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BAM Nuttall Ltd.

Victoria North HIF Infrastructure and Enabling Works

Geotechnical Design Report

Reference: VNIF-ARP-ZZ-YYY-RP-CG-0010

P02 | 3rd November 2022



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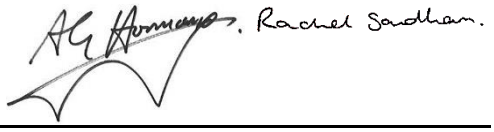
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Ove Arup & Partners Limited
6th Floor 3 Piccadilly Place
Manchester
M1 3BN
United Kingdom
arup.com

ARUP

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		Name	Jonathan Tyrer Maciej Kolodziejski	Richard Deakin	Andrew Hornung
		Signature			
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			Prepared by	**Checked by**	**Approved by**
		Name	Jonathan Tyrer	A Hornung	R Sandham
		Signature			
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1. Introduction

1.1 General

Ove Arup and Partners Ltd (Arup) has been commissioned by BAM Nuttall Ltd. (BAM) to provide design services relating to infrastructure works for the proposed redevelopment of the Victoria North site. Planit-IE has been subcontracted to Arup provide landscape architect services. The site is divided into a number of main areas as shown in Figure 1 and summarised below.



Figure 1: Site plan showing the main site areas

- Redbank Plateau – which is largely proposed for residential development. The exception to this is in the north of the plateau where there is a proposed non-residential plot (RB05b, a proposed school development).
- Redbank Terrace - the plateau is separated from the Redbank Terrace by a slope, with the terrace area lying several metres below the plateau. Currently, the terrace area is occupied by a number of commercial activities. Redbank Terrace is also planned for residential development with areas of public realm.
- St. Catherine's Wood - from the plateau, wooded slopes (St Catherine's Wood and the P&P slope area) extend down to the banks of the River Irk. St. Catherine's Wood is to be developed for public open space.

Redbank Plateau lies at circa. 40mOD to 43mOD and was constructed by filling during the late 1800s to create railway sidings. From the plateau, St Catherine's Wood extends down to circa. 30mOD along the

banks of the river. At the northern boundary of St. Catherine's Wood, slopes also extend down towards the adjacent P&P site beyond the site boundary. Redbank Viaduct area is generally flat, circa 31mOD, and is separated from the plateau by a slope some 9m high.

A new access road is proposed to enter the development through plot RB12b (Figure 1) and onto Redbank Plateau. To link the various parts of the site, development proposals include the provision of landscaped areas, with footpaths through Redbank Terrace and St. Catherine's Wood.

1.2 Purpose and scope of this report

The purpose of this geotechnical design report (GDR) is to communicate the assumptions, basis of design and key outcomes from the geotechnical design of particular elements of the scheme, prepared in accordance with BS EN 1997-1:2004+A1:2013.

The focus of this report is the stability of steep slopes previously identified to present risks to the scheme, and new retaining walls associated with the access road and landscaping footpaths through the scheme.

The geotechnical assets that are addressed by this GDR are as follows:

- Asset 1: Plateau Road embankment.
- Asset 2: Creamline RC retaining wall, to support asset 1.
- Assets 3 and 4: gabion retaining walls, in Redbank Terrace and St Catherine's Wood (Supplier designed elements) The design of the gabion structures is preliminary at this stage until supplier design has been confirmed.
- Asset 5: Plateau slope, down to the River Irk (slope regrade area on Figure 1)
- Asset 6: P&P slope, down to the River Irk.

The report does not cover any general earthworks, highway or drainage geotechnical aspects. The future development of individual plots is not considered in this report, in particular no assessment is made of building foundations and the potential impact of new structures on slope stability.

Two phases of GI were undertaken at the site in 2019 and 2021, leading to the production of a Geotechnical Interpretative Report (GIR) issued in January 2022 (VNIF-ARP-ZZ-YYY-RP-CG-0009). The GIR provides a description of the site and the main HIF Infrastructure works, together with a preliminary description of ground conditions.

During the development of the GIR, a Preliminary Geotechnical Design Report (GDR) was produced to address a preliminary slope stability assessment (ref VNIF-ARP-ZZ-YYY-RP-CG-0006) related to Assets 5 and 6 in RIBA stage 3. The outcome of this assessment is reassessed in RIBA stage 4 (current stage when this report was produced) using the 2022 GI data to conclude whether the outcomes are still valid.

Additional ground investigation has been undertaken at the site during 2022. **Sketch 03** presents exploratory hole locations for all phases of GI that have been undertaken at the site, including the 2022 GI.

Programme constraints have meant that the design has been developed in advance of the latest ground investigation report being available. Preliminary field records, draft logs and preliminary lab data from this phase of investigation have therefore been used by the design team.

1.3 Use of this report and limitations

This report has been prepared by Arup on behalf of BAM Nuttall Ltd. in connection with the Victoria North HIF development. It takes into account our Client's particular instructions and requirements and is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party in relation to it.

All reasonable skill, care and diligence have been exercised within the timescale available and in accordance with the technical requirements of the brief.

Version P01 of this report was developed using preliminary and/or partially complete ground investigation data. The current version (P02) addresses comments received from third parties and incorporates additional data obtained during the 2022 ground investigation and received ahead of the final factual report. The final factual report for the 2022 ground investigation was received very late in the development of this geotechnical design report and has not been validated. Any changes between the received data and final 2022 report have not been incorporated. Once the factual report has been fully validated, it may be necessary to make revisions to this interpretative report before final recommendations can be confirmed. Analysis of the factual data has been undertaken to carry out this report as presented in Appendix A.

Notwithstanding the efforts made by the professional team in preparing the report, it is possible that other ground conditions or ground contamination may exist, as yet undetected, and consequently reliance on this report must be limited accordingly.

1.4 Relevant document and drawings

This GDR should be read in conjunction with the following documents:

- Victoria North HIF Infrastructure Works, Ground Investigation Interpretative Report Arup (P02 31 January 2022) – VNIF-ARP-ZZ-YYY-RP-CG-0009
- Victoria North HIF Infrastructure Works, Preliminary Geotechnical Design Report – Slope stability (P01.02, December 2021) – VNIF-ARP-ZZ-YYY-RP-CG-0006
- AEG (2019) Northern Gateway Final Factual Report (Rev.00) NW1580
- AEG (2021) Northern Gateway Phase 2 Final Factual Report (Rev.00) NW1604

Key drawings and sketches relevant to describing the design of elements covered by this report have been attached (Appendix C and Sketch appendices respectively). The following other documents and drawings may also be informative. Some of the drawings are currently being developed, the dates indicated are the versions available at the time of writing this report.

Table 1: Relevant documents that have been used

Reference number	Title	Developed by
VNIF-PLA-ZZ-YYY-DR-L-1011-General Arrangement Plan	Landscape General Arrangements HIF Delivery Plan	Planit (rev. P03.03. 2022-05-26)
VNIF-PLA-ZZ-YYY-DR-L-8009	Typical Gabion Details 2 of 2	Planit (2022-05-27)
VNIF-PLA-ZZ-YYY-DR-L-3102	St Catherine's wood Detailed Area Levels	Planit (2022-05-27)
VNIF-PLA-ZZ-YYY-DR-L-3113	Red Bank Terraces Detailed Area Levels	Planit (2022-05-27)
VNIF-PLA-ZZ-YYY-DR-L-3115	River Embankment Detailed Area Levels	Planit (2022-05-27)
VNIF-PLA-ZZ-YYY-DR-L-3004	Red Bank Sections 1 of 2 – For approval	Planit (2022-06-17)

Reference number	Title	Developed by
VNIF-PLA-ZZ-YYY-DR-L-3005	Red Bank Sections 2 of 2 – For approval	Planit (2022-06-17)
VNIF-PLA-ZZ-YYY-DR-L-3006	St Catherine's Wood Sections	Planit (2022-06-17)
VNIF-ARP-00-YYY-DR-CS-0007	Retaining Walls - General Arrangement Plan	Arup (rev P01.03 2022-05-22)
VNIF-ARP-00-YYY-DR-CS-0008	Retaining Walls - Sections	Arup (rev P01.03 2022-05-22)
VNIF-ARP-00-YYY-DR-CH-3020	Site highways long section	Arup (rev P02 2022-06-30)
VNIF-ARP-00-YYY-DR-CH-3031	Site highways cross sections sheet 2	Arup (rev S3 2022-06-28)
VNIF-BNL-ZZ-YYY-DR-CE-0001	Highway Isopach drawing to show levels of embankment	Arup (P04.01)

2. Basis of design

2.1 Design standards

Geotechnical design has been undertaken in accordance with the following:

- BS EN 1990:2002 + UK NA Eurocode 0: Basis for structural design
- BS EN 1991-1-1:2002 + UK NA Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings
- BS EN 1991-1-7:2006 + A1: 2014 +NA Eurocode 1: Actions on Structures. Part 1-7: General actions: Accidental actions
- BS EN 1992-1-1:2004 + UK NA Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings
- BS EN 1992-2: 2005 (+ Corr: 2010) +NA Eurocode 2: Design of Concrete Structures. Concrete bridges. Design and detailing rules
- BE EN 1997-1:2004 + UK NA Eurocode 7: Geotechnical design - Part 1: General rules
- BS EN 1997-2:2007 + UK NA Eurocode 7: Geotechnical design - Part 2: Ground investigation and testing
- BS 8002: 2015 Code of practice for earth retaining structures
- BS EN 206 Concrete Specification, Performance, Production and Conformity
- BRE Special Digest 1 Concrete in Aggressive Ground (3rd Edition) February 2017 amendments
- PD 6694-1:2011+A1:2020 Recommendations for the design of structures subject to traffic loading to BS EN 1997-1:2004+A1:2013

2.2 Geotechnical category

All geotechnical design elements associated with the scheme are considered to be Geotechnical Category 2 in accordance with BS EN 1997-1:2004. (i.e. conventional types of structures and foundations with no exceptional risk, difficult ground or load conditions).

2.3 Design working life

Design working life category for Asset 2 is 120 years, category 5, BS EN 1990:2002+A1:2005 Table NA.2.1 was determined according to Table NA.2.1. Design working life for Asset 3 to 4 is 60 years.

2.4 Design approach – limit states and partial factors

Geotechnical design relating to the proposed assets has been carried out using the limit state design principles outlined in BS EN 1997-1:2004 Eurocode 7 Part 1.

The following limit states have been considered as part of geotechnical design (GEO = geotechnical ultimate limit state; SLS = serviceability limit state). See Table 2.

Table 2: Geotechnical Limit State Design Categories

Design Element	Global stability	Overturning failure	Sliding failure	Bearing capacity failure	Vertical Settlement (SLS)
Embankment (Asset 1)	✓				✓
RC retaining wall (Asset 2)	✓	✓	✓	✓	✓

Design Element	Global stability	Overturning failure	Sliding failure	Bearing capacity failure	Vertical Settlement (SLS)
Gabion retaining walls (Asset 3-4)	✓	S	S	S	✓
Slope Stability assessments Assets 5&6	✓				
S denotes Preliminary design undertaken by Arup – Subject to supplier design					

Partial factors, as defined within the UK National Annex to Eurocode 7 (NA+A1:2014 to BS EN 1997-1:2004+A1:2013), for soil properties have been applied. For the verification of serviceability limit state, partial factors of 1.0 have been used.

Actions have been factored in accordance with the UK National Annex to BS EN 1990:2002+A1:2005. The following geotechnical combinations have been considered:

- Design Approach 1, Combination 1: A1+M1+R1.
- Design Approach 1, Combination 2: A2+M2+R1.

2.5 Actions

Table 3 below presents a summary of the load cases that have been assessed.

Table 3: Applied loading based on requirements set out in PD 6694:1:2011 and EN1991-2:2003

Loads	Transience	Characteristic magnitude (kN/m^2)	Related assets	Basis
Light vehicles Live Load	Variable	10	P&P slope and Plot RB02 & RB03 slope regrade	Represents light vehicle loading
Pedestrian Live Load	Variable	5	Assets 1-4	BS EN 1991- 2:2003

For Asset 2, The traffic loads were applied according to table 5 of PD 6694:1:2011. The highway is offset 9m from the back face of the retaining wall, as such falls below the zone of influence. Therefore, only pedestrian loading is applied.

For Assets 5 and 6, light vehicle live loading of 10kpa was considered for maintenance/emergency vehicles at the crest of the slope.

2.6 Analysis method and assumptions

The following methods were used for geotechnical analysis, considering the limit states discussed above.

The bearing capacity of all spread foundations was assessed using the approach set out in BS EN 1997-1.

Slope stability assessments and retaining wall global stability was assessed using the OASYS Slope software package. Slope is a two-dimensional limit equilibrium package. The user inputs geometrical, actions and ground conditions data and an Over Design Factor (ODF) is generated. A static analysis was undertaken using the Bishop method of slip circle generation which considers interslice normal forces. This is also compared to Morgenstern and Price's method which considers both interslice normal and shear forces. Circular slip surfaces were analysed in both cases to assess and potential undermining of the river wall. The Morgenstern and Price method suggested no notable difference in ODF results, therefore, the Bishop's

method of slip analysis has been selected for the analysis, which represents the most common analysis method for slip analysis. Local slope stability assessments are not carried out on proposed constructued slopes with a gradient less than 1:3 because these lower gradient slopes have proven to be safe. Only DA1 – Combination 2 (EC7) approaches are reported because this condition governs the stability analayis.

The retaining walls (including gabions) were assessed using OASYS Greta software package. Greta uses a 2D limit equilibrium approach of geotechnical analysis compliant with BS EN 1997-1. This includes stability and bearing capacity. Only the stability results from the largest retained height of the Creamline wall is presented in the report. The average bearing pressure from an SLS assessment was used to calculate the expected vertical settlement of the Creamline retaining wall.

2.7 Description of assets

This GDR reports on the following structural assets and slope stability assessments. Indicative locations of the structural assets are show in **Sketch 01.**

2.7.1 Embankment and retaining walls

Asset 1 - Redbank Plateau Road embankment

The proposed development access from the existing public highway, is on elevated ground, supported by a 4m high masonry retaining wall (Honey Street retaining wall), above Redbank Plateau. To accommodate Redbank Plateau Rd, the Honey Street retaining wall will be reduced in height, with cut behind the wall and embankment fill in front of the wall. The embankment will be 4m high at the entrance over the Honey Street retaining wall, dropping to approximately 1m high further along the Plateau road (Appendix D, drawing VNIF-ARP-00-YYY-DR-CH-3020).

Asset 2 - Creamline retaining wall

Due to space constraints a new retaining wall is be required to support a section of the embankment (Asset 1) on its south face. The reinforced concrete cantilever wall will retain between 2m and 4m height of embankment. The retaining wall is presented as Wall type B (Appendix D, drawing VNIF-ARP-00-YYYY-DR-CS-0008). For assessment, the proposed Creamline retaining wall has been split in to 3 zones based on retained height: namely, 2m, 3m and 4m.

Asset 3 Small gabion retaining walls

Numerous small gabion retaining walls have been proposed as part of the landscape design for footpaths in Redbank Terrace (Asset 3A) and St. Catherine's Wood (Asset 3B) as illustrated on plan in Drawing 1. (Appendix D, drawing VNIF-PLA-ZZ-YYY-DR-L-8009 for cross sections)

Asset 3A has a maximum retained height is 0.6 m (Figure 3)**.**

Asset 3B has a retained height between 0.6m and 1.7m (Figure 4).

Both assets have maximum slope angle above and below the walls of 1(v):3(h).

Asset 4 - St. Catherine's Wood gabion wall

A single gabion structure with a retained height of 2.05m is proposed in St. Catherine's Wood. The regraded slope area at the top of this wall will be flat and carries a pedestrian footpath (**Figure** 5).

It has been assumed that the gabion retaining walls will be procured as supplier designed elements. The level of design undertaken by Arup is preliminary sizing and global stability. Internal stability will be designed by the supplier.

2.7.2 Slope stability assets

Redbank Terrace and St Catherine's wood provide a pedestrianised route down from the Redbank Plateau area (Approximately 40mOD) to river level (Approximately 30mOD) through a series of terraced pathways supported by gabions. Global slope stability assessments have been undertaken for the proposed earthworks and landscaping features related to assets 2-4.

In addition to the structural assets, there are two areas consisting of steep slopes which descend from the Redbank Plateau area to the river. Firstly, the slope in front of plots RB02 and RB03 (Redbank plateau) which is currently proposed to be regraded, known as the plateau slope (**asset 5**), and an existing slope which, subject to satisfactory results from the analysis, is to remain unmodified known as the P&P slope (**asset 6**) for environmental reasons.

The plateau slope regrade zone (**asset 5**) is shown in Figure 1. This area was part of a rail siding expansion in the mid-1800s. It was typical for railway earthworks to be constructed by end tipping locally available material without compaction. The current condition of this slope suggests some features of marginal stability with evidence of surface slips around the crest area. Existing gradients of the Plateau slope range from approximately 32^{o} or 1 in 1.6 at the steepest point to 26^{o} (1 in 2) elsewhere. The Plateau slope is proposed to be regraded to a 1 in 2.5 gradient slope with a 2m wide footpath at the river edge.

The existing P&P slope zone (**asset 6**) is shown in Figure 1. At this location, there is an existing small access road from the P&P bridge which reaches the crest of the slope to be used for emergency access. The slope has a constant gradient of approximately 32^{o} down to the riverbank. The cross section used for this analysis was the steepest continuous section of this slope where the access road is at the crest of the slope.

Sketch 02 shows the Topographical section lines that were used for stability assessments as follows:

- Redbank Terrace (Topographical section lines 1-2),
- St Catherine's wood (Topographical section lines 3-4),
- Plateau slope regrade zone (Topographical section lines 5-6), and
- P&P slope stability zone (Topographical section line 7)**.**

Sketch 07 shows the existing and design profiles cut from the 3D model.

3. Ground conditions and ground models

3.1 Ground conditions

A summary of the ground conditions and a preliminary ground model for the HIF works was presented in the GIR (VNIF-ARP-ZZ-YYY-RP-CG-0009). Since then, the 2022 ground investigation was undertaken to refine the ground conditions. Ground models were created to understand the complexity of the site and to show the spatial variability of the anthropogenic and natural material regarding the assets. They concluded that glacial till deposits are found at shallower depths to the north of the site along the road alignment (north side of the existing Redbank viaduct wall) which thin out towards the river. Made ground is prominent across the Redbank Terrace, St Catherine's wood and Plateau slope area which were part of the rail siding expansion to help build up the ground levels. Here the material generally sits directly above bedrock represented as loose granular material with inconsistent zones of cohesive material. Ground models for the specific assets are described in sections 3.2 below, and illustrated on **Sketch 04A to 06**, and **Sketch 08 to 09**.

Geotechnical parameters derived from the 2022 ground investigation are presented in a series of tables and charts in Appendix A. The methods used to derive design values for relevant parameters are also documented in Appendix A. The data summarised in Appendix A includes the results of in-situ and laboratory test data obtained during all previous phases of GI including the 2022 GI.

The tables in Appendix A include:

- Global assessments of the relevant geotechnical test data for each of the strata types encountered in the three areas of the site (Redbank Plateau, Redbank Terrace and St Catherine's Wood). The parameters derived from these global assessments have been applied to all structure assets (Assets 1, 2, 3A, 3B and 4) as well as the global stability checks undertaken for areas of Redbank Terrace and St Catherine’s Wood.
- More localised assessments of the relevant geotechnical test data for the areas of slope stability assessment (Plateau slope and P&P slope zone). These more localised assessments have been used during the validation of the Preliminary GDR.

3.2 Ground models for assets 1 to 4

3.2.1 Asset 1 ground model - Redbank plateau embankment

Assessments were required to establish likely settlement of existing soils induced by the construction of the Redbank Plateau retained embankment. At this location, 3m to 5m of made ground overlies natural glacial till deposits. For the assessments, two topographic cross sections have been considered (cross-sections A and B), the location of these can be seen on plan in **Sketch 01.** The ground conditions are based on geological cross sections which are shown on **Sketch 04A** and **04B**.

The location of Cross section A (**Sketch 01)** has been selected because it represents the most onerous loading case where the embankment is at its highest (4m) and retained by the Creamline retaining wall. BH313 is used to derive the local ground model which suggests 10m of granular material overlying the Chester Pebble Formation bedrock. Groundwater level generally appears at river level (30mOD) according to the CWRA report (VNIF-ARP-ZZ-YYY-RP-CG-0011), therefore this is not considered to influence the placement of the embankment. Note, for the plateau slope stability assessment, an elevated groundwater level has been assumed to allow for more conservative conditions, refer to section 3.3.3.

The location of Cross Section B (**Sketch 01)** has been selected because it represents a full width (18m) embankment which is 2m high and there is a change in ground conditions. (Appendix D, Drawing VNIF-ARP-00-YYY-DR-CH-3031, Chainage 90.0). The ground model used in this assessment has been based on WS213A and BH105 (**Sketch 03**). There is evidence of a fairly consistent 2m to 3m thick clay layer within the made ground at shallow depths (WS213A, BH105) which represents a change in ground conditions. Therefore, a settlement calculation has been undertaken for this arising in response to the placed fill loading.

3.2.2 Asset 2 – Creamline retaining wall – Redbank Plateau

The ground model adopted for the assessment of Asset 2 is illustrated on **Sketch 04A** using ground condition information from BH313 which is in the area of the proposed creamline retaining wall. It suggests 10m of granular material comprising of made ground and natural material. Figure 2 shows an idealised diagram of the structure adopted for analysis. The Creamline RC wall is to be founded at shallow depths within the existing shallow made ground which is granular in nature. Here the existing ground level is approximately 40mOD with approximately 3m of made ground material, some of which may be removed behind the retaining wall and replaced with engineered fill. The base of the retaining wall does not come in to contact with the underlying glacial till deposits**.** In front of the retaining wall, the ground level begins to slope down from approximately 40mOD to 30mOD representing the Redbank Terrace area. However, this is outside of the zone of influence for the retaining wall.

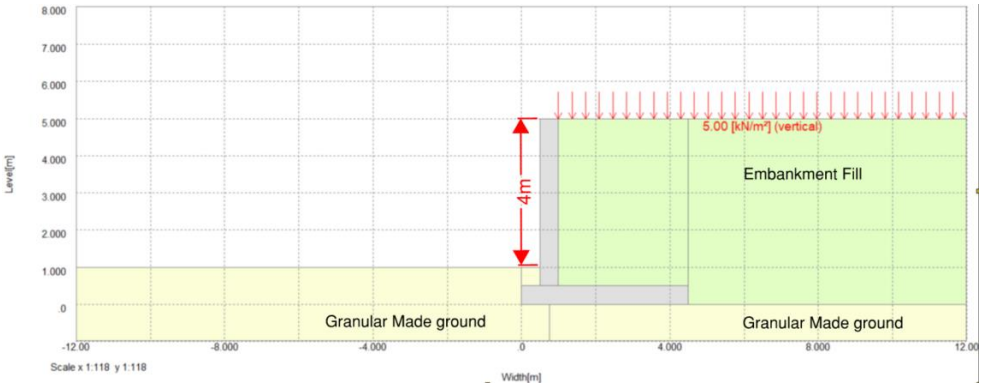


Figure 2: Asset 2 – Creamline retaining wall ground model

3.2.3 Assets 3 & 4 – St Catherine's Wood and Redbank Terrace

Assets 3A, 3B and 4 are related to gabion wall structures within the Redbank Terrace and St Catherine's Wood areas (see **Sketches 05 and 06** for geological cross sections for these areas). For both Redbank Terrace and St Catherine's Wood, the made ground forms the greatest thickness of the stratigraphy. The glacial till deposits in the Redbank Terrace area are very thin and don't appear in St Catherine's Wood. In St Catherine's Wood, there is evidence of alluvium deposits from the adjacent river which pinch out into the stratigraphy.

The gabion structures are proposed to be founded on existing granular made ground as shown indicatively in the idealised diagrams below (Figures 3 to 5) which have been adopted for analysis. Redbank Terrace is an area which will undergo cutting to help form the terracing structure with support of the gabion structures. There will be the placement of suitable reworked engineered fill in front and behind the gabions. For St Catherine's Wood, site-won engineered fill material will be placed over the natural slope to help build up the required levels supported by the gabion structures. The gabion structures are constructed to support the level changes for the pathways in both areas, so the slopes Infront and behind the structures are no steeper than 1 in 3.

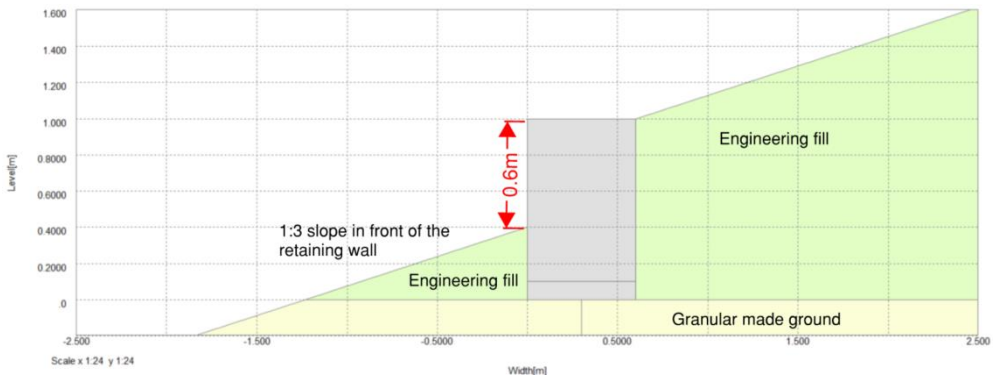


Figure 3: Asset 3A ground model

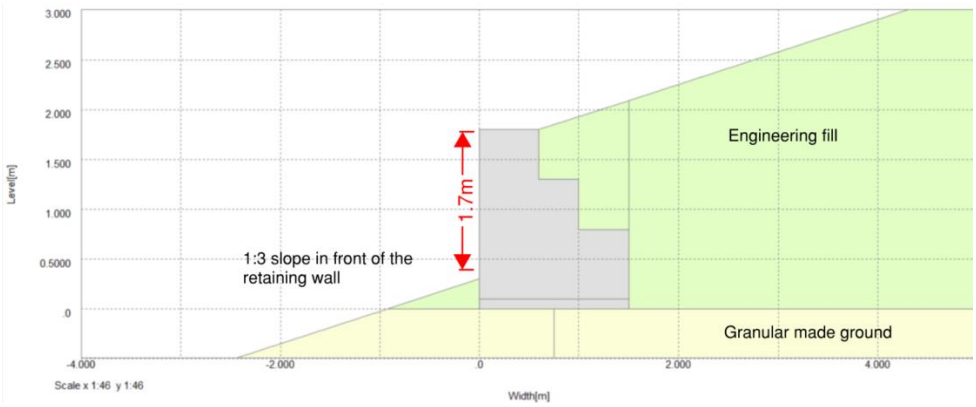


Figure 4: Asset 3B ground model

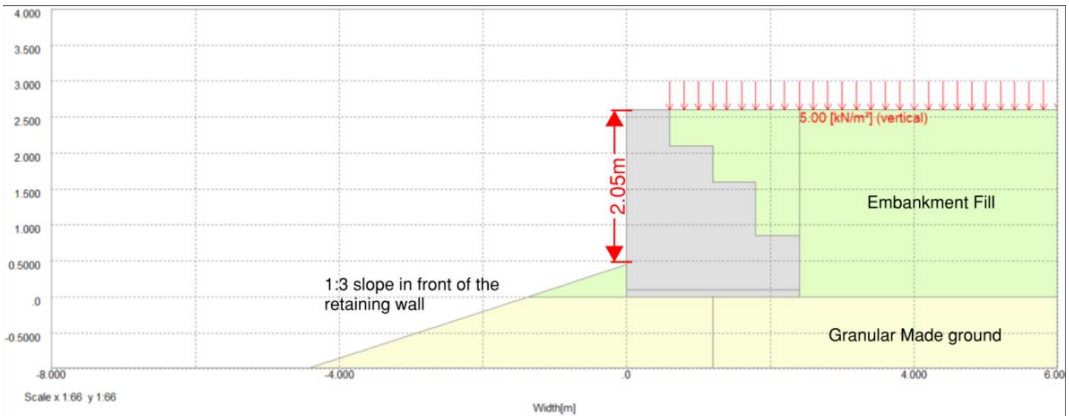


Figure 5: Asset 4 ground model

3.2.4 Material parameters for assets 1-4

Table 4 presents the material properties adopted for design of the proposed structural assets across Redbank Plateau, Redbank Terrace and St Catherine's Wood. The parameter values adopted are based upon interpretation of GI data from the 2019, 2020 and 2022 investigations, as summarised in Appendix A. Due to the widespread coverage of these assets within these locations, general material properties relating to the whole area are used. The design parameters have been cross analysed based on different methods of testing with comparisons between estimations and laboratory results. These values have been concluded from trends seen in charts and engineering judgment using industry approved standards where appropriate.

Groundwater levels are shown on the relevant geological cross sections (**Sketch 05 and 06**), and are well below the formation level of the assets. Consequently, groundwater is only considered for the slope stability assessments related to these assets.

Table 4: Superficial deposit material properties used for design in Redbank Plateau, Redbank Terrace and St Catherine's Wood

Stratum	Redbank Plateau	Redbank Terrace	St Catherine's Wood	Basis
Embankment/engineering fill (class 1)				
Bulk Unit weight, γ (kN/m^3)	20	20	20	BS8002 Figure 1
Angle of shearing resistance φ' (°)	32	32	32	Assumed minimum value
Granular made ground				
Bulk Unit weight, γ (kN/m^3)	18	18	18	Loose to medium dense – BS8002 Figure 1
Angle of shearing resistance φ' (°)	30	30	30	Estimated from SPT N results
Drained Young's modulus (kPa)	15 000	n/a	n/a	Correlated from SPT N, E' = 1.5N_{60} (CIRIA 143). For embankment settlement calculation only
Cohesive made ground				
Bulk Unit weight, γ (kN/m^3)	18	18	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	27	28	27	Estimated from Plasticity Index results and consolidation test results
Cohesion (c') (kPa)	1	1	1	Assumed for drained analysis
Drained Young's modulus (kPa)	17 000	n/a	n/a	Estimated from SPT N and PI / OCR relationship established. For embankment settlement calculation only
Undrained shear strength (kPa)	35	50	51	Average results from Quick Undrained Triaxial results for St Catherine's Wood and Redbank Plateau. SPTN Cu correlation used for Redbank Terrace
Granular glacial till				
Bulk Unit weight, γ (kN/m^3)	19	19	19	medium dense – BS8002 Figure 1
Angle of shearing resistance φ' (°)	31	33	34	Estimated from SPT N results
Drained Young's modulus (kPa)	30 000	n/a	n/a	Correlated from SPT N, E' = 1.5N_{60} (CIRIA 143). For embankment settlement calculation only

Stratum	Redbank Plateau	Redbank Terrace	St Catherine's Wood	Basis
Cohesive glacial till				
Bulk Unit weight, γ (kN/m^3)	19	19	n/a	medium dense – BS8002 Figure 1
Angle of shearing resistance φ' (°)	27	27	n/a	Estimated from Plasticity Index results
Cohesion (C') (kPa)	1	1	n/a	Assumed for drained analysis
Undrained shear strength (kPa)	100	70	n/a	Average results from estimated from SPTN results
Alluvium				
Bulk Unit weight, γ (kN/m^3)	n/a	n/a	19	medium dense – BS8002 Figure 1
Angle of shearing resistance φ' (°)	n/a	n/a	30	Estimated from SPT N results

3.3 Ground models for assets 5 and 6

The following sub sections provides updated ground condition information and localised ground models for the plateau slope and P&P slope zone.

3.3.1 Asset 5, plateau slope ground investigation

Additional GI was undertaken to improve the accuracy of the ground model used in the previous slope stability assessment. The past phase of slope assessment was heavily reliant on the results from BH208. The 2022 ground investigation provided a significant number of supplementary investigation points along the crest of the slope as illustrated in Figure 6**.** It was intended to obtain additional boreholes at the top of the slope however there were too many constraints to safe access at the time of the investigation.

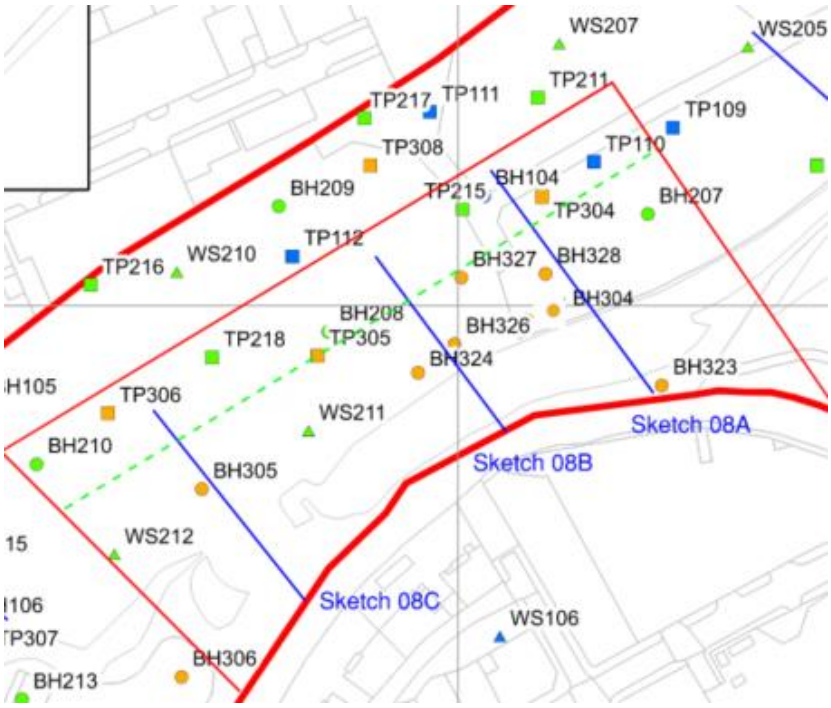


Figure 6: Ground Investigation plan showing slope stability sections for the plateau slope zone

BH304 & 305 were undertaken to provide data at the crest of the slope on the flanks. BH324 was originally scheduled for the toe of the slope to confirm rock levels and material behind the river wall, but was moved to the crest of the slope due to access constraints. BH326 to 328 were supplementary holes sunk to delineate the extent of cohesive deposits encountered in BH304.

Three geological cross sections have been prepared (**Sketch 08A, 08B** & **08C**) to show the variability in ground conditions across the area, the location of each section is illustrated in Figure 6**.**

3.3.2 Asset 5, plateau slope ground model

The boreholes in this area confirmed the previous understanding of the ground from the site history and past investigation. There was a significant thickness of granular made ground, typically described as a loose to medium dense ash sandy gravel. The made ground forms the Redbank Plateau and existing slopes down to the River Irk.

Glacial till was encountered at depth beneath the north-west boundary of the asset, thinning out towards the south-west (as illustrated in the geological sections in **Sketch 08A** and **08C**). Bedrock underlies the glacial deposits to the NW and directly underlies the made ground adjacent to the river. Through this asset, the channel of the river is lined by a masonry retaining wall.

Localised pockets of cohesive material were encountered with in the made ground in the following holes only.

BH304, on the eastern side of asset 5 encountered approximately 15m of granular ash fill above bedrock. However, a zone of cohesive made ground was identified between 4.5 and 7.0mbgl. To establish the lateral extent of the cohesive made ground in BH304, three additional window sample holes (BH326, BH327, BH328) were drilled. However, none of these boreholes encountered cohesive material at the same depth, indicating that the cohesive deposits are localised and not laterally extensive.

BH104, to the north of BH304 encountered a pocket of cohesive material identified between 2.5 and 6mbgl.

BH324 and WS211, to the west of the asset encountered small pockets of cohesive material identified between 3m and 5mbgl, and 2.5m and 5mbgl respectively.

It is concluded that the cohesive material encountered in BH304, BH324 and WS211 is not laterally extensive or continuous, but indicates the variability of material used during the formation of the sidings.

Although the available data suggests material used to construct Redbank Plateau is predominantly granular, the sensitivity of the slope stability due to the presence of cohesive layers has been assessed by analysing the slope with two different ground models, ground model 5A including a cohesive band which combines the information seen in **Sketch 08A and 08B**; and Ground model 5B with no cohesive made ground as illustrated by **Sketch 08C**.

3.3.3 Asset 5, groundwater

The Controlled Waters Risk Assessment (VNIF-APR-ZZ-YYY-RP-CG-0011) reviews groundwater levels and indicates that groundwater levels beneath this particular area is generally at river level. Piezometer data from the 2022 GI in BH304 and BH305 confirms this. However, this may not be a true representation of worst case conditions considering seasonal fluctuations. There was some elevated groundwater levels seen at the rear of the slope area in BH105 which could be representing perched levels. To take into account the potential for seasonal variation, a conceptual groundwater surface has been adopted to allow for these more onerous conditions that could be expected in wetter conditions by accounting for higher water levels at the back of the slope as illustrated on Ground model 5A and 5B (**Sketch 08A-C**).

In addition, at this location, the river flood level for a 1 in 100-year event with climate change was estimated to be 31.95mOD according to the flood estimation report (VNIF-ARP-00-YYY-RP-CH-0001). The potential impact of this on groundwater level in proximity to the watercourse has been considered during the assessment.

3.3.4 Asset 5, evaluation of selected design parameters

Assessment of shearing resistance of made ground

The additional 2022 GI data has helped to confirm trends in behaviour of the granular made ground based on SPT data (Figure 7). Boreholes near the crest of the slope (BH304, BH324 and BH305) have recorded low N values, typically between N=2 and N=6 (average N=5), which indicates very loose material, especially in the upper 6m. Made ground set-back from the crest of the slope (e.g. BH104, BH207 and BH210) appears to be more dense, with recorded SPT values generally in the range N=8 and N=13 (average N=10) and with a general increase with depth. The 2022 GI data indicates that loose material is more widespread than had been indicated by earlier phases of GI and there is evidence of a decrease in soil density towards the crest of the slope. The green dotted line on Figure 6 shows the approximate position of the change in density towards the crest of the slope. There is also evidence of a change in SPT N with depth, with typical SPT N = 5 in the upper 6m and SPT N = 10 below 6m (Figure 7).

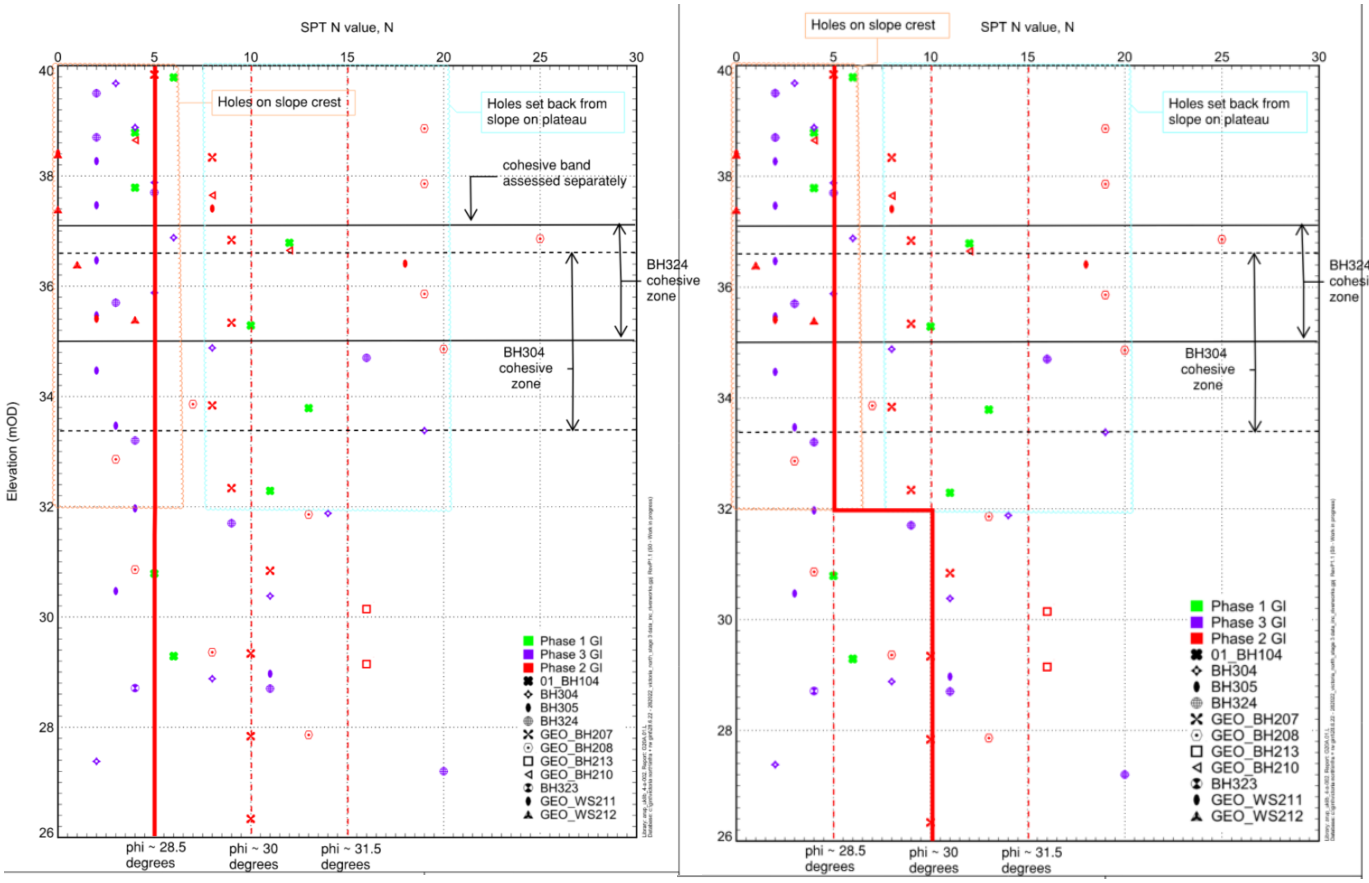


Figure 7: SPT N graph showing derived friction angles for granular made ground. The graph on the left represents the derived friction angle used for granular made ground in ground model 5A and 5B. The right graph represents the change in SPTN past 32mOD which is used for ground model C.

BH208 shows relatively high SPT N values between ground level and 4mbgl which is likely to be a result of localised compaction. BH304 and BH324 also show relatively high SPT N values associated with the cohesive made ground deposits that have been identified. These relatively high SPT values do not govern the overall behaviour of the slope.

BH305 reveals the lowest SPT N values observed, which are consistent with the existing low slope angle at this location observed during geomorphological assessments (Topographical Section 5, **Sketch 07**). This corelates with the slope at this location being at its angle of repose.

Two strength profiles have been adopted for the granular made ground for stability assessment as follows:

For initial stability analyses, ground models 5A and 5B were adopted, conservatively assuming a characteristic phi value of 28.5 ^{o} applied to all granular made ground based on an SPT N value of 5. The strength properties of the cohesive band included in ground model 5A have been addressed separately, refer to Table 5 below.

Ground model 5C takes account of the increase in relative density observed below 32.0mAOD. For this model, a characteristic phi angle of 28.5 ^{o} has been adopted above 32.0mAOD, with a phi angle of 30 ^{o} (based on an SPT N value of 10) assigned to the material below 32mAOD reflecting the higher SPTN value beyond this depth.

In addition to SPT tests, a series of shear box tests were also undertaken. These were undertaken on samples recompacted in the laboratory and therefore do not reflect the conditions on site. High friction angles (40°-45°) were obtained for the made ground. However, given that a high proportion of made ground described as loose ash fill, the test results are considered unconservative. On this basis, the direct shear test data has not been used for design (See Appendix A for analysis).

Summary of material properties

Table 5 summarises the suite of material properties adopted for the assessments of stability for the Plateau slope zone based on the interpretation of GI data. The GI data summaries are presented in Appendix A.

For the slope stability assessments, bedrock has been represented as a rigid boundary and so the strength parameters assumed in design have been based on engineering judgment.

Table 5: Selected superficial deposit material properties used for design in the Plateau slope regrade zone

Stratum	Selected parameter value used in design	Basis
Made Ground Granular (Ground model A, B and C)		
Bulk Unit weight, γ (kN/m^3)	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	28.5 above 32mAOD	Derived from SPT N results as seen in figure 7 assuming typical N value of 5 throughout granular made ground
	30 below 32mAOD	Derived from SPT N results as seen in figure 7 assuming typical N value of 10 below 32mAOD (Ground model C only)
Made Ground Cohesive (Ground model A)		
Bulk Unit weight, γ (kN/m^3)	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	27	Assumed based on triaxial results from Asset 6
Cohesion (C') (kPa)	3	Assumed based on triaxial results from Asset 6
Undrained shear strength (kPa)	26	Parameter has been assessed from quick undrained triaxial tests

3.3.5 Asset 6, P&P slope ground investigation

The preliminary phase of slope assessment was heavily reliant on the results from BH203 and BH204 which suggested granular material. The 2022 ground investigation provided a significant number of supplementary investigation points across the slope as illustrated Figure 8. Additional boreholes BH301, BH302 and BH315 suggested thick deposits of cohesive made ground material across the whole P&P slope area. There were no boreholes undertaken at the toe of this slope area, therefore, BH310 was extrapolated to help provide an alternative ground model.

Geological cross sections (**Sketch 09A** and **09B)** have been prepared to show the expected ground conditions.

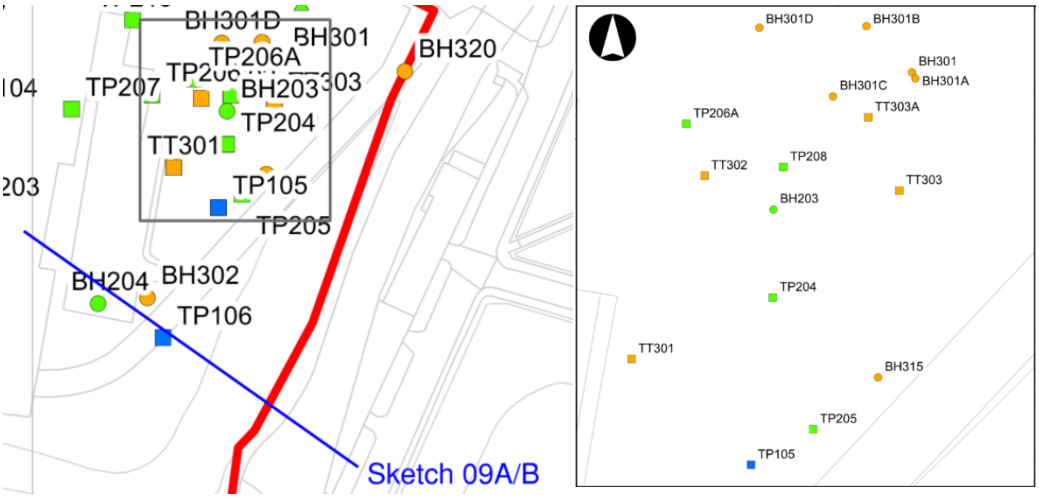


Figure 8: Ground Investigation plan showing section for ground model 6A and 6B for the P&P slope

3.3.6 Asset 6, P&P slope ground model

The additional boreholes undertaken in this area in 2022 have resulted in a change to the ground model that was adopted in the preliminary GDR. The 2022 GI data has indicated that there is less granular made ground in this zone that had previously been indicated. The updated ground model comprises granular made ground in the upper section of the slope (approximately 2-3m thick) overlying cohesive made ground in (approximately 10m thick). No glacial till is present in this zone.

Two ground models have been adopted for analysis. Ground model 6A, based on **Sketch 09A,** comprises a layer of granular made ground beneath the plateau, overlying a large proportion of moderately stiff clay, seen in BH204, BH301, BH302 and BH315 which represents ground conditions surrounding the middle and rear of the slope. Due to the uncertainty of ground conditions at the toe of the slope, ground model 6B, based on **Sketch 09B,** includes a granular made ground layer extending from the plateau down the face of the slope underlain by a thin cohesive layer (a relict surface) beneath the toe of the slope, with granular alluvium below that.

3.3.7 Asset 6, groundwater

The Controlled Waters Risk Assessment (VNIF-APR-ZZ-YYY-RP-CG-0011) indicates that groundwater levels beneath this particular area generally fall towards to the toe beneath the Redbank Plateau. In particular, BH204, towards the rear of the slope, has consistently shown groundwater elevations during long term monitoring at approximately 40mAOD. The groundwater then drops to river level in BH315. This groundwater profile is used for the conceptual groundwater surface which also allows for wetter conditions, although it is noted that the elevated groundwater levels seen in the P&P slope area could be a response to perched water levels above the cohesive layers.

In addition, the flood level for a 1 in 100-year event with climate change is estimated to be 32.6mOD at this location according to the flood estimation report (VNIF-ARP-00-YYY-RP-CH-0001). The impact that this could have on groundwater level in proximity to the watercourse was also considered during the assessment.

3.3.8 Asset 6, evaluation of selected design parameters

Drained strength parameters were obtained for the cohesive made ground from consolidated undrained triaxial tests using the 2022 GI data. Quick undrained triaxial tests provided average undrained shear strength values throughout the cohesive soils (Appendix A). The undrained shear strength test results showed an increase in depth from approximately 20 to 90 kPa as would be expected in normally consolidated clays, so a representative average of 51kPa across the full thickness was used. The selected value is representative of a moderately stiff clay, which is consistent with descriptions presented on the relevant borehole records.

For the potentially weak zone at the toe of the slope, strength parameters have been estimated from the description of the clay which was described as soft using assumed lower bound results. The alluvium uses strength parameters derived from SPT N results in St Catherine's Wood (Appendix A).

Table 6 shows material properties adopted for the slope stability assessment of the existing P&P slope zone based on the interpretation of the GI data. The GI data summaries are presented in Appendix A.

For the slope stability assessments, bedrock has been represented as a rigid boundary and so the strength parameters assumed in design have been based on engineering judgment.

Table 6: Selected superficial deposit material properties used for design in the P&P slope zone

Stratum	Selected parameter value used in design	Basis
Made Ground Granular (Drawing 09A and 09B Ground model)		
Bulk Unit weight, γ (kN/m^3)	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	30	Estimated from SPT N results
Made Ground Cohesive (Drawing 09A Ground model)		

Stratum	Selected parameter value used in design	Basis
Bulk Unit weight, γ (kN/m^3)	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	27	Derived from CU triaxial test for P&P slope zone
Cohesion (C') (kPa)	3	Derived from CU triaxial test for P&P slope zone
Undrained shear strength (kPa)	51	Parameter has been derived from Quick Undrained tests.
Weak made Ground Cohesive (Drawing 09B Ground model)		
Bulk Unit weight, γ (kN/m^3)	18	BS8002 Figure 1
Angle of shearing resistance φ' (°)	25	Assumed based on lower bound strength
Cohesion (C') (kPa)	1	Assumed based on lower bound strength
Undrained shear strength (kPa)	35	Typical Cu for a soft clay
Alluvium granular (Drawing 09B Ground model)		
Bulk Unit weight, γ (kN/m^3)	19	BS8002 Figure 1
Angle of shearing resistance φ' (°)	29	Estimated from SPT N results

3.3.9 Sensitivity analysis

Both the plateau slope regrade and P&P slope zone have been analysed using multiple potential ground models to assess the effect of variability and uncertainty on the outcome of the stability analysis, as described in the preceding sections.

The sensitivity of the stability of the slopes to groundwater level has been assessed considering two scenarios. Flood level within the River Irk is likely to have a significant impact on stability. Where the slope is granular it may be assumed that groundwater level will respond directly with river level. It is considered feasible that following a flood, groundwater could be elevated within the slope for a transient condition, especially where the river wall may trap water limiting dissipation. Therefore, the following scenarios have been assessed, considering typical groundwater and post flood groundwater conditions:

The first scenario conservatively adopts a groundwater surface daylighting at the centre of the river wall. This is above the level generally observed to account for general wetter conditions. The second scenario considers the groundwater level after a 100-year flood event using data from the Victoria North river works Arup 2022 hydraulic model (Flood estimation report, VNIF-ARP-00-YYY-RP-CH-0001). The data represents a baseline result prior to works to the river channel. This provides for a conservative analysis assessing the impact of drawdown effects within the slope toe following flood events in both areas.

A sensitivity check on loading at the crest was undertaken which explored pedestrian loading (5kpa) and vehicle loading (10kpa) which concluded no difference in stability results.

4. Results of analysis - Assets 1 to 4

4.1 Asset 1 - Redbank plateau embankment

The settlement of the Redbank Plateau road embankment has been analysed along Cross-sections A and B. The analysis was undertaken by hand calculations using representative ground models and potential scenarios to then provide the maximum expected settlement values.

The results of the calculations indicate the maximum settlement to be 18mm at cross section A where the embankment is 4m high. The expected settlement at cross section B is predicted to be 11-14mm where the embankment is 2m high, which includes 6-9mm of consolidation in the shallow clay layer, with consolidation time estimated to be 2 weeks.

Settlement occurring in the granular material is expected to occur concurrent with construction, therefore the designer has considered the potential implications of the predicted consolidation. The results suggest that consolidation will be largely complete by the end of the embankment construction works and therefore, prior to the completion of the road construction, which will not occur until subsequent development phases of Victoria North site. Monitoring of the constructed embankment is recommended to verify anticipated settlement during the construction works.

The embankment slopes will be engineered 1 in 3 slopes, so have not been considered for slope stability checks.

4.2 Asset 2 - Creamline retaining wall

An assessment of ULS overturning, sliding and bearing capacity was undertaken for the Creamline retaining wall (Asset 2) using OASYS software GRETA. The results of this analysis (for the maximum retained height) are presented in Table 7.

Table 7: ULS overturning, sliding, bearing capacity and Slope stability results for Asset 2

Zone	Case	ODF (DA1-1)	ODF (DA1-2)
Zone III	Sliding check	2.3	2.0
	Overturning check	>3	>3
	Bearing capacity check	>3	2.8
	Bearing capacity check (peak value)	>3	2.7
	Slope Stability	N/A	2.0

The settlement of Asset 2 was assessed by hand calculations using average bearing pressure data obtained from the GRETA SLS analysis. The calculation was based on full elastic settlement of granular material and predicted a total vertical settlement of 22mm, which would be expected to occur concurrent with construction.

4.3 Assets 3A, 3B & 4 – Gabion structures

An assessment of ULS overturning, sliding and bearing capacity was undertaken for Assets 3A, 3B and 4 was undertaken using OASYS software GRETA. The results of this analysis are preliminary subject to supplier design and is presented in Table 8.

Table 8: ULS Overturning, Sliding, Bearing Capacity, Stability check and SLS settlements

Software	Asset No.	Design case	ODF (DA1-1)	ODF (DA1-2)
Oasys GRETA	Asset 3A	Sliding check	1.4	1.2
		Overturning check	2.5	2.3
		Bearing capacity check	>3	3.0
		Bearing capacity check (peak bearing pressure)	2.4	2.3
	Asset 3B	Sliding check	1.3	1.0
		Overturning check	>3	>3
		Bearing capacity check	>3	2.3
		Bearing capacity check (peak bearing pressure)	>3	1.9
	Asset 4	Sliding check	2.0	1.7
		Overturning check	>3	>3
		Bearing capacity check	>3	>3
		Bearing capacity check (peak bearing pressure)	>3	>3

A separate analysis was undertaken to assess potential settlement of the gabion structures, which suggested maximum expected settlements of the structures to minimal (<5mm). All gabion structures are required to be constructed on granular material which needs to be engineered and compacted appropriately.

The results from slope stability analysis related to the gabion structures (Assets 3-4) in Redbank Terrace and St Catherine's Wood are shown in Table 9. The location of the cross sections used for slope stability assessment are shown on **Sketch 02** (topographical sections 1-4). **Sketch 07** shows the topography section of the existing and proposed surface. All of the analyses yielded acceptable over design factors under DA1 Combination 2 EC7 conditions.

Table 9: General Slope stability results for Assets 3-4

Topography section	Location	Condition	ODF (DA1-C2)
1	Redbank Terrace	Drained/Undrained	1.1
2	Redbank Terrace	Drained/Undrained	1.1
3	St Catherine's Wood	Drained	1.2
4	St Catherine's Wood	Drained	1.0

5. Asset 5: Plateau slope stability assessment

5.1 Introduction

The plateau slope located in front of plots RB02 and RB03 is currently at steep gradient of approximately 32°. The available imagery suggested some notable features of the slope: Unable to sustain vegetation, variable slope profiles, toe debris and over steepened crest towards the south.

A geomorphological assessment has revealed signs of instability including minor back escarpments with large bulges of material accumulated at the toe; hummocky slope profile, and what appears to be slumped material, exposing an over-steepened slope at the crest. This morphology is indicative of a slip with a back-scar near the crest and toe debris from slumped material.

5.1.1 Summary from previous assessment

The preliminary GDR concluded the existing slope shows signs of past instability, confirmed by aerial imagery and site visits; the existing slope has marginal stability, with little or no capacity to accommodate changes in conditions, and there is a risk of future instability that could impact the development.

The assessment assumed that the steepest part of the slope was granular material standing at it's angle of repose; the slope gradient approximately matched parameters derived from the upper bound SPT N values in BH208.

A preliminary slope stability analysis of the existing profile indicated that the slope has a global factor of safety close to unity and that the current marginal stability of the slope is dependent upon the weight at the toe of the slope (the river bank and river retaining wall). The river wall provides protection to erosion of the toe by river water and progressive degradation of the slope.

The report recommended that the existing steep slopes beneath these development plots should be regraded to a maximum gradient of 1 in 2.5 and that ground levels at the crest should be reduced to 38.5mOD.

5.1.2 Stage 4 assessment approach

The current stage 4 assessment was undertaken to validate the recommendations in the preliminary GDR, taking account of the full available data set. The preliminary GDR analysis of a 1 in 2.5 gradient slope concluded over design factors of approximately 1. The approach in stage 4 is to check that those conclusions are still valid in light of the new GI information. By inspection, ground conditions were confirmed to be less favourable. Therefore, the do nothing option previously discounted was not investigated further. This phase of design focussed on whether the proposed 1 in 2.5 slope was still considered adequate taking account of the new ground model.

A thorough review of supplementary GI results along the crest of the slope has revealed variable conditions. Essentially, very loose granular deposits were identified beneath the slope, which corresponds to loose ash fill end tipped when the sidings were formed, with more dense material further back beneath the plateau giving rise to ground model 5B. Additionally, zones of localised cohesive material were also found.

The variable topography and existing slope angles appear to correlate with the update GI information: slopes that are shallower than the steepest section previously analysed are now understood to match areas where loose materials are present. The cohesive deposits occur where slope angles are locally steeper than the angle of repose for a purely granular material.

The ground conditions are worse than previously assessed. An assessment has therefore been undertaken at stage 4 design to check whether the proposed regrading of the slope to 1(v) in 2.5(h) and reducing the crest level still serves to adequately mitigate the risk of instability, or whether any modification to the design is required.

Ground models 5A, 5B and 5C were analysed using the variable groundwater conditions described in section 3.3.9.

5.2 Stability analysis

A 1 in 2.5 regraded slope (Topographical section 5 and section 6, **Sketch 07**) including the 2m wide footpath at the river edge was assessed using an EC7 Combination 2 approach. The river wall was modelled as a 1m wide masonry block to force slips above or below the wall. A surcharge of 10kPa was also applied across a 3m width, 1m offset from the crest of the slope, representing light maintenance activity at the crest of the slope. Refer to Table 10 for clarity on slope stability sections with ground models. The slope runs related to all ground models 5A, 5B and 5C can be seen in Appendix B.

Table 10: Slope stability analysis runs in relation to ground models

Ground model reference	Description	Topography section for slope stability
5A	Cohesive band as seen in sketch 08A and 08B	6
5B	Weak granular material at slope front seen in figure 07, Sketch 08C	5
5C	Weak granular material at top of slope, and stronger material below seen in figure 07, Sketch 08C	5

For analysis purposes, the cohesive made ground seen in ground model 5A was modelled as a continuous layer. Circular slip mechanisms were assessed. It is recognised by the designer that localised circular slips at the toe of the slope can result in progressive shallow secondary slips further up the slope. This effect has been considered 'by inspection' by the designer when reviewing the location of the critical slip surfaces. The analysis is focused on deeper slips that could potentially undermine the existing river wall.

The results from the analyses are summarised in Table 11 and presented in Appendix B.

Table 11: Over design factors for deep circular slips at topography section 5 and 6 of the plateau slope regrade zone

Condition	Topography section 6 ODF for ground model 5A (normal GWL)	Topography section 6 ODF for ground model 5A (Post flood GWL)	Topography section 5 ODF for ground model 5B (normal GWL)	Topography section 5 ODF for ground model 5B (Post flood GWL)	Topography section 5 ODF for ground model 5C (normal GWL)	Topography section 5 ODF for ground model 5C (Post flood GWL)
Drained	1.2	1.0	1.2	1.0	1.2	1.1
Undrained	1.2	1.0	N/A	N/A	N/A	N/A

Although the ground conditions indicated by GI are more adverse than was reported in the preliminary GDR, the slope stability analysis still resulted in a minimum over-design factor of 1.0 for the regraded 1 in 2.5 slope. Both stability analysis at topography sections 5 and 6 have reported similar results for long term drained conditions. The analyses incorporating the clay band in ground model 5A and the more dense material below 32.0mAOD in ground model 5C did not have much effect on the results. The minimum over design factors were obtained from post-flood analyses, assuming conservative rapid drawdown conditions.

5.3 Conclusions and recommendations

The existing slopes do not meet current design standards, have low global factors of safety and there is evidence that instability has occurred in the past. The risk of further instability within the existing slope is considered too high for a 'do nothing' option.

Engineered solutions were sought to bring the slope to current design standards, considering the potential hazards which impact slope stability and mitigating risk to more reasonable levels for acceptance by MCC and FEC.

Using engineering principals of slope stability regardless of the actual soil parameters, the slope stability can be improved from the current position of marginally stability by:

- Reducing the weight at the top of the slope
- Improving the weight at the toe
- Reducing water levels

The Stage 4 analysis considers two of the engineering principals to improve stability of the slope.

Alternative solutions for slope stabilisation have been considered and discounted, due to practicality, cost benefit and effectiveness.

The updated ground model for this area suggested that the plateau slope is not consistent in stratigraphy, and therefore three ground models were analysed. The analyses of the three models are presented in this report:

All ground models were modelled adopting a 1 in 2.5 design slope under a range of groundwater conditions, in accordance with recommendations presented in the Preliminary GDR. For both sections modelled, all deep-seated slips yielded ODF values greater than or equal to one in EC7 combination 2 conditions. Therefore, the design 1:2.5 slope and 38.5mOD plot level proposal remains appropriate.

The presence of a clay band in ground model 5A did not materially affect the outcome of the analysis, nor did the introduction of a more dense, higher strength layer below 32.0mAOD in ground model 5C.

It is recommended that the 1 in 2.5 design slope, with reduced platform level of 38.5mOD to minimise building plot footprint reduction is adopted. The removal of material to achieve this modification is presented in the Earthworks Specification (VNIF-ARP-ZZ-YYY-SP-C-001).

An option to split the plot level, with the riverward part of the plot at 38.5mOD and the landward area closer to existing ground level could be considered. This has not been assessed in this GDR and further analysis would be required if this option is to be pursued.

6. P&P slope stability assessment

6.1 Introduction

The existing P&P slope includes an access ramp from the P&P bridge which will be used for emergency vehicles. The access road ascends to the crest level, which is where the cross section used in the slope stability assessment is taken (refer to topographical section 7, Sketch 02). This therefore represents the steepest continuous gradient, which is approximately 32^{o} down to the riverbank adjacent to the weir. No evidence of instability has been observed or seen on aerial imagery, and vegetation coverage remains intact.

6.1.1 Summary from previous assessment

The Preliminary GDR concluded that the existing P&P slope has a global factor of safety close to one, which does not meet current design standards. This means that it is marginally stable, and changes to ground or groundwater conditions, increased crest load, or reduced toe weight could trigger instability. The steepest section of slope was found to be entirely dependent upon the toe retaining wall, both for stability and to prevent erosion and progressive degradation of the slope.

It was also observed that the slope has marginal stability for deep seated slips beneath the river wall. Critical slips did not extend beyond the crest of the slope into the development area. However, it should be noted that if a slip were to occur on the lower slope, it would leave the upper slope over steep and result in progressive, secondary slips impacting beyond the crest. The stability risk at this location is not considered as high as the plateau slope. Therefore, there was a case for leaving the existing vegetation un-touched and accepting the existing slopes do not meet current standard.

6.1.2 Managed risk approach

Although a 1 in 2.5 slope regrade solution would mitigate the identified risk of slope instability in the P&P zone, the environmental impact associated with regrading the existing slope was considered to be high. The Preliminary GDR therefore recommended that this slope should be left in its current condition, and that a managed risk approach should be adopted with a defined risk zone which avoids increased loading on the crest of the existing slope and avoids development within the risk zone.

6.1.3 Stage 4 assessment approach

The current stage 4 assessment was undertaken to validate the recommendations of a managed risk approach, taking into account the full available data set. The approach at stage 4 is to focus on the critical mechanisms related to the potential deep slips that could occur where the slope is at its steepest gradient and loading is at the slope crest. The preliminary GDR concluded that the lower slope/berm interaction to the north of the P&P slope area were satisfactory, would not change the managed risk zone and did not suggest any critical slips that could undermine the existing river wall, therefore these have not been assessed any further.

A thorough review of the updated GI data has revealed ground conditions which are more favourable than considered in the preliminary GDR. Essentially, most of the P&P area is distinguished by soft to firm cohesive made ground rather than loose granular made ground. This correlates with the existing steep topography that is present and lack of instability from aerial photography observations.

Regarding asset 6, both ground models 6A and 6B were assessed using the same variable groundwater conditions that were adopted at the plateau slope, i.e. conservative “normal” groundwater levels and rapid drawdown following a 1 in 100-year river flood event. Ground model 6B (based on **sketch 09B**) represents the most onerous likely conditions which uses stratigraphical data pulled in from BH310 to provide an indication of ground conditions at the toe of the slope.

The stage 4 approach will be to reassess the steepest slope with the new ground conditions and to update the managed risk zone that was established in stage 3.

6.2 Stability analysis

The existing steepest slope section (Topography section 7, **sketch 07**) including the 2m wide footpath at the river edge was assessed using an EC7 Combination 2 approach. The river wall was modelled as a 1m wide masonry block to force slips above or below the wall. A surcharge of 10kPa was also applied across a 3m width, 1m offset from the crest of the slope, representing the potential for emergency vehicle access at the crest of the slope. The results are summarised in Table 12. The slope runs for both ground models can be seen in Appendix B.

Table 12: Over design factors for deep circular slips at Topography section 7 of the P&P slope zone

Condition	Topography Section 7 ODF for ground model 6A (normal GWL)	Topography Section 7 ODF for ground model 6A (Post flood GWL)	Topography Section 7 ODF for ground model 06B (normal GWL)	Topography Section 7 ODF for ground model 06B (Post flood GWL)
Drained	1.0	1.0	1.0	1.0
Undrained	1.0	1.0	1.0	1.0

The presented results are for deep slips which could undermine the existing river wall. Both ground models (6A and 6B) suggest an EC7 over-design factor of between 1 and 1.1 for both drained and undrained conditions under conservative normal groundwater conditions and post river flood levels at this location. Therefore, as expressed in the preliminary GDR, the P&P slope zone experiences stability above unity and satisfies EC7 Combination 2 conditions.

However, as pointed out in the previous GDR, there is still potential for shallow slips. For ground model B, the weak clay layer behind the river wall which represents less favourable ground conditions at toe of the slope could facilitate some shallow slips, especially under the 100-year river flood conditions. However, it must be noted that the slope is currently well vegetated which will be introducing cohesion along the slope surface to help stabilise potential slips, which has not been considered in the slope analysis. The potential slip volumes are relatively small and does not impact the development area behind the crest, therefore these will be addressed as part of the managed risk approach.

The ground water profile for the 100-year flood scenario assumed high water levels behind the wall which had an effect on decreasing the ODF value. However, it is considered unlikely that rapid drawdown conditions will actually develop because the material below flood level is low permeability clay, therefore in a transient flood even the flood water will not penetrate far into the ground. Consequently, the analysis assuming rapid drawdown is very conservative.

The analyses also yielded over-design factors for shallow slips close to unity. However, the analysis does not take into account the stabilising effect of vegetation on the near surface soils, consequently the ODF's for near surface slips is likely to be underestimated. The associated slips do not intrude the development zone. Notwithstanding the comments above, two inclinometers have been installed to monitor the slope and a monitoring programme commenced.

6.2.1 Risk zone update

The results from the stage 4 slope run analysis suggests that potential deep slips with ODF's close to unity extend behind the crest (emergency access road) as shown in Appendix B, but do not reach the development area. The analysis has shown that for slip surfaces that daylight on the plateau less than 50m back from the crest of the slope, ODF's are between 1.1-1.4, albeit greater than unity. Therefore, this information is used to identify and update the risk zone where there should be no development, no new landscaping and no temporary loading. Beyond this distance, the analyses shows that the ODF is substantially greater than 1.5.

Taking into account the stage 4 analysis, the risk zone defined in the preliminary GDR has been slightly modified and the revised zone is shown in Figure 10.

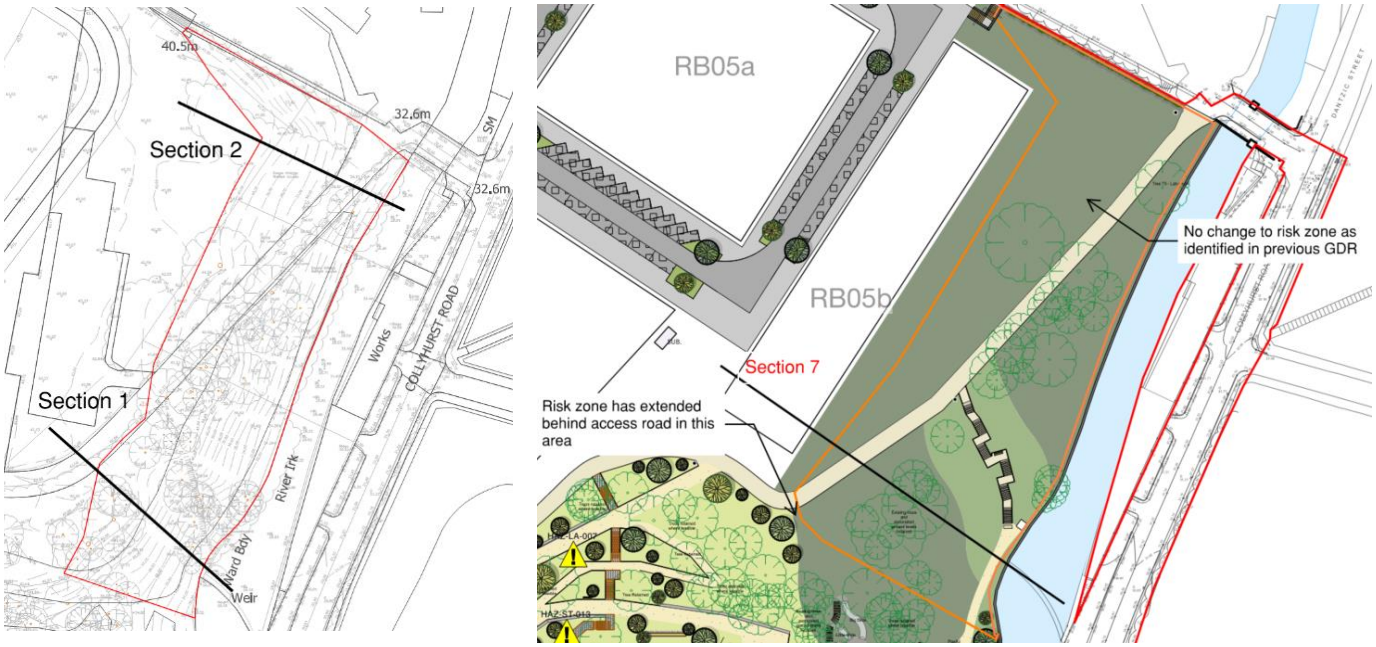


Figure 10: Stage 3 risk zone shown to the left. Updated Stage 4 risk zone marked on the masterplan (VNIF-PLA-ZZ-YYY-DR-L-1011) shown to the right

6.2.2 Off-site slope areas

There is an area of sloping ground beyond the northern site boundary which appears steeper than 1 in 2.5. Given the steepness of this slope, there still remains a risk for slope instability if the current loading conditions on this external slope were increased. Currently there are no proposed developments that would increase surface loading in this zone. Data from the inclinometers (relating to BH301 in particular) will be used for assessing the long-term monitoring of this part of the slope in reaction to potential changes in conditions.

6.3 Conclusions and recommendations

The additional ground investigation information has resulted in an updated ground model for this area of the site which includes a greater proportion of cohesive material than was modelled in the preliminary GDR. This cohesive material is typically a soft to moderately firm clay. The subsequent slope stability assessments have confirmed the conclusion reached in the preliminary GDR that the current profile can be retained, with a managed risk approach being adopted.

The post 1 in 100 year flood event rapid drawdown scenarios yielded the lowest over design factors (1.0) for significant slips. However, the rapid drawdown case modelled is considered to be highly conservative due to the low permeability of the cohesive made ground which will limit the extent to which flood water penetrates. The ODFs calculated for rapid drawdown are therefore likely to be underestimated. Notwithstanding, it should still be identified as a future risk which needs to be considered in the remediation and modification of the river channel as part of the river works programme.

The existing lower slopes do not meet current design standards, as mentioned in the preliminary GDR and proven to be the case in this GDR; however, this area of potential instability is related to shallow slips which are considered to be small scale and manageable, therefore will not be modified which reduces the environmental impact.

Given the findings of the assessment described above, the original proposal of a managed risk approach to this existing slope, with a defined no-development zone at the top of the slope, is considered to remain valid. The design development has incorporated the requirement of the preliminary GDR to avoid developing in the risk zone and to avoid increased crest loading (e.g. additional landscaping).

The preliminary GDR recommended the installation of inclinometers and that a monitoring programme should be established. During the 2022 GI, inclinometers were installed in BH301 and BH302, and these are being used to establish the baseline prior to commencement of the works and monitor for evidence of movement in the P&P slope area. Available monitoring data indicates some possible evidence for movement. The data requires validation, and further monitoring data is required before any firm conclusions can be drawn regarding the current stability of the existing slopes. Prior to commencement of the works, a monitoring plan will be developed which will set out slope monitoring locations and frequency and will establish trigger values for the initiation of additional monitoring, further investigation or remedial action. The monitoring plan will also include identify responsibility and communication requirements for the monitoring results and actions.

The inclinometer installations BH301 and BH302 are to be protected as stated on drawing VNIF-ARP-00-YYY-DR-CE-0008 to allow for sufficient long-term monitoring.

7. Geotechnical risks

7.1 Risk register

Refer to extracts of the project CDM risk register which also include additional risks related to specific GDR elements. Presented in Appendix C

7.2 Key ground risks

The following are considered to be key ground risks for the scheme:

- Highly variable ground conditions with risk of ground conditions encountered during the work being different to those identified and modelled to date.
- Unforeseen instability of plateau slope during the regrade excavation works.
- Temporary loading resulting in instability during the works.
- Risk of buried obstructions impacting works, particularly during the construction of the Creamline retaining wall.
- Existing retaining wall depth is not proven as construction forms are unknown, therefore there is a risk of stability.
- Embankment design accounts for presence of granular deposits where settlement rates are expected to be quick. Should more extensive cohesive material be present then consolidation may take more time to occur across the full stretch of the road embankment, resulting in residual settlement impacting the finished highway surface or services.
- Risk of sewer impacting slope regrade works at Asset 5. The works should plan for diversion/relocation of this and safe temporary works should be installed in the vicinity of the sewer.
- Contact with contaminated land during excavation and construction of the retaining walls including Asbestos material and needlestick injuries.

7.3 Uncertainty, hazard and risk assessment for slope stability

The following sub sections describes principles of uncertainty, hazard and risks that were used when assessing the plateau slope and P&P slope.

7.3.1 Uncertainty

The ground is variable, it being made ground, and all infrastructure construction will be in contact with this. Therefore, the following considerations are critical to slope stability:

- Soil variability;
- varying groundwater in slope; and
- changing in loading on slope.

Changes to the existing groundwater regime experienced by the slope are expected due to:

- Potential impact of SuDs solutions along Redbank Plateau on groundwater paths;
- New features on the site which promote new water pathways; and
- Climate change/varying river conditions which has been assessed.

Unknown loading in future needs to be considered with respect to the potential impact it may have of existing slope stability.

7.3.2 Hazards

The following hazards have been identified as potentially impacting the steep slopes along the plateau edge:

- Deep slip due to removal of the toe of the slope:
  - By the action of the river, and
  - By deterioration of river wall.
- Deep slip due to increase loading on crest.
- Potential reduction in deep slip surface factor of safety due to:
  - Varying groundwater and new groundwater paths,
  - Variation of groundwater in slope during flood events, and
  - Vibration of piling impacting friction/pore water pressure.

Evidence of shallow slips affecting the slope as a result of gradual deterioration and the material reverting to its ‘angle of repose’ due to its granular nature.

Due to evidence of instability within the slope it is considered that there is a reasonably high risk of further instability developing in the future prior to works.

8. Construction validation and monitoring

The following construction validation and monitoring are recommended:

- Ground conditions at foundation formation level (all design elements) to be inspected by a suitably qualified geotechnical engineer/engineering geologist. There is potential for the buried existing viaduct retaining wall to be uncovered at formation level, so careful inspection and removal is required.
- Continue to monitor inclinometers installed in BH301 and BH302 for any stability issues concerning the P&P slope before works are instated, and later review the data to consider whether monitoring is needed post development.
- A program of monitoring should be undertaken to monitor settlement of soils underlying the proposed embankment at specified locations. Refer to Specification ref (VNIF-ARP-ZZ-YYY-SP-C-001) which outlines the strategy.
- Place and testing of earthworks materials in accordance with specification requirements.
- Post construction survey to confirm design gradients and levels have been achieved.

Sketches

A1

KEY

SITE BOUNDARY

PROPOSED HARDWORKS

Refer to detail drawings VNIF-PLA-ZZ-YY-DR-L-5000-5002 for more information.

S1 — **CLAY PAVING** - Pedestrian grade
Product: Netland Clay Paving by Handscape (DSA)
Colour: several colour mixes in warm buff tones, subject to further detailed design.
Size: 200mm(l) x 50mm(w) x 85mm(d)
Finish: sanded/watertruck (TBC)
Laid: stretcher/herringbone bond as shown (TBC)

S1.1 — **CLAY PAVING** - Vehicular grade
Product: Netland Clay Paving by Handscape (DSA)
Colour: several colour mixes in warm buff tones, subject to further detailed design.
Size: 200mm(l) x 50mm(w) x 85mm(d)
Finish: sanded/watertruck (TBC)
Laid: stretcher/herringbone bond (TBC)

S2 — **HRA SURFACING (Vehicular)**
Location: to vehicular carriageway on Plateau Avenue
Material: HRA to Arup details and specification. Refer to Arup drawings.
VNIF-ARP-00-YYY-DR-CH-3006-3007

S2.1 — **HRA SURFACING (Temporary Carriageway)**
Location: to vehicular carriageway on Plateau Avenue
Material: HRA to Arup details and specification, Surface Course not to be installed for temporary carriageway. Refer to Arup drawings
VNIF-ARP-00-YYY-DR-CH-3006-3007

S2.2 — **PERMEABLE SURFACING (Parking/Loading Bays)**
Location: to parking and loading bays on Plateau Avenue
Material: Permeable block paving, Surface Course not to be installed for temporary carriageway. Refer to Arup drawings
VNIF-ARP-00-YYY-DR-CH-3006-3007

S2.3 — **ASPHALT SURFACE (Pedestrian)**
Location: to pedestrian routes on Plateau Avenue
Material: Asphalt Surfacing, Surface Course not to be installed for temporary footway. Refer to Arup drawings VNIF-ARP-00-YYY-DR-CH-3006-3007

S3 — **NATURAL STONE SETT PAVING**
Location: to St Catherine's Wood entrance area, Union Waterfront & Red Bank Terrace
Material: European granite natural stone setts
Colour: warm buff tones (TBC)
Size: 100mm (l) x 100mm (w) x 80mm (d)
Finish: cropped sides, flamed/picked top (TBC)
Laid: stretcher bond, with single course of setts to perimeter edges.

S4 — **RESIN BOUND GRAVEL SURFACING**
Resin Bound Gravel
Spec: Addaset Resin Bound Surfacing System
Supplier: Addagrip
Finish/Colour/Bond: 1-3mm New Scandinavian Pearl.
Refer to detail drawing
VNIF-PLA-ZZ-YYY-DR-L-5000 for more information

S5 — **GREEN GAP BLOCK PAVING**
Location: to Union Bridge Waterfront
Product: Reclaimed cobbles with spacers incorporated, further details tbc
Colour: TBC
Size: TBC
Finish: TBC
Laid: linear bands with gaps for planting/grass

S6 — **STEEL GRATING DECKS**
Location: Red Bank Terraces, St Catherine's Wood
Material: Corten steel structural frame with galvanised steel deck infill.
Grating Product: Walkway Grating Serrated by Weland AB (USA). To meet required slip resistance standards
Finish: Corten frame, galvanised steel deck/grating

S6.1 — **STEEL GRATING STEPS**
Location: Red Bank Terraces, St Catherine's Wood
Material: Corten steel structural frame with galvanised steel deck infill.
Grating Product: Walkway Grating Serrated by Weland AB (USA). To meet required slip resistance standards
Finish: Corten frame, galvanised steel deck/grating

S6.2 — **TACTILE HAZARD WARNING STRIPS**
Location: Red Bank Terraces and St Catherine's Wood wherever there are steel grating steps
Material: Tactile strips mechanically fixed to metal decking or rust fixed into groundplane

S7 — **COMPOSITE TIMBER DECKING**
Location: to elevated walkway/cycle route in St. Catherine's Wood and Union Waterfront deck
Corten steel structural frame with composite deck surfacing.
Surfacing Product: Lasta-Grip composite decking by Millboard (USA)
Colour: Coppered Oak
Finish: to meet required slip resistance

S8 — **PRE-CAST CONCRETE STEPS**
Location: to Union Bridge Waterfront and Red Bank Terraces
Material: Pre cast concrete with stone aggregate
Product: Mix design ref BLSC185
Supplier: Evans Concrete Products Ltd (USA)
Colour: buff/natural tone
Finish: combination of light/medium/heavy acid etched finishes with contrasting nosings

S8.1 — **PRE-CAST CONCRETE SEATING STEPS**
Location: to Union Bridge Waterfront and lower Red Bank Terraces
Material: Pre cast concrete with stone aggregate
Product: Mix design ref BLSC185
Supplier: Evans Concrete Products Ltd (USA)
Colour: buff/natural tone
Finish: combination of light/medium/heavy acid etched finishes

S8.2 — **TACTILE CORDUROY HAZARD PAVING**
Location: Red Bank Terraces and Union Waterfront wherever there are steps
Material: natural stone corduroy paving units
Colour: European granite natural stone, colour to contrast with step units (TBC)
Size: 400mm (l) x 400mm (w) x 50mm (d)
Finish: flamed
Laid: stack bond

S9 — **TACTILE BLISTER HAZARD PAVING**
Location: road crossings
Material: pre-cast concrete blister pavers
Colour: natural TBC
Size: 400mm (l) x 400mm (w) x 50mm (d)
Finish: as cast
Laid: stack bond

S11 — **BARK CHIPPINGS**
Location: to secondary pedestrian paths in St. Catherine's Wood
Material: Bark chippings, opportunity to use chipped site wood timber from tree clearance

S11.1 — **TIMBER SLEEPER STEPS ALONG BARK PATH**
Location: to informal tertiary routes within St Catherine's Wood
Material: Pressure treated FSC timber sleepers
Colour: natural
To have GRP Anti-Slip flat plate strips by GripClad (USA) to be mechanically fixed to the sleeper tops.

S12 — **RUBBER BARK LOOK CHIPPINGS**
Location: to St. Catherine's Wood Play Area
Material: Tiger Bark or similar and approved
Colour: natural

S13 — **STEPPING STONE PATH**
Location: to St Catherine's Wood tertiary routes
Material: European granite natural stone slabs
Colour: buff/natural tones TBC
Size: 800m(L) x 400mm(W) x 75mm(D)
Finish: to meet required slip resistance TBC
Laid: on concrete haunchings

S14 — **TEMPORARY TARMACADAM SURFACING**
Location: to provide link between Union Waterfront and Red Bank Terraces
Material: Asphalt to engineers details and specification.
Note: to be replaced by future landscaping

S15 — **COLOURED ASPHALT SURFACING**
Location: to ridge promenade at Plateau level and cyclist loop on Red Bank Terraces
Material: Buff /Viscolour by Tarmac or similar and approved.

S16 — **TIMBER SLEEPERS IN SELF BINDING GRAVEL**
Location: to Red Bank Viaduct
Self Binding: Breedon Golden Amber Gravel or similar and approved.

PROPOSED SUBSTATION

RB05 — **PLOT FOOTPRINT**
Plot groundworks prepared but no construction work as part of HIF infrastructure.

EXISTING CONDITION
No groundworks or preparation as part of HIF infrastructure work.

PROPOSED SOFTWORKS

PROPOSED TREE PLANTING
Subject to further detailed design

EXISTING TREES RETAINED
Subject to further detailed design

EX1 — **EXISTING WOODLAND RETAINED**
To St. Catherine's Wood

EXISTING WOODLAND ENHANCED

M1 — To St. Catherine's Wood
Refer to drawing for notes
Approx area: 12215m²

M2 — **WOODLAND MATRIX MIX**
To St. Catherine's Wood
Refer to drawing for notes
Approx area: 5980m²

M3 — **WOODLAND EDGE MIX**
To St. Catherine's Wood
Refer to drawing for notes
Approx area: 1265m²

M4 — **ORNAMENTAL PLANTING**
To Red Bank Terraces
Refer to drawing for notes
Approx area: 3155m²

M5 — **ORNAMENTAL PLANTING**
To Viaduct Linear Park
Refer to drawing for notes
Approx area: 1422m²

M6 — **AQUATIC MARGINAL VEGETATION**
To Rivers Edge
Refer to drawing for notes
Approx area: 2690m²

HEDGE PLANTING
Mixed native species hedgerow mix to northern boundary
Approx area: 73m², Approx length: 50m

RB05a
RB05b
RB05c
RB03
RB02
RB01
RB12b
RB12a
RB11
RB08
RB07
RB09
RB06
RB16
RB17
NT04
NT03
NT02
NT01

Asset 1
Asset 2
Asset 3A
Asset 3B
Asset 4
Section A
Section B

PEEL LANE
COLLINGHAM STREET
PEEL LANE
QUAYSIDE STREET
DANTZIC STREET
DALTON STREET
NEW QUAY STREET
ST THOMAS PLACE
RED BANK
HONEY STREET
HONEY STREET
RED BANK
RED BANK
RED BANK
DANTZIC STREET
DANTZIC STREET
DALTON STREET
DALTON STREET
DALTON STREET
BROMLEY STREET
BROMLEY STREET
BURSTOCK STREET
BLEAKLOW STREET
WILLIAMSON STREET
PICKAY STREET
NEW QUAY STREET
Union Bridge
Signal Gantry
Footbridge

0 10 20 50 100
Scale bar (m)

Do not scale

NOTE: Future Plot Extents are Indicative Only

Revision Notes:

1. Plateau Avenue - layout updated to incorporate Arup revised layouts
2. Drainage basin - layout & levels updated to coordinate with Arup's storage strategy.
3. Steps to north of SCW - levels reviewed and additional steps added to meet plot levels on RB05
4. Cycle parking relocated

Rev	Date	Description	By	Chkd	Appd	Auth
P03.03	25.05.22	Interim GA Issue - for coordination	BM/SR	MS	GB	GB
P03.02	03.05.22	Interim GA Issue for costing	BM/SR	MS	GB	GB
P03.01	22.04.22	Interim GA issue - for coordination/costing	BM/SR	MS	GB	GB
P03	07.03.22	Costing	BM	MS	GB	GB
P02.08	02.03.22	Final Draft Planning	CL	MS	GB	GB
P02.07	14.02.22	Draft Planning	CL	MS	GB	GB
P02.06	14.02.22	Draft Planning	BM	MS	GB	GB
P02	11.02.22	Draft Planning	BM	MS	GB	GB
P02.05	04.02.22	Draft Planning	BM	MS	GB	GB
P02.04	31.01.22	Draft Planning	SR	MS	GB	GB
P02.03	27.01.22	Draft Planning	BM	MS	GB	GB
P02.02	27.01.22	Draft Planning	BM	MS	GB	GB
P02.01	25.01.22	Draft Planning Issue	BM	MS	GB	GB
P01	17.12.21	Stage 3 Issue	SR	MS	GB	GB
P01.02	10.12.21	For Information	SR	MS	GB	GB
P01.01	07.12.21	For Information	SR	MS	GB	GB

Client

MANCHESTER CITY COUNCIL
bam nuttall

Project Title

Victoria North HIF Infrastructure

Key Plan

Current Masterplan showing the location of structure assets

Sketch 01

Drawing Title

Landscape General Arrangement
HIF Delivery Plan

Scale at A1	Planit-IE Job No
1:1000	2700

Role: Landscape Architect

Suitability: S4

Rev	By	Chkd	Appd
P03.03	SR	MS	MS
	Date	Date	Date
	03.05.22	03.05.22	03.05.22

Name

Project	Originator	Volume	Location	Type	Role	Number
VNIF	PLA	ZZ	YYY	DR	L	1011

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ARUP

Job Title
Victoria North

Cross section line locations for slope stability assessments

Job No
282022

Sketch 02

A3

384400 384600 384800

399800 399600 399400

BH301D BH301B BH301 BH301A BH301C TT303A TP206A TT302 TP208 TT303 BH203 TP204 TT301 BH315 TP205 TP105

BH201 TP101 BH101 TP209 TP201 WS201B WS201 WS201A TP202A TP103 TP213 WS202 BH301D BH301 TP206A BH320 TP202 TP202B TP104 TP207 BH203 TP204 TP102 BH205 TP202C TT301 TP105 TP203 TP205 BH202 TP310 TP107 BH204 BH302 TP106 TP108 BH103 BH206 TP210 BH102 WS207 WS205 BH303 TP211 TP111 TP217 TP109 TP110 TP212 BH321 BH310 BH309 WS206 BH209 TP215 BH104 TP304 BH207 TP112 TP216 WS210 BH327 BH328 BH304 WS101 WS103 BH208 TP305 BH326 TP218 BH324 BH323 BH322 WS102 WS204 WS203A WS203 BH105 TP306 WS211 BH210 BH305 WS212 BH311 TP214 BH215 WS213A WS213 TP115 BH312 BH211A BH106 BH313 BH314 TP307 BH306 WS106 BH112 BH213 TP119 TP124 BH107 WS208 WS104 TP120 TP219 BH307 BH110 TP122 WS209 BH212A BH212 TP126 BH308 TP121 TP125 BH109 BH214 BH325 BH214A TP127

Sketch 04A Sketch 04B Sketch 06 Sketch 08A Sketch 08B Sketch 08C Sketch 05 Sketch 09A/B

Legend

Site Boundary

Phase 1 GI
- Borehole
- Trial pit
- Window sample

Phase 2 GI
- Borehole
- Trial pit
- Window sample

Phase 3 GI
- Borehole
- Trial pit
- Window sample

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Issue	Date	By	Chkd	Appd
P0	2022-06-23	LH	LH	LH

Metres 0 25 50 100

ARUP

6th Floor, 3 Piccadilly Place
Manchester M1 3BN
Tel+44(0161) 228 2331 Fax+44(0161)228 6879
www.arup.com

Client
BAM Nuttall Limited

Project Title
Victoria North

Drawing Title
Ground investigation and geological cross section locations

Scale at A3
1:1,900

Arup Job No
282022

Suitability
Preliminary

Name
Sketch 03

Rev
P0

© Arup

Distance along baseline (m)

0 10 20 30 40 50 60 70 80 90

Elevation (mOD)

46 44 42 40 38 36 34 32 30 28 26

GEO_BH215 (-5.8) N29 N19 N20 N23 N22 N19 N23 N36

BH312 (2.9) N6 N14* N97* N31 N38 N214* N300* N130* N500* N1000*

BH313 (7.2) N27 N23 N12 N16 N17 N24 N27 N43 N375* N1500*

GEO_BH211A (-26.6) N4 N10 N9 N5 N13 N3 N11 N16 N5 N333* N750*

BH314 (-9.1) N2 N4 N2 N7 N11 N12 N17 N188* N429*

honey street wall

viaduct wall

Made ground

Glacial till

Chester Pebble Bed Formation

Road embankment passes over existing honey street retaining wall. BH312 and BH313 are used for ground model

BH211A and BH314 are part of the Redbank Terrace ground model (refer to drawing 06)

Ground level from EA LiDAR data

SCALE 1:111V 1:250H @ A3-L

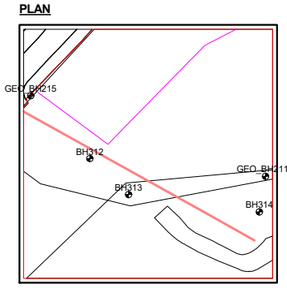
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Made Ground - Concrete [MG-Conc]
- Glacial Till Deposits - Cohesive [GTD - CO]
- Glacial Till Deposits - Granular [GTD - G]
- Chester Formation [CHES]

MATERIALS

- Fill (MADE GROUND)
- Gravelly CLAY
- Clayey gravelly SAND
- Silty gravelly CLAY
- SAND and GRAVEL
- SAND
- SANDSTONE
- Sandy CLAY
- Sandy gravelly CLAY

ARUP

Job Title
Victoria North

Figure Title
Geological cross section and ground model (Asset 1 and 2)

Job No
282022

Sketch 04A

ARUP, gINT v10.00.01.07. Made by Jonny Tyrer on 27-May-22

Library: arup_uklib_4-a-002. Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: c:\gint\victoria northlinfra ++\gint\25-22 - 282022_victoria_north_stage 3 data_inc_riverworks.gpj Rev:P1.1 (SO - Work in progress)

Distance along baseline (m)

0 10 20 30 40 50 60 70 80 90

Elevation (mOD)

48 46 44 42 40 38 36 34 32 30 28

BH311
(-1.3)
N10
N12
N22
N75*
N33
N25
N25
N40
N42
N67*
N375*
N1500*

GEO_TP214
(-4.4)

GEO_WS213
(-4.9)

GEO_WS213A
(-6.9)
N2
N7
N14

01_TP115
(-3.4)

01_BH106
(8.7)
N
N9
N
N15
N
N8
N
N7
N
N11
N
N12
N
N15
N405*
N938*

MG-CO cohesive material beneath proposed embankment.

Made ground

Glacial till

Chester Pebble Bed Formation

Ground level from EA LiDAR data

SCALE 1:111V 1:250H @ A3-L

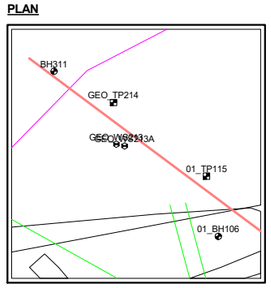
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID
(Offset)
N20*

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Made Ground - Concrete [MG-Conc]
- Glacial Till Deposits [GTD]
- Glacial Till Deposits - Cohesive [GTD - CO]
- Glacial Till Deposits - Granular [GTD - G]
- Chester Formation [CHES]

MATERIALS

- Fill (MADE GROUND)
- Sandy gravelly CLAY
- SANDSTONE
- Gravelly CLAY
- Gravelly SAND
- Silty sandy CLAY
- Sandy cobbly GRAVEL

ARUP

Job Title
Victoria North

Figure Title
Geological cross section and ground model (Asset 1)

Job No
282022

Sketch 04B

ARUP_gINT v10.00.01.07. Made by Jonny Tyrer on 20-Jun-22

Library: arup_uklib_4-a-002; Report: 2_1 01 SECTION WITH WATER & SPT (A3)
Database: C:\gint\victoria north\ifm • I•v gint\68.22 - 282002_victoria_north_stage 3 data_inc_rivenworks.gpj RevP1.1 (SO - Work in progress)

Distance along baseline (m)

Elevation (mOD)

GEO_WS205 (6.6)

BH303 (-8.9)

01_WS101 (11.9)

BH322 (47.4)

01_WS102 (11.5)

GEO_WS204 (-8.2)

Made ground - granular

Historical mill race alluvial deposits - treated a reworked (made ground)

Base of made ground

Marl -bedrock

Alluvium

Water strike.

< 20min Moderate inflow.

?

Ground level from EA LiDAR data

SCALE 1:133V 1:500H @ A3-L

LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID

(Offset)

N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

Water strikes during boring / excavation

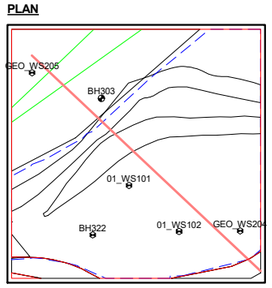
Time for reported water rise and flow rate remarks

20min Steady flow

Level that water rose to

Level of water strike

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Alluvium Cohesive [ALV-CO]
- Alluvium granular [ALV-G]
- Glacial Till Deposits - Cohesive [GTD - CO]
- Manchester Marls Formation [MM]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- Silty Clay
- MUDSTONE
- Clayey sandy GRAVEL
- Sandy CLAY
- Clayey SAND
- SAND
- SAND and GRAVEL
- Sandy gravelly CLAY

ARUP

Job Title
Victoria North

Geological cross section and ground model
St Catherine's Wood (Asset 3 and 4)

Job No
282022

Sketch 05

ARUP, gINT v10.00.01.07. Made by Jonny Tyrer on 24-Jun-22

Library: arup_uk\b_4-a-0\02 Report 2.1.0 \ SECTION WITH WATER & SPT (A3) Database: c:\gints\victoria north\ins +++ gint\08.0122 - 282022_victoria_north_stage 3 data_inc_riverworks.gpj RevP1.1 (SO - Work in progress)

Distance along baseline (m)

0 10 20 30 40 50 60 70 80 90 100

Elevation (mOD)

42 40 38 36 34 32 30 28 26 24 22 20

GEO_BH211A (5.0)
N4 N10 N9 N5 N13 N3 N11 N16 N68* N333* N750*

01_BH106 (-11.3)
N N9 N N15 N N8 N N7 N N11 N N12 N N15 N405* N938* N188* N429*

BH314 (10.1)

GEO_BH213 (-20.6)
N16 N N N691* N1671*

01_TP119 (-25.2)

01_TP120 (9.3)

BH307 (8.3)
N6 N6 N40 N214* N750* N750*

Made ground - granular

GTD - cohesive

?

Chester Pebble Bed Formation

Historical reservoir has been infilled during the expansion of the rail sidings which has caused variation in the Glacial till profile. It is more conservative to assume a greater thickness of made ground because this material is dictating the stability of the structures when looking at the global stability analysis

Ground level from EA LiDAR data

SCALE 1:122V 1:278H @ A3-L

Library: arup_ukllb_4-s-002; Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: C:\gINT\victoria north\victoria north v14.gpj\GEO 22 - 282022_victoria_north_stage 3 data_inc_riverworks.gpj RevP1.1 (SO - Work in progress)

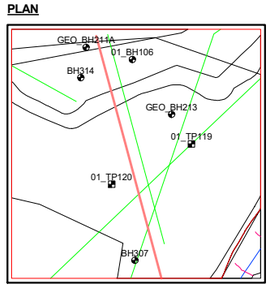
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Glacial Till Deposits [GTD]
- Glacial Till Deposits - Granular [GTD - G]
- Chester Formation [CHES]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- Sandy gravelly CLAY
- SANDSTONE
- SAND and GRAVEL
- Clayey gravelly SAND
- Gravelly SAND
- CLAY
- SAND

ARUP

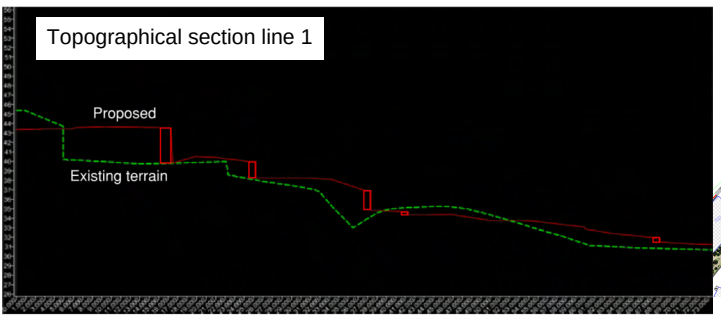
Job Title
Victoria North

Geological cross section and ground model
Redbank Terrace (Asset 3 to 4)

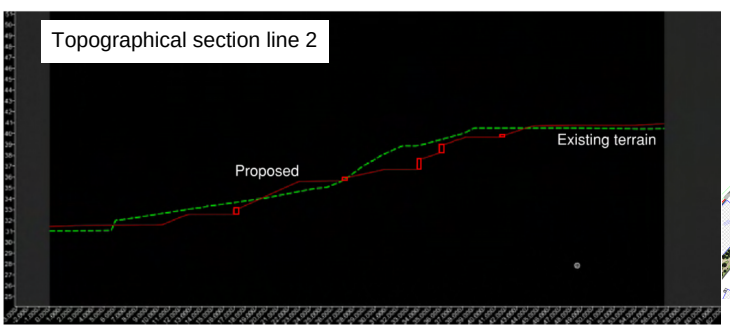
Job No
282022

Sketch 06

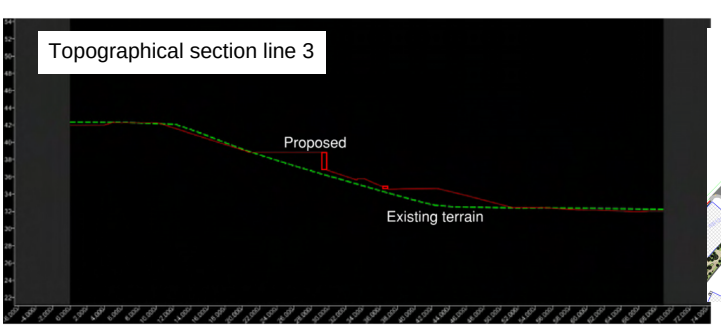
ARUP gINT v10.00.01.07. Made by Jonny Tyrer on 14-Jun-22



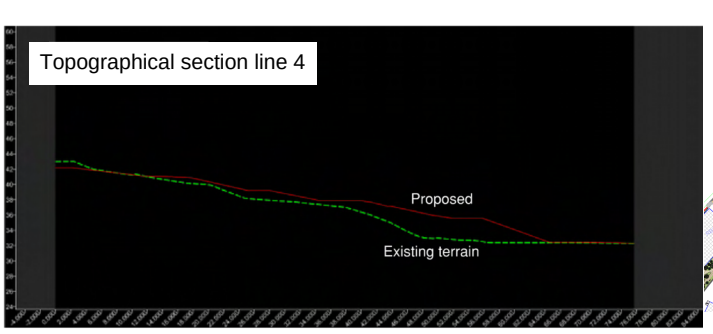




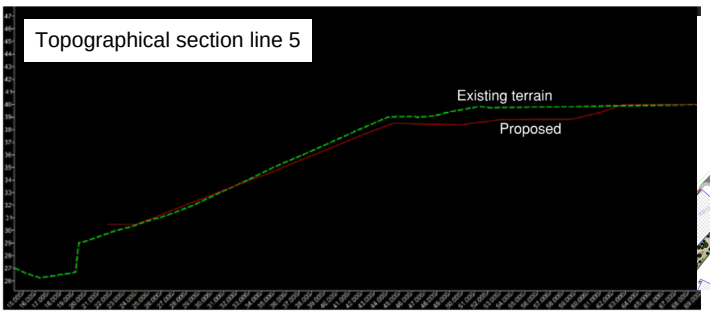




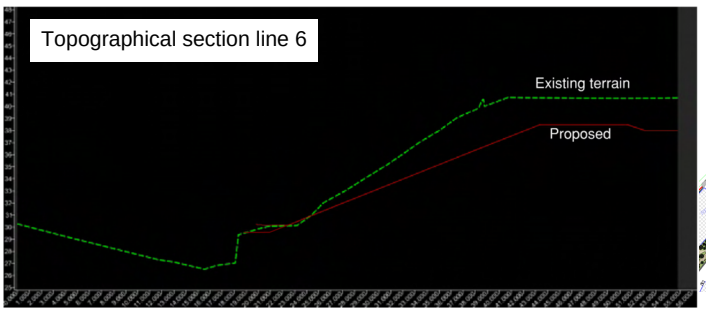




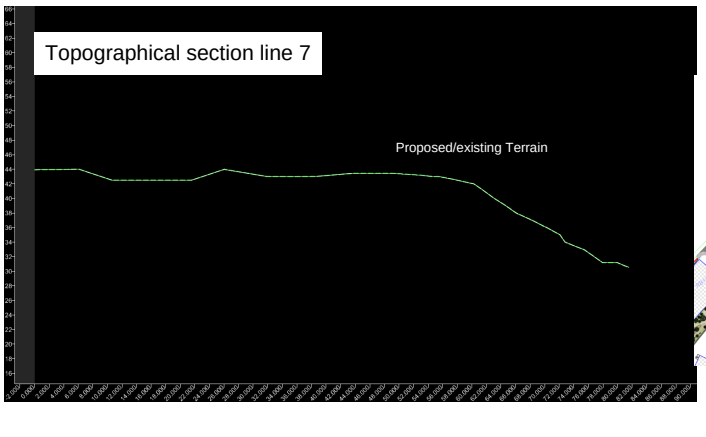














ARUP

Job Title
Victoria North

Figure Title
Topographical section lines used for Slope stability assessments

Job No
282022

Sketch 07

Distance along baseline (m)

Elevation (mOD)

GEO_BH209 (36.4)
GEO_WS207 (-55.3)
01_BH104 (-11.2)
BH327 (8.6)
BH328 (-10.6)
BH304 (-0.1)
BH304A (2.1)
BH323 (-15.8)
52_WS4 (-0.4)

Cohesive pockets

Made ground - granular

Assessed sensitivity to presence of cohesive material in this zone

Cohesive pockets

BH323 is upstream to the east. Bedrock drops in elevation to the west

Design water level behind river wall takes account of 100 year +CC flood event

Original rail viaduct present to the left and rail sidings expanded to the right of this line

Transition from higher density MG behind plateau and loose material forming plateau slope

Assumed relic surface soil material containing tree remnants

Bedrock

Honey street retaining wall

Ground level from EA LiDAR data

SCALE 1:133V 1:389H @ A3-L

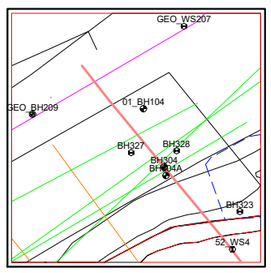
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

PLAN



COLOUR LEGEND

- Made Ground [MG]
- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Alluvium granular [ALV-G]
- Glacial Till Deposits - Cohesive [GTD - CO]
- Glacial Till Deposits - Granular [GTD - G]
- Manchester Marls Formation [MM]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- Sandy gravelly CLAY
- SAND
- CLAY
- SANDSTONE
- TOPSOIL
- Silty gravelly SAND
- MUDSTONE
- Gravelly SAND
- Clayey gravelly SAND

ARUP

Job Title
Victoria North

Ground model 5A
Plateau Slope (Asset 5)

Job No
282022

Sketch 08A

ARUP. gINT v10.00.01.07. Made by Jonny Tyner on 8-Jul-22

Library: arup_gklib_4-a-002. Report: 2.1 01 SECTION WITH WATER & SPT (A3)
Database: c:\gint\victoria north\ifc\ • rw gint2019.2.2 - 282022_victoria_north_stage 3 data_inc_rivenworks.gpj

Distance along baseline (m)

0 10 20 30 40 50 60 70 80

Elevation (mOD)

44 42 40 38 36 34 32 30 28 26 24 22 20 18

GEO_BH208
(11.9)
N19
N19
N25
N19
N20
N7
N3
N13
N4
N8
N13
N85*
N1071*

BH324
(-8.1)
N2
N2
N5
N3
N16
N4
N9
N11
N20
N429*
N1500*

?

?

MG-CO
lenses

Made ground
- granular

Cohesive band at same elevation as BH304. Slope stability analysis is undertaken at this location (centre of regrade zone) using a continuous cohesive band based on clay seen in BH324, BH304 and BH104 to model sensitivity of the layer

Bedrock

?

Ground level from EA LiDAR data

SCALE 1:144V 1:222H @ A3-L

Library: arup_gIntb_4-s-002; Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: C:\gINT\Victoria North\Vic North.GPJ; 22 - 282022_victoria_north_stage 3.data_inc_riverworks.gpj

ARUP gINT v10.00.01.07. Made by Jonny Tyrer on 23-May-22

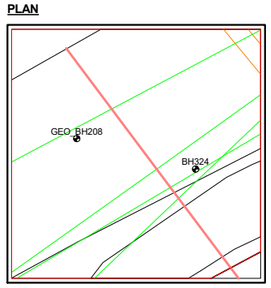
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID
(Offset)
N20*

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Glacial Till Deposits - Granular [GTD - G]
- Manchester Marls Formation [MM]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- Gravelly CLAY
- Clayey gravelly SAND
- MUDSTONE

ARUP

Job Title
Victoria North

Ground model 5A - Topographical section line 6
Plateau Slope (Asset 5)

Job No
282022

Sketch 08B

Distance along baseline (m)

Elevation (mOD)

01_BH105 (27.3)
GEO_WS210 (-39.7)
GEO_BH210 (26.8)
GEO_WS212 BH305 (27.6) (-6)

Loose granular material with no cohesive material

Transition from higher density MG beneath plateau and loose material forming plateau top

Made ground - granular

Design water level behind river wall takes account of 100 year +CC flood event

Glacial Till Deposits

?

>50 SPT - bedrock

Bedrock

?

Ground level from EA LiDAR data

SCALE 1:133V 1:361H @ A3-L

Library: arup_ukltb_4-s-002; Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: C:\gINT\victoria north\vic n v gint\282022 - 282022_victoria_north_stage 3 data_inc_riverworks.gpj; Rev:P1.1 (SO - Work in progress)

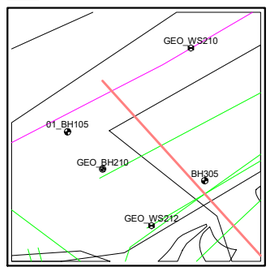
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Glacial Till Deposits - Granular [GTD - G]
- Chester Formation [CHES]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- Silty gravelly SAND
- SAND
- Gravelly SAND
- Silty SAND
- SANDSTONE
- Clayey SAND
- Clayey gravelly SAND
- Clayey sandy GRAVEL

ARUP

Job Title
Victoria North

Ground model 5B - Topographical section line 5
Plateau Slope (Asset 5)

Job No
282022

Sketch 08C

ARUP_gINT v10.00.01.07. Made by Jonny Tyrer on 8-Jul-22

Distance along baseline (m)

Elevation (mOD)

records consistently high groundwater levels

Made ground - granular

BH301 is extrapolated in to the ground model to illustrate that this thick layer of cohesive made ground (approx 10m) Is consistent across the P&P slope area

Made ground - cohesive

GWL based on 100-year flood event - 32.6mOD

Made ground - granular

Made ground - cohesive

Historical mill race

Chester Pebble Beds Formation (bedrock)

BH315 Is extrapolated in to show that cohesive material is still very thick at the middle of the slope area. It also marks the location of the historical mill race which has eroded bedrock level to weathered sandstone (high SPT values)

Ground level from EA LiDAR data

SCALE 1:144V 1:278H @ A3-L

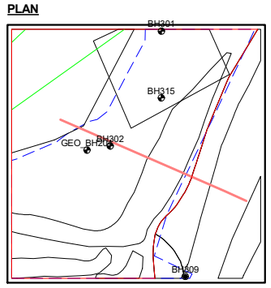
LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Made Ground - Concrete [MG-Conc]
- Alluvium granular [ALV-G]
- Manchester Marls Formation [MM]
- Collyhurst Sandstone Formation [CS]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- SANDSTONE
- TOPSOIL
- Sandy CLAY
- Silty sandy CLAY
- Silty SAND
- Sandy gravelly CLAY
- Clayey sandy GRAVEL

ARUP

Job Title
Victoria North

Figure Title
Ground model 6A - Topographical section line 7
P&P Slope (Asset 6)

Job No
282022

Sketch 09A

ARUP_gINT v10.00.01.07. Made by Jonny Tyrer on 1-Jul-22

Library: arup_uklib_4-s-002. Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: C:\gint\victoria northbiffa • • • v gint282022 - 282002_victoria_north_stage 3 data_inc_riverworks.gpj RevP1.1 (SO - Work in progress)

Distance along baseline (m)

Elevation (mOD)

Made ground
- granular

Made ground
- cohesive

Chester Pebble
Beds Formation
(bedrock)

Alluvium - granular

Made ground
- granular

Made ground
- cohesive

GWL based on 100-year flood event - 32.6mOD

BH315 shows presence of granular material associated with the historical meander bend

BH310 is the nearest borehole to the section which provides ground conditions near the toe of the slope area. This shows the presence of granular material above bedrock and a weaker cohesive layer.

Bedrock increases in elevation westwards (upstream)

Ground level from EA LiDAR data

SCALE 1:156V 1:278H @ A3-L

LEGEND

Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset) N20*

SPT N value, * denotes N extrapolated by gINT: * from main blows ** from seating blows

Piezometer readings

Range of water levels recorded

Piezo response zone

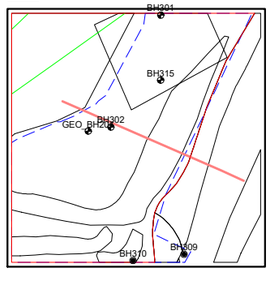
Tip depth

Type of piezometer

SPE

Key to piezo types: SP Standpipe

PLAN



COLOUR LEGEND

- Made Ground - Granular [MG-G]
- Made Ground - Cohesive [MG-CO]
- Made Ground - Concrete [MG-Conc]
- Alluvium granular [ALV-G]
- Manchester Marls Formation [MM]
- Collyhurst Sandstone Formation [CS]
- Assumed ground water profile

MATERIALS

- Fill (MADE GROUND)
- SANDSTONE
- TOPSOIL
- Sandy CLAY
- Silty sandy CLAY
- Silty SAND
- Sandy gravelly CLAY
- Clayey sandy GRAVEL
- Gravelly SAND
- SAND and GRAVEL

ARUP

Job Title
Victoria North

Ground model 6B - Topographical section line 7
P&P Slope (Asset 6)

Job No
282022

Sketch 09B

ARUP, gINT v10.00.01.07. Made by Jonny Tyrer on 12-Jul-22

Library: arup_uklib_4-a-002. Report: 2.1.01 SECTION WITH WATER & SPT (A3)
Database: c:\gint\victoria north\line 4 +ve gint282.6.22 - 282022_victoria_north_stage 3 data_inc_riverworks.gpj Rev:P1.1 (SO - Work in progress)

Appendix A - Geotechnical material properties from updated GIR

The following sections present Geotechnical information taken from the GIR, which is used to assess material parameters for the design work undertaken. Charts are presented to highlight key trends and notes are presented for the method for deriving and correlating material parameters. Estimated parameters are based on chart trends and data after outliers are removed. The following section presents: SPT results, Atterberg results and Shear strength test results.

SPT results

Red Bank Plateau									
Stratum	**No. of tests**	**No. of outliers**	**Lower bound SPT N**	**Upper bound SPT N**	**Average SPT N (excluding outliers)**	**Average SPT N 60 (excluding outliers)**	**Avg. phi (degrees)**	**Cu (kPa)**	**Avg. E' (kPa)**
Cohesive made ground	42	2	2	26	7	7		35	15 000
Granular made ground	78	3	2	27	10	10	30		15 000
Cohesive glacial till	19	7	12	53	20	21		100	44 000
Granular Glacial till	38	8	8	50	15	16	31		24 000
Red Bank Terrace									
Stratum	**No. of tests**	**No. of outliers**	**Lower bound SPT N**	**Upper bound SPT N**	**Average SPT N (excluding outliers)**	**Average SPT N 60 (excluding outliers)**	**Avg. phi (degrees)**	**Cu (kPa)**	**Avg. E' (kPa)**
Cohesive made ground	13	2	6	27	10	10		50	20 000
Granular made ground	36	3	2	27	9	9	30		14 000
Cohesive glacial till	2	0	12	15	14	14		70	30 000
Granular Glacial till	8	1	12	43	20	21	33		30 000
St. Catherine's Wood									

Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Average SPT N 60 (excluding outliers)	Avg. phi (degrees)	Cu (kPa)	Avg. E' (kPa)
Cohesive made ground	39	3	2	25	12	12		60	26 000
Granular made ground	37	1	2	28	10	10	30		15 000
Granular Glacial till	3	0	19	28	22	23	34		34 000
Granular Alluvium	18	2	2	11	7	7	29		11 000
Plateau Slope regrade zone									
Stratum	**No. of tests**	**No. of outliers**	**Lower bound SPT N**	**Upper bound SPT N**	**Average SPT N (excluding outliers)**	**Average SPT N 60 (excluding outliers)**	**Avg. phi (degrees)**	**Cu (kPa)**	**Avg. E' (kPa)**
Cohesive made ground	13	0	2	12	7	7		35	15 000
Granular made ground	53	2	2	20	8	9	30		13 000
P&P slope zone									
Stratum	**No. of tests**	**No. of outliers**	**Lower bound SPT N**	**Upper bound SPT N**	**Average SPT N (excluding outliers)**	**Average SPT N 60 (excluding outliers)**	**Avg. phi (degrees)**	**Cu (kPa)**	**Avg. E' (kPa)**
Cohesive made ground	31	2	2	25	10	10		50	22 000
Granular made ground	5	1	4	8	7	7	29		10 000

Parameters	Method of deriving	Source
Phi' (Granular)	$27.1 + (0.3*SPTN) - (0.00054*SPTN^2)$	Wolf 1989
Undrained shear strength (Cohesive)	5*SPTN	CIRIA 143 - Stroud
E' (Granular)	1.5*SPTN (MPa)	CIRIA 143 - Stroud
E' (Cohesive)	E' = 0.73.(600.Cu)	Barnes f.g 9.8 - Eu vs SPT, PI, OCR

Atterberg Limits

Red Bank Plateau			
Stratum	**No. of tests**	**PI Avg.**	**phi (degrees)**
Cohesive made ground	41	15	27
Cohesive glacial till	24	15	27
Redbank Terrace			
Stratum	**No. of tests**	**PI Avg.**	**phi (degrees)**
Cohesive made ground	5	14	28
St Catherine's Wood			
Stratum	**No. of tests**	**PI Avg.**	**phi (degrees)**
Cohesive made ground	31	15	27
Plateau Slope			
Stratum	**No. of tests**	**PI Avg.**	**phi (degrees)**
Cohesive made ground	7	15	27
P&P Slope			
Stratum	**No. of tests**	**PI Avg.**	**phi (degrees)**
Cohesive made ground	17	15	27

Parameters	Method of deriving	Source	Notes
Phi' (Cohesive)	$42 - 12.5\log_{10}(PI)$	BS8002 - Terzagi and peck	

4.3.1.4.8 For fine soils, the characteristic constant volume (also known as critical state) effective angle of shearing resistance ($\varphi'_{cv,k}$) may, in the absence of reliable test results, be estimated from:

$$\varphi'_{cv,k} = (42° - 12.5\log_{10} I_P) \text{ for } 5\% \le I_P \le 100\% \quad (8)$$

where:

I_p is the soil's plasticity index (entered as a %).

NOTE 1 Equation (8) is based on an expression proposed by Santamarina and Diaz-Rodriguez [23], which fits data presented by Terzaghi, Peck and Mesri [24].

NOTE 2 Values of $\varphi'_{cv,k}$ based on this expression are given in Table 2.

1.1 Quick Undrained tests results

Stratum	average Cu (MG-CO)	Average Cu (GTD-CO)	Notes
Redbank Plateau	35	n/a	MG-CO Cu is similar for QUT result and SPT estimate
Redbank Terrace	12	24	MG-CO value Based on one result – not used. SPT estimate disagrees
St Catherine's Wood	51	n/a	MG-CO Cu is similar for QUT result and SPT estimate
Plot RB02 and RB03 regrade zone	26	n/a	MG-CO Cu is similar for QUT result and SPT estimate
P&P slope zone	51	n/a	MG-CO Cu is similar for QUT result and SPT estimate

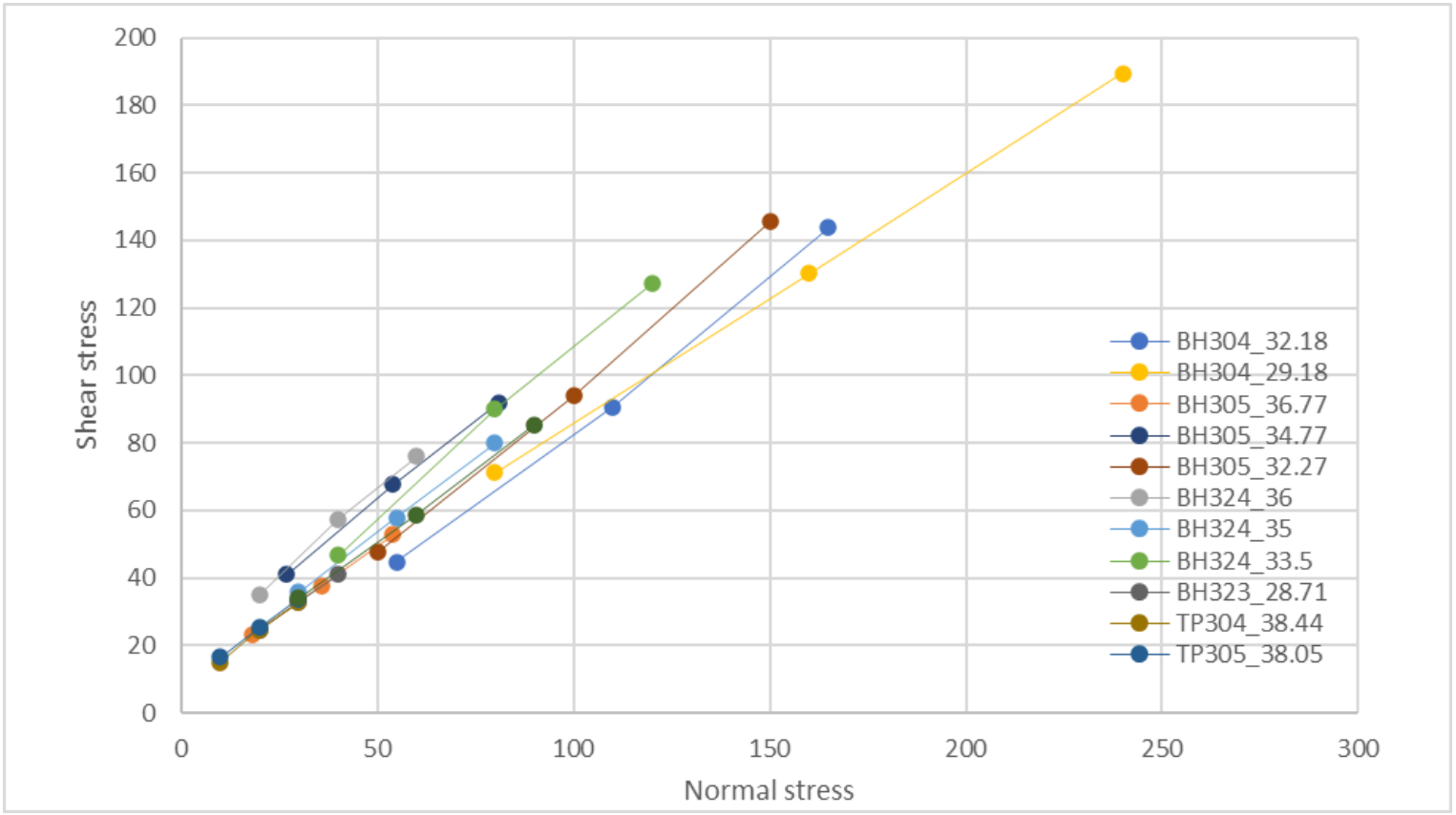
1.2 Undrained triaxial Consolidation results – P&P slope cohesive made ground

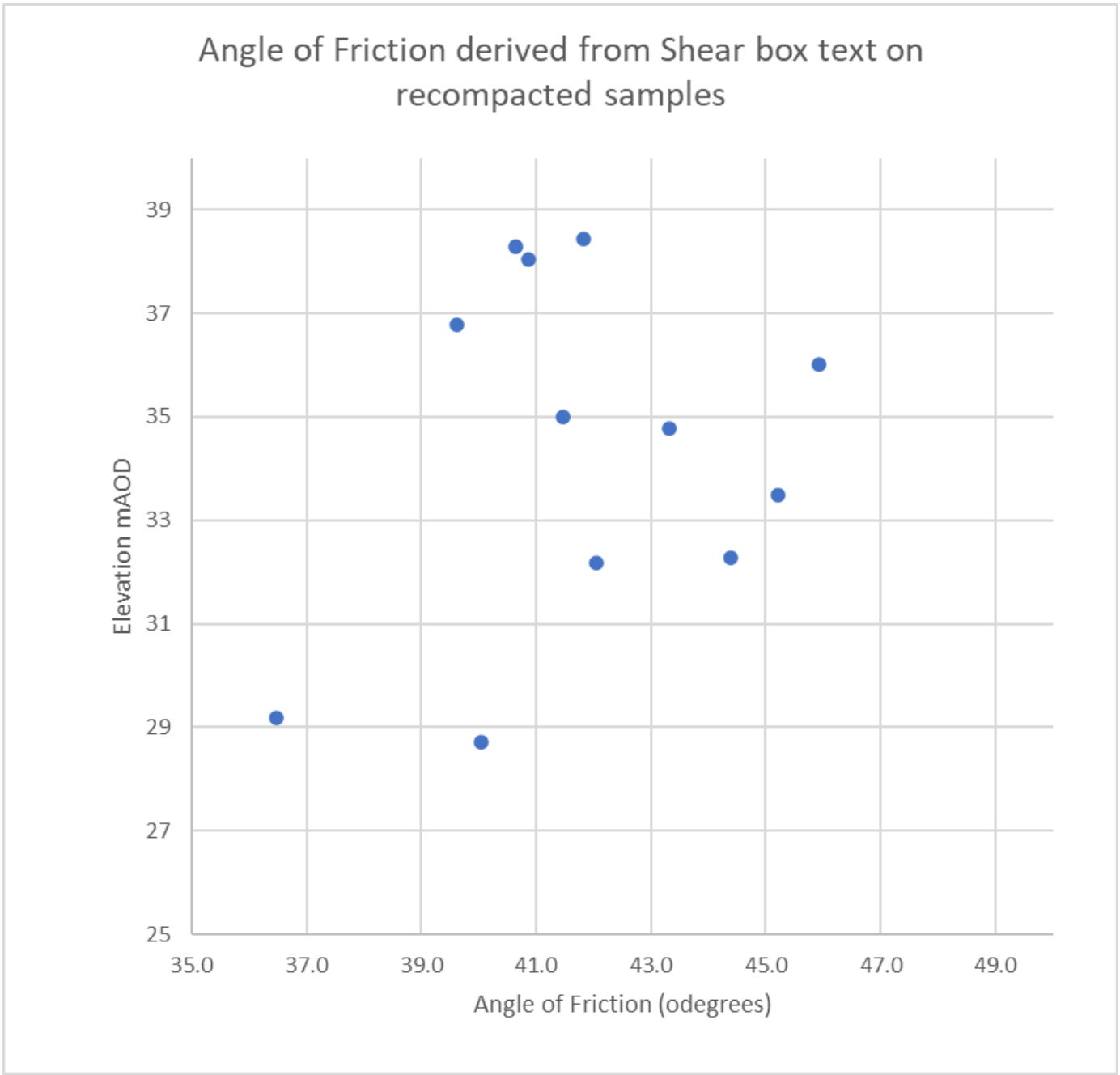
Hole ID	Geol code	Elevation	Sample depth	Sample type	Triaxial normal stress s'	Triaxial shear stress t
BH301B	MG-CO	37.96	4	UT	123.5	62.5
BH301B	MG-CO	34.46	7.5	UT	229.5	102.5
BH301B	MG-CO	29.96	12	UT	427	242
BH302	MG-CO	35.26	7.5	UT	100.5	47.5
BH302	MG-CO	35.26	7.5	UT	191.5	87.5
BH302	MG-CO	35.26	7.5	UT	315.5	146.5
BH315	MG-CO	37.26	2	UT	100.5	49.5
BH315	MG-CO	35.26	4	UT	125.5	56.5
BH315	MG-CO	31.76	7.5	UT	245	119

1.3 Shear box results

BH ID and elevations	Hole type	Zone	Geology	Sample depth	Normal stress	Peak shear stress	Estimated Phi
BH304_32.18	CP	Redbank Plateau,Slope regrade area	MG-G	9	55	44.7	42.0
BH304_32.18	CP	Redbank Plateau,Slope regrade area	MG-G	9	110	90.7	
BH304_32.18	CP	Redbank Plateau,Slope regrade area	MG-G	9	165	143.9	
BH304_29.18	CP	Redbank Plateau,Slope regrade area	MG-G	12	80	71.1	36.5
BH304_29.18	CP	Redbank Plateau,Slope regrade area	MG-G	12	160	130.2	
BH304_29.18	CP	Redbank Plateau,Slope regrade area	MG-G	12	240	189.4	
BH305_36.77	CP	Redbank Plateau,Slope regrade area	MG-G	3	18	23.1	39.6
BH305_36.77	CP	Redbank Plateau,Slope regrade area	MG-G	3	36	37.8	
BH305_36.77	CP	Redbank Plateau,Slope regrade area	MG-G	3	54	52.9	
BH305_34.77	CP	Redbank Plateau,Slope regrade area	MG-G	5	27	41	43.3
BH305_34.77	CP	Redbank Plateau,Slope regrade area	MG-G	5	54	67.7	
BH305_34.77	CP	Redbank Plateau,Slope regrade area	MG-G	5	81	91.9	
BH305_32.27	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	50	47.6	44.4
BH305_32.27	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	100	94	
BH305_32.27	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	150	145.5	
BH324_36	CP	Redbank Plateau,Slope regrade area	MG-G	5	20	34.8	45.9
BH324_36	CP	Redbank Plateau,Slope regrade area	MG-G	5	40	57.4	
BH324_36	CP	Redbank Plateau,Slope regrade area	MG-G	5	60	76.1	
BH324_35	CP	Redbank Plateau,Slope regrade area	MG-G	6	30	35.7	41.5
BH324_35	CP	Redbank Plateau,Slope regrade area	MG-G	6	55	57.9	
BH324_35	CP	Redbank Plateau,Slope regrade area	MG-G	6	80	79.9	
BH324_33.5	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	40	46.6	45.2
BH324_33.5	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	80	90.1	
BH324_33.5	CP	Redbank Plateau,Slope regrade area	MG-G	7.5	120	127.2	
BH323_28.71	WLS	St Catherine's wood zone,Slope regrade area	MG-G	1.5	20	24.3	40.0
BH323_28.71	WLS	St Catherine's wood zone,Slope regrade area	MG-G	1.5	30	32.9	
BH323_28.71	WLS	St Catherine's wood zone,Slope regrade area	MG-G	1.5	40	41.1	
TP304_38.44	TP	Redbank Plateau,Slope regrade area	MG-G	2.9	10	14.9	41.8

TP304_38.44	TP	Redbank Plateau,Slope regrade area	MG-G	2.9	20	24.5	
TP304_38.44	TP	Redbank Plateau,Slope regrade area	MG-G	2.9	30	32.8	
TP305_38.05	TP	Redbank Plateau,Slope regrade area	MG-G	3	10	16.5	40.9
TP305_38.05	TP	Redbank Plateau,Slope regrade area	MG-G	3	20	25.2	
TP305_38.05	TP	Redbank Plateau,Slope regrade area	MG-G	3	30	33.8	
TP306_38.29	TP	Redbank Plateau,Slope regrade area	MG-G	1	30	34	40.6
TP306_38.29	TP	Redbank Plateau,Slope regrade area	MG-G	1	60	58.8	
TP306_38.29	TP	Redbank Plateau,Slope regrade area	MG-G	1	90	85.5	




Angle of Friction derived from Shear box text on recompacted samples
Elevation mAOD
39
37
35
33
31
29
27
25
35.0
37.0
39.0
41.0
43.0
45.0
47.0
49.0
Angle of Friction (odegrees)

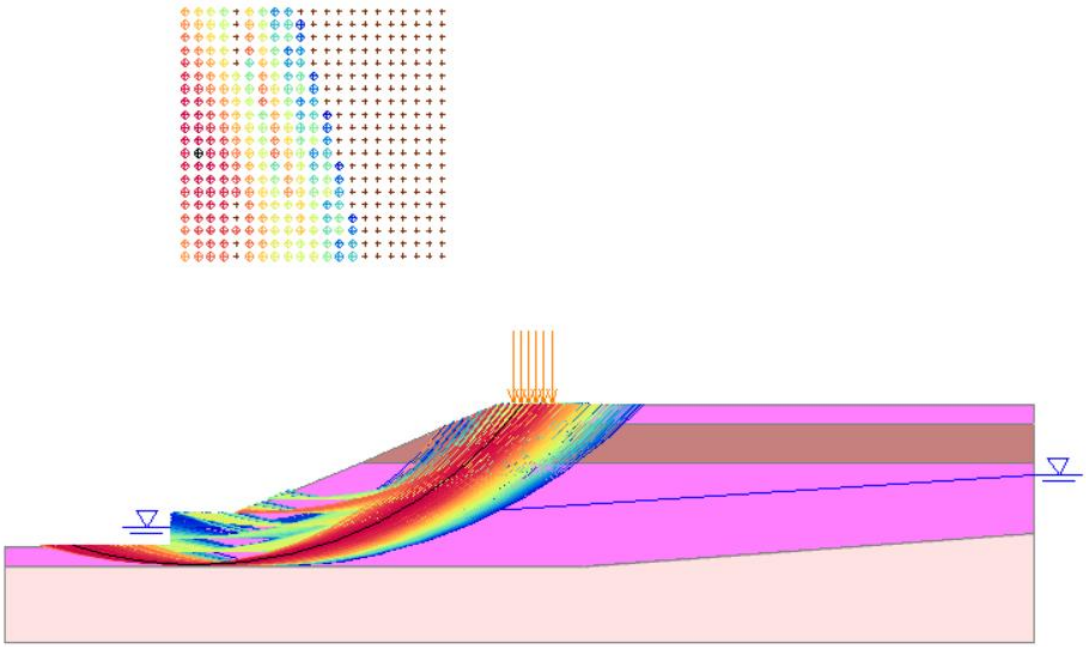
Appendix B – Asset 5 and 6 slope run output

Plateau slope runs

Asset slope run No.	Scenario	Condition	ODF (Deep critical slopes)
A5.1	ground model 5A (Cohesive band) with normal GWL	drained	1.2
A5.2	ground model 5A (Cohesive band) with normal GWL	undrained	1.2
A5.3	ground model 5A (Cohesive band) with a 100-year Flood event GWL	drained	1
A5.4	ground model 5A (Cohesive band) with a 100-year Flood event GWL	undrained	1
A5.5	Ground model 5B (Full granular using lower bound SPTN) with normal GWL	drained	1.2
A5.6	Ground model 5B (Full granular using lower bound SPTN) with a 100-year Flood event GWL	drained	1
A5.7	Ground model 5C (Full granular using higher bound and lower bound SPTN) with normal GWL	drained	1.2
A5.8	Ground model 5C (Full granular using higher bound and lower bound SPTN) with a 100-year Flood event GWL	drained	1.1

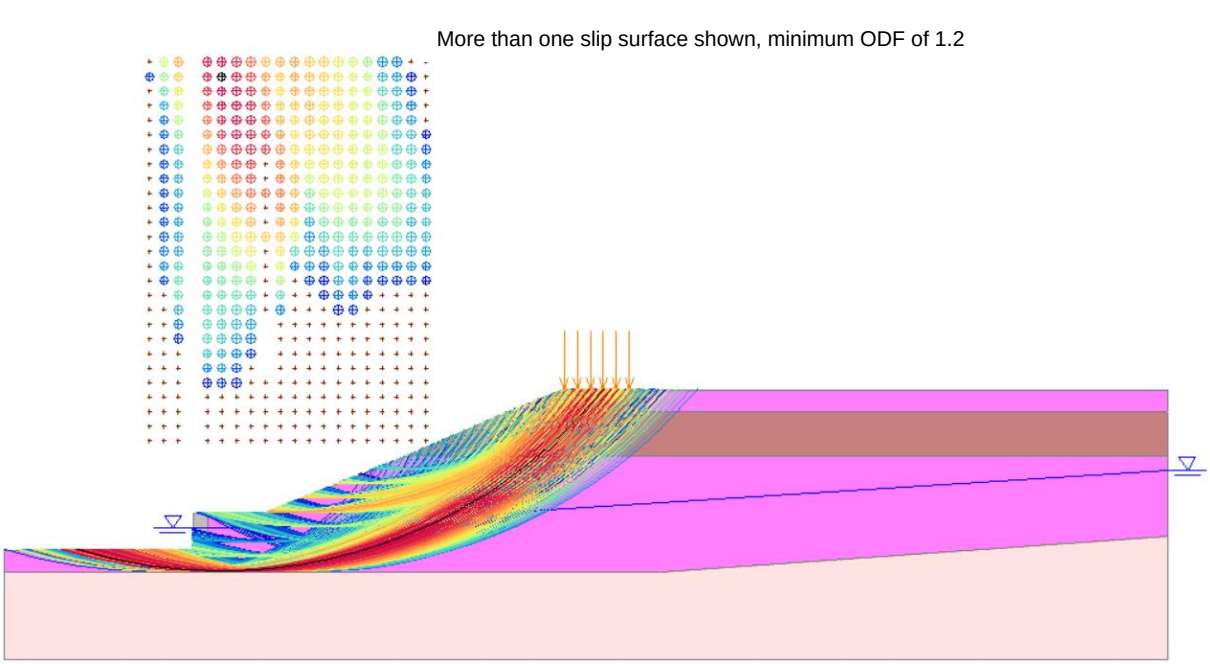
A5.1

More than one slip surface shown, minimum ODF of 1.2



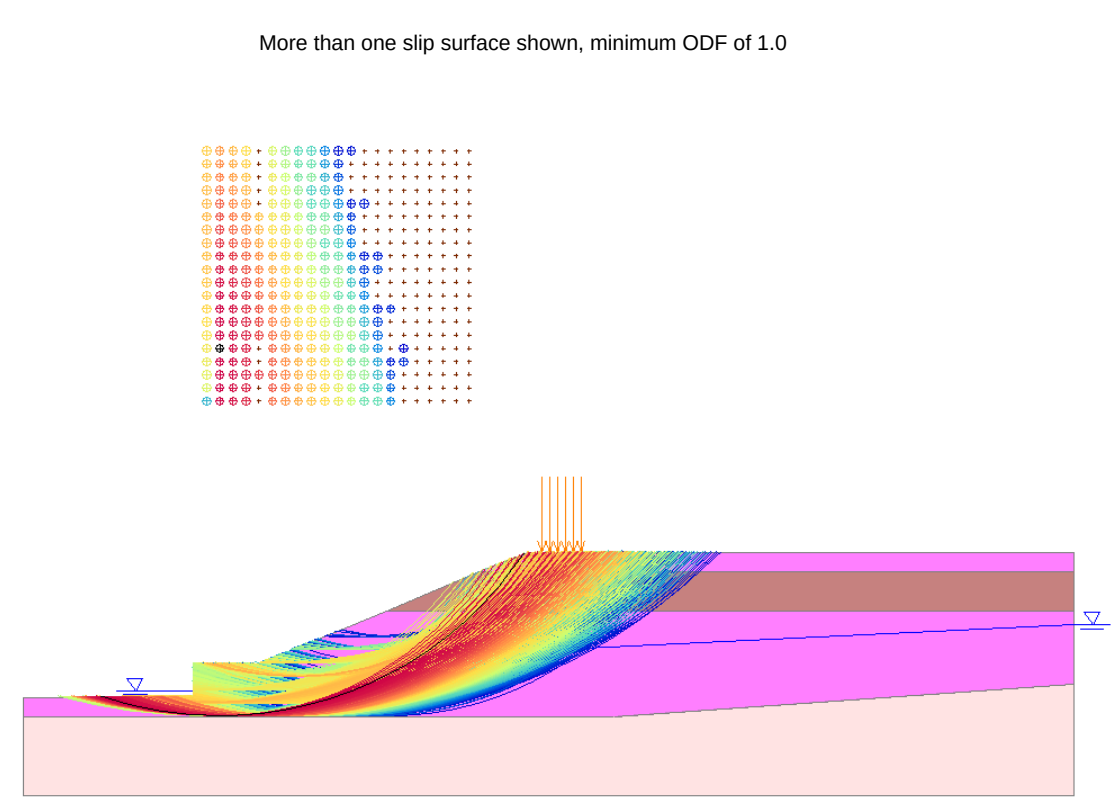
A5.2

More than one slip surface shown, minimum ODF of 1.2



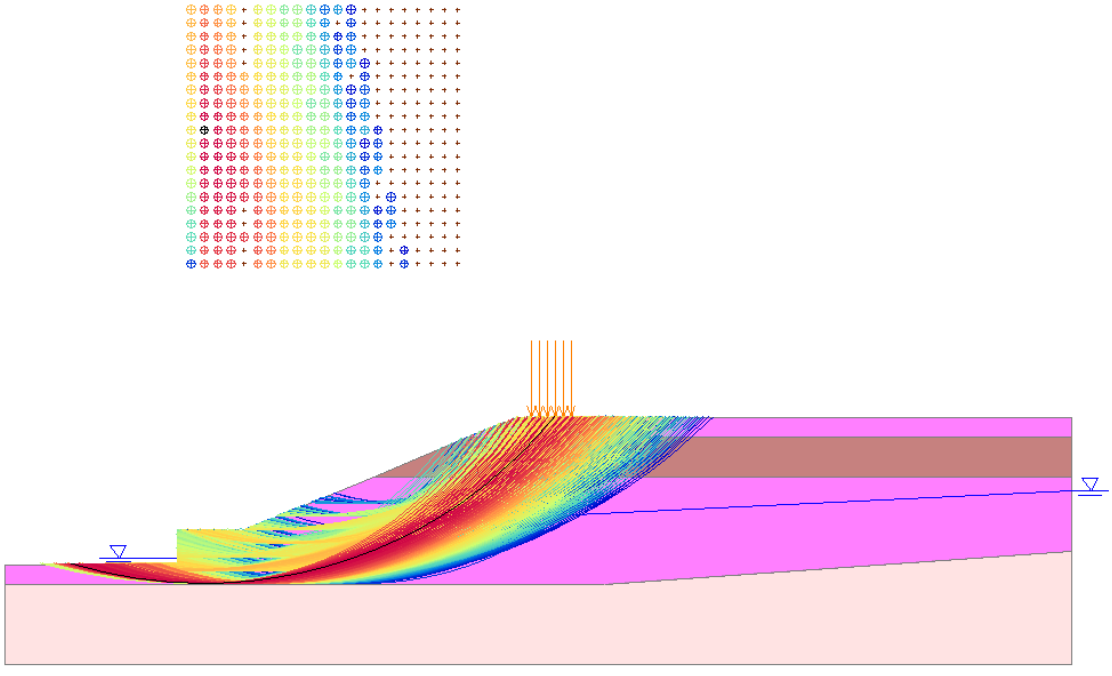
A5.3

More than one slip surface shown, minimum ODF of 1.0



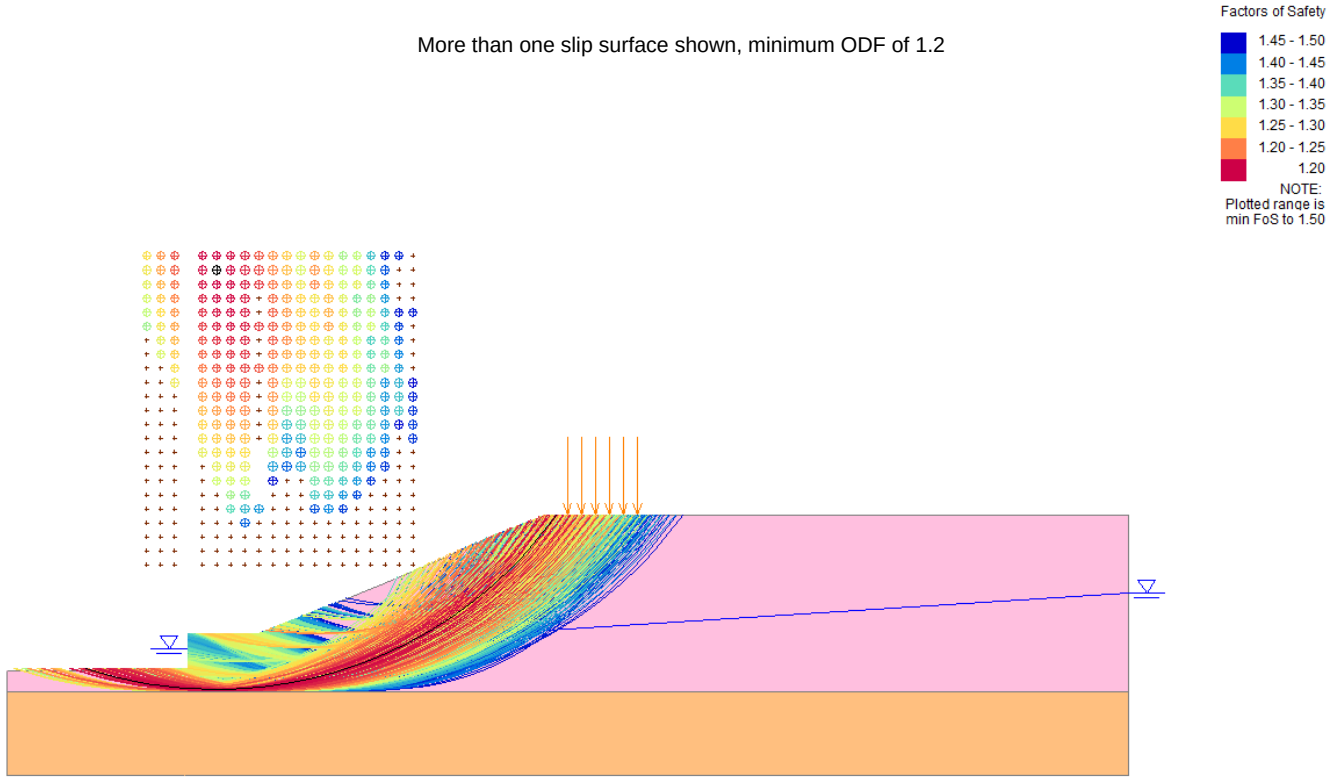
A5.4

More than one slip surface shown, minimum ODF of 1.0



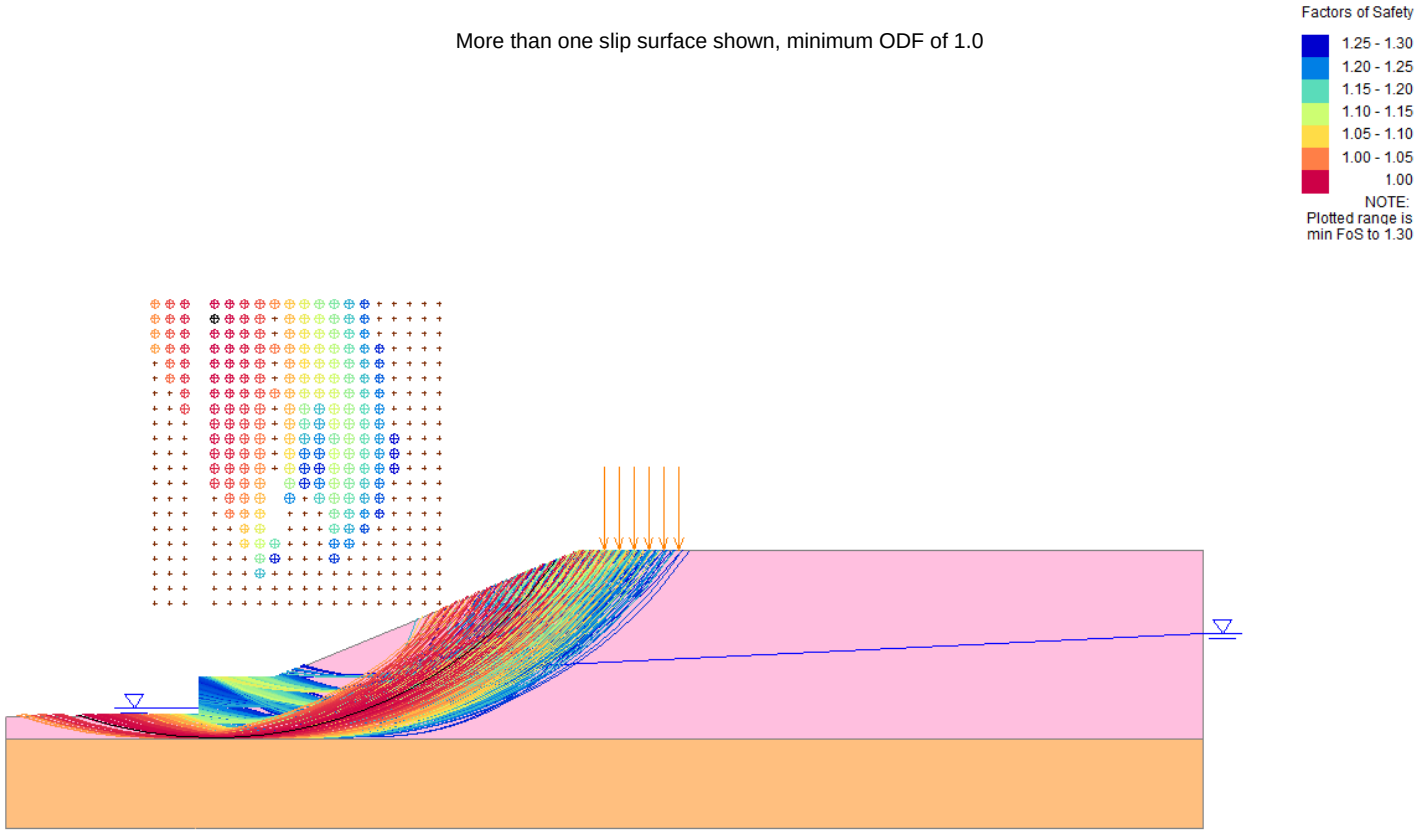
A5.5

More than one slip surface shown, minimum ODF of 1.2

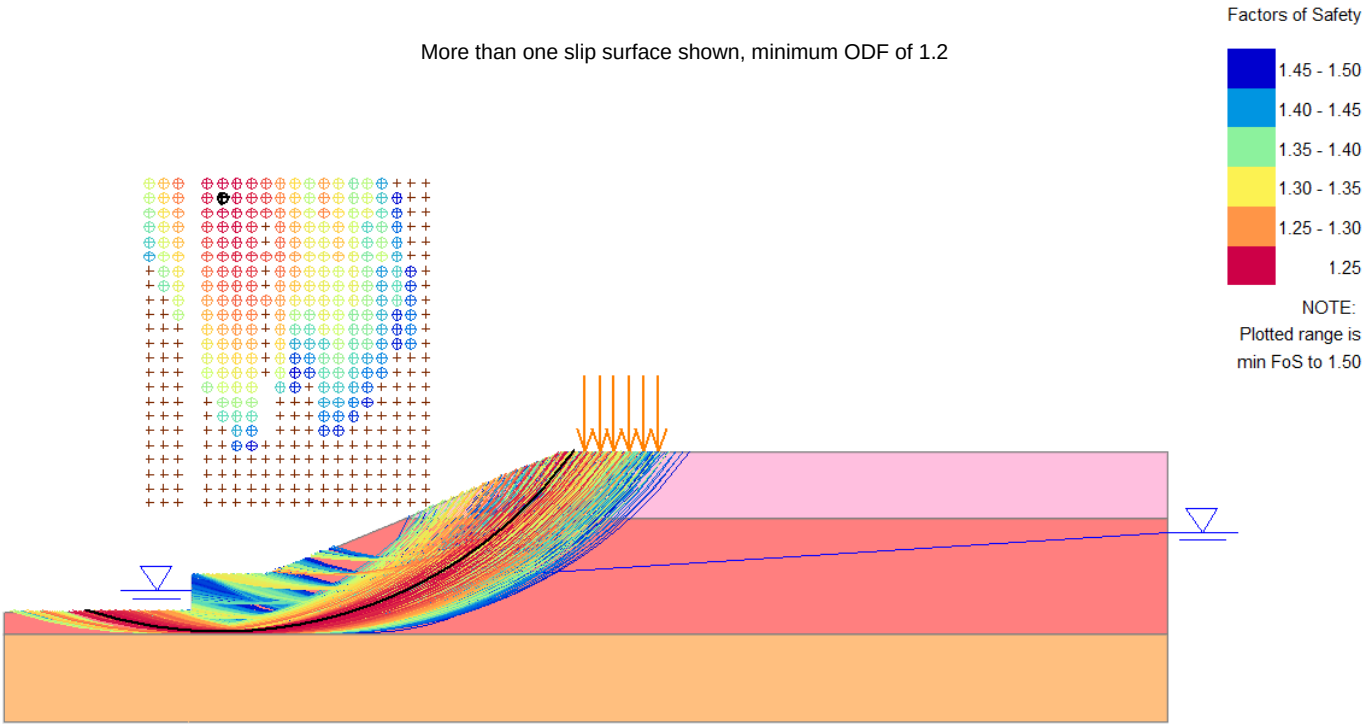


A5.6

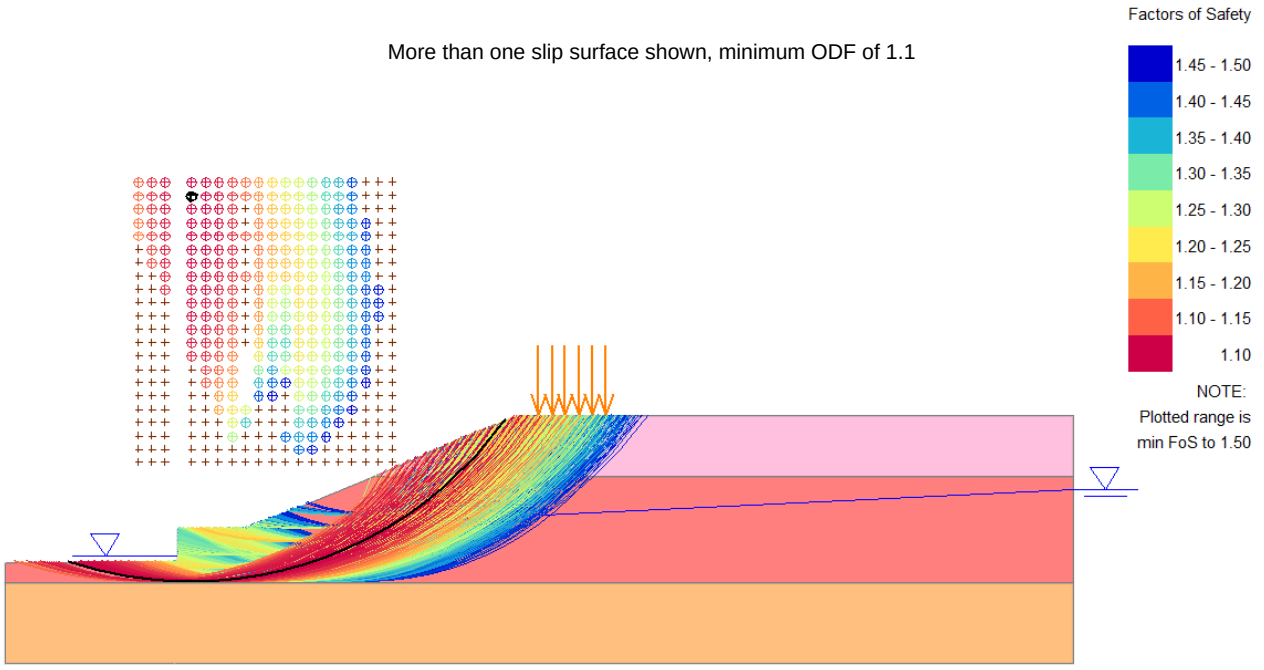
More than one slip surface shown, minimum ODF of 1.0



A5.7


More than one slip surface shown, minimum ODF of 1.2
Factors of Safety
1.45 - 1.50
1.40 - 1.45
1.35 - 1.40
1.30 - 1.35
1.25 - 1.30
1.25
NOTE:
Plotted range is
min FoS to 1.50

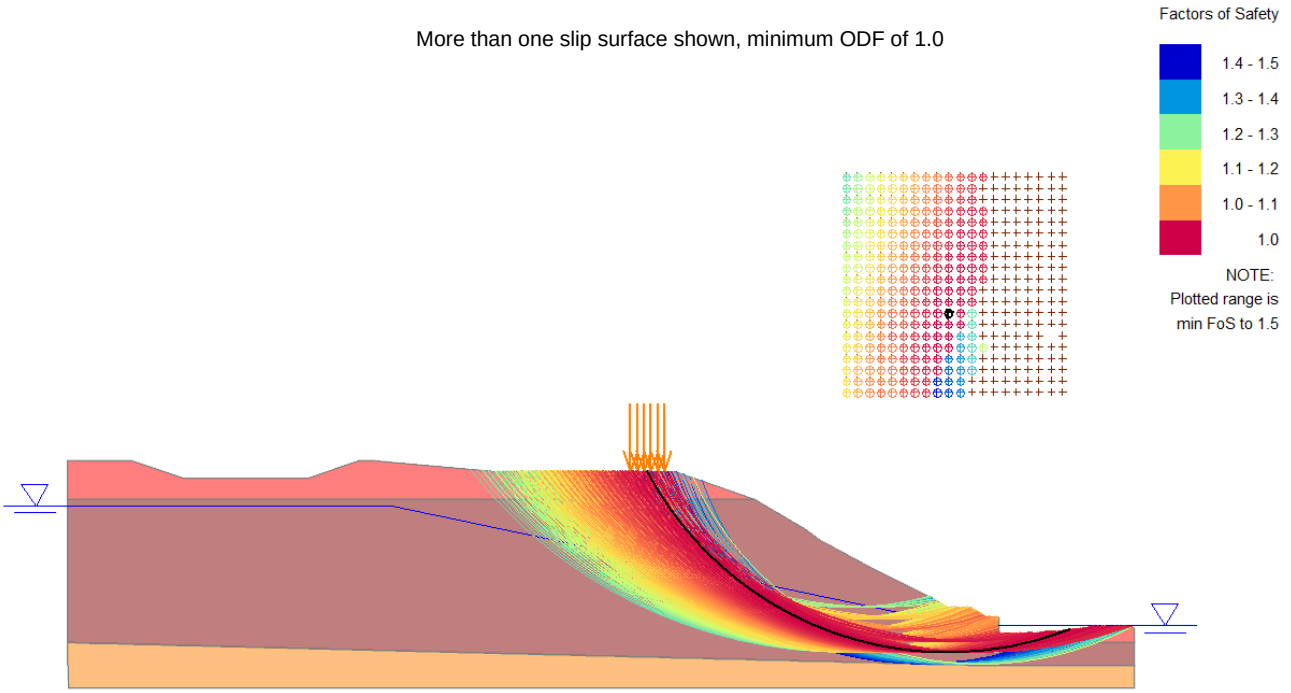
A5.8


More than one slip surface shown, minimum ODF of 1.1
Factors of Safety
1.45 - 1.50
1.40 - 1.45
1.35 - 1.40
1.30 - 1.35
1.25 - 1.30
1.20 - 1.25
1.15 - 1.20
1.10 - 1.15
1.10
NOTE:
Plotted range is
min FoS to 1.50

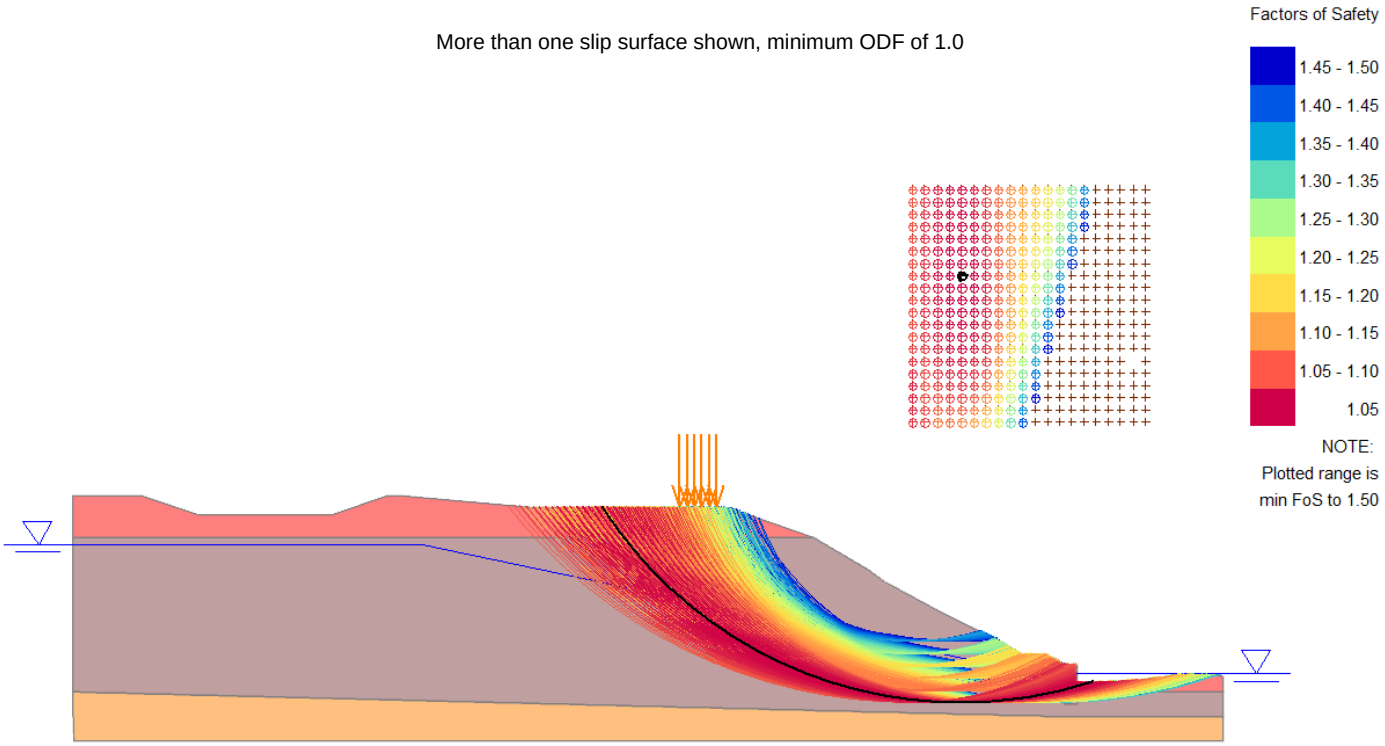
P&P slope runs

Asset slope run No.	Scenario	Condition	ODF (deep critical slopes)
A6.1	Ground model 6A with normal GWL	drained	1.0
A6.2	Ground model 6A with normal GWL	undrained	1.0
A6.3	Ground model 6A with a 100-year Flood event GWL	drained	1.0
A6.4	Ground model 6A with a 100-year Flood event GWL	undrained	1.0
A6.5	Ground model 6B with normal GWL	drained	1.0
A6.6	Ground model 6B with normal GWL	undrained	1.0
A6.7	Ground model 6B with a 100-year Flood event GWL	drained	1.0
A6.8	Ground model 6B with a 100-year Flood event GWL	undrained	1.0

A6.1

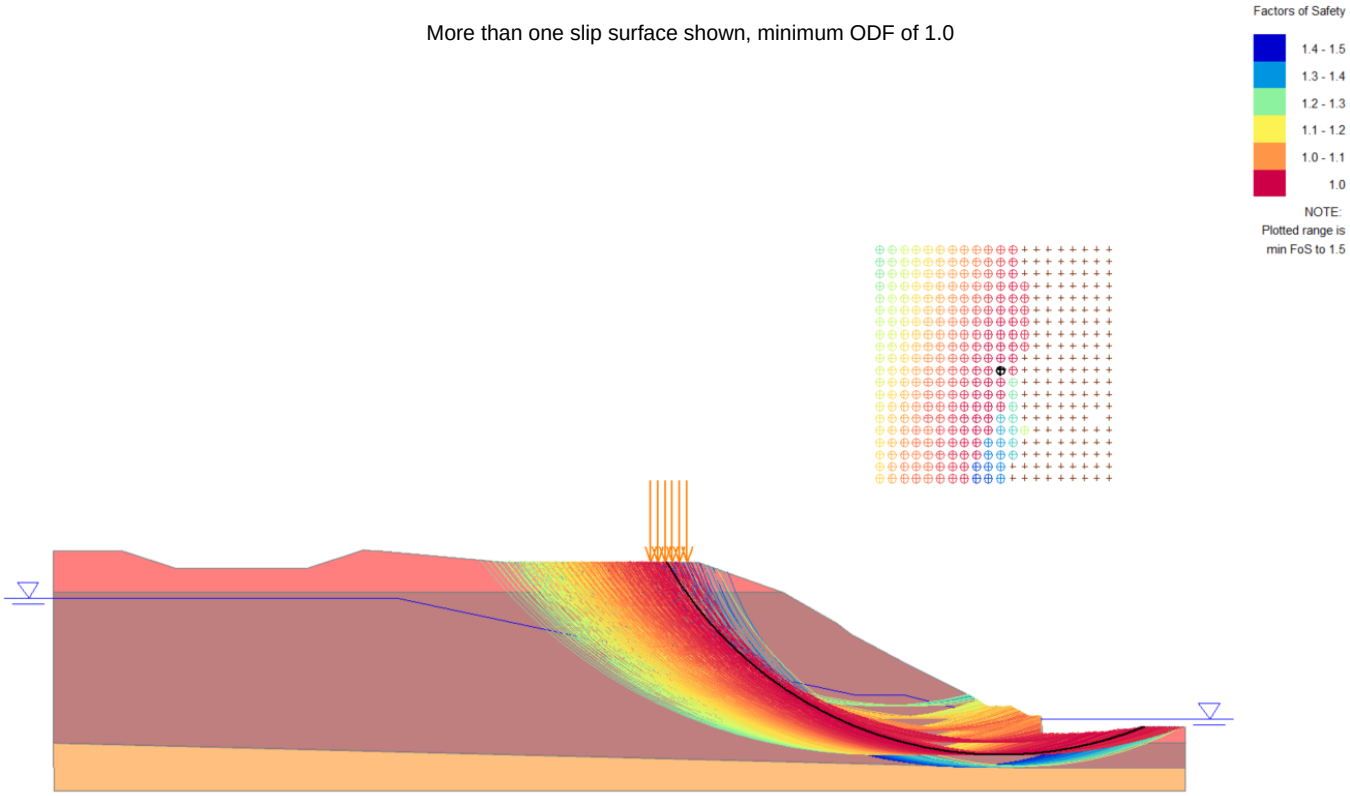

More than one slip surface shown, minimum ODF of 1.0
Factors of Safety
1.4 - 1.5
1.3 - 1.4
1.2 - 1.3
1.1 - 1.2
1.0 - 1.1
1.0
NOTE:
Plotted range is
min FoS to 1.5

A6.2


More than one slip surface shown, minimum ODF of 1.0
Factors of Safety
1.45 - 1.50
1.40 - 1.45
1.35 - 1.40
1.30 - 1.35
1.25 - 1.30
1.20 - 1.25
1.15 - 1.20
1.10 - 1.15
1.05 - 1.10
1.05
NOTE:
Plotted range is
min FoS to 1.50

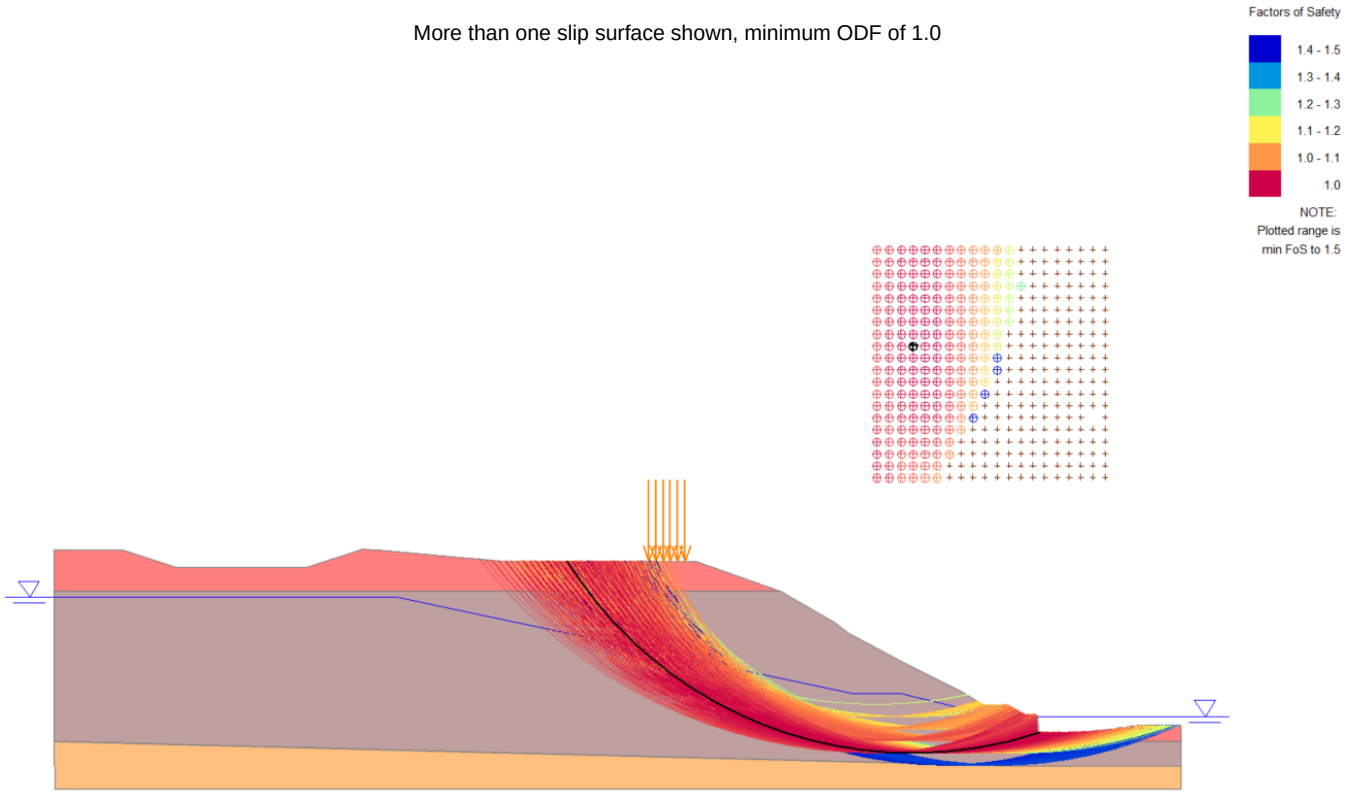
A6.3

More than one slip surface shown, minimum ODF of 1.0

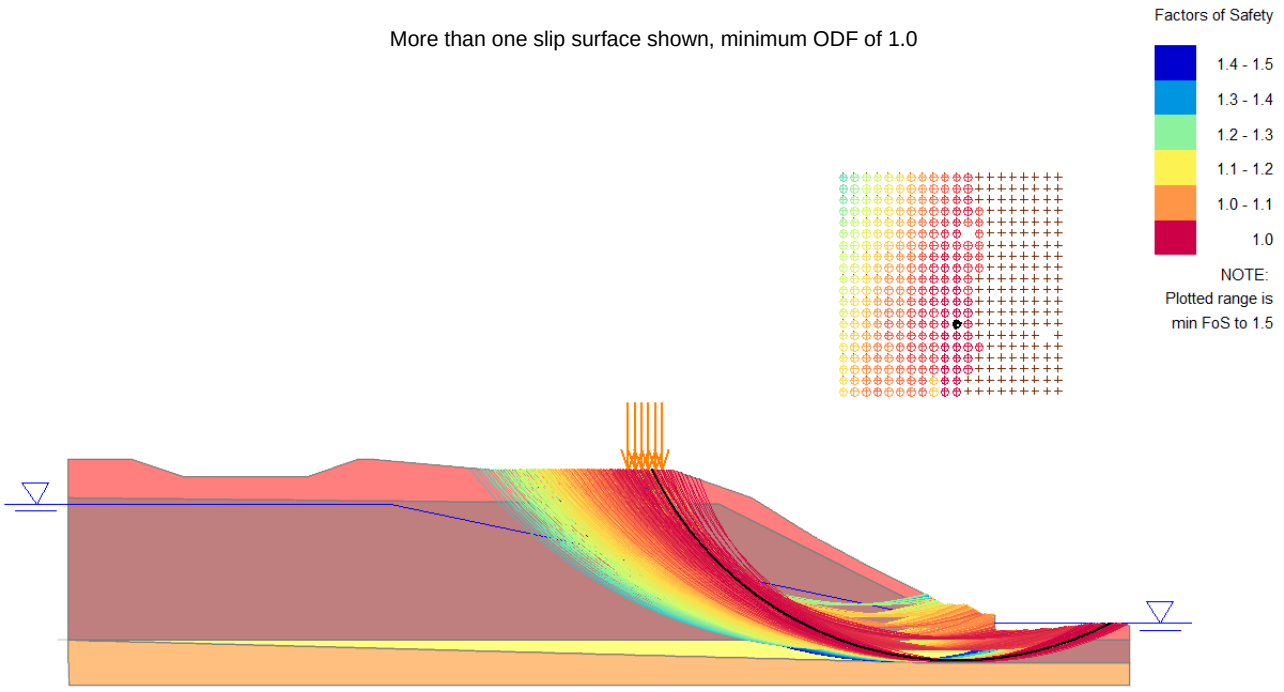


A6.4

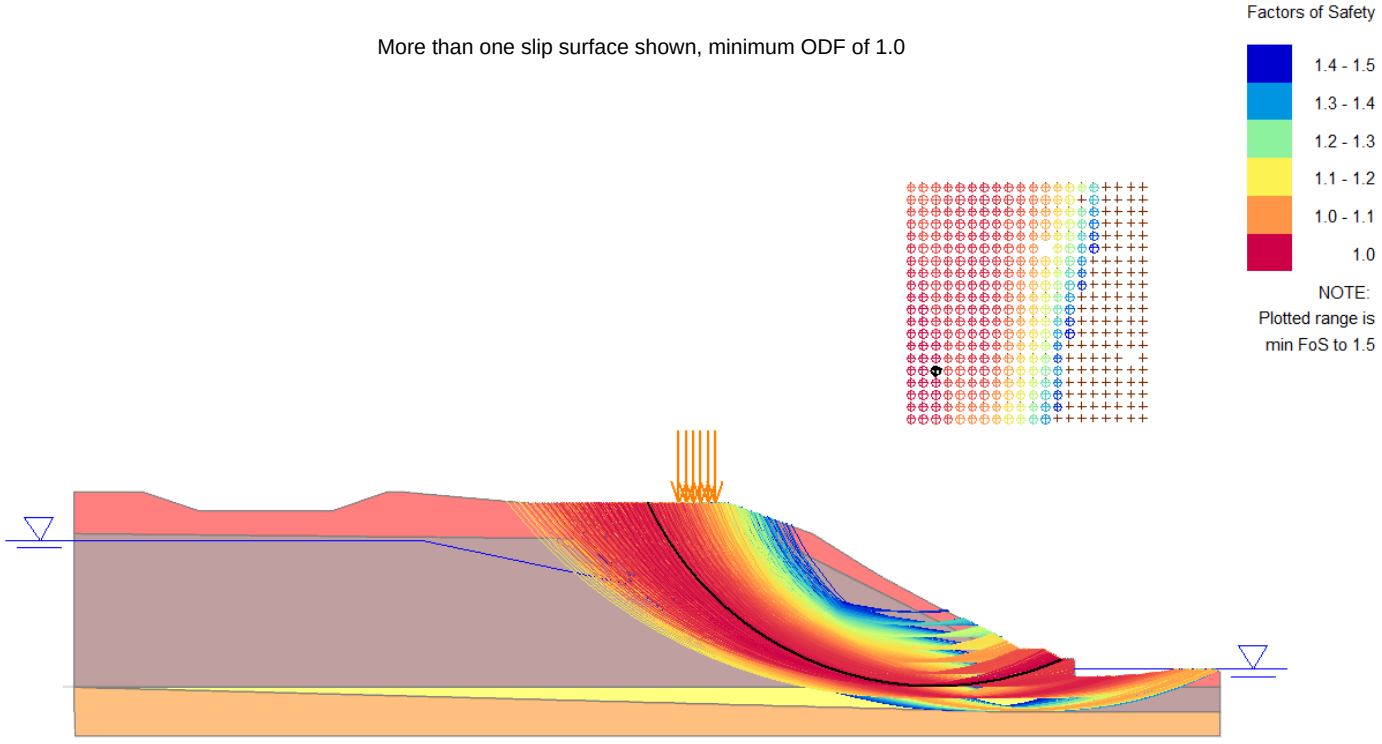
More than one slip surface shown, minimum ODF of 1.0



A6.5

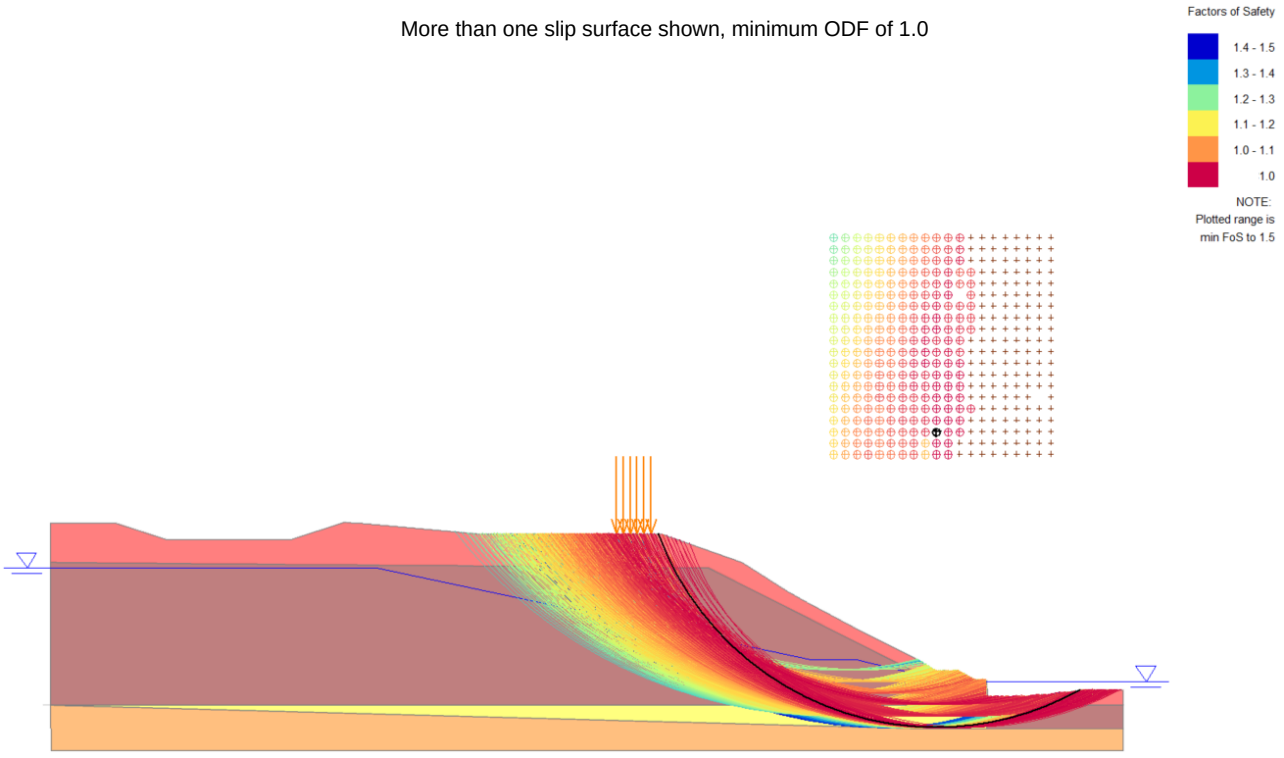

More than one slip surface shown, minimum ODF of 1.0
Factors of Safety
1.4 - 1.5
1.3 - 1.4
1.2 - 1.3
1.1 - 1.2
1.0 - 1.1
1.0
NOTE:
Plotted range is
min FoS to 1.5

A6.6


More than one slip surface shown, minimum ODF of 1.0
Factors of Safety
1.4 - 1.5
1.3 - 1.4
1.2 - 1.3
1.1 - 1.2
1.0 - 1.1
1.0
NOTE:
Plotted range is
min FoS to 1.5

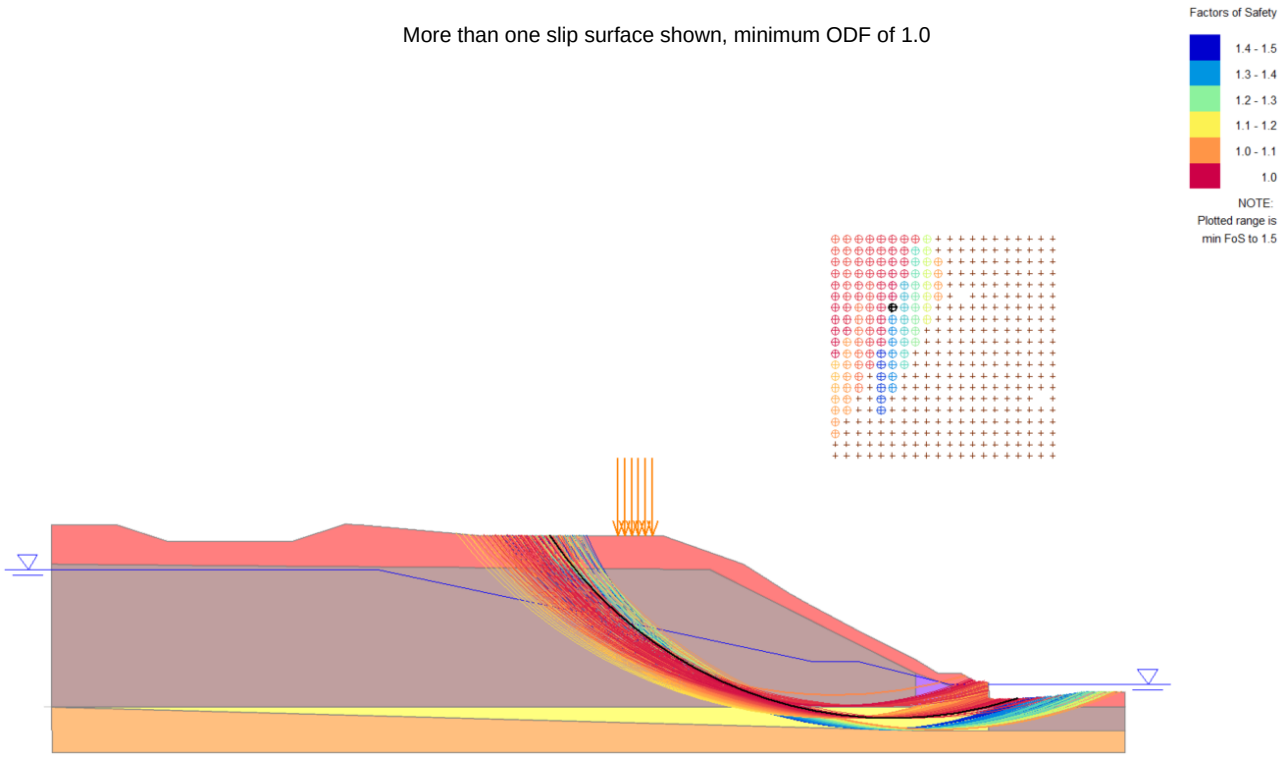
A6.7

More than one slip surface shown, minimum ODF of 1.0



A6.8

More than one slip surface shown, minimum ODF of 1.0



Appendix C – GA Drawings

A1

Proposed access junction on Red Bank subject to a Section 278 agreement.

CH 0

CH 20

CH 40

CH 60

CH 80

CH 100

CH 120

CH 140

CH 160

CH 180

CH 200

CH 220

CH 240

CH 260

CH 280

RB12a

RB12b

1 in 3 slopes to existing ground level.

Existing wall to be tapered down to road level. Refer to structures drawings.

R 30.00m

7.30m

2.50m

3.00m

6.00m

3.00m

11.00m

11.00m

R 450.00m

R 500.00m

For continuation refer to drawing VNIF-ARP-00-YYY-DR-CH-3003

Check locations of lighting columns

Proposed retaining wall from existing wall down to Red Bank Terrace.

Temporary Vertical Concrete Barrier (TVCB) to be provided at back of footway to mitigate risk of vehicles impacting the retaining wall parapet. Hardstaff Multibloc units or similar to be provided, ensuring a minimum containment provision of N1. Barriers to extend beyond extents of hazard as shown. Barriers may be removed by developer following risk assessment and design of public realm works.

RB01

RB02

Plateau Avenue carriageway to be constructed up to binder course. Refer to drawing VNIF-ARP-00-YYY-DR-CH-3008 for typical sections of the highway and drawing VNIF-ARP-00-YYY-DR-CH-3006 for the proposed paving build ups.

Plateau Avenue footway sub-base to be extended to finished level as a temporary surface.

RB03

RB06

RB07

RB16

RB17

NT02

Do not scale

Notes:

1. All dimensions are in mm, all levels in mAOD, unless specified otherwise.
2. This map is reproduced from Ordnance Survey Material with the permission of the Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office (c) Crown Copyright. Licence Number 100019568 (2021).
3. Topographical data based on Paragon Surveys Drawings No. PS-2158-TS Issue P.
4. Refer to drawing VNIF-ARP-00-YYY-DR-CH-3003 for Site Highway GA Sheet 2 of 2.
5. Landscaping proposals based on Planit drawing VNIF-PLA-ZZ-YYY-DR-L-1011-HIF General Arrangement Plan Rev P02. Refer to Planit drawings for details of soft and hard landscaping.
6. Plot boundaries are indicative based on FEC masterplan.
7. Provision for 129 parking bays including 10% accessible bays has been allowed for in the design of Plateau Avenue based on Shultze Grassov drawing No. RDB-SPG-XX-XX-SK-LA-8004 Rev B (26/10/2021).
8. Design and setting out of pedestrian / cycle routes and public realm areas by Landscape Architect.
9. Refer to drawings VNIF-ARP-00-YYY-DR-CH-4001 to 4007 for Section 278 works.
10. Refer to drawing VNIF-ARP-00-YYY-DR-CH-3006 and VNIF-ARP-00-YYY-DR-CH-3007 for the proposed paving build ups.

Key:

- Proposed Highway
- Proposed Footway
- Proposed Landscaping
- FEC Plot not included within Scope of HIF Works
- Red Line Boundary
- Development Plot Boundaries
- Existing Ordnance Survey/ Topographical Survey
- Highway centreline tangent
- Highway centreline radius

Rev	Date	Description	By	Chkd	Appd	Auth
P01	01/03/22	Issued for Costing	SM	RS	CW	—
P02	27/06/22	Stage 4 Draft	ID	RS	LS	—

ARUP

6th Floor 3 Piccadilly Place
Manchester M1 3BN
Tel +44 161 228 2331 Fax +44 161 228 6879
www.arup.com

Client

MANCHESTER CITY COUNCIL

bam nuttall

Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Site Highways
General Arrangement
Sheet 1 of 2

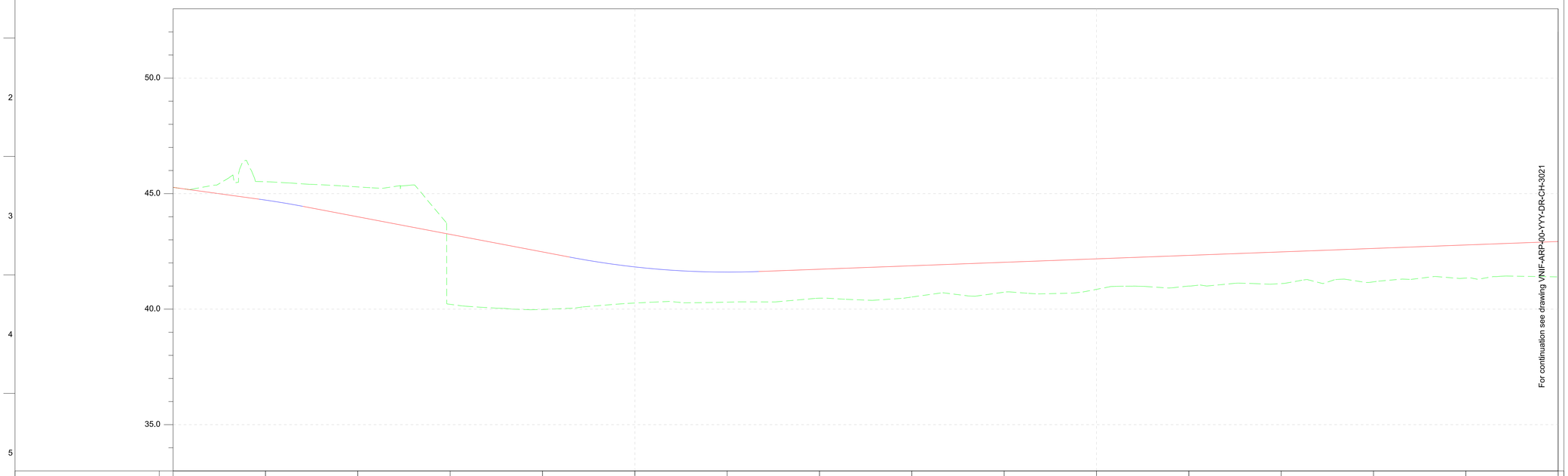
Scale at A1	1:500	Arup Job No	282022-00
Role	Civil - Highways		
Suitability	S3 - Issued for Review and Comment		

Rev	By	Chkd	Appd	
P02	ID	RS	LS	—
	Date 27/06/22	Date 27/06/22	Date 27/06/22	—

Name

VNIF	- ARP -	00	- YYY -	DR	- CH -	3002
Project	Originator	Volume	Location	Type	Role	Number

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CHAINAGE	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000
EXISTING LEVEL	45.270	45.514	45.289	40.209	39.985	40.266	40.302	40.475	40.525	40.734	40.856	41.000	41.106	41.182	41.344	41.397
PROPOSED LEVEL	45.270	44.721	43.997	43.237	42.477	41.828	41.603	41.727	41.877	42.027	42.177	42.327	42.477	42.627	42.777	42.927
HORIZONTAL GEOMETRY		L = 21.639m	L = 29.928m R = 30.000m		L = 52.043m R = 100.000m		L = 7.843m	L = 121.271m R = 450.000m					L = 22.110m	L = 72.818m R = 500.000m		
VERTICAL GEOMETRY		L = 18.607m G = -2.74%	L = 9.508m K = -9		L = 57.778m G = -3.80%		L = 40.950m K = 9	L = 324.282m G = 0.75%								

Notes:

1. Topographical data based on Paragon Surveys Drawing No. PS-2158-TS Issue P.
2. Refer to General Arrangement drawings VNIF-ARP-00-YYY-DR-CH-3002 and VNIF-ARP-00-YYY-DR-CH-3003.

Key:

Proposed ground

Existing ground

Rev	Date	Description	By	Chkd	Appd	Auth
P01	27/06/22	Stage 4 Draft	ID	RS	LS	—
P02	04/07/22	Stage 4 Draft	ID	RS	LS	—

ARUP

6th Floor 3 Piccadilly Place
Manchester M1 3BN
Tel +44 161 228 2331 Fax +44 161 228 6879
www.arup.com

Client

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Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Site Highways
Long Section
Sheet 1 of 3

Scale at A1	1:500	Arup Job No	282022-00

Role: Civil - Highways

Suitability: S3 - Issued for Review and Comment

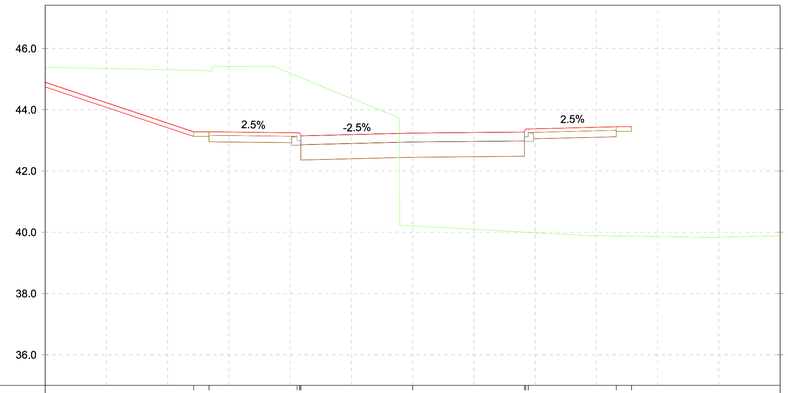
Rev	By	Chkd	Appd	
P02	ID	RS	LS	—
	Date 29/06/22	Date 30/06/22	Date 04/07/22	—

Name

VNIF	- ARP -	00	- YYY -	DR	- CH -	3020
Project	Originator	Volume	Location	Type	Role	Number

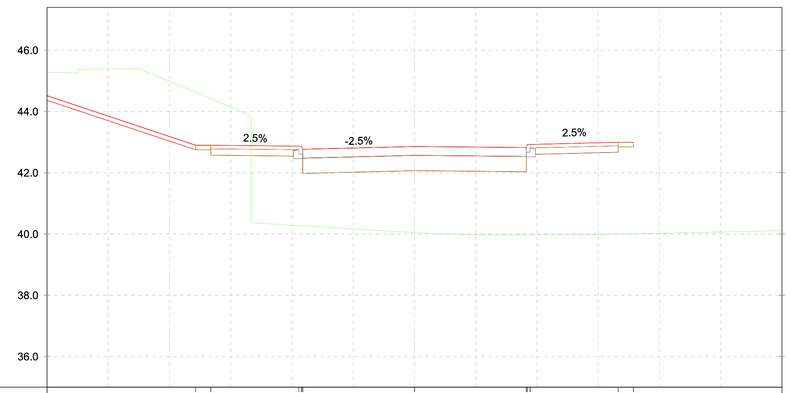
Do not scale

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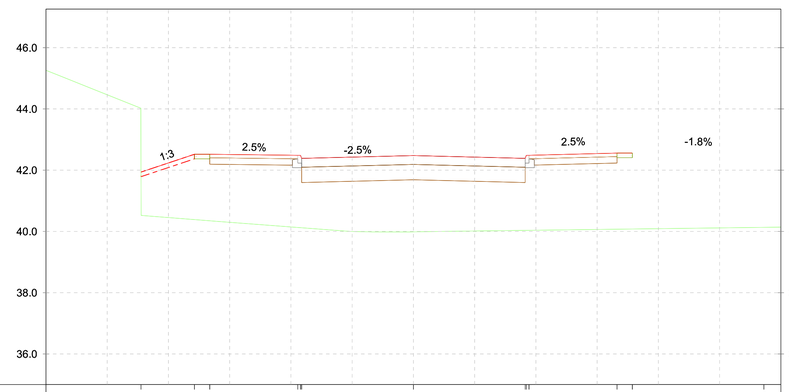
OFFSET	-7.150	-6.650	-3.775	-3.690	-3.650	0.000	3.650	3.690	3.775	6.650	7.150
PROPOSED ELEVATION	43.318	43.318	43.246	**43.246**	43.146	43.237	43.328	43.428	43.428	43.500	43.500
EXISTING ELEVATION	45.287	45.259	45.100	45.065	45.049	40.208	40.000	40.000	40.000	39.948	39.935

CH 60.000



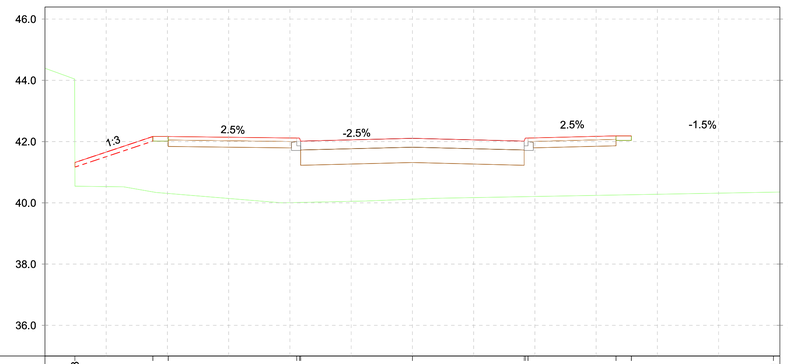
OFFSET	-7.150	-6.650	-3.775	-3.690	-3.650	0.000	3.650	3.690	3.775	6.650	7.150
PROPOSED ELEVATION	42.938	42.938	42.866	42.866	42.766	42.857	42.948	43.048	43.048	43.120	43.120
EXISTING ELEVATION	44.627	44.417	40.273	40.288	40.266	40.044	39.977	39.977	39.977	39.992	40.003

CH 70.000



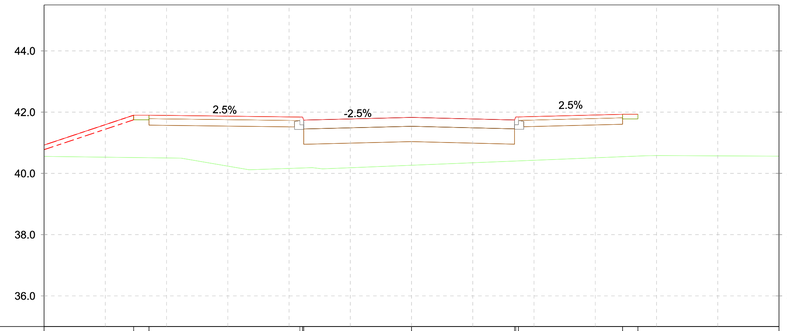
OFFSET	-8.895	-7.150	-6.650	-3.775	-3.690	-3.650	-0.000	3.650	3.690	3.775	6.650	7.150	11.445
PROPOSED ELEVATION	41.976	42.558	42.558	42.486	42.486	42.386	42.477	42.568	42.668	42.668	42.740	42.740	42.663
EXISTING ELEVATION	41.986	40.386	40.347	40.129	40.123	40.120	39.985	40.035	40.035	40.037	40.073	40.079	40.133

CH 80.000



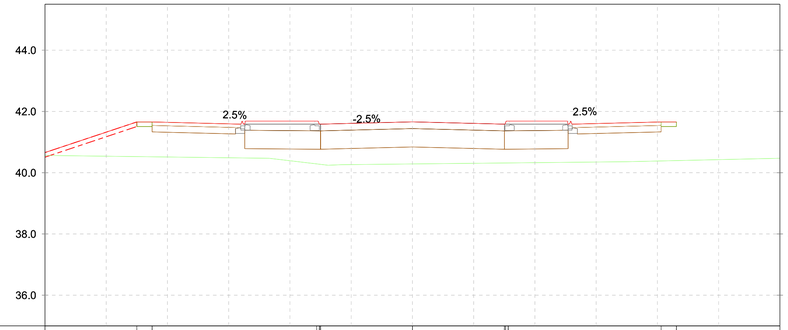
OFFSET	-11.023	-8.475	-7.975	-3.775	-3.690	-3.650	0.000	3.650	3.690	3.775	6.650	7.150	11.789
PROPOSED ELEVATION	41.362	42.211	42.211	42.106	42.106	42.006	42.097	42.188	42.288	42.288	42.360	42.360	42.289
EXISTING ELEVATION	41.372	40.356	40.305	40.010	40.012	40.013	40.119	40.201	40.201	40.203	40.255	40.264	40.348

CH 90.000



OFFSET	-9.074	-8.574	-3.646	-3.561	-3.521	0.000	3.365	3.405	3.490	6.892	7.392
PROPOSED ELEVATION	41.911	41.911	41.788	41.788	41.688	41.776	41.860	41.960	41.960	42.045	42.045
EXISTING ELEVATION	40.517	40.511	40.173	40.176	40.178	40.266	40.402	40.404	40.407	40.545	40.566

CH 100.000



OFFSET	-9.000	-8.500	-3.125	-3.040	-3.000	0.000	3.002	3.042	3.127	8.121	8.621
PROPOSED ELEVATION	41.726	41.726	41.591	41.591	41.491	41.566	41.606	41.706	41.706	41.831	41.831
EXISTING ELEVATION	40.525	40.519	40.287	40.277	40.272	40.285	40.316	40.317	40.318	40.383	40.395

CH 110.000

Notes:

1. Topograhical data based on Paragon Surveys Drawing No. PS-2158-TS Issue P.
2. Refer to drawings VNIF-ARP-00-YYY-DR-CH-3002 and VNIF-ARP-00-YYY-DR-CH-3003 for Plateau Avenue General Arrangement.

Key:

Proposed Ground Level

Existing Ground Level

Rev	Date	Description	By	Chkd	Appd	Auth
P01	28/06/22	Stage 4 Draft	ID	RS	LS	—

ARUP

6th Floor 3 Piccadilly Place
Manchester M1 3BN
Tel +44 161 228 2331 Fax +44 161 228 6879
www.arup.com

Client

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Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Site Highways
Cross Sections
Sheet 2 of 14

Scale at A1	1:100	Arup Job No	282022-00
Role	Civil - Highways		
Suitability	S3 - Issued for Review and Comment		

Rev	By	Chkd	Appd	
P01	ID	RS	LS	—
	Date 28/06/22	Date 28/06/22	Date 28/06/22	—

Name

VNIF	- ARP -	00	- YYY -	DR	- CH -	3031
Project	Originator	Volume	Location	Type	Role	Number

Do not scale

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A1

N

RB02

6m wide carriageway

Builders Yard

Warehouse

RED BANK

RB12b

7.3m carriageway width on entry to allow large vehicles to pass on low bend radius

25253

Elevation A-A

SUB.

7412

RB01

Existing retaining wall broken down to allow for new access road with new sloped retaining wall constructed to allow for reduction in levels.

RB12a

34895

15229

8256

Wall Type A: Length 23.5m

29410

New retaining wall descending from Creamline Dairies site to Red Bank Square. See typical section for details

RB11

Viaduct

RB06

Wall Type D: Length 16.8m

16778

Wall Type A: Length 17.8m

12868

Wall Type C: Length 13.0m

13000

4882

5119

Wall Type B: Length 13.2m

Lincoln Gate

LORD STREET

CHASE STREET

CRABBE STREET

RB08

RB07

ROGER STREET

T CHAD'S STREET

ge House

lelia House

HORNBEAM WAY

Do not scale

Rev	Date	Description	By	Chkd	Appd	Auth
P01.02	11/05/22		---	---	---	---

ARUP

6th Floor 3 Piccadilly Place
Manchester M1 3BN
Tel +44 161 228 2331 Fax +44 161 228 6879
www.arup.com

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Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Retaining Walls - General Arrangement Plan

Scale at A1	AS SHOWN	Arup Job No	282022-00
Role	Structural Engineers		
Suitability	S0 - Initial Status or WIP		

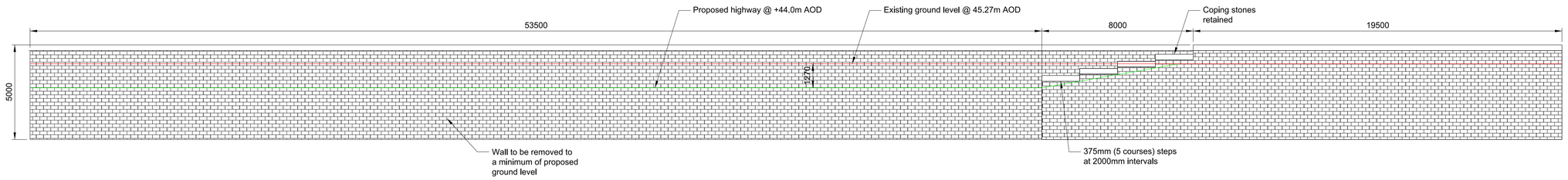
Rev	By	Chkd	Appd	
P01.02	---	---	---	---
	Date	Date	Date	
	---	---	---	---

Name

VNIF - ARP - 00 - YYY - DR - CS - 0007

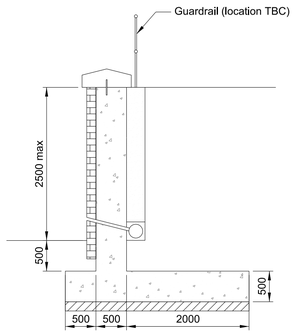
Project | Originator | Volume | Location | Type | Role | Number

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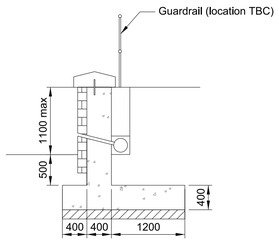
Elevation A-A
Creamline Dairies Existing Wall

scale 1:125



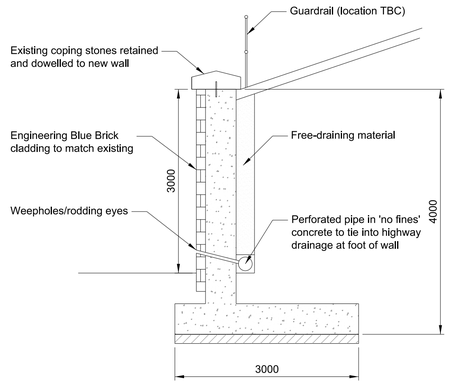
Section A-A: Wall Type A

Scale 1:50



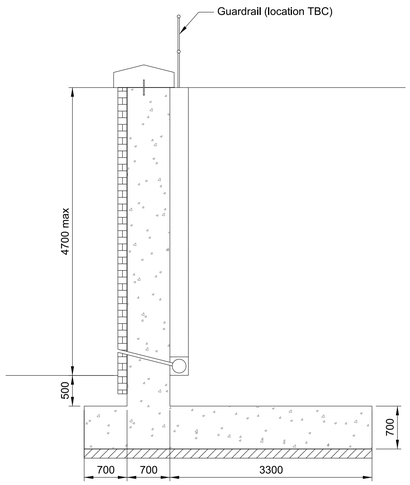
Section C-C: Wall Type C

Scale 1:50



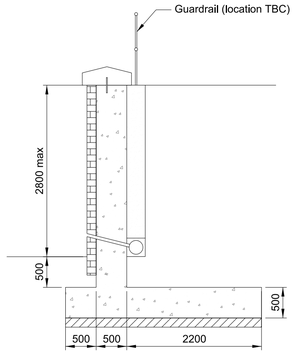
Typical Section Through Proposed Creamline Dairies Wall

Scale 1:50



Section B-B: Wall Type B

Scale 1:50



Section D-D: Wall Type D

Scale 1:50

Notes

1. All dimensions are in mm, all levels in mAOD, unless specified otherwise.
2. Refer to drawing VNIF-PLA-ZZ-YYY-DR-L-3008 Accessible Link from Viaduct to Red Bank/Roger Street.
3. Concrete C40/50 according to BS 8500-2 and the MCHW specification.Reinforcement density to be 200 kg/m³.

Rev	Date	Description	By	Chkd	Appd	Auth
P01.02	11/05/22		---	---	---	---

ARUP

6th Floor 3 Piccadilly Place
Manchester M1 3BN
Tel +44 161 228 2331 Fax +44 161 228 6879
www.arup.com

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Project Title

Victoria North HIF Infrastructure & Enabling Works

Drawing Title

Retaining Walls - Sections

Scale at A1: AS SHOWN		Arup Job No: 282022-00	
Role: Structural Engineers			
Suitability: S0 - Initial Status or WIP			
Rev: P01.02	By: ---	Chkd: ---	Appd: ---
	Date: ---	Date: ---	Date: ---

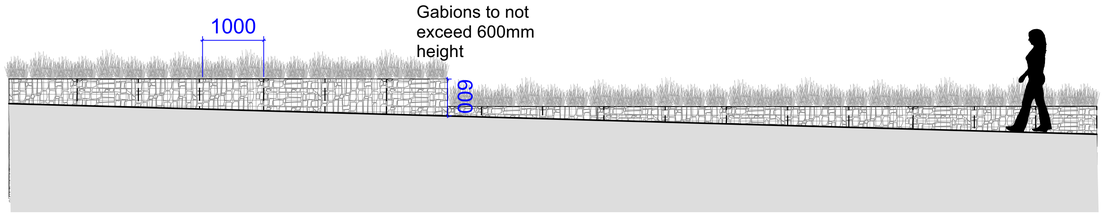
Name

VNIF - ARP - 00 - YYY - DR - CS - 0008

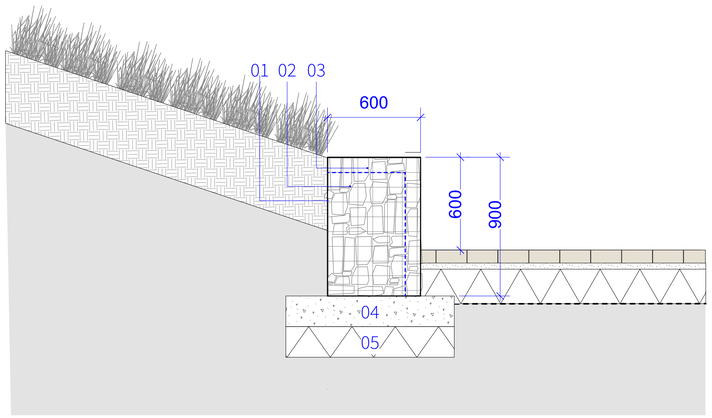
Project | Originator | Volume | Location | Type | Role | Number

Do not scale

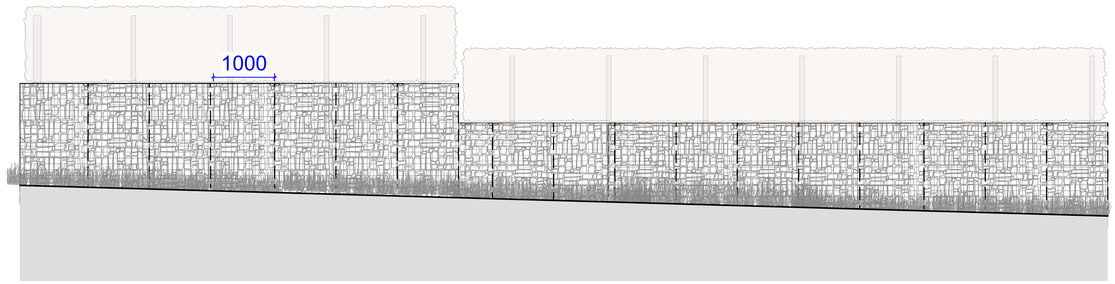
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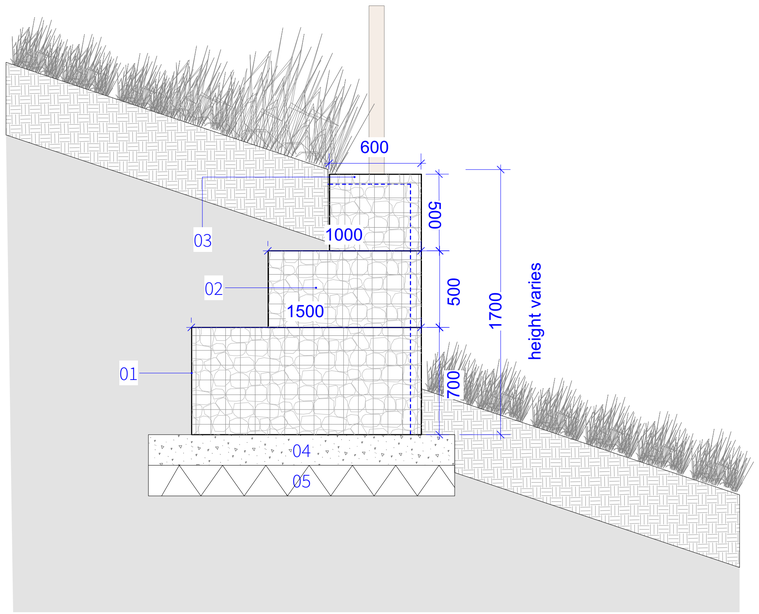
1 Low Gabions beside footpath - Elevation A-A'
Scale: 1:50



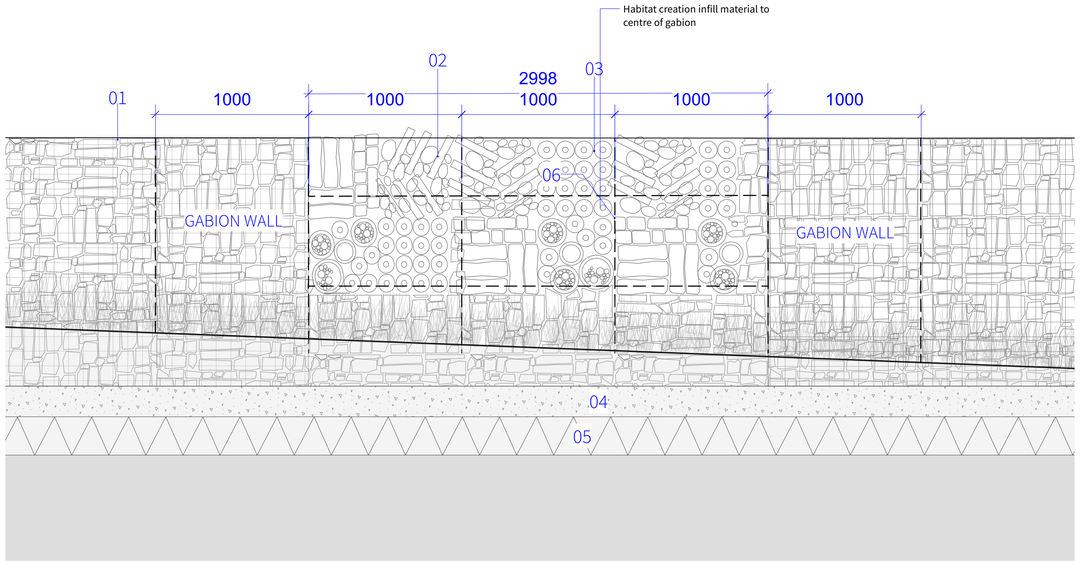
2 Gabion - Section B-B'
Scale: 1:20



3 High Gabions beside footpath - Elevation C-C'
Scale: 1:50



4 Gabion - Section D-D'
Scale: 1:20



5 Typical Gabion Detail
Scale: 1:20

KEY

01. Gabion baskets to be constructed from galvanised (min. 85 micron) rigid welded wire mesh. Mesh thickness 4.0mm. Mesh size 75mm x 75mm.

02. Gabion Fill - Opportunity to use site won material

03. All exposed faces of gabion to have hand placed, locally sourced 6G Yorkstone material fill

04. Foundation material to comprise either compacted 6F1 or No-Fines concrete, minimum 300mm thickness.

05. MOT Type 1 to engineers specification

NOTE.

All gabions to be assembled, filled and joined in accordance with manufacturer's instructions.

Fill behind to be compacted class 6N granular backfill.

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Rev	Date	Description	By	Chkd	Appd	Auth
P03	14.06.22	Stage 4 Issue	BM	MS	GB	GB
P02	13.06.22	Stage 4 Issue	BM	MS	GB	GB
P01	27.05.22	Interim Issue	JN	MS	GB	GB

Client

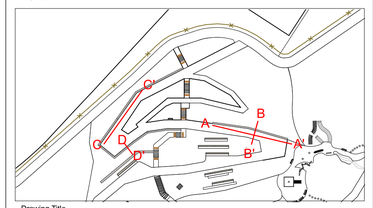
MANCHESTER CITY COUNCIL

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Project Title

Victoria North HIF Infrastructure

Key Plan



Drawing Title

Typical Gabion Details - St Catherine's Wood

Scale at A1	Planit-IE Job No
1:20	2700

Role: Landscape Architect

Suitability: S2

Rev	By	Chkd	Appd	
P03	BM	MS	MS	
	Date	Date	Date	
	13.06.22	13.06.22	13.06.22	

Name

Project	Originator	Volume	Location	Type	Role	Number
VNIF	PLA	ZZ	YYY	DR	L	8009

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Appendix D – Design Risk Register

Hazard ID	Date and Author	Discipline	Location	Description of Hazard and Risk Exposure	Mitigation of Risk (Potential or Achieved)	Avoid	Reduce	Control	Mitigation / Further Action	Risk Owner	Hazard Status
HAZ-GE-001	31/01/2022 (CR)	Geotechnics	Adjacent to Red Bank Terrace	**Excavation at top and bottom of slope causing instability**	Potential - Cut trenches in short sections			✔		Arup	Active
HAZ-GE-002	31/01/2022 (CR)	Geotechnics	P&P slope/Adjacent to RB05b	**Slope instability in future due to change in conditions (e.g flood event or deteriation of river wall)**	Achieved - Build RB05 outside slope instability risk zone. Maintain river wall to current condition or better.	✔	✔	✔	Inclinometers installed and monitored long term in slope	Arup/ BAM /MCC/developer	Active
HAZ-GE-003	24/03/2022 (CR)	Geotechnics	All existing slopes	**Induced slope instability due to inappropriate siting of stockpiles during earthworks**	Potential - Zone to be defined on contract drawings in which stockpiling is to be prohibited	✔			Contract drawings to be produced with relevant information shown	Arup	Active
HAZ-GE-007	13/07/22 (JT)	Geotechnics	St Catherine's wood and Redbank terrace	**Slumping risk of newly placed engineering fill**	Topsoil and tree root remains to be removed prior to fill placement	✔	✔	✔	Needs to be confirmed in Ground preparation tasks	BAM	Active
HAZ-GE-008	13/07/22 (JT)	Geotechnics	St Catherine's wood and Redbank Terrace	**Gabion foundation instability from risk of loose poor material below Gabion formation level**	All tree roots need to be removed and ground material below Gabion needs to be compacted well before Gabion construction. suitable fill to be placed at foundation	✔	✔	✔	Needs to be confirmed in Ground preparation tasks and structures/Geotechnics to define subbase material	Arup/ BAM	Active
HAZ-GE-009	19/07/22 (JT)	Geotechnics	P&P slope area	**Instability of 'off-site' slope area located at the northern boundary**	This area of slope is out of the scheme, but is currently less then a 1:2.5 slope which could experience instability due to changes in load conditions at the crest as a works develop		✔	✔	Careful monitoring of slope using inclinometer results. Avoid excessive loading in this area. Development plots are away from this zone	Arup/ BAM	Active
HAZ-GE-010	19/07/22 (JT)	Geotechnics	P&P slope area	**Identified risk zone map may change in the future in response to long term monitoring**	The inclinometers were installed in BH301 and BH302 which are being used to monitor potential movement in the P&P slope area. The system can serve as a baseline to allow periodic inspection and review of the slope through operation, and to update the current proposal.		✔	✔	Continued monitoring of the slope and to update risk zone map when necessary	Arup	Active
HAZ-GE-011	19/07/22 (JT)	Geotechnics	Plateau Slope area	**Interactions with drainage sewers during the regrade of the slope**	This could impact the regrade process due to unknown ground conditions relating to buried structures leading to relocation/diversion		✔	✔	Drainage and GI are mapping out extent of drainage connections to help understand where the obstruction are.	Arup/ BAM	Active
HAZ-GE-012	19/07/22 (JT)	Geotechnics	Plateau Slope area	**Risk of local instability of the slope during regrading**	Instability could be induced by machinery and general work procedures which could be unforeseeable		✔	✔	Careful regrade procedure to be set in place	BAM	Active
HAZ-GE-013	19/07/22 (JT)	Geotechnics	Plateau Slope and P&P area	**Larger loads at crest have not been assessed**	Only a 10kpa loading at the crest of the Plateau slope and P&P slope has been assessed representing emergency light vehicle access			✔	Additional loading may need to be accounted for should the situation change	Arup/ BAM	Active
HAZ-GE-014	19/07/22 (JT)	Geotechnics	Redbank Plateau	**Risk of longer time for consolidation under embankment loading**	There could be residual embankment settlement should the ground conditions be more onerous further up the road alignment		✔	✔	Must be suitable time between haul road and final road finishings to allow for any additional residual settlement	BAM	Active
HAZ-ST-003	09/12/2021 (MA	Structures	Honey street Wall	**Demolition of Honey street Wall Height risk Falling debris**	Potential - Appropriate safe method of working from contractor	✔	✔	✔		BAM	Active
HAZ-ST-005	09/12/2021 (MA)	Structures	Honey street retaining wall	**Potential instability of remaining retaining wall at Creamline Diaries area**	Potential - Removal of sections of the wall could lead to instability of the remaining structure.			✔	A qualitative review will be undertaken of the form following receipt of coring information. The cutting and reinstate of the face of the wall will be	Arup BAM	Active

									undertaken in a suitable fashion to ensure long term stability.		
HAZ-ST-012	12/05/2022 (AM)	Structures	Eastern end of viaduct	**Buried Structures**	Potential - There are a number of buried structures believed to be around the brownfield site. One area in particular is at the eastern end of the viaduct, off the end of the visible parapet. Construction of any structures in the area may require some removal of these buried structures to provide a uniform formation stiffness.		✔	✔	Review SI in specific areas at detailed design to determine extent of risk. During construction phase, hard spots to be removed to appropriate depth and reinstated with well compacted engineered fill.	Arup BAM	Active
HAZ-ST-013	13/07/22	Structures	Redbank viaduct wall	**Foundation level of wall is not known – instability issue when constructing Gabions at Redbank Terrace**	Controlled dig and temporary shoring in place when constructing gabions near to it. Viaduct wall extends near to bedrock, therefore there is approximately 10m of material supporting the front of the wall. Stability should be okay.			✔	Confirm depth of wall with structures	Arup BAM	Active
HAZ-GE-004	23/06/2021 (CR) (DH)	All	Site wide	**Contact with contaminated land during excavation** Operatives in contact with chemotoxic contaminated material leading to immediate and long-term health issues.	Potential - Risk cannot be removed due to industrial history of site. Potential - Where possible buried obstruction removal or excavation to be minimised. Achieved - Review existing contaminated land information and site history.	✘	✔	✔	Following on from desk top study areas of high risk communicated through drawings in Stage 3. Treat any residual hazardous materials that cannot be avoided through design proposals	BAM	Active
HAZ-SW-006	23/06/2021 (TW)	All	Site wide (Creamline Dairies & Travellers site)	**Asbestos** **Operatives in contact with asbestos materials during excavation and/or demolition of existing buildings leading to long term health issues.**	Risk cannot be removed due to industrial history of site and requirement to demolish buildings potentially containing asbestos substances. Achieved - Review existing contaminated land information and site history. Achieved - Review building history that require demolishing and share findings with wider team. Achieved - Review of 2019/2021 GI data has confirmed the presence of asbestos fibres in the made ground.	✘	✘	✔	Risk will need to be addressed in construction method statements	BAM	Active
HAZ-SW-013	04/08/2021 (GB)	All	Site Wide	**Needlestick injuries, contact with potentially contaminated material**	Potential - Wear appropriate protective clothing, visually inspect the site prior to undertaking any works, do not remove by hand use a picker. Do not disperse by incorporation into the ground. Dispose of potentially hazardous material to approved refuse sites. Be aware of potential risks and report to first aid/hospital if any potential contact is made	✘	✔	✔	Appropriate briefings, method statements and risk assessments to be carried out for all works being undertaken on site.	BAM	Active