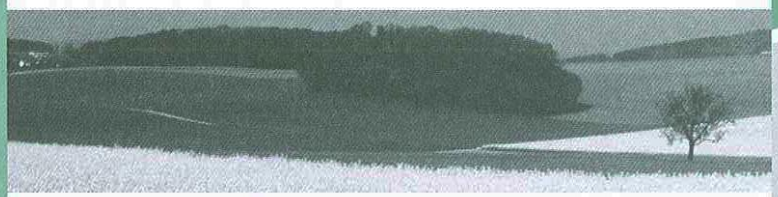
Preliminary Slope Stability Analysis
Proposed Residential Development
Northcliff Lodge
Penarth

Prepared for:
Celtic Developments Penarth Limited

November 2016

Job No: 13124/1

terrafirma



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REPORT TITLE	**:**	**Preliminary Slope Stability Analysis: Northcliff Lodge, Penarth**
REPORT STATUS	**:**	**FINAL**
JOB NUMBER	**:**	**13124/1**
DATE	**:**	**November 2016**
PREPARED BY	**:**	**……..** **(Mathew Lake)**
REVIEWED BY	**:**	**……..** **(Ruth Howells)**
APPROVED BY	**:**	**……..** **(Dr Gwyn C. Lake)**

Executive Summary

Site Location	*The site is located at the top of the Penarth Escarpment, at the eastern end of North Cliff Drive, at an approximate National Grid Reference of 318900, 172370. The site is located on three terraces. The upper, middle and lower terraces have an approximate altitude of 37m AOD, 29m AOD and 20m AOD respectively. The base of the Escarpment has an altitude of approximately 10m AOD.*
Proposed Development	*Celtic Developments Penarth Limited are planning a residential development of the site.*
Site History	*The history maps apart for the construction of Northcliff Lodge the site has remained undeveloped.*
Geology & Landslip History	*The Geology Report shows the site to be underlain in stratigraphical sequence by rocks of the St Mary's Well Bay Formation, Penarth Group, Blue Anchor Formation and Mercia Mudstone Formation.* *In 2006 Thomas et al published a paper titled 'Implications of urban development on escarpment instability'. The paper detailed that between 1859 and 1865 the Penarth Dock was developed and railway sidings and shunting yards, associated with the adjacent Penarth Dock, ran along the base of the escarpment.* *Historically limestone was also quarried from the escarpment. The toe of the escarpment has therefore been subject to haphazard excavation historically.* *Thomas et al (2006) record at least three previous slope failure events preceding their paper which, itself, details a fourth event in 2004. During an inspection of the slope, Thomas et al (2006) encountered morphological evidence of a large scale historical failure in the slope previously obstructed by vegetation.* *In 2013 Terra Firma Wales Ltd were engaged to assess a landslide at Penarth Marina, located immediately east of the current study site. A failure had occurred on the slope and Terra Firma Wales Ltd performed an inspection of the slope and the surrounding area. Landslide morphology was apparent and features including tree 'piston gripping' (i.e., curvature in the base of trees as they correct themselves to vertical following historical ground movement events) was noted adjacent to the slide, indicating further historical land movement to the northwest of the 2013 landslide.*
Ground Conditions	*Ground condition encountered comprised a stiff and very stiff gravelly clay overlying the St Mary's Well Bay Formation, over the Penarth Group over the Blue Anchor Formation over the Mercia Mudstone. Groundwater was encountered within the Blue Anchor Formation.*
Slope Stability Analysis	*A computer slope stability Analysis was carried out using the results of a single on site borehole enhanced by boreholes from a previous investigation with effective stress shear parameters derived from published data.* *The stability analysis has shown that all unstable factors of safety are with the shallow superficial deposits, in particular at the rear of the existing retaining wall and at the top of the escapement embankment to the north of the site.* *It was acknowledged that the analysis was based upon limited site investigation data and generic shear stress parameters derived from published data. However a sensitivity analysis undertaken using a reduction in shear strength parameters of 25% showed little change in the overall stability of the site.* *Based upon the above it was concluded that a steel pile solution socketed within the underlying competent bedrock would maintain the current stability of the site. All minor slippages encountered in the analysis would be easily dealt with using standard engineering techniques.* *It was recommended that a comprehensive site investigation including trial pits, rotary coreholes, the installation of piezometers to monitor groundwater and inclinometers to monitor ground movement, soil shear stress parameter laboratory testing and an enhanced*

	computer slope stability analysis should be carried out to confirm the finding of the preliminary analysis.

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SECTION 1 Introduction

Celtic Developments Penarth Limited are planning a residential development of a site at Northcliff Lodge, Penarth.

In December 2015, Terra Firma (Wales) Limited were commissioned to undertake a Desk Study of the site. This report (No. 13124) highlighted the past instability of the general area with regard to landslip potential.

Recommendations were made to undertake a comprehensive site investigation and computer slope stability analysis of the site to investigate the sites current stability and provide foundation recommendations to ensure its future long term stability. The proposed investigation comprised a number of rotary coreholes, trial pitting and soil instrumentation within the boreholes including inclinometers for monitoring long term slope movement and piezometers to monitor groundwater fluctuation. Samples of the various strata were also to be taken to determine soil shear stress parameters for input into the slope instability analysis.

Following completion of the above investigation a computer slope stability analysis was to be carried out in order to determine the sites current stability and to determine the slip planes with the lowest factor of safety against slope movement.

The report also recommended a tentative foundation solution of rotary installed steel piles extending through the deepest slip planes to ensure future stability of the site. With this foundation solution that can also be used on retaining walls no additional loads are placed upon shallow deposits.

Terra Firma (Wales) have been commissioned by Celtic Developments Penarth Limited to undertake a Preliminary Site Investigation and Slope Stability Analysis in order to determine the likely depth of all slip planes and hence the viability of the envisage foundation solution.

1.1 Limitations and Exceptions of Investigation

Celtic Developments Penarth Limited has requested that a Preliminary Slope Stability Analysis be performed.

The preliminary slope stability analysis was conducted and this report has been prepared for the sole internal reliance of Celtic Developments Penarth Limited and its design and construction team. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

The report represents the findings and opinions of experienced geo-technical consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may also be required.

It should be noted that only a very limited investigation could be carried out due to the presence of Northcliff Lodge and consequently the subsurface geological profiles, hydrostatic levels and plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths tested.

SECTION 2 Slope Stability Parameters

2.1 Site Investigation

Only the middle tier of the site was accessible to the rotary drilling rig.

One rotary probe/core hole was subsequently sunk with the central ties of the site within the garden of Northciff lodge in order to determine the nature and depth of underlying strata.

The probe/core holes was sunk into the underlying Mercia Mudstone Bedrock using a Beretta T41 drilling rig. Open hole drilling was employed within the superficial deposits and a and highly weathered solid geology. Once encountered rock cores of the bedrock were obtained. In addition to the above Standard/Cone Penetration (SPT/CPT) tests were undertaken at regular intervals throughout extent of the borehole. Compressed air was used as the flushing medium.

The fieldworks were supervised by Terra Firma (Wales) Limited, who also logged the boreholes to the requirements of BS5930: 2015.

The rotary probe/corehole logs is presented in **Annexes A**.

The exploratory hole location is illustrated on **Drawing 01**.

In addition to the above rotary probeholes (BH01-BH03) sunk as part of an investigation for the redevelopment of Marine Buildings (Report No 11458 dated 2012) were abstracted for used in the analysis.

The location of the probeholes are shown in **Drawing 02**.

2.2 Slope Cross Sections and Geological Profile

Slope stability analyses for a single section through the centre of the site was undertaken. The boundary between each strata has been determined from depths confirmed during drilling and estimated where required though extrapolation taking into account ground conditions in general across the site.

The section line is shown on **Drawing 01**.

This section was chosen as it contained the most precipitous slopes is are presented below.

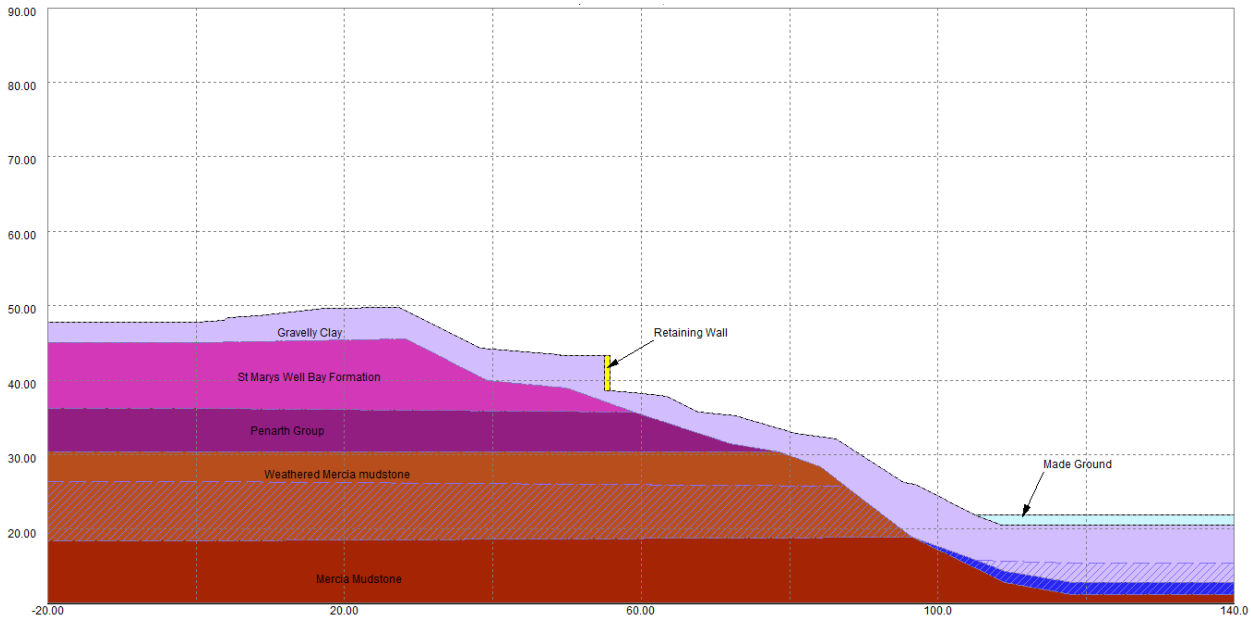

Figure 2.1 - Profile for Slope 1

2.3 Geotechnical Parameters

2.3.1 Effective Angle of Shear Resistance and Effective Cohesion

Parameters for drained conditions have been chosen through inspection of site soils, interpretation of in-situ test results and from appropriate published data as detailed in the Notes at the foot of **Table 2.1**.

These have been allocated to ensure the most critical failure circles are considered.

Table 2.1: Angle of Effective Shear Resistance and Effective Cohesion

Soil Sample	Angle of Shearing Resistance, ° (ϕ´)	Effective Cohesion, kPa (c´)
Made Ground	28°	0
Stiff and very stiff gravelly Clay[1]	36°	0
St Mary's Well Bay Formation[2]	32°	5
Penarth Group[2]	35°	8
Blue Anchor Formation[2]	35°	12
Weathered Mercia mudstone[3]	38°	0
Mercia Mudstone[3]	40°	15

Notes:

1 Relationship between angle of shearing resistance and SPT N value (Peck, Hanson and Thornburn)
2 Engineering Geology of British Rocks and Soils - Lias Group (BGS Internal Report OR/12/032)
3 Engineering Geology of British Rocks and Soils - Mudstones of the Mercia Mudstone Group

2.3.2 Pore Water Pressure

Groundwater was encountered within the Penarth Group at 17.2m depth in BH01 sunk as part of the current investigation. With regards to the boreholes sunk as part of the Marine Buildings investigation groundwater at the base of the escarpment was encountered at approximately 6 to 8m depth near the top of the Mercia Mudstone Group. Overall groundwater levels have been interpolated to link the two as shown in the computer model.

2.3.3 Soil Density

A soil density of 18kN/m^3 has been applied to the made ground and stiff to very stiff gravelly clays.

A soil density of 20kN/m^3 has been applied all other soil/rock types.

2.3 Computer Analytical Set-up

Computer Slope Stability Analyses were performed using the SLOPE v.19 Computer Programme by OASYS.

2.4.1 Bishop Slope Failure Mechanism

Due to the thickness of the made ground relative to the height of the proposed slopes, circular slip mechanisms were considered during computer analysis. Circular slopes were assessed by the Bishop Method. Further details of this method can be found in published literature.

The analyses were performed using the grid method to specify a large number of potential rotation points for the centre of the slip circles. Grids were set up with 1.0m spacing between points. The radius of the potential slip circles was not limited.

2.4.1.1 Operational Setting

Analyses were performed based on shear strength parameters. The circular slips were divided into the default number of interslice sections. Interslice forces were accommodated into the calculations via the variably inclined interslice method. All other settings were left in default mode.

2.4.1.2 Factors of Safety

The programme assesses multiple failure circles rotating about centre points within the predetermined grid. The Factors of Safety presented in this report represent the most unstable failure circles.

BS 6031Section 6.5 sub section 6.5.1.2 suggests that a safety factor of between 1.3 and 1.4 should be designed for.

A factor of safety of 1.3 has, therefore, been taken as adequate. It is against this factor of safety that the results are assessed.

SECTION 3 Results of Stability Analysis

3.1 Bishop Analysis Method

The Slope 19 Computer Programme was set up to determine the most unstable failure circle for the analysis. Any slope with a factor of safety less than 1 is considered to be unstable. The minimum acceptable factor of safety is 1.3. Those slopes with a factor of safety greater than 1.3 are considered sufficiently stable that a slip is unlikely to occur. Slips achieving a factor of safety of between 1 and 1.3 although unlikely, are considered to have the potential to occur.

The resultant Factors of Safety for the most unstable circles within these slopes are presented in **Table 3.1**.

Table 3.1. Factors of Safety for Least Stable Failure Circles

Slope Section	Analysis Method	Factor of Safety
1	Bishop	0.810

The computer slope stability analysis is presented in **Annex C**.

The predicted slip surface identified is seen to pass through the existing retaining wall. Figure 3.1 shows the analysed failure planes. All failure planes with a factor of safety of less than 1.3 are located directly behind the existing retaining wall a on the surface of the escarpment face as it drops towards Marine Buildings/ Custom House.

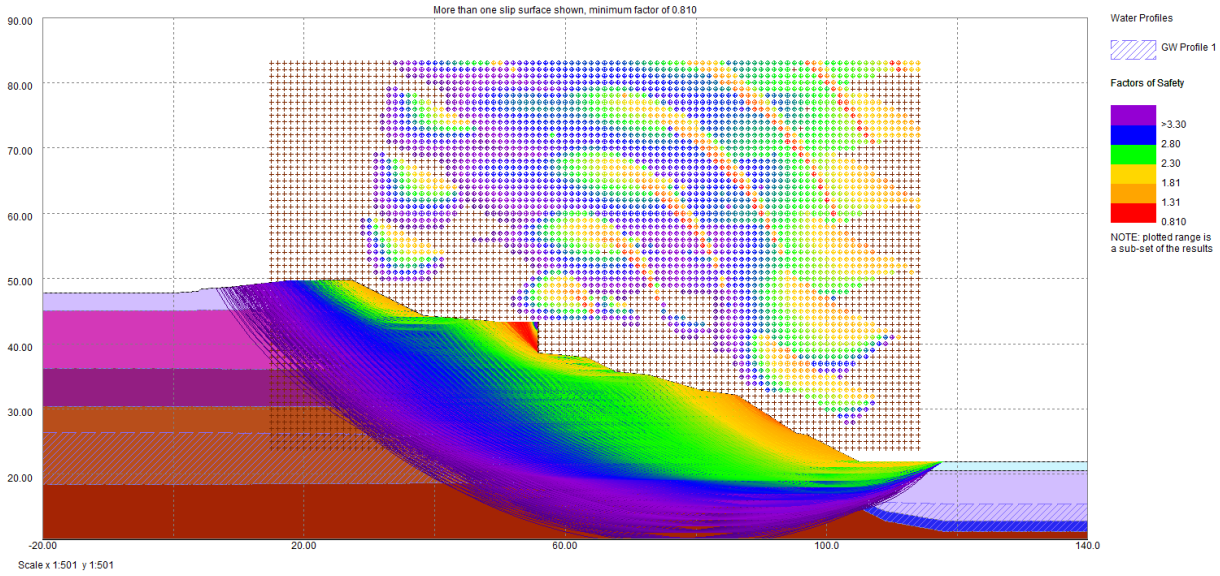

Figure 3.1: Failure Surfaces - Bishop Method Slip Surface

SECTION 4 Sensitivity Analysis

4.1 Introduction

Sensitivity analyses were performed upon the Bishop Method slope analysis to determine the effect of varying principle parameters upon the resultant factor of safety.

All shear strength parameters were reduced by 25% and the model re-run.

4.2. Shear Strength

The shear strength parameters were reduced by 25%. The resultant Factors of Safety of presented in **Table 4.1**. The graphical output of the analysis is shown in **Figure 4.1.**

Table 4.1 Factor of Safety for Least Stable Failure Circles - 25% Reduction in Shear Strength Parameters

Stability Run	Factor of Safety
Original	0.810
-25%	**0.735**

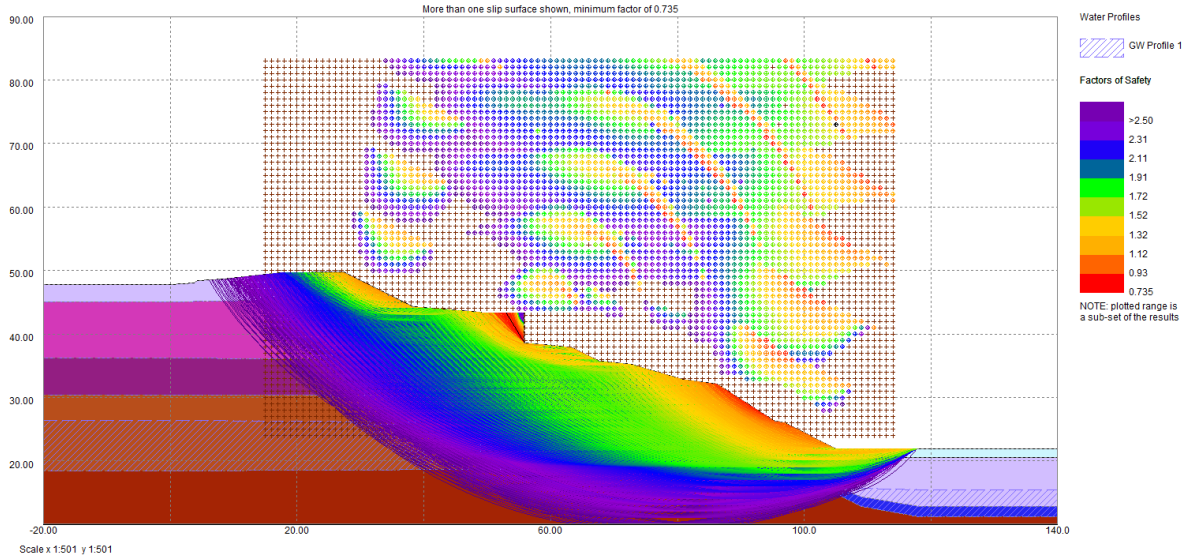

Figure 4.1: Failure Surfaces – 25% reduction in shear strength

Again the predicted failure planes pass through or behind the retaining wall with a lowered factor of safety. The analysis has also shown an increased area of shallow failure on the escarpment slope.

4.3 Pore Water Pressure

In addition to the groundwater profile discussed in Section 2.3.2, an increase in groundwater levels has been modelled. The results of the analysis are presented in **Table 4.2**.

4.3 **Pore Water Pressure** (Continued)

It can be seen that the increase in groundwater has a negligible impact on the stability of the slope.

Table 4.2. Porewater Sensitivity Analysis

Stability Run	Hydraulic Head within Made Ground, (m)	Factor of Safety
Original	Within Blue Anchor Formation	0.810
Sensitivity 1	Top of Penarth Group	0.810
Sensitivity 2	Middle of St Mary's Well Bay Formation	0.810

SECTION 5 Conclusions

5.1 Modelled Slope

In Section 2.4.1.2 it was stated that BS 6031Section 6.5 sub section 6.5.1.2 suggests that a safety factor of between 1.3 and 1.4 should be designed for.

The slope stability of the area has therefore, been analysed on the basis of a factor of safety of 1.3 guaranteeing stability for the site with the assumption that any factors of safety below 1.3 are potentially at risk.

The slope stability analysis has revealed that based upon the soil profile and generic soil shear stress parameters all significant failure plains are within the stiff and very stiff gravelly clays generally located behind the existing retaining wall with very shallow failure planes at the top of the escarpment slope. The presence of cracking in the wall would confirm this.

A 25% reduction in shear strength showed a reduced factor of safety, though the significant failure planes generally remained behind the retaining wall with slightly deeper failure planes at the top of the escarpment slope. The occurrence of the past slope instability to the east of the site confirms this.

SECTION 6 Further Work

The slope stability modelling has not identified an unacceptable risk of deep seated failure beneath the site. The shallow slip circles with unacceptable factors of safety identified can be engineered using common design techniques.

However, as previously stated the analysis is based upon limited data both in term of site investigation and soil parameter testing.

In order to confirm the results of the analysis the following investigation should be carried out:

- The sinking of eight rotary coreholes to a depth of typically 40m over the site area
- The installation of piezometers within the boreholes to monitor the fluctuation of ground water levels wit time
- The installation of inclinometers within the borehole to monitor ground movements before during and after construction through the full depth of the borehole
- Trial pitting to determine/confirm shallow ground conditions
- A comprehensive computer slope stability Analysis over a number of sections using the enhanced data and site specific parameters

All of the above is required to confirm that the findings of the preliminary slope stability analysis.

However, from the preliminary analysis it appears that all lightly failure plains are shallow and confined to the superficial deposits.

The recommended foundation solution of steel piles installed into the underlying competent bedrock will not add any weight to the ground surface and will maintain the stability of the development.

This should be demonstrated by the continued monitoring of the inclinometers.

It is recommended that in the long term (before, during and after construction) the slope be monitored for signs of movement and small scale slippage. Small slips provide an indication as to whether any larger scale slips may occur.

Should any unacceptable movement of the slope be recorded that significantly increases the risk from further and greater slips, appropriate steps can be made to secure the slope as necessary.

ANNEX A
Rotary Probe/Corehole Logs

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Borehole No. **BH01**
Sheet 1 of 4

Project Name: North Cliff Lodge	Project No. 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016	Logged By

Water Strikes	Depth (m)	Type /FI	Coring TCR	Coring SCR	Coring RQD	Depth (m)	Level (m)	Well	Legend	Stratum Description
										Stiff light greyish brown silty CLAY.
						2.40				Very stiff dark greyish brown becoming dark grey CLAY with rare white shell fragments.
	4.00 - 5.50		30	20	7	4.00				Limited recovery. Recovered as strong light grey LIMESTONE. Fractures are subhorizontal very closely and closely spaced undulating smooth.
	5.50 - 7.00		22	0	0	5.50				Limited recovery. Recovered as very stiff dark blueish grey CLAY.
	7.00 - 8.50		34	9	0	7.00				Limited recovery. Recovered as very stiff to extremely weak dark grey CLAY/MUDSTONE. Fractures are subhorizontal extremely closely and very closely spaced planar smooth.
	8.50 - 10.00		100	68	14	8.50 8.80 9.00				Extremely weak dark grey MUDSTONE. Fractures are subhorizontal very closely spaced planar smooth. Weak to medium strong grey and dark grey LIMESTONE. Fractures are subhorizontal very closely and closely spaced undulating smooth. Extremely weak dark grey MUDSTONE. Fractures are subhorizontal extremely closely to closely spaced planar locally undulating

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Borehole No. **BH01**
Sheet 2 of 4

Project Name: North Cliff Lodge	Project No. 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016	Logged By

Water Strikes	Depth (m)	Type /FI	Coring TCR	Coring SCR	Coring RQD	Depth (m)	Level (m)	Well	Legend	Stratum Description
	10.00 - 11.50		61	33	0					smooth. *10° planar smooth fracture.*
	11.50 - 13.00		27	6	0	11.50				Limited recovery. Recovered as very weak light brown and dark greenish grey SILTSTONE and MUDSTONE. Non intact.
	13.00 - 14.50		95	23	17	13.00				Very weak dark greenish grey locally dark brown MUDSTONE. Fractures are subvertical and 40-70° very closely and closely spaced planar locally undulating smooth. Fracture locally with veneer of clay. *Medium strong dark grey LIMESTONE.*
	14.50 - 16.00		100	50	23					*Weak dark grey SILTSTONE.*
	16.00 - 17.50		96	17	14	16.20				Extremely weak to very weak greenish grey MUDSTONE. Fractures are subvertical and 40-70° very closely and closely spaced planar locally undulating smooth. *Soft to firm sandy clay band (40mm thick)*
	17.50 - 19.00		83	0	0					*Non intact.* *Non intact.*
	19.00 - 20.50		81	0	0	19.00 19.50 19.85				Very weak light greenish grey MUDSTONE. Fractures are 40-60° very closely spaced planar smooth. *Non intact.* Very weak greenish grey MUDSTONE. Fractures are 5-25° extremely closely and very

11 12 13 14 15 16 17 18 19 20

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Borehole No. **BH01** Sheet 3 of 4

Project Name: North Cliff Lodge	Project No. 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016	Logged By

Water Strikes	Depth (m)	Type /FI	Coring TCR	Coring SCR	Coring RQD	Depth (m)	Level (m)	Well	Legend	Stratum Description
										closely spaced planar smooth. *Non intact.*
						20.50				Very weak greenish grey MUDSTONE. Fractures are 60-70° extremely closely spaced planar locally undulating smooth. Locally non intact.
	20.50 - 22.00		98	18	0	21.30				Very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 30-40° closely spaced planar smooth. *65° undulating smooth fracture.*
										Very weak light greenish grey and brownish grey MUDSTONE. Fractures are 50-65° closely spaced planar smooth. Locally non intact. *Non intact.* *Non intact.* *Non intact.* *Fracture infilled with soft pinkish brown clay (20mm thick).* *Non intact. Locally tending to claybound tabular fine and medium gravel sized mudstone lithorelicts.*
	22.00 - 23.50		97	33	17	22.40				
										Very weak to weak light greenish grey and light brownish grey MUDSTONE. Fractures are 50-60° closely and medium spaced undulating locally planar smooth. *Subvertical undulating smooth fracture.* *Non intact.*
	23.50 - 25.00		91	43	37	24.10				
						24.40				Extremely weak light greenish grey MUDSTONE. Fractures are 60-70° extremely closely spaced undulating smooth.
						25.00				Very weak to weak light greenish grey and light brownish grey MUDSTONE. Fractures are 60-70° closely and medium spaced planar smooth.
	25.00 - 26.50		89	45	35					Extremely weak to very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 50-60° closely and medium spaced undulating locally planar smooth. *Non intact.*
						26.50				Extremely weak dark reddish brown MUDSTONE. Fractures are 20-60° extremely closely and very closely spaced planar locally undulating smooth. Locally non intact.
	26.50 - 28.00		77	6	0					*Subvertical undulating smooth fracture.*
						27.70				Very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 70-80° medium spaced planar smooth. *Non intact.*
	28.00 - 29.50		96	71	54					*Non intact (30mm thick)*
						29.10				Very weak locally extremely weak dark reddish brown MUDSTONE. Fractures are subhorizontal to 20° very closely to medium spaced planar smooth. *60° planar smooth fracture.*

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Borehole No. **BH01**
Sheet 4 of 4

Project Name: North Cliff Lodge	Project No. 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016	Logged By

Water Strikes	Depth (m)	Type /FI	Coring TCR	Coring SCR	Coring RQD	Depth (m)	Level (m)	Well	Legend	Stratum Description
	29.50 - 31.00		100	63	41					*Extremely weak.* *80° planar smooth fracture.*
	31.00 - 32.50		97	45	31	31.60				*Non intact.* *Locally non intact. Tending to claybound tabular fine and medium gravel sized lithorelicts.* Very weak dark reddish brown locally spotted light greenish grey MUDSTONE. Fractures are 60° closely and medium spaced planar smooth.
	32.50 - 34.00		97	65	55					
	34.00 - 35.50		96	36	23	34.00				Very weak dark reddish brown locally spotted light greenish grey MUDSTONE. Fractures are subhorizontal to 30° very closely and closely spaced planar smooth. *2no. 60-70° planar smooth fractures.* Extremely weak dark reddish brown MUDSTONE. Non intact. *50° planar smooth fracture.* *Vuggy. Vugs up to 10mm diam.*
	35.50 - 37.00		91	0	0	35.00				Very stiff dark reddish brown locally light greenish grey silty CLAY. *70-80° curved locally stepped smooth fissure.*
	37.00 - 38.50		95	31	7	36.00				Extremely weak to very weak dark reddish brown MUDSTONE. Fracture are 5-40° very closely and closely spaced planar smooth. *3no. 50-55° planar smooth fractures.*
	38.50 - 40.00		93	0	0	37.00				Very stiff dark reddish brown locally spotted light greenish grey silty CLAY. Extremely weak dark reddish brown MUDSTONE. Non intact. *Quartz vein.* *75° planar smooth fracture.* *75° undulating smooth fracture.*
						38.20				
						38.50				
						40.00				End of Borehole at 40.000m

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Borehole No.
BH01
Sheet 1 of 5

Project Name: North Cliff Lodge	Project No: 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016 -	Logged By

Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Well	Legend	Stratum Description
	Depth (m)	Type	Results					
	1.00	SPT	N=29 (5,4/3,4,4,7,15)					Stiff light greyish brown silty CLAY.
	2.50	SPT	N=22 (2,3/4,4,6,8)	2.40				Very stiff dark greyish brown becoming dark grey CLAY with rare white shell fragments.
	4.00	SPT	N=49 (6,7/7,8,16,18)	4.00				Limited recovery. Recovered as strong light grey LIMESTONE. Fractures are subhorizontal very closely and closely spaced undulating smooth.
				5.50				Limited recovery. Recovered as very stiff dark blueish grey CLAY.
	7.00	SPT	50 (8,12/50 for 225mm)	7.00				Limited recovery. Recovered as very stiff to extremely weak dark grey CLAY/MUDSTONE. Fractures are subhorizontal extremely closely and very closely spaced planar smooth.
				8.50				Extremely weak dark grey MUDSTONE. Fractures are subhorizontal very closely spaced planar smooth.
				8.80				Weak to medium strong grey and dark grey LIMESTONE. Fractures are subhorizontal very closely and closely spaced undulating smooth.
				9.00				Extremely weak dark grey MUDSTONE. Fractures are subhorizontal extremely closely to closely spaced planar locally undulating smooth.
	10.00	SPT	50 (8,11/50 for 35mm)					*10° planar smooth fracture*.

Continued on Next Sheet

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Borehole No. **BH01**

Project Name: North Cliff Lodge	Project No: 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016 -	Logged By

Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Well	Legend	Stratum Description
	Depth (m)	Type	Results					
								11
				11.50				Limited recovery. Recovered as very weak light brown and dark greenish grey SILTSTONE and MUDSTONE. Non intact.
								12
	13.00	SPT	50 (25 for 5mm/50 for 3mm)	13.00				Very weak dark greenish grey locally dark brown MUDSTONE. Fractures are subvertical and 40-70° very closely and closely spaced planar locally undulating smooth. Fracture locally with veneer of clay.
								13
								Medium strong dark grey LIMESTONE.
								14
								Weak dark grey SILTSTONE.
								15
	16.00	SPT	50 (25 for 10mm/50 for 5mm)	16.20				Extremely weak to very weak greenish grey MUDSTONE. Fractures are subvertical and 40-70° very closely and closely spaced planar locally undulating smooth.
								16
								Soft to firm sandy clay band (40mm thick)
								17
								Non intact.
								18
								Non intact.
	19.00	SPT	50 (25 for 135mm/50 for 90mm)	19.00				Very weak light greenish grey MUDSTONE. Fractures are 40-60° very closely spaced planar smooth.
								19
								Non intact.
				19.50				Very weak greenish grey MUDSTONE. Fractures are 5-25° extremely closely and very closely spaced planar smooth.
				19.85				
								20

Continued on Next Sheet

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Borehole No. **BH01**
Sheet 3 of 5

Project Name: North Cliff Lodge	Project No: 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016 -	Logged By

Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Well	Legend	Stratum Description
	Depth (m)	Type	Results					
								Non intact.
								Very weak greenish grey MUDSTONE. Fractures are 60-70° extremely closely spaced planar locally undulating smooth. Locally non intact.
				20.50				Very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 30-40° closely spaced planar smooth.
								65° undulating smooth fracture.
				21.30				Very weak light greenish grey and brownish grey MUDSTONE. Fractures are 50-65° closely spaced planar smooth. Locally non intact.
	22.00	SPT	50 (25 for 0mm/50 for 3mm)					*Non intact.*
								Non intact.
								Non intact.
				22.40				*Fracture infilled with soft pinkish brown clay (20mm thick).*
								Non intact. Locally tending to claybound tabular fine and medium gravel sized mudstone lithorelicts.
								Very weak to weak light greenish grey and light brownish grey MUDSTONE. Fractures are 50-60° closely and medium spaced undulating locally planar smooth.
								Subvertical undulating smooth fracture.
								Non intact.
				24.10				Extremely weak light greenish grey MUDSTONE. Fractures are 60-70° extremely closely spaced undulating smooth.
				24.40				Very weak to weak light greenish grey and light brownish grey MUDSTONE. Fractures are 60-70° closely and medium spaced planar smooth.
	25.00	SPT	50 (25 for 110mm/50 for 70mm)	25.00				Extremely weak to very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 50-60° closely and medium spaced undulating locally planar smooth.
								Non intact.
				26.50				Extremely weak dark reddish brown MUDSTONE. Fractures are 20-60° extremely closely and very closely spaced planar locally undulating smooth. Locally non intact.
								Subvertical undulating smooth fracture.
				27.70				Very weak dark reddish brown locally light greenish grey MUDSTONE. Fractures are 70-80° medium spaced planar smooth.
	28.00	SPT	50 (25 for 115mm/50 for 40mm)					*Non intact.*
				29.10				*Non intact (30mm thick)*
								Very weak locally extremely weak dark reddish brown MUDSTONE. Fractures are subhorizontal to 20° very closely to medium spaced planar smooth.
								60° planar smooth fracture.
								Continued on Next Sheet

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Borehole No.
BH01
Sheet 4 of 5

Project Name: North Cliff Lodge	Project No: 13124	Co-ords:	Hole Type BH
Location: Penarth		Level:	Scale 1:50
Client: Celtic Developments Penarth Limited		Dates: 07/11/2016 -	Logged By

Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Well	Legend	Stratum Description
	Depth (m)	Type	Results					
	31.00	SPT	50 (25 for 70mm/50 for 25mm)					*Extremely weak.*
								80° planar smooth fracture.
								Non intact.
				31.60				*Locally non intact. Tending to claybound tabular fine and medium gravel sized lithorelicts.*
								Very weak dark reddish brown locally spotted light greenish grey MUDSTONE. Fractures are 60° closely and medium spaced planar smooth.
	34.00	SPT	50 (25 for 50mm/50 for 35mm)	34.00				Very weak dark reddish brown locally spotted light greenish grey MUDSTONE. Fractures are subhorizontal to 30° very closely and closely spaced planar smooth.
				35.00				*2no. 60-70° planar smooth fractures.*
								Extremely weak dark reddish brown MUDSTONE. Non intact.
								50° planar smooth fracture.
								Vuggy. Vugs up to 10mm diam.
				36.00				Very stiff dark reddish brown locally light greenish grey silty CLAY.
	37.00	SPT	50 (25 for 5mm/50 for 5mm)	37.00				*70-80° curved locally stepped smooth fissure.*
								Extremely weak to very weak dark reddish brown MUDSTONE. Fracture are 5-40° very closely and closely spaced planar smooth.
								3no. 50-55° planar smooth fractures.
				38.20				Very stiff dark reddish brown locally spotted light greenish grey silty CLAY.
				38.50				Extremely weak dark reddish brown MUDSTONE. Non intact.
								Quartz vein.
								75° planar smooth fracture.
								75° undulating smooth fracture.
				40.00				Continued on Next Sheet

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Borehole No.
BH01
Sheet 5 of 5

Project Name:	North Cliff Lodge	Project No: 13124	Co-ords:	Hole Type BH
Location:	Penarth		Level:	Scale 1:50
Client:	Celtic Developments Penarth Limited		Dates: 07/11/2016 -	Logged By

Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Well	Legend	Stratum Description
	Depth (m)	Type	Results					
	40.00	SPT	50 (25 for 0mm/50 for 2mm)					End of Borehole at 40.000m

41
42
43
44
45
46
47
48
49
50

Remarks:

ANNEX B
Site Investigation Data

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Borehole No **BH01**
Sheet 1 of 2

Project Name	Project No.	Co-ords: -	Hole Type
Marine Buildings	11458		Rotary
Location: Penarth Marina, Cardiff		Level: -	Scale 1:50
Client:		Dates: 20/12/2011	Logged By APEX&TF

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								MADE GROUND. (Driller's description)
					1.40			Stiff CLAY (Driller's Description).
					3.20			Stiff CLAY and weathered MUDSTONE (Driller's description).
					4.50			Firm to stiff, tan brown to grey, gravelly CLAY. Gravel is fine to coarse, subangular to subrounded of mudstone. Laminated in places.
					6.00			Stiff, tan brown, gravelly CLAY with occasional cobbles. Gravel is fine to coarse, subangular to subrounded of mudstone.
		7.50-9.00	27	5 0	7.50			Very weak MUDSTONE. Recovered as grey cobbles with red mottling and staining. (MMG)
		9.00-10.50	66	40 1 +8	9.00			Very weak to moderately weak red brown MUDSTONE with light blue grey separations. Fractures are very closely spaced rough and stepped. (MMG) 45 degree smooth fracture with dark staining. 45 degree rough fracture
			TCR	SCR RQD FI				

Continued next sheet

Remarks:

AGS

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Borehole No
BH01
Sheet 2 of 2

Project Name	Project No.	Co-ords: -	Hole Type
Marine Buildings	11458		Rotary
Location: Penarth Marina, Cardiff		Level: -	Scale 1:50
Client:		Dates: 20/12/2011	Logged By APEX&TF

Well	Water Strikes	Rotary Coring Depth (m)	TCR	SCR	RQD	FI	Depth (m)	Level (m AOD)	Legend	Stratum Description
										Remaining Detail : 9.66m - 9.66m : Horizontal smooth fracture with dark brown staining.
							10.50			End of Borehole at 10.50 m

11 12 13 14 15 16 17 18 19

Remarks:

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Borehole No **BH02** Sheet 1 of 2

Project Name	Project No.	Co-ords: -	Hole Type
Marine Buildings	11458		Rotary
Location: Penarth Marina, Cardiff		Level: -	Scale 1:50
Client:		Dates: 20/12/2011	Logged By APEX&TF

Well	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Soft to firm, tan brown, gravelly CLAY. Gravel is fine to coarse, subangular to subrounded of mudstone.
					0.50			Firm to stiff, tan brown, gravelly CLAY. Gravel is fine to coarse, subrounded of mudstone.
					1.10			
					1.20			Very stiff, tan brown, CLAY with lithorelicts of mudstone.
								Very stiff, tan brown, gravelly CLAY. Gravel is fine to coarse, angular of mudstone with lithorelicts.
					2.70			Very stiff, tan brown, CLAY with lithorelicts of mudstone.
					4.20			No recovery.
					5.70			
					5.90			Fine to coarse, angular to subangular GRAVEL of mudstone and possible calcified gypsum.
	▽							Very stiff, tan brown, gravelly CLAY. Gravel is fine to coarse, angular of mudstone.
					7.20			Weak MUDSTONE. Recovered as grey and occasionally red, clayey, fine to coarse, angular to subangular GRAVEL of mudstone.
					8.70			Weak MUDSTONE. Recovered as medium to coarse, angular, red, GRAVEL of mudstone.
					9.50			Weak MUDSTONE. Recovered as fine to coarse, angular, red, GRAVEL of mudstone. Red staining and mineralisation.
			Type	Results				Continued next sheet

Remarks:

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Borehole No **BH02** Sheet 2 of 2

Project Name	Project No.	Co-ords: -	Hole Type
Marine Buildings	11458		Rotary
Location: Penarth Marina, Cardiff		Level: -	Scale 1:50
Client:		Dates: 20/12/2011	Logged By APEX&TF

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results			Depth (m)	Level (m AOD)	Legend	Stratum Description
										Weak MUDSTONE. Recovered as fine to coarse, angular, red, GRAVEL of mudstone. Red staining and mineralisation.
							10.50			Weak MUDSTONE. Recovered as fine to coarse, angular, red and grey, GRAVEL of mudstone. Red staining and mineralisation.
		10.50-12.00	66	10	15					
							12.00			Weak MUDSTONE. Recovered as red, fine to coarse, angular, gravel.
							12.40			45 degree smooth red brown stained fracture
		12.00-13.50	90	13	20	+15				Weak to moderately weak, red and grey banded MUDSTONE. 75 degree smooth fracture with red brown staining. Closely spaced horizontal stepped fractures.
							13.50			45 degree smooth red brown stained fracture.
							13.90			Weak MUDSTONE. Recovered as fine to coarse, angular, red, GRAVEL of mudstone. Red staining and mineralisation and calcified gypsum.
		13.50-15.00	73	27	16					Weak to moderately weak, red and grey banded MUDSTONE. Horizontal red brown stained fracture. 45 degree smooth red brown stained fracture.
							15.00			End of Borehole at 15.00 m
			TCR	SCR	RQD	FI				

Remarks:

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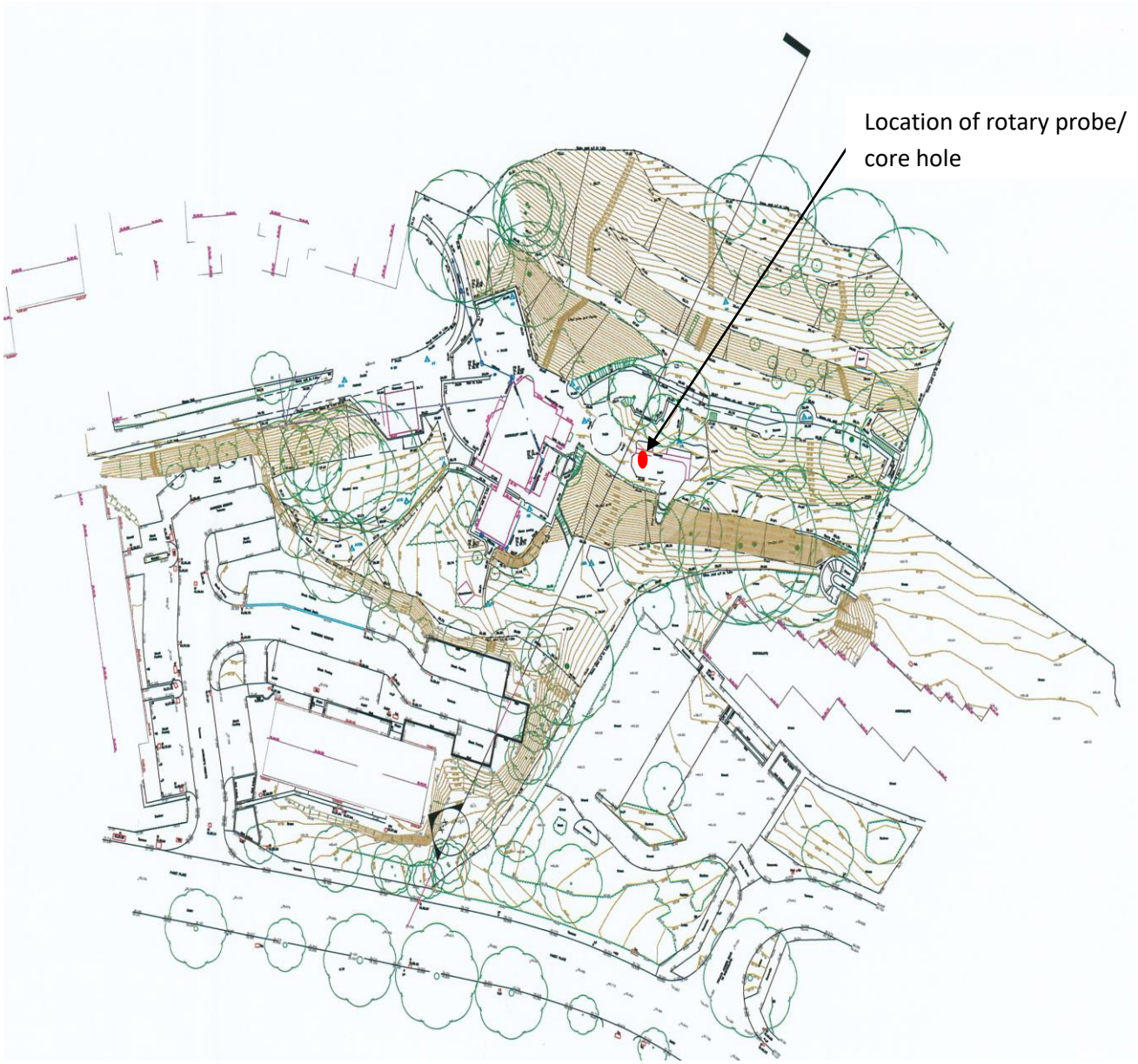
Borehole No **BH03** Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Hole Type
Marine Buildings	11458		RO
Location: Penarth Marina, Cardiff		Level: -	Scale 1:50
Client:		Dates: 20/12/2011	Logged By APEX

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Backfill (Drillers Description)
		1.20	CPT	N=13 N=13 (3,3,3,2,4,4)	1.20			Clay and Gravel (Drillers Description)
		3.00	CPT	N=6 N=6 (3,3,2,1,2,1)	3.30			Alluvium (Drillers Description)
		4.50	CPT	N=3 N=3 (1,0,1,0,1,1)	5.80			Weathered Mudstone (Drillers Description)
		6.00	CPT	N=41 N=41 (7,6,8,10,10,13)	6.00			Weathered Mudstone and Clay (Drillers Description)
		7.50	CPT	N=12 N=12 (2,3,3,2,3,4)	7.30			Clay (Drillers Description)
		9.00	CPT	N=15 N=15 (3,3,2,2,4,7)	8.80			Weathered Mudstone and Clay (Drillers Description)
			Type	Results				End of Borehole at 10.00 m

Remarks: No ground water encountered.

AGS



terrafirma

Job Number:

13124

Job Title:

Northcliff Lodge Penarth

Drawing Title:

Site Layout

Drawing Number:

01

Scale:

Not To Scale

North

terrafirma

Job Number:

11458

Job Title:

Marine Buildings, Penarth Marina

Drawing Title:

Site Investigation Data

Drawing Number:

02

Scale:

Not To Scale

Legend:

TP01 — Position of machine excavated trial pit

SA02 — Position of cable percussive borehole

BH03 — Position of rotary borehole