REDSTART

Tylorstown Landslide

Environmental Impact Assessment

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December 2021

Appendix 13.1

Slope Stability Report

REDSTART

Tylorstown Phase 4

Slope Stability Report

March 2021

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Rhondda Cynon Taf County Borough Council

March 2021

Tylorstown Phase 4

Slope Stability Report

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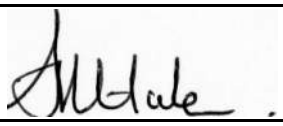
APPROVER	Andrew Hale		10/03/2021

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1. Introduction

1.1 Background

On Sunday 16th February, Storm Dennis instigated the failure of Llanwonno Upper Tip (also referred to as RH01). The largest (main) slip occurred overnight, where the upper part of the tip complex failed in a classical circular slip movement (see Photo 1 below). A further landslide/debris flow (video footage on internet on 16.02.2020, Ref. 1), appears to show a secondary slip mechanism where water had accumulated and burst through (breached) the southern end of the tips (adjacent to former ponds) and flowed down the hillside in a fully saturated state (flow slide failure).

Photo 1: Backscarp of main landslide

Approximately 60,000 m^3 of colliery spoil was deposited in the valley bottom at the toe of slope, blocking the river channel, and diverting the river to the western side of the valley bottom.

Following the landslide, a four-phase remediation plan has been implemented, and is briefly outlined below:

- Phase 1 - Emergency drainage works to divert water away from Llanwonno Upper Tip.
- Phase 2 - Embankment scour repairs adjacent to the river, beneath the landslide area.
- Phase 3 - Moving of landslide material from the valley bottom to nearby receptor sites.
- Phase 4 - Removal of colliery spoil and reprofiling of Llanwonno Upper Tip depositing surplus material to the rear of 'Old Smokey' (Tylorstown

Tip – RH02), which is designated Receptor Site C. Phase 4 is subject to a further planning application process.

1.2 Site location

Llanwonno Upper Tip is located to the north-east of Tylorstown and lies on the eastern side of the Rhondda Fach valley.

The site area is centred at approximate National Grid reference (NGR) 301107E 196330N and is presented on drawing GC3613-RED-61-RSC-DR-C-0001 – Phase 4 Location Plan.

Access to Llanwonno Upper Tip is via Llanwonno Road, which is located above the Upper Tip, and links Blaenllechau to the north-west, with Llanwonno to the south-east.

1.3 Site Description

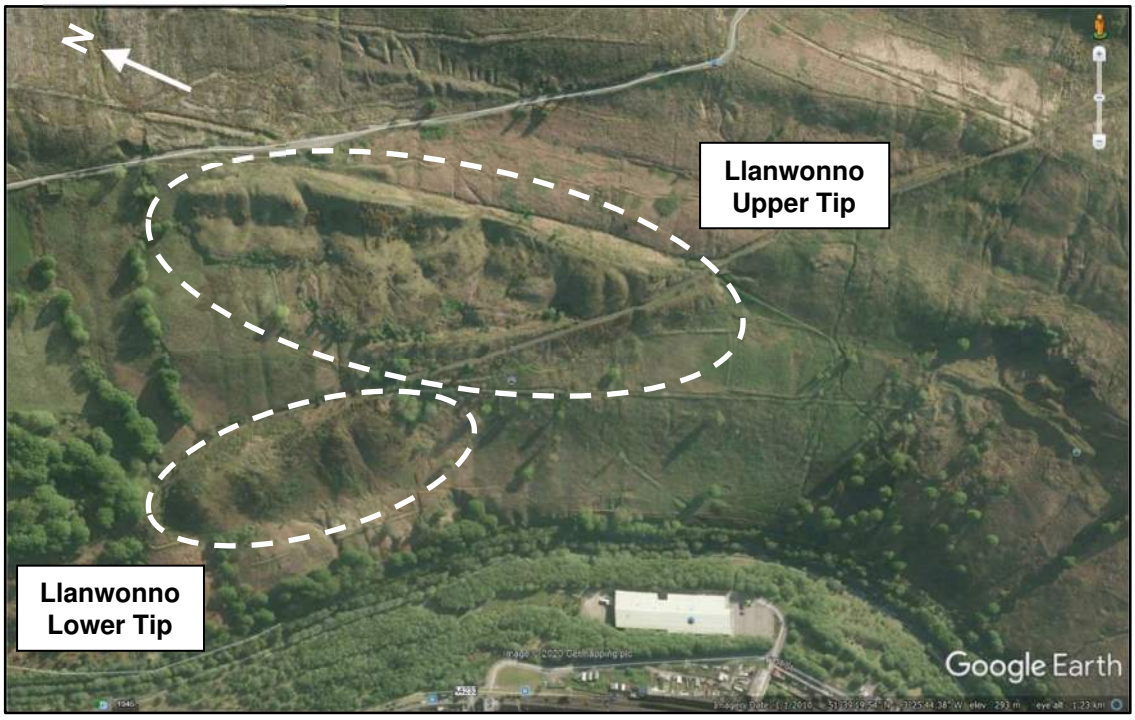
1.3.1 *General*

The Llanwonno Tip complex (RH01) comprises two distinct parts, referred to as the Upper Tip and Lower Tip (see Figure A below). Llanwonno Upper Tip has been placed on the south-west facing hillside of the Rhonnda Fach Valley. The tip has been placed across a concave area of the hillside formed by the intersection of a steep section and a slack below. As typical with many colliery tips in the area, the main tip slope faces the same orientation as the natural hillside, but at a steeper gradient.

A ‘V’ shaped ditch had been formed behind the Upper Tip where it met the natural ground. This ditch carried surface water to the south-east of the tip. The Upper Tip was typically vegetated with rough grass, heather, and gorse, with occasional trees also established.

The Lower Tip lies below the Upper Tip, and slightly to the west. Remedial works to the Lower Tip are not included in the Phase 4 remediation plan.

Figure A: Ariel view of Llanwonno Upper and Lower Tips (prior to landslide)



1.3.2 *Topography and Geomorphology*

The Rhondda Fach is a steeply incised valley within the large upland plateau of the South-Wales Coalfield. The eastern valley slopes are 'stepped' due to the alternating geology of hard sandstone, forming the steeper slopes, and weak mudstones, forming broad lower angled steps, known locally as 'slacks'.

Quarries are present at the level of Llanwonno Upper Tip, both up and down valley, and there is some evidence that a buried quarry lies beneath the southern end of Llanwonno Upper Tip.

Spring lines and boggy ground are present along the slacks, due to groundwater in the fractured sandstones being prevented from percolating downwards by the impermeable mudstones and coal seat earths. During and immediately after periods of high/prolonged precipitation the spring lines discharge strongly but dry up during periods of drier weather.

Substantial deep mining across the area has led to past subsidence and mining related fissures, which may have altered natural groundwater flows in the area. Coal crop workings and adits are present on the hillside above Llanwonno Road and potentially beneath the tips, which issue water during periods of high precipitation (Ref. 3).

There are several watercourses and issues above Llanwonno Tips that have been captured by temporary drainage measures, installed during Phase 1 emergency works. These drainage measures formed by a series of 6-inch plastic pipes, collect water from culverts along Llanwonno Road, and along a small upper valley feature on the uphill side of the Upper Tip. The drainage water is discharged at the southern end of the tip, where it meets the former tramway and subsequently into the former historical drainage system.

The base of the Upper Tip lies on a 'slack', which has water issues along its entire length and inevitably beneath the tip itself. Since the landslide has occurred, water issues have formed deep erosive gullies down to the valley bottom (see Photo 2). It is considered that prior to the slip, a longitudinal drain, below the tramway, captured these issues and took the water away to the north, and then down to the valley bottom, via a channel that is still partially present, immediately south of Llanwonno Lower Tip.

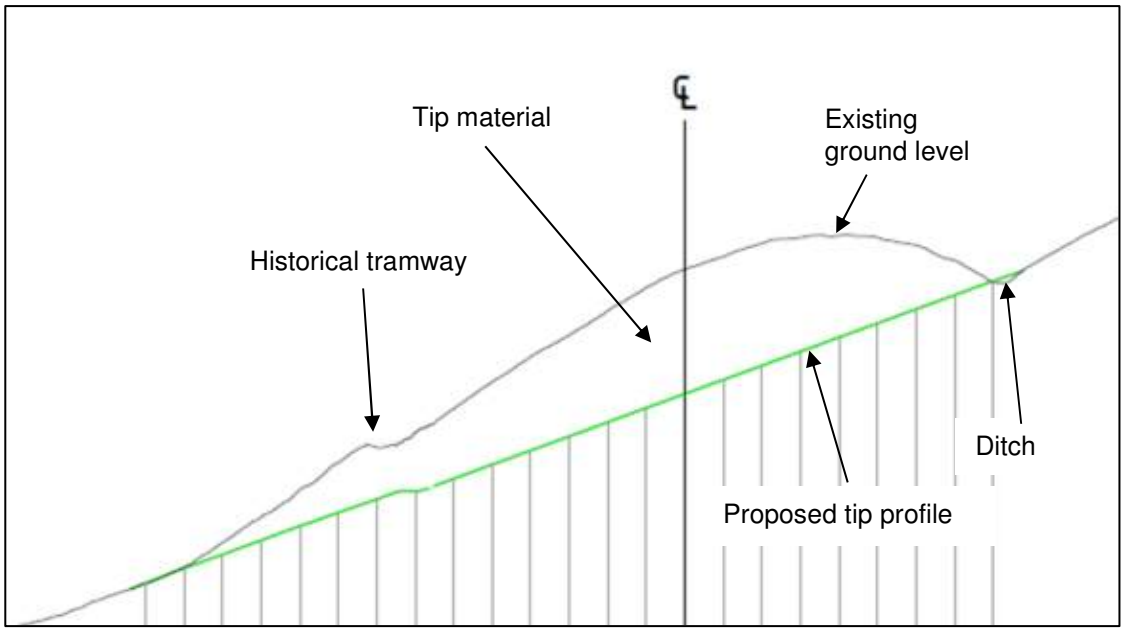
Following the landslide, Llanwonno Upper Tip can be separated into three distinct areas, the South-Western Area, the Landslide Area (central section), and the North-Eastern Area. Chainages referred to in this document are presented on drawing GC3613-RED-61-RSC-DR-C-0002 – Tip Reprofile General Arrangement.

1.3.3 *South-Western Area (Ch. 0m to 160m)*

The south-western part of the site is volumetrically the largest part of Llanwonno Upper Tip. A historical tramway traverses the toe of the tip (see cross-section below) in a north-east direction.

Historical ground investigations suggest a former quarry, which exploited the Rhondda Sandstone, is present beneath this part of the Tip (see Section 2.3).

Typical cross-section through the south-eastern part of the site (Ch.120m).



1.3.4 *Landslide Area (Ch. 160m to 340m)*

Within Llanwonno Upper Tip, where the landslide occurred, there are three distinct areas (i) rear backscarp, (ii) lower / front colliery spoil slope, separated by (iii) a back-tilted block between (i) and (ii) forming the landslide bowl.

Several issues / spring lines have been exposed within this part of the site (see Section 2.4 for further information). Within the lower / front part of the landslide, water has scoured significant channels through the remaining layer of colliery spoil to expose natural superficial soils.

Typical cross-section through the central part of the site (Ch.280m).

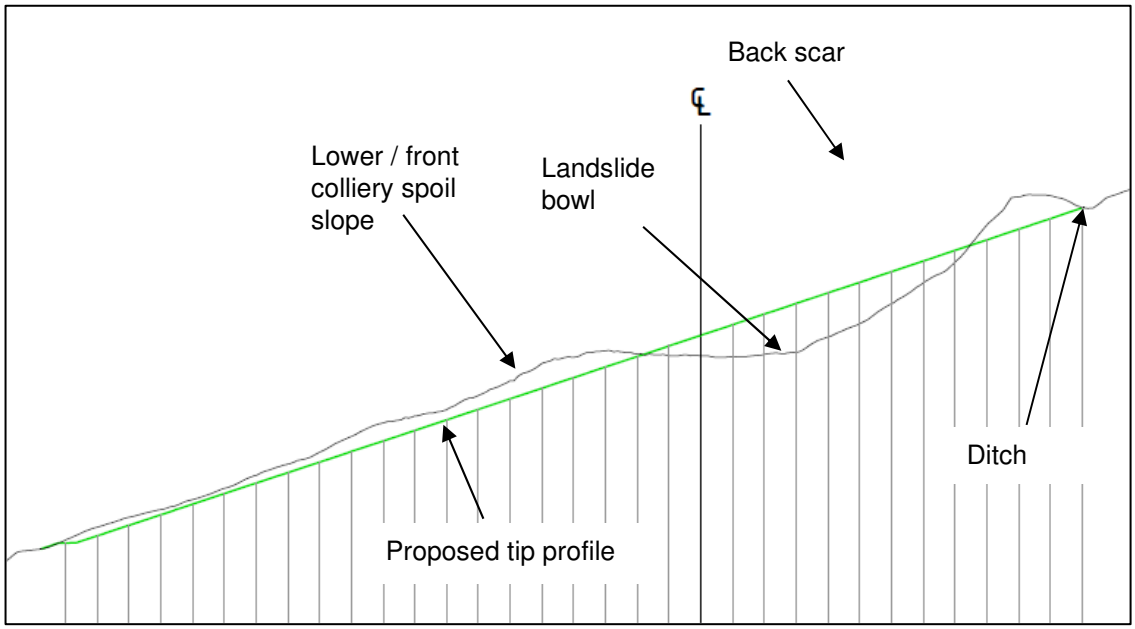


Photo 2: Central part of landslip looking from the northwest

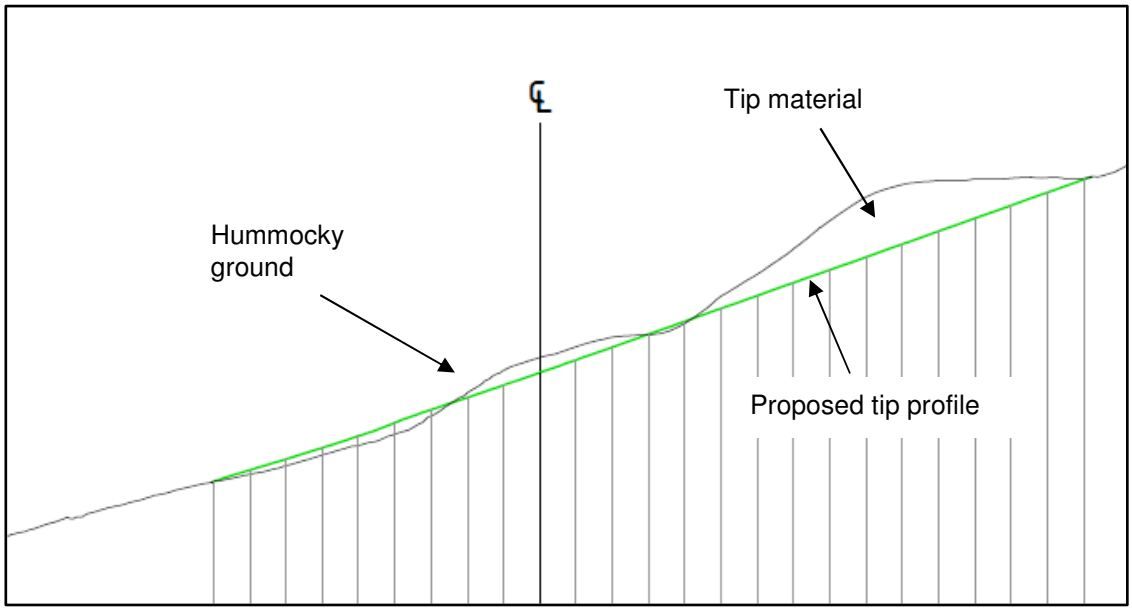
1.3.5 *North-Eastern Area (Ch. 340m to 527m)*

The north-eastern part of the tip is narrower than the central section (prior to landslide) and south-eastern parts, with the majority of the colliery spoil placed on the higher part of the natural hillside and extending a shorter distance downhill.

A previous stability report by Halcrow (Ref. 3) suggests that an ancient landslide is present within the natural hillside beneath the northern end of Llanwonno Upper Tip, hummocky (undulating) ground between the Upper and Lower Tips support this landslide concept. The Halcrow report

states that '*available inspection and monitoring data indicate that some ground movements have taken place in the recent past'.*

Typical cross-section through the north-western part of the site (Ch.420m).



1.4 Proposed Works

Topographical surveys and 3D modelling information suggests that approximately 200,000 m^3 of colliery spoil is required to be removed from, or redistributed at, the site. For the Phase 4 works, it is proposed that approximately 50,000 m^3 of the colliery spoil will be used to infill the backscarp / bowl area, with the remaining 150,000 m^3 being taken off site to Receptor Site C.

The green line shown on the typical sections presented in Section 1.3 represents the proposed ground levels for the re-profiled Llanwonno Upper Tip. A complete set of the cross-sections including ground levels before and after the proposed re-profiling are provided in Drawings GC3613-RED-61-RSC-DR-C-0005 to 0008 – Cross Sections Tip Reprofile.

1.5 Report Objectives

Redstart have been commissioned to provide a Slope Stability Report to assess the long-term stability of the Llanwonno Upper Tip area following completion of the Phase 4 remediation works.

2. Site Conditions

2.1 Available Information

The following sources have been referenced for the identification of the geology, soils, hydrology and hydrogeology of the site:

- Llanwonno Tips Reclamation Scheme, Stability Report, Halcrow, 2004 (Ref. 3).
- Tylorstown Landslide Debris Removal, Preliminary Sources Study Report (PSSR), Redstart, 2020 (Ref. 2).
- Report on a Site Investigation at Tylorstown and Llanwonno Tips, Thyssen Geotechnical, 1993 (Ref. 4).
- Tylorstown and Llanwonno Tips, Ground Investigation Report, Thyssen Geotechnical, 1996 (Ref. 5).
- Llanwonno Tips Reclamation Scheme, Report on Ground Investigation, Halcrow, 2001 (Ref. 6).
- Tylorstown Landslip, Factual Site Investigation Letter Report, Integral Geotechnique, May 2020 (Ref. 7).

2.2 Geology

The geological sequence at the site is discussed in detail within Section 2 of Halcrow's 2004 Stability Report (Ref. 3) and in Section 4 of the Redstart PSSR (Ref. 4) and is summarised below.

Material parameters are discussed in Section 3.2.3. of Halcrow's report (Ref. 3).

2.3 Superficial Deposits

2.3.1 *Colliery Spoil*

Colliery Spoil is present across the site area. Halcrow's report states that this material predominantly comprises *'sand, gravel and cobble-sized fragments of mudstone and coal with lesser quantities of siltstone, sandstone and ironstone.'*

The maximum thickness of the colliery spoil encountered in the Upper Tip was 24.0 m (in borehole LWN3 presented on Figure No. LWTR/R2/1 of the Halcrow Report). This borehole is located in the south-eastern part of the tip, which did not form part of the landslide, but will be reprofiled during the Phase 4 remediation works. The thickness of the colliery spoil reduces to approximately 5.0 m in the north-west part of the Upper Tip.

Following the landslide, a number of Particle Size Distribution (PSD) tests were undertaken on the material deposited within the river valley. The colliery spoil was typically described as '*dark grey or grey brown variably silty variably sandy fine to coarse gravel with variable cobble and boulder content. The coarse constituents comprised variable amounts of mudstone, coal and sandstone*.' (Ref. 7).

2.3.2 *Natural Superficial Deposits*

Halcrow describe the upper valley slopes, which underlie Llanwonno Upper Tip, as *'mantled with locally derived 'head' or slope deposits. These are variable in composition, consistent with the interbedded argillaceous and arenaceous parent rocks from which the materials are derived'.* The maximum thickness of these deposits proved beneath the Llanwonno Upper Tip was 7.9 m in borehole LWT5 (Ref. 6). This stratum is sub-divided into 'cohesive' and 'granular' slope deposits.

2.3.2.1 Cohesive Slope Deposits

The finer slope deposits are generally described by Halcrow as '*slightly sandy gravelly CLAY, sand is fine to coarse, gravel is angular fine to coarse of mudstone, siltstone and sandstone*'.

2.3.2.2 Granular Slope Deposits

The coarser slope deposits underlie the finer slope deposits and are typically described by Halcrow as *'very dense clayey sandy fine to coarse GRAVEL of sandstone with occasional cobbles of sandstone'*.

2.4 Bedrock

Upper Coal Measures (Pennant Measures) underlie the site. The Halcrow Stability Report states *'The Geological Survey of Great Britain Map, Sheet 248, Pontypridd, shows the Upper Tip straddling outcrops of thin argillaceous horizons associated with an un-named thin coal, the No. 1 Rhondda Rider and the No. 1 Rhondda seams. Coal seams were encountered in three of the boreholes within the Upper Tip.'*

Halcrow surmise that, while not present on records, a historical quarry, exploiting the Rhondda Sandstone, is located beneath the deepest portions of Llanwonno Upper Tip (see Halcrow Cross Section C-C within Appendix B). This prediction is, according to Halcrow, supported by geophysical surveys.

Highly weathered argillaceous (clayey) material was recorded beneath the Upper Tip in boreholes LWN1 (1996 ground investigation) and LWT5 (2001), likely associated with the weathering of coal seams to low strength soils (clays) in the presence of groundwater.

Available published information and borehole evidence suggests the bedrock dips at approximately 6 degrees to the south-east.

The site lies between two faults: the Llanwonno Fault present along the valley top trending NNW-SSE and downthrown to the east, and an unnamed fault along the valley bottom also trending NNW-SSE and downthrown to the east. Neither directly underlie the Llanwonno Upper Tip area.

2.5 Groundwater

Groundwater levels at the site have been assessed using a combination of historical piezometer monitoring data (prior to the landslide) and post landslide on-site visual observations and both have been utilised in the stability analysis.

2.5.1 *Piezometers*

Within the Upper Tip area, piezometers were installed and monitored as part of previous ground investigations. The Redstart PSSR (Ref. 2) surmises the following:

'*Those piezometers installed in the colliery spoil and superficial deposits recorded groundwater level variations of the order of 1.0 m, whereas within the sandstone and siltstone this was much more variable between approximately 0.5 and 4.0 m over the monitoring period. The small variation in groundwater level in the colliery spoil indicates a high porosity material, whereas the generally higher variation in level in the sandstone and siltstone indicates a lower porosity material. This is supported by the regional data which states that the effective porosity of the siltstone and sandstone is low and is principally due to fractures rather than inaccessible intergranular porosity.*

Ten piezometers were installed in Llanwonno Upper Tip at various points between 1995 and 2004, with a recorded head of water varying between 0.73 m and 2.43 m above the base of the tip. Three locations were noted to frequently seep at the toe of the Upper Tip. Six piezometers, located in superficial deposits beneath the Upper Tip, reported a head of water between 0.00 m and 6.87 m above the base of the deposit.

Six piezometers were installed in bedrock below the Upper Tip. Readings from four piezometers installed in siltstone and sandstone generally indicated piezometric heads between 3.82 and 1.59 m above rockhead. Halcrow (2004) state that the piezometric levels in rockhead are comparable to levels obtained in overlying piezometers installed within colliery spoil. From the cross sections, this does not appear to be entirely the case at depth, as stated earlier.'

2.5.2 *Interactions with Surface Water*

In 1875 the Llanwonno Tip complex comprised open hillside and was wooded on the lower slopes. At least five streams descended the hillside in the vicinity of the current tips, flowing generally towards the south west. Creation of the tips resulted in streams being diverted around and, in some cases, beneath the tips and a more complex pattern to this surface water drainage developing. The central incline (tramway) acts as an unlined channel, conveying the majority of run-off from the Upper Tip and adjacent hillside behind and past the Lower Tip. Construction of the lowest tier of the Upper Tip also created a series of ponds, fed by surface water run-off and seepage through the tip.

2.5.3 *On-site Observations*

The following on-site groundwater and surface water features have been observed following the landslide. The approximate location of these features is shown on Figure B.

A. Seepages have been observed within the exposed back scarp feature, occasionally resulting in ponding water within the landslip bowl feature.

B. Issue / spring line within exposed colliery spoil. Highly responsive during periods of intensive rainfall.

C. Series of issues / spring lines (and soft cohesive material present).

D. Surface water scouring deep downslope channels through the colliery spoil.

Figure B: Approximate location of on-site observations of water features post landslip

2.5.4 *Other Considerations*

Phase 1 emergency remediation works involved the installation of a temporary drainage system to capture several surface watercourses and issues from above the Upper Tip and divert them south-east of the site (see Figure B above).

To reduce the volume of water entering the former Upper Tip area, Phase 4 works will include the installation of a permanent drainage system to collect surface water and groundwater (where possible) and divert it away from the former Upper Tip area. The objective of the drainage system is to control the groundwater levels, and therefore reduce the build-up of excessive pore pressures, within the retained colliery spoil material remaining on the slope.

As part of the Phase 3 remediation works, mid-slope drainage has been installed within the Upper Tip (February 2021), to collect surface water (primarily sourced from mid-slope issues / spring lines) and divert it away from the reinstatement works within the valley bottom.

3. Slope Stability

3.1 Introduction

To achieve long-term stability of Llanwonno Upper Tip, Phase 4 of the remediation works includes the removal of the majority of colliery spoil, reprofiling of the failed slope and installation of permanent drainage systems.

Stability analysis has been undertaken on the proposed finished ground levels at the Upper Tip area on completion of the Phase 4 works.

3.1.1 *Past Stability Analysis*

The following documents relating to the stability of Llanwonno Upper Tip have been reviewed and are summarised below.

3.1.1.1 *Llanwonno Tips Reclamation Scheme, Stability Report, Halcrow, 200*4 (Ref. 3)

This report discusses the following:

- Intrusive ground investigations undertaken in 2001.
- The stability of the site prior to the landslide, including stability modelling of the Upper Tip.
- Potential management / stabilisation options for the Upper Tip.

3.1.1.2 *Llanwonno Upper Tip (RH01) – Stability Statement, Capita, May* 2020 (Ref. 8)

To assess any residual risk from the recent landslide and to allow Phases 2 and 3 of the remediation works to be undertaken safely, stability analysis of the material remaining at Tylorstown Upper Tip was undertaken by Capita (Redstart). Following analysis, a 'Stability Statement' was issued, which is presented in Appendix A.

For continuity of analysis, Capita re-created Halcrow's stability models through the Upper Tip to achieve the same baseline ground model as Halcrow. The ground model was subsequently updated to reflect the changes to the site topography following the landslide (ground level difference between the Halcrow topographical slope model (pre landslide) and the post landslide drone model). The stability analysis was then re-run using previous residual parameters and critical water table levels.

The ground models were further revised to reflect the following on-site observations:

- The rear back scarp feature comprises natural glacial materials not colliery spoil (original mountainside slope) with a capping of colliery spoil at the crest of the slope only (see Photo 3).
- Visible groundwater and surface water levels such as issues and seepages.

Photo 3: View of main back scarp showing exposed glacial deposits.

Back analysis of the exposed back scarp suggested that the soil parameters used for the natural glacial deposits may have been conservative, and potentially material parameters used should be equal to peak and not residual strength values as previously analysed.

The analysis concluded that, in terms of overall stability, the Factor of Safety on the materials (colliery spoil) left on the slope is close or at unity and these materials will need to be removed in the long term if other remediation measures are not implemented.

3.2 Stability Analysis Overview

3.2.1 *Method of Analysis*

The slope stability analysis was undertaken using the GEOSLOPE software SLOPE/W (Version.11.0.1.21429) (Ref. 9), adopting the principles of the Morgenstern-Price method (analysis of slices).

3.2.2 *Adopted Factor of Safety*

It is currently recommended that earthworks design in undertaken in accordance with BS EN 1997-1:2004 (Ref. 10) using partial factors applied to loads and material parameters. However, to achieve a direct comparison with previous stability analysis (Ref. 3) the traditional 'global factor of safety' approach has been adopted.

As discussed in Section 6.2 of the Halcrow Report, the minimum Factor of Safety (FoS) for active spoil heaps and closed classified tips is set out in the Mines & Quarries (Tips) Regulations, 1971 and the National coal Board (NCB) 'Codes and Rules - Tips' (NCB, 1971). These documents suggest a minimum FoS of 1.20 is appropriate for closed classified tips where water tables are known (recorded) and conservative geotechnical parameters are adopted. Although not a classified tip, disused tips, such as the Upper Tip, were reviewed in the same manner.

Additionally, British Standard, BS 6031:1981 (Ref. 11), now superseded by BS 6031:2009 (Ref. 12), distinguishes between first time landslides and landslides on pre-existing slip surfaces for over-consolidated soils and suggests that for a slope with pre-existing slip surfaces, a FoS of 1.20 should be provided.

In accordance with the above, a minimum FoS of 1.20 is considered appropriate for the stability analysis where movement has been recorded. Where no ground movement is evident, a target FoS of 1.30 is required.

3.2.3 *Material Properties*

For continuity with the previous stability analysis undertaken at the site and following a review of the rationale within Section 3 of the Halcrow Stability Report, the material parameters proposed by Halcrow have been adopted for the latest stability analysis. These parameters are summarised in Table 3.1 below.

Table 3.1: Halcrow Material Design Parameters

Material	ρ	γ	ϕ' (°)		C' (kN/m²)	
	(Mg/m³)	(kN/m³	PEAK	RESIDUAL	PEAK	RESIDUAL
Colliery Spoil	1.94	19.0	33.5	26.5	6.0	3.0
Glacial Till	2.14	21.0	32.0	32.0	12.0	0.0
Cohesive Slope Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Slope Deposits	2.04	20.0	32.0	-	0.0	-
Bedrock (highly weathered Mudstone)	2.24	22.0	-	20.0	-	0.0

Notes

ρ = Bulk density
γ = Unit weight
Φ' = Angle of shearing resistance
C' = Cohesion

3.2.4 *Groundwater Levels*

The groundwater table used in analysis is based on water strikes in the exploratory holes, water levels recorded during monitoring and visual observations following the landslide event. See Section 2.5 for further details.

Phase 4 of the remediation works will also include the installation of comprehensive drainage systems to reduce the volume of water entering the reprofiled Upper Tip slope.

To assist in the drainage design, sensitivity analysis comparing how different groundwater profiles impact on the FoS has also been undertaken.

3.2.5 *Design loadings*

On completion of the Phase 4 works, vehicle trafficking of the Upper Tip is not anticipated, and Llanwonno Road does not encroach within 10 m of the Upper Tip boundary. Therefore, traffic loading has been omitted from the analysis.

3.2.6 *Ground profiles.*

For continuity of slope stability analysis of the Upper Tip, Redstart have re-created three cross-sections presented in Halcrow's stability report. These cross-sections represent three distinct parts of the Upper Tip (see Section 1.3) and are summarised in Table 3.2 below. Representative historical boreholes were also reviewed in the production of the ground profiles.

Table 3.2: Summary of cross-sections used for stability analysis

Area Reference	Cross-section Chainage	Redstart Drawing Reference	Halcrow Section	Halcrow Figure Reference
South-western Area (Ch. 0m -160m)	120m	GC3613-RED-61-RSC-DR-C-0004	C-C	LWTR/R2/4
Landslide Area (Ch. 160m – 340m)	280m	GC3613-RED-61-RSC-DR-C-0006	B-B	LWTW/R2/3
North-western Area (Ch. 340m – 527m)	440m	GC3613-RED-61-RSC-DR-C-0007	A-A	LWTR/R2/2

The location of the separate parts of the site and cross-sections are shown on Drawing GC3613-RED-61-RSC-DR-C-0002. The location of the corresponding Halcrow sections and historical boreholes are shown on Figure LWTR/R2/1. The Halcrow figures referenced are presented in Appendix B.

3.3 Stability Analysis (SlopeW) Output

3.3.1 *South-Western Area (Ch. 0m to 160m)*

The existing ground profile for this part of the site was reproduced from Halcrow Figure LWTR/R2/4, and a review of historical boreholes BH4 (1993 ground investigation (Ref. 4)) and borehole LWN3 (1996 ground investigation (Ref. 5)). To represent the general ground profile across the site, a veneer of cohesive slope deposits has been added to the toe of the slope. The proposed ground surface profile is extracted from the cross-section for Ch. 120m, shown on Drawing GC3613-RED-61-RSC-DR-C-0004.

There is no evidence of historical or recent ground movement with this part of the site, therefore peak strength parameters for the colliery spoil were used for analysis, and a target FoS of 1.30 applied.

No groundwater was recorded in BH4 (1993) or borehole LWN3 (1996). Therefore, a 'worst case' ground water level was inferred at the base of the deepest borehole at this location (LWN3). Halcrow Figure LWTR/R2/1 shows a 'marshy' area near the toe of the slope, to represent this feature, the groundwater at the toe of the slope has been modelled at ground level.

Table 3.3: Summary of SlopeW models and output for South-Western Area (Ch. 120m)

Slope/w Output Figure Ref.	Description	Factor of Safety (critical)	Slope Stability Criteria Satisfied (FOS >1.30)
1	Existing ground profile	**1.19**	No
2	Phase 4 proposed slope profile	**1.39**	**Yes**
3	Phase 4 proposed slope profile Water table +1.0m	**1.37**	**Yes**

Stability analysis suggests the FoS of the existing tip profile is slightly below the target FoS of 1.30. The proposed reprofiled slope increases the stability of the tip, achieving a minimum FoS of 1.37 (design water table +1.0m), and therefore deemed acceptable.

3.3.1.1 Landslide Area (Ch. 160m to 340m)

The ground profile prior to the landslide along this part of the site was reproduced from Halcrow Figure LWTR/R2/3, and a review of historical boreholes LWT4, LWT4A, LWT5, LWT6 and LWT7 (2001 ground investigation (Ref. 6)). The ground surface profile following the landslip and proposed ground profile are extracted from the cross-section for Ch. 280m, shown on Drawing GC3613-RED-61-RSC-DR-C-0006.

Ground movement was recorded before the landslide occurred, therefore residual strength parameters for the colliery spoil and slope deposits have been used for analysis prior and post landslide. The one exception is colliery spoil, which will be compacted and engineered back within the tip area as part of the Phase 4 works, and assigned peak strength values.

The groundwater tables used in analysis is based on water strikes in the exploratory holes, water levels recorded during monitoring and visual observations following the landslide. Again, a sensitivity analysis comparing how different groundwater profile impacts the FoS has also been undertaken.

Table 3.4: Summary of SlopeW models and output for Landslide Area (Ch. 280m)

Slope/w Output Figure Ref.	Description	Factor of Safety (critical)	Slope Stability Criteria Satisfied (FOS >1.20)
4	Ground profile prior to landslide (Halcrow) Maximum water table prior to landslide	**1.03**	No
5	Ground profile after landslide (back scar) Revised ground profile from on-site observations	**0.76**	No
6	Ground profile after landslide (back scar) Revised ground profile from on-site observations	**0.83**	No
7	Ground profile after landslide Maximum water table prior to landslide *	**1.03**	No
8	Phase 4 proposed slope profile Maximum water table prior to landslide	**0.92**	No
9	Phase 4 proposed slope profile Revised ground profile from on-site observations	**1.32**	**Yes**
10	Phase 4 proposed slope profile Revised ground profile from on-site observations +0.5m	**1.20**	**Yes**
11	Phase 4 proposed slope profile Revised ground profile from on-site observations +1.0m	**1.17**	No

* Maximum groundwater level adjusted to reflect current ground conditions.

Figure 4 shows the reproduction of Halcrow's stability model with the critical slip (FoS = 1.03) replicating the Halcrow pre-defined critical slip 'S2' from Figure LWTR/R2/3 (FoS = 1.06), confirming continuity of analysis between models. However, due to the changes in topography in this part of the site following the landslide, direct analysis on how the proposed Phase 4 reprofiling will affect the FoS of Halcrow's pre-defined slip planes (S1 to S8 on Figure LWTR/R2/3) is not possible. Therefore, to encompass potential methods of failure post Phase 4 works, the general global stability of the area was analysed using the 'grid and radius' and 'entry and exit' slip surface options, instead of pre-defined slip planes.

Stability analysis of the slope following the landslide shows a FoS of 0.76 (Figure 5) within the back scar, which cannot be representative of the ground conditions, as the slope has not failed in the 12 months following the landslip. The ground model was updated (Figure 6) as visual observations show the back scar comprises natural materials (granular glacial deposits) with a capping of colliery spoil at the crest of the slope. This increased the FOS to 0.83.

Further sensitivity analysis was undertaken by varying the groundwater table within the back scar, which resulted in little change to the overall stability, and the FoS remaining below unity.

Visible evidence that the back scar has not failed, and is not showing signs of global instability, suggests the material parameters are over-conservative, and should be equal to peak and not residual strength parameters or a higher component of cohesion or increased phi angle could be assigned to the slope deposits. However, as discussed in Section 3.2.2. conservative geotechnical parameters should be adopted when analysing coal tips, and therefore the original peak and residual strength parameters were used for the analysis.

To reflect periods of intensive rainfall, the current slope profile has been modelled in combination with the maximum groundwater table recorded prior to the landslide (the maximum groundwater table had to be adjusted to reflect the current ground profile, as the actual maximum groundwater was above ground level, and therefore not realistic). As shown on Figure 7, if the water table rises and saturates the lower spoil slope, the global stability of the existing slope is at approximate unity with a FoS of 1.03.

Stability analysis has been undertaken on the proposed slope profile for the Phase 4 remediation works (colliery spoil assigned peak strength values). The original model (Figure 8) utilised the maximum groundwater table recorded at the site, recording a FoS of 0.92. This groundwater scenario is not considered to be a realistic estimate of the potential maximum groundwater level following the landslide. The rational for this is that the Phase 4 works will include a comprehensive drainage system to collect surface water and groundwater (where possible) and divert it away from the area, and the lower 'lobe' which formed the ponds is no longer present, allowing surface water and groundwater to flow downslope and not 'build up'.

Modelling the proposed ground profile in combination with the revised water table (from on-site observations) produces a FoS of 1.32 (Figure 9).

It is possible that the replacement (re-compaction) of spoil material within the tip area, may result in the groundwater levels rising during periods of intensive rainfall, as the water cannot dissipate as quickly from the tip area. Increasing the groundwater levels by 0.5m and 1.0m resulted in a FoS of 1.20 (Figure 10) and 1.17 (Figure 11) respectively.

To summarise, this part of the Upper Tip has a FoS close to unity (FoS = 1.03) under revised maximum water levels. The proposed reprofiled slope increases the stability of the tip, achieving a minimum FoS of 1.32 in combination with the water table currently observed on-site (design water table), and is therefore acceptable. However, the overall stability at this part of the site is sensitive to changes in groundwater levels, with an increase of 1.0m giving a FoS of 1.17, which is slightly lower than the required FoS of 1.20.

3.3.1.2 North-Eastern Area (Ch. 340m to 527m)

The ground profile prior to the landslide along this part of the site was reproduced from Halcrow Figure LWTR/R2/2, and a review of historical boreholes LWT1, LWT2, LWT3 (2001), LWN1 (1996) and trial pit LWTP3 (2001). The proposed ground surface profile is extracted from the cross-section for Ch. 440m, shown on Drawing GC3613-RED-61-RSC-DR-C-0007.

There is evidence of past ground movement along this part of the Upper Tip (see Section 1.3.3.), therefore residual strength parameters for the colliery spoil and slope deposits have been used for analysis. Where colliery spoil is relocated within the tip area as part of the Phase 4 works, it is assigned peak strength values.

The groundwater table used in analysis is based on water strikes in the exploratory holes and water levels recorded during monitoring.

Table 3.5: Summary of SlopeW models and output for North-Eastern Area (Ch. 440m)

Slope/w Output Figure Ref.	Description	Factor of Safety (critical)	Slope Stability Criteria Satisfied (FOS >1.20)
12	Existing ground profile	**0.96**	No
13	Phase 4 proposed slope profile Maximum water table recorded	**0.91**	No
14	Phase 4 proposed slope profile Design water table (0.3m above rockhead)	**1.20**	**Yes**
15	Removal of all colliery spoil Design water table +0.5m	**1.14**	No
16	Removal of all colliery spoil Design water table +1.0m	**1.09**	No
17	Existing ground profile Granular Slope Deposits	**0.95**	No
18	Phase 4 proposed slope profile Granular Slope Deposits Maximum water table recorded	**1.03**	No
19	Phase 4 proposed slope profile Granular Slope Deposits Design water table (1.0m above rockhead)	**1.26**	**Yes**
20	Phase 4 proposed slope profile Granular Slope Deposits Design water table +0.5m	**1.18**	No
21	Phase 4 proposed slope profile Granular Slope Deposits Design water table +1.0m	**1.12**	No

Figure 12 shows the reproduction of Halcrow's stability model with the critical slip (FoS = 0.96) replicating the Halcrow critical slip 'S2' from Figure LWTR/R2/2 (FoS = 0.97), confirming continuity of analysis between models. As with the Landslide Area (Section 3.3.1.1.) the general global stability of the area was analysed using the 'grid and radius' and 'entry and exit' slip surface options.

The proposed reprofiled slope for Phase 4, combined with the maximum water table recorded a FoS of 0.91 (Figure 13). However, this elevated groundwater profile is not considered to be realistic following the completion of the Phase 4 works, as in addition to the proposed reprofiling of the slope, the remediation works will also include the installation of drainage systems, such as interceptor ditches, to collect surface water and groundwater and divert it away from the slope area.

The design water table (0.3m above rockhead) is shown on Figure 14, and produces a FOS of 1.20, marginally achieving the target FoS.

Increasing the design water table by 0.5m and 1.0m resulted in the FoS reducing to 1.14 (Figure 15) and 1.09 (Figure 16) respectively.

Following the initial analysis using Halcrows ground profile, further scrutiny of boreholes LWT2 and LWT3 (2001) suggests the 'cohesive slope deposits' underlying the colliery spoil are coarser in nature and fall under the 'granular slope deposits' description. These boreholes are presented in Appendix C. This revision to the ground profile also provides continuity with the natural deposits overlying the bedrock within the Landslip Area.

Stability analysis of the revised ground model of the existing slope (Figure 17), gave a FoS slightly below unity (0.95) under extreme groundwater (maximum recorded) conditions.

The proposed reprofiled slope combined with the maximum water table recorded a FoS slightly above unity (1.03), showing an improvement in the stability of the slope (Figure 18).

With the addition of a drainage system, the groundwater levels will be controlled and a design water table 1.0m above the bedrock has been modelled (Figure 19). Analysis showed the FoS increasing to 1.26, therefore exceeding the required FoS of 1.20.

Sensitivity analysis modelled the effects of raising the design water table by 0.5m and 1.0m, which resulted in the FoS reducing to 1.18 (Figure 20) and 1.12 (Figure 21) respectively.

In summary, stability analysis suggests the existing slopes along this part of the Upper Tip are slightly below unity under the maximum water levels recorded (FoS = 0.95). The proposed reprofiling of the slope improves the stability (FoS = 1.03) and when combined with lowering the water table the FoS increases to 1.26. The slope stability is sensitive to changes in groundwater levels, with an increase of 1.0m reducing the FoS to 1.12, which is slightly lower than the required FoS of 1.20, but above unity.

4. Conclusions and Recommendations

4.1 Stability Analysis Summary

In general, the stability analysis undertaken suggests the remaining Llanwonno Upper Tip complex is at approximate unity in terms of overall global stability (FoS ≈ 1.00). The proposed reprofiling of the Upper Tip area combined with drainage measures to control the groundwater levels, increases the stability of the area achieving the target Factor of Safety of 1.20 in the Landslide and North-Eastern areas, and the target FoS of 1.30 for the South-Western Area.

Further analysis using design and enhanced groundwater levels shows the overall stability of the Upper Tip to be sensitive to changes in groundwater levels and that robust and maintained drainage systems must be implemented as part of the Phase 4 remediation works.

The output from the three sections analysed is summarised below.

4.1.1 *South-Western Area (Ch. 0m to 160m)*

The ground profile for this part of the tip is not representative of the general Upper Tip area, as a quarry is interpreted to directly underlie the colliery spoil deposits. The existing tip profile has a FoS of 1.19. The proposed Phase 4 reprofiled slope increases the stability of the tip, achieving a minimum FoS of 1.37 (design water table +1.0m), and is therefore acceptable.

4.1.2 *Landslide Area (Ch. 160m to 340m)*

This part of the Upper Tip is currently close to unity (FoS = 1.03) under revised maximum water levels. The proposed slope reprofiling in combination with the water table currently observed on-site (design water table) increases the stability of the tip, achieving a minimum FoS of 1.32, and is therefore acceptable. The overall stability at this part of the site is sensitive to change in groundwater levels, with an increase of 1.0m giving a FoS of 1.17, which is slightly below the target FoS of 1.20.

4.1.3 *North-Eastern Area (Ch. 340m to 527m)*

Stability analysis suggests the existing slopes along this part of the Upper Tip are slightly below unity under the maximum water levels recorded (FoS = 0.95). Proposed reprofiling of the slope improves the stability (FoS = 1.03) and when combined with lowering the water table (design water table) the FoS increases to 1.26 and is therefore acceptable. As with the landslide area, the stability of the tip is sensitive to change in groundwater levels, with an increase of 1.0m reducing the FoS to 1.12, which is lower than the required FoS of 1.20, but above unity expressing the need for robust drainage systems to be installed as part of the Phase 4 works.

4.2 Recommendations

4.2.1 *Phase 4 Drainage System*

Following stability analysis undertaken, it is evident that the stability of the Upper Tip is sensitive to changes in groundwater levels.

To control the groundwater levels within the Upper Tip, it is essential that the Phase 4 remediation works include the installation of robust permanent and maintained drainage systems to collect surface and groundwater and divert it away from the Llanwonno Upper Tip area.

Potential options for the drainage system include the installation of:

- Interception ditches at the crest of slope (all areas).
- Granular drainage blankets (or ditches) where colliery spoil is being relocated with the top area (Landslide Area).
- Granular downslope trench drains where colliery spoil is being reprofiled (North-Eastern Area).

The mid-slope drainage, recently installed as part of the Phase 3 remediation works, should be incorporated into the final drainage design.

As discussed in Section 2.5 of this report, the surface water and groundwater network at the Upper Tip area is complex and responds rapidly to periods of intense rainfall. To ensure any proposed drainage system is effective, the surface and groundwater network needs to be extensively reviewed as part of the permanent drainage design.

4.2.2 *Post Phase 4 Ground Investigation*

To confirm both the ground profiles, groundwater levels and material parameters used in the stability analysis, it is recommended that a ground investigation is undertaken on completion of the Phase 4 remediation works. Boreholes should be positioned along the sections used in analysis.

If the ground investigation records any significant changes to the assumptions made within this stability report, the slope stability analysis should be revisited and updated accordingly.

To monitor groundwater levels at the site on completion of the Phase 4 works, groundwater monitoring installations should be installed within selected boreholes. Remote telemetry units could also be installed to provide continuous ‘real-time’ monitoring of the groundwater regime and provide an alert system if the groundwater reaches critical levels.

5. References

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4. Report on a Site Investigation at Tylorstown and Llanwonno Tips, Thyssen Geotechnical, Report No. 7640/39, October 1993

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6. Llanwonno Tips Reclamation Scheme, Report on Ground Investigation, Ref. 151258 Halcrow, 2001.

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8. Llanwonno Upper Tip (RH01) – Stability Statement, Capita, May 2020

9. SLOPE/W, GEO-SLOPE International Ltd, Geostudio 2021 (Version.11.0.1.21429),

10. BS EN 1997-1:2004 Eurocode 7: Geotechnical design. General rules (+A1:2013)

11. Code of Practice for Earthworks. BS 6031:1981. BSi.

12. Code of Practice for Earthworks. BS 6031:2009. BSi.

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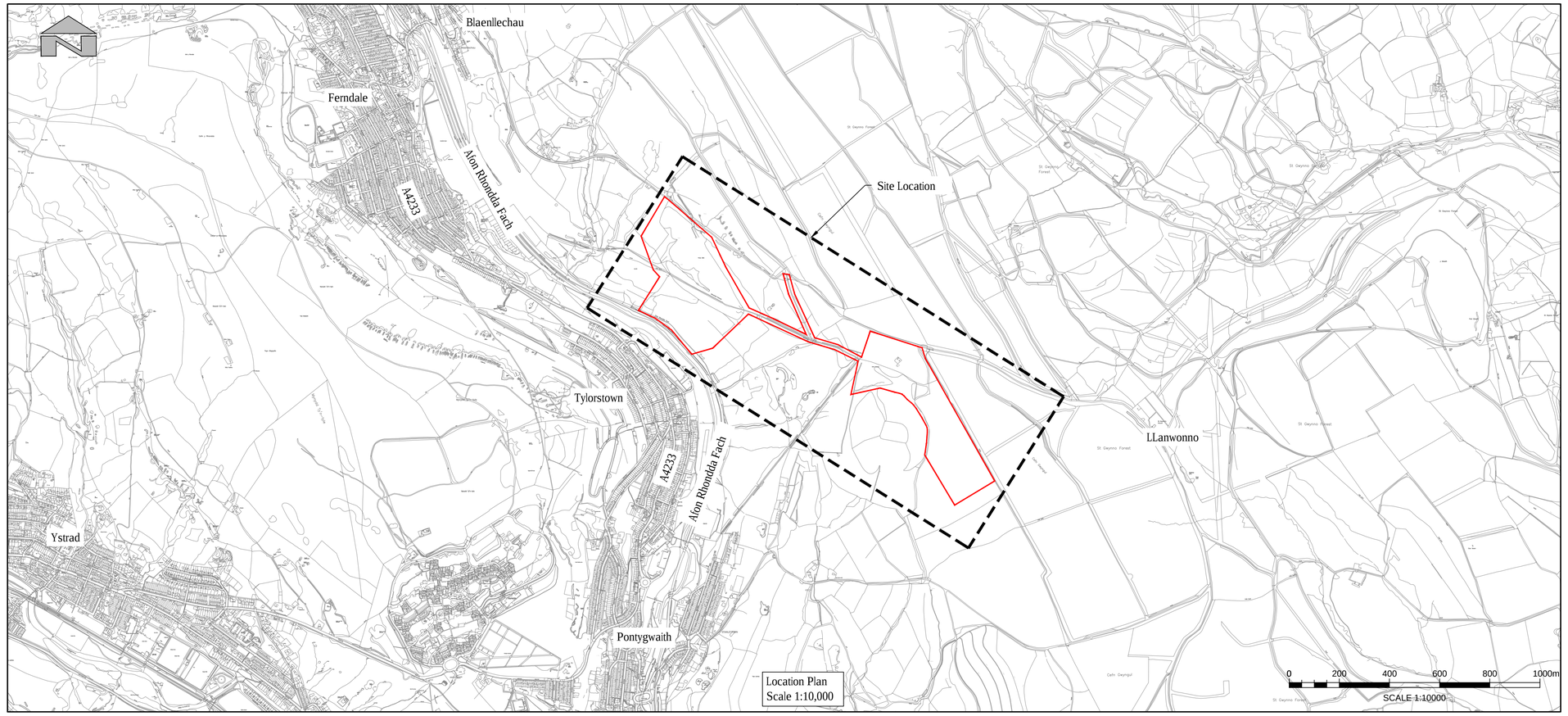
DRAWINGS

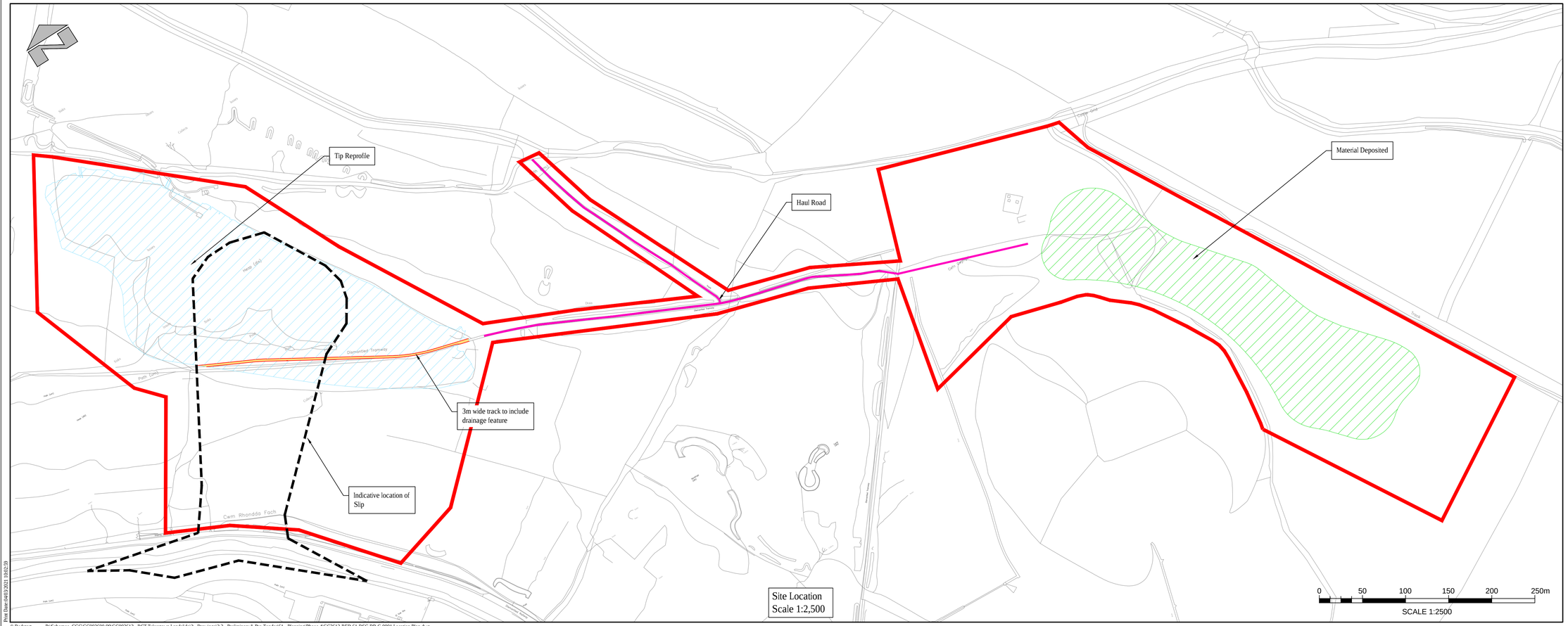


Key:

- Planning Boundary
- Proposed Tip Reprofile (including Tramway)
- Proposed Material deposit
- Proposed Haul Route
- Proposed 3m wide track to include drainage feature
- Indicative location of Slip

Notes:

1. For Tip Reprofile General Arrangement refer to drawing : GC3613-RED-61-RSC-DR-C-0002
2. For Receptor Site C General Arrangement refer to drawing : GC3613-RED-61-RSC-DR-C-0003
3. For cross sections of Tip Reprofile refer to drawings: GC3613-RED-61-RSC-DR-C-0004-0008
4. For cross sections of Receptor Site C refer to drawings: GC3613-RED-61-RSC-DR-C-0009-0013



Rev	Drwn	Chkd	Apprd	Description	Date

Purpose of Issue
D5 - Suitable for Planning

Classification
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Client
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County Borough Council

Project
Tylorstown Landslide

Drawing
Phase 4
Location Plan

Scale @ A1	Drawn	Checked	Approved
As Shown	MH	NG	PH

Project No.: GC/3613
Date: March 2021

Drawing Identifier (Project - Originator - Zone - Level - File Type - Role - Number): GC3613-RED-61-RSC-DR-C-0001
BS1192 Compliant revision: P01

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Typical Section
Scale 1:50

Key:

- Proposed Tip Reprofile (including Tramway)
- Proposed 2m wide track and 1m wide drainage feature
- Existing Drainage Ditch

Notes:

1. For Location Plan refer to drawing : GC3613-RED-61-RSC-DR-C-0001
2. For Receptor Site C General Arrangement refer to drawing : GC3613-RED-61-RSC-DR-C-0003
3. For cross sections of Tip Reprofile refer to drawings: GC3613-RED-61-RSC-DR-C-0004-0010
4. For Receptor Site C Cross Sections refer to drawings: GC3613-RED-61-RSC-DR-C-0009-0013

Rev	Drwn	Chkd	Apprd	Description	Date

Purpose of Issue
D5 - Suitable for Planning

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Project
Tylorstown Landslide

Drawing
Phase 4
General Arrangement
Tip Reprofile

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Project No.	Date
GC/3613	March 2021

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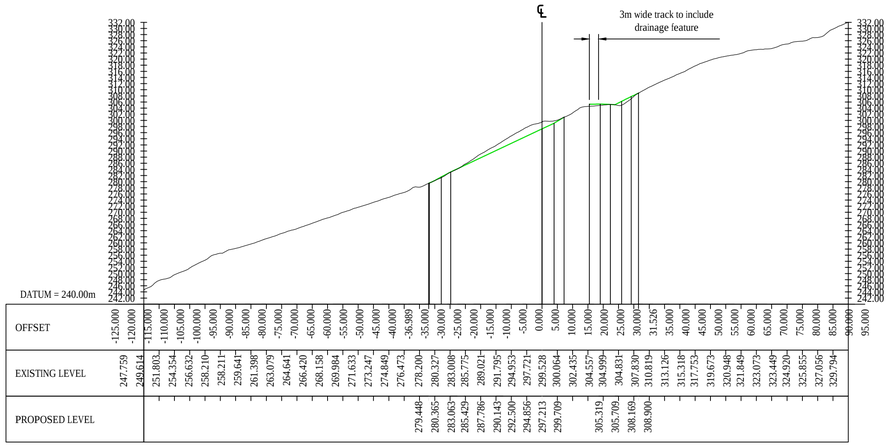

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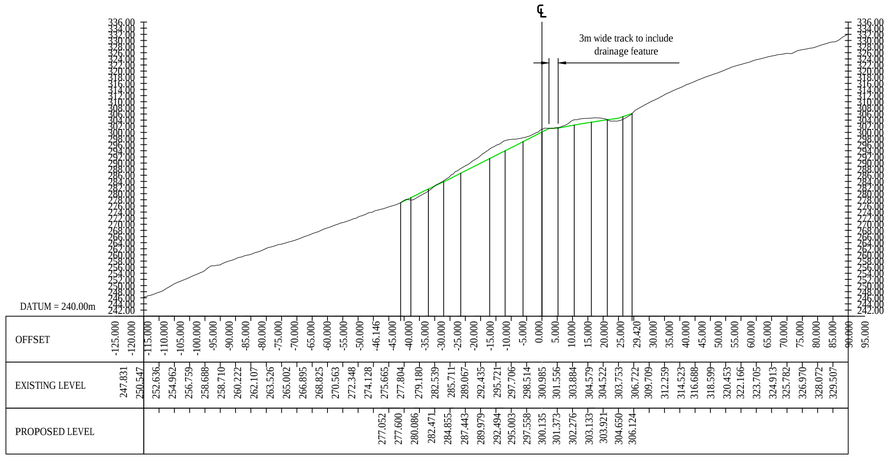

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PHASE 4 - TIP REPROFILE - CH100.000
SCALE 1:1000

PHASE 4 - TIP REPROFILE - CH120.000
SCALE 1:1000

SCALE 1:1000

Key:

Proposed Levels

Existing Levels

Notes:

1. For cross sections markers refer to drawing: GC3613-RED-61-RSC-DR-C-0002
2. For Location Plan refer to drawing: GC3613-RED-61-RSC-DR-C-0001
3. For General Arrangement Plan of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0003
4. For Cross Sections of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0009-0013

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Purpose of Issue

D5 - Suitable for Planning

Classification

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Project

Tylorstown Landslide

Drawing

Phase 4
Cross Sections - Tip Reprofile
Sheet 1 of 5

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Project No.: GC/3613

Date: March 2021

Drawing Identifier: GC3613-RED-61-RSC-DR-C-0004

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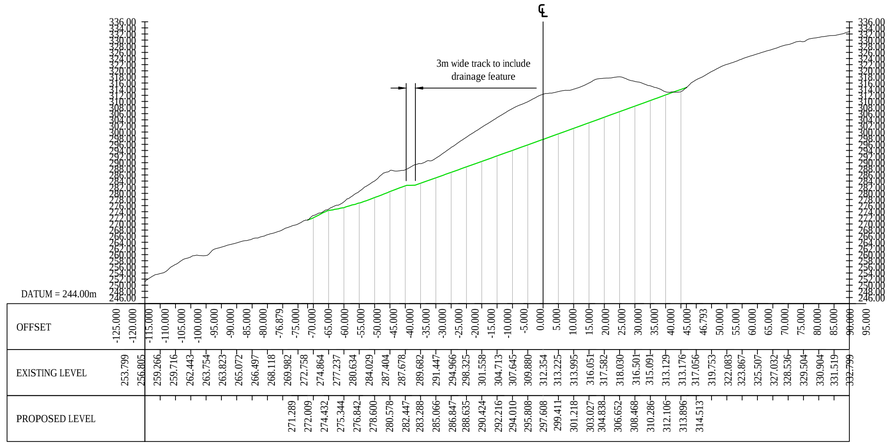

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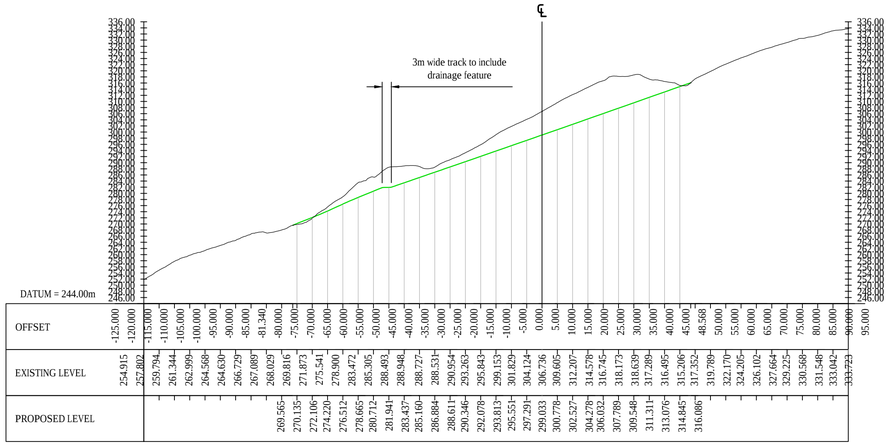

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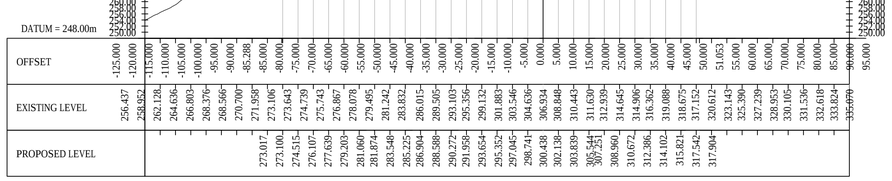

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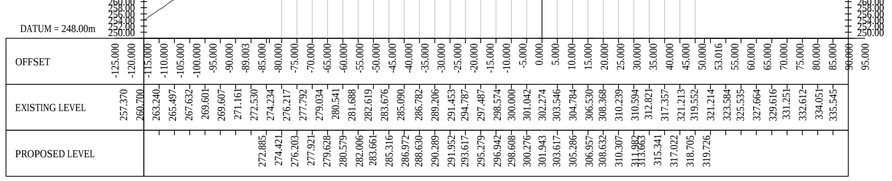

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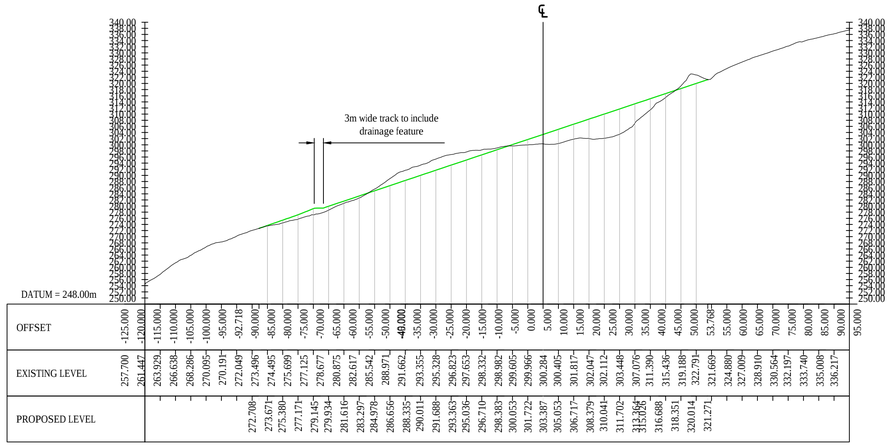

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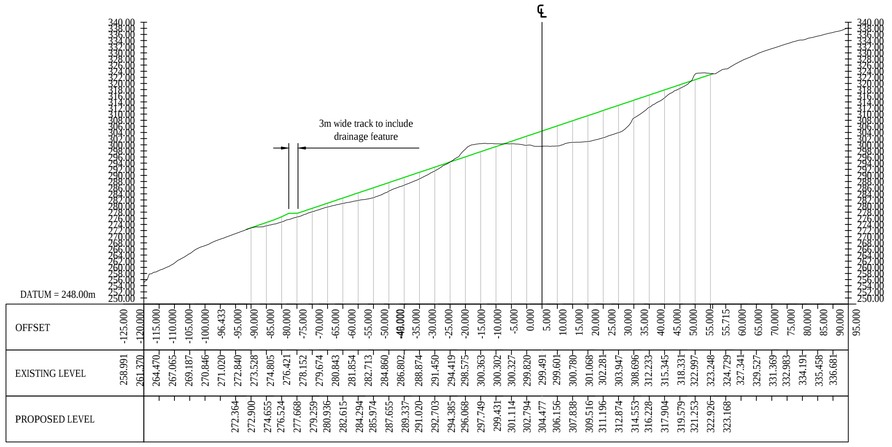

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Key:

Proposed Levels

Existing Levels

Notes:

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2. For Location Plan refer to drawing: GC3613-RED-61-RSC-DR-C-0001
3. For General Arrangement Plan of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0003
4. For Cross Sections of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0009-0013

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Purpose of Issue

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Tylorstown Landslide

Drawing

Phase 4
Cross Sections - Tip Reprofile
Sheet 2 of 5

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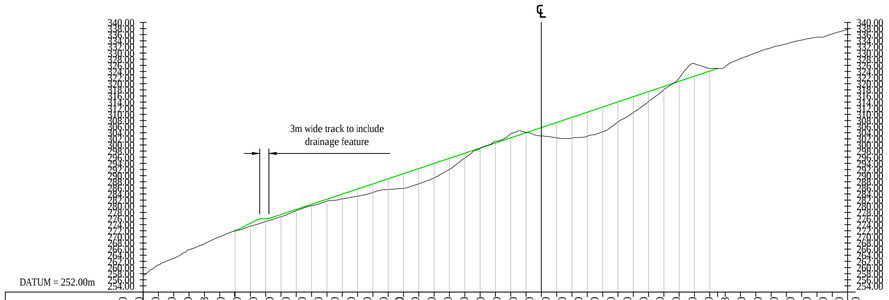

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EXISTING LEVEL	260.849	262.954	265.820	267.742	270.020	271.869	271.923	273.483	274.994	276.582	278.574	280.146	281.683	282.426	283.240	284.498	285.456	285.845	287.334	289.249	291.983	295.718	298.832	301.176	303.641	304.086	302.962	302.325	302.260	302.842	304.284	307.520	310.597	314.176	317.424	318.034	319.103	320.785	321.837	326.517	324.947	325.504	328.200	330.123	331.736	332.991	334.259	335.185	336.247
PROPOSED LEVEL						271.906	271.974	274.472	274.994	275.945	277.302	278.966	280.632	282.297	283.964	285.631	287.299	288.967	290.635	292.306	293.976	295.646	297.317	298.990	300.662	302.335	304.009	305.683	307.359	309.035	310.710	312.388	314.065	315.744	317.424	319.103	320.785	322.466	324.148	324.995											

PHASE 4 - TIP REPROFILE - CH260.000
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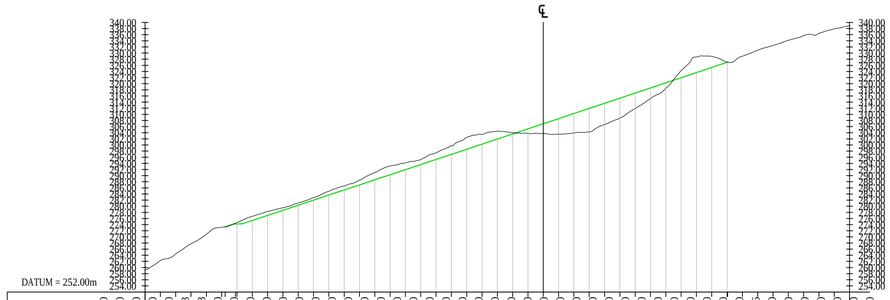

OFFSET	-125.000	-120.000	-115.000	-110.000	-105.000	-103.863	-100.488	-100.000	-95.000	-90.000	-85.000	-80.000	-75.000	-70.000	-65.000	-60.000	-55.000	-50.000	-45.000	-40.000	-35.000	-30.000	-25.000	-20.000	-15.000	-10.000	-5.000	0.000	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	60.176	65.000	70.000	80.000	85.000	90.000	95.000
EXISTING LEVEL	262.242	264.438	267.751	270.846	273.142	274.428	274.428	274.694	276.729	277.010	278.280	279.500	281.054	282.828	284.883	286.620	288.519	291.015	293.145	294.233	295.226	297.446	299.730	302.490	303.472	304.481	303.981	303.734	303.528	303.910	304.265	306.661	308.749	311.888	315.164	318.471	321.958	324.289	328.724	328.912	327.091	328.989	330.910	332.460	334.152	335.732	336.434	337.913	338.959
PROPOSED LEVEL						273.262	274.220	274.227	275.353	277.010	278.668	280.327	281.985	283.645	285.305	286.965	288.627	290.287	291.951	293.610	295.276	296.936	298.603	300.266	301.930	303.597	305.264	306.931	308.598	310.266	311.934	313.604	315.275	316.943	318.614	320.286	321.958	323.630	325.304	326.979	327.040										

PHASE 4 - TIP REPROFILE - CH280.000
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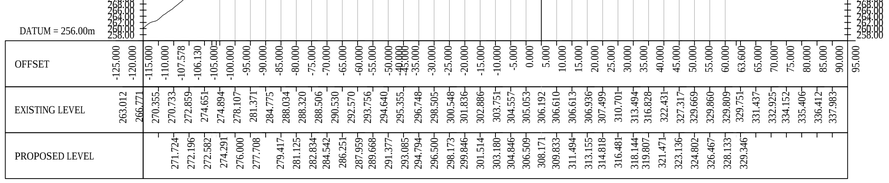

OFFSET	-125.000	-120.000	-115.000	-110.000	-107.578	-106.130	-105.000	-100.000	-95.000	-90.000	-85.000	-80.000	-75.000	-70.000	-65.000	-60.000	-55.000	-50.000	-45.000	-40.000	-35.000	-30.000	-25.000	-20.000	-15.000	-10.000	-5.000	0.000	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000	70.000	75.000	80.000	85.000	90.000	95.000
EXISTING LEVEL	263.012	266.771	270.355	270.733	272.859	274.651	274.894	278.107	281.371	284.775	288.034	288.320	288.506	290.530	292.570	293.756	294.640	295.355	296.748	298.505	300.548	301.836	302.886	303.751	304.557	305.653	306.192	306.610	306.613	306.936	307.499	310.701	313.494	316.828	322.431	323.136	324.802	326.467	329.860	329.809	329.751	331.437	332.925	334.152	335.406	336.412	337.983
PROPOSED LEVEL				271.724	272.196	272.582	274.291	276.000	277.708	279.417	281.125	282.834	284.542	286.251	287.959	289.668	291.377	293.085	294.794	296.500	298.173	299.846	301.514	303.180	304.846	306.509	308.171	309.833	311.494	313.155	314.818	316.481	318.144	319.807	321.471	323.136	324.802	326.467	328.133	329.346									

PHASE 4 - TIP REPROFILE - CH300.000
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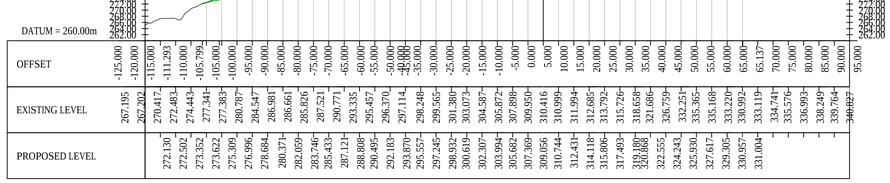
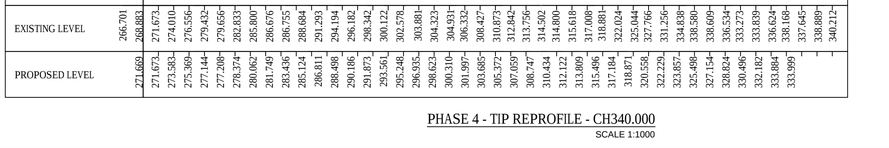


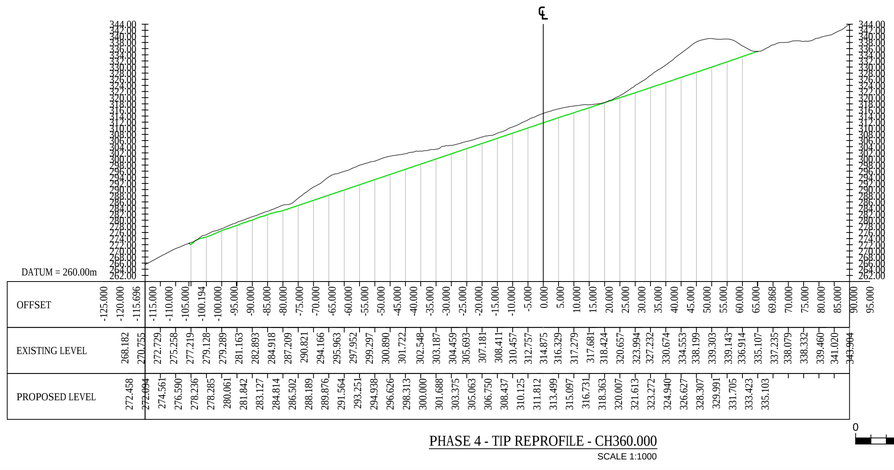
OFFSET	-125.000	-120.000	-115.000	-111.293	-110.000	-105.799	-105.000	-100.000	-95.000	-90.000	-85.000	-80.000	-75.000	-70.000	-65.000	-60.000	-55.000	-50.000	-45.000	-40.000	-35.000	-30.000	-25.000	-20.000	-15.000	-10.000	-5.000	0.000	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000	65.137	70.000	75.000	80.000	85.000	90.000	95.000
EXISTING LEVEL	267.195	267.202	270.417	272.483	274.443	277.341	277.383	280.787	284.547	286.981	286.661	285.826	283.746	285.433	287.521	290.771	293.335	295.457	296.370	297.114	293.870	295.557	297.245	298.932	300.619	302.307	303.994	305.682	307.369	309.056	310.744	312.431	314.118	315.806	317.493	319.180	320.868	322.555	324.243	325.930	327.617	329.305	330.957	331.004	334.741	336.993	338.249	339.764	340.827
PROPOSED LEVEL				272.130	272.502	273.352	273.622	275.309	276.996	278.684	280.371	282.059	283.746	285.433	287.121	288.808	290.495	292.183	293.870	295.557	297.245	298.932	300.619	302.307	303.994	305.682	307.369	309.056	310.744	312.431	314.118	315.806	317.493	319.180	320.868	322.555	324.243	325.930	327.617	329.305	330.957	331.004							

PHASE 4 - TIP REPROFILE - CH320.000
SCALE 1:1000



OFFSET	-125.000	-120.000	-115.000	-110.000	-105.000	-100.201	-100.000	-95.000	-90.000	-85.000	-80.000	-75.000	-70.000	-65.000	-60.000	-55.000	-50.000	-45.000	-40.000	-35.000	-30.000	-25.000	-20.000	-15.000	-10.000	-5.000	0.000	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000	70.000	75.000	80.000	85.000	90.000	95.000
EXISTING LEVEL	266.701	268.883	271.673	274.010	276.556	279.432	279.656	282.833	285.800	286.676	286.755	288.684	291.293	294.194	296.182	298.342	300.122	302.578	303.881	304.323	304.931	306.332	308.427	310.873	312.842	313.756	314.502	314.800	315.618	317.008	318.881	322.024	325.044	327.766	331.256	334.838	338.500	338.609	336.534	333.273	333.839	336.624	338.168	337.645	338.889	340.212
PROPOSED LEVEL	271.669	271.673	273.583	275.369	277.144	277.208	278.374	280.062	281.749	283.436	285.124	286.811	288.498	290.186	291.873	293.561	295.248	296.935	298.623	300.310	301.997	303.685	305.372	307.059	308.747	310.434	312.122	313.809	315.496	317.184	318.871	320.558	322.229	323.857	325.488	327.154	328.824	330.496	332.182	333.884	333.999						

PHASE 4 - TIP REPROFILE - CH340.000
SCALE 1:1000



OFFSET	-125.000	-120.000	-115.696	-110.000	-105.000	-100.194	-100.000	-95.000	-90.000	-85.000	-80.000	-75.000	-70.000	-65.000	-60.000	-55.000	-50.000	-45.000	-40.000	-35.000	-30.000	-25.000	-20.000	-15.000	-10.000	-5.000	0.000	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000	69.868	70.000	75.000	80.000	85.000	90.000	95.000
EXISTING LEVEL	268.182	270.255	272.729	275.258	277.219	279.128	279.289	281.163	282.893	284.918	287.209	290.821	294.166	295.963	297.952	299.297	300.890	301.722	302.548	303.187	304.459	305.693	307.181	308.411	310.457	312.757	314.875	316.229	317.681	318.424	320.657	323.994	327.232	330.674	334.553	338.199	339.303	339.143	336.914	335.107	337.235	338.079	339.460	341.020	343.994		
PROPOSED LEVEL	272.458	272.494	274.561	276.590	278.236	279.385	279.289	281.163	281.842	283.127	284.814	286.502	288.189	289.876	291.564	293.251	294.938	296.626	298.313	300.000	301.688	303.375	305.063	306.750	308.437	310.125	311.812	313.499	315.097	316.731	318.363	320.007	321.613	323.272	324.940	326.627	328.307	329.991	331.765	333.423	335.103						

PHASE 4 - TIP REPROFILE - CH360.000
SCALE 1:1000

0 20 40 60 80 100m
SCALE 1:1000

Key:

Proposed Levels

Existing Levels

Notes:

1. For cross sections markers refer to drawing: GC3613-RED-61-RSC-DR-C-0002
2. For Location Plan refer to drawing: GC3613-RED-61-RSC-DR-C-0001
3. For General Arrangement Plan of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0003
4. For Cross Sections of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0009-0013

Rev	Drwn	Chkd	Apprd	Description	Date

Purpose of Issue
D5 - Suitable for Planning

Classification
Public

Client
Rhondda Cynon Taf
County Borough Council

Project
Tylorstown Landslide

Drawing
Phase 4
Cross Sections - Tip Reprofile
Sheet 3 of 5

Scale @ A1	Drawn	Checked	Approved
1:1000	MH	NG	PH

Project No.: GC/3613
Date: March 2021

Drawing Identifier: GC3613-RED-61-RSC-DR-C-0006
Project - Originator - Zone - Level - File Type - Role - Number
BS1192 Compliant revision: P01

REDSTART
St David's House, Pascal Close, St Mellons, Cardiff, CF3 0LW
www.redstartwales.com

P:\Schemes_CGC\GC003600-99\GC003613 - RCT Tylorstown Landslide\2 - Drawings\2.3 - Preliminary & Pre-Tender\61 - Planning\Phase 4\GC3613-RED-61-RSC-DR-C-0004 - 0008 Cross Sections Tip Reprofile.dwg
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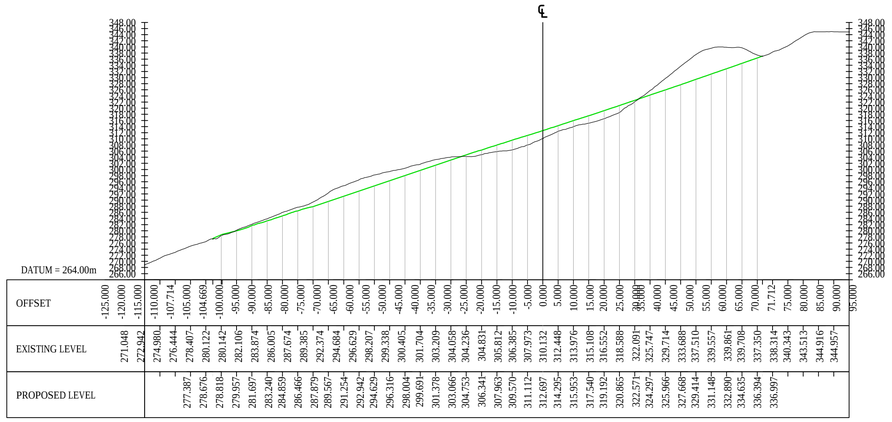
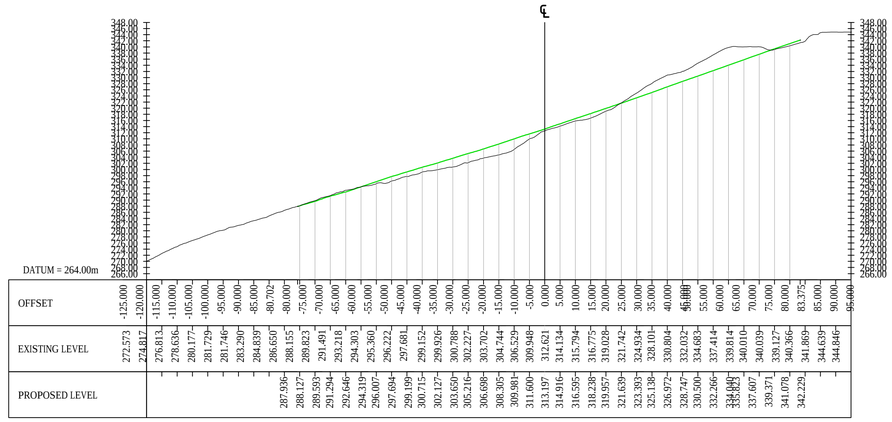


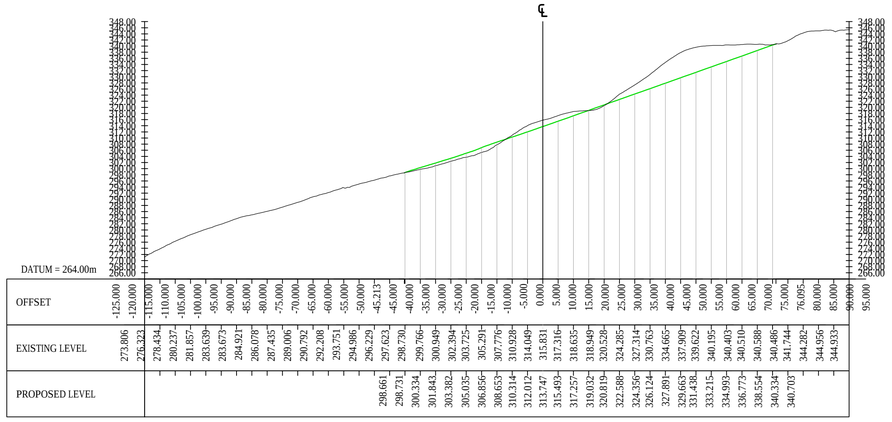
PHASE 4 - TIP REPROFILE - CH380.000

SCALE 1:1000



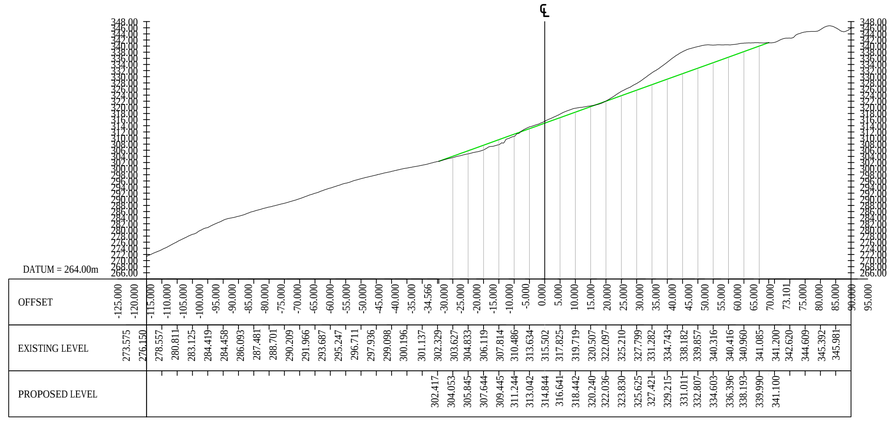
PHASE 4 - TIP REPROFILE - CH400.000

SCALE 1:1000



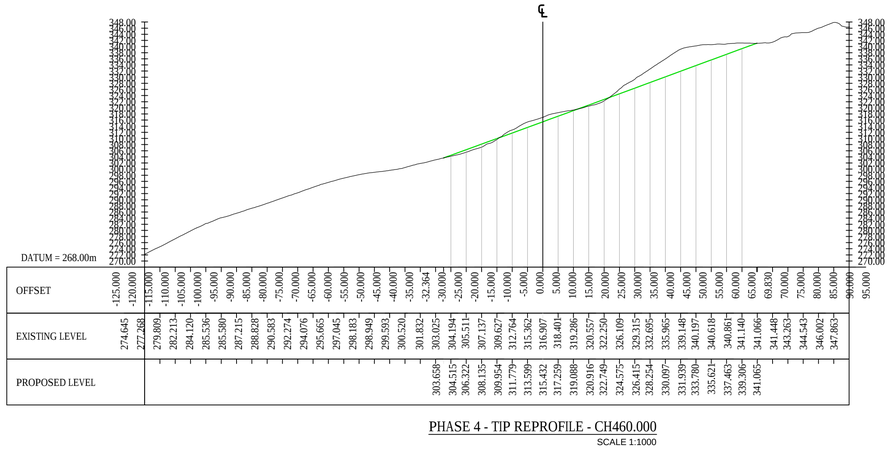
PHASE 4 - TIP REPROFILE - CH420.000

SCALE 1:1000



PHASE 4 - TIP REPROFILE - CH440.000

SCALE 1:1000



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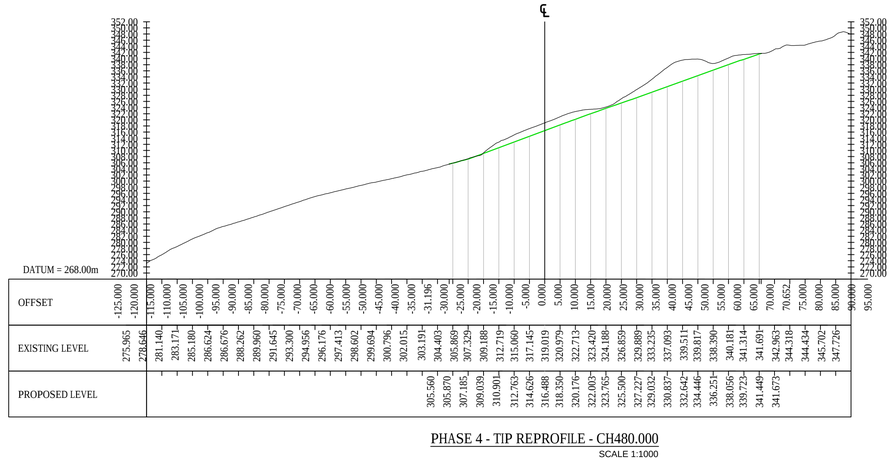
SCALE 1:1000



PHASE 4 - TIP REPROFILE - CH480.000

SCALE 1:1000

0 20 40 60 80 100m

SCALE 1:1000

Key:

Proposed Levels

Existing Levels

Notes:

1. For cross sections markers refer to drawing: GC3613-RED-61-RSC-DR-C-0002
2. For Location Plan refer to drawing: GC3613-RED-61-RSC-DR-C-0001
3. For General Arrangement Plan of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0003
4. For Cross Sections of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0009-0013

Rev	Drwn	Chkd	Apprd	Description	Date

Purpose of Issue

D5 - Suitable for Planning

Classification

Public

Client

Rhondda Cynon Taf
County Borough Council

Project

Tylorstown Landslide

Drawing

Phase 4
Cross Sections - Tip Reprofile
Sheet 4 of 5

Scale @ A1	Drawn	Checked	Approved
1:1000	MH	NG	PH

Project No. GC/3613

Date March 2021

Drawing Identifier (Project - Originator - Zone - Level - File Type - Role - Number): GC3613-RED-61-RSC-DR-C-0007

BS1192 Compliant revision: P01

REDSTART

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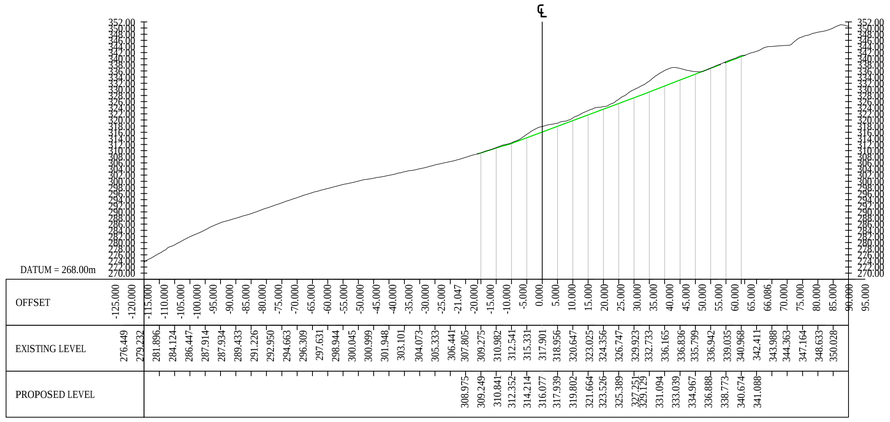
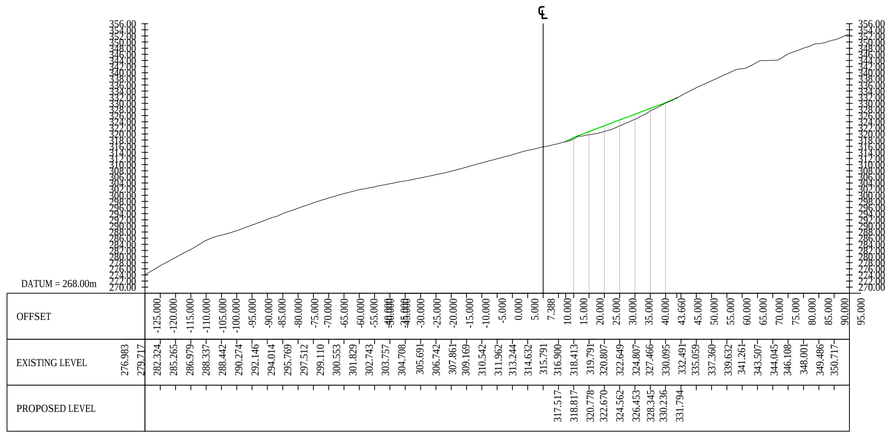
P:\Schemes_CGC\GC003600-99\GC003613 - RCT Tylorstown Landslide\2 - Drawings\2.3 - Preliminary & Pre-Tender\61 - Planning\Phase 4\GC3613-RED-61-RSC-DR-C-0004 - 0008 Cross Sections Tip Reprofile.dwg



PHASE 4 - TIP REPROFILE - CH500.000

SCALE 1:1000



PHASE 4 - TIP REPROFILE - CH520.000

SCALE 1:1000

0 20 40 60 80 100m

SCALE 1:1000

Key:

Proposed Levels

Existing Levels

Notes:

1. For cross sections markers refer to drawing: GC3613-RED-61-RSC-DR-C-0002
2. For Location Plan refer to drawing: GC3613-RED-61-RSC-DR-C-0001
3. For General Arrangement Plan of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0003
4. For Cross Sections of Receptor Site C refer to drawing: GC3613-RED-61-RSC-DR-C-0009-0013

Rev	Drwn	Chkd	Appr'd	Description	Date

Purpose of Issue

D5 - Suitable for Planning

Classification

Public

Client

Rhondda Cynon Taf
County Borough Council

Project

Tylorstown Landslide

Drawing

Phase 4
Cross Sections - Tip Reprofile
Sheet 5 of 5

Scale @ A1	Drawn	Checked	Approved
1:1000	MH	NG	PH

Project No.: GC/3613

Date: March 2021

Drawing Identifier
Project - Originator - Zone - Level - File Type - Role - Number: GC3613-RED-61-RSC-DR-C-0008

BS1192 Compliant revision: P01

REDSTART

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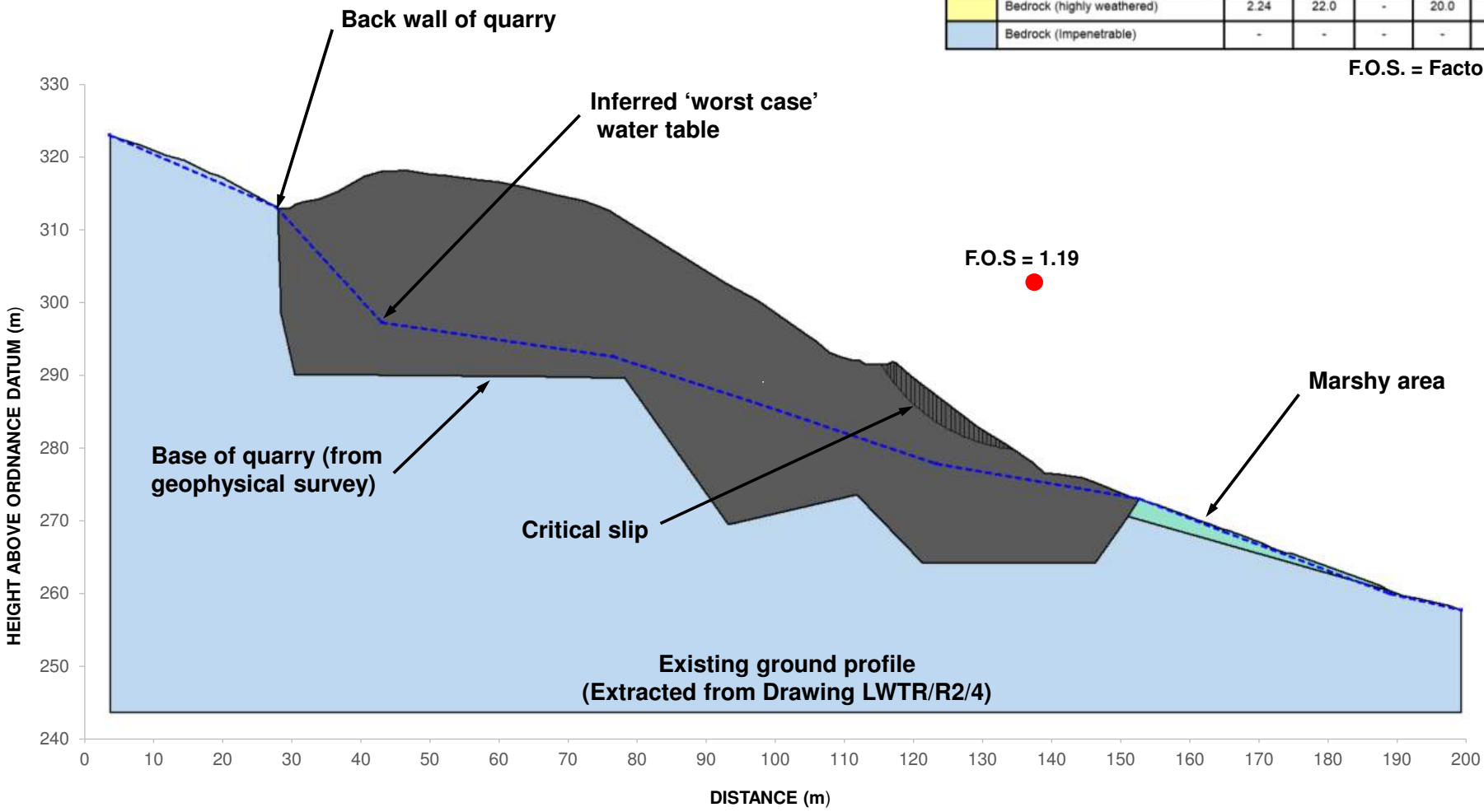
P:\Schemes_CGC\GC003600-99\GC003613 - RCT Tylorstown Landslide\2 - Drawings\2.3 - Preliminary & Pre-Tender\61 - Planning\Phase 4\GC3613-RED-61-RSC-DR-C-0004 - 0008 Cross Sections Tip Reprofile.dwg

REDSTART

FIGURES

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety



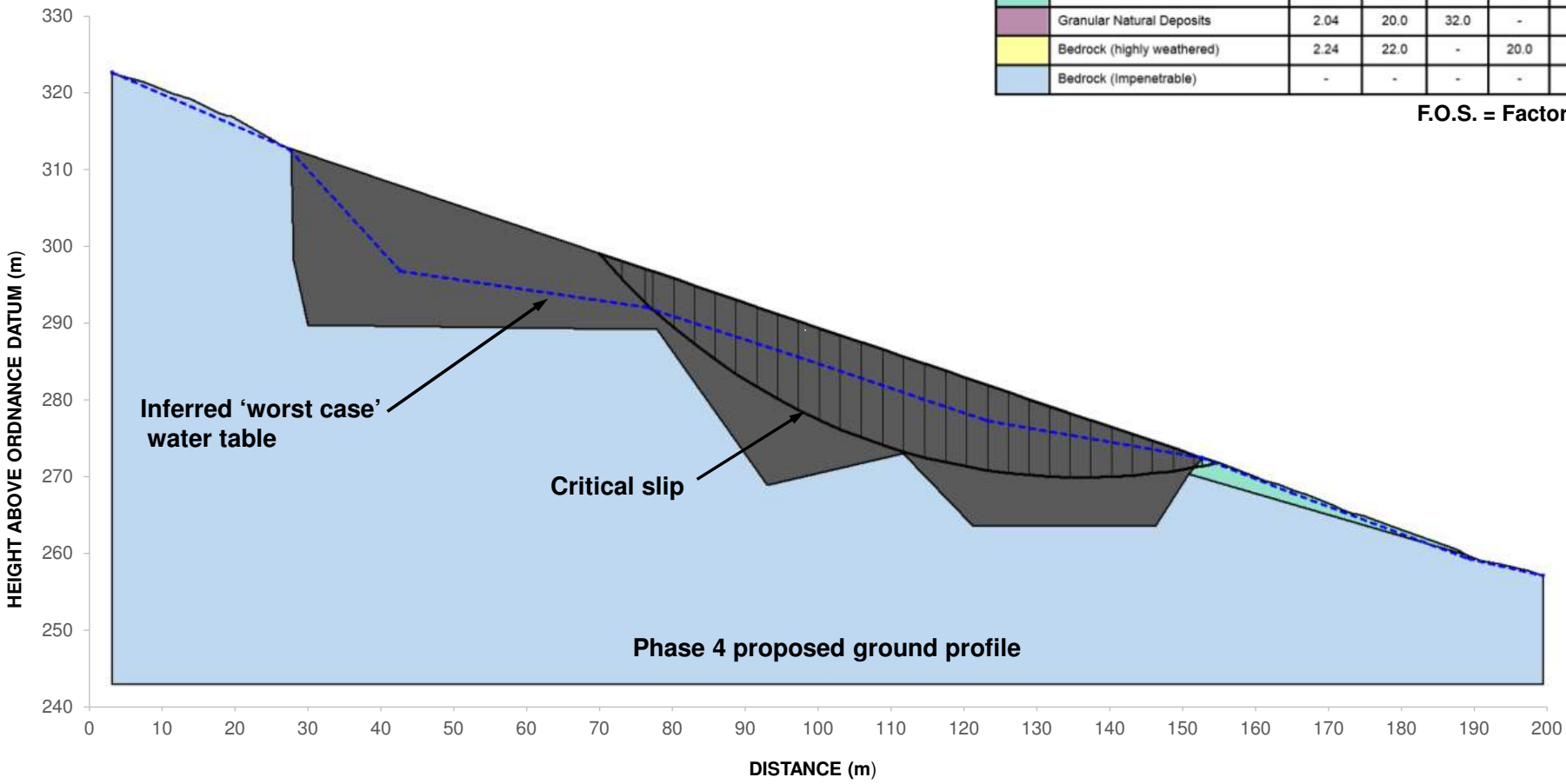
Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001
	Chainage 120m	Fig. No. 1

REDSTART
St David's House, Pascal Close
St Mellons, Cardiff. CF3 0LW
Tel. 029 20803500

F.O.S = 1.39

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

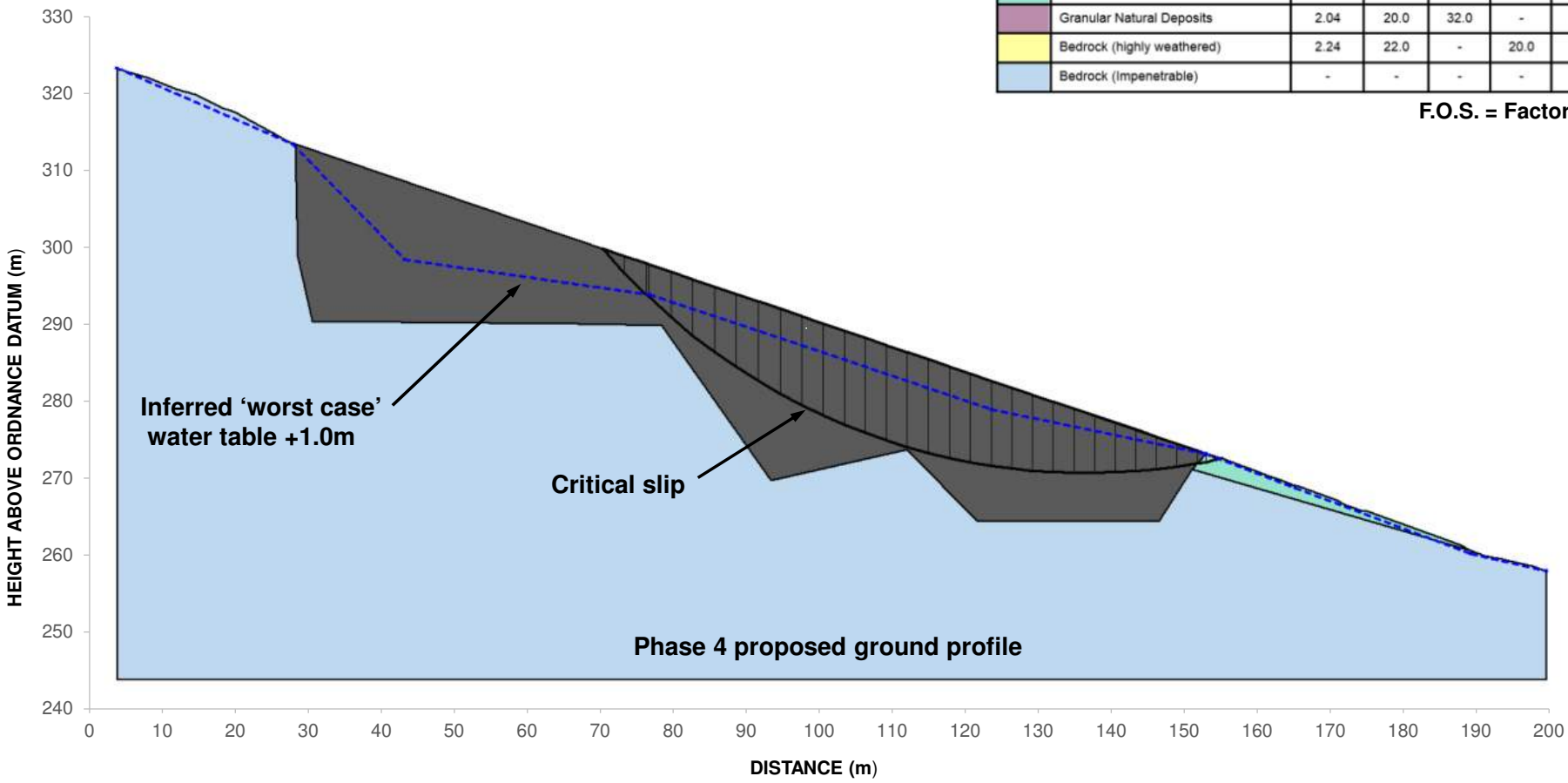


Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 120m	Fig. No. 2	

F.O.S = 1.37

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

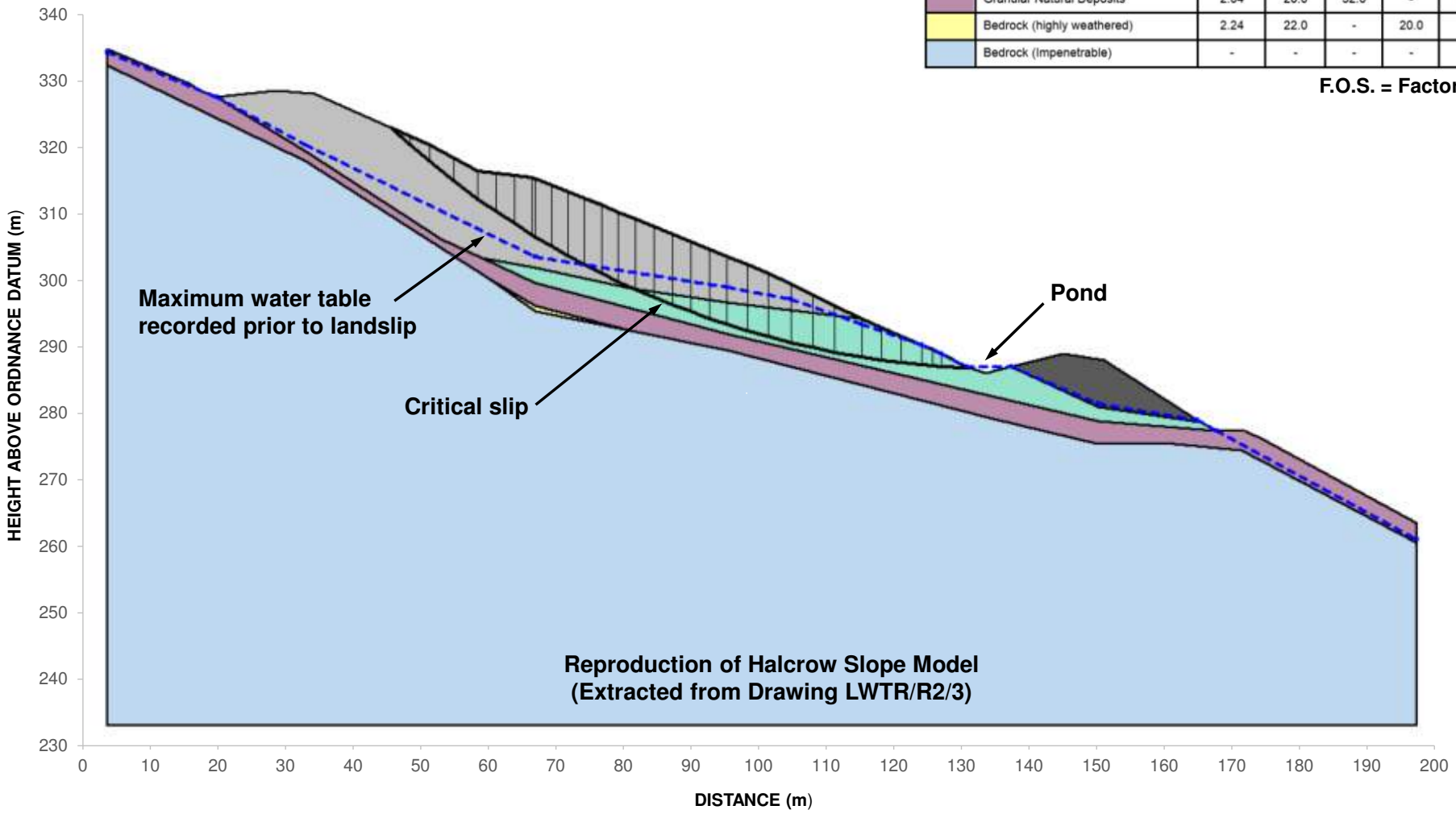


Client			
RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 120m	Fig. No. 3	

F.O.S = 1.03

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

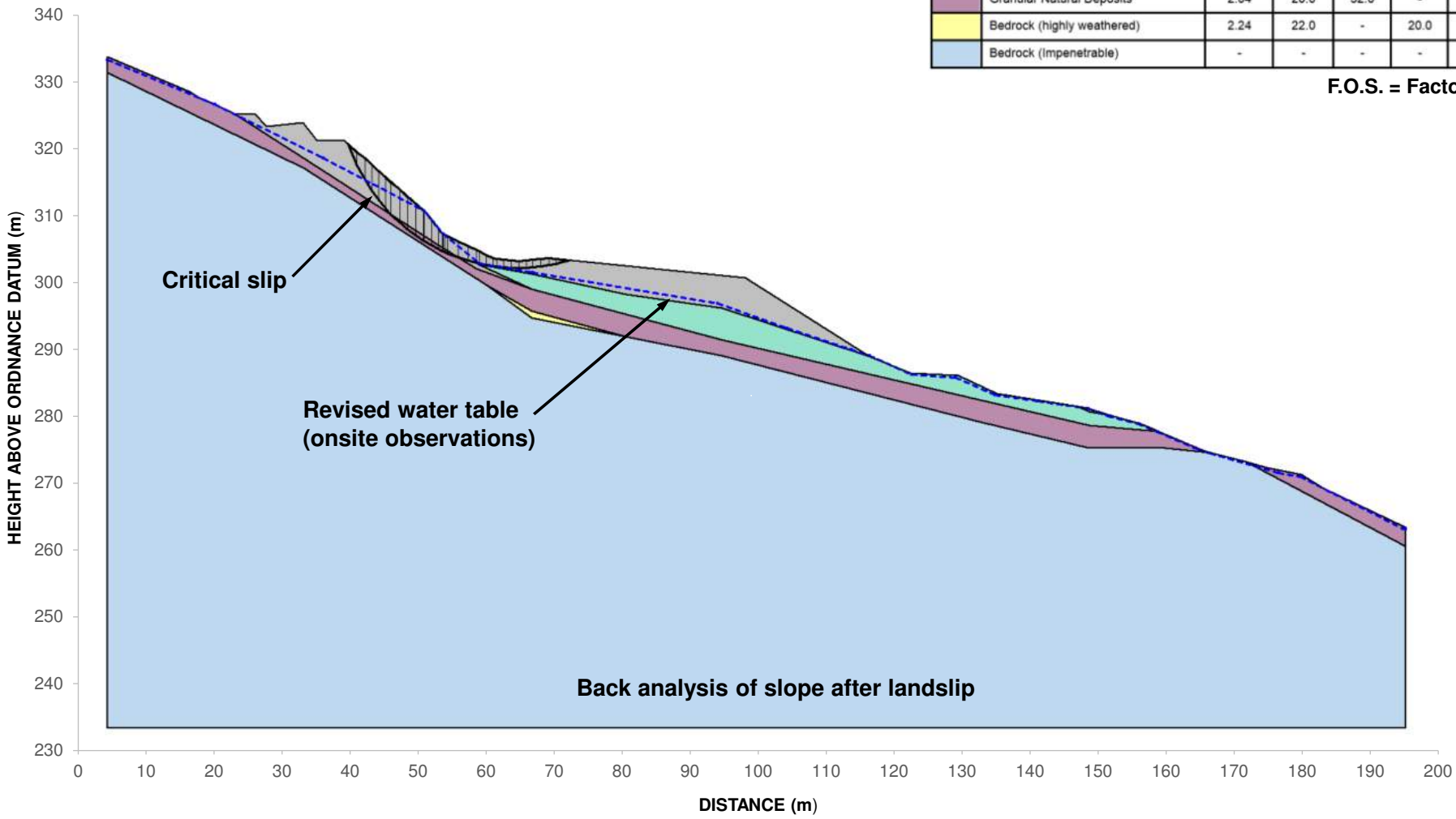


Client			
RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 4	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 0.76

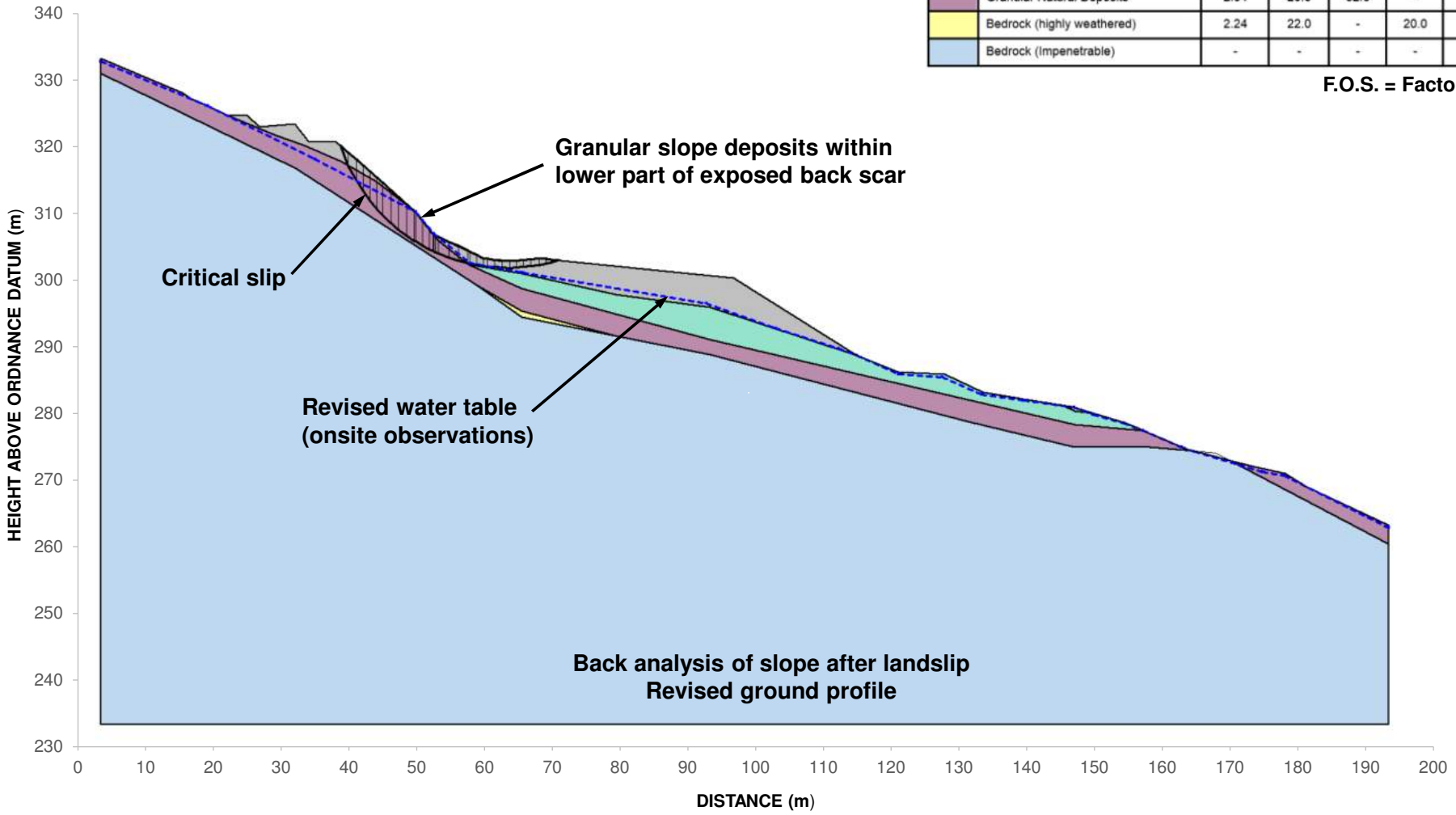
F.O.S. = Factor of Safety



Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 5	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety



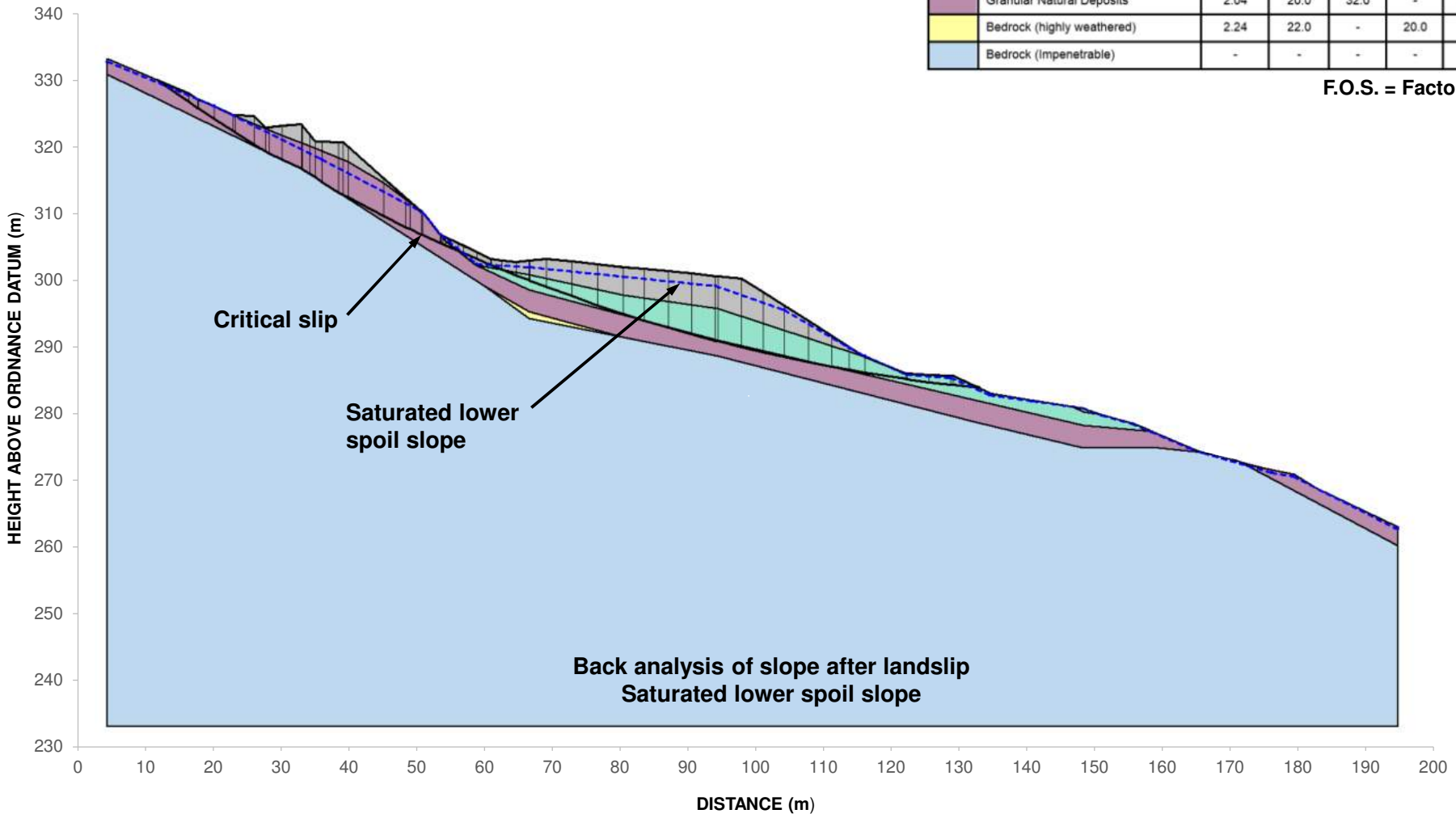
Client		Doc. No.
RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	CS/100303/SSR/001
	Chainage 280m	Fig. No. 6

REDSTART
St David's House, Pascal Close
St Mellons, Cardiff. CF3 0LW
Tel. 029 20803500

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.03

F.O.S. = Factor of Safety

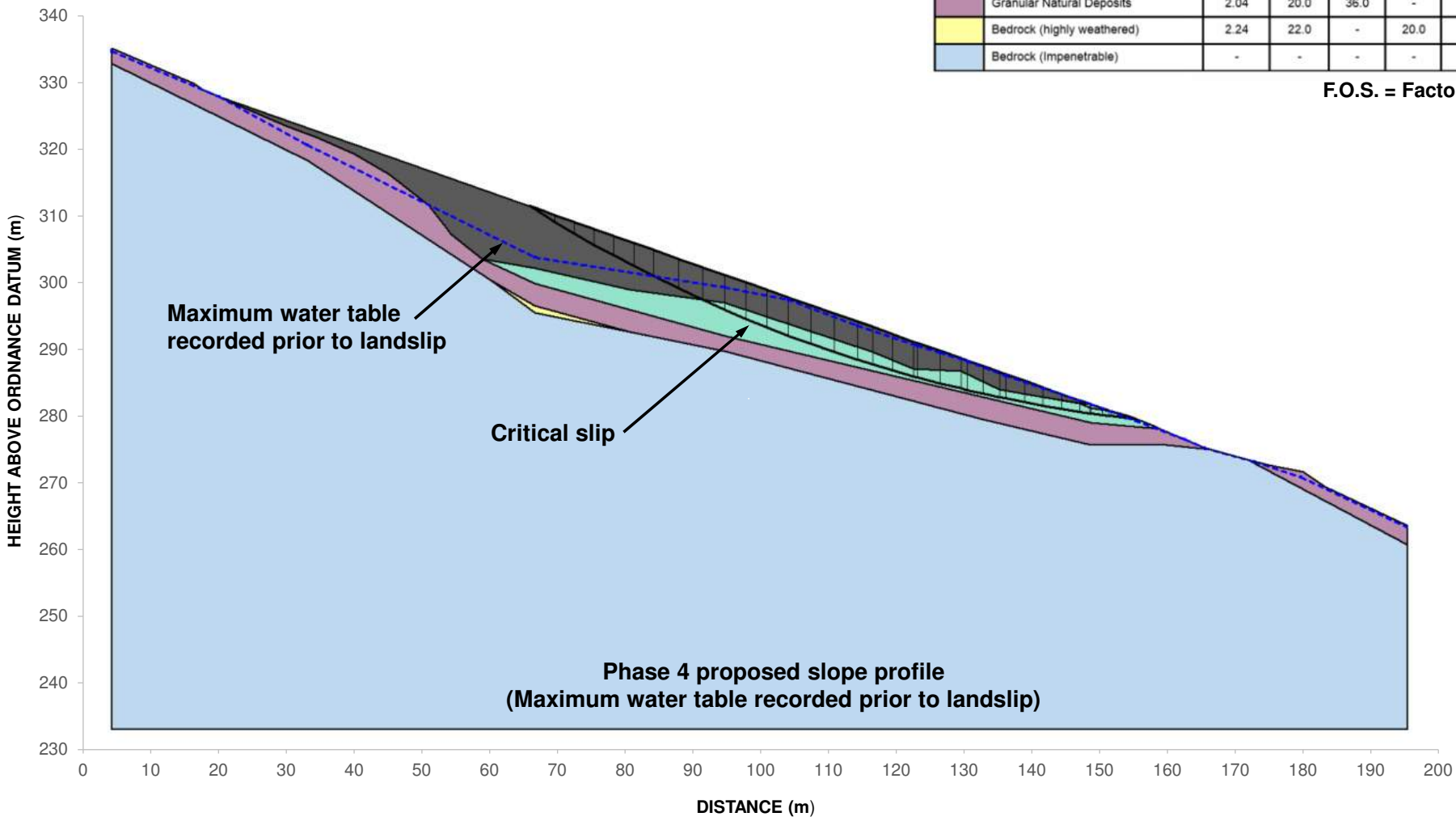


Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 7	

F.O.S = 0.92

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	36.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

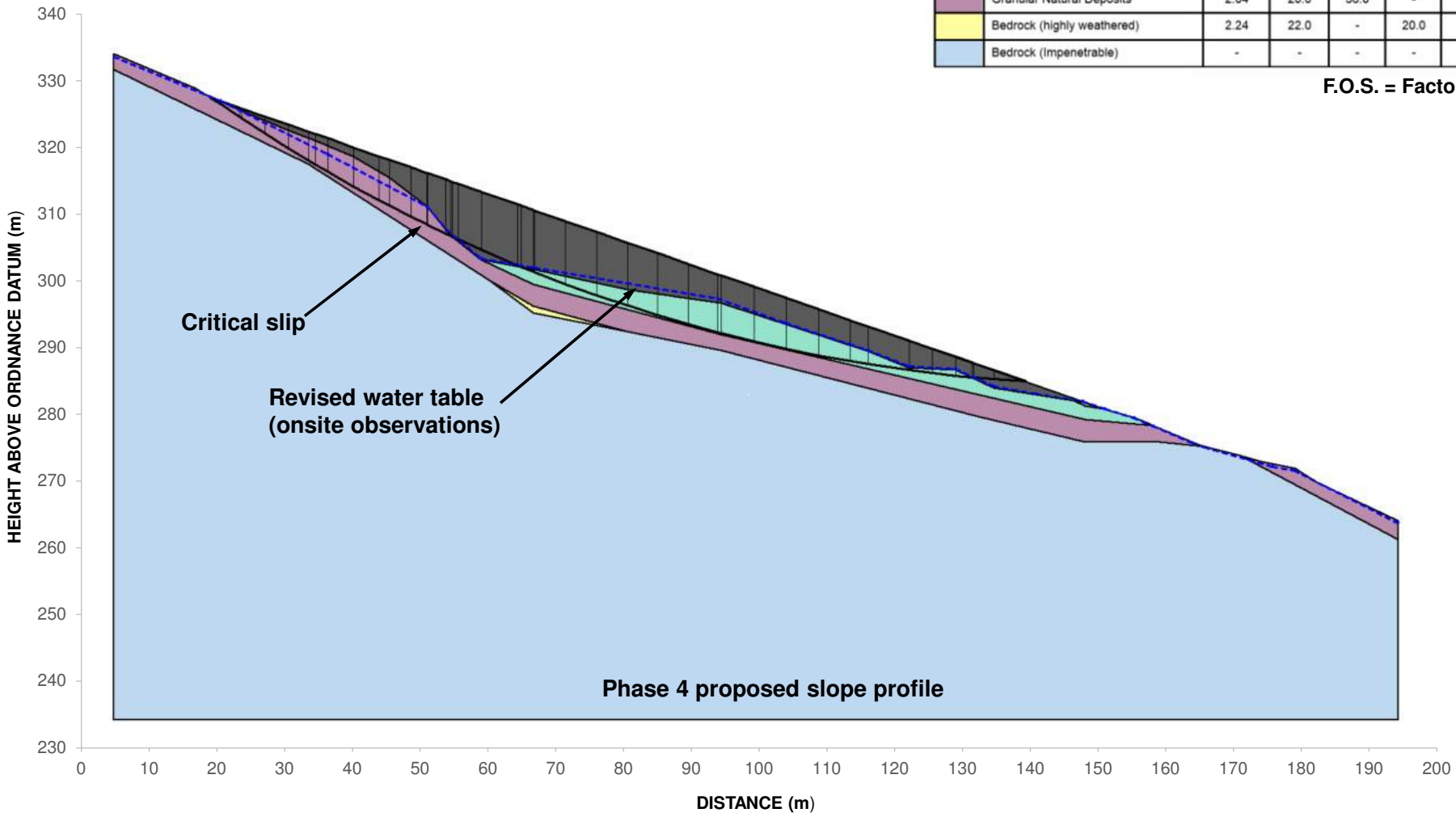


Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 8	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	36.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.32

F.O.S. = Factor of Safety

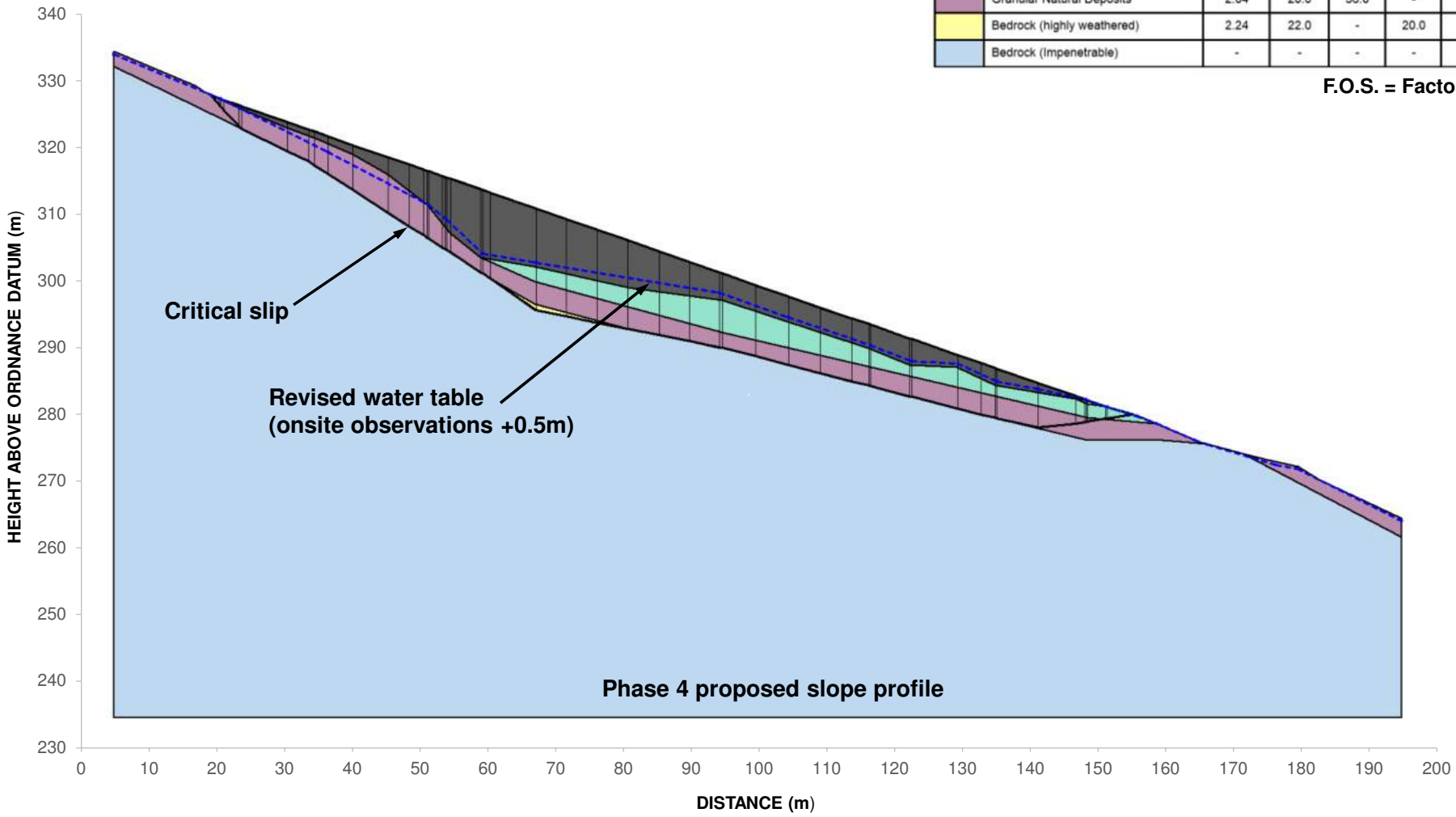


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 9	

F.O.S = 1.20

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	36.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

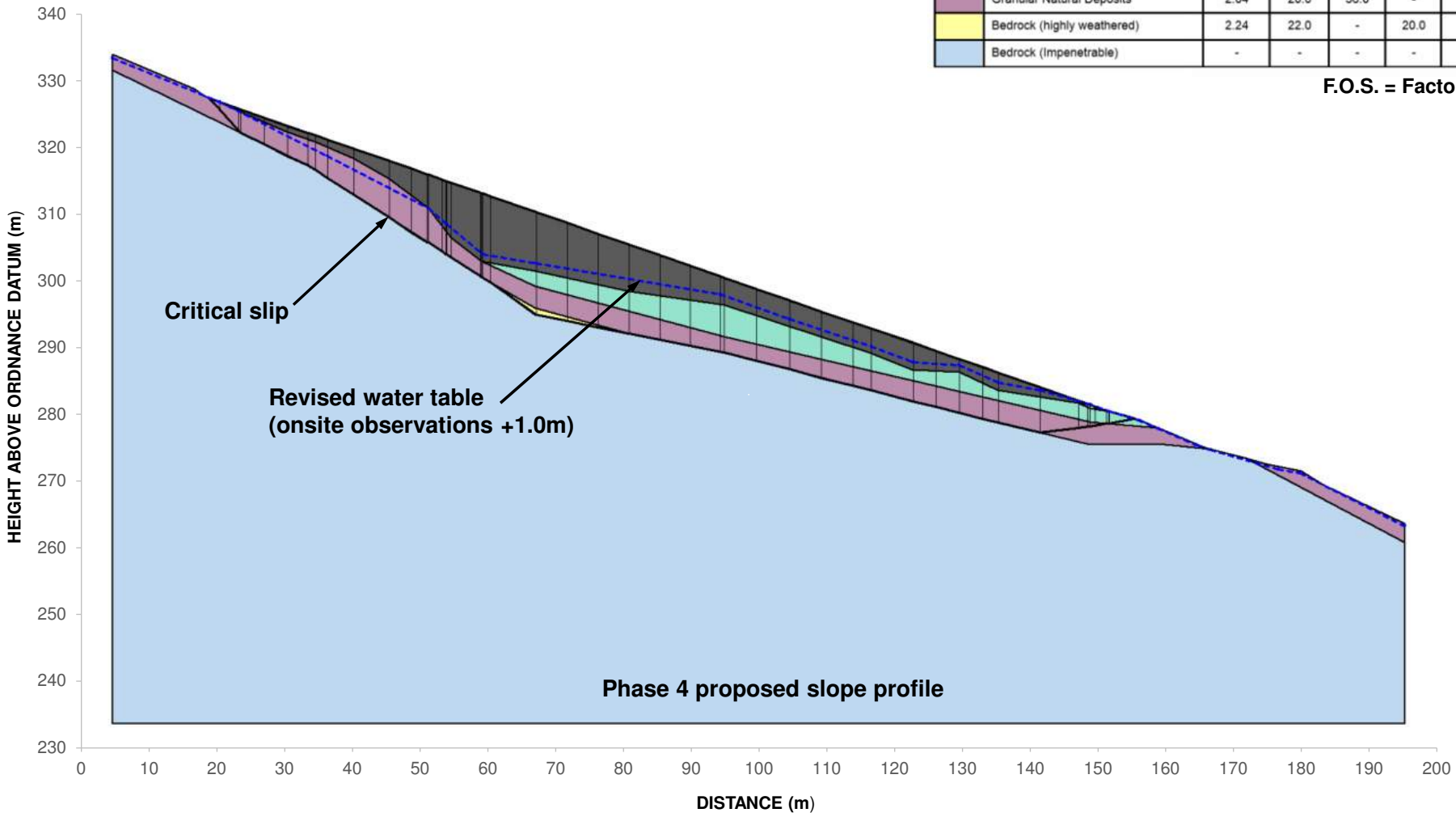


Client			
RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 280m	Fig. No. 10	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	36.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.17

F.O.S. = Factor of Safety

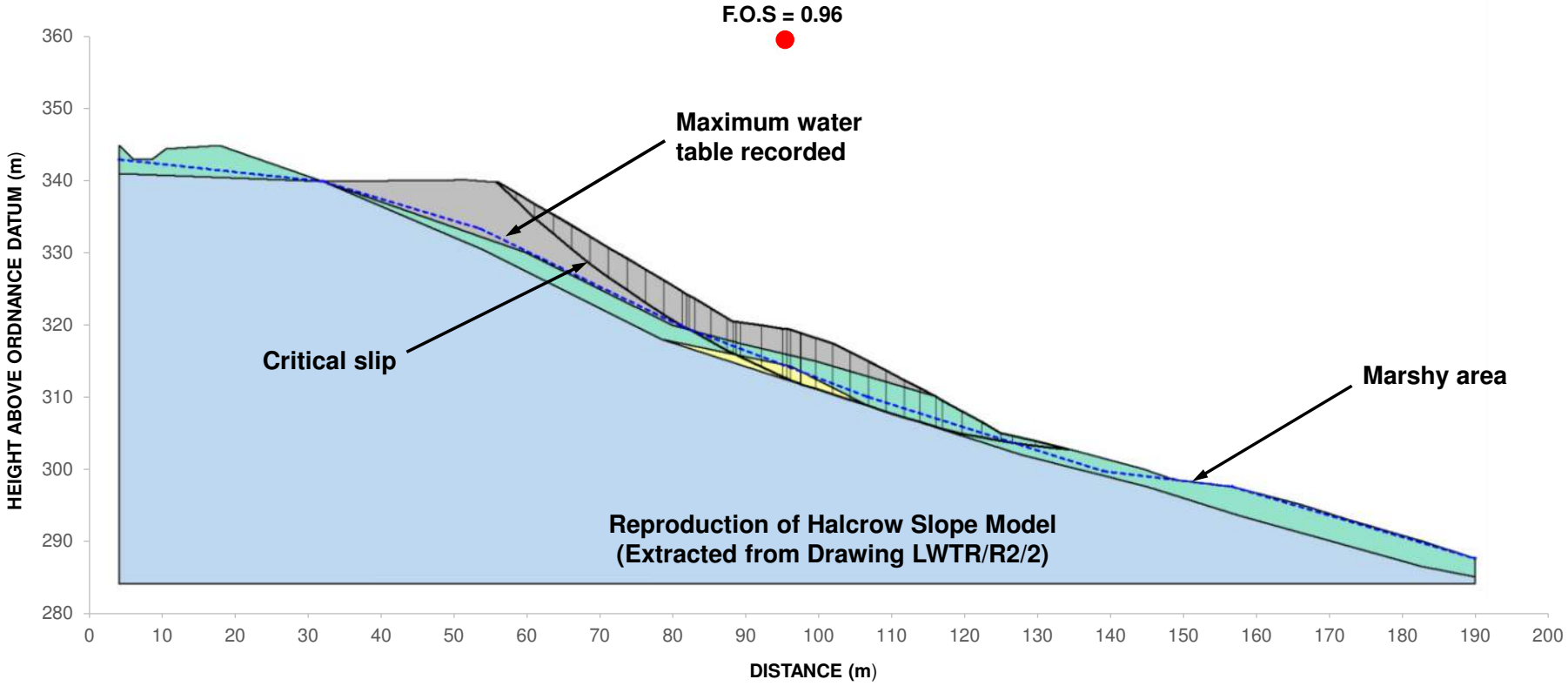


Client		Doc. No.
RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	CS/100303/SSR/001
	Chainage 280m	Fig. No. 11

REDSTART
St David's House, Pascal Close
St Mellons, Cardiff. CF3 0LW
Tel. 029 20803500

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

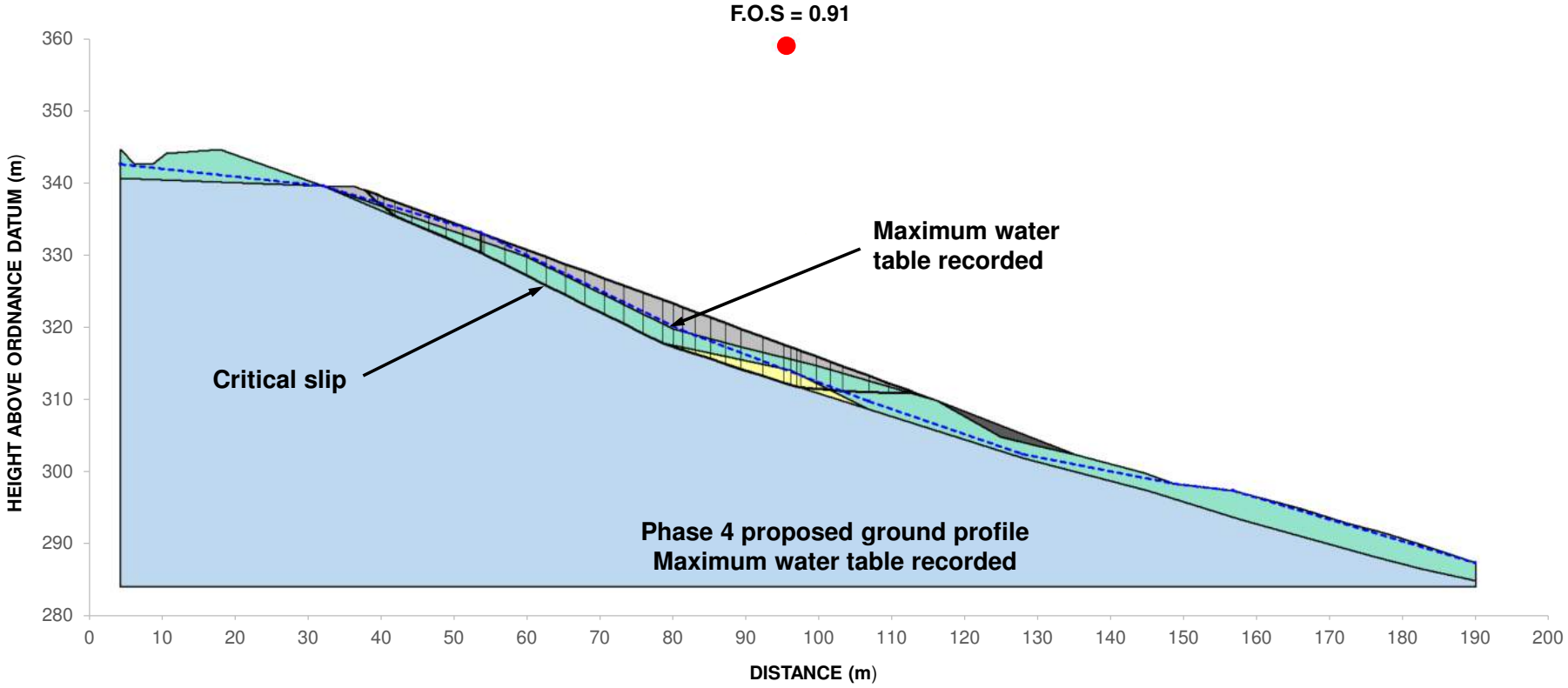


Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001
	Chainage 440m	Fig. No. 12

REDSTART
St David's House, Pascal Close
St Mellons, Cardiff. CF3 0LW
Tel. 029 20803500

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

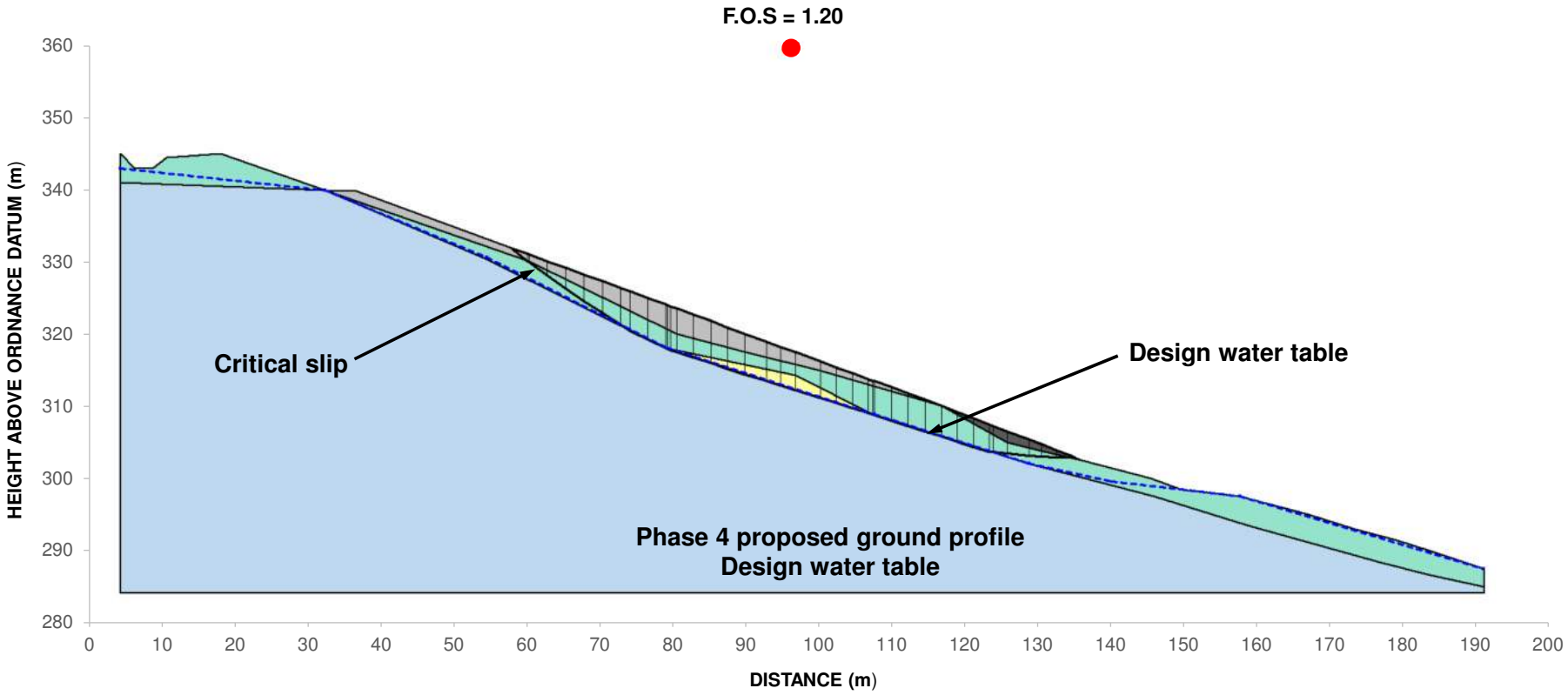
F.O.S. = Factor of Safety



Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 13	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

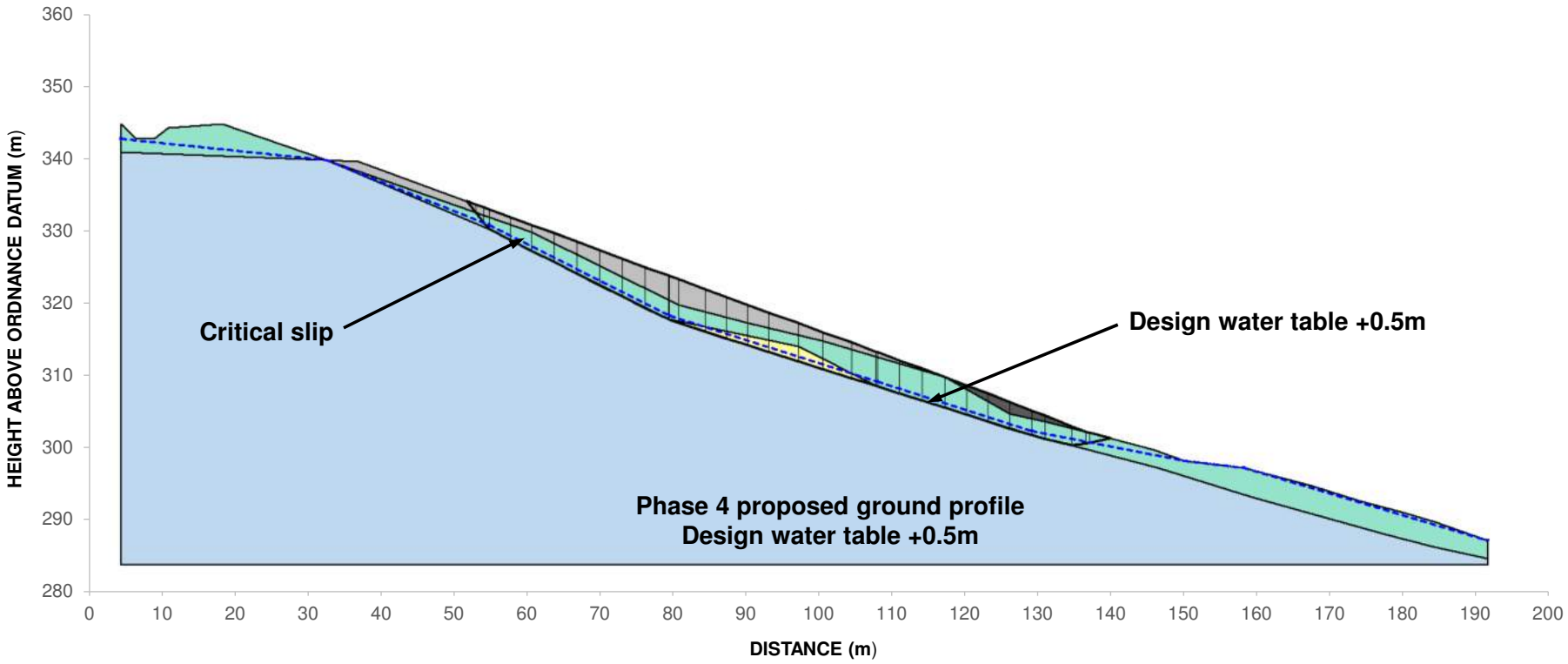


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 14	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.14

F.O.S. = Factor of Safety

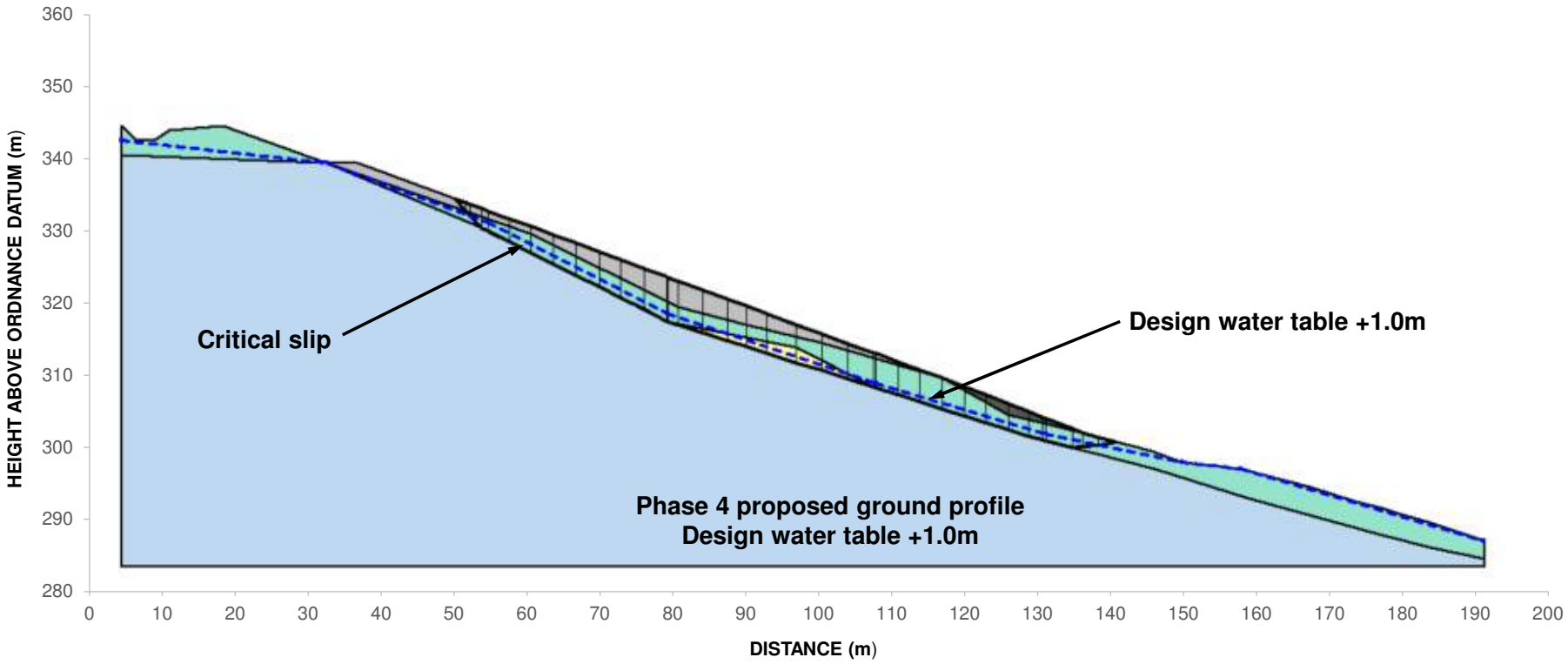


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 15	

F.O.S = 1.09

Material	ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

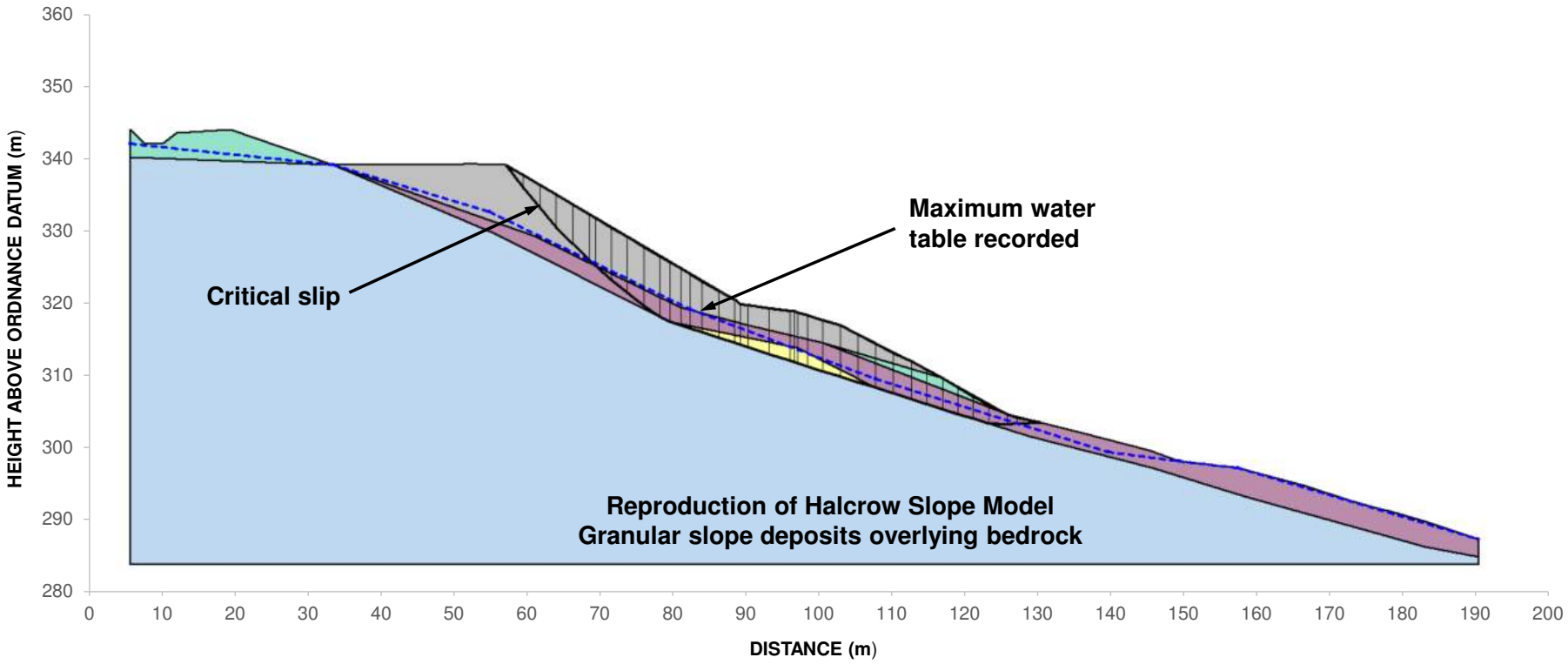


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 16	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 0.95

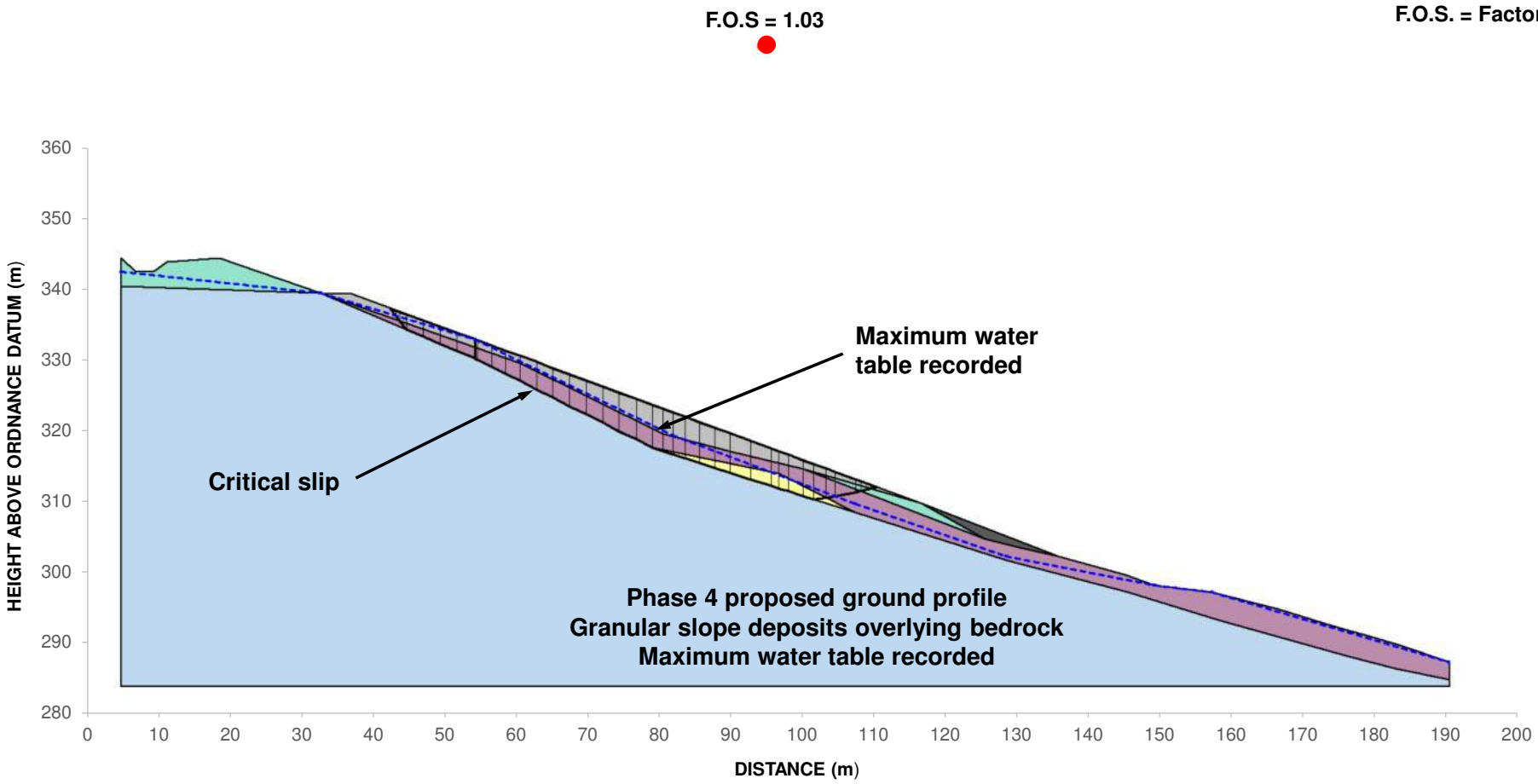
F.O.S. = Factor of Safety



Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 17	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S. = Factor of Safety

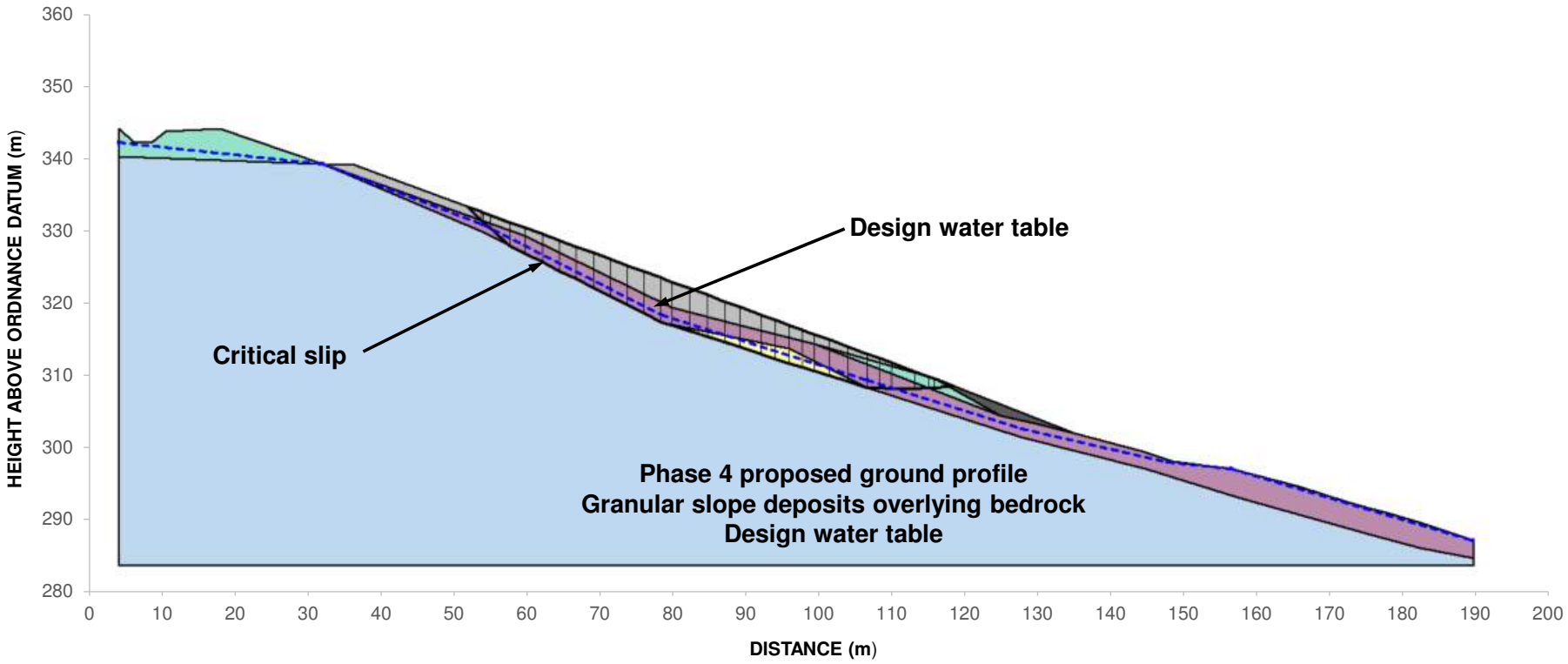


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 18	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.26

F.O.S. = Factor of Safety

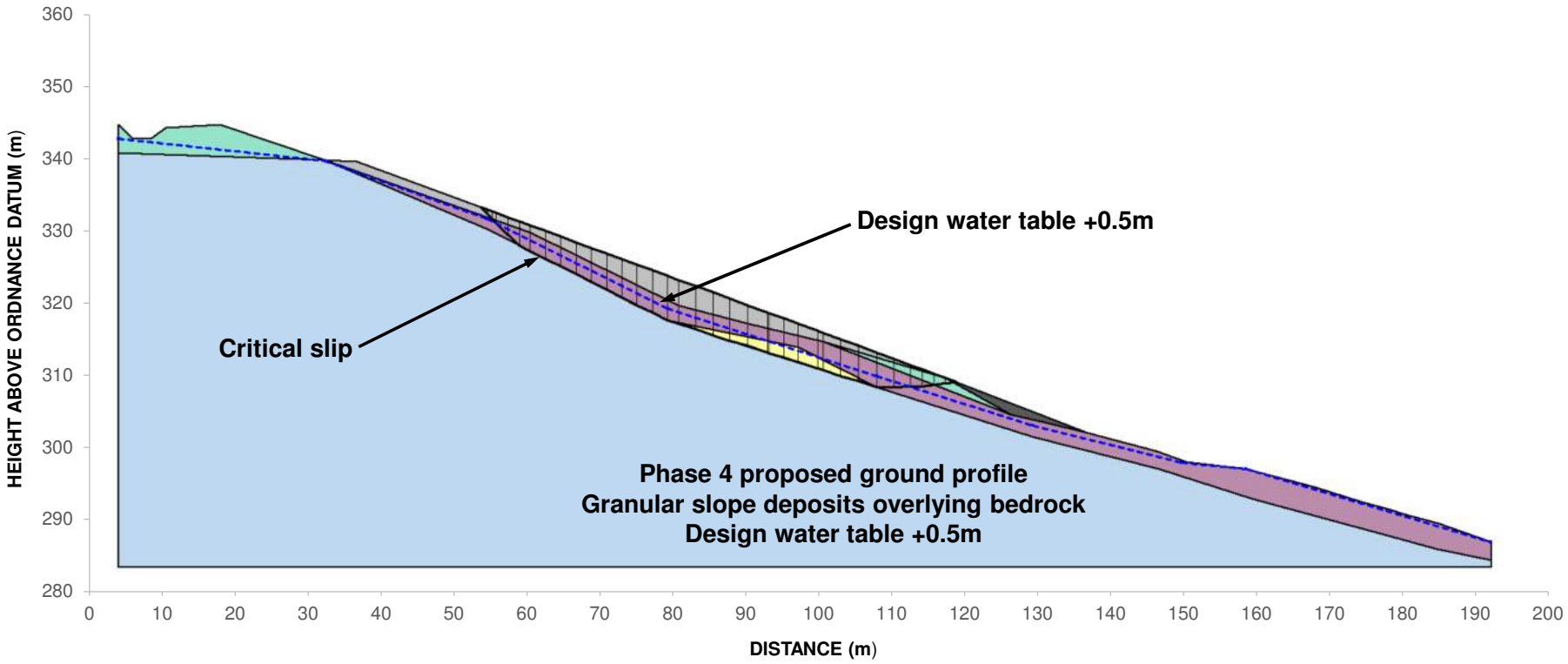


Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 19	

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.18

F.O.S. = Factor of Safety



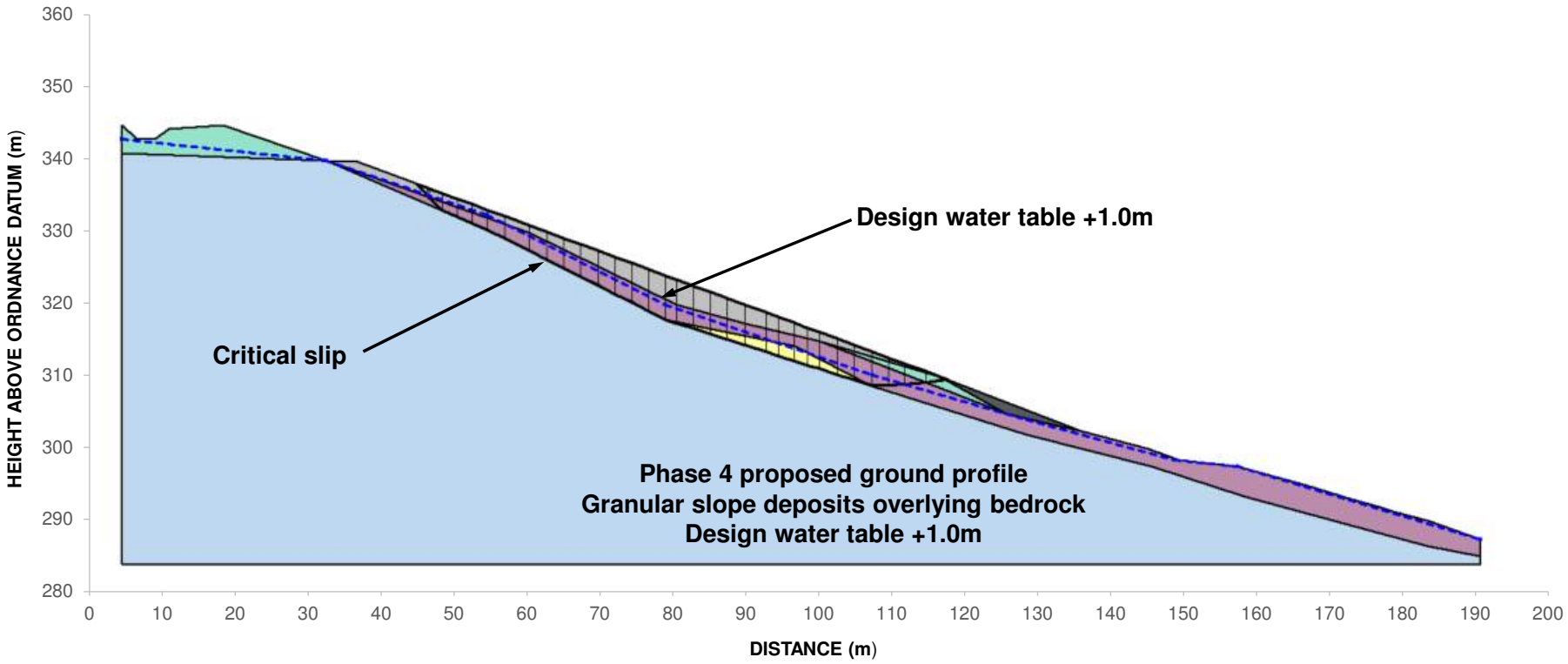
Client: RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001
	Chainage 440m	Fig. No. 20

REDSTART
St David's House, Pascal Close
St Mellons, Cardiff. CF3 0LW
Tel. 029 20803500

Material		ρ (Mg/m³)	γ (kN/m³)	ϕ (°) PEAK	ϕ (°) RESIDUAL	C (kN/m²) PEAK	C (kN/m²) RESIDUAL
	Colliery Spoil (Peak)	1.94	19.0	33.5	-	6.0	-
	Colliery Spoil (Residual)	1.94	19.0	-	26.5	-	3.0
	Cohesive Natural Deposits	2.04	20.0	29.0	25.5	10.0	2.0
	Granular Natural Deposits	2.04	20.0	32.0	-	0.0	-
	Bedrock (highly weathered)	2.24	22.0	-	20.0	-	0.0
	Bedrock (Impenetrable)	-	-	-	-	-	-

F.O.S = 1.12

F.O.S. = Factor of Safety



Client RHONDDA CYNON TAF	Tylorstown Phase 4 - Slope Stability Report	Doc. No. CS/100303/SSR/001	REDSTART St David's House, Pascal Close St Mellons, Cardiff. CF3 0LW Tel. 029 20803500
	Chainage 440m	Fig. No. 21	

APPENDIX A

Llanwonno Upper Tip (RH01)

Stability Statement, Capita, May 2020

Llanwonno Upper Tip (RH01) – Stability Statement

Background

On Sunday 16th February, Storm Dennis instigated the failure of Tylorstown Upper Tip (Llanwonno Tip and RH01). The initial larger (main) slip appears to have occurred overnight, upslope within the main tip complex and failed in a classical circular slip movement. A further landslide (video footage on internet on 16.02.2020), appears to show a secondary slip mechanism where water had accumulated and burst through (breached) the southern end of the slope and flowed down the hillside in a fully saturated state (wash out type failure).

Inspection of the wider environs surrounding the slip determined that water had entered the slip from two distinct locations.

Firstly, the viewpoint / parking spot / turning area on the mountain road at the northern end of a relatively level area where water from the mountainside above collected and was channelled beneath the road, at several locations. Each of these merges into a channel formed between the natural hillside and the rear of the upper tip, falling gradually to the south. At the southern end of the tip, this channel ends in a small pond and a small plastic overflow pipe takes excess water under the former tramway and into a further channel down the natural hillside. It should be noted that a lot of water was lost in the channel (not lined) and was diverted down the interface between original ground and the tip.

Secondly, the tramway follows the hillside falling south to north. Approximately 300m south of the southern end of the tip, a 'slack' meets the tramway and high groundwater levels have formed a series of spring-lines and overland flows. These flows converged and flowed down the tramway to meet the ponds at the toe of the tip.

The water entered the tips from the unlined channel to its rear, the tramway and spring-lines (third location) beneath the tip. Groundwater levels within the colliery spoil tip were raised quickly and in conjunction with the ponds present on the tip, groundwater pressures were not able to dissipate, and the lower part of the tip became saturated and flowed down the hillside.

The landslip debris flowed downslope and created a bow wave in the valley bottom, which in turn flattened trees and threw debris up, approximately 20m, onto the opposite side of the river embankment. This occurred at the northern end of the partly constructed overflow car park to the rear of the leisure centre.

Due to approximately 28,000m^3 of slipped debris filling the valley bottom from the toe of slope outwards in an extremely low angled and widely distributed debris envelope, the river channel was filled, and its course diverted to the western side of the valley bottom. The displaced river has eroded the toe of the slope beneath the leisure centre overflow car park, creating an approximately 5m vertical unstable face.

A Welsh Water main sewer was damaged by the landslide, in at least one location, beneath the leisure centre, downstream of the landslide toe. It is also known that a significant Welsh Water main runs along the Railway Path (Eastern side of the river) below the landslip toe debris, which has been reported to not have been damaged. Additionally, overhead Western Power lines disrupted on the hillside part way down the slope, which were damaged by the debris flow.

Emergency Works Undertaken to Date

Immediately, post landslide, Walters were commissioned to install temporary drainage measures along Blaenllechau Road and at the spring-lines occurring along the tramway. These were effective at diverting large quantities of overland flow from the landslide area and remain effective in the short to medium term until a permanent remediation solution can be undertaken.

The reduction in water entering the tips and the recent dry weather has permitted access to the toe of the slip without significant risk of further failure under the current conditions.

A drone survey was undertaken through the Coal Authority and has been provided to RCTCBC for use in planning remedial works and has helped to model the current slope.

Emergency tree felling was undertaken on the slopes beneath the car park to help stabilise (prevent wind loading) the scoured slopes and permit access for repairs to be undertaken when conditions dictate.

A small ground investigation was undertaken on 20 April 2020 to determine the character of the slipped material. The investigation found that the slipped material is extremely wet (saturated), which makes excavation, transportation and engineering placement and compaction, very difficult to impossible. Laboratory testing of the material is underway to determine its engineering properties and chemical composition. These tests will provide crucial information on what can be done to the materials, i.e. processing and re-use, permit a human health risk assessment and determine its waste categorisation.

Welsh Water are currently repairing the sewer, which has been discharging raw sewage into the river for the past two months. These repair works need to be completed before any remediation works to the river embankment and landslip debris can proceed.

Issues Created by Landslide

The main issues to contend with post landslide are:

(i) the scour of the embankment along the western side of the river,
(ii) the reinstatement of the eastern side of the river to former ground levels (this is the location of a partially designed active travel route and a significant Welsh Water main) and
(iii) the remediation of the tip material remaining on the hillside.

The current area of embankment scour has created an unstable slope, which will either regress with time or catastrophically fail. The area above the current scour is used as a footpath but there was a construction scheme planned to utilise the area as an overflow car park for the leisure centre, this has been put on hold. Scour will undoubtedly occur in a downstream direction if the river is not put back to its original position, and the embankment edge protected. The leisure centre and infrastructure could then potentially be at risk should this occur.

The Welsh Water main is present on the eastern side of the valley and is buried beneath a thickness of slipped material in excess of 5m depth. Welsh Water have requested this material is removed so

that the main is not under pressure and can be maintained in the future. Additionally, the track on the eastern side of the valley is a popular leisure walking route and was due to be purchased by RCTCBC and upgraded as part of a scheme to connect the valley.

This statement covers the overall stability of the tip complex as it now stands in order to be able to remediate the two lower issues (i & ii) and to assess the risk for construction works to commence.

Slope Stability Analysis

Capita were provided with a former slope stability assessment report prepared by Halcrow, which was used to assess the overall tip stability of RH01(upper tip) on behalf of RCTCBC. Capita have re-created Halcrow's stability models through RH01 to ensure continuity of analysis.

Capita then removed the slipped mass (difference between the Halcrow topographical slope model and the post slip drone model) and re-run the analysis using previous residual parameters and critical water table levels.

The tip as is now, comprises three distinct areas (i) rear backscarp and (ii) lower front colliery spoil slope, separated by (iii) a flattened section between the two (landslip bowl), which site inspection shows significant tension cracking and landslip features (back leaning trees).

Upper Slip (Rear Backscarp)
Slope stability analysis shows a factor of safety (FOS) of circa 0.6 when doing a like for like comparison, which cannot be the case as it would have failed. Further sensitivity analysis was then carried out by lowering the ground water table, which also shows little difference in overall stability. Therefore, the original model must have been very conservative and/or not quite correct in terms of the model i.e. the material deposit thicknesses. Following this initial phase, Capita have re-assessed the ground model coupled with site evidence and it is now clear that the rear back scarp feature comprises natural glacial materials not colliery spoil (original mountainside slope) with a capping of colliery spoil at the crest of the slope.

Capita have now re-assessed this rear backscarp slope and consider material parameters should be equal to peak and not residual strength parameters as previously analysed. Additionally, when substituting the colliery spoil for glacial deposits this brings the FOS closer to unity. However, more testing will be required to adequately assess the soil parameters but site evidence and the steepness of the rear slope suggest that either a higher component of cohesion is warranted to enable the slope to stand in its current position or that the slope contains a significant proportion of coarser material.

Lower Front (colliery Spoil) Slope
This slope is deemed to be the main risk to construction works below. Site evidence suggests that front slope material to comprise Colliery Spoil and like the rear scarp slope, Capita have re-analysed the current slope on this basis. However, Capita have had to lower the groundwater accordingly (as previous analysis would have had water levels above ground level on a like for like basis). Lowering of the groundwater table to below current ground levels (capita Model BB9) shows a FOS of 0.921. It is considered that in this case the water levels better reflect the current position, albeit the parameters are deemed to be slightly conservative.

A further factor to take into account when considering the failure of the lower part of the tip was that prior to and at the time of the failure ponds were located in this vicinity, which would have had a considerable detrimental contribution to the slip mechanism as the volume of water entering this area was substantial as the lower part of the tip got overwhelmed and breached. The additional water

captured in the upper slope would have also added considerable mass to the driving force of the slip, further destabilising the area.

The conditions (morphology) on site now are totally different and the more likely scenario in Capita's opinion is that the flatter section between the two slopes would become saturated (under extreme conditions and/or if surface water re-entered the area) and cause movement downslope onto the frontal section of the remaining tip (Lower Front Slope).

The stability undertaken to date shows that the materials left on the slope are at unity in terms of stability and will need to be removed in the longer term without remediation.

Slope Stability Summary

Under the initial emergency works, Walters have installed temporary water diversion drainage, which has effectively removed most of the surface water entering the slip complex and have also diverted some of the spring lines entering the area. Therefore, the overall stability of the tip has been enhanced by the introduction of the early surface water diversion works. Additionally, given that there is no longer any impounded water (ponds), the overall global stability is enhanced from previous pre-slipped conditions. Our current view is that the risk of further slippage of any significant magnitude in the short term are extremely low as a significant mass has been removed from the upper slopes removing the amount of material to slip, including the mass providing an additional diving force.

There will however be some 'minor' ravelling and slight regression of the upper tip surfaces and local areas where the slope has become over steep (side of the dry ravines and rear colliery spoil at the head of the slope for example) and will fail. However, it is considered that failed volumes will be of a relatively minor quantity (dry in nature) and relatively local in nature.

To ensure the risk is managed, whilst carrying out works to the toe debris and river embankment, it is deemed necessary that mitigation is put in place comprising:

1. Inspecting the site on a weekly basis and after any significant rainfall event.

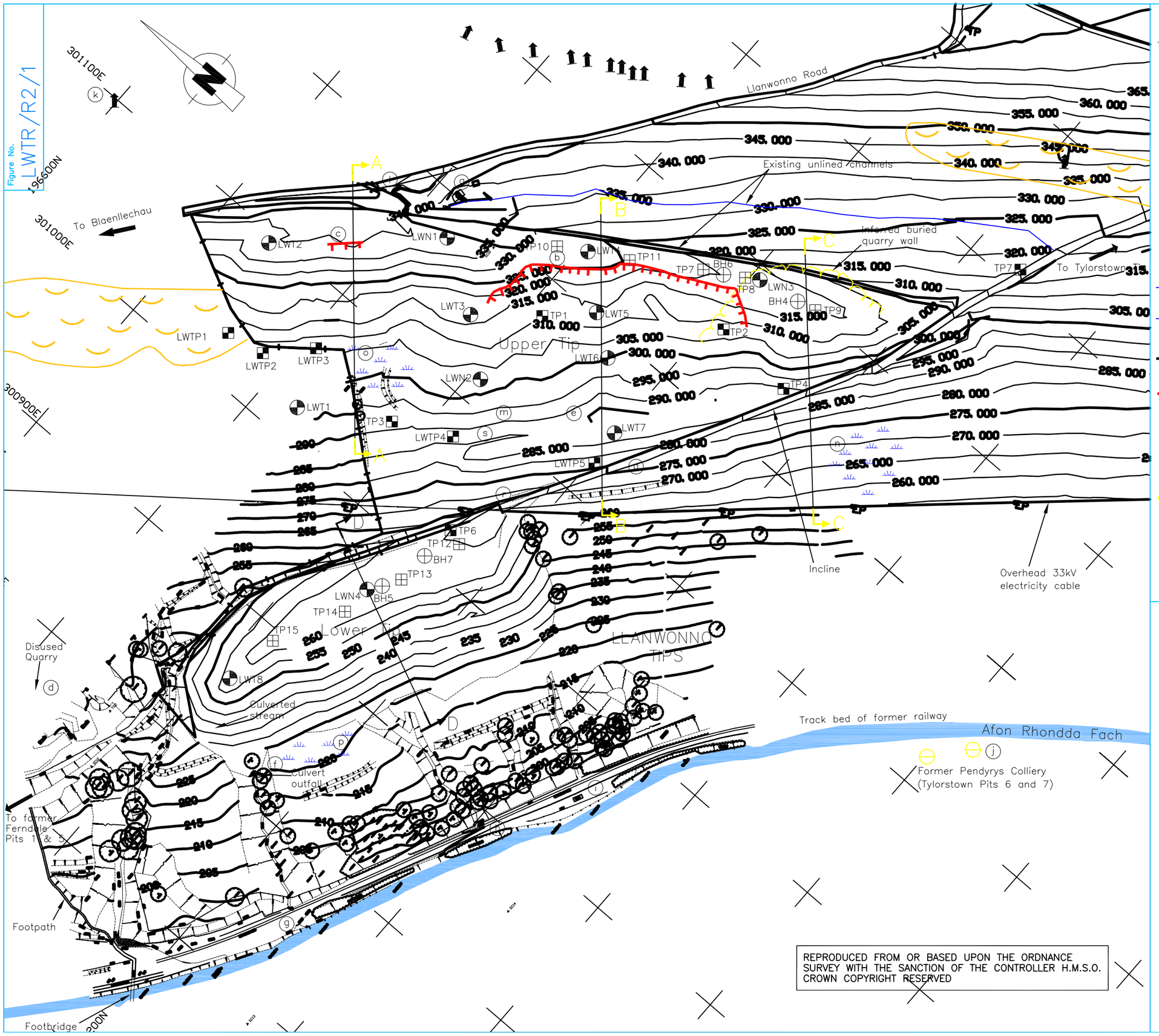
2. During the remediation works to the lower area, a monitoring regime is put in place. Monitoring of key points on the upper slope should be undertaken throughout the working day (and first thing prior to works commencing) and a warning system in place if movement to any detection limits is reached at which point a geotechnical engineer should inspect to confirm if movement is related to a local or more significant slip.

REDSTART

APPENDIX B

Halcrow Figures

Figure No. LWTR/R2/1



KEY

- Known location of former mining adit
- BH5 — Borehole BH5 (1993 Investigation)
- TP15 — Trial Pit 15 (1993 Investigation)
- LWN2 — Borehole LWN2 (1996 Investigation)
- TP4 — Trial Pit 4 (1996 Investigation)
- LWT2 — Borehole (2001 Investigation)
- LWTP1 — Trial pit (2001 Investigation)
- Watercourse
- Approximate line of overtipped watercourse
- Boundary of Llanwonno Tips
- Tension crack
- Former shaft
- Area of shallow instability
- A — A — Section line
- (a) — Location referred to in text

Client

RHONDDA CYNON TAFF COUNTY BOROUGH COUNCIL

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Halcrow

Project

LLANWONNO TIPS RECLAMATION SCHEME

Figure Title

EXISTING SITE PLAN

Scale 1:2500 Date Dec. 2003

Figure No. LWTR/R2/1

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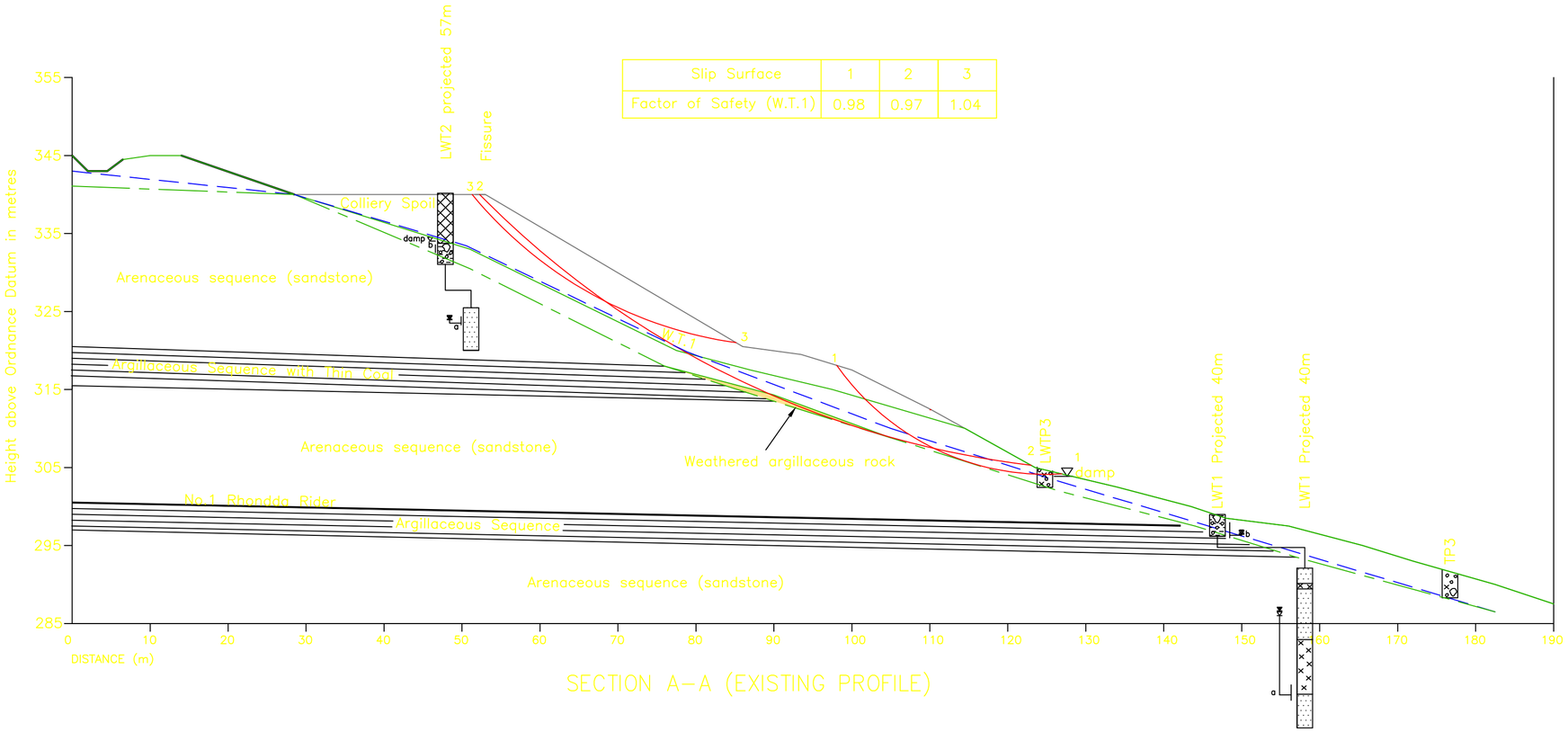
Figure No.
LWTR/R2/2

Slip Surface	1	2	3
Factor of Safety (W.T.1)	0.98	0.97	1.04



SECTION A–A (EXISTING PROFILE)

NOTES

1. Boreholes not on the Section line have been projected as follows.
   – Superficial deposits ; along surface contours
   – Rock ; along rockhead contours or along dip

KEY

- Slip Surface
- Surface of colliery spoil
- Original ground surface
- Rockhead
- Water table

- Colliery spoil
- Superficial deposits
- Weathered argillaceous rock
- Mudstone
- Sandstone
- Siltstone
- Maximum recorded water level
- Minimum recorded water level
- Piezometer and sand filter

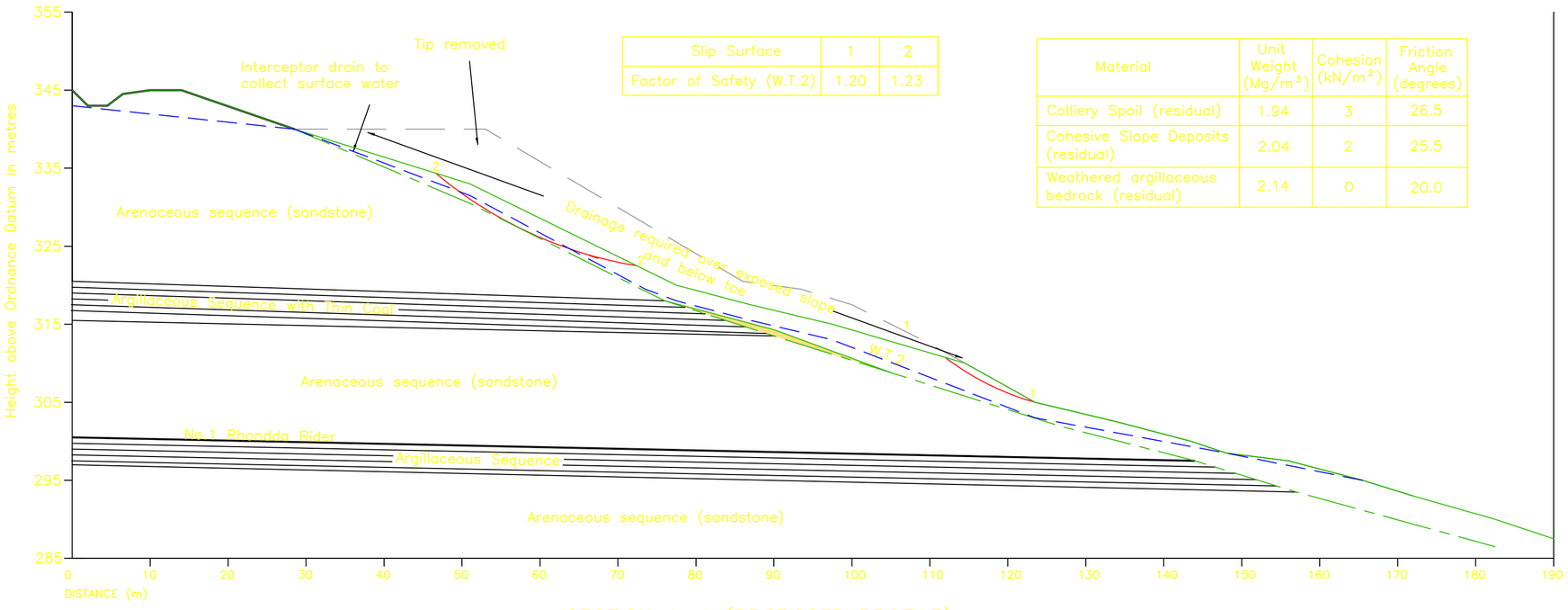
W.T.1 Maximum recorded water table

W.T.2 Design water table

Weathered argillaceous rock

Slip Surface	1	2
Factor of Safety (W.T.2)	1.20	1.23

Material	Unit Weight (Mg/m^3)	Cohesion (kN/m^2)	Friction Angle (degrees)
Colliery Spoil (residual)	1.94	3	26.5
Cohesive Slope Deposits (residual)	2.04	2	25.5
Weathered argillaceous bedrock (residual)	2.14	0	20.0



SECTION A–A (PROPOSED PROFILE)

Client

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Email cardiff@halcrow.com

Halcrow

Project

LLANWONNO TIPS
RECLAMATION SCHEME

Figure Title

CROSS SECTION A–A

Scale 1:500 Date Dec. 2003

Figure No.

LWTR/R2/2

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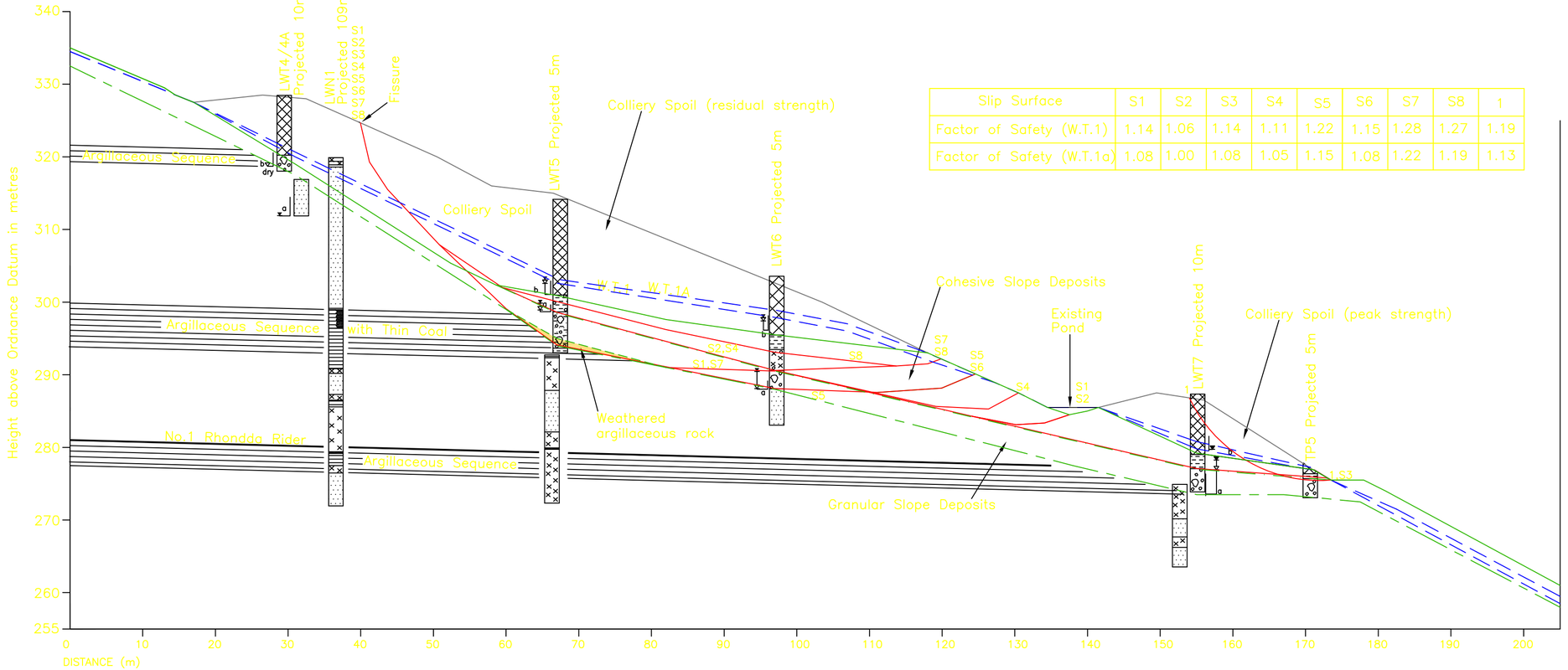
Figure No. LWTR/R2/3



SECTION B–B (EXISTING PROFILE)

Slip Surface	S1	S2	S3	S4	S5	S6	S7	S8	1
Factor of Safety (W.T.1)	1.14	1.06	1.14	1.11	1.22	1.15	1.28	1.27	1.19
Factor of Safety (W.T.1a)	1.08	1.00	1.08	1.05	1.15	1.08	1.22	1.19	1.13

NOTES

1. Boreholes not on the Section line have been projected as follows.
   – Superficial deposits ; along surface contours
   – Rock ; along rockhead contours or along dip

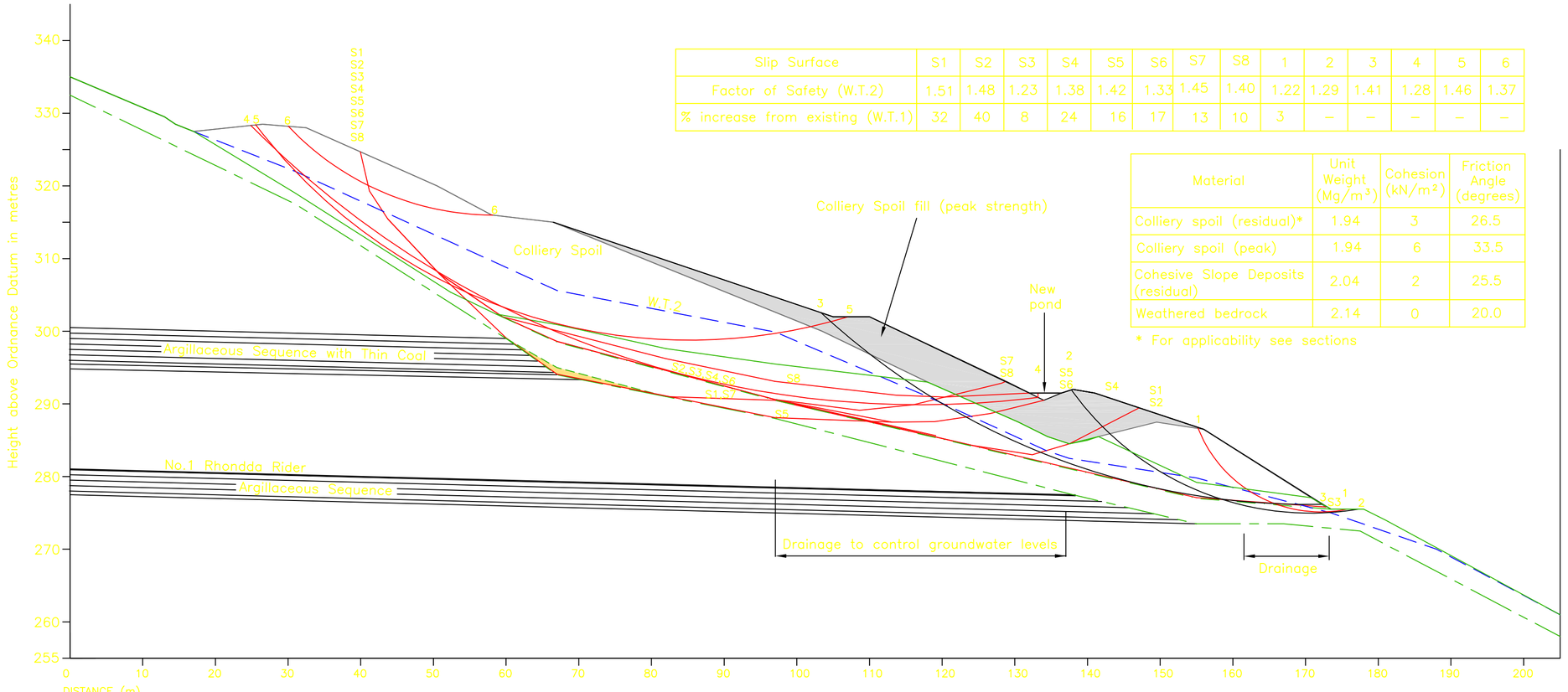
KEY

- Slip Surface
- Surface of colliery spoil
- Original ground surface
- Boundary between cohesive and granular slope deposits
- Rockhead
- Water table
- Colliery spoil
- Superficial deposits
- Weathered argillaceous rock
- Mudstone
- Sandstone
- Siltstone
- Maximum recorded water level
- Minimum recorded water level
- Piezometer and sand filter

W.T.1 Maximum recorded water table
W.T.1A Maximum recorded water table + 1m
W.T.2 Design water table

Weathered argillaceous rock

Proposed fill



SECTION B–B (PROPOSED PROFILE)

Slip Surface	S1	S2	S3	S4	S5	S6	S7	S8	1	2	3	4	5	6
Factor of Safety (W.T.2)	1.51	1.48	1.23	1.38	1.42	1.33	1.45	1.40	1.22	1.29	1.41	1.28	1.46	1.37
% increase from existing (W.T.1)	32	40	8	24	16	17	13	10	3	–	–	–	–	–

Material	Unit Weight (Mg/m^3)	Cohesion (kN/m^2)	Friction Angle (degrees)
Colliery spoil (residual)*	1.94	3	26.5
Colliery spoil (peak)	1.94	6	33.5
Cohesive Slope Deposits (residual)	2.04	2	25.5
Weathered bedrock	2.14	0	20.0

* For applicability see sections

Client

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Halcrow

Project

LLANWONNO TIPS
RECLAMATION SCHEME

Figure Title

CROSS SECTION B–B

Scale 1:500 Date Dec. 2003

Figure No.

LWTR/R2/3

CAD PATH P:\pool\Geot\Schemes TEMP\Tylorstown landslip\Drawings\LWT R2 3.dwg (Printed at 08:24 05/
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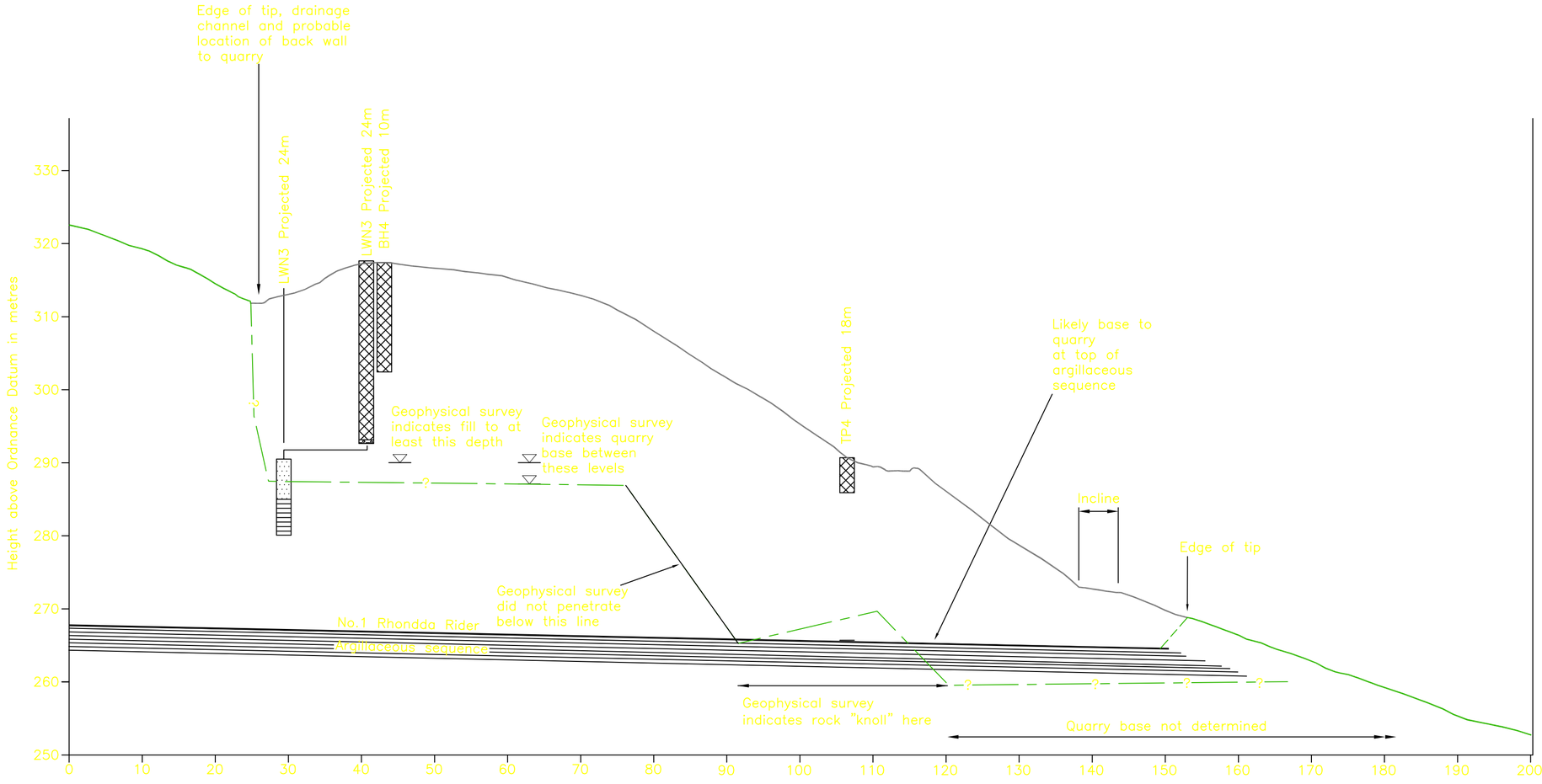
Figure No. LWTR/R2/4



SECTION C–C (EXISTING PROFILE)

NOTES

1. Boreholes not on the Section line have been projected as follows.
   – Superficial deposits ; along surface contours
   – Rock ; along rockhead contours or along dip

KEY

- Slip Surface
- Surface of colliery spoil
- Original ground surface
- Rockhead
- Water table

Colliery spoil
Superficial deposits
Weathered argillaceous rock
Mudstone
Sandstone
Siltstone

Maximum recorded water level
Minimum recorded water level
Piezometer and sand filter

W.T.1 Maximum recorded water table

W.T.2 Design water table

Client

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Project

LLANWONNO TIPS
RECLAMATION SCHEME

Figure Title

CROSS SECTION C–C

Scale 1:500 Date Dec. 2003

Figure No.

LWTR/R2/4

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APPENDIX C

Select Boreholes

Borehole Log

Exploration Associates

Drilled by	MJ	Equipment and Methods	Ground Level +299.31 m OD
Logged by	CW	Rotary Open Hole 115 mm diameter from 0.00m to 3.50m. Rotary Cored 75 mm diameter from 3.50m to 23.50m using air flush.	National Grid Coordinates E 301024.01 N 188377.88
Checked by	SC		

Samples and Tests

Depth	TCR SCR RQD	IF	Records	Date Casing	Time Water
				06/12/2001 0.00	dry
3.50 - 5.00m	91 65 57	Nil 30 100			
5.00 - 6.20m	88 54 31	Nil Nil 90			
6.20 - 7.70m	90 50 25	Nil 70 120			
7.70 - 9.20m	96 94 93	150 400 500			
9.20 - 11.00m	79 66 50	Nil 150 300			

Strata

Description	Depth/Level (Thickness)	Legend
Boulder Clay.**	(2.80)	
Moderately weak to moderately strong grey brown fine medium SANDSTONE. Highly weathered to non intact fracture discontinuity set 1 is subhorizontal closely spaced planar rough moderately open with some clay infilling and some carbonisation. Two subvertical fractures 80 - 90 degrees from 3.50m to 4.40m terminating on a subhorizontal fracture planar rough and open with sandy clay infill.	2.80 +296.21	
From 3.50 to 3.80m Non intact: Recovered as red brown and grey slightly clayey angular medium coarse GRAVEL of highly weathered sandstone.	(2.20)	
Very weak and weak dark grey SILTSTONE. Highly weathered. fracture discontinuities are subhorizontal very closely spaced to non intact rough planar light with red ferrous staining and carbonisation.	5.00 +294.01	
From 5.20 to 5.90m Non intact: Recovered as dark grey sandy GRAVEL of siltstone.	(0.70)	
From 6.60 to 6.90m Non intact: Recovered as highly weathered sandy GRAVEL of sandstone.	5.70 +293.31	
From 7.50m. Fracture discontinuities medium spaced are horizontal closely spaced rough planar and light, with occasional carbonisation and occasional clay infill.		
Strong grey fine medium SANDSTONE. Slightly weathered - with occasional iron staining. fracture discontinuities are horizontal closely spaced rough planar and light with occasional carbonisation and occasional clay infill.	(6.50)	

Groundwater
Borehole wet at 6.70m.

Remarks
Standpipe piezometer installed, 19 mm diameter, response zone from 18.00m to 20.00m
Hole backfill : 0.00m to 0.30m Concrete (c), 0.30m to 0.50m Grout (g), 0.50m to 1.00m Bentonite (b), 3.00m to 3.50m Bentonite (b), 3.50m to 17.50m Grout (g), 17.50m to 18.00m Bentonite (b), , 20.00m to 20.50m Bentonite (b), 20.50m to 23.50m Grout (g). Surface protection : Stop Cock Cover
Standpipe Piezometer installed, 19mm diameter, response zone from 1.00m to 3.00m.

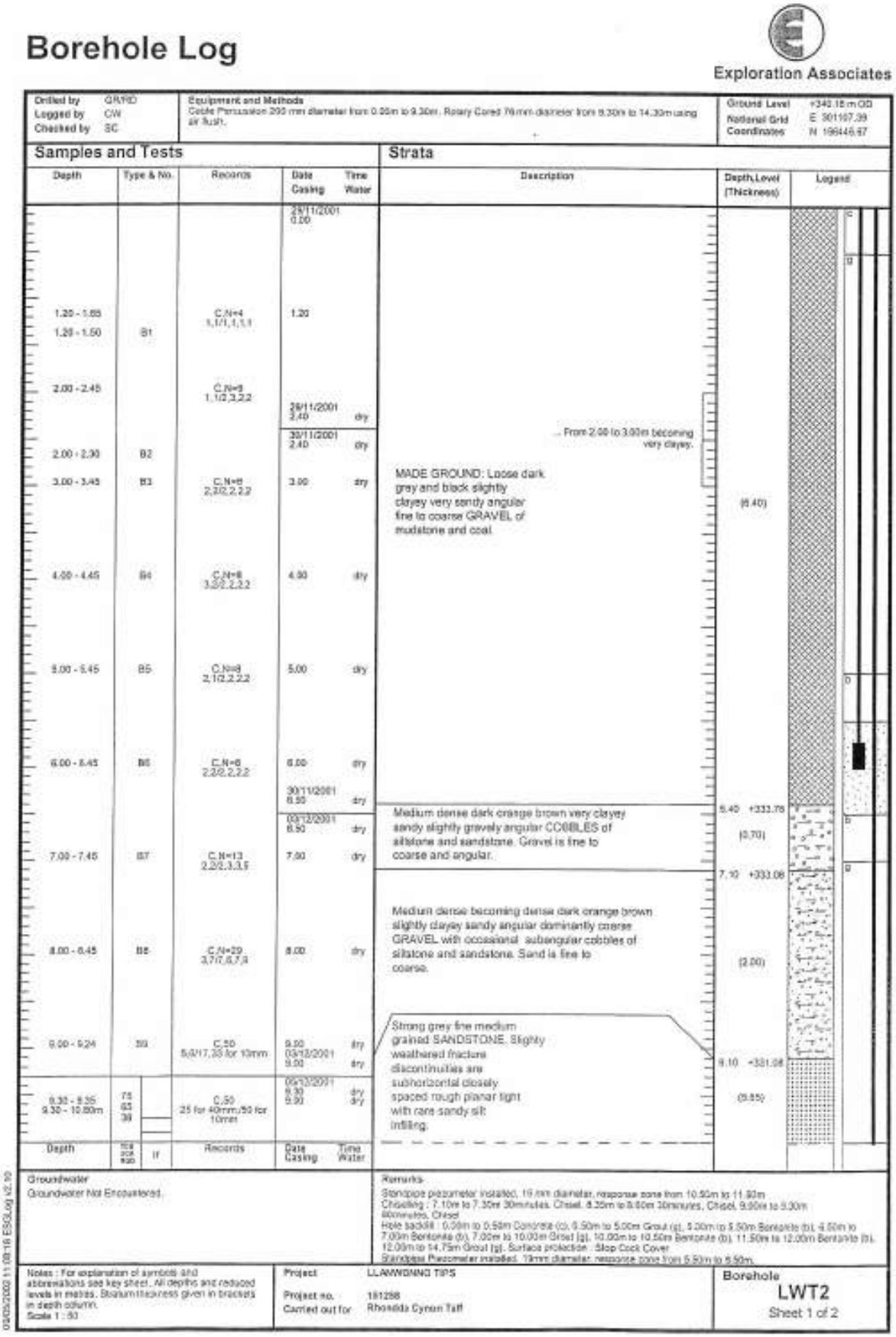
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project: LLANWONNO TIPS
Project no.: 151258
Carried out for: Rhondda Cynon Taff

Borehole: LWT1
Sheet 1 of 3

Borehole log extracted from the following report.

Llanwonno Tips Reclamation Scheme, Report on Ground Investigation, Ref. 151258 Halcrow, 2001.



Borehole Log

Exploration Associates

Drilled by	GRND	Equipment and Methods	Ground Level +340.15 m OD
Logged by	CW	Cable Percussion 200 mm diameter from 0.00m to 9.30m. Rotary Cored 76 mm diameter from 9.30m to 14.30m using air flush.	National Grid Coordinates E 301197.39 N 199446.67
Checked by	SC		

Samples and Tests

Depth	Type & No.	Records	Date Casing	Time Water
			29/11/2001 0.00	
1.20 - 1.65		C,N=4 1,1/1,1,1,1	1.20	
1.20 - 1.50	B1			
2.00 - 2.45		C,N=5 1,1/2,1,2,2	29/11/2001 2.40	dry
			30/11/2001 2.40	dry
2.00 - 2.30	B2			
3.00 - 3.45	B3	C,N=6 2,2/2,2,1,1	3.00	dry
4.00 - 4.45	B4	C,N=8 3,2/2,2,2,2	4.00	dry
5.00 - 5.45	B5	C,N=8 2,1/2,2,2,2	5.00	dry
6.00 - 6.45	B6	C,N=6 2,2/2,2,1,1	6.00	dry
			30/11/2001 6.50	dry
			03/12/2001 6.50	dry
7.00 - 7.45	B7	C,N=13 2,2/3,3,3,4	7.00	dry
8.00 - 8.45	B8	C,N=29 3,7/7,6,7,9	8.00	dry
9.00 - 9.24	B9	C,50 5,6/17,33 for 10mm	9.00	dry
			03/12/2001 9.00	dry
9.30 - 9.35	75	C,50 25 for 40mm/50 for 10mm	03/12/2001 9.30	dry
9.30 - 10.80m	63		9.90	dry
	38			

Depth	Type & No.	If	Records	Date Casing	Time Water

Strata

Description	Depth,Level (Thickness)	Legend
From 2.00 to 3.00m becoming very clayey. MADE GROUND: Loose dark grey and black slightly clayey very sandy angular fine to coarse GRAVEL of mudstone and coal.	(6.40)	
Medium dense dark orange brown very clayey sandy slightly gravely angular COBBLES of siltstone and sandstone. Gravel is fine to coarse and angular.	6.40 +333.75 (0.70)	
Medium dense becoming dense dark orange brown slightly clayey sandy angular dominantly coarse GRAVEL with occasional subangular cobbles of siltstone and sandstone. Sand is fine to coarse.	7.10 +333.05 (2.00)	
Strong grey fine medium grained SANDSTONE. Slighty weathered fracture discontinuities are subhorizontal closely spaced rough planar tight with rare sandy silt infilling.	9.10 +331.05 (5.85)	

Groundwater

Groundwater Not Encountered.

Remarks

Standpipe piezometer installed, 19 mm diameter, response zone from 10.50m to 11.80m
Chiselling : 7.10m to 7.30m 30minutes. Chisel. 8.35m to 8.60m 30minutes, Chisel, 9.00m to 9.30m 60minutes, Chisel
Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 5.00m Grout (g), 5.00m to 5.50m Bentonite (b), 5.50m to 7.00m Bentonite (b), 7.00m to 10.00m Grout (g), 10.00m to 10.50m Bentonite (b), 11.50m to 12.00m Bentonite (b), 12.00m to 14.75m Grout (g). Surface protection : Stop Cock Cover
Standpipe Piezometer installed. 19mm diameter, response zone from 5.50m to 6.50m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project: LLANWONNO TIPS
Project no.: 151258
Carried out for: Rhondda Cynon Taff

Borehole: LWT2
Sheet 1 of 2

03/05/2002 11:08:16 ESG.Log v2.10

Borehole log extracted from the following report.

Llanwonno Tips Reclamation Scheme, Report on Ground Investigation, Ref. 151258 Halcrow, 2001.

Borehole Log

Exploration Associates

Drilled by	JR/MJ	Equipment and Methods See sheet 1	Ground Level	+315.04 m OD
Logged by	CW		National Grid	E 301147.81
Checked by	SC		Coordinates	N 196319.12

Samples and Tests

Depth	Type & No.		Records	Date Casing	Time Water
10.00 - 10.40	S10		C,9 2,1/2,2,1,4 for 25mm	10.00	damp
10.60 - 11.00	S19				
11.00 - 11.50	U17		30 blows 450mm recovered	10.90	dry
11.50	D18				
11.75 - 12.15	S19		C,50 6,4/4,3,14,29 for 20mm	11.75	dry
12.50 - 12.84	S20		C,50 4,11/15,20,15 for 40mm	12.50	dry
				05/12/2001 13.00	dry
				06/12/2001 06/12/2001 13.40	dry
13.40 - 13.50m				07/12/2001 13.40 13.00	dry dry
13.40 - 13.42			C,50 25 for 10mm/50 for 10mm		
13.50 - 15.00m	47 14 0	NI NI 40			
15.00 - 15.50m	60 0 0				
15.50 - 17.00m	87 35 0	NI 60 240			
17.00 - 18.50m	63 45 42			07/12/2001 18.50	dry
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water

Strata

Description	Depth, Level (Thickness)
As sheet 1	(10.75)
Very stiff slightly sandy slightly gravelly SILT. Sand is fine to coarse, gravel is angular to subangular fine to coarse of siltstone and sandstone.	10.75 +304.29 11.00 +304.04
Very stiff orange brown slightly sandy slightly gravelly SILT, with occasional subangular to subrounded cobbles of sandstone. Sand is fine to coarse, gravel is angular to subangular of siltstone and sandstone.	(1.50)
Sandstone.**	12.50 +302.54 (0.50)
Orange brown generally weak occasionally moderately weak SANDSTONE. Highly weathered, fracture discontinuities are extremely closely spaced randomly orientated generally non intact. Recovered as sandy angular fine to coarse GRAVEL.	13.00 +302.04 (2.50)
Very weak becoming moderately weak dark grey SILTSTONE. Moderately weathered fracture discontinuities are horizontal closely spaced planar smooth moderately open with some clay infill. From 15.50 to 15.90m Non intact: Recovered as very clayey sandy angular fine to medium GRAVEL of siltstone. From 17.00 to 17.40m non intact: Recovered as clayey slightly sandy GRAVEL of siltstone.	15.50 +299.54 (3.00pen)
EXPLORATORY HOLE ENDS AT 18.50 m.	18.50 +296.54

Groundwater
No. Struck Behaviour

Remarks
TCR/SCR/RQD: 13.40m to 13.50m I/D
Chiselling: 11.80m to 12.50m 105minutes, Chisel, 12.50m to 13.00m 75minutes, Chisel, 13.00m to 13.40m 90minutes, Chisel

Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

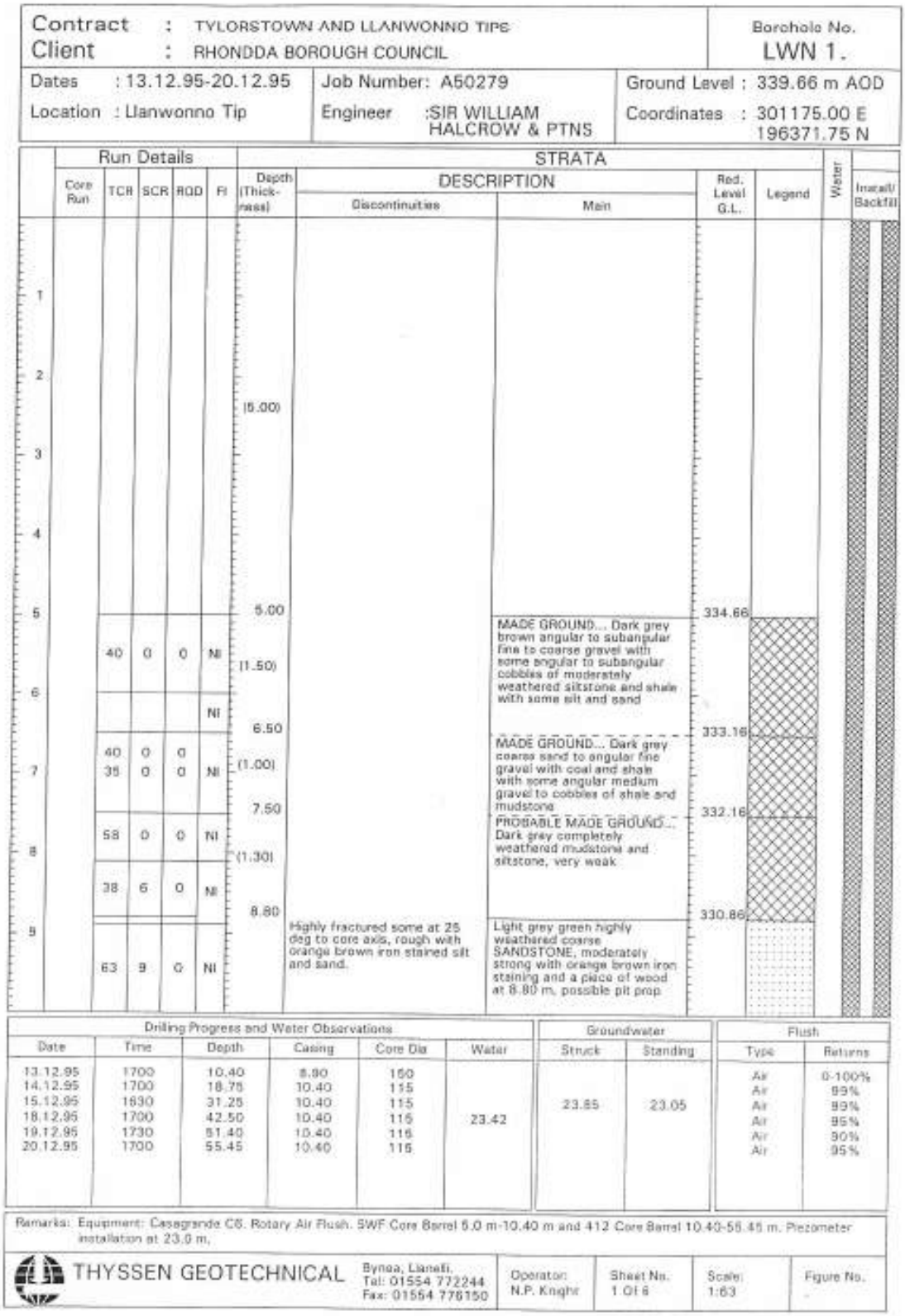
Project	LLANWONNO TIPS
Project no.	151258
Carried out for	Rhondda Cynon Taff

Borehole LWT3
Sheet 2 of 2

09/05/2002 11:06:27 EBGLog v2.10

Borehole log extracted from the following report.

Llanwonno Tips Reclamation Scheme, Report on Ground Investigation, Ref. 151258 Halcrow, 2001.



Borehole log extracted from the following report.

Tylorstown and Llanwonno Tips, Ground Investigation Report, Thyssen Geotechnical, Report No. A50279, February 1996.

Contract : TYLORSTOWN AND LLANWONNO TIPS Client : RHONDDA BOROUGH COUNCIL	Borehole No. LWN 2

Dates : 9.1.96-10.1.96 Location : Llanwonno Tip	Job Number: A50279 Engineer : SIR WILLIAM HALCROW & PTNS	Ground Level 304.51 m A.O.D. Coordinates 301117.50 E 198292.50 N

	Samples & Tests			STRATA			
	Depth	Type No	Test Result, N, Blow Counts	Depth (Thickness)	DESCRIPTION	Red. Level O.D.	Legend
	0.00-0.50	B1			MADE GROUND... Loose black coal slag with grey brown mudstone cobbles and boulders		
	0.50-0.95	D2	19 [illegible]				
1	1.00-1.45	U3	[illegible]	(2.00)			
	1.45-1.60 1.60-2.00	D4 B5					
2				2.00	MADE GROUND... Black clayey coal slag with brown grey mudstone cobbles and boulders	302.51	
	2.50-2.95	U6	[illegible]				
3	2.95-3.10 3.10-4.10	D7 B8		(2.70)			
4	4.10-4.55	U9	[illegible]				
	4.55-4.70 4.70-5.50	D10 B11		4.70	MADE GROUND... Black slag fill with grey brown mudstone cobbles and boulders	299.81	
5							
	5.50-5.95	CD12	36 [illegible]				
6	6.00-7.00	B13		(3.70)			
7	7.00-7.10	U14	[illegible]				
	7.40-7.85	U15	[illegible]				
8	7.85-8.10	D16					
	8.40-8.80	B17		8.40 (0.60)	Grey brown firm to stiff CLAY with fine medium to coarse gravel	296.11	
	8.80-9.25	U18	[illegible]	9.00 (0.50)	Light brown SAND with firm to stiff clay with fine to coarse gravel occasional sandstone boulder	295.51	
9	9.25-9.40 9.40-13.00	D19 B20		9.50	Light brown grey firm to stiff weathered MUDSTONE becoming hard with depth	295.01	

Boring Progress and Water Observations						Groundwater			Chiselling		
Date	Time	Depth	Casing	Cas Dia	Water	Struck	Behaviour	Sealed	From	To	Hours
10.01.96		13.10	9.20	200 mm		5.60	Rose to 5.50 m	8.50	7.10 12.00	7.40 13.00	30 Mins 1 Hr

Remarks: Equipment: Dando 150. Borehole 200 mm. Piezometer installation at 8.40 m.

THYSSEN GEOTECHNICAL	Burry Port, Llanelli Tel: 01554 772244 Fax: 01554 779100	Operator P. Chappell	Sheet No. 1 Of 2	Scale 1:50	Figure No. -

Borehole log extracted from the following report.

Tylorstown and Llanwonno Tips, Ground Investigation Report, Thyssen Geotechnical, Report No. A50279, February 1996.

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