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Ground Investigation Report - Geotechnical

Ground Stability at Cellars Clough, Marsden

Nov 2019

Site Ref: 6018/CCZ-G v1.0

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Ground Investigation Report – Slope Stability Assessment

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Ground Investigation Report – Slope Stability Assessment

1. Executive Summary

Client	Cubic Surveying Solutions Limited
Site	Ground Stability at Cellars Clough, Marsden
Authorisation Instruction	The work was commissioned following acceptance of the fee proposal and an instruction to proceed issued by Brennan Consult Ltd on behalf of Cubic Surveying Solutions Limited on 11th October 2019
Site Location	398800E, 427270N
Current state	Steeply sloping slipped ground. The current slopes are generally stable except for the upper scarp area.
Proposed to restore slopes and retaining walls	The re- construction of the two retaining walls and restoartaion of the slopes and upper hard standing to its original state prior to incident.
Site History	Historical mapping shows that Cellars Clough House and The Carriage House were established at some point between 1854 and 1892 and have for the most part remained unchanged. Some minor alterations to the driveway in the area now affected by the slipped ground are shown on 1960s plans
Geology	The 1 in 10,000 scale geological map of the area SE01SW and SE01SE as provided by the BGS, shows the site to be located over solid geology of the Marsden Formation comprising Siltstones and Mudstones. No superficial drift deposits are shown as being present on the geological plan. No faults in the solid geology are shown as passing directly beneath the site
Ground Condition	The subsoil profile obtained from the exploratory holes consists of made ground over a series of clays over sandy gravel over siltstone and mudstone bedrock.
Groundwater	Monitoring of groundwater levels in standpipes installed in WS1 to WS3 and spanning a period from 28th October to 11th November 2019, provided groundwater levels for use in the stability analyses
Slope Stability	The relevant typical section of the site has been analysed using propriety software and engineering judgement of the likely ground and ground water conditions in areas where information is absent. The results of these analyses indicate that the current slopes are generally stable with the upper scarp unstable. The restored section should be stable provided that two retaining walls are suitably designed and constructed to retain the ground retained and adequate drainage is installed. The assessment of the original slope section indicates that the inundation with flood water results in instability of the section in all scenarios.

2. Introduction

This Geotechnical report is an account of Slope Stability Assessment undertaken by GeoAssist Limited, at the request of the Client Cubic Surveying Solutions Limited, as the Loss Adjusters for the Insurance Company on the property known as Cellars Clough House, Marsden.

The object of the GeoAssist Limited geotechnical investigation was to obtain information on the nature, depth and extent of the superficial deposits and bedrock beneath the site to enable a more detailed slope stability assessment to be undertaken for the current slope configuration and the reinstatement of the property to its condition prior to the recent inundation and adverse collapse of retaining walls and slopes.

The work was commissioned following acceptance of the quotation and an instruction to proceed issued by Cubic Surveying Solutions Limited on 11th October 2019.

This report summarises the information obtained from this supplementary intrusive geotechnical ground investigation in order to enable a slope stability assessment to be undertaken in respect of current and post remediation conditions.

3. Description of the Site

3.1 Present

The approximate grid reference for the centre of the site is 398800E, 427270N and the total area of the site is approximately 4,500m². The area of the site is outlined with a red line on the site plan in Appendix A1.

The area of investigation is located on land immediately to the east (upper) and west (lower) of an area of slope failure. The general topography of the area is steeply sloping from the A62 Marsden Road to the River Colne. The Land slip falls within the curtilage of Cellars Clough House which sits on a cut and fill plateau partially set into the hillside. The driveway of the property spirals down from the main road to the rear of the property into a courtyard area. The slope suffering the failure sits immediately to the north and west of the courtyard and to the west of the driveway as it enters the courtyard. At the time of the field work the slope had already been subject to significant movement affecting the driveway, an outbuilding and the carriage house on the lower slope. An obvious scar from the movement was visible and foundations of the outbuilding were exposed in the north west corner.

There are no buildings on the site although the site was previously developed with residential property located either side of the central road/pathway that runs west to east through the centre of the site.

The slopes are generally overgrown with mature and immature trees and other thick vegetation.

3.2 Proposed

At present the proposed plan for the site is to restore the slope damage to a similar state to the pre failure condition and ensure stability is acceptable.

3.3 History

Historical mapping shows that Cellars Clough House and The Carriage House were established at some point between 1854 and 1892 and have for the most part remained unchanged. Some minor alterations to the driveway in the area now affected by the slipped ground are shown on 1960s plans.

4. Geology

The 1 in 10,000 scale geological map of the area SE01SW and SE01SE as provided by the BGS, shows the site to be located over solid geology of the Marsden Formation comprising Siltstones and Mudstones.

No superficial drift deposits are shown as being present on the geological plan.

The dip of the bedrocks in the area is not discernible from the BGS information.

The BGS on-line lexicon indicates that the lithological description of the Marsden Formation is 'fine- to very coarse-grained and pebbly feldspathic sandstone, interbedded with grey siltstone and mudstone, and subordinate marine black shales, thin coals and seatearths'.

No faults in the solid geology are shown as passing directly beneath the site.

5. Ground Investigation

5.1 Fieldwork

Three geotechnical exploratory holes referenced WS1 to WS3 were located as shown on the site plan in Appendix A1. The exploratory holes were positioned to the top and base of the slip area as there was no safe accessibility to the actual slip area of the site.

Two hand excavated pits referenced TP1 and TP2 were undertaken immediately adjacent to the west wall of the existing property in order to allow inspection of the foundations.

Table 5.1 Summary of Fieldwork

	Investigation Method				
Exploratory Hole Reference	Windowless sampling/Probing m		Total Depth m below ground level	Elevation at base m AOD	Comment
Geotechnical Exploratory Holes - 2019					
	WLS	DCP			Groundwater monitoring standpipes were installed in WS1 to WS3
WS1	9.00	3.92	12.92	160.02	
WS2	8.00	6.36	14.36	158.48	
WS3	4.27	nil	4.27	158.58	
TP1	Hand excavation		0.60		
TP2	Hand excavation		0.30		

The details of the strata in the exploratory holes were recorded by ground engineering professionals.

The locations of the exploratory holes are shown on the plan in Appendix A1.

Exploratory hole records are presented in Appendix C1 and C2.

Photographs of the samples recovered from the WLS holes and the photographs of the Trial Pits are given in Appendix C3.

5.2 Monitoring

Continuous monitoring of the groundwater levels was undertaken in WS1 to WS3 with the plots summarised in Appendix C4.

5.3 Surveying

All exploratory holes were surveyed at the time of the investigation. The easting, northing and Ordnance datum elevation for each hole is presented on the borehole logs.

5.4 In-Situ Testing - Standard Penetration Tests

Standard Penetration Tests (SPTs) were performed within the exploratory holes and the results are presented on the exploratory hole records.

Summaries of SPT N_{60} (corrected for hammer efficiency) for the exploratory holes WS1 to WS3 are presented in Appendix E1.

5.5 Laboratory Testing

The following geotechnical tests were performed in GeoAssist's laboratory on samples recovered from the exploratory holes WS1 to WS3.

Table 5.5 Geotechnical Testing

Test	Purpose
Natural Moisture Content and Classification test	Assessment of in-situ subsoil conditions of cohesive deposits
Unconsolidated Undrained Triaxial Compression test	Determination of undrained shear strength characteristics of cohesive subsoils
Particle Size Distribution test	Determination of grading characteristics of granular subsoils

5.6 Test Results

The results of the laboratory geotechnical tests are given in the laboratory test results summary sheets, which form Appendices D1 to D5 to this report.

6. Subsurface Stratigraphy

The subsoil profile obtained from the exploratory holes consists of Topsoil/Made Ground to depths between 0.50m to 4.80m over sands/gravels over gravelly sandy clay with cobbles over siltstone and mudstone bedrocks.

Table 6.0 Conceptual Ground Model

Strata	Depth of Strata (m) below ground level	
	Top	Base
Made Ground – MG	Ground Level	1.00 to 1.90
Gravelly sandy Clay – Clay 1	1.00 to 1.90	2.40 to 3.50
Gravelly sandy Clay – Clay 2	2.40 to 3.50	2.80 to 5.40
Gravelly sandy Clay – Clay 3	2.80 to 5.40	3.20 to 7.00
Clayey Sands and Gravels with cobbles - SG	6.10 to 7.00 (not present in WS3)	12.90 to 14.30
Siltstone/Mudstone – M1	12.92 present in WS3 only	Not proven

Further details of the subsurface stratigraphy can be found in the exploratory hole log sheets which form Appendix C1 and C2 to this report.

6.1 Made Ground - MG

The made ground consists generally of sandy gravel with sandstone fragments.

6.1 Gravelly sandy Clay – Clay 1

The cohesive fraction of these deposits varies from firm to stiff, is intermediate to low in plasticity and low in sensitivity. Sandstone and siltstone fragments were present within these deposits.

6.2 Organic very silty Clay – Clay 2

The cohesive fraction of these deposits varies from soft to firm, is intermediate to low in plasticity and low in sensitivity. Siltstone and mudstone fragments were present within these deposits.

6.3 Very gravelly sandy Clay – Clay 3

The cohesive fraction of these deposits varies from firm to very stiff, is low in plasticity and low in sensitivity. Sandstone fragments were present within these deposits. The granular fraction of these deposits varies from medium dense to dense in state of compaction.

6.2 Clayey sandy Gravel - SG

Medium dense to very dense clayey sandy Gravel with sandstone fragments was present across the site.

These deposits may represent the weathering and disintegration of the sandstone bedrocks of the area.

6.4 Clayey Siltstone/Mudstone – M1

Exploratory hole WS3 was terminated in the siltstone/mudstone bedrocks.

The upper zone of the siltstone/mudstone is very weak in strength.

7. Groundwater

Seepage groundwater was recorded in WS1 to WS3 at depths ranging from 3.30m to 2.00m during the course of the fieldwork. The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken.

Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.

Subsequent monitoring of groundwater levels in standpipes installed in WS1 to WS3 and spanning a period from 28th October to 11 November 2019, indicated the groundwater levels vary as shown in Appendix C4 and as summarised on the table 7.0 below

The readings obtained can only be considered to be representative of the groundwater levels at the top and base of the slip area. It is possible that elsewhere, localised water flows may be present particularly at the interface between more permeable granular deposits and the less permeable deposits.

Table 7.0 Fluctuation of lowest and highest groundwater levels during monitoring period.

Exploratory Hole	Highest (mAOD)	Lowest (mAOD)	Fluctuation (m)
WS1	168.23	165.97	2.26
WS2	170.05	167.89	2.16
WS3	159.56	159.48	0.08

The results from the monitoring of groundwater levels across the site have been used to plot the groundwater flow on Section AA as part of the slope stability calculations

8. Geotechnical Parameters

Derived values for the main strata as given in the conceptual ground model, table 6.0 have been determined, based on in situ SPT testing and laboratory testing undertaken as part of the investigation encompassed by exploratory holes WS1 to WS3. Where limited or no relevant test results are available, an assessment has been made based on the material type compared to published data and the Geotechnical Engineers experience of the materials.

Determination of geotechnical parameters has been based on cautious estimates of laboratory derived results, published correlations, and other field tests, complemented with engineering judgement.

Where material parameters are assumed, derived by calculation, or taken from published sources, further details are provided as to their derivation.

Table 8.1 Geotechnical Ground Parameters

Material	Unit Weight (kN/m ³)	Angle of Friction ϕ_{peak} (°)	Effective Cohesion c (kPa)
Made Ground – MG	18 ¹	44 ¹	NA
Sandy silty Clay – Clay 1	20.3 ¹	33 ¹	taken as zero
Organic silty Clay – Clay 2	15.9 ¹	31 ²	taken as zero
Gravelly sandy silty Clay – Clay 3	21.7 ¹	33 ¹	taken as zero
Clayey Sand and Gravel – SG	22.0 ¹	45 ¹	NA
Clayey Siltstone/Mudstone – M1	24.0 ¹	45 ²	taken as zero

1. BS8002: 1995 and 2015 and see Appendix D1 and D2
2. Soil properties and Correlations – Figure 6.11 (Gibson 1953)

9 Slope Stability Assessment

The information obtained from the limited number of exploratory holes and the derived subsoil parameters together with topographical information allows a schematic cross-section to be constructed at the location of interest across the site.

The location of the cross-section AA used for slope stability analysis on this site is shown in Appendix A1. This section has been chosen as it best reflects the impact on the property under consideration and does not necessarily mean that it is the most critical section in terms of slope stability.

It should be appreciated that schematic sections are an interpretation based on background data and the information at the exploratory holes locations and given the limited number of exploratory holes undertaken to date on this site can only be regarded as a reasonable assessment of the ground conditions that possibly exist. It should be appreciated that no ground investigation, however, carefully done, ever examines more than a very small proportion of the ground.

The slope stability analyses were undertaken utilising Fine GEO 5 Slope Stability Software version 2020.6

The analyses undertaken followed EN 1997 Design Approach 1, Combination 1 and 2.

Analyses using historical Factor of Safety methods were also undertaken for comparison purposes.

9.1 Geotechnical Input Data

The geotechnical properties for the main strata to be input in the Slope Stability Assessment calculations are as given in Tables 8.1 above. The groundwater level at the section was interpreted using the highest groundwater levels recorded during the monitoring period.

10. Slope Stability Analyses

10.1 Software Output

The slope stability analyses encompassed section with various circular and planar slip surfaces optimised where appropriate. Because of the situation on this site, Section AA was analysed at various stages from the current state, through restoration to the assumed original profile with retaining wall(s). An analysis was also undertaken assuming inundation of the ground due to flood water encroaching the upper part of the property.

The output from the slope stability analysis are given in Appendix F2.

A summary of the results of the slope stability analyses is given in Table 10.1.

Table 10.1 Summary of Slope Stability Analyses

Section	Analysis	Slip Type	Output	
			Utilisation Combination 1	Utilisation Combination 2
AA	EN 1997 Design Approach 1 Current State	Circular – Bishop Upper section	108% *	135% *
		Circular – Bishop Central section	72%	85%
		Planar – Sarma	78%	93%
	EN 1997 Design Approach 1 Restored State	Circular – Bishop Upper section	83%	97%
		Circular – Bishop Central section	72%	83%
		Planar – Sarma	75%	91%
	EN 1997 Design Approach 1 Flood water present	Circular – Bishop Upper section	166% *	164% *
		Circular – Bishop Central section	121% *	124% *
		Planar – Sarma	93%	112%
			Factor of Safety	
AA	Traditional Factor of Safety Current State	Circular – Bishop Upper section	0.9 *	
		Circular – Bishop Central section	1.5	
		Planar – Sarma	1.3	
	Traditional Factor of Safety Restored State	Circular – Bishop Upper section	1.3	
		Circular – Bishop Central section	1.5	
		Planar – Sarma	1.4	
	Traditional Factor of Safety Flood water present	Circular – Bishop Upper section	0.8 *	
		Circular – Bishop Central section	1.0 *	
		Planar – Sarma	1.1 *	

* Indicates failure of slope

The results of these analyses indicate that the current slopes are generally stable except for the upper section at the top of the slip scarp.

The restored slopes including the two retaining walls will be stable provided the retaining walls are designed and build appropriately and adequate drainage is included to ensure that groundwater levels do not rise to influencing depth of the wall base.

The assumed section with the flood water present such that the groundwater rises to essentially ground level indicates failure in all scenarios.

11. Reinstatement Options

11.1 Sheet Piling

Sheet piling is not recommended due to the likely required depth of penetration into stable ground and the introduction of a relatively impermeable barrier to the flow of groundwater through the slope.

11.2 Piles

Piles are not recommended due to the likely required depth of penetration to produce adequate stability of the ground profile.

11.3 Gabion Walls

A terraced solution incorporating gabion walls is considered the preferred option as they provide improved stability and are permeable to groundwater flow.

The proposed section incorporating gabions as designed by others must be checked for overall stability by a competent geotechnical engineer.

11.4 Surcharge

The top of the slopes should not be subjected to surcharge from placement of excess spoil in these areas.

If specific construction operations require plant, equipment or spoil to be placed at the top of the slopes, then more detailed analysis of the actual conditions during construction will be required.

11.5 Reinstatement Operations

Excavations for the foundations for the gabion walls will require temporary excavation into the current slopes and should be undertaken in short sections under controlled conditions with temporary support where required and the first gabion placed immediately the excavation depth is reached.

The information obtained as part of this investigation indicate that excavations will be into made ground and the underlying gravelly very sandy clays. Groundwater ingress into this excavation is not anticipated.

Excavations must be inspected at various stages to confirm that the assessment assumptions are appropriate.

The methodology of operations on site should be determined by the reinstatement contractor based on the scale of the excavation, gabions to be placed and accessibility of suitable plant.

12. Supervision and Monitoring

It should be appreciated that no ground investigation, however, carefully done, ever examines more than a very small proportion of the ground. It is essential that the soil conditions revealed during progress of the reinstatement operations are checked by a competent person with relevant geotechnical feedback to see that they correspond with those forming the basis for the reinstatement design as interpreted from the ground investigation.

It is important to note that ground investigation is not complete once the design of the geotechnical solution is completed. Investigation is an on-going process during the construction phase with observations being made to confirm assumptions made in the design and to look for any deviations from the expected ground or groundwater conditions.

It is recommended that monitoring be undertaken of critical structures and the ground potentially affected by the reinstatement operations. The actual method, frequency of monitoring and the location of selected points should be determined in conjunction with relevant stake holders.

13. GeoAssist General Notes

Project No: 6018/CCZ

Title: Ground Investigation Report: Ground Stability at Cellars Clough, Marsden

Client: Cubic Surveying Solutions Limited

Date: Nov 2019

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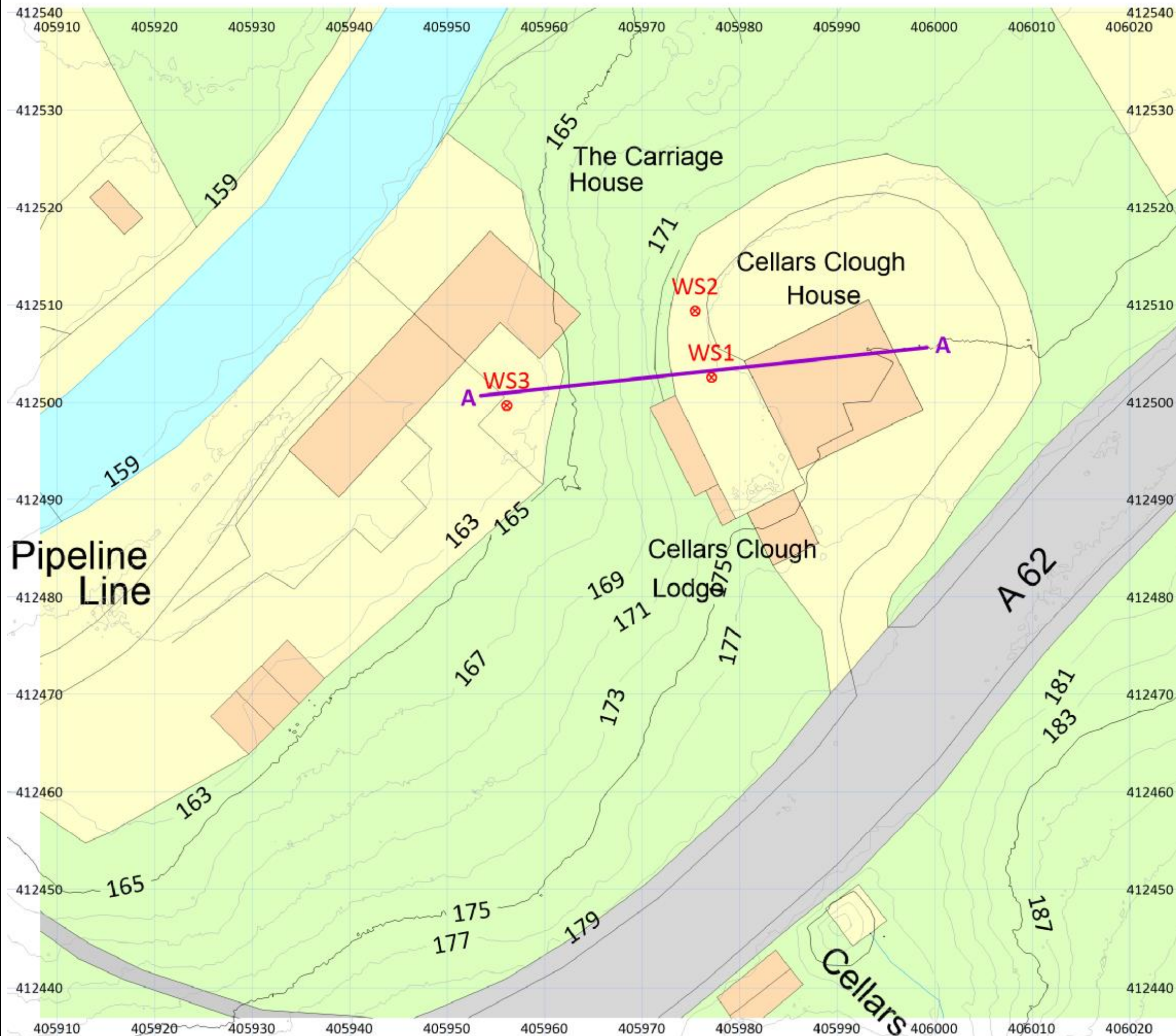
Field investigations have been restricted to a level of detail required to achieve the stated objectives of the work. Ground conditions are, and can be, variable and have only been tested at isolated locations across the site. Therefore, the potential exists for ground conditions to be encountered which are different to those considered in this report.

This report has been prepared by GeoAssist Limited with all reasonable professional skill, care and diligence within the terms of the contract with Cubic Surveying Solutions Limited. The report is confidential to Cubic Surveying Solutions Limited, their/the named persons advisors and bankers, and GeoAssist Limited accepts no responsibility of whatever nature to third parties to whom this report may be divulged. GeoAssist Limited owns the copyright in this report. All rights are reserved, and unauthorised use is prohibited. Cubic Surveying Solutions Limited may use the report for their/her/his own purposes.

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GeoAssist Limited cannot and will not accept liability for any deficiencies in third party information.

	Appendix A
A1	Site Location Plan and Site Plan with Exploratory Hole Locations and Cross Section



A1 Site Plan

Site Name	Ground Stability at Cellars Clough
Location	Marsden
GeoAssist Ref	6018CCZ
Client	Cubic Surveying Solutions Limited
	3 Wilmslow Rd Handforth Wilmslow SK9 3EN
Planning Consultant	Brennan Consult Ltd
NGR (centre of site)	398800,427270
Production Date	Oct 2019
Survey Method	
Surveyor	Others
Status	Final v1.00
Base Survey	OSGB36

Notes:

Appendix B

B1	Terminology used in Soil Descriptions
B2	List of Abbreviations
B3	Concrete in Aggressive Ground

Terminology used in Soil Descriptions

The procedure and principles given in BS EN ISO 14688-1:2002 Part 1: 'Identification and description' have been adopted in producing the soil descriptions contained within this report.

The general identification and description of soils is based on a flexible system for immediate (field) use by experienced persons, covering both material and mass characteristics by visual and manual techniques.

Details are given of the individual characteristics for identifying soils and the descriptive terms in regular use, including those related to the results of tests from the field.

This part of ISO 14688 is applicable to natural soils *in situ*, similar man-made materials *in situ* and soils redeposited by man.

Particular sections of BS EN ISO 14688-1:2002 Part 1 are reproduced here in order to clarify the production of the soil descriptions contained within this report.

Identification of soil

General

Soil characteristics that generally permit soil to be identified with adequate accuracy for general (or preliminary) characterization are outlined below. A more accurate identification and classification based on grading, plasticity or organic content can be achieved by laboratory tests. In addition to identifying soils, the condition in which a soil is encountered, any particular secondary constituents, other features of a soil, such as carbonate content, particle shape, surface roughness of particles, odour, any common names and the geological classification are indicated.

The identification and description of soils generally follows the flow chart in Figure B1.1 attached.

Particle size

Particle size is the fundamental basis for designating mineral soils using particle fractions to distinguish the soil mechanical behaviour.

Table B1 shows the terms to be used for each soil fraction and its sub-fractions, together with the corresponding chosen range of particle sizes.

Basic soils are soils with uniform grading (i.e. they consist of particles of only one size range as specified in Table B1.1

Table B1.1 Particle Size Fractions

Soil fractions	Sub-fractions	Symbols	Particle sizes mm
Very coarse soil	Large boulder	LBo	> 630
	Boulder	Bo	> 200 to 630
	Cobble	Co	> 63 to 200
Coarse soil	Gravel	Gr	> 2,0 to 63
	Coarse gravel	CGr	> 20 to 63
	Medium gravel	MGr	> 6,3 to 20
	Fine gravel	FGr	> 2,0 to 6,3
	Sand	Sa	> 0,063 to 2,0
	Coarse sand	CSa	> 0,63 to 2,0
	Medium sand	MSa	> 0,2 to 0,63
	Fine sand	FSa	> 0,063 to 0,2
Fine soil	Silt	Si	> 0,002 to 0,063
	Coarse silt	CSi	> 0,02 to 0,063
	Medium silt	MSi	> 0,006 3 to 0,02
	Fine silt	FSi	> 0,002 to 0,006 3
	Clay	Cl	≤ 0,002

APPENDIX B1

Form No.: QF029AEN

Composite soils

General

Most soils are composite and consist of principal and secondary fractions. They are designated by a noun (main term) describing the principal fraction and by one or more adjectives (qualifying terms) describing the secondary fractions (e.g. sandy gravel saGr, gravelly clay grCl).

Principal fraction

The principal fraction in terms of mass determines the engineering properties of the soil and is given in capital letters for clarity.

In the case of very coarse soils, the principal fraction is the relevant very coarse soil fraction predominating in terms of mass. The very coarse fraction should be separated from the sample before identifying the fine and coarse fractions.

In the case of coarse soils, the principal fraction is the relevant coarse soil fraction predominating in terms of mass.

Composite coarse soils include a fines fraction (silt and/or clay) that does not determine the engineering properties of the soil.

In the case of fine soils, the principal fraction is the relevant fine soil type determining the engineering properties of the soil.

In the case of composite fine soils, the fines fraction determines the engineering properties of the soil. The fines fraction is regarded as determining the characteristics of a composite soil if this is of at least medium dry strength or exhibits a certain degree of plasticity.

In both cases, the soil is termed either "clay" or "silt", depending on the plasticity of the fines fraction and not on the grading.

Secondary fractions

Secondary and further fractions do not determine but will affect the engineering properties of the soil. The secondary fractions as adjectives are placed with the term describing the principal fraction in the order of their relevance.

If coarse secondary fractions are present in a particularly small or particularly large proportion, the term "slightly" or "very" shall precede the qualifying term.

If it is a fine soil, the properties of which are determined by fines fractions, a soil can be identified as "silt" or "clay" by checking for the presence of fine secondary constituents on the basis of its plasticity properties.

If, in the case of coarse soils, two soil fractions are present in approximately equal proportions, an oblique shall be placed between the relevant terms, e.g. gravel/sand (Gr/Sa) or fine/medium sand (FSa/MSa).

Plasticity

Assessment of the plasticity and identification of a soil as either silt or clay permits the soil to be qualified as being of low plasticity or high plasticity.

An exact determination can only be made by establishing the liquid limit and the plastic limit in laboratory tests.

Organic content

Small quantities of dispersed organic matter in a soil can produce a distinctive odour and colour. The intensity of odour and colour indicates the proportion of organic matter and should be described.

Determination of consistency

The consistency of a cohesive soil shall be determined in a manual test, permitting the following identification and description:

- a) a soil is to be identified as **very soft** if it exudes between the fingers when squeezed in the hand;
- b) a soil is to be identified as **soft** if it can be moulded by light finger pressure;
- c) a soil is to be identified as **firm** if it cannot be moulded by the fingers, but rolled in the hand to thick threads without breaking or crumbling;
- d) a soil is to be identified as **stiff** if it crumbles and breaks when rolled to thick threads but is still sufficiently moist to be moulded to a lump again;
- e) a soil is to be identified as **very stiff** if it has dried out and is mostly light coloured. It can no longer be moulded but crumbles under pressure. It can be indented by the thumbnail.

Preliminary descriptions are based on visual and manual identification only.

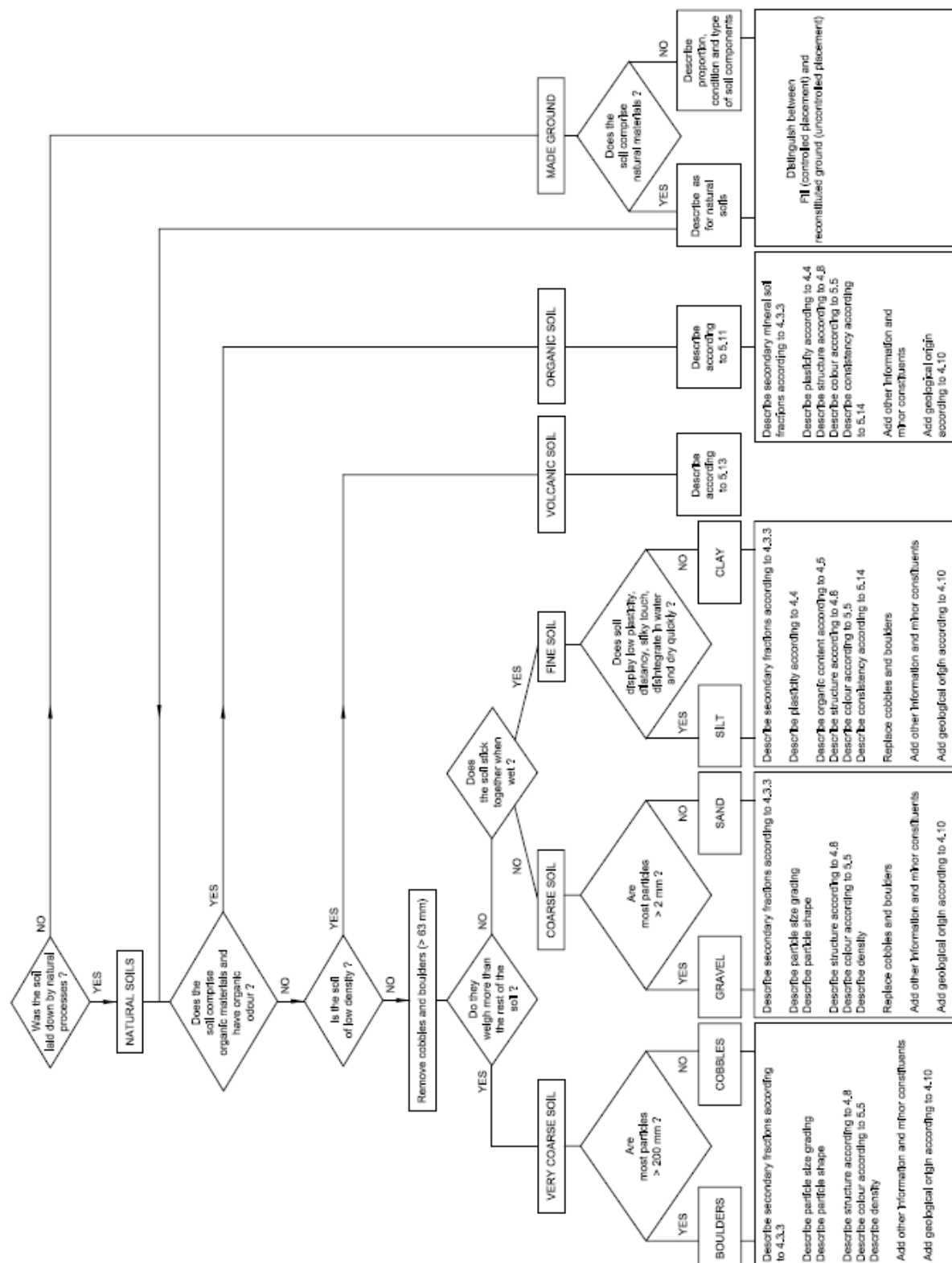


Figure B1.1 Flow chart for the identification and description of soils

Terminology used in Soil Classification

The procedure and principles given in BS EN ISO 14688-2:2004 Part 2: 'Principles for a classification' have been adopted in producing the soil descriptions contained within this report where laboratory or in situ field tests have been carried out.

The classification principles established in this part of ISO 14688 permit soils to be grouped into classes of similar composition and geotechnical properties and, with respect to their suitability for geotechnical engineering purposes.

This part of ISO 14688 is applicable to natural soil and similar man-made material *in situ* and redeposited, but it is not a classification of soil by itself.

Particular sections of BS EN ISO 14688-1:2002 Part 2 are reproduced here in order to clarify the production of the soil descriptions contained within this report.

Principles of soil classifications

General

Soils shall be classified into soil groups on the basis of their nature, which is the composition only, irrespective of their water content or compactness, taking into account the particle size distribution (grading), plasticity, organic content, genesis as appropriate.

The most common approach to classification is to divide the soils on the basis of particle size grading and plasticity. The division is made on the relative size fractions present for the coarser soil fractions, determined on the whole sample, and on the plasticity of the finer fractions (Table B1.2).

Table B1.2 Principles of a classification of soils

Criterion	Soil group	Quantification	Denomination into groups of similiar properties			Further subdivision as appropriate by
Wet soil does not stick together	very coarse	most particles > 200 mm	Bo	xBo		Requires special consideration
			boCo	coBo		
	most particles > 63 mm	Co	saCo, grCo	sagrCo		
	coarse	most particles > 2 mm	Gr	coGr	cosaGr	Particle size (grading) Shape of grading curve Relative density Permeability
		saGr, grSa	sasiGr, grsiSa			
		most particles > 0,063 mm	Sa	siGr, clGr orSa	siSa, clSa, saclGr	(Mineralogy) (Particle shape)
Wet soils sticks together	fine	low plasticity dilatant	Si	saSi	sagrSi saclSi	Plasticity Water content Strength, sensitivity Compressibility, stiffness (Clay mineralogy)
			clSi, siCl			
		plastic non-dilatant	Cl	orSi, orCl	sagrCl	
Dark colour, low density	organic		Or	saOr, siOr	clOr	Requires special consideration
Not naturally	Made ground	deposited	Mg	xMg	Man-made material	Requires special consideration
					Relaid natural materials	As for natural soils
Key to symbols						Cases requiring special consideration should be classified according to national or project requirements
Soil	Principal	Secondary or tertiary component				
Boulders	Bo	bo				
Cobbles	Co	co				
Gravel	Gr	gr	Gr(gr) and Sa(sa) can be subdivided into fine F(f), medium M(m) or coarse C(c)			
Sand	Sa	sa				
Silt	Si	si				
Clay	Cl	cl				
Organic	Or	or				
Made ground	Mg	—				
		x	any combination of components			

APPENDIX B1

Form No.: QF029AEN

Fractions

Soil is a mixture of materials of different particle size, which are grouped into fractions as specified in BS EN ISO 14688-1.

Classification of coarse and very coarse soils is to be based on the particle size distribution alone (see Table B1.3)

Table B1.3 Classification of very coarse soils

Fraction	Percent by mass	Term
Boulders	< 5	low boulder content
	5 to 20	medium boulder content
	> 20	high boulder content
Cobbles	< 10	low cobble content
	10 to 20	medium cobble content
	> 20	high cobble content

In the case of soils composed of both fine and coarse material, classification is to be based on both plasticity and particle size distribution.

Particle size distribution (grading)

The particle sizes and their distribution in a soil are determined by mechanical analysis carried out by the separation of the coarser fractions by sieving on a series of standard sieves and the determination of the finer fractions by sedimentation.

The results of the sieving and sedimentation process are plotted as a grading curve.

Plasticity

The fine fractions of soil, represented by clay and silt and containing clay minerals (see also BS EN ISO 14688-1), both alone or in mixtures with coarser material, are usually classified according to their plasticity characteristics. This is carried out on the basis of laboratory tests to determine the liquid limit w_L and plastic limit w_P .

Organic content

When soils with organic constituents are classified according to their organic content (Table B1.4), a distinction is to be made between organic soils and mineral soils with an organic content.

Table B1.4 Classification of soils with organic constituents

Soil	Organic content (≤ 2 mm) % of dry mass
Low-organic	2 to 6
Medium-organic	6 to 20
High-organic	> 20

Classification of coarse and composite organic soils accumulated *in situ* is based on the type of organic matter and that of organic soils, on the genetic origin and the degree of decomposition of the organic constituents.

APPENDIX B1

Form No.: QF029AEN

Undrained shear strength of fine soils

The terms to be used for the designation of the undrained shear strength according to the results of laboratory and field tests are given in Table B1.5.

Table B1.5 Undrained shear strength of fine soils

Undrained shear strength of clays	Undrained shear strength c_u kPa
Extremely low	< 10
Very low	10 to 20
Low	20 to 40
Medium	40 to 75
High	75 to 150
Very high	150 to 300
Extremely high ^a	> 300
^a Materials with shear strength greater than 300 kPa may behave as weak rocks and should be described as rocks according to ISO 14689-1.	

Table B1.6 Guiding values for the division of mineral soils on a basis of the contents of various fractions

Fraction	Content of fraction in wt % of material ≤ 63 mm	Content of fraction in wt % of material ≤ 0,063 mm	Name of soil	
			Modifying term	Main term
Gravel	20 to 40 > 40		gravelly	gravel
Sand	20 to 40 > 40		sandy	sand
Silt + clay (fine soil)	5 to 15 15 to 40 > 40	< 20 ≥ 20 < 20 ≥ 20 < 10 10 to 20 20 to 40 > 40	slightly silty slightly clayey silty clayey clayey silty	 silt silt clay clay

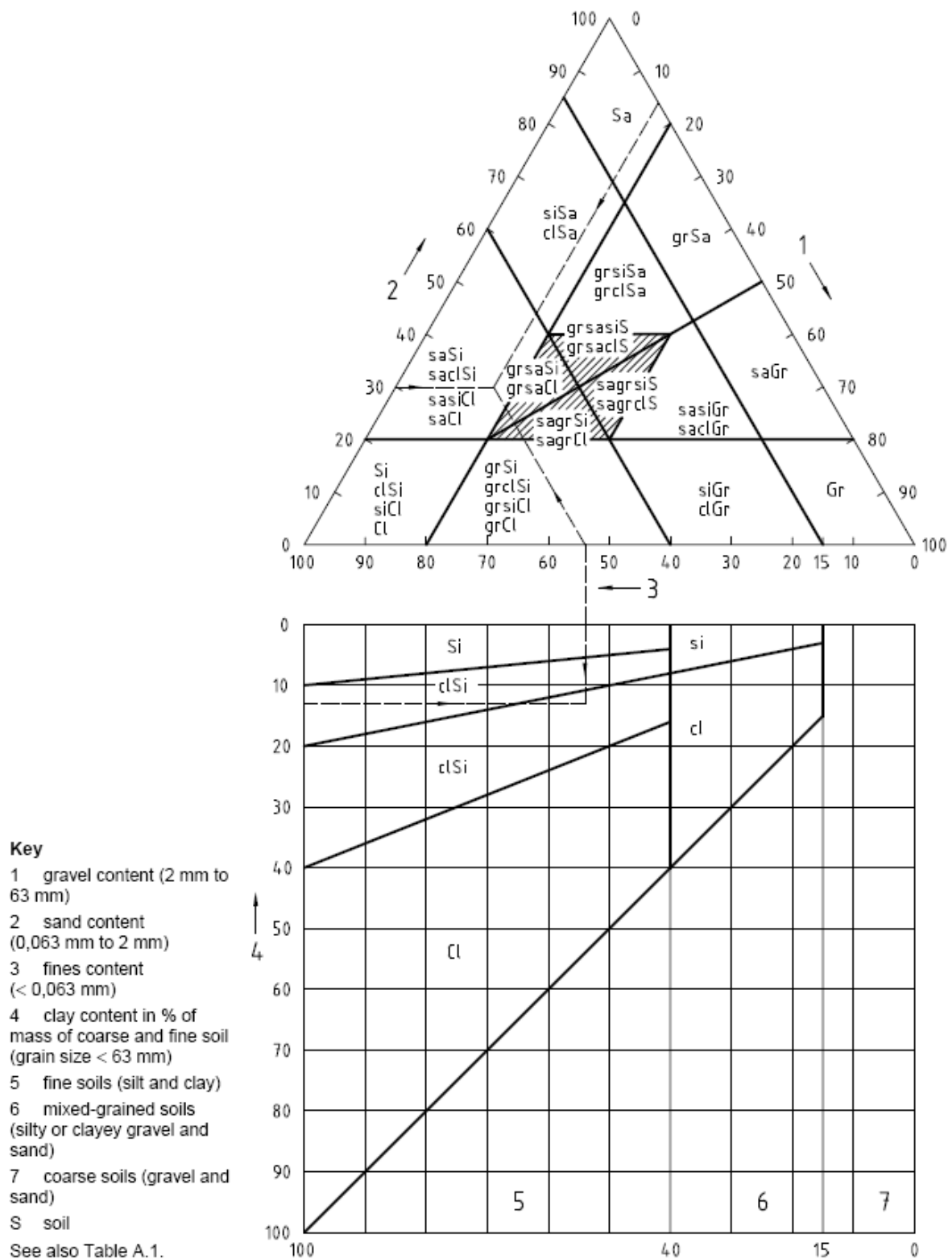


Figure B1.2 Classification of soils, based on grading alone

References

BS EN ISO 14688-1: 2002

Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description

BS EN ISO 14688-2: 2004

Geotechnical investigation and testing — Identification and classification of soil — Part 2: Principles for a classification

Abbreviations**Exploratory Hole log****Sample Type**

AGS Code	Sample Type	AGS Code	Sample Type
B	Bulk Disturbed sample	SPT	Penetration Test – split spoon
CBR	CBR sample	U	Undisturbed sample – open drive
CPT	Penetration Test – cone	UF	Undisturbed sample failed recovery
D	Small disturbed sample	W	Water sample
PU	Piston sample	C - ES	Environmental sample

SPT and CPT – Standard Penetration Test

Blow Count (N) – If full penetration of 450mm then the total number of blows for the last 300mm is given.

If limited penetration following 150mm seating blows then the number of blows for the stated penetration is given.

If limited penetration then the total number of blows for the stated penetration is given.

The N values are actual blows recorded and uncorrected.

U - Undisturbed Sample

Blow Count – total number of blows for recovered length

Legend – As per British Standard – if blank then CAVITY/OPEN HOLE

Core Rec.:

T - Total Core Recovery as a percentage of the cored run

S – Solid Core Recovery as a percentage of the cored run

RQD – Rock Quality Designation as a percentage of the cored run

FI – Fracture index as number of fractures per metre

l_f – Fracture spacing as the average length of solid core pieces between natural fractures over core length of reasonable uniform characteristics

APPENDIX B2

Form No.: QF033AEN

Laboratory Test Summary Sheet

Tests on Soils

AGS Code	Test Name	AGS Code	Test Name
ASB	Asbestos	IDEN	In Situ Density
BDEN	Bulk Density	IGNIS	Loss on Ignition
CBR	California Bearing Ratio	IVAN	In Situ Vane
CD	Consolidated drained (single stage)	LS	Linear shrinkage
CDM	Consolidated drained (multi stage)	MCVG	Moisture Condition Value
CLSS	Atterberg Limits	NMC	Natural Moisture content
CMPG	Compaction	OMS	Organic Matter
CNMT	Contaminant and Chemical	PD	Particle density
CONG	Consolidation	PHS	pH
CU	Consolidated undrained with pwp measurement (single stage)	PTST	Laboratory permeability
CUM	Consolidated undrained with pwp measurement (multi stage)	RELD	Relative Density
DDEN	Dry Density	SHBG	Shear box
FRST	Frost Susceptibility	SLIM	Shrinkage Limit
GRAD HY	Particle Size (Hydrometer)	SULWS	Sulphate on 2:1 Water:Soil Extract
GRAD WS	Particle size (wet Sieve)	TNPC	Ten Per Cent Fines
HVP	Hand vane – peak	UU	Unconsolidated quick undrained (single stage)
ICBR	In situ CBR	UUM	Unconsolidated quick undrained (multi stage)

Tests on rocks and Aggregates

AGS Code	Test Name	AGS Code	Test Name
ACV	Aggregate crushing value	SHOR	Shore hardness
BRAZ	Tensile Strength by Brazilian method	SOUN	Aggregate Soundness Test
LOSA	Aggregate Los Angeles Abrasion	UCS	Uniaxial Compressive Strength
PLSI	Point Load Index – size corrected	WTAB	Aggregate Water Absorption

4. Reference AGS Format Edition 3

Concrete in Aggressive Ground

1. Assessing the Aggressive Chemical Environment

In order to assess the levels of sulphate in the ground or groundwater, which may have a deleterious effect on concrete, the sulphate content of soil and groundwater may be determined in accordance with BS 1377 (2001) Test 3:5. The sulphate contents determined are grouped into Aggressive Chemical Environment for Concrete (ACEC) site classifications in Building Research Establishment Special Digest 1 – Part 1 (2005) Tables C1 and C2 as reproduced below.

Based on this classification BRE Special Digest 1 gives recommendations for the design of suitable concrete mixes to resist chemical attack for each ACEC classification. Care should be taken in the interpretation of results over the site area, if classification is based solely on groundwater analysis, it should be based on the highest sulphate concentration recorded. Where a large number of results from soil analysis are available it should be based on the average of the highest 20 per cent of the results. If a varied set of results are recorded from a limited sampling programme it is important to carry out further analyses before a detailed classification is given.

2. References

BS 1377: 2001: 'Methods of Test for Soils for Civil Engineering Purposes': British Standards Institution.

BRE Special Digest 1: 2005: 'Concrete in Aggressive Ground': Building Research Establishment.

Table C1 Aggressive Chemical Environment for Concrete (ACEC) classification for natural ground locations ^a						
Sulfate Design Sulfate Class for location	2:1 water/soil extract ^b	Groundwater	Total potential sulfate ^c	Groundwater Static water	Mobile water	ACEC Class for location
1	2 (SO ₄ mg/l)	3 (SO ₄ mg/l)	4 (SO ₄ %)	5 (pH)	6 (pH)	7
DS-1	< 500	< 400	< 0.24	≥ 2.5	> 5.5 ^d 2.5–5.5	AC-1s AC-1 ^e AC-2z
DS-2	500–1500	400–1400	0.24–0.6	> 3.5 2.5–3.5	> 5.5 2.5–5.5	AC-1s AC-2 AC-2s AC-3z
DS-3	1600–3000	1500–3000	0.7–1.2	> 3.5 2.5–3.5	> 5.5 2.5–5.5	AC-2s AC-3 AC-3s AC-4
DS-4	3100–6000	3100–6000	1.3–2.4	> 3.5 2.5–3.5	> 5.5 2.5–5.5	AC-3s AC-4 AC-4s AC-5
DS-5	> 6000	> 6000	> 2.4	> 3.5 2.5–3.5	≥ 2.5	AC-4s AC-5

Notes

- Applies to locations on sites that comprise either undisturbed ground that is in its natural state (ie is not brownfield – Table C2) or clean fill derived from such ground.
- The limits of Design Sulfate Classes based on 2:1 water/soil extracts have been lowered relative to previous Digests (Box C7).
- Applies only to locations where concrete will be exposed to sulfate ions (SO₄) which may result from the oxidation of sulfides (eg pyrite) following ground disturbance (Appendix A1 and Box C8).
- For flowing water that is potentially aggressive to concrete owing to high purity or an aggressive carbon dioxide level greater than 15 mg/l (Section C2.2.3), increase the ACEC Class to AC-2z.

Table C2 Aggressive Chemical Environment for Concrete (ACEC) classification for brownfield locations ^a								
Sulfate and magnesium						Groundwater		ACEC
Design Sulfate Class for location	2:1 water/soil extract ^b		Groundwater		Total potential sulfate ^c	Static water	Mobile water	Class for location
1	2	3	4	5	6	7	8	9
	(SO ₄ mg/l)	(Mg mg/l)	(SO ₄ mg/l)	(Mg mg/l)	(SO ₄ %)	(pH) ^d	(pH) ^d	
DS-1	< 500		< 400		< 0.24	≥ 2.5	> 6.5 ^e 5.5–6.5 4.5–5.5 2.5–4.5	AC-1s AC-1 AC-2z AC-3z AC-4z
DS-2	500–1500		400–1400		0.24–0.6	> 5.5 2.5–5.5	> 6.5 5.5–6.5 4.5–5.5 2.5–5.5	AC-1s AC-2 AC-2s AC-3z AC-4z AC-5z
DS-3	1600–3000		1500–3000		0.7–1.2	> 5.5 2.5–5.5	> 6.5 5.5–6.5 2.5–5.5	AC-2s AC-3 AC-3s AC-4 AC-5
DS-4	3100–6000	≤ 1200	3100–6000	≤ 1000	1.3–2.4	> 5.5 2.5–5.5	> 6.5 2.5–6.5	AC-3s AC-4 AC-4s AC-5
DS-4m	3100–6000	> 1200 ^e	3100–6000	> 1000 ^e	1.3–2.4	> 5.5 2.5–5.5	> 6.5 2.5–6.5	AC-3s AC-4m AC-4ms AC-5m
DS-5	> 6000	≤ 1200	> 6000	≤ 1000	> 2.4	> 5.5 2.5–5.5	> 2.5	AC-4s AC-5
DS-5m	> 6000	> 1200 ^e	> 6000	> 1000 ^e	> 2.4	> 5.5 2.5–5.5	≥ 2.5	AC-4ms AC-5m

Notes

- a Brownfield locations are those sites, or parts of sites, that might contain chemical residues produced by or associated with industrial production (Section C5.1.3).
- b The limits of Design Sulfate Classes based on 2:1 water/soil extracts have been lowered from previous Digests (Box C7).
- c Applies only to locations where concrete will be exposed to sulfate ions (SO₄²⁻), which may result from the oxidation of sulfides such as pyrite, following ground disturbance (Appendix A1 and Box C8).
- d An additional account is taken of hydrochloric and nitric acids by adjustment to sulfate content (Section C5.1.3).
- e The limit on water-soluble magnesium does not apply to brackish groundwater (chloride content between 12 000 mg/l and 17 000 mg/l). This allows 'm' to be omitted from the relevant ACEC classification. Seawater (chloride content about 18 000 mg/l) and stronger brines are not covered by this table.

Appendix C

C1	Exploratory Hole Logs WS1 to WS3
C2	Exploratory Hole Logs TP1 and TP2
C3	Sample and Trial Pit Photographs
C4	Groundwater Monitoring Plots

GeoAssist Limited		Exploratory Hole Record Sheet					Ref: WS1	
Consultant:		Project: Ground Stability at Cellars Clough					Sheet: 1	
Brennan Consult Ltd		Location: Marsden						
Client:		Equipment:				Ground Level: 172.94 m.AOD		
Cubic Surveying Solutions Limited		Archway Dart Rig with 100mm sampling				Co-ordinates: Easting: 405977.1(m) Northing: 412502.5(m) Dates: 15/10/2019 to 15/10/2019		
Drilling Foreman: M Walton		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests			Field Records
STRATUM DESCRIPTION					Depth (m) from to	Sample Type/No	N blows [Cu-kPa]	
Engineer/Geologist: M Benson								
0 Tarmac over grey/brown gravel - MADE GROUND		0.15	172.79					
Brown gravelly sandy silty CLAY with cinders, sandstone fragments and cobbles - MADE GROUND		(0.85)						
1		1.00	171.94					
Stiff brown with grey high strength very gravelly very sandy silty CLAY with angular sandstone fragments		(1.90)			1.00 1.20 1.50 1.50 1.80 2.00 2.20 2.30 2.50	CP1 D1 D2 B1 D3 CP2 D4 U1 D5	8 [111]	Hand vane at 1.20m - 36kPa Hand penetrometer at 1.20m - 84kPa Hand penetrometer at 1.50m - 119kPa Hand penetrometer at 1.80m - 149kPa Hand penetrometer at 2.20m - 145kPa Hand penetrometer at 2.50m - 127kPa
3 Dark grey organic silty CLAY with coal fragments		2.90	170.04		2.80 2.90	D6		
Firm light grey medium strength very silty CLAY with dark grey organic bands at 3.50m and 3.70m		3.10	169.84		3.00 3.20 3.50 3.80 4.00	CP3 D7 U2 D8 CP4	5 [66]	Hand penetrometer at 2.80m - 92kPa Wet from 3.00m to 3.10m depth Hand vane at 3.20m - 42kPa Hand vane at 3.80m - 55kPa
4 Stiff brown with light brown high strength very gravelly sandy silty CLAY with sandstone fragments		(1.30)	168.94		4.30 4.50 4.70 4.80 5.00	D9 B2 U3 D10 CP5	11 [89]	Hand penetrometer at 4.90m - 144kPa Hand penetrometer at 5.20m - 139kPa Hand penetrometer at 5.50m - 157kPa
5 Very stiff brown ironstained very high strength very gravelly sandy silty CLAY with sandstone fragments		5.30	167.64		5.20 5.50 5.80 6.00	D11 D12 D13 CP6	19 26	
6 Dense grey/brown clayey silty sandy angular sandstone GRAVEL		(1.70)			6.50 6.60	D14		Hand penetrometer at 6.50m - 197kPa
7		7.00	165.94		7.00 7.50 8.00 8.30	CP7 B3 CP8 D15	23 37	
8 Dense clayey silty sandy angular sandstone GRAVEL - Interpreted Stratum		(2.00)			9.00	CP9	39	Hand penetrometer at 8.30m - >250kPa
9 Dynmic Probe only from 9.00m		9.00	163.94					
10		(1.00)	162.94					
10.00								
Remarks: 15/10/2019: Inspection Pit excavated by hand to 1.00m to avoid services							Logged: M Benson	
The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken.							Date: 17/10/2019	
Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.							Checked: M Richardson	
							Date: 17/10/2019	
							Site Ref: 6018/CCZ	
							Scale 1:50	

GeoAssist Limited		Exploratory Hole Record Sheet					Ref: WS1		
Consultant: Brennan Consult Ltd		Project: Ground Stability at Cellars Clough Location: Marsden					Sheet: 2		
Client: Cubic Surveying Solutions Limited		Equipment: Archway Dart Rig with 100mm sampling				Ground Level: 172.94 m.AOD Co-ordinates: Easting: 405977.1(m) Northing: 412502.5(m) Dates: 15/10/2019 to 15/10/2019			
Drilling Foreman: M Walton STRATUM DESCRIPTION Engineer/Geologist: M Benson		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests Depth (m) from to		Sample Type/No	N blows [Cu-kPa]	Field Records
10(continued stratum) Dense clayey silty sandy angular sandstone GRAVEL - Interpreted Stratum					10.00	CP10	48	CP13 - 50 blows for 20mm 15/10/2019: On completion of exploratory hole at 12.92m. Casing at 3.00m. Standing water level Nil. On withdrawal of casing groundwater monitoring standpipe installed to 9.00m depth with response zone from 1.00m to 9.00m. 16/10/2019: Standing water level 5.20m depth.	
-11					11.00	CP11	37		
-12		(2.92)			12.00	CP12	47		
-13		12.92	160.02		12.90	CP13			
-14 -15 -16 -17 -18 -19 -20 Exploratory Hole complete at 12.92m									
Remarks: 15/10/2019: Inspection Pit excavated by hand to 1.00m to avoid services The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken. Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.							Logged: M Benson Date: 17/10/2019 Checked: M Richardson Date: 17/10/2019 Site Ref: 6018/CCZ Scale 1:50		

GeoAssist Limited		Exploratory Hole Record Sheet						Ref: WS2		
Consultant:		Project: Ground Stability at Cellars Clough						Sheet: 1		
Brennan Consult Ltd		Location: Marsden								
Client:		Equipment:				Ground Level: 172.84 m.AOD				
Cubic Surveying Solutions Limited		Archway Dart Rig with 100mm sampling				Co-ordinates: Easting: 405975.5(m) Northing: 412509.3(m) Dates: 16/10/2019 to 16/10/2019				
Drilling Foreman: M Walton		STRATUM DESCRIPTION		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests			Field Records
Engineer/Geologist: M Benson							Depth (m) from to	Sample Type/No	N blows [Cu-kPa]	
0 Tarmac over grey/brown gravel - MADE GROUND		0.15	172.69							
Brown gravelly sandy silty CLAY with sandstone fragments		(1.15)								
1		1.30	171.54			1.00		CP1	2	
Stiff orange/brown with grey high strength gravelly sandy silty CLAY with sandstone and siltstone fragments		(0.50)				1.40	1.50	D1		Hand penetrometer at 1.40m - 92kPa
2 Stiff brown high strength very sandy silty CLAY		(0.40)				1.90	2.00	D2		Hand penetrometer at 1.90m - 135kPa
Firm oranmge/brown with light grey medium strength gravelly sandy silty CLAY with sandstone fragments		2.20	170.64			2.00	2.30	CP2	3	Hand penetrometer at 2.20m - 129kPa
		(0.80)				2.30	2.50	D3	[51]	Hand vane at 2.50m - 66kPa
		3.00	169.84			2.90	3.00	D4		Hand penetrometer at 2.50m - 77kPa
3 Stiff grey with brown high strength gravelly sandy silty CLAY with sandstone fragments and organic inclusions		(0.50)				3.00	3.20	CP3	6	Hand penetrometer at 2.90m - 105kPa
Firm light grey with orange ironstained medium strength very silty CLAY with siltstone and mudstone fragments and organic inclusions		3.50	169.34			3.20	3.40	D5		Hand penetrometer at 3.20m - 90kPa
		(0.70)				3.40	3.60	B1		Wet at 3.30m depth
4 Soft light grey with orange ironstained low strength sandy very silty CLAY with siltstone and mudstone fragments		4.20	168.64			3.60	3.90	D6		Hand vane at 3.90m - 46kPa
		(1.20)				3.90	4.00	CP4	6	Hand penetrometer at 3.90m - 69kPa
		5.40	167.44			4.00	4.20	D8		Hand vane at 4.20m - 27kPa
		(1.20)				4.20	4.30	B2	8	Wet from 4.60m to 5.80m depth
		5.40	167.44			4.50	4.60	D9		Hand vane at 4.80m - 22kPa
		(1.20)				4.80	4.90	CP5		
		5.40	167.44			5.00	5.20	D10		
		(1.20)				5.10	5.20	B2	8	
6 Firm grey medium strength sandy silty CLAY with siltstone and mudstone fragments		(0.70)				5.50	5.60	D11		Hand vane at 5.50m - 40kPa
		6.10	166.74			5.90	6.00	D12	24	Hand penetrometer at 5.50m - 65kPa
		(0.90)				6.00	6.00	CP6		Hand penetrometer at 5.80m - 159kPa
7 Orange/brown clayey silty SAND and angular sandstone GRAVEL		(0.90)				6.50	6.60	B3		
		7.00	165.84			6.50	6.60	B3		
		(0.90)				6.50	6.60	B3		
8 Dense brown ironstained clayey silty sandy angular sandstone GRAVEL		(1.00)				7.00	7.00	CP7	54	
		8.00	164.84			7.50	7.60	D13		
		(1.00)				7.50	7.60	D13		
9 Dense clayey silty sandy angular sandstone GRAVEL - Interpreted Stratum		8.00	164.84			8.00	8.00	CP8	35	
		(2.00)				9.00	9.00	CP9	27	
		(2.00)				9.00	9.00	CP9	27	
10		10.00	162.84							
Remarks: 16/10/2019: Inspection Pit excavated by hand to 1.00m to avoid services										Logged: M Benson
The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken.										Date: 17/10/2019
Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.										Checked: M Richardson
										Date: 17/10/2019
										Site Ref: 6018/CCZ
										Scale 1:50

GeoAssist Limited		Exploratory Hole Record Sheet					Ref: WS2			
Consultant: Brennan Consult Ltd		Project: Ground Stability at Cellars Clough Location: Marsden					Sheet: 2			
Client: Cubic Surveying Solutions Limited		Equipment: Archway Dart Rig with 100mm sampling				Ground Level: 172.84 m.AOD Co-ordinates: Easting: 405975.5(m) Northing: 412509.3(m) Dates: 16/10/2019 to 16/10/2019				
Drilling Foreman: M Walton Engineer/Geologist: M Benson		STRATUM DESCRIPTION		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests		Field Records	
							Depth (m) from to	Sample Type/No		N blows [Cu-kPa]
10(continued stratum) Dense clayey silty angular sandstone GRAVEL - Interpreted Stratum							10.00	CP10	50	CP15 - 50 blows for 60mm 16/10/2019: On completion of exploratory hole at 14.36m. Casing at 3.00m. Standing water level 7.90m depth. On withdrawal of casing groundwater monitoring standpipe installed to 8.00m depth with response zone from 1.00m to 8.00m.
-11							11.00	CP11	59	
-12							12.00	CP12	47	
-13							13.00	CP13	42	
-14							14.00	CP14	48	
Exploratory Hole complete at 14.36m				14.36	158.48		14.30	CP15		
-15										
-16										
-17										
-18										
-19										
-20										
Remarks: 16/10/2019: Inspection Pit excavated by hand to 1.00m to avoid services								Logged: M Benson Date: 17/10/2019		
The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken. Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.								Checked: M Richardson Date: 17/10/2019 Site Ref: 6018/CCZ Scale 1:50		

GeoAssist Limited		Exploratory Hole Record Sheet				Ref: WS3			
Consultant: Brennan Consult Ltd		Project: Ground Stability at Cellars Clough Location: Marsden				Sheet: 1			
Client: Cubic Surveying Solutions Limited		Equipment: Geotool Lightweight Rig				Ground Level: 162.85 m.AOD Co-ordinates: Easting: 405956.1(m) Northing: 412499.7(m) Dates: 23/10/2019 to 23/10/2019			
Drilling Foreman: M Walton STRATUM DESCRIPTION Engineer/Geologist: M Benson		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests Depth (m) from to		Sample Type/No	N blows [Cu-kPa]	Field Records
0 Brown/grey clayey sandy gravel with sandstone and siltstone fragments - MADE GROUND		(1.50)							
1 Dark grey sandy cinders and sandstone fragments - MADE GROUND		1.50	161.35		1.00		CP1	8	
2 Brown/grey with dark grey organic very sandy silty CLAY		(0.40)	160.95		1.90	2.00	D1		
Brown ironstained sandy angular sandstone GRAVEL		2.00	160.85		2.00		CP2	9	Wet at 2.00m depth
Soft brown low strength gravelly sandy silty CLAY		(0.40)	160.45						
Firm to stiff brown/grey very sandy silty CLAY		(0.40)	160.05		2.60	2.70	D2		Hand vane at 2.60m - 32kPa
3 Dark grey clayey MUDSTONE with siltstone		(0.40)	160.05		2.90	3.00	D3		
Dark grey clayey MUDSTONE with siltstone - Interpreted Stratum		(0.40)	159.65		3.00		CP3	12	
4 Dark grey clayey MUDSTONE with siltstone - Interpreted Stratum		(0.60)			3.40	3.50	D4		
Exploratory Hole complete at 4.27m		3.80	159.05		3.60	3.70	D5		
5		(0.47)							
6		4.27	158.58		4.20		CP4		
7									
8									
9									
10									
Remarks: 23/10/2019: Inspection Pit excavated by hand to 1.00m to avoid services								Logged: M Benson Date: 23/10/2019 Checked: M Richardson Date: 23/10/2019 Site Ref: 6018/CCZ Scale 1:50	
The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken. Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.									

GeoAssist Limited		Exploratory Hole Record Sheet					Ref: TP1			
Consultant: Brennan Consult Ltd		Project: Ground Stability at Cellars Clough Location: Marsden					Sheet: 1			
		Equipment: Hand Excavation					Ground Level: m.AOD Co-ordinates: Easting: (m) Northing: (m) Dates: 15/10/2019 to 15/10/2019			
Client: Cubic Surveying Solutions Limited		Drilling Foreman: M Walton STRATUM DESCRIPTION Engineer/Geologist: M Benson		Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests Depth (m) from to	Sample Type/No	Blow Count N/(U)	Field Records
0 Tarmac over orange/brown clayey sandstone gravel - MADE GROUND 150mm thick concrete foundation base at 0.15m - face flush with sandstone blocks		(0.40) 0.40								15/10/2019: On completion of trial pit at 0.60m exploratory hole backfilled and reinstated.
-0.5 Brown clayey silty sandstone gravel - MADE GROUND		0.60								
Exploratory Hole complete at 0.60m										
-1 -1.5 -2 -2.5 -3 -3.5 -4 -4.5 -5										
Remarks: The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken. Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.										Logged: M Benson Date: 17/10/2019 Checked: M Richardson Date: 07/10/2019 Site Ref: 6018/CCZ Scale 1:25

GeoAssist Limited		Exploratory Hole Record Sheet				Ref: TP2		
Consultant: Brennan Consult Ltd		Project: Ground Stability at Cellars Clough				Sheet: 1		
Client: Cubic Surveying Solutions Limited		Location: Marsden				Equipment: Hand Excavation		
		Ground Level: m.AOD				Co-ordinates: Easting: (m) Northing: (m)		
						Dates: 16/10/2019 to 16/10/2019		
Drilling Foreman: M Walton		STRATUM DESCRIPTION	Depth (Thick) (m)	Reduced Level (mAOD)	Strata Legend/ Standpipe Backfill	Samples/Tests		Field Records
Engineer/Geologist: M Benson						Depth (m) from to	Sample Type/No	
0 Sandstone Flagstone over black silty sand with gravel - MADE GROUND			0.15					16/10/2019: On completion of trial pit at 0.30m exploratory hole backfilled and reinstated.
Orange/brown gravelly silty clay with sandstone fragements - MADE GROUND			0.30					
Exploratory Hole complete at 0.30m								
-0.5 Sandstone block base at 0.15m located on thin mortar/cement screed								
-1								
-1.5								
-2								
-2.5								
-3								
-3.5								
-4								
-4.5								
5								
Remarks: The groundwater conditions entered on the exploratory hole logs are those observed at the time of the drilling operations and the water level may not have reached equilibrium with the surrounding water level prior to the record being taken. Standing groundwater levels will be subject to seasonal variation or changes in local drainage conditions and could be higher at certain times of the year particularly after periods of heavy rainfall.						Logged: M Benson Date: 17/10/2019 Checked: M Richardson Date: 07/10/2019 Site Ref: 6018/CCZ Scale 1:25		

Ground Stability at Cellars Clough, Marsden



WS1 – as recovered



WS1 – after sub sampling

Ground Stability at Cellars Clough, Marsden



WS2 – as recovered



WS2 – after sub sampling

Ground Stability at Cellars Clough, Marsden



WS3 – as recovered



WS3 – after sub sampling

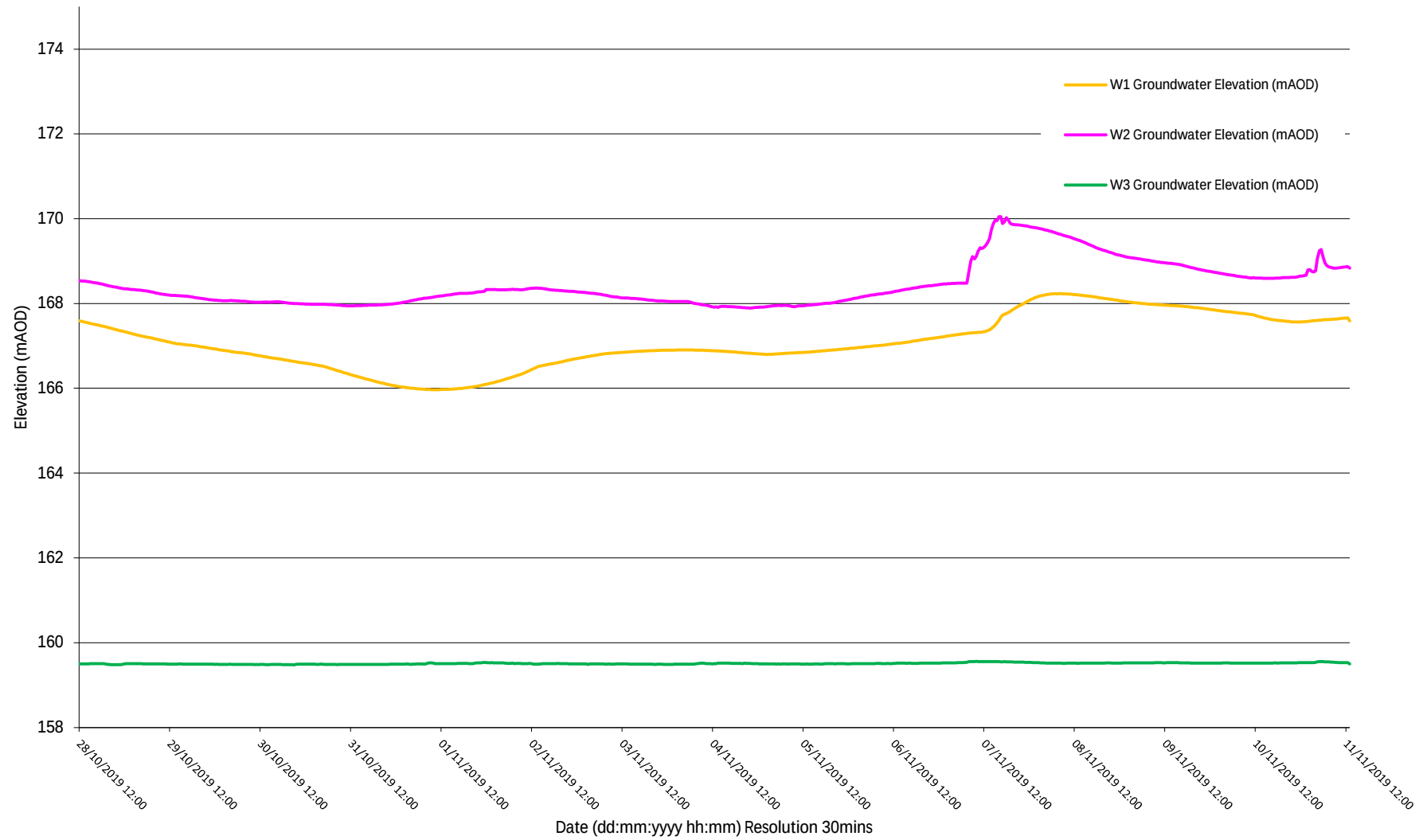


TP1



TP2

6018 CCZ Groundwater Level Time Series



Appendix D

D1	Laboratory Test Results Sheet
D2	Classification Test Summary
D3	Triaxial Test Results Summary
D4	Particle Size Distribution Graphs
D5	Moisture Content Test Summary

GeoAssist Limited SOIL LABORATORY SUMMARY SHEET	Project: Ground Stability at Cellars Clough Location: Marsden Client: Cubic Surveying Solutions Limited Consultant : Brennan Consult Ltd	Site Ref: 6018/CCZ Project Code :
		Hole Ref WS1 to WS3

Sample Ref.	Depth m	Sample Description	Classification					Triaxial Compression					Chemical		Test Code
			LL %	PL %	PI %	% passing 425 m	Moist Cont. %	Bulk Density Mg/m ³	Sample Diameter mm	Lateral Pressure kN/m ²	Deviator Stress kN/m ²	Shear Cohesion kN/m ²	So ₄ 2:1 extract Soil:Water mg/l	pH	
WS1 D1	1.20	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments					26								NMC
WS1 D2	1.50	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments					13								NMC
WS1 B1	1.50	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments													NMC GRAD WS
WS1 D3	1.80	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments					17								NMC
WS1 D4	2.20	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments					19								NMC
WS1 U1	2.30	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments				NP	16	2.08	100	200	222	111			NMC UU
WS1 D5	2.50	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments					20								NMC
WS1 D6	2.80	Brown with grey very gravelly very sandy silty CLAY with angular sandstone fragments	31	18	13	100	23 23								NMC CLSS
WS1 D7	3.20	Light grey very silty CLAY with organic inclusions					62								NMC LOI = 23%
WS1 U2	3.50	Dark grey organic very silty CLAY					119	1.59	100	200	132	66			NMC UU LOI = 33%
WS1 D8	3.80	Light grey very silty CLAY					22								NMC
WS1 D9	4.30	Brown with light brown very gravelly sandy silty CLAY with sandstone fragments					15								NMC
WS1 B2	4.50	Brown with light brown very gravelly sandy silty CLAY with sandstone fragments													NMC GRAD WS
WS1 U3	4.70	Brown with light brown very gravelly sandy silty CLAY with sandstone fragments					16	2.48	80	200	177	89			NMC UU
WS1 D10	4.80	Brown with light brown very gravelly sandy silty CLAY with sandstone fragments					16								NMC
WS1 D11	5.20	Brown with light brown very gravelly sandy silty CLAY with sandstone fragments					18								NMC

GeoAssist Limited SOIL LABORATORY SUMMARY SHEET	Project: Ground Stability at Cellars Clough Location: Marsden Client: Cubic Surveying Solutions Limited Consultant : Brennan Consult Ltd	Site Ref: 6018/CCZ Project Code :
		Hole Ref WS1 to WS3

Sample Ref.	Depth m	Sample Description	Classification					Triaxial Compression					Chemical		Test Code
			LL %	PL %	PI %	% passing 425 m	Moist Cont. %	Bulk Density Mg/m ³	Sample Diameter mm	Lateral Pressure kN/m ²	Deviator Stress kN/m ²	Shear Cohesion kN/m ²	So ₄ 2:1 extract Soil:Water mg/l	pH	
WS1 D12	5.50	Brown ironstained very gravelly sandy silty CLAY with sandstone fragments	30	19	11	95	17 18								NMC CLSS
WS1 D13	5.80	Brown ironstained very gravelly sandy silty CLAY with sandstone fragments					14								NMC
WS1 D14	6.50	Brown ironstained very gravelly sandy silty CLAY with sandstone fragments					15								NMC
WS1 B3	7.50	Grey/brown clayey silty sandy angular sandstone GRAVEL													NMC GRAD WS
WS1 D15	8.30	Grey/brown clayey silty sandy angular sandstone GRAVEL					14								NMC
WS2 D1	1.40	Orange/brown with grey gravelly sandy silty CLAY with sandstone and siltstone fragments					25								NMC
WS2 D2	1.90	Brown strength very sandy silty CLAY					30								NMC
WS2 D3	2.20	Orange/brown with light grey gravelly sandy silty CLAY with sandstone fragments					22								NMC
WS2 U1	2.30	Orange/brown with light grey gravelly sandy silty CLAY with sandstone fragments	37	19	18	100	24 25	1.98	100	100	102	51			NMC CLSS UU
WS2 D4	2.90	Orange/brown with light grey gravelly sandy silty CLAY with sandstone fragments					27								NMC
WS2 D5	3.20	Grey with brown gravelly sandy silty CLAY with sandstone fragments and organic inclusions					22								NMC
WS2 B1	3.30	Grey with brown gravelly sandy silty CLAY with sandstone fragments and organic inclusions					24								NMC
WS2 D6	3.50	Grey with brown gravelly sandy silty CLAY with sandstone fragments and organic inclusions					90								NMC LOI = 9.4%

GeoAssist Limited SOIL LABORATORY SUMMARY SHEET	Project: Ground Stability at Cellars Clough Location: Marsden Client: Cubic Surveying Solutions Limited Consultant : Brennan Consult Ltd	Site Ref: 6018/CCZ Project Code :
		Hole Ref WS1 to WS3

Sample Ref.	Depth m	Sample Description	Classification					Triaxial Compression					Chemical		Test Code
			LL %	PL %	PI %	% passing 425 m	Moist Cont. %	Bulk Density Mg/m ³	Sample Diameter mm	Lateral Pressure kN/m ²	Deviator Stress kN/m ²	Shear Cohesion kN/m ²	So ₄ 2:1 extract Soil:Water mg/l	pH	
WS2 D7	3.90	Light grey with orange ironstained very silty CLAY with siltstone and mudstone fragments and organic inclusions					70								NMC LOI = 2.1%
WS2 D8	4.20	Light grey with orange ironstained sandy very silty CLAY with siltstone and mudstone fragments					24								NMC
WS2 B2	4.50	Light grey with orange ironstained sandy very silty CLAY with siltstone and mudstone fragments					23								NMC
WS2 D9	4.80	Light grey with orange ironstained sandy very silty CLAY with siltstone and mudstone fragments					27								NMC
WS2 D10	5.10	Light grey with orange ironstained sandy very silty CLAY with siltstone and mudstone fragments	30	19	11	99	27 27								NMC CLSS
WS2 D11	5.50	Grey sandy silty CLAY with siltstone and mudstone fragments					22								NMC
WS2 D12	5.90	Grey sandy silty CLAY with siltstone and mudstone fragments					23								NMC
WS2 B3	6.50	Orange/brown clayey silty SAND and angular sandstone GRAVEL					9.6								NMC
WS2 D13	7.50	Brown ironstained clayey silty sandy angular sandstone GRAVEL					12								NMC
WS3 D1	1.90	Dark grey sandy cinders and sandstone fragments - MADE GROUND				NP	24								NMC CLSS
WS3 D2	2.60	Brown gravelly sandy silty CLAY	37	21	16	99	28 30								NMC CLSS
WS3 D3	2.90	Brown/grey very sandy silty CLAY					15								NMC
WS3 D4	3.40	Dark grey clayey MUDSTONE with siltstone					23								NMC

GeoAssist Limited SOIL LABORATORY SUMMARY SHEET	Project:	Ground Stability at Cellars Clough	Site Ref:	6018/CCZ
	Location:	Marsden	Project Code :	
	Client:	Cubic Surveying Solutions Limited		
	Consultant :	Brennan Consult Ltd	Hole Ref	WS1 to WS3

Sample Ref.	Depth m	Sample Description	Classification					Triaxial Compression					Chemical		Test Code
			LL %	PL %	PI %	% passing 425 m	Moist Cont. %	Bulk Density Mg/m ³	Sample Diameter mm	Lateral Pressure kN/m ²	Deviator Stress kN/m ²	Shear Cohesion kN/m ²	So ₄ 2:1 extract Soil:Water mg/l	pH	
WS3 D5	3.60	Dark grey clayey MUDSTONE with siltstone					14								NMC LOI = 4.9%

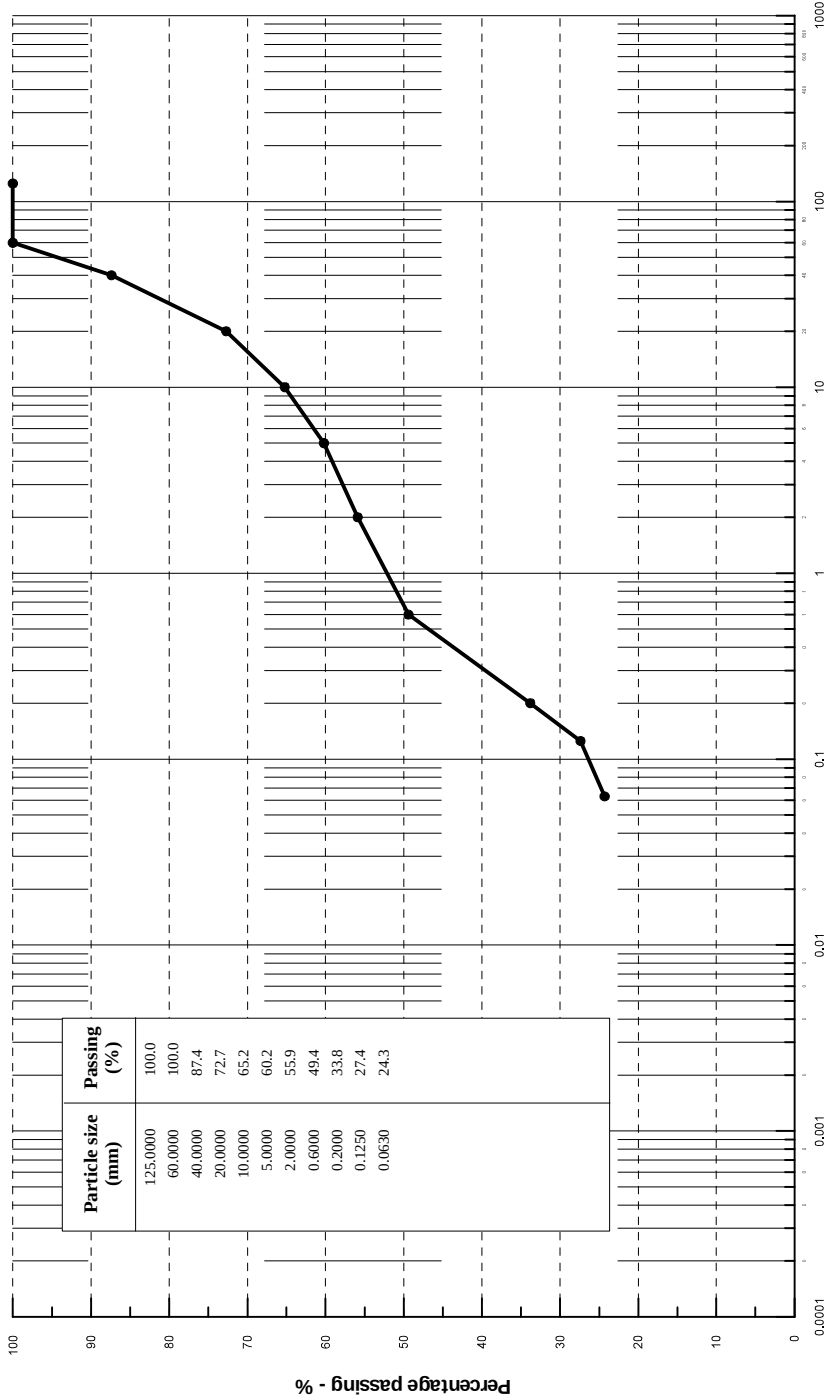
Site Reference:			6018 CCZ							
Project Site:			Ground Stability at Cellars Clough							
Project Location:			Marsden							
Client:			Cubic Surveying Solutions Limited							
Consultant:			Brennan Consult Ltd							
CLASSIFICATION TEST										
Borehole Reference	Sample	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% passing 425 micro	Natural Moisture Content	Material Code	Liquidity Index	Consistency Index
WS1	U1	2.30				100	16	CL1		
WS1	D6	2.80	31	18	13	100	23	CL1	-0.4	0.6
WS2	U1	2.30	37	19	18	100	24	CL1	-0.3	0.7
WS3	D1	1.90				100	28	CL1		
		Mean	34	19	16	100	23			
CLAY 1		Maximum	37	19	18	100	28			
		Minimum	31	18	13	100	16			
		Count	2	2	2	4	4			
WS2	D10	5.10	30	19	11	99	27	CL2	-0.7	0.3
WS3	D2	2.60	37	21	16	99	28	CL2	-0.4	0.6
		Mean	34	20	14	99	28			
CLAY 2		Maximum	37	21	16	99	28			
ORGANIC		Minimum	30	19	11	99	27			
		Count	2	2	2	2	2			
WS1	D12	5.50	30	19	11	95	17	CL3	0.2	1.2
		Mean	30	19	11	95	17			
CLAY		Maximum	30	19	11	95	17			
TILL		Minimum	30	19	11	95	17			
		Count	1	1	1	1	1			

Site Reference:			6018	CCZ				
Project Site:			Ground Stability at Cellars Clough					
Project Location:			Marsden					
Client:			Cubic Surveying Solutions Limited					
Consultant:			Brennan Consult Ltd					
	TRIAXIAL TEST RESULTS SUMMARY							
BH No	Sample	Depth m	Moisture Content %	Bulk Density MN/m3	Diameter mm	Strength kN/m ²	Equivalent Undrained Shear Strength	Material Code
WS1	U1	2.30	16	2.08	100	111	High	CL1
WS2	U1	2.30	25	1.98	100	51	Medium	CL1
		Mean	20	2.03		81		
CLAY 1		Maximum	25	2.08		111		
		Minimum	16	1.98		51		
		Count	2	2		2		
WS1	U2	3.50	119	1.59	95	66	Medium	CL2
		Mean	119	1.59		66		
CLAY 2		Maximum	119	1.59		66		
ORGANIC		Minimum	119	1.59		66		
		Count	1	1				
WS1	U3	4.70	16	2.17	80	89	High	CL3
		Mean	16	2.17		89		
CLAY 3		Maximum	16	2.17		89		
TILL		Minimum	16	2.17		89		
		Count	1	1				

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS1
Sample: B1
Depth: 1.50m

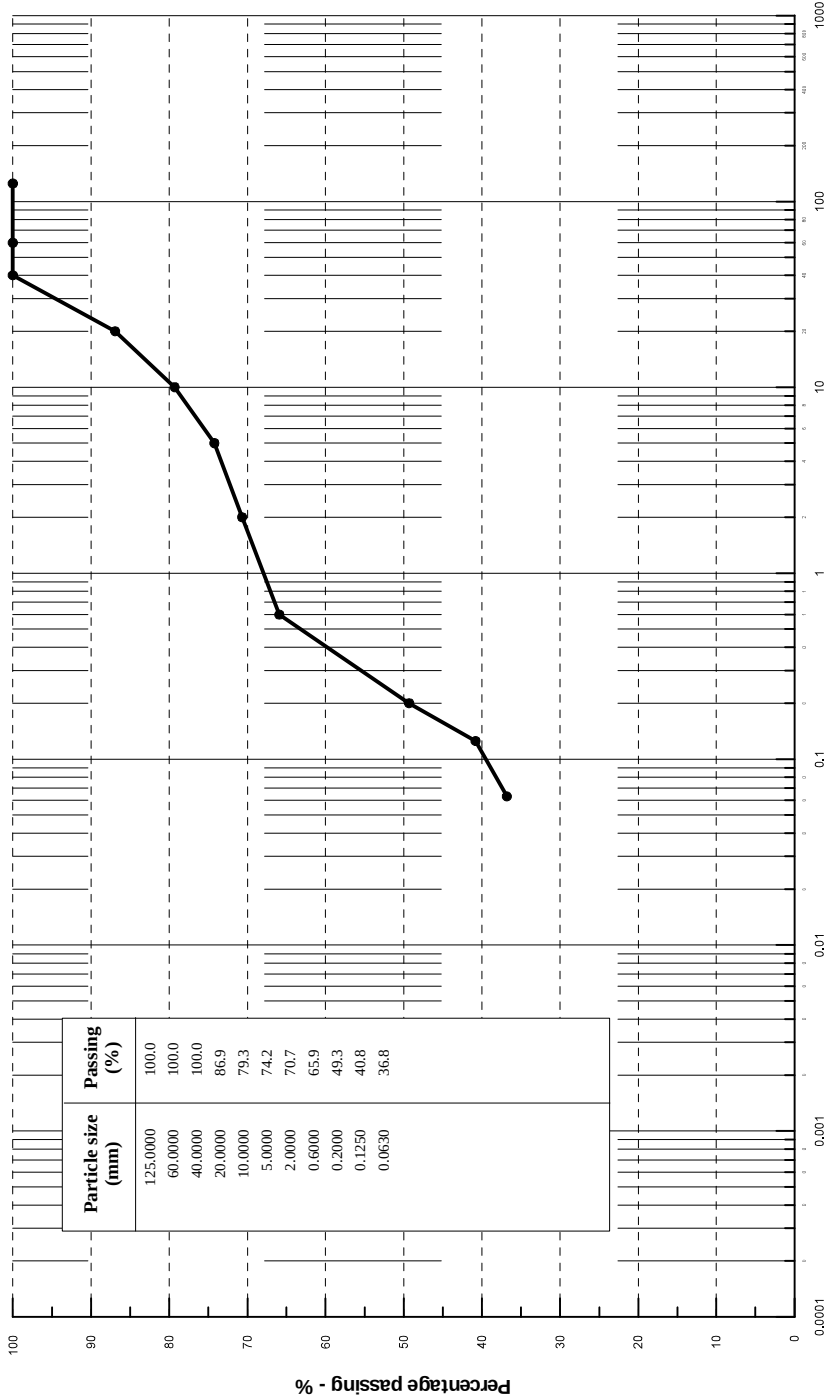
%	SIZE
0.0	Cobbles
44.1	Gravel
31.7	Sand
24.3	Silt and Clay

CLAY	SILT			GRAVEL	COBBLES	BOULDERS
	Fine	Medium	Coarse			

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS1
Sample: B2
Depth: 4.50m

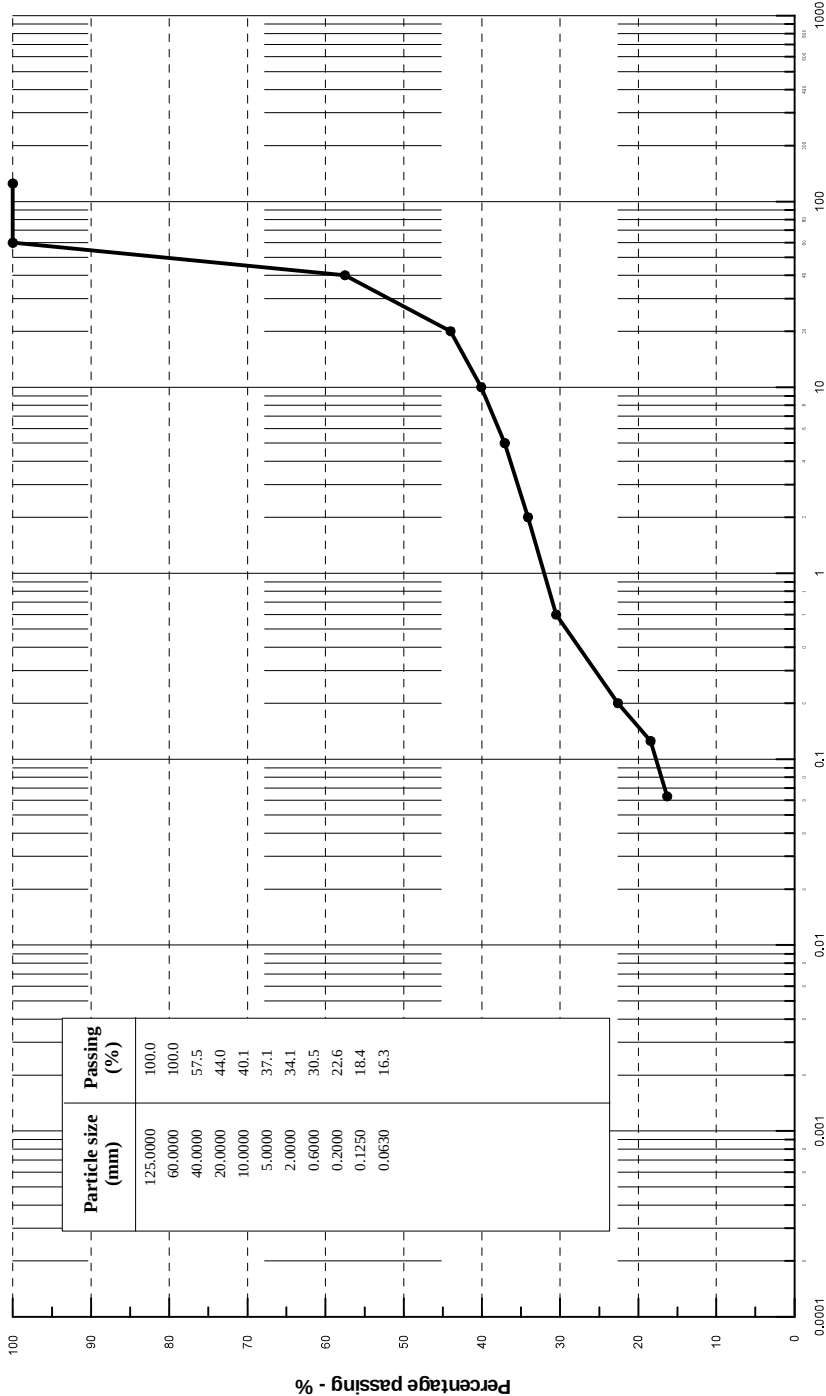
%	SIZE
0.0	Cobbles
29.3	Gravel
33.9	Sand
36.8	Silt and Clay

CLAY	SILT			SAND			GRAVEL	COB- BLES	BOUL- DERS
	Fine	Medium	Coarse	Fine	Medium	Coarse			

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS1
Sample: B3
Depth: 7.50m

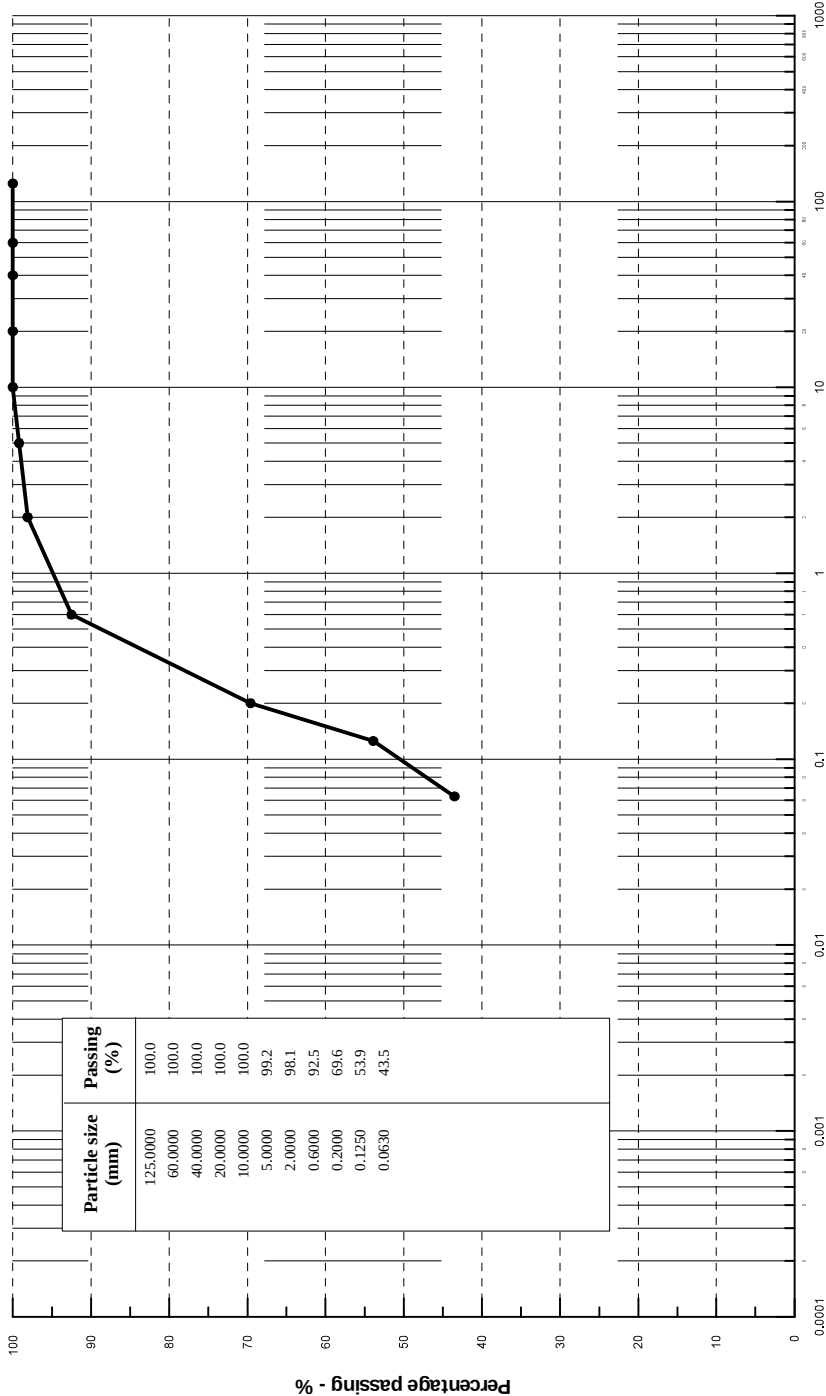
%	SIZE
0.0	Cobbles
65.9	Gravel
17.8	Sand
16.3	Silt and Clay

CLAY	SILT			SAND			GRAVEL	COB- BLES	BOUL- DERS
	Fine	Medium	Coarse	Fine	Medium	Coarse			

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS2
Sample: B1
Depth: 3.30m

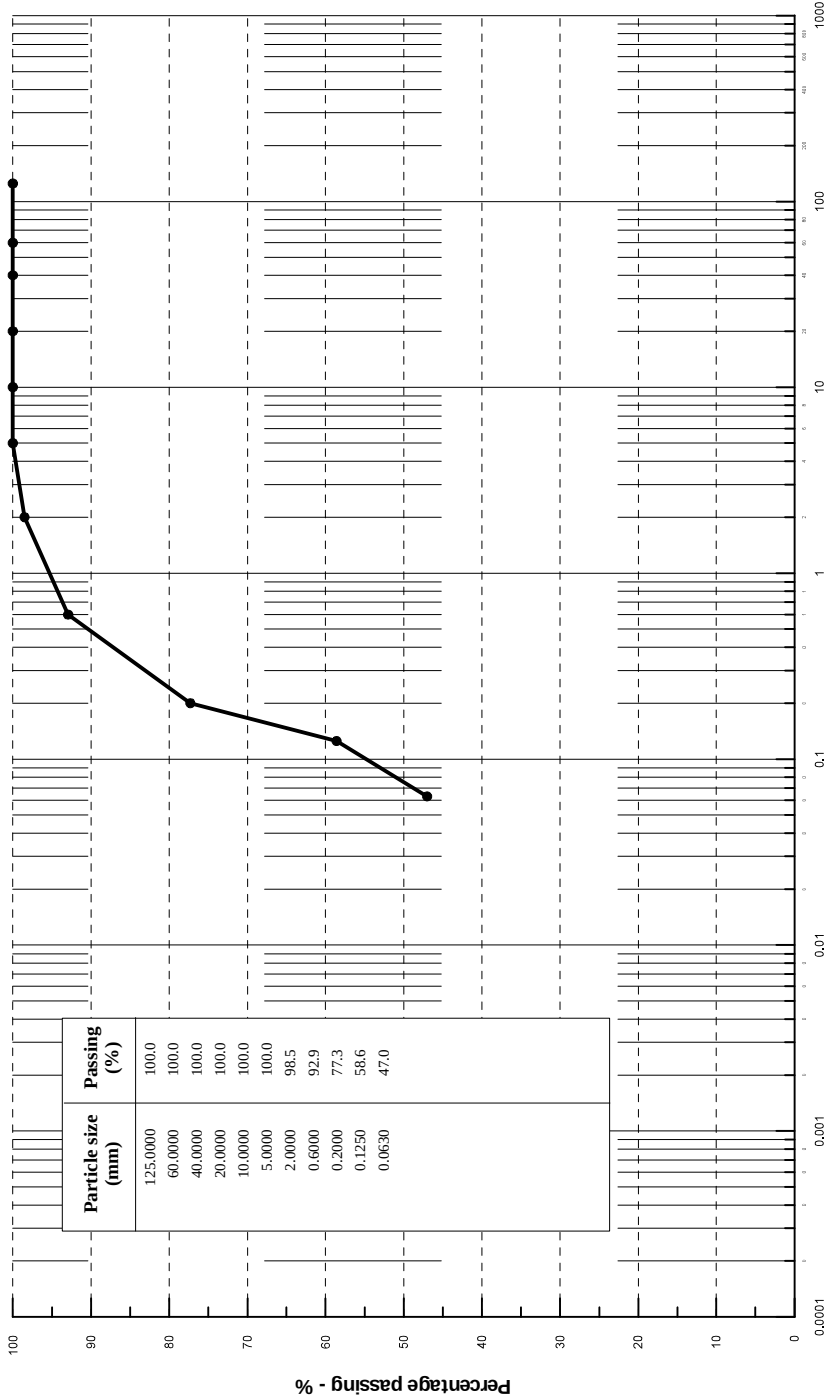
%	SIZE
0.0	Cobbles
1.9	Gravel
54.7	Sand
43.5	Silt and Clay

CLAY	SILT			SAND			GRAVEL	COB- BLES	BOUL- DERS
	Fine	Medium	Coarse	Fine	Medium	Coarse			

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS2
Sample: B2
Depth: 4.50m

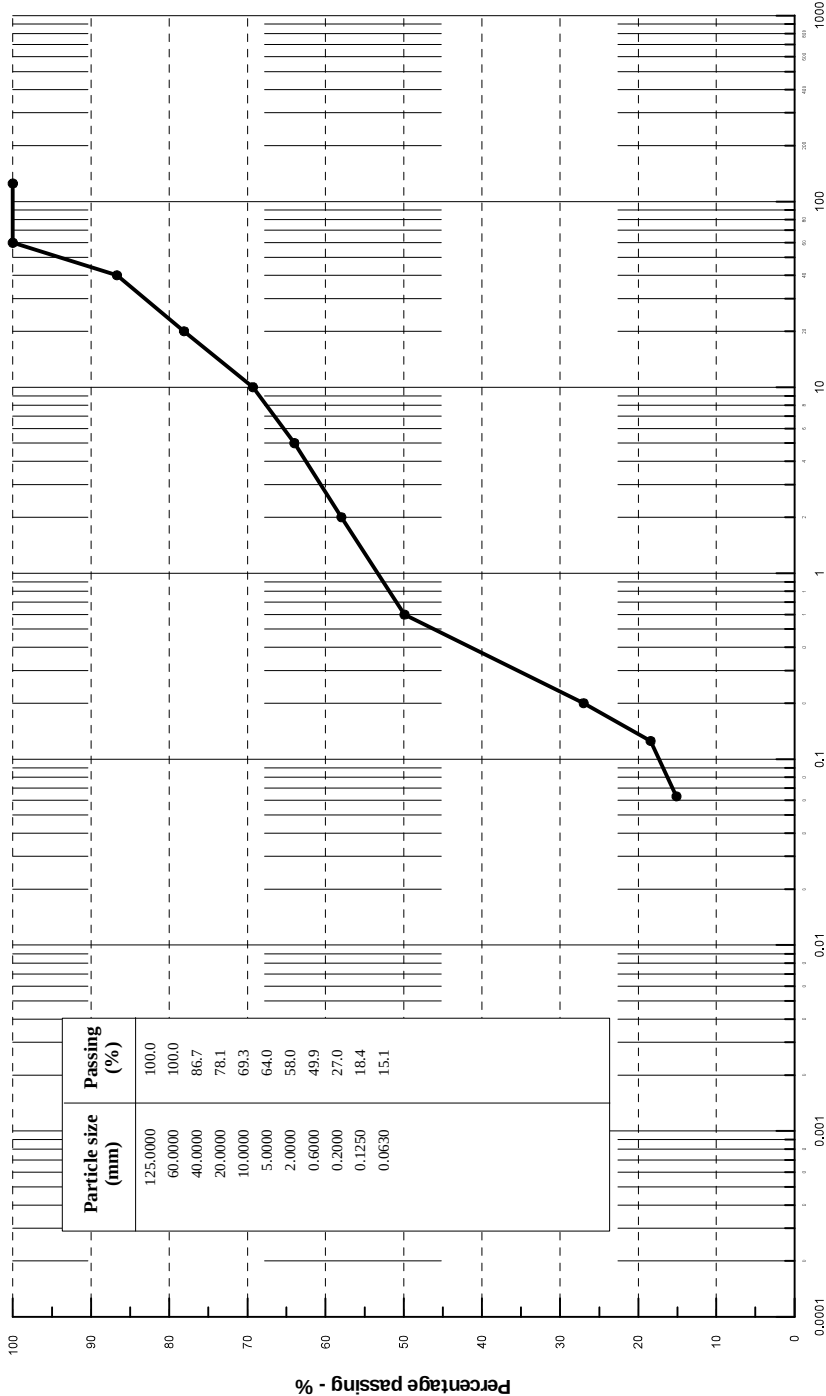
%	SIZE
0.0	Cobbles
1.5	Gravel
51.6	Sand
47.0	Silt and Clay

CLAY	SILT			SAND			GRAVEL	COB- BLES	BOUL- DERS
	Fine	Medium	Coarse	Fine	Medium	Coarse			

PARTICLE SIZE DISTRIBUTION GRAPH

Site Number: 6018
Site Reference: CCZ

Project: Ground Stability at Cellars Clough
Location: Marsden
Client: Cubic Surveying Solutions Limited
Consultant: Brennan Consult Ltd



BH No: WS2
Sample: B3
Depth: 6.50m

%	SIZE
0.0	Cobbles
42.0	Gravel
42.8	Sand
15.1	Silt and Clay

CLAY	Fine	Medium	Coarse	SILT	SAND	GRAVEL	COBBLES	BOULDERS

Site Reference:			6018 CCZ					
Project Site:			Ground Stability at Cellars Clough					
Project Location:			Marsden					
Client:			Cubic Surveying Solutions Limited					
Consultant:			Brennan Consult Ltd					
	MOISTURE CONTENT							
Borehole Reference	Sample	Depth					Natural Moisture Content	Material Code
WS1	D1	1.20					26	CL1
WS1	D2	1.50					13	CL1
WS1	D3	1.80					17	CL1
WS1	D4	2.20					19	CL1
WS1	D5	2.50					20	CL1
WS1	D6	2.80					23	CL1
WS2	D1	1.40					25	CL1
WS2	D2	1.90					30	CL1
WS2	D3	2.20					22	CL1
WS2	U1	2.30					25	CL1
WS2	D4	2.90					27	CL1
WS2	D5	3.20					22	CL1
WS2	B1	3.30					24	CL1
WS3	D1	1.90					24	CL1
		Mean					23	
CLAY 1		Maximum					30	
		Minimum					13	
		Count					14	
WS1	D7	3.20					62	CL2
WS1	D8	3.80					22	CL2
WS2	D6	3.50					90	CL2
WS2	D7	3.90					70	CL2
WS2	D8	4.20					24	CL2
WS2	B2	4.50					23	CL2
WS2	D9	4.80					27	CL2
WS2	D10	5.10					27	CL2
WS3	D2	2.60					30	CL2
		Mean					42	
CLAY 2		Maximum					90	
ORGANIC		Minimum					22	
		Count					9	
WS1	D9	4.30					15	CL3
WS1	D10	4.80					16	CL3
WS1	D11	5.20					18	CL3
WS1	D12	5.50					18	CL3
WS1	D13	5.80					14	CL3
WS1	D14	6.50					15	CL3
WS2	D11	5.50					22	CL3
WS2	B3	6.50					9.6	CL3
WS2	D12	5.90					23	CL3
WS3	D3	2.90					15	CL3
		Mean					17	
CLAY 3		Maximum					23	
TILL		Minimum					10	
		Count					10	
WS1	D15	8.30					14	SG
WS2	D13	7.50					12	SG
		Mean					13	
SAND/GRAVEL		Maximum					14	
CLAYEY		Minimum					12	
		Count					2	
WS3	D4	3.40					23	MDT
WS3	D5	3.60					14	MDT
		Mean					19	
MUDSTONE		Maximum					23	
		Minimum					14	
		Count					2	

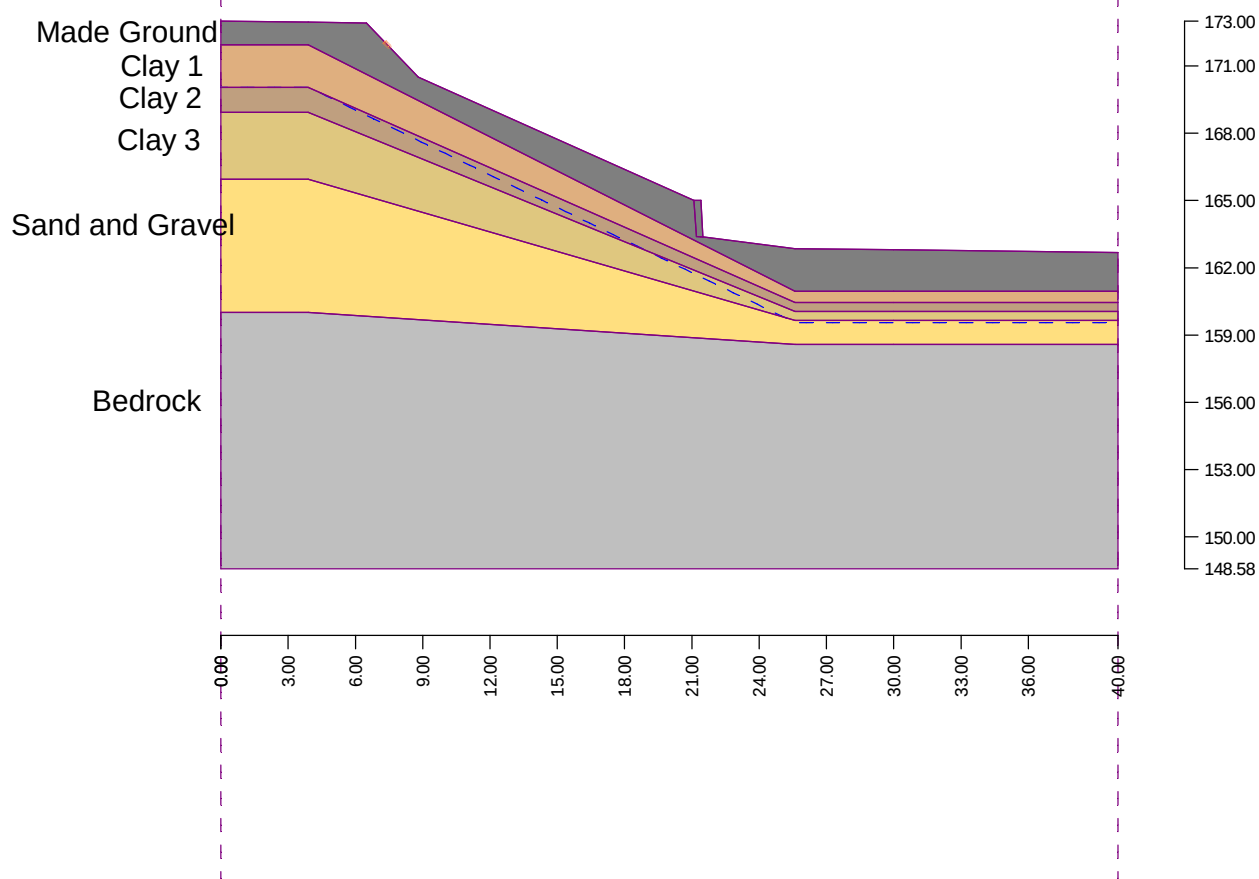
E1	SPT/CPT Summary	Appendix E
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Site Reference:			6018 CCZ					
Project Site:			Ground Stability at Cellars Clough					
Project Location:			Marsden					
Client:			Cubic Surveying Solutions Limited					
Consultant:			Brennan Consult Ltd					
	SPT SUMMARY							
Borehole Reference	Depth m	Test Type	Blow count	Penetration mm	N Value	N ₆₀ Value	Note	Material
MG								
WS3	1.00	C	8	300	8	10		MG
				Mean	8	10		
				Maximum	8	10		
	Made Ground - MG			Minimum	8	10		
				Count	1	1		
WS1	1.00	C	8	300	8	10		CL1
WS1	2.00	C	9	300	9	11		CL1
WS2	1.00	C	2	300	2	2		CL1
WS2	2.00	C	3	300	3	4		CL1
WS2	3.00	C	6	300	6	7		CL1
WS3	2.00	C	9	300	9	11		CL1
				Mean	6	8		
				Maximum	9	11		
				Minimum	2	2		CL1
	Clay with gravel - CL1			Count	6	6		
WS1	3.00	C	5	300	5	6		CL2
WS2	4.00	C	6	300	6	7		CL2
WS2	5.00	C	8	300	8	10		CL2
				Mean	6	8		
				Maximum	8	10		
				Minimum	5	6		CL2
	Clay with gravel - GL2			Count	3	3		
WS1	4.00	C	11	300	11	14		CL3
WS1	5.00	C	9	300	9	11		CL3
WS1	6.00	C	26	300	26	32		CL3
WS2	6.00	C	24	300	24	30		CL3
WS3	3.00	C	12	300	12	15		CL3
				Mean	16	20		
				Maximum	26	32		
				Minimum	9	11		CL3
	Clay with gravel - GL3			Count	5	5		

Site Reference:			6018 CCZ					
Project Site:			Ground Stability at Cellars Clough					
Project Location:			Marsden					
Client:			Cubic Surveying Solutions Limited					
Consultant:			Brennan Consult Ltd					
	SPT SUMMARY							
Borehole Reference	Depth m	Test Type	Blow count	Penetration mm	N Value	N ₆₀ Value	Note	Material
WS1	7.00	C	23	300	23	28	omitted	SAG
WS1	8.00	C	37	300	37	46		SAG
WS1	9.00	C	39	300	39	48		SAG
WS1	10.00	C	48	300	48	59		SAG
WS1	11.00	C	37	300	37	46		SAG
WS1	12.00	C	47	300	47	58		SAG
WS2	7.00	C	54	300	54	67		SAG
WS2	8.00	C	35	300	35	43		SAG
WS2	9.00	C	27	300	27	33		SAG
WS2	10.00	C	50	300	50	62		SAG
WS2	11.00	C	59	300	59	73		SAG
WS2	12.00	C	47	300	47	58		SAG
WS2	13.00	C	42	300	42	52		SAG
WS2	14.00	C	48	300	48	59		SAG
				Mean	42	52		
				Maximum	59	73		
				Minimum	23	28		SAG
	Clayey Sand and Gravel - SAG			Count	14	14		

F1 Appendix E
Output from Stability Analyses - Fine GEO5 Slope Stability Software

Name : Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 0.19 \text{ kN/m}$

Sum of passive forces : $F_p = 0.18 \text{ kN/m}$

Sliding moment : $M_a = 10.61 \text{ kNm/m}$

Resisting moment : $M_p = 9.82 \text{ kNm/m}$

Utilization : 108.0 %

Slope stability NOT ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 0.14 \text{ kN/m}$

Sum of passive forces : $F_p = 0.11 \text{ kN/m}$

Sliding moment : $M_a = 7.86 \text{ kNm/m}$

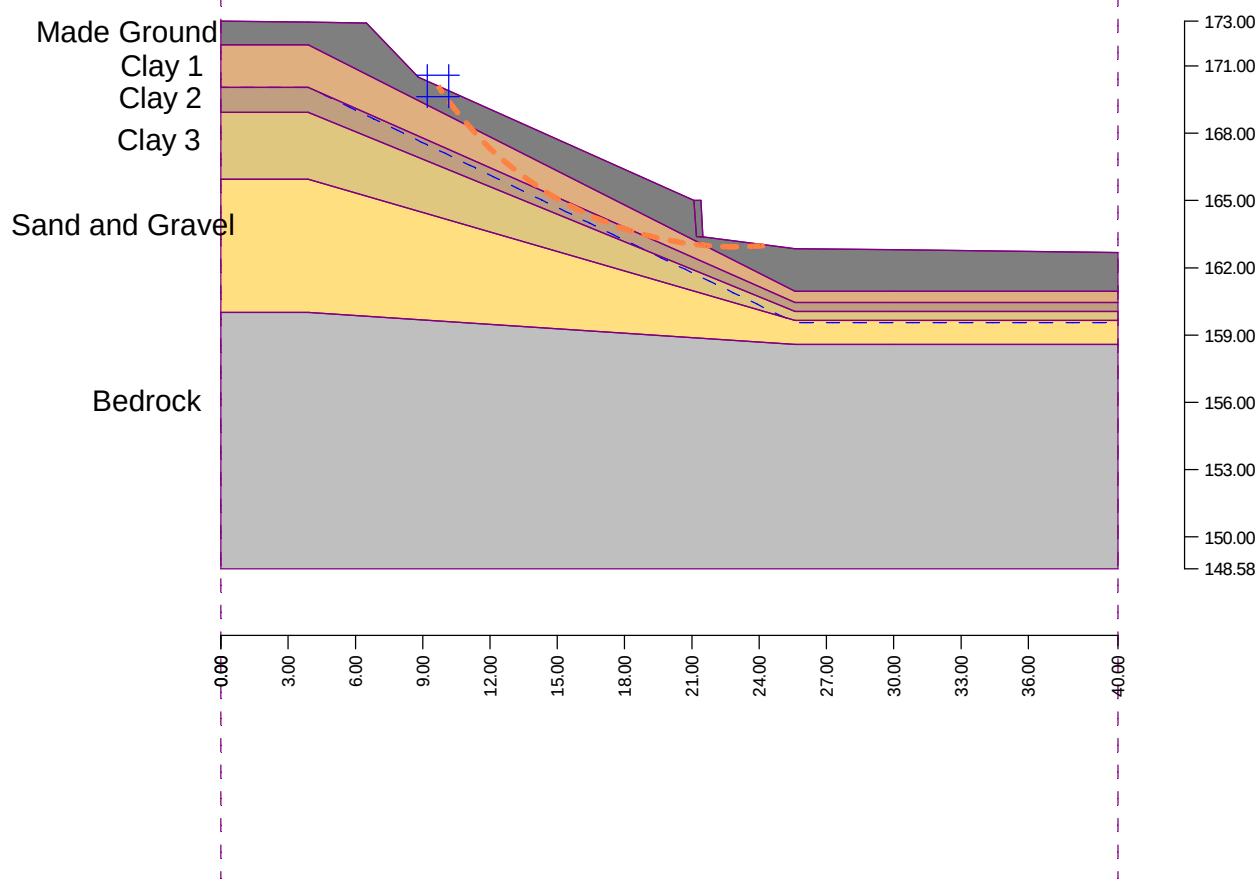
Resisting moment : $M_p = 5.82 \text{ kNm/m}$

Utilization : 135.1 %

Slope stability NOT ACCEPTABLE

Optimized slip surface for : Combination 2

Name : Stage - analysis : 1 - 2



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 245.01$ kN/m

Sum of passive forces : $F_p = 339.11$ kN/m

Sliding moment : $M_a = 3765.79$ kNm/m

Resisting moment : $M_p = 5212.13$ kNm/m

Utilization : 72.3 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 200.72$ kN/m

Sum of passive forces : $F_p = 236.23$ kN/m

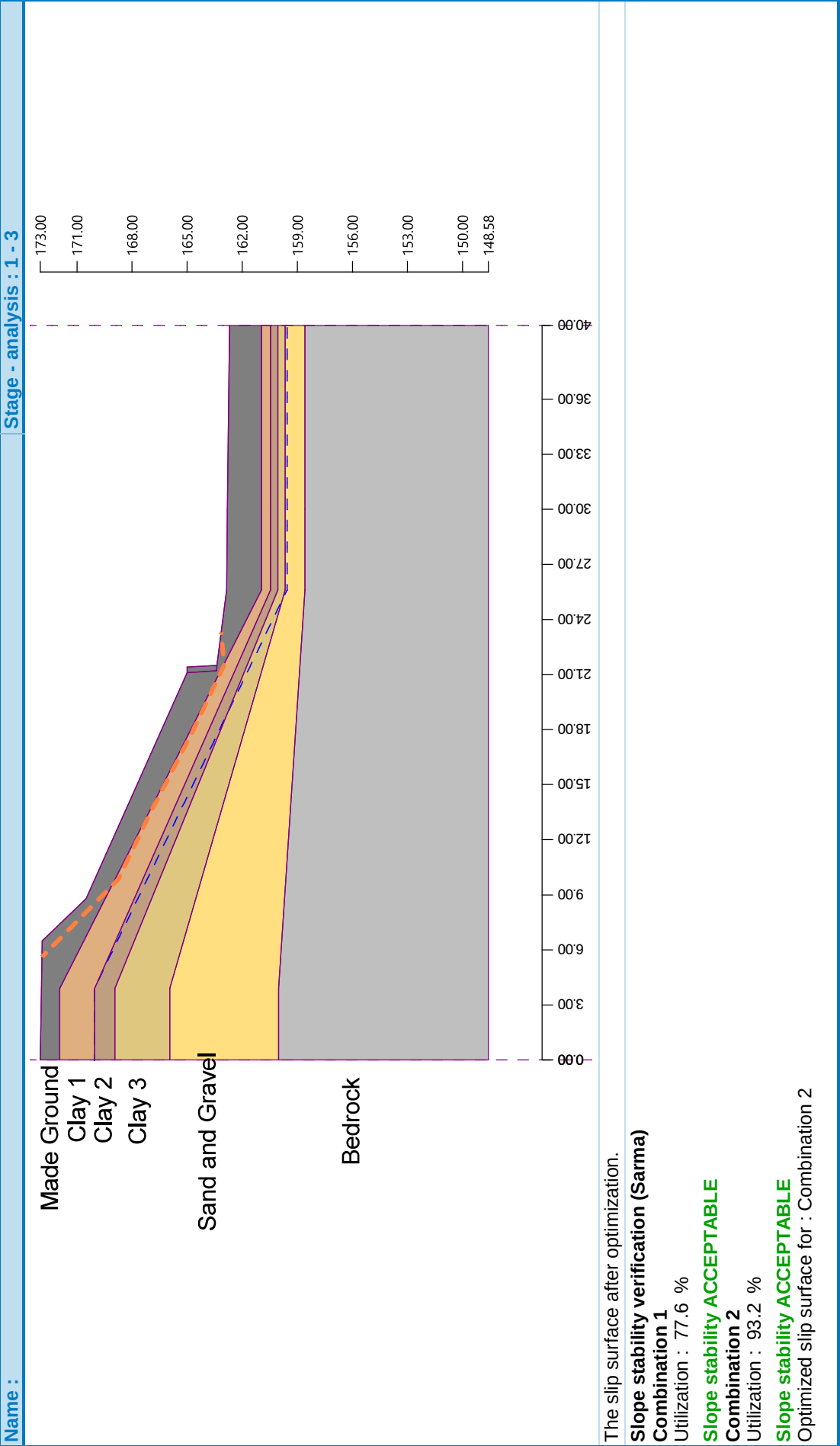
Sliding moment : $M_a = 3191.50$ kNm/m

Resisting moment : $M_p = 3756.12$ kNm/m

Utilization : 85.0 %

Slope stability ACCEPTABLE

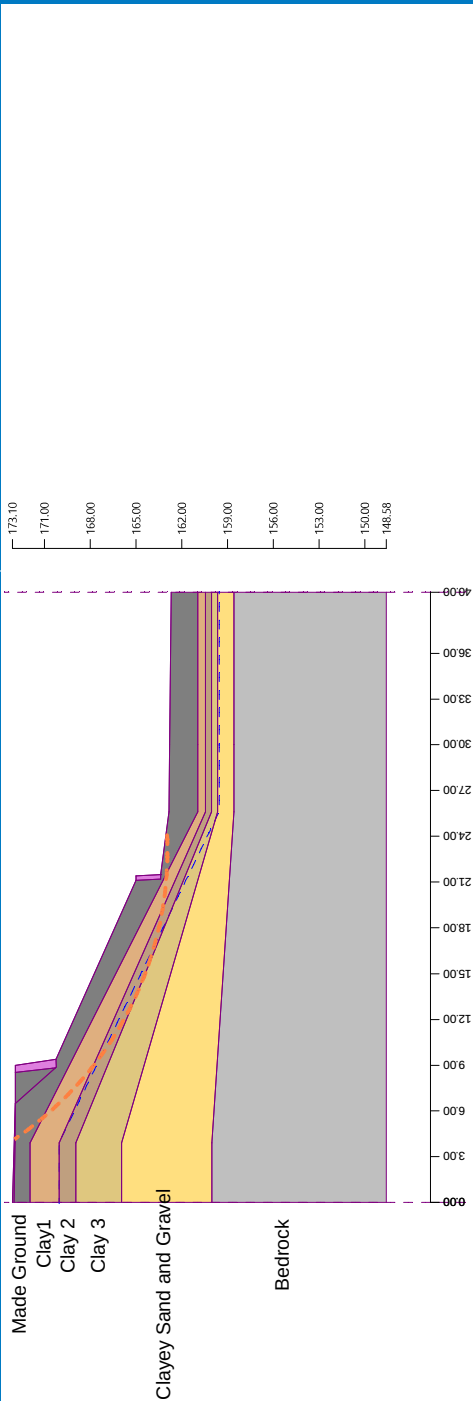
Optimized slip surface for : Combination 2



6018 Section AA DA restored slope schematic optimised.gst

Name :

Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 517.87$ kN/m
Sum of passive forces : $F_p = 625.15$ kN/m
Sliding moment : $M_a = 11802.22$ kNm/m
Resisting moment : $M_p = 14247.23$ kNm/m
Utilization : 82.8 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 428.55$ kN/m
Sum of passive forces : $F_p = 443.95$ kN/m
Sliding moment : $M_a = 9766.63$ kNm/m
Resisting moment : $M_p = 10117.66$ kNm/m
Utilization : 96.5 %

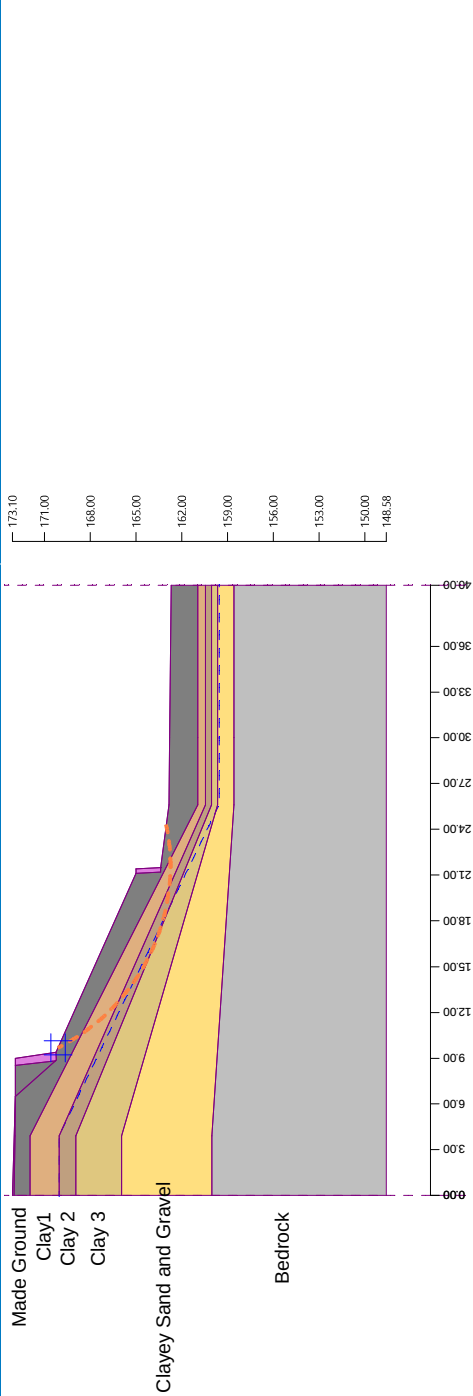
Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

6018 Section AA DA restored slope schematic optimised.gst

Name :

Stage - analysis : 1 - 2



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 279.40$ kN/m
Sum of passive forces : $F_p = 389.19$ kN/m
Sliding moment : $M_a = 3738.37$ kNm/m
Resisting moment : $M_p = 5207.32$ kNm/m
Utilization : 71.8 %

Slope stability ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 232.77$ kN/m
Sum of passive forces : $F_p = 281.11$ kN/m
Sliding moment : $M_a = 3114.48$ kNm/m
Resisting moment : $M_p = 3761.31$ kNm/m
Utilization : 82.8 %

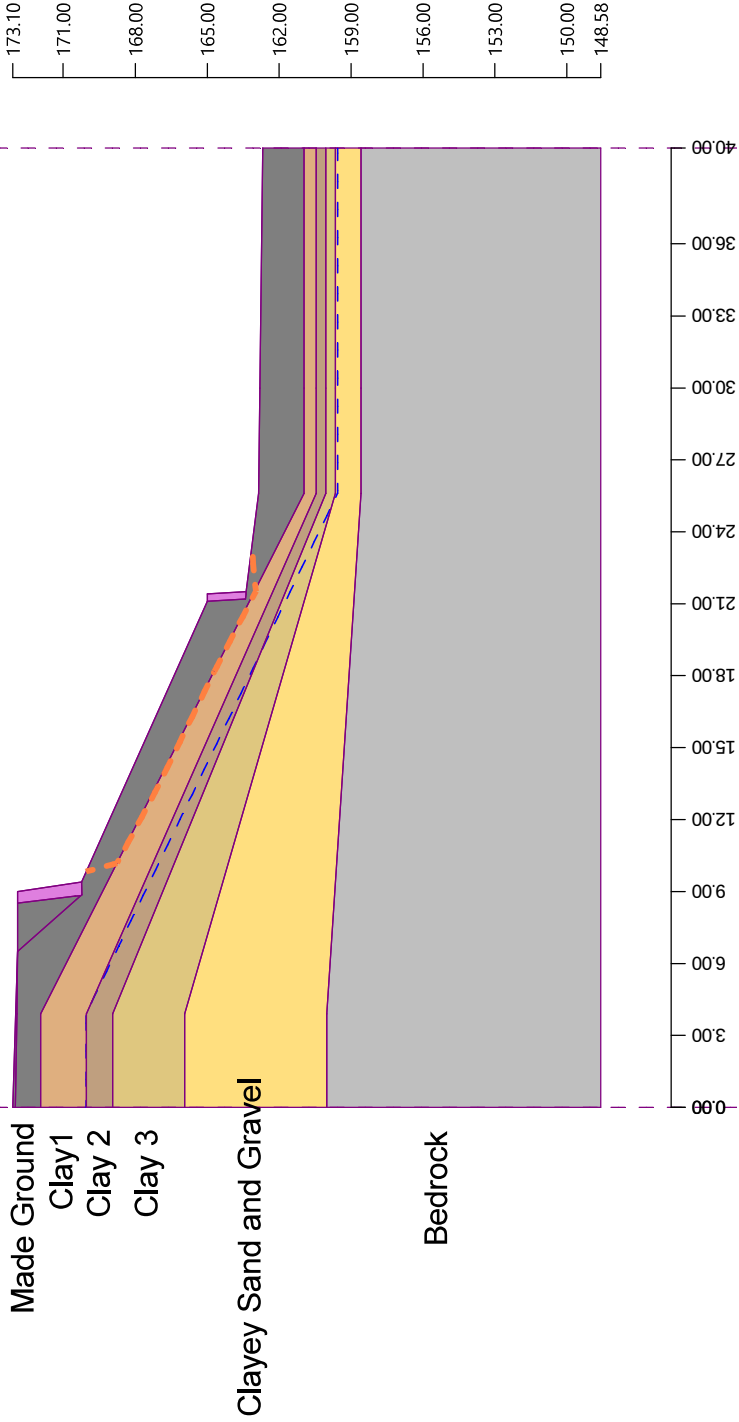
Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

6018 Section AA DA restored slope schematic optimised.gst

Name :

Stage - analysis : 1 - 3



The slip surface after optimization.

Slope stability verification (Sarma)

Combination 1

Utilization : 74.6 %

Slope stability ACCEPTABLE

Combination 2

Utilization : 91.3 %

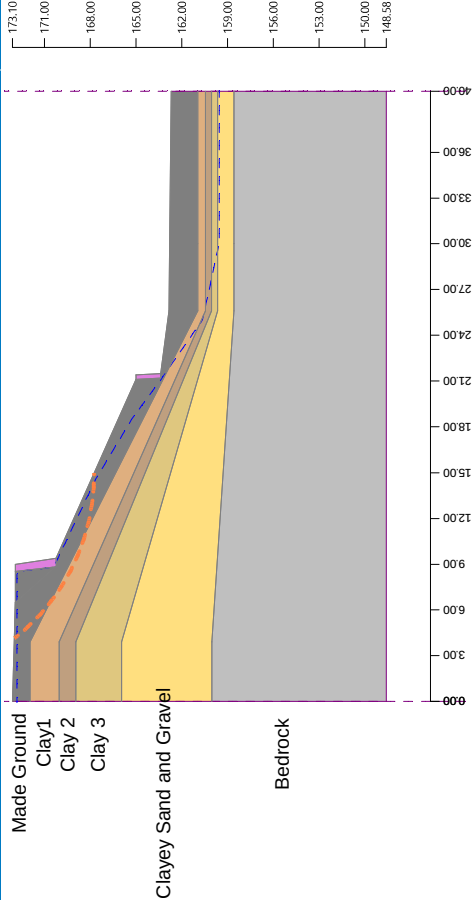
Slope stability ACCEPTABLE

Optimized slip surface for : Combination 2

6018 Section AA DA flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 163.32$ kN/m
Sum of passive forces : $F_p = 98.23$ kN/m
Sliding moment : $M_a = 2221.12$ kNm/m
Resisting moment : $M_p = 1335.91$ kNm/m
Utilization : 166.3 %

Slope stability NOT ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 463.38$ kN/m
Sum of passive forces : $F_p = 283.13$ kN/m
Sliding moment : $M_a = 11329.65$ kNm/m
Resisting moment : $M_p = 6922.61$ kNm/m
Utilization : 163.7 %

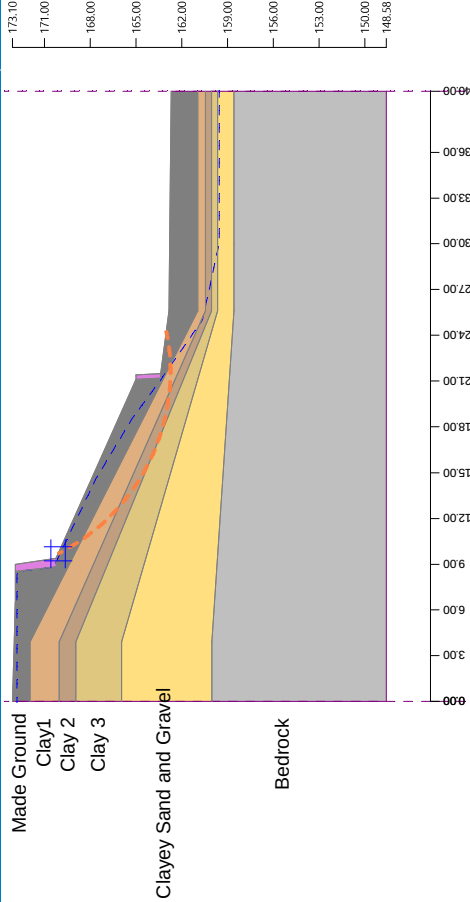
Slope stability NOT ACCEPTABLE

Optimized slip surface for : Combination 1

6018 Section AA DA flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 2



The slip surface after optimization.

Slope stability verification (Bishop)

Combination 1

Sum of active forces : $F_a = 292.55$ kN/m
Sum of passive forces : $F_p = 242.07$ kN/m
Sliding moment : $M_a = 3914.26$ kNm/m
Resisting moment : $M_p = 3238.93$ kNm/m
Utilization : 120.9 %

Slope stability NOT ACCEPTABLE

Combination 2

Sum of active forces : $F_a = 243.49$ kN/m
Sum of passive forces : $F_p = 196.33$ kN/m
Sliding moment : $M_a = 3257.86$ kNm/m
Resisting moment : $M_p = 2626.95$ kNm/m
Utilization : 124.0 %

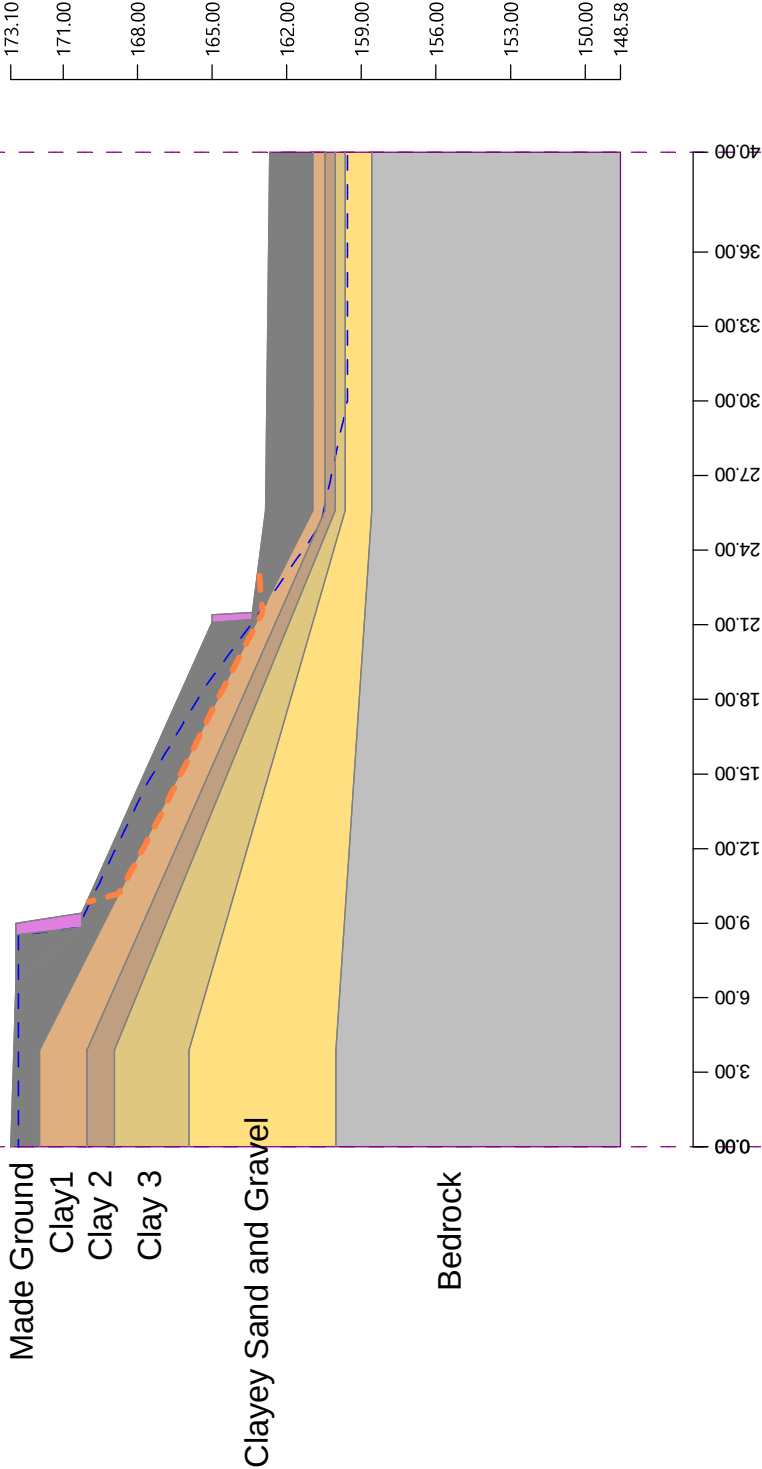
Slope stability NOT ACCEPTABLE

Optimized slip surface for : Combination 2

6018 Section AA DA flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 3



Analysis of the slip surface without optimization.

Slope stability verification (Sarma)

Combination 1

Utilization : 92.5 %

Slope stability ACCEPTABLE

Combination 2

Utilization : 111.5 %

Slope stability NOT ACCEPTABLE

6018 Section AA FOS current slope schematic OPTIMISED.gst

Name :

Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

Sum of active forces : $F_a = 0.14 \text{ kN/m}$

Sum of passive forces : $F_p = 0.13 \text{ kN/m}$

Sliding moment : $M_a = 7.86 \text{ kNm/m}$

Resisting moment : $M_p = 7.28 \text{ kNm/m}$

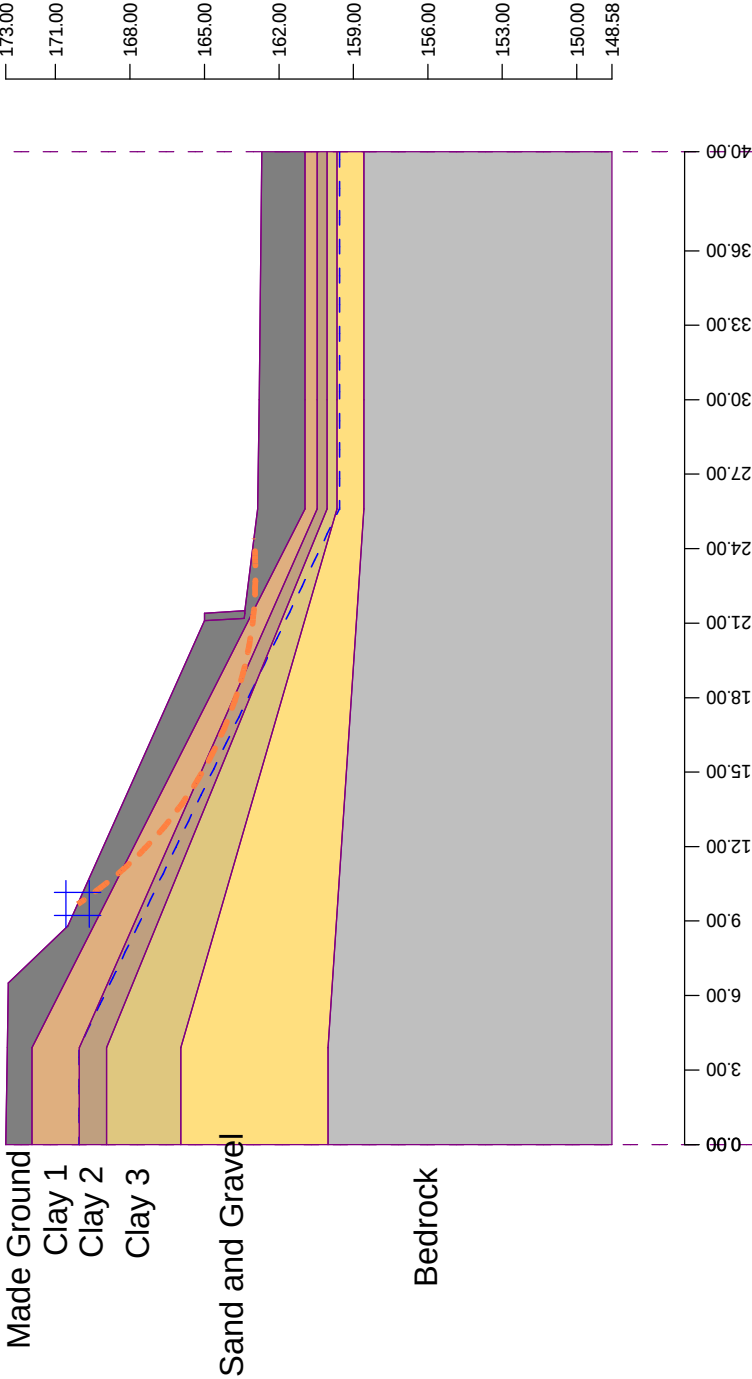
Factor of safety = $0.93 < 1.50$

Slope stability NOT ACCEPTABLE

6018 Section AA FOS current slope schematic OPTIMISED.gst

Name :

Stage - analysis : 1 - 2



The slip surface after optimization.

Slope stability verification (Bishop)

Sum of active forces : $F_a = 200.72$ kN/m

Sum of passive forces : $F_p = 295.27$ kN/m

Sliding moment : $M_a = 3191.50$ kNm/m

Resisting moment : $M_p = 4694.83$ kNm/m

Factor of safety = $1.47 < 1.50$

Slope stability NOT ACCEPTABLE

6018 Section AA FOS current slope schematic OPTIMISED.gst

Name :

Stage - analysis : 1 - 3

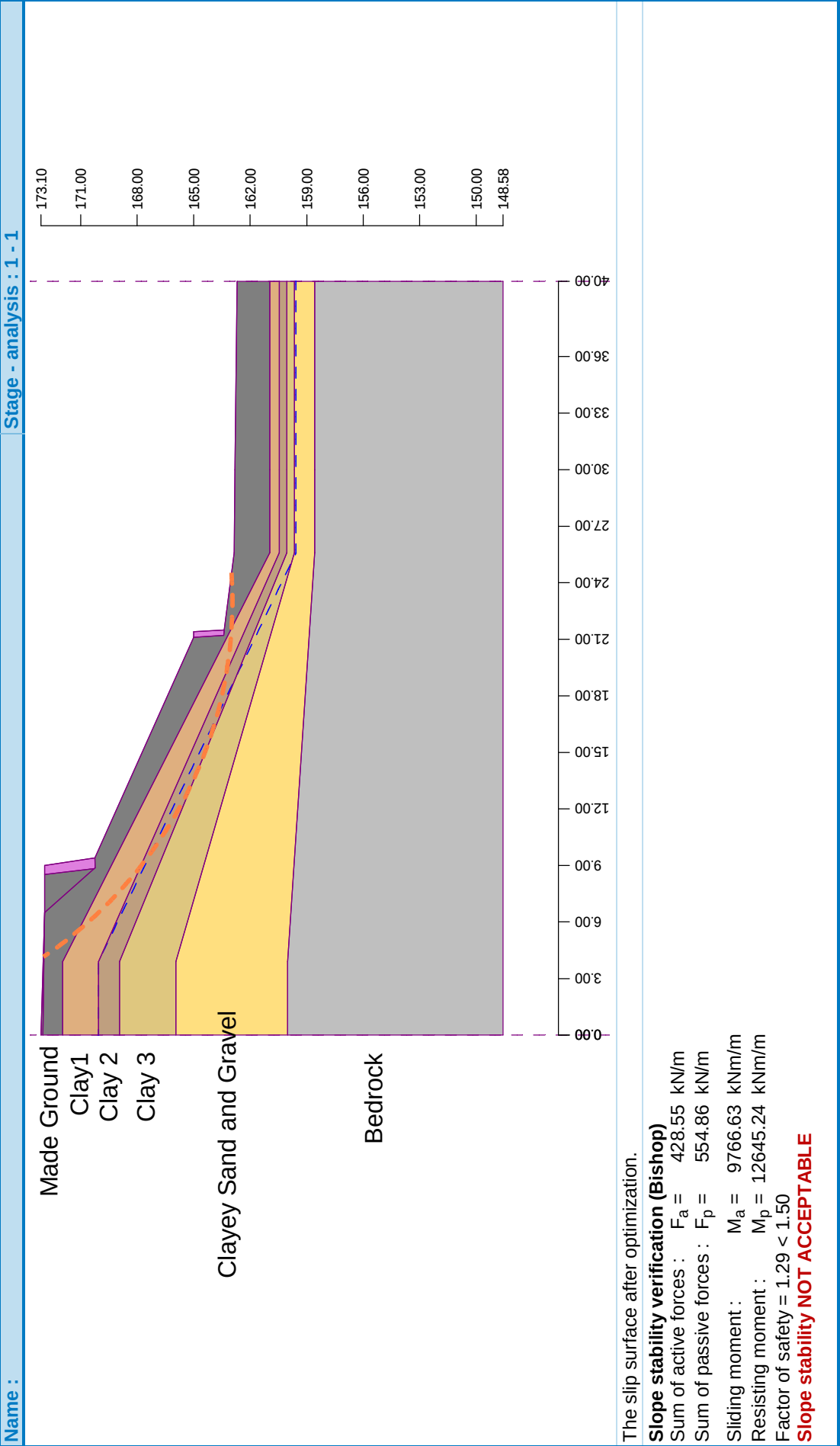


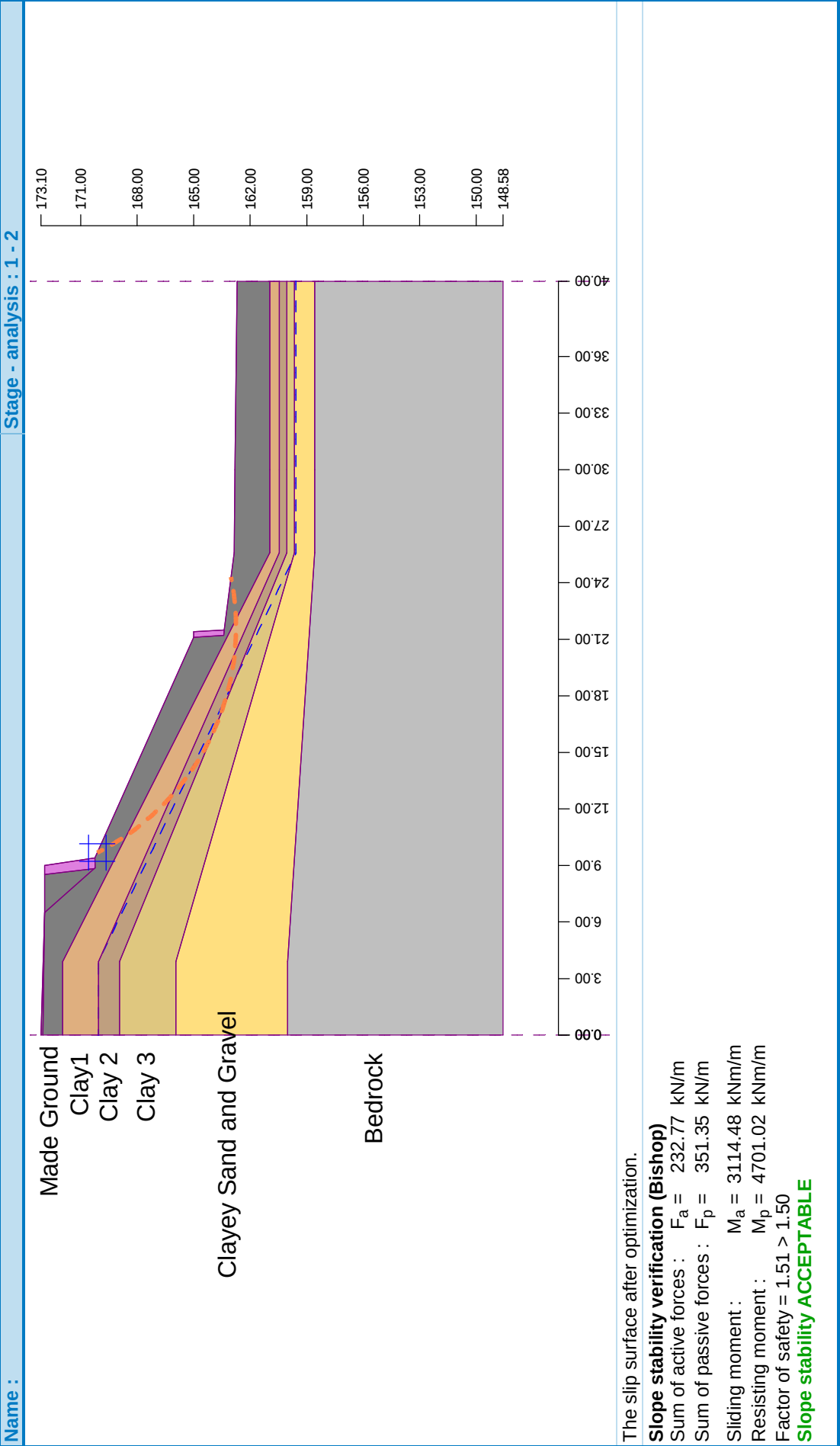
The slip surface after optimization.

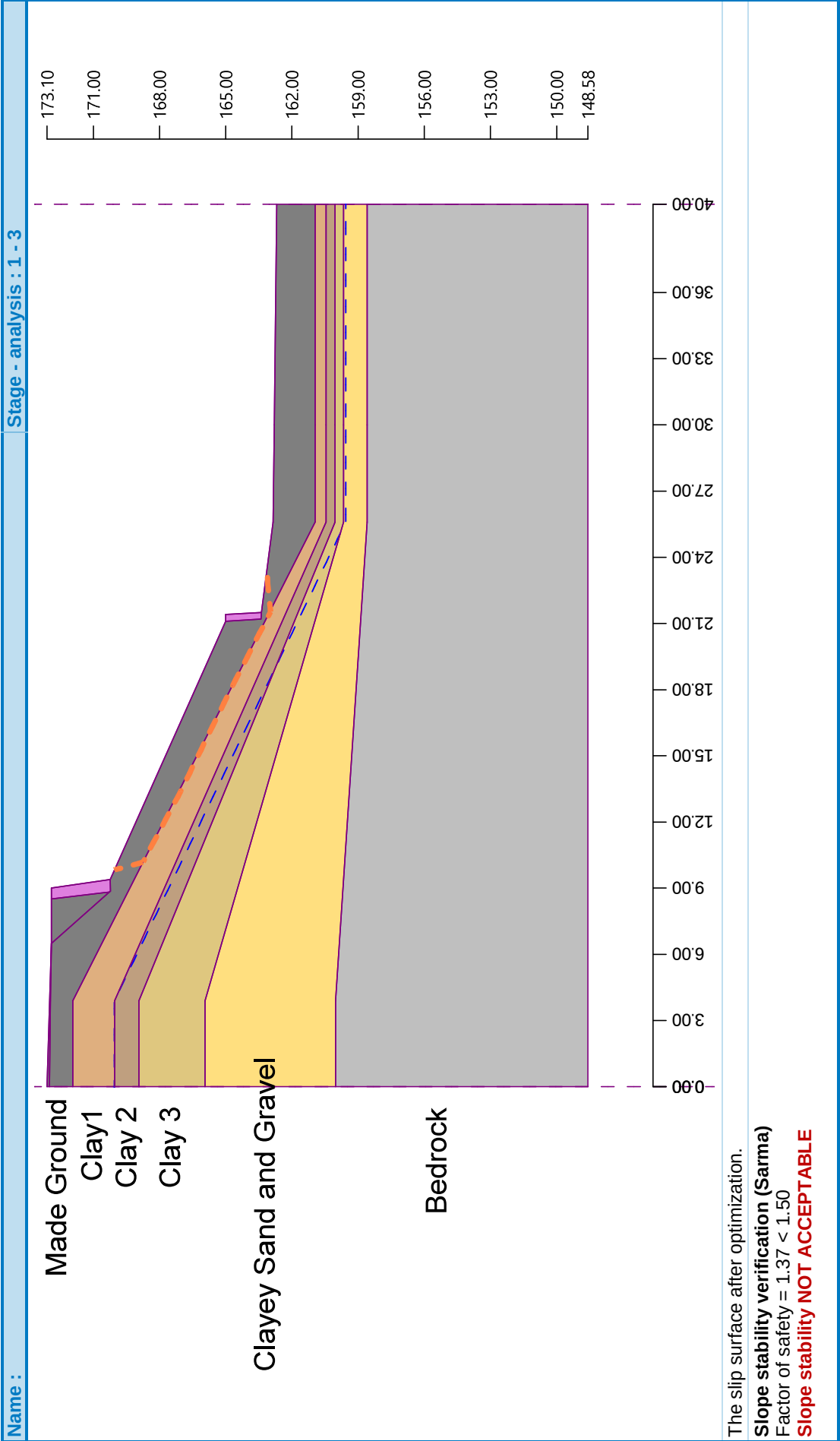
Slope stability verification (Sarma)

Factor of safety = 1.34 < 1.50

Slope stability NOT ACCEPTABLE



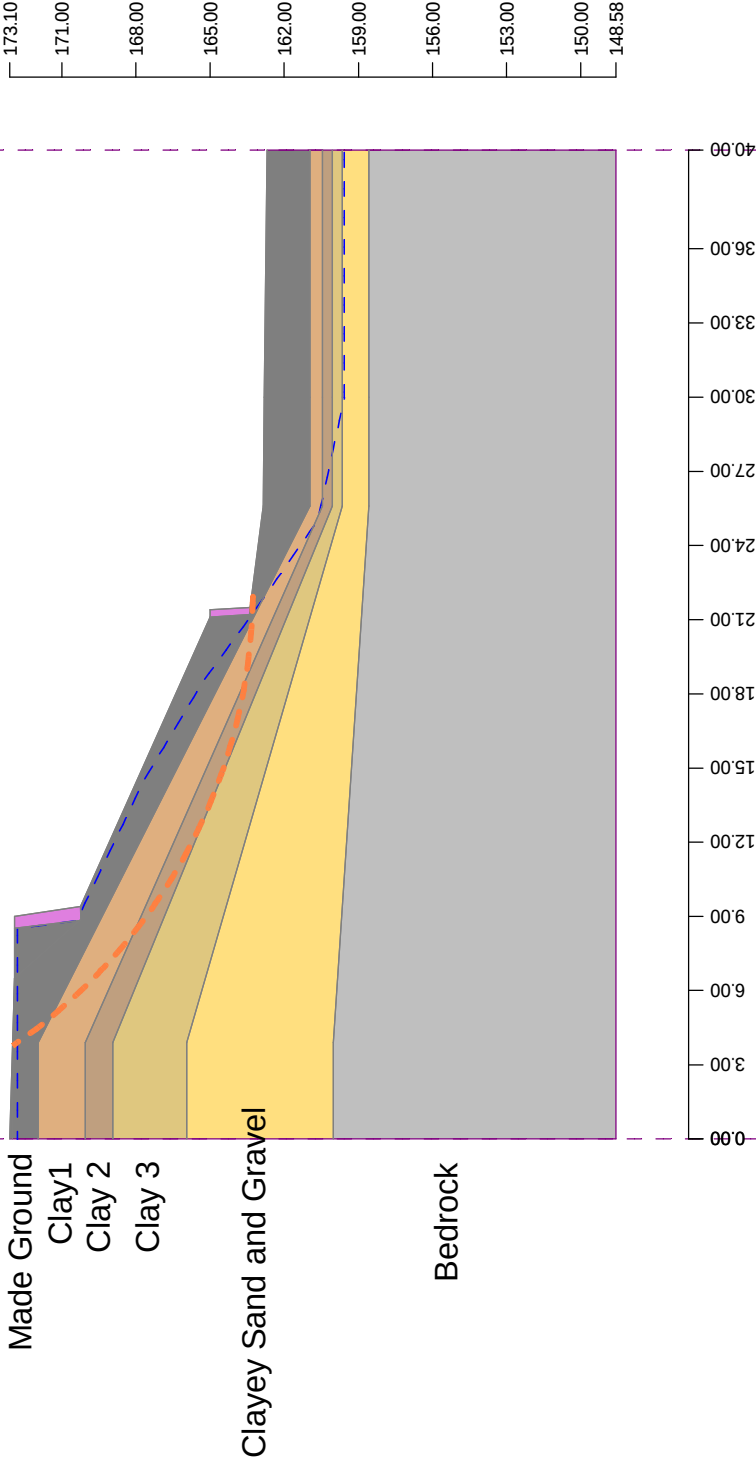




6018 Section AA FOS flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 1



The slip surface after optimization.

Slope stability verification (Bishop)

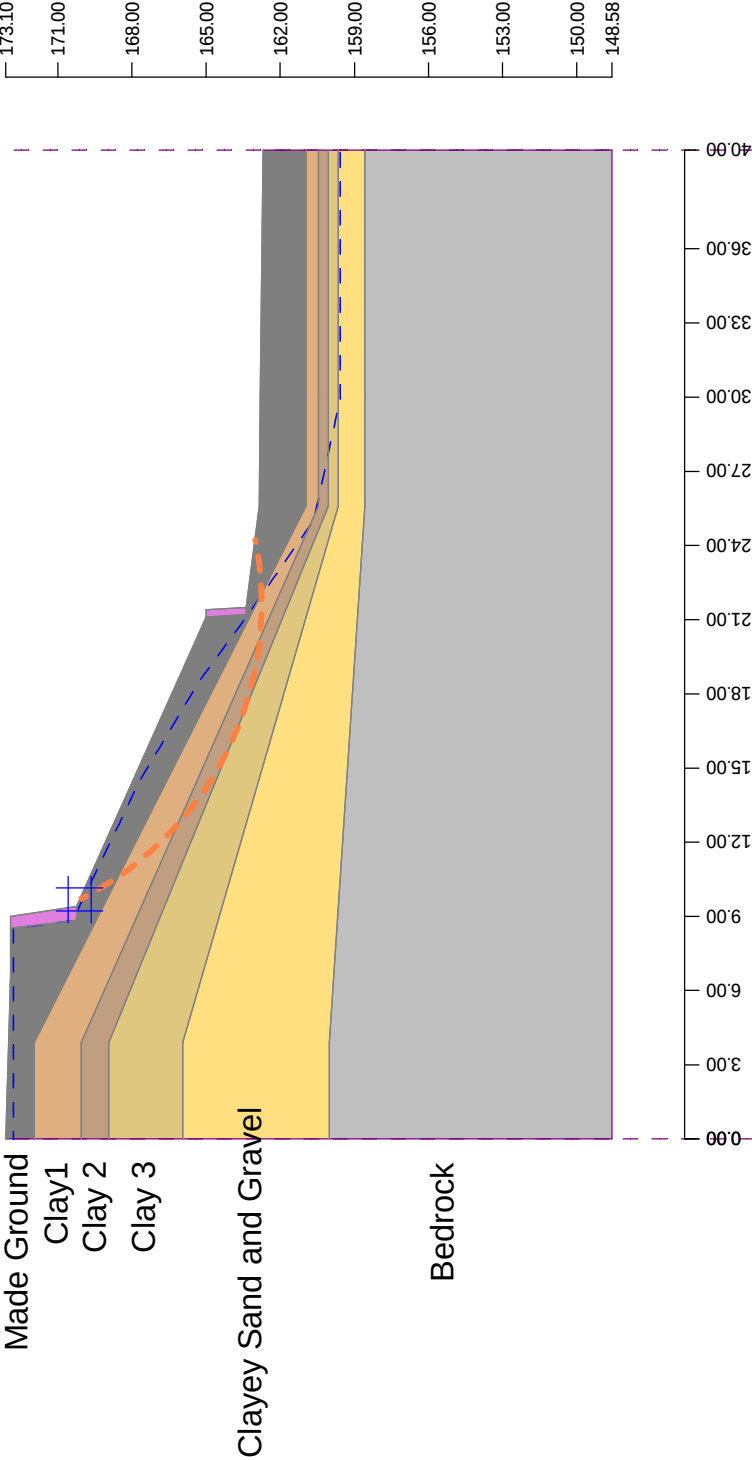
Sum of active forces : $F_a = 451.51$ kN/m
Sum of passive forces : $F_p = 349.18$ kN/m
Sliding moment : $M_a = 10086.84$ kNm/m
Resisting moment : $M_p = 7800.59$ kNm/m
Factor of safety = $0.77 < 1.50$

Slope stability NOT ACCEPTABLE

6018 Section AA FOS flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 2



The slip surface after optimization.

Slope stability verification (Bishop)

Sum of active forces : $F_a = 243.49$ kN/m

Sum of passive forces : $F_p = 245.38$ kN/m

Sliding moment : $M_a = 3257.86$ kNm/m

Resisting moment : $M_p = 3283.24$ kNm/m

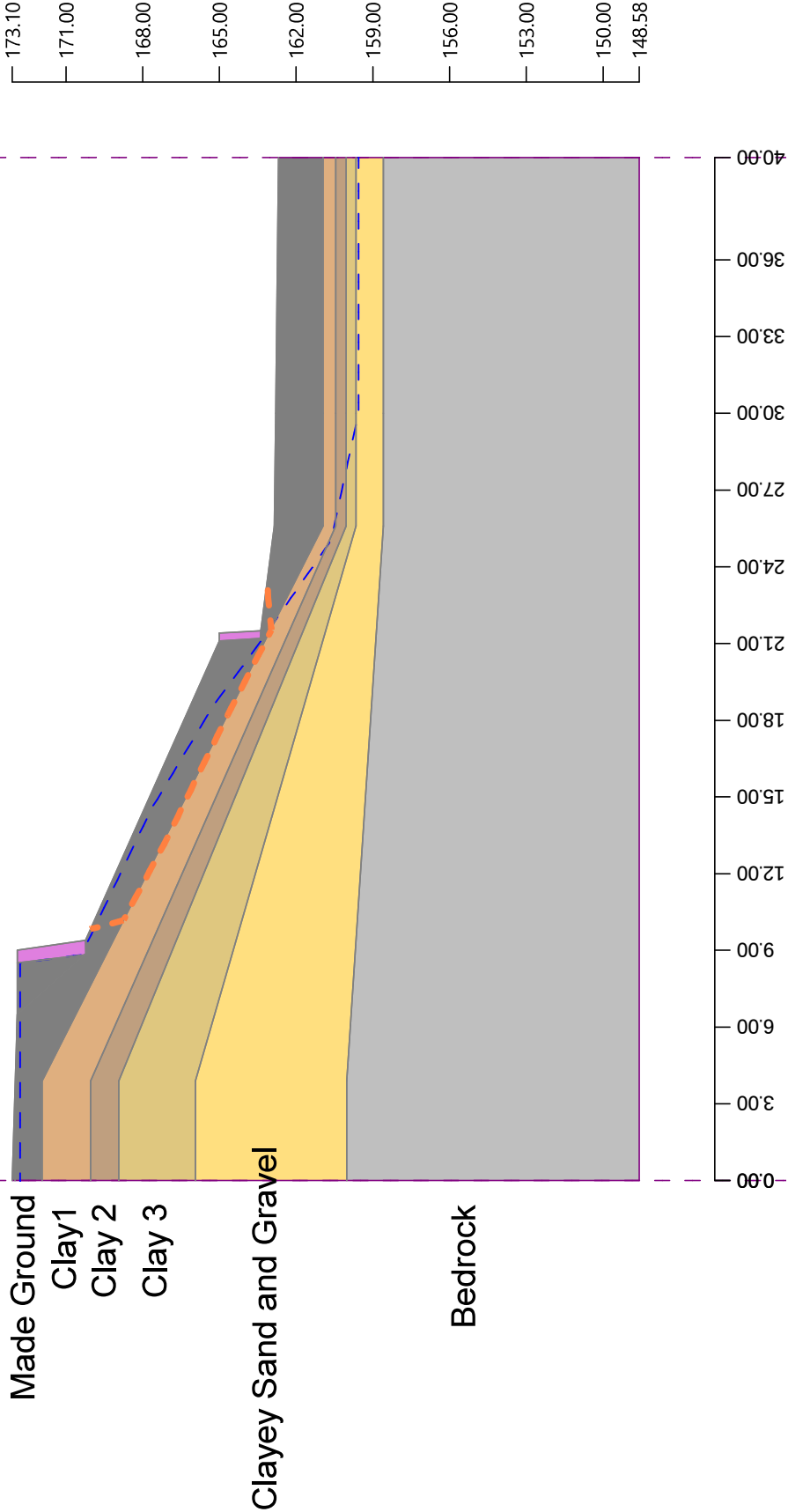
Factor of safety = $1.01 < 1.50$

Slope stability NOT ACCEPTABLE

6018 Section AA FOS flood water original slope schematic optimised.gst

Name :

Stage - analysis : 2 - 3



Analysis of the slip surface without optimization.

Slope stability verification (Sarma)

Factor of safety = 1.12 < 1.50

Slope stability NOT ACCEPTABLE