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BALLINA SHIRE COUNCIL

GEOTECHNICAL REPORT ON LANDSLIDE REMEDIATION COAST ROAD, LENNOX HEAD

10644/1-C July 2011

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Attention: Mr Paul Busmanis

RE: LANDSLIDE REMEDIATION, COAST ROAD, LENNOX HEAD

Please find attached our report on geotechnical studies for the remediation of a landslide at the above location. The report presents the results of field investigations, laboratory testing and slope stability studies and presents options for remediation of the landside and the adjacent areas.

If you have any questions or wish to discuss or clarify any of the issues raised in this report, please contact Philip Shaw at our Brisbane office.

For and on behalf of

SHAW URQUHART PTY LTD

Philip Shaw

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1. INTRODUCTION

This report describes geotechnical studies carried out by Shaw Urquhart Pty Ltd at the site of a landslide on Coast Road, approximately 1km south of Lennox Head. At this location, Coast Road, the main transport route between Lennox Head and Ballina, is located on a fill embankment which carries the two-lane road over a broad embayment in the hillside. The embankment is around 200m long and rises to approximately 7m above the natural ground level. It is understood to have been constructed around 1971, with a footpath berm added in 1995-1996.

In January 2011, a 40m-long section of the north eastern (down-slope) side of the embankment experienced a landslide, and a further 50m of tension cracking extended north westerly along the Coast Road shoulder. The landslide occurred progressively over a number of days and resulted in an approximately 4m-high slip scarp in the edge of the south-bound carriage-way. The south bound lane was closed to traffic and remains closed at the time of preparing this report.

It is understood that the embankment has been subject to creep and on-going minor pavement cracking since 2005.

Shaw:Urquhart was commissioned by Council to carry out geotechnical studies to assess local subsurface and geological conditions, identify the failure mechanism and extent of the failure and formulate options for stabilisation and remediation of the road embankment.

2. FIELD WORK

Field work for the geotechnical studies consisted of the following elements:

- At the request of Council, an initial visit to the site was carried out by a Geotechnical Engineer from our Brisbane office (Dr. Philip Shaw) on the morning of 7 January 2011. Discussions were held with Paul Busmanis, Greg Heathwood and Max Beecher of Council regarding clearing of vegetation and survey work to assist with identifying the extent of the landslide and providing slope geometry for use in slope stability analyses.
- Subsequent to clearing of the vegetation along survey lines and around the perimeter of the landslip, an Engineering Geologist from our Brisbane office visited the site on 12 January 2011 to map the site features and local surface geology and to assess site access for subsurface investigations.
- Eight test pits were excavated at selected locations on 1 February 2011 and a further single test pit (TP3A) was excavated and test pit TP7 deepened on 8 March 2011. The test pits were excavated in the full time presence of an Engineering Geologist who was responsible for locating the test pits, preparing field logs of the soil profiles encountered and retrieving representative soil

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samples as required. Test pit locations, with the exception of test pit TP8, were pegged and surveyed by Council.

- Four boreholes were drilled to depths of between 12.75m (borehole BH1) and 15.75m (borehole BH4) between 3 February 2011 and 10 February 2011. The boreholes were all located on the pedestrian access path which runs along the central part the north-eastern embankment batter. Boreholes BH1 and BH2 were located within the landslide area, borehole BH3 was located approximately 10m north-west of the landslide and borehole BH4 was located approximately 60m north-west of the landslide.
- The boreholes were drilled in the full time presence of a Geotechnician who was responsible for locating the boreholes, nominating and directing sampling and testing and preparing field logs of the soil profiles encountered. Boreholes were drilled using auger techniques until an obstruction or increased resistance was encountered. The boreholes were then deepened using diamond coring techniques. The borehole locations were pegged and surveyed by Council.

3 SITE CONDITIONS

3.1 Surface Conditions

The site is located approximately 1km to the south east of Lennox Head where Coast Road crosses a gently-curved fill embankment which carries the two-lane road over a broad embayment in the hillside.

To the south west of the embankment, natural hill slopes rise steeply to the crest of a prominent escarpment. At the base of these slopes, the ground levels out to fall at around 10° to the north east, under the road embankment and towards the nearby coastline.

The height of the crest of the embankment above natural ground is typically around 7m at the south eastern end and 5m towards the north western end. The embankment profiles at selected locations are shown on the survey cross-sections presented in Appendix D. From these survey cross-sections it appears that the down-slope, north eastwards-facing batter was formed at around 30° to 45° , steeper towards the south eastern end. The batter has a stepped profile, with a 3m-wide berm forming a pedestrian access pathway. In the area of the landslide, it appears that around 1m to 1.5m of fill has been placed on the ground to the north east of the embankment for a distance of around 10m to 12m from the toe of the road embankment.

The batter on the up-slope side of the embankment is typically around 2m high and formed at around 30° . The embankment cuts off the natural drainage paths from the adjacent hill slopes and an unlined drain runs along the up-slope side of the embankment to collect surface water flow and channel it into a stormwater pipe crossing under the embankment towards its north western end.

Vegetation cover on the road embankment batters is grass, with long cane grass on the filled area to the north east of the road embankment and areas of scrub and low trees.

The landslide is around 40m in length and occurred towards the south eastern end of the embankment. The rear scarp of the failure, located adjacent to the edge of the south-bound road seal, is approximately semi-circular with a central straight section and, at the time of the investigations, was approximately 3.8m in vertical height at its highest point. The ground level at the base of the scarp, on the pedestrian pathway, appears to have dropped by between 1m and 2.2m and "before and after" survey cross-sections provided by Council indicate that the toe of the embankment has moved down-slope by around 6m to 7m.

A number of large, open ground cracks were noted within the failure zone, resulting in terracing of a section of the rear scarp on the north western end and, what appears to be rotated soil masses, in the central area of the landslide.

3.2 Local Geology and Subsurface Conditions

According to the published geology map of the area (1:100,000 scale "Lismore" sheet), the site is underlain by weathered volcanic rocks of the Tertiary Lismore Basalt. This was confirmed by site observations.

Generally, the site is underlain by varying thickness of embankment fill underlain by natural colluvial soils.

The embankment fill consists predominantly of red brown, silty clay with varying amounts of gravel. Other soils types present include but may not be limited to clayey gravel, clay/gravel/cobble layers and sand.

The natural soils present on site consist predominantly of silty clay and silty gravelly clay, varying in colour from dark grey to blue grey and grey brown, with red brown and orange mottling. The natural clay soils are generally blocky and friable to varying degrees. Layers containing basalt gravel, cobbles and occasional boulders are present. These soils are interpreted to be colluvium and/or hillwash, derived from the down-slope movement of soils from the nearby raised escarpment.

The subsurface conditions encountered in each borehole and test pit are summarised in Table 1.

Test Location	Generalised Soil Profile				
	FILL	Silty CLAY/Clayey SILT	SAND, Clayey SAND	Gravelly CLAY/Clayey GRAVEL	GRAVEL, COBBLES, BOULDERS
			Depth (m)		
BH1	0.0-4.4	4.4-5.0, 8.6- 10.4, 10.85- 12.2		5.0-8.6	10.4-10.85, 12.2-12.75
BH2	0.0-4.0	4.0-13.9			13.9-15.0, 15.0-15.6
BH3	0.0-2.9	2.9-3.3, 5.0- 6.5, 7.0- 12.5, 13.0- 14.15	3.3-4.4	4.4-5.0, 6.5- 7.0,	12.5-13.0
BH4	0.0-1.6	1.6-2.5, 4.0- 10.55, 13.8- 14.6	11.0-13.5	2.5-4.0, 14.8-15.4	10.55-11.0, 13.5-13.8, 14.6-14.8, 15.4-15.75
TP1	0.0-2.0	2.0-4.1			
TP2	0.0-0.8	0.8-3.0			
TP3	0.0-2.1	2.1-4.2			
ТРЗА	0.0-1.8	1.8-5.7, 6.3- 6.4			5.7-6.3
TP4	0.0-1.3	1.3-2.0			
TP5	0.0-1.8	1.8-4.1			
TP6	0.0-1.0	1.0-3.2			
TP7	0.0-4.1	4.1-6.0			
TP8	0.0-1.0	1.0-2.5			

TABLE 1: SUMMARY OF SUBSURFACE CONDITIONS

Engineering logs of the boreholes and test pits are presented in Appendix A along with explanation sheets describing the terms and symbols used. Borehole and test pit locations are shown on Figure 1.

3.3 Groundwater

Groundwater inflows were encountered in a number of the boreholes and test pits in various materials and at different depths. These groundwater levels are summarised in Table 2.

Test Location	Depth (m)	Standing Water Level Depth (m)
BH1	NR	NR
BH2	2.8	4.0
BH3	NR	NR
BH4	NR	NR
TP1	2.0	NR
TP2	0.8	NR
TP3	2.3	NR
ТРЗА	4.2	NR
TP4	1.0	NR
TP5	NE	NE
TP6	1.0	NR
TP7	1.5	NR
TP8	NE	NE

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NR -Not Recorded NE - Not Encountered

4. LABORATORY TESTING

Atterberg limits tests along with a direct shear test, were carried out on an undisturbed sample of firm clay from 5.5m depth in borehole BH2.

The results are presented in Appendix B.

The direct shear test obtained peak shear strength parameters of cohesion 68.10kPa and friction angle 37.7° reducing to residual shear strength parameters of cohesion 60.9kPa and friction angle 37.5° . These results are not consistent with expectations for firm clay and have been ignored in the analyses. From discussions with the testing laboratory, the sample may have contained a localised concentration of peat fibres which have resulted in the unexpected higher strength.

5. GEOTECHNICAL ENGINEERING DISCUSSION

5.1 Construction History

From information provided by Council, it is understood that the Coast Road embankment was originally constructed around 1971. A toe berm was constructed around 1995/1996 to provide support for the existing road batter and to form a pedestrian access pathway.

It is understood that the current landslide occurred on or around 7 January 2011 after a period of heavy rainfall. Eyewitness reports indicate that the initial movement comprised tension cracking with minor slumping (in the order of 0.3m) over a limited length of the embankment, but that the movement continued over a period of several days until the rear scarp was around 4m in vertical height over a length of about 40m, with the crest of the scarp at the edge of the bitumen seal.

5.2 Landslide Geometry and Mode of Failure

The landslide is located at the south eastern end of the embankment on the north eastern, sea-ward side. The zone of ground movement is approximately 40m long (north west-south east) by 35m wide (south west – north east). A survey record of topographic features and site observations relating to the landslide is shown on Figure 1.

In plan view, the rear scarp of the landslide is broadly semicircular and has extended approximately 0.8m behind the crest of the embankment batter. The height of the rear scarp of the landslide is around 4m. The body of the landslide is crossed by a number of large, open ground cracks, some of which are shown on Figure 1. The north western side of the landslide is terraced, with approximately three small slip scarps with vertical heights of around 0.2m to 0.6m.

From survey and site observations, the surface of the pedestrian path has dropped by a round 1m at the north western end of the landslide and 2.2m at the south eastern end. Evidence of off-sets of layers of soil in test pit TP7 indicated that the rear scarp of the landslide has a vertical displacement of approximately 2.4m.

In terms of the mode of failure of the landslide, surface survey data and observations from test pit TP7 of the shape of the slip plane indicates that the landslide is formed from two to three rotated blocks and possibly one translational or lateral sliding block of soil, with the base of the landslide located within or at the base of a layer of natural firm silty clay. This model closely fits the geometry of the upper and middle part of the landslide however the lack of evidence of an obvious failure plane or zone of significant soil disturbance at the toe of the landslide is problematic. Also, site observations indicate that the landslide has rotated in a horizontal plane with the centre of rotation in an area approximately 15m north-west of test pit TP5.

An interpreted cross-section geometry of the landslide based on survey Cross-Section 2 is shown on Figure 2.

The trigger for the landslide is speculative, but raised groundwater levels in the natural soils and in permeable soil layers within the embankment are likely to be contributing factors.

5.3 Remedial Works – Within Landslide Area

5.3.1 Computer Stability Analyses

Computer stability analyses of the landslide were carried out with the assistance of the computer program SLOPE/W. The analyses were carried out in two stages, as follows:

- Stability analysis of the landslide to confirm assumptions regarding the soil effective stress shear strength parameters and groundwater conditions at the time of failure.
- Formulation of options for remedial works.

Stability analyses were carried out for the pre-failure batter geometry as interpreted from previous survey provided to Shaw:Urquhart by Council. The analyses indicated that the original batter had a factor of safety of around 1.0 for raised groundwater conditions. It is expected that this would result in initial creep movement of the outer part of the batter followed by larger-scale movement as soil peak shear strength parameters reduced to residual shear strengths. It is understood that heavy rainfall at the time of failure may have raised the groundwater level within the embankment to a critical level.

The stability analyses for the remedial works were carried out using assumed effective stress shear strength parameters for the various soil materials, based on our experience with similar soil types elsewhere. The analyses considered both raised groundwater levels and suppressed groundwater levels where additional drainage measures are proposed. A traffic loading of 20kPa was also assumed.

The design of the remedial works adopted a target factor of safety of not less than 1.5 for long term operating conditions for the re-constructed embankment.

A number of options for remediation of the landslide area were assessed. These included the following:

- Excavation and replacement of the failed soil mass with reconstruction of the outer face of the road embankment and construction of a toe berm to support the new construction. This option does not provide an adequate factor for safety.
- Partial or total excavation of the foundation soils beneath the road embankment in conjunction with the use of geofabric reinforcement and/or improved drainage. These options are feasible and would permit reconstruction of the pedestrian access path.
- Leaving the landslide debris in place and supporting the existing batter using bored piles at the crest of the existing road embankment or supporting a reconstructed batter using bored piles on the existing footpath alignment. Only a

preliminary design has been carried out at this stage but these options are feasible. The footpath alignment would need to be permanently closed unless further works were carried out to stabilise the landslide area.

The geotechnical issues relating to each of the above options are discussed in Section 5.3.2. For the purpose of remedial design, Cross Section 2 has been taken as representative of the landslide area.

5.3.2 Options for Landslide Area Remediation

5.3.2.1 Construction of Toe Berms

This option has been considered in an attempt to minimise the amount of earthworks carried out at the site whilst allowing reconstruction of the pedestrian access path.

It has been assumed that the landslide debris will be excavated and replaced with engineered fill. The outer face of the road embankment will be reinstated with batter slopes no steeper than 1V:2H and two berms. The location of the berms will vary depending on the location of the pedestrian access path but for the purpose of analyses the upper berm has been assumed at RL20.5m and 3m wide and the lower berm has been assumed at RL19m and 2m wide.

Computer stability analyses were carried for a variety of different heights and widths of rock-fill toe berms constructed at the base of the re-constructed embankment to provided additional toe support. The results of the analyses indicated that this option was not feasible as the potential slip surfaces simply moved towards the down-slope side of the embankment without an acceptable increase in factor of safety. This was due to the presence of the soft to firm clay layer within the foundation subsurface profile.

This option does not provide an adequate factor of safety.

5.3.2.2 Partial or Total Excavation & Replacement of Foundation Soils

These options are shown in schematically on Figures 3 to 6 and allow for reconstruction of the pedestrian access path. The requirement for partial or total excavation will depend on the nature of the replacement materials, drainage conditions and the factor safety considered acceptable to Council.

Computer stability analyses indicate that it is necessary to excavate and replace the landslide debris and the low strength foundation soils (soft to firm clay) down to the surface of the stiff clay which was encountered at about 6.5m to 7m depth in boreholes BH1 and BH2. The inferred extent of excavation and replacement for each option is shown on Figures 3 to 6.

In order to maintain stability during excavation and replacement of the foundation soils it is necessary to entirely remove the existing road embankment. Preliminary analyses indicate that a short term factor of not less than 1.3 can be achieved during construction and after the road embankment is removed by excavating at 40° with a 2m wide mid-

height bench. Depending on the actual conditions exposed at the time of construction it may be possible to excavate with steeper slopes.

Test pit TP7 encountered a loose layer of gravel and cobbles in a silty clay matrix with strong seepage and organic odour within the central part of the existing embankment. This suggests that unsuitable material may have been disposed of by encasing it within the core of the embankment.

It has been assumed that the road embankment will be reinstated with batter slopes no steeper than 1V:2H and two berms. The location of the berms will vary depending on the location of the pedestrian access path but for the purpose of analyses the upper berm has been assumed at RL20.5m and 3m wide and the lower berm has been assumed at RL19m and 2m wide as shown on Figures 3 to 6. It has been assumed that the road embankment will be constructed of clayey materials similar to the existing construction.

Different factors of safety are obtained depending on the nature of the material used in the replacement zone, the adequacy of subsurface drainage and whether geofabric reinforcement is used in the reconstruction of the road embankment. The factors of safety for each option are presented in Table 3.

The results of the stability analyses suggest that feasible options are clay replacement in conjunction with geofabric reinforcement or rock fill replacement. The use of geofabric reinforcement in conjunction with the rock fill is not necessary but if used will provide increased global stability.

If graded rock fill is to be used, geofabric separation layers will be required above and below the rock fill. A free draining, durable, well graded, crushed rock fill material with a maximum particle of 150mm is recommended. The material should be placed in layers not exceeding 300mm in thickness and compacted by a minimum of 6 passes of a smooth drum vibrating roller or grid roller of at least 10 tonne static weight. The compaction should continue until no further reduction of the layer surface height occurs.

The free draining rock fill will be able to accommodate seepage from the surrounding area and will not be susceptible to softening during periods of elevated groundwater levels such as may occur during periods of prolonged intense rainfall.

The installation of high strength, uniaxial woven geofabric layers at the base of the reconstructed embankment will assist in improving stability. The analyses indicate that two layers of 200kN working strength uniaxial woven geofabric would be required, installed at the base of the embankment during the early stages of the embankment reconstruction.

The lowered groundwater level option assumes that subsurface drains can be installed to lead water from the rock fill replacement zone and permanently maintain a lowered groundwater level beneath the road embankment.

Toe drains and table drains under the embankment should be constructed for the clay fill option to prevent raised groundwater levels developing within the road embankment.

Condition Analysed	Factor of Safety		
	Clay Fill in Replacement Zone	Graded Rock Fill in Replacement Zone	
Partial replacement with elevated groundwater levels	1.31*/1.35	1.40*/1.51	
Partial replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.59	1.64	
Partial replacement with lowered groundwater levels	Not considered feasible	1.41*/1.58	
Total replacement with elevated groundwater levels	1.35*/1.36	1.45*/1.56	
Total replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.61	1.74	
Total replacement with lowered groundwater levels	Not considered feasible	1.61*/1.69	

TABLE 3: FACTORS OF SAFETY FOR EXCAVATION & REPLACEMENT

* Factor of safety of lower berm.

5.3.2.3 Piled Support

These options are shown in schematically on Figures 7 and 8 and been considered to minimise work within the landslide area. The pedestrian access path would need to be permanently closed unless further works were carried out to stabilise the landslide area.

The options involve leaving the landslide debris in place and supporting the existing batter using bored piles at the crest of the existing road embankment (Figure 7) or supporting a reconstructed batter using bored piles on the existing footpath alignment (Figure 8). Only a preliminary design has been carried out at this stage and further detailed analyses would be required, along with the involvement of a specialist piling contractor if these options are to be considered further.

Preliminary design indicates that for the option shown on Figure 7, 20m long, 1200mm diameter piles at 1.8m centres will provide an adequate factor of safety. Lateral deflections at the pile head are estimated to be in the order of 80mm. The piles would be installed from the existing road embankment and for in-service use would require the road to be moved towards the hillside to provide sufficient width for a road shoulder. It is assumed that road crash barriers could constructed within the capping beam. It will also be necessary to construct shotcrete or panel facing on the upstand section of the piles to bridge the gaps between the piles and support the soil.

The option shown on Figure 8 assumes that the outer face of the road embankment will be reconstructed at 1V:2H with the toe supported by a capping beam connected to 15m long, 1200mm diameter piles at 1.8m centres. Lateral deflections at the pile head are estimated to be in the order of 100mm. Preliminary discussions with Wagstaff Piling indicate that to enable this option to be constructed will require a temporary working platform to be constructed across the landslide zone using layers of geofabric and gravel supported on timber piles driven into the underlying natural profile.

If the pedestrian access path is to be reinstated, further stabilisation works will be necessary.

5.4 Remedial Works – Outside of Landslide Area

5.4.1 Computer Stability Analyses

Tension cracks were observed in the road shoulder to the north of the landslide as shown on Figure 1.

Cross Section 6 was selected as being representative of this area and the subsurface profile of borehole BH3 was used in the analyses of the stability of the existing road embankment. The subsurface profile is similar to that at the landslide location in that there is a significant layer of soft to firm clay at depth beneath the road embankment.

For assumed peak shear strength parameters and groundwater conditions similar to those likely to have occurred at the time of the landslide to the south, a factor of safety of about 1.3 was estimated. This is less than would generally be desirable at this location. If the subsidence observed in the existing road embankment is assumed to be due to the presence of the soft to firm clay layers and the shear strength is reduced slightly to take account of strain softening, a factor of safety approaching 1.0 can be readily obtained with the rear scarp of the potential failure surface at approximately the location of the existing tension cracks.

If large scale failure of the road embankment, as has occurred further to the south, is to be avoided, it is recommended that remedial works be carried out to arrest the creep movement and improve the stability of the embankment in the area extending from the current landslide to the car-park area to the north.

5.4.2 Options for Remediation

5.4.2.1 Partial Excavation & Replacement of Foundation Soils

This option is shown in schematically on Figures 9 and 10 and includes provision for the pedestrian access path.

Computer stability analyses indicate that it is necessary to excavate and replace the low strength foundation soils (soft to firm clay and firm to stiff clay) down to the surface of the very stiff clay which was encountered at about 8.2m depth in borehole BH3 which is approximately 1m deeper than at the landslide location. The inferred extent of excavation and replacement is shown on Figures 9 and 10.

In order to maintain stability during excavation and replacement of the foundation soils it is necessary to entirely remove the existing road embankment. Construction excavation batter slopes similar to those recommended in Section 5.3.2.2 will be acceptable.

It has been assumed that the road embankment will be reinstated with batter slopes no steeper than 1V:2H and one berm at about mid-height. The location of the berm will vary depending on the location of the pedestrian access path but for the purpose of analyses the berm has been assumed at RL18m and 3m wide. It has been assumed that the road embankment will be constructed of clayey materials similar to the existing construction.

Different factors of safety are obtained depending on the nature of the material used in the replacement zone, the adequacy of subsurface drainage and whether geofabric reinforcement is used in the reconstruction of the road embankment. The factors of safety for each option are presented in Table 4.

Condition Analysed	Factor of Safety		
	Clay Fill in Replacement Zone	Graded Rock Fill in Replacement Zone	
Partial replacement with elevated groundwater levels	1.18*/1.28	1.49	
Partial replacement with elevated groundwater levels and two layers of 200kN geofabric at base of road embankment fill	1.58	1.65	
Partial replacement with lowered groundwater levels	Not considered feasible	1.64	

TABLE 4: FACTORS OF SAFETY FOR EXCAVATION & REPLACEMENT

* Factor of safety of lower berm.

As for the landslide area, the results of the stability analyses suggest that feasible options are clay replacement in conjunction with geofabric reinforcement or rock fill replacement. The use of geofabric reinforcement in conjunction with the rock fill is not necessary but if used will provide increased global stability.

If graded rock fill is to be used, geofabric separation layers will be required above and below the rock fill. A free draining, durable, well graded, crushed rock fill material with a maximum particle of 150mm is recommended. The material should be placed in layers not exceeding 300mm in thickness and compacted by a minimum of 6 passes of a smooth drum vibrating roller or grid roller of at least 10 tonne static weight. The compaction should continue until no further reduction of the layer surface height occurs.

The free draining rock fill will be able to accommodate seepage from the surrounding area and will not be susceptible to softening during periods of elevated groundwater levels such as may occur during periods of prolonged intense rainfall.

The installation of high strength, uniaxial woven geofabric layers at the base of the reconstructed embankment will assist in improving stability. The analyses indicate that two layers of 200kN working strength uniaxial woven geofabric would be required, installed at the base of the embankment during the early stages of the embankment reconstruction.

The lowered groundwater level option assumes that subsurface drains can be installed to lead water from the rock fill replacement zone and permanently maintain a lowered groundwater level beneath the road embankment.

Toe drains and table drains under the embankment should be constructed for the clay fill option to prevent raised groundwater levels developing within the road embankment.

5.4.2.2 Piled Support

This option is shown in schematically on Figure 11.

Stability analyses indicate that a piled solution providing lateral support of 300kN/m length of embankment will increase the factor of safety of the existing embankment to greater than 1.5. For the soil profiles in boreholes BH3 and BH4, this can be achieved by installing 12m long, 900mm diameter piles at 1.5m centres along the pedestrian access path alignment. It is recommended that the piles be connected by a capping beam.

In addition to the piles it is recommended that 150mm diameter subsurface drains be drilled into the base of the road embankment as shown on Figure 11 at not less than 3m centres. It will be necessary for the drains to be spaced between the piles.

5.5 Other Necessary Remedial Works

In addition to the specific items discussed for each remedial option it will be necessary to improve the existing stormwater drainage associated with the road embankment.

An adequately sized, fully lined table drain should be constructed on the up-hill side of the embankment. Stormwater collected by this drain should be conveyed in pipes through the embankment and discharged on the down-hill side of the embankment. The discharge should be sufficiently down-slope so as not to result in water infiltrating the embankment foundation. Adequate erosion protection should be provided at both the inlet and outlet structures.

It is recommended that suitably experienced personnel inspect the exposed foundation materials at the time of construction and prior to placing backfill or embankment fill to ensure that the exposed conditions are consistent with the design assumptions.

All earthworks should be carried out in accordance with guidelines of AS3798-2007. It is recommended that fill placement be carried out under Level 1 supervision as described in AS3798.

6.0 PRELIMINARY COST ESTIMATE OF PROPOSED REMEDIAL WORKS

6.1 Earthworks Options

It is understood that preliminary estimates of costs associated with the earthworks options (excavation and replacement) will be prepared by Ballina Shire Council.

There are a number of options and the extent of earthworks required for each option is shown on the various cross sections of Figures 3 to 6 and 9 to 10.

The approximate extent of the various earthworks options is shown in plan view on Figure 12 along with the piling options.

6.2 Piling Options

Wagstaff Piling has assisted Shaw:Urquhart is preparing preliminary cost estimates for the various piling options which are shown on the cross sections of Figures 7 to 8 and 11.

The approximate extent of the various piling options is shown in plan view on Figure 13 along with the earthworks options.

Preliminary cost estimates are as follows:-

Mobilisation/Demobilisation	\$50,000		
Within Failure Zone - Crest Piles (Refer Section 5.3.2.3)			
Chainage 1020m to 1072.2m			
30 No. 1200mm diameter piles at 1.8m centres and 20m long (14N28, W10 @ 150 spiral)	\$600,000		
Within Failure Zone – Pedestrian Access Pat	h Piles (Refer Section 5.3.2.3)		
Chainage 1020m to 1072.2m			
Preparation across failure zone – 60 No 210 diameter HW timber piles at 2m centres and 12.5m long	\$66,000		
30 No. 1200mm diameter piles at 1.8m centres and 15m long (14N28, W10 @ 150			
spiral)	\$450,000		
Outside Failure Zone – Pedestrian Access Pa	th Piles (Refer Section 5.4.2.2)		
Chainage 960m to 1027.5m			
46 No 900mm diameter piles at 1.5m centres and 12m long (10N28, W12 @ 100 spiral)	\$315,000		

Philip Shaw

For and on behalf of SHAW URQUHART PTY LTD

UNDERSTAND THE LIMITATIONS OF YOUR GEOTECHNICAL REPORT

This report has been based on project details as provided to us at the time of the commission. It therefore applies only to the site investigated and to a specific set of project requirements as understood by Shaw:Urquhart.

If there are changes to the project, you need to advise us in order that the effect of the changes on the report recommendations can be adequately assessed. Shaw:Urquhart cannot take responsibility for problems that may occur due to project changes if they are not consulted.

It is important to remember that the subsurface conditions described in the report represent the state of the site at the time of investigation. Natural processes and the activities of man can result in changes to site conditions. For example, ground water levels can change or fill can be placed on a site after the investigation is completed. If there is a possibility that conditions may have changed with time, Shaw:Urquhart should be consulted to assess the impact on the recommendations of the report.

The site investigation only identifies the actual subsurface conditions at the location and time when the samples were taken. Geologists and engineers extrapolate between then the investigation points to provide an assumed three-dimensional picture of the site conditions. The report is based on the assumption that the site conditions identified as at the investigation locations are representative of the actual conditions throughout an area. This may not be the case and actual conditions may



differ from those inferred to exist. This will not be known until construction has commenced. Your geotechnical report and the recommendations contained within it can therefore only be regarded as preliminary.

In the event that conditions encountered during construction are different to those described in the report, Shaw:Urguhart should be consulted immediately. Nothing can be done to change the actual site conditions which exist but steps can be taken to reduce the impact of unexpected conditions. For this reason, the services of Shaw:Urguhart should be retained through the development stage of a project.

Problems can occur when other design professionals misinterpret a report. To help avoid this, Shaw:Urquhart should be retained to work with other design professionals to explain the implications of the report.

This report should be retained as a complete document and should not be copied in part, divided or altered in any way.

It is recommended that Shaw:Urquhart is retained during the construction phase to confirm that conditions encountered are consistent with design assumptions. For example, this may involve assessment of bearing capacity for footings, stability of natural slopes or excavations or advice on temporary construction conditions.

This document has been produced to help all parties involved recognise their individual responsibilities.

















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APPENDIX A

ENGINEERING LOGS OF BOREHOLES & TEST PITS



Soil Description

Explanation Sheet (1 of 2)

DEFINITION: In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil.

Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 um to 200 um

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH S _v (kPa)	FIELD GUIDE				
Very Soft	<12	A finger can be pushed well into the soil with little effort.				
Soft	12-25	A finger can be pushed into the soil to about 25mm depth.				
Firm	25-50	The soil can be indented about 5mm with the thumb, but not penetrated.				
Stiff	50-100	The surface of the soil can be indented with the thumb, but not penetrated.				
Very Stiff	100-200	The surface of the soil can be marked, but not indented with thumb pressure.				
Hard	>200	The surface of the soil can be marked only with the thumbnail.				
Friable	100	Crumbles or powders when scraped by thumbnall.				

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary	Coarse grained soils: < 5%
	component.	Fined grained soils: < 15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 %
		Fine grained soils:

SOIL STRUCTURE

1	ZONING	CEMENTED		
Layers	Continuous across exposure of sample.	Weakly cemented	Easily broken up by hand in air or water.	
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water	
Pockets	Irregular inclusions of different material			

GEOLOGICAL ORIGIN

Extremely weathered material	Structure	and	fabric	of	parent	rock
Residual soil	Structure	and f	abric o	f pa	rent roc	k not

visible

Aeolian soil	eolian soil Deposited by wind.						
Alluvial soil	ial soil Deposited by streams and rivers.						
Colluvial soil	Deposited on slopes (transported downslope by gravity).						
Fill	Man made deposit. Fill may be significantly more						
	occurring soils.						
Lacustrine soil	occurring soils. Deposited by lakes.						



Explanation Sheet (2 of 2) - Soil Description

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

	(E)	cluding partic	FIELD IDENTIFI	CATION PROCEDURES	stimated mass)	USC	PRIMARY NAME	
	- Carl	E	NN NN	Wide range in grain size an intermediate	nd substantial amounts of all particle sizes.	GW	GRAVEL	
COARSE GRAINED SOILS of material less than 63 mm is larger than 0.075 mm		ELS If of coars than 2.0	CLEA GRAVE (Little or fines)	Predominantly one size or intermediate	a range of sizes with more sizes missing.	GP	GRAVEL	
		half	10.0	Non-plastic fines (for identifica	tion procedures see ML below)	GM	SILTY GRAVEL	
	ad eye)	GR More than fraction is la	GRAVELS WITH FINES (Appreciable amount of fines)	Plastic fines (for identification	in procedures see CL below)	GC	CLAYEY GRAVEL	
		NDS arse fraction is smaller 2.0 mm	NDS arse fraction is smaller 2.0 mm CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing Predominantly one size or a range of sizes with some intermediate sizes missing.		SW	SAND	
	visible to the nak					SP	SAND	
an 50%	the smallest particle (S/ all of co	т eŝ	Non-plastic fines (for identification procedures see ML below).		SM	SILTY SAND	
More that		More than hal	More than half	More than half	SANDS WIT FINES (Appreciable amount of fin	Plastic fines (for identificatio	n procedures see CL below).	SC
-	pont		IDENTI	FICATION PROCEDURES ON FI	RACTIONS <0.2 mm.			
valier	cle is a		DRY STRENGTH	DILATANCY	TOUGHNESS			
FINE GRAINED SOILS an 50% of material leas than 63 mm is sm than 0.075mm	mm parti	LAYS mit 1.50	AYS 60	None to Low	Quick to slow	None	ML	SILT
	(A 0.075	LTS & CL Liquid lin less than	Medium to High	None	Medium	CL	CLAY	
		55	Low to Medium	Slow to very slow	Low.	OL	ORGANIC SILT	
		CLAYS limit tan 50	Low to Medium	Slow to very slow	Low to medium	MH	SILT	
More th		LTS & C Liquid I reater th	LTS & C Liquid I reater th	High	None	High	CH	CLAY
		N 01	Modium to Hinb	None	Low to medium	OH	ORGANIC CLAY	

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM	TERM	DEFINITION	DIAGRAM
CRACK	A surface or discontinuity across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed.		SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content and lower strength than elsewhere.	
PARTING	A surface or discontinuity across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.		TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter- connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter.	T
SHEARED ZONE	Zone of deformation in clayey soil which may contain roughly parallel, near planar, curved or undulating boundaries containing one or more closely spaced, smooth or slickensided, surfaces. The soil within the shear zone is likely to have been significantly remoulded.	A.	TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs in some cases the soil which makes up the tube cast is cemented.	T
FISSURE	A near planar, curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	No.			


Rock Description

Explanation Sheet (1 of 2)

DEFINITIONS: Rock Substance	 Rock substar In engineeri remoulded I anisotronic 	ice, defect and mass are defined as follows: ng terms rock substance is any naturally occurring a by hand in air or water. Other material is described	ggregate of r d using soil d	ninerals and lescriptive t	d organic material erms. Homogono	which cannot be disintegrated or us material, may be isofropic or
Defect Mass	- Discontinuit - Any body of	y or break in the continuity of a substance or substan ir material which is not effectively homogeneous.	ces. It can consist	of two or	more substances	without defects, or one or more
SUBSTANCE DESC	SUBSTANCES	with one or more defects. MS:	ROCK SUP	STANCE	STRENGTH TERM	IS
ROCK NAME	Simple ro classificat	ck names are used rather than precise geological ion.	Term	-iation	Point Load Index, Is50 (MPa)	Field Guide
PARTICLE SIZE Coarse grained Medium grained Fine grained	Grain size -Mainly 0 - Mainly 0 - Mainly 0	terms for sandstone are: .6mm to 2mm .2mm to 0.6mm .06mm (just visible) to 0.2mm	Very Low	VL	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
FABRIC Massive Indistinct Distinct	Terms for cleavage - No layer - Layering - Layering parallel t	layering or penetrative fabric (eg. bedding, etc.) are: ing or penetrative fabric. or fabric just visible. Little effect on properties. or fabric is easily visible. Rock breaks more easily b layering or fabric.	Low	L	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show with firm blows of a pick point; has a dull sound under hammer. Pieces of 50mm diameter core may be broken by hand. Sharp edges of core may be friable and break during handling.
CLASSIFICATION (OF WEATHER Abbreviation	ING PRODUCTS Definition	Medium	м	0.3 to 1.0	Readily scored with a knife: a
Residual Soil	RS	Soil directly derived from the weathering of rock, the rock structure and fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.				piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
Extremely Weathered Material	XW	Material is weathered to such an extent that it has soil properties, ie. it either disintegrates or can be remoulded in water. Original rock fabric still visible.	High	н	1 to 3	A piece of core 150mm long by 50mm can not be broken by hand but can be broken by a pick with a single firm blow, more rings under hammer
Highly Weathered Rock	HW	Rock strength is changed by weathering. The whole of the rock substance is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not	Very High	VH	3 to 10	Hand specimen breaks after more than one blow of a pick; rock rings under hammer.
		recognisable. Some minerals are decomposed to clay minerals. Porosity may be increased by leaching or may be decreased due to the deposition of minerals in pores.	Extremely High	EH	More than 10	Specimen requires many blows with geological pick to break; rock rings under hammer.
Moderately Weathered Rock	MW	The whole of the rock substance is discoloured, usually by iron staining or bleaching, to the extent that the colour of the fresh rock is no longer recognisable.	Notes on I 1 . In anise perper	Rock Subs otropic rock adicular to	tance Strength: s the field guide to the anisotropy.	o strength applies to the strength High strength, anisotropic rocks
Slightly Weathered Rock	SW	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.	may bi 2. The term. makes engine 3. The	reak readily rm "extreme While the te it clear th rering prope unconfined	parallel to the plan ely low [*] is not use erm is used in AS1 eat materials in th orties. compressive str	har anisotropy. ad as a rock substance strength 1726-1993, the field guide therein at strength range have soil-like ength for isotropic rocks (and
Fresh Rock	FR	Rock substance unaffected by weathering.	anisoti	ropic rocks	which fail across I	the planar anisotropy) is typically
Notes on Weatheri 1. AS1726 sug substance w is not practi no advanteg given in AS1 2. Where phys associated "weathering"	ing: gests the term reathering cono cal to delineate e in making su (726. ical and chemic with Igneous to give the ab	"Distinctly Weathered" (DW) to cover the range of litions between XW and SW. For projects where it between HW and MW or it is judged that there is ch a distinction, DW may be used with the definition cal changes were caused by hot gasses and liquids rocks, the term "altered" may be substituted for breviations XA. HA. MA. SA and DA.	10-25 differe than h	times the nt rock type igher streng	point load index es. Lower streng th rocks.	(Isb0). The ratio may vary for th rocks often have lower ratios



Explanation Sheet (2 of 2) - Rock Description

COMMON DEFEC	TS IN ROCK MASSES Definition	Diagram	Мар	Graphic Log	DEFECT SHAP	E TERMS
Bedding	In sedimentary or volcanoclastic rocks, the layers produced by each successive deposition episode. Individual beds may be sub-millimeter to several metres in thickness.		Symbol 20°	(Note 1)	Curved Undulating	orientation. The defect has a gradual change in orientation. The defect has a wavy surface.
Cross-bedding	Also called cross-lamination. Similar to bedding but produced in sandy and silty sediments by the lateral progression of ripples and dunes. Planes may dip at around 25' to 35' to true bedding and may be planar or curved.		Ē		Stepped	The defect has one or more well defined steps. The defect has many sharp changes of orientation.
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or		30°	Keel.	Note: The asse influenced by th	essment of defect shape is partly the scale of the observation
	eg, cleavage). May be open or closed.				ROUGHNESS Slickensided	TERMS Grooved or striated surface, usually polished.
Joint	A surface or crack across which the rock has little or no tensile strength but which is not parallel or sub parallel to layering or planar anisotropy in the rock substance. May be open or closed	7	60°	X	Polished Smooth	Shiny smooth surface. Smooth to touch. Few or no surface irregularities.
Sheared Zone (Note 3)	Zone of rock substance with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge shaped blocks.	1	50'		Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.
Sheared Surface (Note 3)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided.	1	40	Z	Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than yery coarse sand paper
Crushed Seam (Note 3)	Seam with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock substance which may be more weathered than the host rock. The seam has soil properties	in the second se	30'	J.	COATING TER Clean	MS No visible coating.
Infilied Seam	Seam of soil substance usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint. Infilled seams less than 1mm thick may be described as veneer or coating on joint surface.	L	65'		Stained	No visible coating but surfaces are discoloured.
Extremely Weathered Seam	Seam of soil substance, often with gradational boundaries. Formed by weathering of the rock substance in place.	-	30'	1	Veneer	A visible coating of soil or mineral, to thin to measure; may be patchy
					Coating	A visible coating up to 1mm thick. Thicker soil material is usually described using appropriate defect terms (eg. infilled seam). Thicker rock strength material is usually described as a vein.
Notes on Defects:					BLOCK SHAPE	TERMS
 Defects dip ang cross-s 	s snown on borenoie logs generally show the le relative to the borehole axis. Geology ections and sketches generally show the				Blocky	Approximately equi- dimensional.
apparei 2. Parting graphic 3. Sheare seams	nt dip direction and angle. s and joints are not usually shown on the log unless considered significant. d zones, sheared surfaces and crushed are faults in geological terms.				Tabular Columnar	Thickness much less than length or width. Height much greater than cross section.

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AD RR			auger drilling* roller/tricone	3	C	casing			50mm diameter D disturbed sample	based on system	unified cl	assificatio	n	S F	soft
W HA			washbore hand auger						N standard penetration test (SPT) N* SPT - sample recovered	Moisture				St VSt	stiff very stiff
B V			blank bit V bit		w	/ater			Nc SPT with solid cone V vane shear (kPa)	D dry M mo	/ pist			H Fb	hard friable
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Met	hod				<u>s</u>	upport		 n ²	Notes, Samples, Tests	Classifica	tion Syn	nbols And	1 I	Consistency/Density Index
AD RP			auger screwir auger drilling*	iy '	C	casing	N	N FILL	0 ₅₀ unusturbed sample 50mm diameter D disturbed sample	based on	unified cla	assification	n I	vo very soft S soft F firm
WHA			washbore hand auger						N standard penetration test (SPT) N* SPT - sample recovered	Moisture				St stiff VSt verv stiff
B V			blank bit V bit		"	/ater			Nc SPT with solid cone V vane shear (kPa)	D dry M mo	ist			H hard Fb friable
T *bit s	shov	vn by s	TC bit suffix			water on dat	level te shown		P pressure meter Bs bulk sample	W we Wp pla	t stic limit			VL very loose L loose
e.a.			ADT		1.				R refusal	W liau	uid limit			MD medium dense

	6		sł	າa	W	:urquhart							г	D		NL			
			Shaw	Urquh	art Pty	/ Ltd ACN 108 592 623	_	_						She	enoie	NO.	BH1		
E	n	Ŋ	ne	eri	ng	Log - Cored Bor	eho	le)					Job	No.:		10644	/1	
Cli	en	t:		E	BALI	LINA SHIRE COUNCIL								Dat	e star	ted:	3.2.20	11	
Pro	oje	ct:		(COA	ST ROAD LANDSLIDE, LENN	юхн	EA	D					Dat	e com	pleted	4.2.20	11	
Во	reł	nole	Locati	on:	REFE	ER FIGURE 1								Log	ged b	y:	BD		
Co	oro	dinat	es:	5	5587	19.00mE 6813283.00mN								Che	ecked	by:			
Dri		lodel	And M	ounting	: N	1D100 TRACKED				Slo	ope:	-90	Þ			R.L.	Surface:	20.093 m	
D	rilli	ing I	nform	ation	o Ma	terial Substance				Бе	anng:	R	ock M	ass	Defe	cts	arn:		
					og very	material	þ	e	estin	nated	Is(50)		defe	ct			defect desc	cription	
method	core-lift	water	RL	depth metres	graphic lo core reco	rock type; grain characteristics, colour, structure, minor components	weatherin	alteration EL	stre	ngtn	D- diam- etral A- axial	RQD %	spacin mm		partic	type, ind ular	clination, plan coating, thi	arity, rough ckness	ness, general
NMLC			_11.0	9. <u>0</u> - -		Silty CLAY: high plasticity, red brown to orange brown and blue grey mottled, blocky, some fine to coarse grained grave and cobbles composed of slightly weathered, high strength basalt.	əl					0			- Sil an bo ba	DLLUVI ty CLA nounts g ulders o salt.	UM Y colluvium wi gravel, cobble composed of v	ith varying is and small weathered	
			_10.5	9. <u>5</u>	XXXX	CORE LOSS													-
	Ħ			-		Silty CLAY: high plasticity, red brown to orange brown and grey mottled, blocky,													-
			_10.0	10. <u>0</u>		cobbles composed of slightly weathered, high strength basalt.													-
				-								0							
				10. <u>5</u>		BASALT: grey, fine grained (cobble or	SW	/	8										-
			_9.5	-	\bigotimes														-
				-		Silty CLAY: high plasticity red brown to	_					<<							-
			_9.0	11. <u>0</u>		orange brown and grey mottled, blocky, some fine to coarse grained gravel and cobbles composed of slightly weathered													
				-		high strength basalt.													
			0.5	11. <u>5</u>															-
			_8.5	-															-
				-								0							
			_8.0	12. <u>0</u>															-
				-	KIII K	BASALT: grey, slighty weathered, high strength (cobble or small boulder)	SW	/	**										-
				12. <u>5</u>	\bigotimes		d MAC												-
			_7.5	-	X	red brown mottled, fine grained, locally grading to silty clay (extremely weathered						1							-
				-	, <u> </u>	Basalt) BH1 terminated at 12.75m	_/												-
			_7.0	13. <u>0</u>															-
				-															-
				13. <u>5</u>															
			_6.5	-															-
Me AS RF CE NN	2, H0	d Q, PQ	auge auge roller claw NML wirel	r screwin r drilling /tricone or blade C core ine core	g bit	Case-Lift Wate	water leve on date sh water inflo partial drill complete (lugeons) f interval sh	l Iown I fluid I drill flu ssure to for dep own	loss uid los test re pth	s sult		Fr SW MW HW EW	thering/A (W/A fre sli m hiç ex	Vitera) ghtly odera ghly treme	tion tely ely	Streng EL VL H H VH EH	th extremely low very low low medium high very high extremely high	Defects JT join PT par SM see PL pla CV cur IR irre RO rou SO sm SL slic	it ing mar ved gular gh ooth kensided





BOREHOLE BH1

		Shaw Urqu	ihart	Pty Lto	ACN	N 108	592 62			E	Boreho Sheet	ble No. BH2 1 of 3
n	gı	neer	IN	JL	og	- t	sore			J	lob No	.: 10644/1
ent	•		BA	LLIN	A SH	IIRE	COUI			[Date st	tarted: 7.2.2011
ojec	ct:		CO	AST	ROA	ND LA	ANDS	LIDE, LENNOX HEAD			Date co	ompleted: 8.2.2011
reh	ole L	ocation:	RE	FER	FIGU	JRE '	1			L	ogged	i by: WJB
ord	linate	es:	558	8708.	00ml	E 68	1329	5.00mN		C	Checke	ed by:
	odel /	And Mountir	ng:	MD10	00 TRA	ACKED		Slope:	-90°			R.L. Surface: 19.204 m
illi	ng Ir	formation	1	100	Mate	erial S	ubstar	ICE	J.			Datum.
LT .		notes samples,			ic log	fication ol		material		ure tion	stency/ ty index	structure and additional observations
suppc	water	lesis, elc	RL	depth metres	graph	classi symbo		soil type: plasticity or particle characteristics colour, secondary and minor components.	S,	moist condit	consis densit	
				_		SP	Grave	ly Silty SAND: fine to medium grained, brown grained gravel.	n, fine to	D	L	FILL
			19.0									
				0.5								
			18.5	-								
				_								
				1.0		СН	Silty C	LAY: high plasticity, red brown, some find an	ained	М	F-St	-
		SPT	_18.0	-			sand.	Erri ingri prasucity, red brown, some inte gr	anieu	IVI	1-31	
		N*=4		-								
				1. <u>5</u>		СН	Grave	ly CLAY: high plasticity, grey brown, fine to c	coarse	M/W		
			_17.5	-			graine	d gravel, with some cobbles.				
				-								
				2.0								PP=0kPa on auger sample.
			_17.0	-								
				25								
				- 2. <u>5</u>								
		SPT	16.5	-								PP=25kPa on SPT sample
		N*=16		3. <u>0</u>		СН	Sandy	Silty CLAY: high plasticity, dark grey, with so	ome root	W	S-F	4
			16.0	-			tibres, organi	some fine grained gravel, some basalt cobble c odour.	es and			
	_		_ 10.0	-								
	2/201			3. <u>5</u>								
	Irs 7/2		_15.5	-								
	1200h			-								
	<u> </u>			4.0		GC	Grave	ly Silty CLAY: high plasticity, dark grey brow	n, fine to		St	4
		SPT 3 2 5	_15.0	-			coarse	grained gravel, with discrete silt and clay ba	nds.			
		N*=7		-								
				4. <u>5</u>								
			14.5	-								
				50		СН	Silty C some	LAY: high plasticity, dark brown to dark grey, fine to coarse grained gravel.	, with			NATURAL/COLLUVIUM
hod		auger screwir auger drilling*	ng*	Si Si M	upport 1 mud casing	٢	N nil	Notes, Samples, Tests U ₅₀ undisturbed sample 50mm diameter	Classifica Soil Desc based on	ation Syn cription unified cla	n bols An assificatio	nd Consistency/Density Index VS very soft on S soft
		roller/tricone washbore						D disturbed sample N standard penetration test (SPT)	system			F firm St stiff
		hand auger blank bit			1-4- ···			N [*] SPT - sample recovered Nc SPT with solid cone	Moisture D dry	/		VSt very stiff H hard
ch~	wn by -	v bit TC bit			vater vater	level		v vane snear (KPa) P pressure meter Bs bulk sample	M mo W we	oist et		Fb thable VL very loose
51 IOV	wii by S	ADT			- on dat	ie snown inflow		R refusal	vvp pla WI liqi	uid limit		MD medium den:
	nod	ngi int: ject: brdinate Model / 100/us 11/10/us 11/10/us 10/00/us 1/2/200/us 1/2	shaw Urqu ngineer int: ject: ehole Location: rdinates: Model And Mounting Diameter: Illing Information roden samples, tests, etc SPT 1,2,2 N*=4 SPT 1,2,2 N*=4 SPT 1,4,12 N*=16 SPT 1,4,12 N*=16 SPT 3,27 N*=7 SPT 3,27 N*=7 SPT 3,27 N*=7	shaw Urquhart nc: BA ject: CO ehole Location: RE ordinates: 558 Model And Mounting: Diameter: Illing Information Todds samples, tests, etc and and auger screwing N*=4 SPT 1,2,2 N*=4 Info Info Info Info Info Info Info Inf	Shaw Urquhart Pty Ltd ngineering L int: BALLIN ject: COAST ehole Location: REFER intimole Location: REFER indodel And Mounting: MD14 a Diameter: 100 intimole Diameter: 110 intimole Diameter: 110	Shaw Urquhart Pty Ltd ACP Ogineering Log Int: BALLINA SF ject: COAST ROA ehole Location: REFER FIGU Intimates: 558708.00m Model And Mounting: MD100 TRA Diameter: 100 Iting Information Mate Interstee Samples, tests, etc RL depth Interstee Rist, depth Balling Interstee Samples, tests, etc Interstee Interstee Samples, tests, etc Interstee Interstee Sept Interstee Interstee Inter	Shaw Urquhart Py Ltd ACN 108 nci: BALLINA SHIRE ject: COAST ROAD LA ehole Location: REFER FIGURE for ordinates: 558708.00mE 68 Model And Mounting: MD100 TRACKED a Diameter: 100 Illing Information Material S vedage samples, tests, etc etc IL -18.0 0.5 vedage -18.0 0.5 vedage<	shaw Urquhart Pty Ltd ACN 108 592 62: nt: BALLINA SHIRE COUN int: COAST ROAD LANDS ehole Location: REFER FIGURE 1 rdinates: 558708.00mE 6813296 Model And Mounting: MD100 TRACKED a Diameter: 100 Illing Information Material Substan notes amples, tests, etc RL depth graves samples, tests, etc RL depth graves tests, etc RL depth graves tests, etc RL depth graves 100 Illing Information CH Sity C samples, tests, etc RL depth graves tests, etc RL depth graves tests, etc RL depth graves 100 Illing Information CH Sity C samples, tests, etc RL depth graves tests, etc RL depth graves 100 Illing Information CH Sity C 11.5 CH Sity C 1	Shaw Unguhar Pby Lett ACN 108 592 623 mile colspan="2">Second 2 ADD LANDSLIDE, LENNOX HEAD Interim Colspan="2">COAST ROAD LANDSLIDE, LENNOX HEAD Interim Colspan="2">COAST ROAD LANDSLIDE, LENNOX HEAD Interim Colspan="2">Second 2 ADD LANDSLIDE, LENNOX HEAD Interim Colspan="2">Interim Colspan="2">Second 2 ADD Expenses Model And Mounting: Mol 100 TRACKED Slope: adjumente: Totos Interim Colspan="2" Totos material Interim Colspan="2" Material Substance Totos Rearing Interim Rear B SP Carwelly Slity CLAY: high plasticity, or particle characteristic color, secondary and minor components. SPT Totos SP Carwelly CLAY: high plasticity, dark grey, with s SPT SP Carwelly Slity CLAY: high plasticity, dark grey, with s SPT SPT SPT Colspan="2" SPT	Shew Urguhart Pp Lid ACN 108 592 623 Page 2014 Pige 201	Shew Urquhart Py Litt ACN 108 592 623 Image: Construct a construction of the structure of the	Shee Urquhart Fy Lid. ACN 108 592 623 Speet do Nr do Nr

	S		shaw Urqu	ع لا المart آ	V:L		q L N 108 (iha 592 62	arl	t					F	Boreho	le No.	BH2	2	
Ε	n	ai	neer	ind	ı L	oa	- E	Bore	eho	le					ę	Sheet		2 of 3	14/1	
Clie	ent:	<u>9</u> .		BA	2 — LLIN	A SH	IIRE	COUI								Date st	arted:	7.2.2	2011	
Pro	jec	t:		CO	AST	ROA		NDS	LIDE,			D				Date co	ompleted:	8.2.2	2011	
Bor	reho	ole L	ocation:	RE	FER	FIGU	JRE 1	I							L	_ogged	l by:	WJE	3	
Co	ord	inate	es:	558	708.	00m	E 68	1329	5.00m	N					(Checke	ed by:			
Dril	l Mo	odel /	And Mountii	ng:	MD10	00 TR/	ACKED						Slope:	-90°			R.L. \$	Surface:	19.204 m	
lol Dr	e Di illir	iame	ter:	<u> </u>	100	Mat	orial S	ubetar	200				Bearing:				Datur	n:		
		<u>ig ii</u>	notes			Iviat	5									ex lex				
po	ort		samples,			nic log	ificatio				material				ture	stenc ity ind		struc additional	cture and l observations	
meth	ddns	watei	10010, 010	RL	depth metres	grapł	class symb		soil typ colou	pe: plasti ur, secon	city or particl dary and min	le chara lor comp	cteristics	,	moist	consi densi				
AU							СН	Silty C	LAY: hi	igh plasti oarse gra	icity, dark bro ained gravel.	own to d	ark grey, ued)	with	М	F				
				14.0	-					g.	g	()							
					5. <u>5</u>															
				13.5	_															
			U50		-												PP=60kPa	9		
				-	6. <u>0</u>															
				_13.0	-															
					-															
					6.5		СН	Silty C	LAY: h	igh plasti	icity, pale bro	own.				St	-			
				_12.5	-					0	271									
					-															
				-	7. <u>0</u>															
			SPT 2,2,7	_12.0	_															
			N"=9		75															
			U50	1	-															
				11.5	-												PP=150kF	Pa		
					8. <u>0</u>															
				_11.0	-															
				- ···																
					8. <u>5</u>		СН	Silty	LAY	igh nlasti	icity, arev bro	own to re	ed brown	mottled		St-VSt				
			SPT 5 7 8	_10.5					10	3 5.000	, 9.07 010		- 5.000				DD-2001-	Da		
			N*=15															a		
				1	9.0															
				_10.0																
					95															
					J. <u>J</u>															
				_9.5																
					10.0															
l eti S	hod		auger screwir	ng*	Su M	ipport mud	Ν	l nil	Notes, U ₅₀	Samples, undistu	Tests urbed sample			Classific Soil Des	ation Syn cription	nbols An	d	Consiste VS	ncy/Density Index very soft	
D R			auger drilling' roller/tricone	•	C	casing			D	50mm disturb	diameter ied sample	-1/00-		based on system	unified cla	assificatio	'n	S F	soft firm	
A			washbore hand auger black bit						N N*	SPT -	ra penetration tes sample recovere	st (SPT) ed			,			St VSt H	stiff very stiff	
			V bit TC bit		w	ater	lovel		V	Vane s	hear (kPa) Ire meter			M m W w	/ Dist #			Fb VI	friable	
oit s .a.	show	/n by s	Suffix ADT		-⊻	- on da	ievei te shown		Bs R	bulk sa refusal	ample			Wp pla WI lig	astic limit uid limit			L MD	loose medium dens	se
						- water	inflow		E	enviror	nmental sample							D VD	dense	ĺ

	S		Shaw Urqu	}V Ihart	V:l		QU 108 :	11 3 592 62	art ³		Γ	Boreho	le No.	BH2	
E	'n	qi	neer	ind	a L	oq	- E	Bore	ehole		:	Sheet Job No	3 (of 3 10644/1	
Clie	ent	:		BA		A SH	IIRE	COU	NCIL		1	Date st	arted:	7.2.201	1
Pro	ojeo	ct:		со	AST	ROA	D LA	ANDS	LIDE, LENNOX HEAD		1	Date co	ompleted:	8.2.201 ⁻	1
Bo	reh	nole l	_ocation:	RE	FER	FIGL	JRE [·]	1				Logged	l by:	WJB	
Со	orc	dinate	es:	558	3708.	00m	E 68	1329	5.00mN		(Checke	ed by:		
Dril	II M	odel	And Mountir	ng:	MD1	00 TRA	ACKED		Slope:	-90°			R.L. Sur	face: 19	9.204 m
Hol	le D)iame	eter:		100				Bearing	J:			Datum:		
		ng ii				Mate	erial S		ice			X			
p	Ľ		samples,			ic log	ficatic		material		tion	stency ty inde	ade	structure ditional obs	and ervations
nethc	oddns	vater	lesis, elc	RI	depth	graph	classi symbo		soil type: plasticity or particle characteristics	S,	moist	consis			
VB Z		-			meues		CH	Silty C	LAY: high plasticity, grey brown to red brown	n mottled	M	St-VSt	:		
>			U50	_9.0	-			. (con	inued)						
					10.5								PP=150-200	lkPa	
					-										
				8.5	-										
					11. <u>0</u>										
				80	-										
				_0.0	-										
					11. <u>5</u>		СН	Silty S	andy CLAY: high plasticity brown to dark gr						
			SPT	_7.5	-		GI	brown		ey			55 450 000		
			N*=14		-								PP=150-200	кра	
					12. <u>0</u>										
				_7.0	-										
					125										
					-										
				6.5	-										
					13.0										
			SPT	60	-		СН	Sandy sand of	CLAY: high plasticity, brown to dark grey bro content increasing with depth.	own,					
			5,8,12 N*=20	_0.0	-										
					13. <u>5</u>										
				_5.5	-										
							05								
					14. <u>0</u>		GP	GRAV to brow	EL and COBBLES: fine to coarse grained, grownish grey, with silty sandy clay matrix.	ey brown					
				_5.0	-										
					14 5	ŀ									
								Boreh	ole BH2 continued as cored hole						
				_4.5	-										
					15.0										
Mei AS	thod	1	auger screwir	ng*	S M	upport I mud	N	N nil	Notes, Samples, Tests U ₅₀ undisturbed sample	Classific Soil Des	ation Syr cription	mbols An	d	Consistency/D VS	Vensity Index very soft
AD RR			auger drilling* roller/tricone	r	C	casing			50mm diameter D disturbed sample	based on system	unified cl	assificatio	n	S F	soft firm
W HA P			washbore hand auger						N standard penetration test (SPT) N* SPT - sample recovered					St VSt H	stiff very stiff bard
V T			V bit TC hit		<u> </u>	/ater	lovel		V vane shear (kPa) P pressure meter	M m W w	y oist at			Fb	friable verv loose
*bit e.a	shov	wn by	suffix			- on dat	te shown		Bs bulk sample R refusal	Wp pla WI lig	astic limit uid limit			L MD	loose medium dense
						- water	inflow		E environmental sample					D	dense

	S		shaw Urqu	ع لا المart آ	V:L		q L N 108 (iha 592 62	arl	t					F	Boreho	le No.	BH2	2	
Ε	n	ai	neer	ind	ı L	oa	- E	Bore	eho	le					ę	Sheet		2 of 3	14/1	
Clie	ent:	<u>9</u> .		BA	2 — LLIN	A SH	IIRE	COUI								Date st	arted:	7.2.2	2011	
Pro	jec	t:		CO	AST	ROA		NDS	LIDE,			D				Date co	ompleted:	8.2.2	2011	
Bor	reho	ole L	ocation:	RE	FER	FIGU	JRE 1	I							L	_ogged	l by:	WJE	3	
Co	ord	inate	es:	558	708.	00m	E 68	1329	5.00m	N					(Checke	ed by:			
Dril	l Mo	odel /	And Mountii	ng:	MD10	00 TR/	ACKED						Slope:	-90°			R.L. \$	Surface:	19.204 m	
lol Dr	e Di illir	iame	ter:	<u> </u>	100	Mat	orial S	ubetar	200				Bearing:				Datur	n:		
		<u>ig ii</u>	notes			Iviat	5									ex lex				
po	ort		samples,			nic log	ificatio				material				ture	stenc ity ind		struc additional	cture and l observations	
meth	ddns	watei	10010, 010	RL	depth metres	grapł	class symb		soil typ colou	pe: plasti ur, secon	city or particl dary and min	le chara lor comp	cteristics	,	moist	consi densi				
AU							СН	Silty C	LAY: hi	igh plasti oarse gra	icity, dark bro ained gravel.	own to d	ark grey, ued)	with	М	F				
				14.0	-					g.	g	()							
					5. <u>5</u>															
				13.5	_															
			U50		-												PP=60kPa	9		
				-	6. <u>0</u>															
				_13.0	-															
					_															
					6.5		СН	Silty C	LAY: h	igh plasti	icity, pale bro	own.				St	-			
				_12.5	-					0	271									
					-															
				-	7. <u>0</u>															
			SPT 2,2,7	_12.0	_															
			N"=9		75															
			U50	1	-															
				11.5	-												PP=150kF	Pa		
					8. <u>0</u>															
				_11.0	-															
					8. <u>5</u>		СН	Silty	LAY	igh nlasti	icity, arev bro	own to re	ed brown	mottled		St-VSt				
			SPT 5 7 8	_10.5					10	3 5.000	, 9.07 010		- 5.000				DD-2001-	Da		
			N*=15															a		
				1	9.0															
				_10.0																
					95															
					J. <u>J</u>															
				_9.5																
					10.0															
l eti S	hod		auger screwir	ng*	Su M	ipport mud	Ν	l nil	Notes, U ₅₀	Samples, undistu	Tests urbed sample			Classific Soil Des	ation Syn cription	nbols An	d	Consiste VS	ncy/Density Index very soft	
D R			auger drilling' roller/tricone	•	C	casing			D	50mm disturb	diameter ied sample	-1/00-		based on system	unified cla	assificatio	'n	S F	soft firm	
A			washbore hand auger black bit						N N*	SPT -	ra penetration tes sample recovere	st (SPT) ed			,			St VSt H	stiff very stiff	
			V bit TC bit		w	ater	lovel		V	Vane s	hear (kPa) Ire meter			M m W w	/ Dist #			Fb VI	friable	
oit s .a.	show	/n by s	Suffix ADT		-⊻	- on da	ievei te shown		Bs R	bulk sa refusal	ample			Wp pla WI lig	astic limit uid limit			L MD	loose medium dens	se
						- water	inflow		E	enviror	nmental sample							D VD	dense	ĺ

	0		sł	າa	W	urquhart:									1	Bo	rehole	No	BUJ		
	'n	ai	Shaw	Urquh	art Pty	Ltd ACN 108 592 623	roh		~							Sh	eet	110.	DNZ 1 of 1		
		iyi	ne	en	ng	Log - Corea Bo	ren		e							Jo	o No.:		10644/	1	
Cli	ent	:		E	BALL											Da	te sta	ted:	7.2.201	1	
Pro	ojeo	ct:		(ST ROAD LANDSLIDE, LEN	NNOX	HE	AD							Da	te con	npleted	: 8.2.201	1	
Bo	reh	nole l	_ocati	on: F	REFE	ER FIGURE 1										Lo	gged b	y:	WJB		
Co	orc	dinat	es:	5	5587	08.00mE 6813295.00mN					_					Cł	ecked	by:			
Dri		odel	And M	ounting	: N	ID100 TRACKED				:	Slop	be:	-90	0				R.L.	. Surface: 1	9.204 m	
D	rilli	ng l	nform	ation	Mat	erial Substance				1	Sea	nng.	R	loc	k N	las	s Defe	octs	um.		
					g very	material		g	esti	imate	d	ls(50)			defe	ect			defect descr	iption	
ethod	ore-lift	ater		depth	aphic lo ore recov	rock type; grain characteristics, colo structure, minor components	our,	eatherin teration	str	ength	ı	MPa D- diam- etral	QD %	s	pac mn	ing n		type, in	clination, plana coating, thicl	rity, roughr mess	ness,
Ē	8	Ň	RL	metres	<u>р</u> 2	Continued from non-cored borehol	le	a K	╝┤╴	ΣI ΣI	ц Н Н	A- axial	Ř	30	8 9 9 9 9 1	8 9 9 9 1	partic	ular	IM: Interlavere	d sequence	genera
NMLO			_4.5	-		brown to orange brown mottled, some	fine										of	clay, gr	avel and cobble	es.	-
-				-		cobbles composed of Basalt.	~						0								
	\parallel			15.0		GRAVEL and COBBLES: fine to coars	se						\vdash								-
			_4.0	-	•	grained, grey brown to brownish grey, composed of very low to low strength							<<	1							
				-	$\tilde{0}$	Basalt.	ghty						0								
				15.5	000 000	weathered, high strength Basalt, with matrix of red-brown silty clay.															_
			_3.5		-~~~	BH2 terminated at 15.62m				\parallel			┢	┦┼	\parallel	$\uparrow \uparrow$					- -
				-																	
				16.0																	
			_3.0	-																	
				165																	-
				10.5																	-
			_2.5	-																	-
				17.0																	-
				_																	-
			_2.0	-																	
				17.5																	
			15	_																	
			_1.0	-																	
				18.0																	-
			1.0	-																	-
			2	-																	
				18.5																	-
			_0.5	-																	
				-																	-
				19.0																	_
			_0.0	-																	
				-																	
Me AS AE RF CE NM	L ethoo S D C R R S MLC Q, HO	1 d	auge auge rolle claw NML wire	I 19.5 er screwing er drilling /tricone or blade I C core ine core	g bit	Case-Lift W Casing used barrel withdrawn Graphic Log/Core Recovery core recovered - hatching indicates material no core recovered	Vater vater water partia comp water (lugec intervi	· level tte show · inflow I drill flu lete dril · pressu ons) for al show	n iid loss I fluid lo re test i depth n	oss result			Fr SW MW HW EW	i i i i i i i i i i i i i i i i i i i	ing/ (W// fr s n h e	Alter A) esh light! ighly xtren	ation ately ately	Streng EL VL L M H VH EH	th extremely low very low low medium high very high extremely high	Defects JT joint PT part SM sea PL plar CV curv IR irreg RO roug SO smc SL slick	t m nar ved gular gh poth kensided





BOREHOLE BH2

)		Shaw Urqu	1V Ihart	V . L		QU 108 9	592 62	ar L ³		E	Boreho	le No.	BH3	
E	n	gi	neer	ing	<u>g</u> L	og	- E	<u>Sore</u>	ehole		{	Sneet Job No	. <u> </u>	10644/1	
Clie	ent			BA	LLIN	A SH	IIRE	COU	NCIL		[Date st	arted:	9.2.201	1
Pro	ojec	ct:		со	AST	ROA	DLA	NDS	LIDE, LENNOX HEAD			Date co	mpleted:	9.2.201	1
Bo	reh	ole l	_ocation:	RE	FER	FIGL	JRE 1	I			l	_ogged	by:	WJB	
Со	ord	dinate	es:	558	8693.	00ml	E 68	13312	2.00mN		(Checke	d by:		
Dril	II M	odel	And Mountir	ng:	MD10	D0 TRA	CKED		Slope:	-90°			R.L.	Surface: 19	9.178 m
Hol Di	le D rilli)iame na Ir	ter:		100	Mate	arial S	uhstar	Bearing	j :			Datu	m:	
			notes				un no					ex			
ро	ort		samples, tests. etc			nic loç	sificati		material		ture	istenc ity inc		structure additional obs	e and servations
meth	ddns	wate	, 0.0	RL	depth metres	grapł	class symb		soil type: plasticity or particle characteristic: colour, secondary and minor components.	S,	mois condi	consi densi			
AD				10.0	-		GM	Silty G	RAVEL: fine to coarse grained, pale grey, lo ity fines.	w	D	MD	FILL		
				19.0	-				· · ·						
					0.5										
				_18.5	-		SP	Silty S	AND: fine to medium grained, brown.		М	L			
					-										
					1. <u>0</u>		СН	Silty C	LAY: high plasticity, red brown, some fine to	coarse		F-St			
			SPT 2,3,3	_18.0	-			graine	d gravel.						
	N*=6														
				1	1. <u>5</u>										
				_17.5	-										
					2.0										
				17.0	-										
r					-										
NB/RI					2. <u>5</u>										
~				16.5	-										
			SPT 3,3,3 N*-6		-										
			N -0		3. <u>0</u>		СН	Silty C graine	CLAY: high plasticity, dark grey, some fine to d gravel, with root fibres.	medium		S-F			
				_16.0	-										
					- 2 5		SC	Clayey	y SAND: coarse grained, grey.			L			
				45.5	- 0.5										
				15.5	-										
					4. <u>0</u>										
			SPT	_15.0	-										
			1,1,3 N*=4		-							L			
					4. <u>5</u>		СН	Silty C	LAY: high plasticity, grey, some fine grained	gravel.		S/F	NATURA	L/COLLUVIUM	
				_14.5	-										
Met	thod				<u> 5.0</u> S				Notes, Samples, Tests	Classifica	ation Syn	nbols An	d	Consistency/E	Density Index
AS AD RP			auger screwir auger drilling* roller/tricopo	ıg" '	C	mud casing	N	i nil	unaisturbed sample 50mm diameter D disturbed sample	based on	unified cla	assificatio	n	və S F	very soft soft firm
WHA			washbore hand auger						N standard penetration test (SPT) N* SPT - sample recovered	Moisture				St VSt	stiff very stiff
B V			blank bit V bit		 "	/ater			Nc SPT with solid cone V vane shear (kPa)	D dry M mo	/ bist			H Fb	hard friable
T *bit	shov	wn by s	TC bit suffix		_	water - on dat	level æshown		P pressure meter Bs bulk sample	W we Wp pla	t istic limit			VL L	very loose loose
e.g.			ADT						R refusal	WI liqu	ud limit			MD	medium dens

	S		sha	3 M	V:I			iha	arl	t				Γ	Boreho	le No.	BH3		
F	'n	ui	noor	inart	-ıy Lu		_ F	392 02 8 0 r a	。 aho	مار				:	Sheet		2 of 3		
		<u>y</u>		RAI	<u>, </u>										Job No	.: arted:	922	4/1 011	
Pro	oiec	:t·		co	AST	ROA						AD.			Date or	ompleted.	9.2.2	011	
Во	reh	ole l	_ocation:	REI	FER	FIGL	JRE 1		,			-			Logaed	bv:	WJB		
Со	ord	inate	es:	558	693.	00m	E 68	13312	2.00m	ηN					Checke	ed by:			
Dril	I Mo	odel	And Mountin	ng:	MD10	00 TRA	ACKED					Slo	pe: -90°			R.L.	Surface:	19.178 m	
Hol	e D	iame	eter:		100							Bea	aring:			Datu	ım:		
		ng n	notes			Mate	erial 5	ubstar	ice						×9				
p	Ľ		samples,			iic log	ificatic				material			ure tion	stency ty inde		struc additional	ture and observations	
metho	oddns	water	10313, 010	RL	depth metres	graph	classi symb		soil ty colou	pe: plastic ur, secono	city or partic dary and mir	le character	stics, ents.	moist condi	consi densi				
WB					-		ОН	Silty C	LAY: h	igh plasti	city, dark gre	ey, some fin	e to coarse	W	S/F				
-				14.0	-			odour	u yrave	i, with hig	in organic co		liong organic						
					5.5														
			SPT	_13.5	_														-
			1,2,4 N*=6	Γ	-											PP=50kF	Ра		
					6. <u>0</u>			Silty		iah plaati	oity grou			M	-	-			-
				_13.0	-		СП		LAT: N	ign plasti	city, grey.			IVI					
					-														
					6. <u>5</u>		GC	Claye	y GRAV	EL: fine	to coarse gr	ained, grey.		W	L	-			-
				_12.5	-						0								
					-														
					7. <u>0</u>		СН	Silty C	LAY: h	nigh plast	icity, red bro	own.		М	F-St	-			-
			SPT 2,2,3	_12.0	_											PP=100	Pa		
			N*=5		75														
				11.5	-														-
				_11.5	-														
					8.0														_
				_11.0	-														
					_		СН	Silty C	LAY: h	igh plasti	city, brown a	and red brow			VSt				
				-	8. <u>5</u>														
			1150	_10.5	-											DD 000	-D -		
			0.50		-											PP=300	(Pa		
					9. <u>0</u>														-
				_10.0	_														
					- 														
					9. <u>5</u>														-
				_9.5	-														
					10.0														
Met AS	thod		auger screwir	ng*	S M	upport I mud	N	l nil	Notes, U ₅₀	Samples, undistu	Tests Irbed sample		Classific Soil Des	ation Syn cription	mbols An	d	Consister VS	very soft	_
AD RR			auger drilling* roller/tricone	ł	С	casing			D	50mm disturbe	diameter ed sample		based or system	n unified cl	lassificatio	n	S F	soft firm	
HA			washbore hand auger						N N*	standar SPT - s	d penetration te sample recovere	est (SPT) ed	Moisture	•			St VSt	stiff very stiff	
В V т			blank bit V bit		\ \	/ater			NC V	SPT wi vane st	tn solid cone near (kPa) ro motor		D di M m	ry noist not			H Fb	hard friable	
*bit	shov	vn by s	suffix ADT		-	- on dat	ievel te shown		Bs R	pressur bulk sa refilisal	umple		Wp pl Wi lic	a astic limit auid limit			v∟ L MD	very ioose loose medium dens	se
y.						- water	inflow outflow		E	environ	imental sample			,			D VD	dense very dense	

	2		Shaw Urqu	ιhart	V Ltd		ЧU N 108 (592 623		E	Boreho	ole No. BH3
_	'n	gi	neer	ing	g L	og	- E	Borehole		5	Sheet Job No	3 of 3 .: 10644/1
iic	ent:			BA	LLIN	A SH	IIRE	COUNCIL		ſ	Date st	arted: 9.2.2011
ro	ojec	ct:		со	AST	ROA	DLA	NDSLIDE, LENNOX HEAD		ſ	Date co	ompleted: 9.2.2011
or	reh	ole L	_ocation:	RE	FER	FIGL	JRE 1	l		l	_ogged	l by: WJB
00	ord	inate	es:	558	3693.	00ml	E 68	13312.00mN		(Checke	ed by:
rill	I Mo	odel /	And Mountir	ng:	MD10	00 TRA	ACKED	Sic	pe: -90°			R.L. Surface: 19.178 m
)r	e D illir	ng Ir	nformation	1	100	Mate	erial S	ubstance	anng:		-	Datum:
			notes			бо	ation	material			ncy/ ndex	structure and
	support	water	tests, etc	RL	depth metres	graphic l	classifica symbol	soil type: plasticity or particle character colour, secondary and minor component	istics, ents.	moisture conditior	consister density ii	additional observations
			SPT	_9.0	-		СН	Silty CLAY: high plasticity, grey brown, to oran and red brown mottled.	ge brown	М	VSt	
			5,8,12 N*=20		-							
					10.5							
				_8.5	-							
					11.0							
				_8.0	-							
					-							
					11. <u>5</u>							
			SPT 5.7.10	_7.5	-							
			N*=17		12 0							
					12. <u>0</u> 							
				-7.0	-							
					12. <u>5</u>		<u> </u>		d arou harow			
				_6.5	-	0	GC	to brownish grey, with silty clay matrix.	a, grey brown			
	\vdash					r_{0} 0		Borehole BH3 continued as cored hole				
					13. <u>0</u>							
				6.0	-							
					13. <u>5</u>							
				_5.5	-							
					-							
					14. <u>0</u>							
				_5.0	-							
					14.5							
				4.5	-							
					-							
Vloti	bod				15.0			Notes Semples Tests	Clessifica	tion Sur	nhole An	d Consistancy/Density Index
AS AD			auger screwir auger drilling*	ng*	M C	mud casing	N	I nil U ₅₀ undisturbed sample 50mm diameter	Soil Desc based on	unified cl	assificatio	VS very soft S soft
RR N			roller/tricone washbore			5		D disturbed sample N standard penetration test (SPT)	system			F firm St stiff
⊣A 3 √			hand auger blank bit V bit		.	/ater		N* SPT - sample recovered Nc SPT with solid cone V vane shear (kPa)	D dry	nist		VSt very stiff H hard Fh friable
- Γ bits	shov	vn by s	TC bit suffix			water on dat	level te shown	P pressure meter Bs bulk sample	W we Wp pla	t stic limit		VL very loose L loose
e.g.			ADT			- water	inflow	R refusal E environmental sample	W liqu	uid limit		MD medium dense

	0		sł	າa	W	:urquhart									[Во	rehole	No.	BH3		
F	:r	nai	snaw				Rore	hol	A							Sh	eet		1 of 1		
	i on	<u>'y</u>														Jol	0 NO.:	tod	9 2 201	1	
Pn		ct.				ST ROAD I ANDSI IDE		X HE	ΔΠ							Da	te siai	noleted	9 2 201	1	
Bo	oje	01. 1010	Locati	ion:		ER FIGURE 1											and h		WIR	•	
		dinat			586	93 00mE 6813312 00ml	N									Ch	yyeu t	by.	1130		
Dri	ill N	lodel	es. And M	ounting	1: N	1D100 TRACKED					Slo	pe:	-90°	0		CII	eckeu	Uy. R.L	. Surface: 1	9.178 m	
Но	le [Diame	eter:		, 5	1					Bea	aring:						Dat	um:		
	rilli	ing l	nform	ation	Mat	terial Substance							R		k№	ass	Defe	cts	defect descr	intion	
method	core-lift	water	RI	depth	depth metres		, colour, nts	weathering alteration	est str	imate rengt	ed h ェェ	Is ₍₅₀₎ MPa D- diam- etral A- axial	RQD %	s S	defe paci mn	ct ng 1	partic	type, in	clination, plana coating, thicl	rity, rough	ness,
<u> </u>		-		_	XX	BASALT: grey, vesicular, moder	ately to	SW	ш>_	J≥I	<u>>ш</u>			ñ	- m	- œ			JM: Interlayere	d sequenc	e
MN			_6.0	13. <u>0</u> - - 13. <u>5</u>		 Signity weathered, high strength (COBBLE). Sandy Clayey SILT: mediun plas dark brown to red brown mottled, grained sand, blocky, some fine t grained gravel and cobbles, com high strength, slightly weathered 	ticity, fine o coarse posed of basalt.						0					ciay, gi			
	$\left \right $		_5.5	-		· · ·															
				14.0									0								-
			_5.0	-		BH3 terminated at 14.15m							H								
				- - -																	
			4.5	14. <u>5</u> -																	
			_4.5	-																	
				15.0																	-
			4.0	-																	-
				-																	
				15. <u>5</u>																	-
			_3.5	-																	
				-																	
				16.0																	
			_3.0	-																	-
				-																	
				16.5																	_
			_2.5	-																	-
				- 170																	-
			2.0	-																	
			_2.0	-																	-
				17. <u>5</u>																	-
			_1.5	-																	-
M AS AL RF CE NM	etho 5 7 8 9 VILC 2, H	d Q, PQ	auge auge rolle claw NML wire	er screwin er drilling r/tricone r or blade .C core line core	g bit	Case-Lift casing used barrel withdrawn Graphic Log/Core Recovery core recovered - hatching indicates material no core recovered	Water → wa → wa → pai → cor ug ug ug ug ug ug ug ug ug ug	ter level date show tter inflow rtial drill flu mplete dril ter pressu geons) for erval show	n nid loss I fluid l re test depth n	oss result			Fr SW MW HW EW	i i i i i i i i i i i i i i i i i i i	 (W/// fr s n h e	Alter Alter ightly ider ghly ktrem	ation , ately nely	Streng EL VL L M H VH EH	th extremely low very low low medium high very high extremely high	Defects JT joir PT par SM sea PL pla CV cur IR irre RO rou SO sm SL slic	nt ting nar ved gular gh ooth kensided



BOREHOLE BH3

	2	ノ	Shaw Urqu	1 V Ihart I	VI Pty Ltd		U N 108 (4 592 623	ar L 3		E	Boreho	le No.	BH4
F	r	nai	neer	ind	n I	nu	- F	Rore	ahole		S	Sheet		1 of 2
	- I	<u>''</u>		ΒΔ	<u>y –</u>						J г	Job No	.: arted:	10644/1
Drc	nie	nc.		0.0		ROA						Date or	moleted.	10.2.2011
	vro	bolo l	l ocation:	DE				1					hu:	W IR
		dinot		559		00ml		13347	7 00mN			-oggeu	by.	WJB
Dril		/odel	And Mountir	10:	MD10	00 TRA		1334/	Slope	: -90°		JIECKE	R.L.	Surface: 15.802 m
Hol	le l	Diame	eter:	5	100		-		Bearin	ng:			Datu	ım:
Dr	rill	ing l	nformation			Mate	erial S	ubstar	ce					
			notes samples,			log	cation		material		ец	ency/ index		structure and
ethod		ater	tests, etc		depth	aphic	assific mbol		soil type: plasticity or particle characteristi	ics,	oistur	insiste ensity		additional observations
Ē	ū	n S		RL	metres	XXXX P	SP SP	Silty S	colour, secondary and minor component	S.	Ĕ8 м	88	FILL	
A					-		or	graine	d gravel and boulders.	coarse	IVI	L		
				15.5	-									
					0.5		СН	Grave	Iv CLAY: high plasticity, red brown.			St	-	
					-				, , , , , , , , , , , , , , , , , , ,					
				15.0	-									
					1.0_									
			SPT 6,8,5		_									
			N*=13	14.5										
					1.5									
				14.0	-		СН	Silty C	LAY: high plasticity, dark brown, with some d gravel.	e coarse	M/W	F/St	NATURA	AL/COLLUVIUM
				_14.0	20									
					2.0									
				_13.5	-									
					2.5									
			SPT		_		СН	Sandy mediu	Gravelly CLAY: high plasticity, brown, fine m grained sand, fine grained gravel, with fir	e to ne organic	М	St		
			3,5,6 N*=11	_13.0	-			materi	al.				PP=150-	200kPa
					3.0									
					-									
				_12.5	-									
					3. <u>5</u>									
					-									
				_12.0	-									
					4. <u>0</u>		СН	Silty C	LAY: high plasticity, grey and brown.					
			SPT 2,3,4		-								PP=150k	(Pa
			N*=7	11.5	-									
					4. <u>5</u>									
				11.0	-									
				_11.0	50									
Met	tho	d	auger scrowin	<u>ו</u> חמ*	SI SI		۱ ۸	l Inil	Notes, Samples, Tests	Classific	ation Syn	nbols An	d	Consistency/Density Index
AD RR			auger drilling*	5	C	casing	N	• • • •	50mm diameter D disturbed sample	based on	unified cla	assificatio	n	S soft F firm
WHA			washbore hand auger						N standard penetration test (SPT) N* SPT - sample recovered	Moisture				St stiff VSt verv stiff
B V			blank bit V bit		 "	/ater			Nc SPT with solid cone V vane shear (kPa)	eu moisture VSt v D dny H h M moist Fh fr			H hard Fb friable	
T *bit :	sho	own by	TC bit suffix			water - on dat	level te shown		P pressure meter Bs bulk sample	W we Wp pla	et astic limit			VL very loose L loose
			ADT		1.				R refusal	ample – Williquid limit MD medium o				

	9		Shaw Urqu	ιhart F	VILtd		ЧU N 108 (4 (592 62	3				ŀ	Boreho	le No.	BH4
E	n	gi	neer	inç	ιΓ	og	<u> </u>	<u>Bor</u> e	<u>eho</u>	le				Sheet Job_No.	2	of 2 10644/1
Cli	ent:			BA	LLIN	A SH	IIRE	COUI	NCIL				I	Date sta	arted:	10.2.2011
Pro	ojec	:t:		CO	AST	R04	AD LA	ANDS	LIDE,	LENNOX HE	AD		ſ	Date co	mpleted:	10.2.2011
Во	reh	ole l	Location:	RE	FER	FIGU	JRE 1	1					I	Logged	by:	WJB
Со	ord	inat	es:	558	660.	00m	E 68	13347	7.00m	N			(Checke	d by:	
Dril	ll Mo	odel .	And Mountii	ng:	MD10	00 TR/	ACKED				Slop	e: -90°			R.L. S	urface: 15.802 m
D	rillir	ng li	nformatior	1	100	Mat	erial S	ubstar	nce		Dear	ing.		1	Datan	1.
			notes samples			boj	ation			materia	I		a =	ency/ index		structure and
ethod	pport	ater	tests, etc		depth	aphic	assific mbol		soil typ	e: plasticity or parti	cle characteris	tics,	oisture	insiste	8	idditional observations
Ĕ	su	Ň		RL	metres	errer Trees	ਿੱ ਨੇ CH	Silty C		r, secondary and m	inor componen	nts.	Ĕ S M	ତ ଅ St		
Ā										g., practicity, grey d			141			
				10.5												
					5. <u>5</u>		СН	Silty C	LAY: hig	gh plasticity, grey b	rown mottled,	some fine				
			SPT 3,5,8 N*=13	_10.0				grane	a sailu.							
					6.0											
				_9.5	_											
					6. <u>5</u>											
				_9.0	70		1	Boreh	ole BH4	continued as cored	hole					
					,. <u>o</u>											
				_8.5												
					7. <u>5</u>											
					-											
				_8.0												
					8. <u>0</u>											
				_7.5												
					8.5											
					_											
				_7.0												
					9. <u>0</u>											
				_6.5												
					9.5											
				_6.0												
					10.0											
Me AS	thod		auger screwir	ng*	Si M	upport mud	N	l nil	Notes, S U ₅₀	Samples, Tests undisturbed sample		Classific Soil Des	ation Syr	mbols And	d	Consistency/Density Index VS very soft
AD RR			auger drilling' roller/tricone	r	C	casing			D	50mm diameter disturbed sample	tect (SPT)	based on system	unified cl	assification	n	S soft F firm St stiff
HA B			hand auger blank bit						N* Nc	SPT - sample recover SPT with solid cone	red	Moisture D dr	/			VSt very stiff H hard
V T			V bit TC bit			ater water	level		V P	vane shear (kPa) pressure meter		M m W we	oist et			Fb friable VL very loose
*bit e.g.	show	vn by :	suffix ADT			- on da	te shown		Bs R	bulk sample refusal		Wp pla WI liq	astic limit uid limit			L loose MD medium den
oit .g.	show	vn by :	TC bit suffix ADT			water on da water water	level te shown inflow outflow		P Bs R E	pressure meter bulk sample refusal environmental sampl	e	W we Wp pla WI liq	et astic limit uid limit			VL very loc L loose MD mediun D dense VD very de

	6		sł	าล	۱۸	rurquhart											
	C		Shaw	/ Urquh	art Pty	y Ltd ACN 108 592 623						ſ	Bor	ehole N	0.	BH4	
E	Ēr	ŋgi	ine	eri	ng	Log - Cored Bore	ehol	е					She Job	et No.:	1	of 2 10644/ 1	
С	lien	t:		E	BALI	LINA SHIRE COUNCIL							Date	e starteo	d:	10.2.20	11
Ρ	roje	ct:		(COA	ST ROAD LANDSLIDE, LENNO	OX HE	AD)				Date	e comple	eted:	10.2.20	11
В	oreł	nole	Locat	ion:	REFI	ER FIGURE 1							Log	ged by:		WJB	
С	oor	dinat	tes:	ę	5586	60.00mE 6813347.00mN							Che	cked by	:		
D	rill M	lodel	And N	lounting	j: N	ID100 TRACKED			Slo	ope:	-90	0			R.L. Su	urface: 1	5.802 m
	Die L Drilli	ing I	eter: I nform	ation	o Ma	terial Substance			Бе	anng:	R	lock M	ass	Defects	Datum.	•	
					og verv	material	_ و_	ص estimated Is				defe	ct		d	lefect descri	ption
thod	e-lift	ter		donth	phic l	rock type; grain characteristics, colour, structure, minor components	atheri	in -d b -d b -d			% O	mm	ng N	type, inclination, planarity, rough coating, thickness		ity, roughness, ness	
em C		Mai	RL	metres	gra cor	Continued from non-cored borehole	wei alte	L L	_≥±,	A- axial	ВQ	300 300 300	3000	particula	ır		general
IWN			_8.5	7. <u>0</u> - - 7. <u>5</u> - -		brown and orange brown mottled, trace of fine grained sand, occasional gravel fragments.					0						 - - - - - - - - - - - -
			_7.5	8.0		Silty CLAY: high plasticity, brown to grey	_										- - - - - -
			_7.0 _6.5	9.0 - - - 9.5		brown and orange brown mottled, blocky, trace of fine grained sand, occasional Basalt gravel fragments becoming more numerous with depth.					0						
			_6.0		\times	Silty CLAY: high plasticity, brown to grey brown and orange brown mottled, blocky, trace of fine grained sand, occasional Basalt gravel fragments becoming more numerous with depth.					0						
			_5.0	10.5 - - 11.0 - - - - - - - - - - - - - -		GRAVEL: coarse grained, dark brown to red brown and grey, rounded to sub-angular, composed of highly weathered Basalt. SAND: fine to medium grained, dense, dark brown to browish grey, some clay fines, trace of coarse grained gravel.	_				0						
	4.0 CORE LOSS									0							
Method Case-Lift Water AD auger drilling casing used image: addition of the state of			rater level n date show rater inflow artial drill flu omplete dri vater pressu ugeons) for terval show	wn uid los ill fluid ure tes r deptf wn	ss loss st result 1		Fr SW MW HW EW	a thering// (W/A fre sli m hię ex	Alterat) ightly ioderat ghly ktreme	tion S E V L tely N H V V E	Strength EL ∈ /L ∨ /L ∨ / / / H r / H v EH €	extremely low very low ow nedium nigh very high extremely high	Defects JT joint PT parting SM seam PL planar CV curved IR irregular RO rough SO smooth SL slickensided				

CORED BOREHOLE TEST PIT LOGS.GPJ SHAW URQUHART.GDT 5/4/11

	0		sł	າລ	W	urquhart:								_					
			Shaw	Urquh	art Pty	Ltd ACN 108 592 623								Во	rehole	No.	BH4		
E	Ēr	ngi	ne	eriı	ng	Log - Cored Bore	eho	le						Sh Jol	eet o No.:		2 of 2 10644/1	1	
С	ien	t:		E	BALI	LINA SHIRE COUNCIL								Da	te star	ted:	10.2.20	11	
Pr	oje	ct:		C	COA	ST ROAD LANDSLIDE, LENN		EAD)					Da	te con	pleted	10.2.20	11	
В	orel	nole l	Locati	on: F	REFE	ER FIGURE 1								Lo	gged b	y:	WJB		
C	oor	dinat	es:	5	586	60.00mE 6813347.00mN								Checked by:					
Dr	ill M	lodel Diame	And M	ounting	: № 5	ID100 TRACKED				Slop Bea	oe: ring:	-90	0			R.L Dat	. Surface: 1	5.802 m	
C	Drill	ing l	nform	ation	Mat	terial Substance	_			<u>g</u> .	R	lock	Mass	s Defe	cts				
method	core-lift	water	RL	depth metres	graphic log core recovery	rock type; grain characteristics, colour, structure, minor components	weathering	es st	timate	ed h	Is ₍₅₀₎ MPa D- diam- etral A- axial	RQD %	de spa r	efect acing mm	nartic	type, in	defect descri clination, planaı coating, thick	i ption rity, roughnes mess	SS, general
١LC	\uparrow			12.0		CORE LOSS (continued)				> Ш			- m	<u> </u>	partie				-
Ž			_3.5	12.5	$\left \right\rangle$							0							
SPT	Π		3.0	_		SAND: brown, medium grained (from SPT sample).						0							
8	┢		_0.0	13.0		CORE LOSS	_					_							-
5					\bigvee														-
			_2.5	_								0							-
				13.5		GRAVEL: fine to medium grained, some	_												_
			2.0	_		clay fines.													-
MLC	T	1	_2.0	14 0		Silty CLAY: high plasticity, dark brown to orange brown and grey mottled, blocky,							1						-
Z				-		some coarse grained gravel (Basalt fragments).						0							
	Ħ		_1.5	_															-
				14.5								0							_
	Ħ			-	H	BASALT: grey, fine grained (COBBLE).	SW												-
			_1.0	15 0		Gravelly Sandy CLAY: medium plasticity,													-
				15.0		mottled, fine to medium grained sand, fine to coarse grained gravel, occasional Basa	lt												-
			_0.5	-		coddles.						0							-
				15. <u>5</u>	H	BASALT: grey to grey brown (BOULDER)). HW												-
				-	X	4											IN ALL ALL ALL ALL ALL ALL ALL ALL ALL AL	4	-
5			_0.0	-	~ 	BH4 terminated at 15.75m									of	olay, gr	avel and cobble	a sequence - es.	-
D.				16.0															
			0.5	-															-
				16.5															-
HN C				-															-
5.25			1.0	_								Wor			ation	Strong	ith	Defecto	-
	Method Case-Lift Water AS auger drilling Image: casing used Image: casing used AD auger drilling Image: casing used Image: casing used RR roller/tricone barrel withdrawn Image: casing used CB claw or blade bit NMLC core Case-Lift Image: casing used NMLC NMLC core Graphic Log/Core Recovery Image: casing indicates NQ, HQ, PQ wireline core core recovered - hatching indicates Image: casing indicates Image: casing indicates Image: casing used Image: casing used Image: casing used			water level on date sho water inflow partial drill complete c water press lugeons) fi interval sho	own fluid los Irill fluid sure tes or depth own	is loss it result 1			Fr SW MW HW EW	()	W/A) fresh slightly moder highly extrem	, ately nely	EL VL L H H H EH	extremely low very low low medium high very high extremely high	JT joint PT parting SM seam PL planar CV curved IR irregula RO rough SO smoot SL slicken	ar n sided			

10644/1-C 14 July 2011





BOREHOLE BH4 BOX 1 OF 2



BOREHOLE BH4 BOX 2 OF 2



APPENDIX B LABORATORY TEST RESULTS



		ATTERBERG	• LIN 9 2 1	AITS TEST REP	PORT		
Client:	Shaw Urquhart	Pty Ltd	, 2.1.	Report No.	11020651-AL		
Project:	Coast Road, Le	ennox Head		Test Date: Report Date:	10-16/03/11 22/03/11		
Client	t ID: BH2	Depth(m):	5.5		Sample No. 11020)651	
Liqui	d Limit (%):	82	L	inear Shrinkage (%	//////////////////////////////////////	15.0*	
Plast	tic Limit (%):	45	F	Field Moisture Con	tent (%):	63.2	
Plast	ticity Index (%):	37					
The results o	f calibrations and tests of	erformed apply only to th		cific instrument or sam	ole at the time of test unl	ess othe	rwise clearly
stated. Refe	rence should be made to	Trilab Pty Ltd "Standard	I Term	is and Conditions of Bu	isiness" for further details	3.	Bogo: 1 of 1
	This Document is issu accredite Accredited for con The results of the measurements in traceable to Aus	ued in accordance with NA ation requirements. apliance with ISO/IEC 17(e tests, calibrations, and cluded in this document tralian/National standard	ATA's 025 /or are ds	l	Authorised Signatory	ll l	raye. 1 01 1

Manager

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

N ATA Accredited Laboratory Number 9926 Form Number:GT004-5 +61.7 3357 5535 www.trilab.com.au 10/104 Newmarket Rd, Windsor QLD 4030

	D	IRECT SHE	AR TEST R	EPORT					
Client	Test Shaw Urquhart Pty	Method: AS 1289.6.2 Ltd	.2 / KH2 based on K	.H. Head Vol. 2 Report No.	11020651- DS				
Project	Coast Road, Lenno	ox Head		Test Date Report Date	7/03/2011 21/03/2011				
Client ID	BH2			Depth (m)	5.50				
Description	CLAY-brown		Samp	ble Type Three Ir Specim	ndividual Undisturbed Soi ens				
Failure Crit	eria	Res	idual @ 5.5 n	mm Displacement					
ē	Vertical I	Displacement/R	elative Displac	ement Plot					
				150.9 kPa					
ia -0.1 0.2 0.3 −	2	3	4	5 6	7 8				
ed -0.4 -									
Vertical I		Relative D	isplacement (mm))					
		Shear Stress/D	Displacement P	lot					
180				150.9 kPa					
160 ·			~~	100.7 kPa	~~~~				
x 120 . Stress (x 100 .				49.6 kPa					
ю 80 60	A form								
40 -									
0	1 2	3 Polativo D	4	5 6	7 8				
				<i>,</i>					
Notes/Remarks: Graph not to sca	Please review the resule	its if the Cohesion is	s above 2 kPa whe ample/s supplied b	n plotted with a line on plotted with a line on plotted with a line on plotted with a line of the plot	DT DEST TIT Page 1 of 4 REP0330				
This docume requirement results of the document a	ent is issued in accordance with s. Accredited for compliance wi e tests, calibrations, and/or mea re traceable to Australian/Natior	NATA's accreditation ith ISO/IES 17025. The surements included in the nal Standards.	Auti nis <i>Jan</i>	norised Signatory Marka Signatory J. Russell					

 Laboratory No. 9926

 The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated. Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details. Trilab Pty Ltd
 ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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	DIRECT SI			T ol 2			
Shaw Urquha	rt Pty Ltd	5.0.2.2 / Kinz based of	Repor	t No.	11020651	- DS	
Coast Road, I	_ennox Head		Test D)ate t Date	7/03/2011	1	
BH2			De	enth (m)	5 50		
CLAY-brown		Sar	nple Type	Three In Specime	idividual U ens	ndisturbed S	
eria	F	lesidual @ 5.5	mm Dis	olacem	ent		
	Residual - Norma	al Stress vs Shea	ar Stress				
			•				
		►					
40	80 N	120 ormal Stress (kPa)	160		200	240	
Angle (°)	37.5	Cohesion	(kPa)	60.9	R ²	0.999	
ensions (mm)	45*19	Normal	Stress (kPa)		Shear	Stress (kPa)	
mm/min) Content (%)	0.008	Stage 1	49 10).6 0.7		97.6 140.8	
sity(t/m ³)	1.567, 1.562, 1.5	'2 Stage 3 150.9 176.0					
Please review th	e results if the Cohes	ion is above 2 kPa w	hen plotted w	ith a line c	of best fit		
e		Sample/s supplied	d by the clien	t	Р	age 2 of 4 REPO	
nent is issued in accord nts. Accredited for con	dance with NATA's accredi apliance with ISO/IES 1702	tation A 25. The	uthorised Sign	atory 1 11 ANN	//		
are tracephie to Austra	lian/National Standarda		<i>инись р.</i> с./	We E. T. W. V ?		ACCREDITED FOR	
	Shaw Urquha Coast Road, I BH2 CLAY-brown	Test Method: AS 128 Shaw Urquhart Pty Ltd Coast Road, Lennox Head BH2 CLAY-brown Pria Residual - Norma Pria Residual - Norma Add 80 N Angle (°) 37.5 ensions (mm) 45*19 Momenti (%) 63.2 Sity(t/m³) 1.567, 1.562, 1.5 Please review the results if the Cohes e	Test Method: AS 1289.6.2.2 / KH2 based or Shaw Urquhart Pty Ltd Coast Road, Lennox Head BH2 CLAY-brown Sar Intia Residual @ 5.5 Residual - Normal Stress vs Sheat Intia Aria Residual - Normal Stress vs Sheat Intia Residual @ 5.5 Residual - Normal Stress vs Sheat Intia Residual @ 5.5 Aria Residual - Normal Stress vs Sheat Intia Residual @ 5.5 Aria Residual - Normal Stress vs Sheat Intia Residual @ 5.5 Residual - Normal Stress vs Sheat Intia Residual @ 5.5 Angle (°) 37.5 Cohesion Angle (°) 37.5 Cohesion Stage 1 Stage 1 Stage 2 Sample/s supplier Angle (°) 37.5 Cohesion	Test Method: AS 1289.6.2.2 / KH2 based on K.H. Head V Shaw Urquhart Pty Ltd Repor Coast Road, Lennox Head Test D BH2 De CLAY-brown Sample Type rria Residual @ 5.5 mm Disp Residual - Normal Stress vs Shear Stress Optimized and the stress of	Depth Content of the result of the results of the result	Test Method: AS 1289.6.2.2 / KH2 based on KH. Head Vol. 2 Shaw Urquhart Pty Ltd Report No. 11020651 Coast Road, Lennox Head Test Date 7/03/2011 BH2 Depth (m) 5.50 CLAY-brown Sample Type Three Individual U Specimens rria Residual @ 5.5 mm Displacement Residual - Normal Stress vs Shear Stress 40 80 120 160 200 40 80 120 160 200 Angle (°) 37.5 Cohesion (kPa) 60.9 R² ensions (mm) 45'19 Normal Stress (kPa) Stage 1 49.6 Please review the results if the Cohesion is above 2 kPa when plotted with a line of best fit sample's supplied by the client present of the stage 3	

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<u></u>	<u> </u>	т	est Method	d: AS 1289	.6.2.2	/ KH2 bas	sed on	K.H. Head	Vol. 2	110000	
Client	Shaw Ur	quhart	Pty Ltd					Rep	ort No.	1102065	I-DS
Project	Coast P	nad Le	nnov He	ad				_		7/00/00	
i Ujeci	UUASI N	0au, Le		uu				Tes	t Date	7/03/2012	1
	DUO							Кер		21/03/201	11
Description	BH2 CLAY-br	own					Sam	nole Tvr	De Three I) 5.50 ndividual I	Indisturbed
20001010		5.001					Juil	יאיי איאי	Specim	nens	
Failure Cri	teria						Ρ	eak			
			<u>Peak -</u>	Normal	Stre	<u>ss vs S</u>	hear	<u>Stress</u>			
200											
								•			
160											
a)					•						
s (kF											+
3 120											
ear S											
She											
80											
40											
40											
o 🗕											
0		40	1	80		120		160		200	240
				Ν	ormal	Stress	(kPa)				
	Shear A	ngle (°) 37.7			Cohe	sion	(kPa)	68.1	R ²	0.997
pecimen Din	nensions (mm	1)	4	5*19		Norma	Stres	s (kPa)	10.0	Shear	Stress (kPa)
kate of Strain hitial Moisture	(mm/min) e Content (%)	1	0 6	.008 33.2		Stage Stage	1 2		49.6 100.7		108.6 141.6
nitial Wet De	nsity(t/m ³)		1.567, 1	.562, 1.57	2	Stage	3		186.0		
tes/Remarks:	Please rev	/iew the r	esults if th	e Cohesi	on is a	bove 2 k	Pa wh	en plotte	d with a line	of best fit	
aph not to sca	ale				Sar	nple/s su	pplied	by the cl	ent	F	Page 3 of 4 REF
TL '. 1	unant in the second		AND WILL NIAT	Ale	hadi		Au	thorised Si	gnatory		
This doc requirem	ents. Accredited	in accordar d for compli	ance with NAT	A's accredit O/IES 1702	tation 5. The		Â	1	1	//	NATA
results o	f the tests, calibra	ations, and	/or measure	ments inclue	ded in th	nis /	_]A	mlA /	UM	(\sim



	[Tes	DIRECT SHEAR TEST R at Method: AS 1289.6.2.2 / KH2 based on K	EPORT .H. Head Vol. 2	
Client	Shaw Urquhart Pt	ty Ltd	Report No.	11020651- DS
Project	Coast Road, Lenr	nox Head	Test Date	7/03/2011
			Report Date	21/03/2011
Client ID	BH2	2	Depth (m) 5.50
Description	CLAY-brown	Samp	Specin	ndividual Undisturbed Soli nens
CL PR LA BC	AENT: ROJECT: AB SAMPLE No. DREHOLE:	Shaw Urquhart Pty Ltd Coast Road, Lennox Hea 11020651 BH2	d A DATE: DEPTH	FTER TEST 14 /03 /11 1: 5.50
Notes/Remarks:				
Photo not to scale)	Sample/s supplied b	y the client	Page 4 of 4 REP03302
This docun requiremer results of th document a	nent is issued in accordance nts. Accredited for complian ne tests, calibrations, and/or are traceable to Australian/N	e with NATA's accreditation ce with ISO/IES 17025. The measurements included in this lational Standards.		ACCENTED FOR TECHNICAL COMPETENCE

 Laboratory No. 9926

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APPENDIX C

COPIES OF TYPICAL COMPUTER STABILITY ANALYSIS PRINTOUTS





Description: Silty Clay, F Wt. 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27












10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level Re-Profiled Batter, Wider Excavation and Replacement (Clay Fill) Two Layers of 200kN Geotextile





Description: Fill Wt: 20 Cohesion: 5 Phi: 27 Description: Silty Clay, F Description: 3 Phi: 25 Phi: 25 Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25 Description: Silty Clay, Reduced Strengt Wt: 18 Cohesion: 0 Phi: 11



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10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level Re-Profiled Batter, Wider Excavation and Replacement (Rock Fill) Two Layers of 200kN Geotextile

<u>1.642</u>











Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25

Description: Silty Clay, Reduced Strengi Wt: 18 Cohesion: 0 Phi: 11

10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level with Toe Drains Re-Profiled Batter, Clay Fill Replacement





Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25

Description: Silty Clay, Reduced Streng Wt: 18 Cohesion: 0 Phi: 11



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Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, Reduced Strengl Wt: 18 Cohesion: 0 Phi: 11

Description: Rock Fill

Wt: 20 Cohesion: 0 Phi: 45

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10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level with Toe Drains Re-Profiled Batter, Rock Fill Replacement of Firm Clay





Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25

Description: Silty Clay, Reduced Strengl Wt: 18 Cohesion: 0 Phi: 11

Description: Rock Fill Wt: 20 Cohesion: 0 Phi: 45

Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level with Toe Drains Re-Profiled Batter, Clay Fill Replacement 2 layers of 200kN Geotextile 10644/1 Ballina Shire Council





Description: Clay Fill / Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25

Description: Silty Clay, Reduced Strengl Wt: 18 Cohesion: 0 Phi: 11

10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure Raised Groundwater Level with Toe Drains Re-Profiled Batter, Rock Fill Replacement 2 layers of 200kN Geotextile





Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27

Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25

Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27

Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25

Description: Silty Clay, Reduced Strengl Wt: 18 Cohesion: 0 Phi: 11

Description: Rock Fill Wt: 20 Cohesion: 0 Phi: 45



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Description: Silty Clay, Reduced Streng! Wt: 18 Cohesion: 0 Phi: 11 Description: Silty Clay, St-VSt Wt: 18 Cohesion: 8 Phi: 27 Description: Silty Clay, St Wt: 18 Cohesion: 5 Phi: 25 Description: Silty Clay, F Wt: 18 Cohesion: 3 Phi: 25 Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27



10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 2, BH1/TP7/TP3 Soil Profile, Post Failure L0wered Groundwater Level with Toe Drains Re-Profiled Batter, Rock Fill Replacement of Firm Clay





File No. Remediation-Option6-Analysis1a

Description: Rock Fill Wt: 20 Cohesion: 0 Phi: 45

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10644/1





10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 6, BH3 Soil Profile Raised Groundwater Level Remedial Geometry 1V:2H



10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head Section 6, BH3 Soil Profile Raised Groundwater Level Remedial Geometry 1V:2H









Description: Clay Fill Wt: 20 Cohesion: 5 Phi: 27	Description: clayey sand loose Wt: 17 Cohesion: 0 Phi: 28 Description: soft to firm clay Wt: 18 Cohesion: 0 Phi: 20	Description: firm to stiff clay Wt: 18 Cohesion: 4 Phi: 25 Description: Very stiff clay Wt: 18 Cohesion: 8 Phi: 27 Description: Rock Fill Wt: 20 Cohesion: 0 Phi: 45
10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head • • • • • • • • • • • • • • • • • • •		Geduced Level (m) 26 20kPa 20kPa 30kN/m 30kN/m 30kN/m 30kN/m 30kV/m 30

	Description: Clay Fill Wt: 20 Cohesion: 5	Description: clayey sand loose Wt: 17 Cohesion: 0	Phi: 28	Description: soft to firm clay Wt: 18 Cohesion: 0 Phi: 20	Description: firm to stiff clay Wt: 18 Cohesion: 4 Phi: 25	Description: Very stiff clay Wt: 18 Cohesion: 8 Phi: 27	Description: Rock Fill Wt: 20 Cohesion: 0 Phi: 45		
10644/1 Ballina Shire Council Landslip Remediation, Coast Road, Lennox Head • • • • • • • • • • • • • • • • • • •	Existing Geometry	 • •<		30	20kPa	300kN/m 300kN/m	Redion 6 - Existing - Analysis 3 Piled Solution(PS)	5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75	Distance (m)

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APPENDIX D SITE SURVEY CROSS-SECTIONS



IB 520	<u> </u>		
ol Scale 1:.		<i>60</i> ≁ ∙⊊9	729.51
Vertical & Horizon t		816-09	\$E0.\$1
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		<i>∠85·8†</i>	* 8·9/
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		SZ0·97	627·21
		/70.77	860.71
		45.711	I≠E·6I
		39·42	881.12
		E#6·2E	51.444
		865·ZE	160.ES
		36.315	815.52
		768·2E	54.852
			5070
		688•97	149.42
		<i>53</i> .363	54·539
		-89E·77-	- 741154 -
		21.262	£79·£2
		699·21	£28·E2
		13·458	52.336
		9E9·2	826.22
A		0.0	52.008
_	DATUM	CHAINAGE along section (A –B)	SURFACE RL

2B		
20	££2.89	15.054
1:57	27E.99	890.El
i Scale	*EE.*9	₽6 5·EI
<u>تizonta</u>	LE6.09	<i>∠SE·</i> †/
	826.25	#6.#
	26.22	E81.21
Verti	£1·#S	∠EE·91
	21.825	<i>S98·21</i>
	290.05	786.71
	598·27	642.61
	600.54	<i>596</i> .6/
	<i>296</i> ·17	9.61
	7E6.7E	50.203
	663.36	\$20.42
	688.55	861.45
	30.259	73 ∙9¢
	<u>569.97</u>	1#9.62
	55732	LE4.E2
	54.521	53.26
	\$19.02	627.72
	E08-91	51:372
	268.6	52.006

∢		0.0	54.443
Ω	DATUM	CHAINAGE along section (A -B)	SURFACE RL

Scale 1:250		
3B 3B	80E·02	L98·01
Horizonize L	<i>\$17.69</i>	889.11
lertic	277-59	<i>₩€2.51</i>
	<i>\#\L`\9</i>	579·El
	850.95	₩ .51
	≠16.25	12.292
	£01·05	822.81
	824.94	885.61
	43·541	<i>₩02.</i> 61
	991.86	20.077
	875.98	629.62
	€/9•≠€	2:62
	816.0E	624.52
	£E·72	520.62
	55.28	55.792
	811.52	525-393
	<i>€\∠∙8\</i>	880.12
	<i>SE·91</i>	568.02
	EE9·01	51.281

<		0.0	698.62	
Ϋ́.	DATUM	CHAINAGE along section (A –B)	SURFACE RL	

o 4			
		9 <i>5</i> ·22	<i>†22.6</i>
		92.22	802.01
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		710.70	611.51
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		34.325	53.213
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ale I		
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	<u>229-27</u>	677.11
	€1≠•1∠	IE8·11
Vertico	86.89	15.473
	162.49	78E·EI
	90·352	0.41
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	162.95	977.51
	276.43	<i>†</i> IE·SI
	112.22	<i>\$274</i>
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	664.74	101.61
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	126.26	104.52
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	86 7 ·/E	22:22
	920.82	516.12
	610.72	582·17
	59.52	\$89·IZ
	51/601	21.237
	18-335	67E·61
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<		0.0	\$79·27	
Ω	DATUM	CHAINAGE along section (A –B)	SURFACE RL	
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Ō	DATUM	CHAINAGE along section (A – B)	SURFACE RL

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	24.517	508.02
	52.02	285.02
	82.91	291.02
	<u></u>	#10.07
	828.41	£88·6/
	13-522	18:5.91
	<i>∠</i> *1.01	#9 L·LI
	£9 7 .8	9L·LI

		3·5¢	<i>∠02.</i> 61
<		0.0	<i>₹€€∙07</i>
	DATUM	CHAINAGE along section (A -B)	SURFACE RL

8B 8B			
Scale □ Scale		676.49	<i>\8⊊∙0\</i>
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SEC & Hor		811.65	8.11
rtical		<i>\$01.29</i>	981.21
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		£26·24	192.21
		E81.34	62.41
		#EG·/#	760.51
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		કદાન્કટ	50.269
		51.412	580.02
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		<i>₽∠</i> ₽·9 226.#	8EL·61
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		<u>9</u> :2:9	St·6
88		0.0 L	50.725
	DATUM	CHAINAGE along sectio (A –B)	SURFACE RI

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APPENDIX E SITE PHOTOGRAPHS
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Photo 1: Regional view of Coast Road and the landslide area, looking north west.



Photo 2: Regional view of Coast Road and the landslide area, looking west.





Photo 3: View of landslide head scarp and edge of road pavement, looking south east.



Photo 4: View of landslide head scarp and ground cracks on pedestrian path, looking north west.