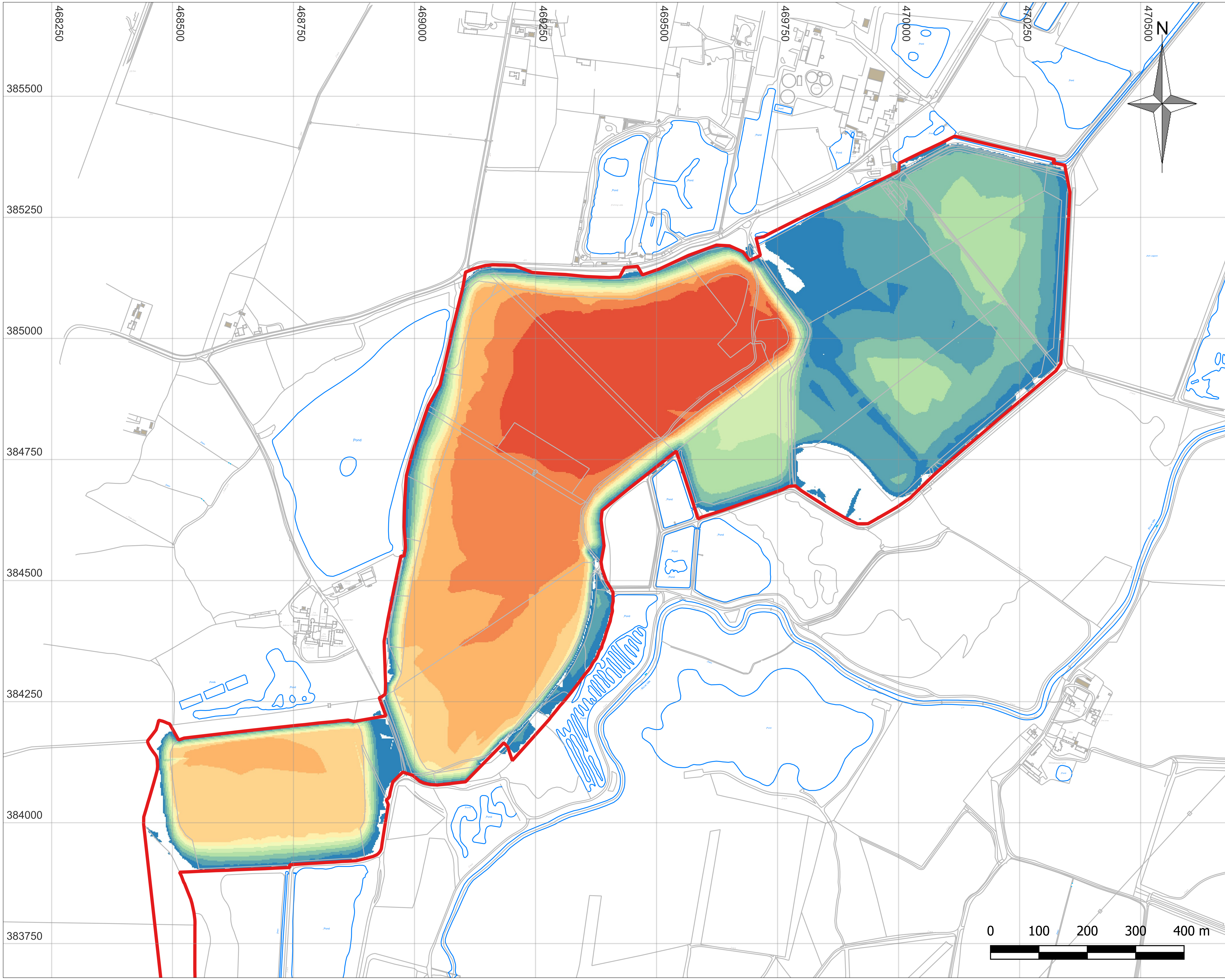
Client: HIVE AGGREGATES LTD

Project: RETFORD CIRCULAR ECONOMY PROJECT

Drawing Title: CROSS SECTIONS PROPOSED RESTORATION

Scale	SLR Project No.		
1:1,500 (3x VA) @ A3	416.064377.00001		
Designed: BM	Drawn: BM	Checked: SH	Authorised: SH
Date: JULY 23	Date: JULY 23	Date: JULY 23	Date: JULY 23
Drawing Number: 017B	Rev: 0		

12/09/2023



Notes:

1.

Legend:

APPLICATION BOUNDARY

LEVEL DIFFERENCE BETWEEN CURRENT TOPOGRAPHY AND PROPOSED RESTORATION LANDFORM

METRES

- >= -10.0 m
- -10.0 - -9.0 m
- -9.0 - -8.0 m
- -8.0 - -7.0 m
- -7.0 - -6.0 m
- -6.0 - -5.0 m
- -5.0 - -4.0 m
- -4.0 - -3.0 m
- -3.0 - -2.0 m
- -2.0 - -1.0 m
- -1.0 - -0.2 m
- NO CHANGE

Rev	Amendments	Date	By	Chk	Auth

SLR

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Client
HIVE AGGREGATES LTD

Project
RETFORD CIRCULAR ECONOMY PROJECT

Drawing Title
LANDFORM CHANGE

Scale 1:7,000 @A3		SLR Project No. 416.064377.00001	
Designed SH	Drawn SH	Checked BM	Authorised BM
Date AUG 2023	Date AUG 2023	Date AUG 2023	Date AUG 2023
Drawing Number 017C			Rev. 0

Appendix B Stability Analyses

RCEP PFA Lagoons

Bund Stability Analysis

Lound Hive Ltd

SLR Project No.: 416.064860.00001

23 November 2023

Stability Analysis Results

Photo 1: Section B Pre-Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1

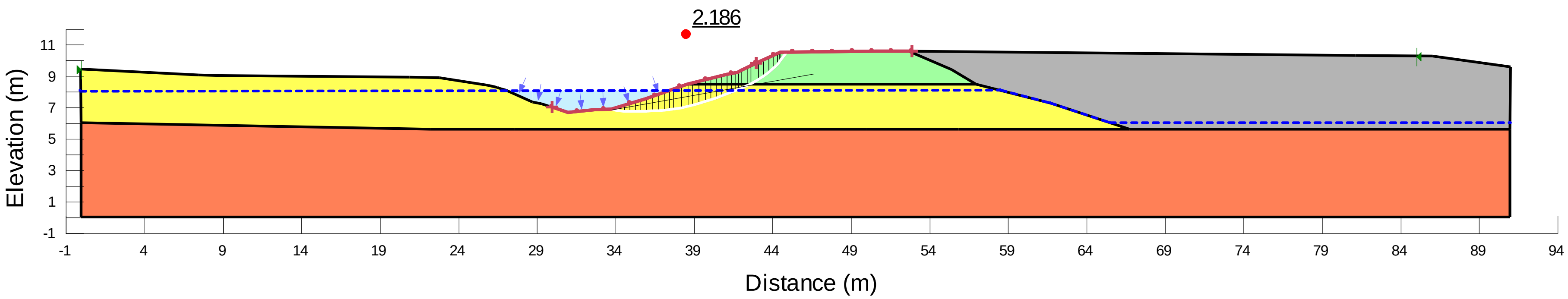


Photo 2: Section B Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1

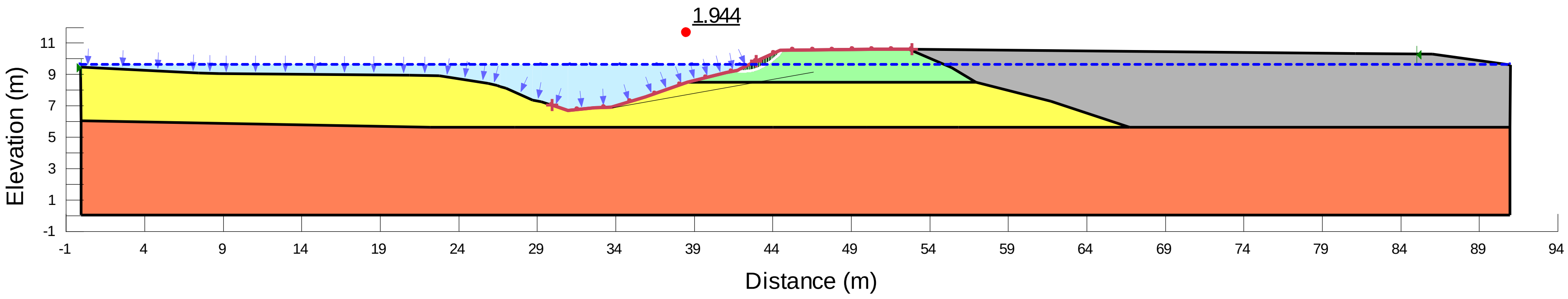


Photo 3: Section B Post-Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1

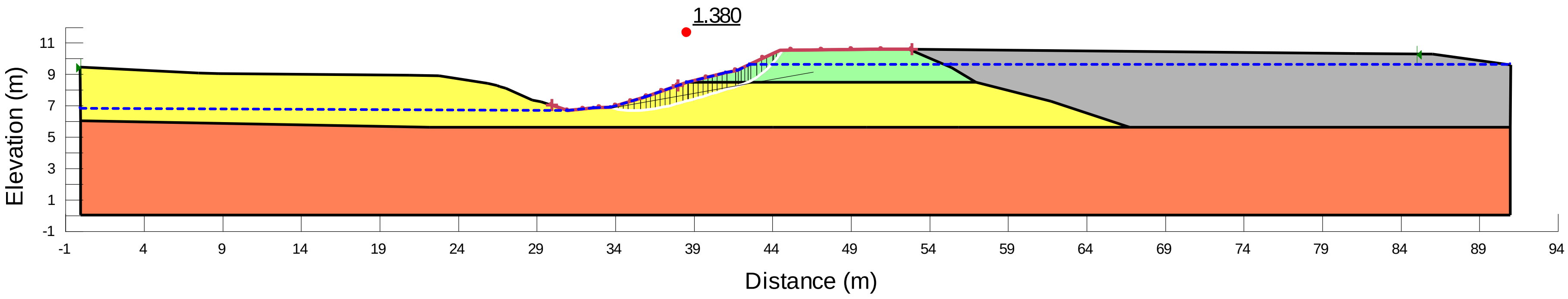


Photo 4: Section D Pre-Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1

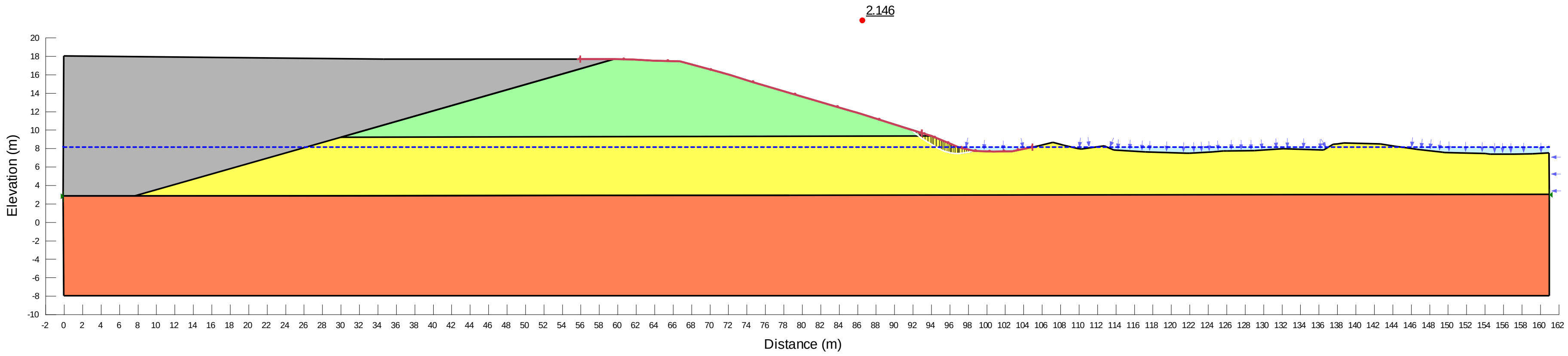


Photo 5: Section D Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1

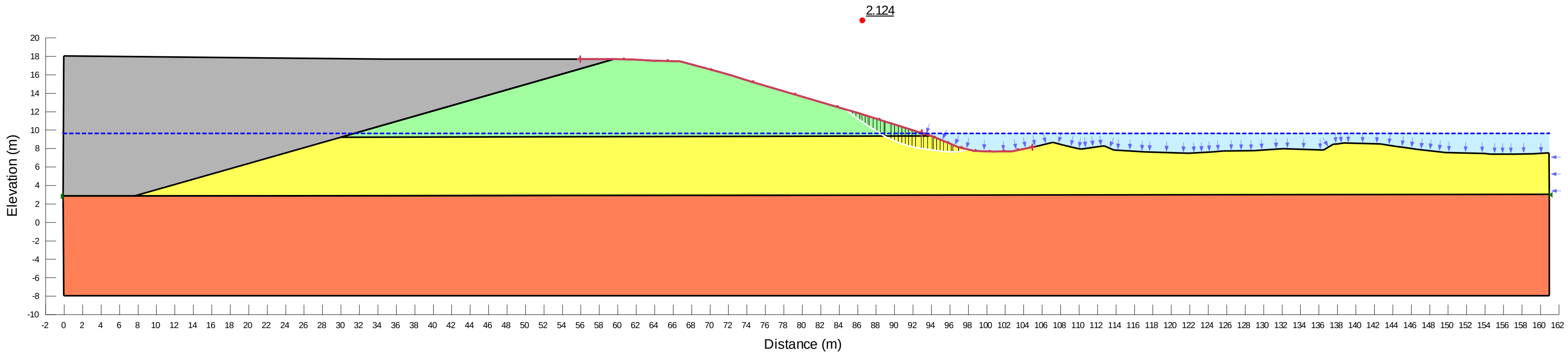
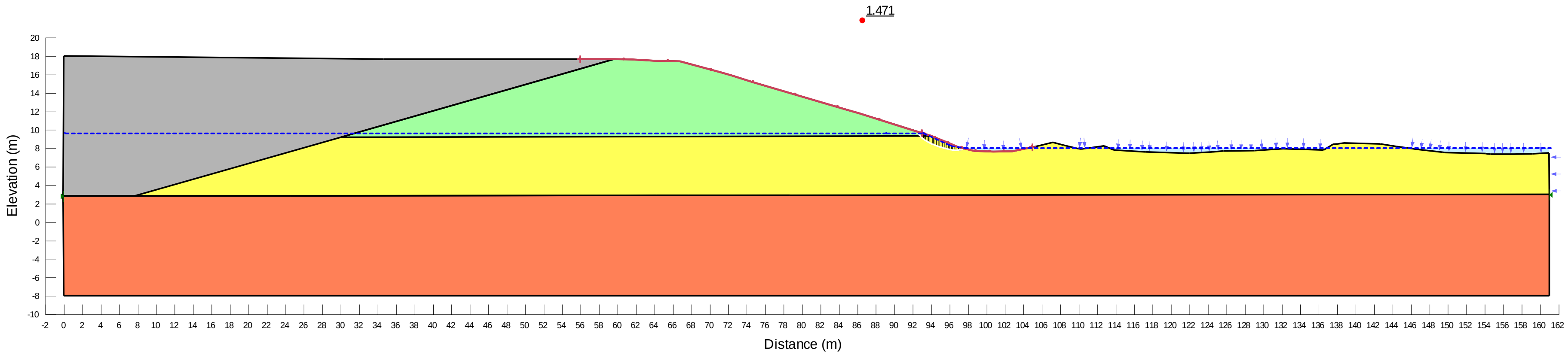


Photo 6: Section D Post-Flood Level

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Total Cohesion (kPa)	Piezometric Line
	PFA	Undrained (Phi=0)	16				45	1
	Retaining Bund	Mohr-Coulomb	21	1	35	0		1
	River Terrace Deposits - Sand and Gravel	Mohr-Coulomb	20	1	35	0		1
	Sherwood Sandstone	Undrained (Phi=0)	21				500	1



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