GREEN GEOTECHNICS

GEOTECHNICAL INVESTIGATION

FOR

BRUCE & ELIZABETH MACDIARMID

24 CABARITA ROAD, AVALON

REPORT GG10371.001A

6 FEBRUARY 2023

Geotechnical Investigation for a proposed new residential dwelling at 24 Cabarita Road, Avalon.

Prepared for

Bruce & Elizabeth MacDiarmid
24 Cabarita Road
Avalon NSW 2107

Prepared by

Green Geotechnics Pty Limited
PO Box 3244
Rouse Hill, NSW, 2155
ABN: 786 438 493 89
www.greengeo.com.au
matt@greengeo.com.au

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For and on behalf of Green Geotechnics

Matthew Green
Principal Engineering Geologist

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Table of Contents

1. INTRODUCTION 1
2. FIELDWORK DETAILS 2
3. RESULTS OF INVESTIGATION 2
3.1 Site Description 2
3.2 Regional Geology & Subsurface Conditions 4
4. LANDSLIDE RISK ASSESSMENT 5
4.1 Introduction 5
4.2 Purpose of the Assessment 5
4.3 Risk Assessment Methodology 5
4.4 Hazard Identification 6
4.5 Risk Assessment to Property 7
4.6 Risk Assessment to Loss of Life 9
5. GEOTECHNICAL RECOMMENDATIONS 11
5.1 Primary Geotechnical Considerations 11
5.2 Excavation Conditions and Vibration Control 12
5.3 Temporary Batter Slopes 14
5.4 Temporary Excavation Support & Retaining Wall Design 14
5.5 Drainage 15
5.6 Foundation Design 16
6. FURTHER GEOTECHNICAL INPUT 17
7. GENERAL RECOMMENDATIONS 18

FIGURES

FIGURE 10371.001A – Site Location

FIGURE 10371.001B – Site Plan and Borehole Locations

FIGURE 10371.001C – Site Photographs

FIGURE 10371.001D – Cross Section

APPENDICIES

Appendix A – Borehole Logs & DCP Test Results

Appendix B – AGS Guidelines

Appendix – Completed Forms 1 and 1A

1. INTRODUCTION

This report presents the results of a geotechnical investigation for a proposed new residential dwelling at 24 Cabarita Road, Avalon, NSW. The investigation was commissioned by Bruce & Elizabeth MacDiarmid by return acceptance of Proposal PROP-2021-0325, dated 6th October 2021.

We understand that the development will comprise the demolition of existing structures on the site prior to the construction of a three level residential dwelling with separate swimming pool, boat shed and garden areas. The development will be carried out on steeply sloping ground. Construction of the lower floor of the main dwelling (Level 3) will require excavating to RL14.0 metres AHD, which is around 6 metres below the existing ground surface. Construction of the boat shed at the rear of the site will require the demolition of an existing sandstone block retaining wall together with localised steepening of existing batter slopes.

The site is located on sloping ground and is positioned within a H1 Hazard Zone under the former Pittwater Council LEP Mapping, therefore Northern Beaches Council require a Landslip Risk Assessment for the site in accordance with AGS 2007 Guidelines and the Geotechnical Risk Management Policy for Pittwater.

The purpose of the investigation was to

- assess the surface and subsurface conditions over the site,
- undertake a slope risk assessment in accordance with AGS2007 Guidelines, assigning both the risk to life and to property,
- provide recommendations regarding the appropriate foundation system for the site, including design parameters,
- comment on excavation conditions including vibration control during rock excavation,
- provide recommendations for temporary batter slopes,
- provide retaining wall design parameters for the design of temporary and permanent retaining structures, and
- provide recommendations to address the outcomes of the slope risk assessment.

2. FIELDWORK DETAILS

The fieldwork was carried out on the 12th and 14th October 2021 and comprised a detailed site walkover together with the drilling of four (4) boreholes numbered BH1 to BH4. BH1 was drilled using rotary solid flight augers attached to a utility mounted drilling rig owned and operated by Green Geotechnics. Due to restricted site access, BH2, BH3 and BH4 were drilled using hand auger equipment.

The site location is shown in the attached Figure A. The borehole locations, as shown on Figure B, were determined by taped measurements from existing surface features overlain on available survey drawings of the site. Photographs of the site are shown on Figure C.

The strength of the soils encountered in the boreholes was assessed by undertaking Dynamic Cone Penetrometer (DCP) tests adjacent to each borehole. The DCP tests were also used to "probe" the depth to the underlying bedrock. An additional DCP (P5) was undertaken adjacent to the sea wall beyond the rear boundary.

Groundwater observations were made in all boreholes during the fieldwork. No longer term monitoring of groundwater was carried out.

The fieldwork was completed in the full-time presence of our senior field geologist who set out the boreholes, nominated the sampling and testing, and prepared the field logs. The logs are attached to this report, together with a glossary of the terms and symbols used in the logs.

For further details of the investigation techniques adopted, reference should be made to the attached explanation notes.

Environmental and contamination testing of the soils was beyond the agreed scope of the works.

3. RESULTS OF INVESTIGATION

3.1 Site Description

The site is identified as Lot 9 in DP 17704, and is rectangular in shape with an area of approximately 619m^2. The site is located on moderately to steeply sloping terrain, at the tow of the east face slope of a north south trending ridgeline that extends out into Careel Bay. The ridgeline has a maximum elevation of approximately RL40 metres AHD, falling to sea level over a horizontal distance of approximately 110 metres.

At the time of the fieldwork the site was occupied by a double storey brick residential dwelling with tile roof and separate car port with metal roof. The ground surface on the site falls approximately 20 metres to the east from RL21.5 metres AHD at the kerb level of Cabarita Road to RL 1.6 metres AHD on the grassed area of the boatshed at the rear of the site.

The existing dwelling is formed on a gently to moderately sloping portion of the site that falls approximately 6 metres over a distance of 16 metres. Approximately 4 metres beyond the rear balcony of the dwelling is a near vertical 2.7 metre high slope that is covered by thick vines and vegetation.

At the base of the bater slope is a 1 metre wide gravel path. On the eastern side of the gravel path is a further 5 metre high near vertical batter slope which is covered by dense vegetation. At the base of the batter slope the vegetation has been locally cleared for the construction of a timber staircase. In the areas where the vegetation has been cleared a shotcrete facing is exposed.

Approximately 1 metre beyond the base of the lower batter slope is a recently constructed sandstone masonry retaining wall. The wall has a height of approximately 4.5 metres and appears in good condition. At the base of the wall is a flat grassed area which includes a single level fibro cement boat house. Sandstone masonry walls also form the sea wall beyond the eastern site boundary.

A metal inclinator runs down the northern site boundary and provides access from the front driveway to the boatshed level. A set of concrete stairs have been formed next to the inclinator. The stairs are in a poor condition and are tilting away from the inclinator, into the adjoining batter slope.

To the east of the site is Careel Bay and to the west is Cabarita Road. Cabarita Road has a width of approximately 20 metres. On the western side of Cabarita Road is a 4 metre high cut embankment. The section of the embankment directly opposite the site is covered by vegetation, however a 20 metre long section of the face immediately to the south of the site is exposed. The exposed face appears to have been formed by a recent landslide. Concrete and water filled barriers have been installed at the base of the slope on the edge of the road, presumably to arrest any further slope movement. The volume of the previous side is estimated to be in the order of $40m^2$.

The rock exposed in the face comprises highly weathered to moderately weathered sandstone bedrock with frequent interbedded clay seams. The bedding has a distinct dip to the east (i.e. into the slope) at around 25° from horizontal. There are bands of high strength rock in the face that are underlain by weaker weathered rock which is not uncommon with bedrock of the Narrabeen Group. To the north of the subject site the face is retained by a 3 metre high concrete crib wall that has been formed at an angle of approximately 70°.

To the north and south of the subject site are three storey residential dwellings. The dwelling to the north (No.22) has been constructed towards the base of the slope and the dwelling to the south (No.26) is constructed towards the top of the slope, in a similar position to the dwelling on the subject site.

3.2 Regional Geology & Subsurface Conditions

The 1:100,000 series geological map of Sydney (Geological Survey of NSW, Geological Series Sheet 9130) indicates that the site is underlain by Triassic Age bedrock belonging to the Newport Formation of the Narrabeen Group.

Bedrock within the Newport Formation comprises interbedded shale, laminite and quartz sandstone. Bedrock within the Narrabeen Group often has a deep weathering profile comprising high plasticity clayey soils with sandstone and ironstone lenses.

For the development of a site-specific geotechnical model, the observed subsurface conditions from the boreholes have been grouped into four (4) geotechnical units which are summarised as follows:

Unit 1 – Fill:

Fill materials were encountered across the site to depths of 0.7 to 1.5 metres and could not be penetrated in BH3 and BH4. The fill materials in BH1 and BH2 comprise a poorly compacted clayey silty sand with gravel inclusions. The fill in BH3 and BH4 comprises a gravelly sandy clay. The fill in BH4 likely overlies bedrock.

Unit 2 – Natural Clays (Soft):

Natural high plasticity soft silty clays were encountered below the fill in BH2 to a depth of 2.0 metres. The soft natural clays were not encountered in BH1 or BH3.

Unit 3 – Natural Residual Clays (Firm to Stiff, Stiff and Very Stiff):

Natural medium to high plasticity residual silty clays and silty sandy clays were encountered below the fill in BH1 and below the soft clays in BH2. The natural soils in BH1 extend to a depth of 5.0 metres, and the natural clays in BH2 extend to a depth of at least 3.0 metres. Based on the DCP results, stiff natural clays are inferred in BH3 at a depth of 1.2 metres, with bedrock likely to be around 2 metres depth. Natural soils are unlikely to be encountered over the lower terrace, which is likely reclaimed filled land over sandstone bedrock.

Unit 4 – Sandstone Bedrock:

Sandstone bedrock was encountered in BH1 at a depth of 5.0 metres and could not be penetrated below a depth of 5.3 metres. Based on the DCP results the depth to bedrock is expected to decrease to around 2-3 metres over the central portion of the site, and is inferred below the lower boat shed terrace at a depth of 1.5 metres.

Groundwater seepage was not observed during auger drilling of the boreholes on the upper slope areas. Based on the DCP results some seepage is however anticipated at the soil/rock interface. Based on the DCP results groundwater is inferred at a depth of around 1 metre on the lower boat shed terrace.

4. LANDSLIDE RISK ASSESSMENT

4.1 Introduction

A landslide risk assessment has been undertaken for 24 Cabarita Road, Avalon. It is not technically feasible to assess the stability of a particular site in absolute terms such as stable or unstable, and it must be recognised by the reader that all sites have a risk of land sliding, however small. However, a risk assessment can be undertaken by the recognition of surface features supplemented by limited information on the regional and local subsurface profile, and with the benefit of experience gained in similar geological environments.

Natural hill slopes are formed by processes that reflect the site geology, environment and climate. These processes include down slope movement of the near surface soil and rock. In geological time all slopes are 'unstable'. The area of influence of these down slope movements may range from local to regional and are rarely related to property boundaries. The natural processes may be affected by human intervention in the form of construction, drainage, fill placement and other activities.

4.2 Purpose of the Assessment

The purpose of this assessment is to enable the owner, potential owner or other parties interested in the site in question, to be aware of the level of risk associated with potential slope movements within the property, and within the area immediately surrounding the property. The risk is assessed considering the existing development of the property and proposed developments of which we have been informed of and which are summarised in this report.

The onus is on the owner, potential owner or other party to decide whether the level of risk presented in this report is acceptable in the light of the possible economic consequence of such risk.

4.3 Risk Assessment Methodology

All The risk assessment in this report is based on the guidelines on Landslide Risk Management (LRM) as presented in the Australian Geomechanics publication, Volume 42, Number 1, dated March 2007. This issue presents a series of LRM guidelines and further understanding on the application of the risk assessments for the recommended use by all practitioners nationwide.

Definition of the terms used in this report with respect to the slope risk assessment and management are given in Appendix C.

It must be accepted that the risks associated with hillside construction are greater than construction on level ground in the same geological environment. The impact of development may be adverse, and imprudent construction techniques can increase the potential for movement. Areas of instability rarely respect property boundaries and poor practices on one property can trigger instability in the surrounding area.

4.4 Hazard Identification

A landslide is defined as "the movement of a mass of rock, debris or earth down a slope". Apart from ground subsidence and collapse, this definition is open to the movement of material types including rock, earth and debris down slope. The causes of landslides can be complex. However, two common factors include the occurrence of a failure of part of the soil or rock material on a slope and the resulting movement is driven by gravity. The actual motion of a landslide is subdivided into the five kinematically distinctive types of material movement including fall, topple, slide, spread, and flow. For further information regarding types of landslides please refer to Appendix C – Landslide Terminology from Australian Geomechanics Practice Note Guidelines For Landslide Risk Management 2007.

The frequency of landslides are difficult to quantify and typically dependant on the inter-relationship between the factors influencing the stability of the slope. Some of the common factors affecting the stability of slopes include the weather (prolonged rainfall with water percolating into rock mass defects can cause washout of fines and reduction of rock mass strength), land development, vegetation removal, changes in drainage and earthquakes. One or a combination of these conditions could result in a landslide failure event.

For the site of 24 Cabarita Road, Avalon, the following landslide hazards have been considered in the risk assessment.

TABLE 4.1 – Landslide Hazard Identification

Position	Hazard Description	Estimated Volume (m^3)	Justification
Above the site	Further failure of rock cut on western side of Cabarita Road	20	Sections of the embankment on the western side of Cabarita Road have previously failed. The section of face directly opposite the site has not failed, however similar failure mechanisms exist, and therefore this section of the face could also fail in a similar manner. However, given the height of the opposing embankment, presence of barriers and width of Cabarita Road it is extremely unlikely that any failure on the adjoining slope would impact the subject site
Next to the site	Nil	-	-
On The Site	Failure of a cut face during excavation	15-30	Construction of the dwelling will require excavating up to 6 metres below the existing ground surface. The cut face is likely to comprise minor fill overlying residual soils and a limited volume of sandstone bedrock. If the cut face is not sufficiently supported or battered, then it is possible the face will collapse.
	Failure of a Retaining Wall During Demolition / Excavation	5-10	There are several retaining walls on the site that vary in their construction type and height that will be demolished as part of the works. This includes the recently constructed sandstone masonry wall behind the boatshed and also the shotcrete faced batter slope above. There is a risk that the walls and batter slopes may collapse during their removal/steepening.
Below the site	Nil	-	-

4.5 Risk Assessment to Property

The Risk to property has been estimated by assessing the likelihood of an event and the consequences if such an event takes place. The relationship between likelihood, consequence and risk is determined by a risk matrix. The risk categories and implications are shown in Attachment 3 of Appendix C (taken from Practice Note Guidelines for Landslide Risk Management 2007, Appendix C).

The assessment process involved the following:

- Risk estimation (comparative analysis of likelihood of a slope failure versus consequence of the failure).

- Evaluation of the estimated (assessed) risk by comparing against acceptance criteria.

The following factors observed during the site walkover were taken into consideration when undertaking the slope risk assessment:

- Topography: The site is situated on moderately to steeply sloping ground with steep vegetated batter slopes, shotcrete covered batter slopes and retaining walls up to 4.5 metres in height.

- Geology: The surface soils comprise topsoil and fill overlying residual clayey soils and sandstone bedrock. The existing fill appears poorly compacted and there are isolated lenses of soft natural clays. The residual clays are mostly stiff and very stiff. The sandstone bedrock that underlies the site is likely to include clays seams and interbedded bands of low and high strength rock. The bedding in the rock may also be aversely dipping into the slope.

- Drainage: The site in general is reasonably drained. No seepage was observed on the site, however it is expected that seepage would occur towards the toe of each terrace following prolonged rainfall events. The site drains to Careel Bay.

- Slope stability: There were no signs of active slope instability on the site noted during the walkover, and the existing retaining walls and batter slopes appear stable. The tilting and displacement of the steps adjacent to the inclinator are likely as a result of the steps being founded on poorly compacted fill. A previous slope failure has occurred on the western side of Cabarita Road. Based on available imagery the failure is likely to have occurred between 2019 and 2020.

Based on the above factors and site observations, an assessment of risk to property have been carried out as shown in Table 4.2 below.

TABLE 4.2 – Risk to Property

Hazard		Failure of rock face on Cabarita Road	Failure of a Cut	Failure of a Retaining Wall / Embankment
Likelihood	Descriptor	Likely	Unlikely*	Unlikely*
	Approximate Annual Probability	1×10^{-2}	1×10^{-4}	1×10^{-4}
Consequence		Insignificant	Medium	Medium
Risk Category		Low	Low	Low

*Provided good hillside construction practices are followed and the recommendations provided in Section 5 of this report are incorporated into the design and construction phases of the development.

The assessed risk to property is assessed to be low risk. Based on the information provided by the AGS and presented in Attachment 1, Appendix C, the implications for a risk level of low is it is usually acceptable to regulators.

4.6 Risk Assessment to Loss of Life

A risk assessment for the loss of life was undertaken for the identified geotechnical hazards for the site. The risk assessment and management process adopted for this study was carried out in general accordance with AGS (2007a).

In accordance with the AGS 2007c Landslide Risk Management Guidelines for loss of life, the individual risk for loss of life can be calculated from:

$$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where

- $R_{(LoL)}$ is the risk - annual probability of loss of life (death) - of an individual.
- $P_{(H)}$ is the annual probability of the landslide.
- $P_{(S:H)}$ is the probability of spatial impact of the landslide impacting on a location potentially occupied by a person.
- $P_{(T:S)}$ is the temporal spatial probability (e.g. of the location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.
- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

In accordance with AGS 2007, the regulator should set risk acceptance criteria. In this case, Northern Beaches Council is the regulator, and requires the risk to life post development to be 'Tolerable' for existing areas of residential subdivision, provided risk control measures are put in place to control the risk

The risk acceptance criteria consider the occurrence of the potential geotechnical hazards identified for the site and evaluate the risk against a Tolerable Risk Criteria for loss of life. In this instance, the individual risk is accepted due to being tolerable or risk mitigation measures are undertaken to reduce the risk to more tolerable levels.

The AGS 2007 guidelines indicate that the regulator, with assistance from the practitioner where required, is the appropriate authority to set the standards for risk relating to perceived safety in relation to other risks and government policy. The importance of the implementation of levels of the tolerable risk should not be understated due to the wide ranging implications, both in terms of the relative risks or safety to the community and the potential economic impact to the community. The AGS provide recommendations in relation to tolerable risk for loss of life as shown below in Table 4.3.

TABLE 4.3 – AGS Recommendations – Risk to Life

Situation	Suggested Tolerable Loss of Life Risk for Person Most at Risk
Existing Slope(1) / Existing Development(2)	10^{-4}/annum
New Constructed Slope(3) / New Development(4) / Existing Landslide	10^{-5}/annum

Notes:

1. "Existing Slopes" in this context are slopes that are not part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

2. "Existing Development" includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

3. "New Constructed Slope" includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).

4. "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope/Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.

5. "Existing Landslides" have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of "public safety".

Given the depth of proposed excavation, the proposed development at 24 Cabarita Road must be considered a New Development. The AGS risk threshold provided in Table 3.3 for new developments suggests the 'Tolerable Loss of Life for the person most at risk' is 10^{-5} per annum.

The risk assessment has been based on observations made during the site visit by an experienced engineering geologist, and by reviewing available geotechnical data and the future geotechnical requirements for development as outlined elsewhere in this report. Departures from the recommendations in this report may change the quantification of the hazard risk. A risk assessment has been carried out for the identified geotechnical hazards and is presented in Section 4.4 of this report.

The annual probability of a failure occurring has been calculated based on engineering judgement and observations made during the site visit. The probability of spatial impact is calculated by dividing the size of the estimated landslide by the size of the buildings usable area, 450m^2.

The temporal spatial probability for the failure on Cabarita Road has been calculated based on the assumption that someone residing in the dwelling will be using Cabarita Road at the time of failure. In this regard we assume a person would make up to 6 trips per day from the dwelling and be on the road outside the dwelling for 5 minutes each trip. This equates to around 1 hour per day. The probability for failure of an embankment or cut during construction has been taken as a 10 hour working day. This is then divided by the number of hours in a day. The vulnerability of an individual is based on values from Australian Geomechanics Vol. 42. If visitor numbers to the site were to increase, then this would change the risk to loss of life. This could affect whether the risk is considered tolerable or otherwise.

Any changes to the site will affect the risk assessment outcome, making it necessary to carry out the risk assessment again.

From our quantitative risk to life assessment, we have estimated the annual probability of risk to life to be in the range of 1.2×10^{-5} to 4.5×10^{-7}. These values are considered acceptable using the AGS risk acceptance criteria.

5. GEOTECHNICAL RECOMMENDATIONS

5.1 Primary Geotechnical Considerations

Based on the results of the assessment, we consider the following to be the primary geotechnical considerations for the development:

- Bulk excavation for “Level 4” of the main dwelling, and potential ground loss as a result of excavations, resulting in damage to existing structures,
- Removal of existing retaining walls and the steepening of existing batter slopes, and
- Foundation design for structural loads.

5.2 Excavation Conditions and Vibration Control

All excavation recommendations should be complemented with reference to the NSW Government Code of Practice for Excavation work, dated January 2020.

It would be appropriate before commencing excavation to undertake a dilapidation survey of any adjacent structures that may potentially be damaged. This will provide a reasonable basis for assessing any future claims of damage.

Based on the subsurface conditions observed in boreholes, the proposed excavations for Level 4 of the main dwelling are expected to encounter limited fill overlying natural residual clayey soils and sandstone bedrock. Similar conditions are expected to be encountered during removal of the sandstone retaining wall and steepening of the existing batter slopes.

Medium to large sized excavators fitted with a toothed bucket attachment should be capable of removing the soils and sandstone bedrock to the proposed excavation depth of 6.0 metres. Some limited use of ripping tynes may be required if higher strength bands of sandstone are encountered. Hydraulic rock hammers may also be required if extensive lenses of high strength sandstone or ironstone lenses are encountered.

During the use of hydraulic impact hammers, precautions must be made to reduce the risk of vibrational damage to adjoining structures. At the commencement of the use of hydraulic impact hammers we recommend that full time quantitative vibration monitoring be carried out on the adjoining residences or at the boundaries by an experienced vibration consultant or geotechnical engineer to check that vibrations are within acceptable limits.

Australian Standard AS 2187: Part 2-2006 recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 “Evaluation and measurement for vibration in buildings Part 2” as they “are applicable to Australian conditions”. The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where the minimal risk for a named effect is usually taken as a 95% probability of no effect. Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (e.g. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

For residential structures, BS 7385 recommends vibration criteria of 7.5 mm/s to 10 mm/s for frequencies between 4 Hz and 15 Hz, and 10 mm/s to 25 mm/s for frequencies between 15 Hz to 40 Hz and above. These values would normally be applicable for new residential structures or residential structures in good condition. Higher values would normally apply to commercial structures, and more conservative criteria would normally apply to heritage structures.

However, structures can withstand vibration levels significantly higher than those required to maintain comfort for their occupants. Human comfort is therefore likely to be the critical factor in vibration management. Excavation methods should be adopted which limit ground vibrations at the adjoining developments to not more than 10mm/sec. Vibration monitoring is recommended to verify that this is achieved. The limits of 5mm/sec and 10mm/sec are expected to be achievable if rock breaker equipment or other excavation methods are restricted as indicated in Table 5.1.

Table 5.1 – Recommendations for rock breaking equipment

Distance from adjoining structure (m)	Maximum Peak Particle Velocity 5mm/sec		Maximum Peak Particle Velocity 10mm/sec	
	Equipment	Operating Limit (% of maximum capacity)	Equipment	Operating Limit (% of maximum capacity)
1.5 to 2.5	Hand operated hack hammer only	100	300 kg rock hammer	50
2.5 to 5.0	300 kg rock hammer	50	300 kg rock hammer	100
			600 kg rock hammer	50
5.0 to 1.0	300 kg rock hammer	100	600 kg rock hammer	100
	600 kg rock hammer	50	900 kg rock hammer	50

At all times, the excavation equipment must be operated by experienced personnel, per the manufacturer's instructions, and in a manner, consistent with minimising vibration effects.

If during excavation with the hydraulic impact hammers, vibrations are found to be excessive or there is concern, then alternative lower vibration emitting equipment, such as rock saws, rock grinders or smaller hammers may need to be used. The use of a rotary grinder or rock sawing in conjunction with ripping presents an alternative low vibration excavation technique, however, productivity is likely to be slower. When using a rock saw or rotary grinder, the resulting dust must be suppressed by spraying with water.

Excavation contractors should refer to the detailed engineering logs and where available, core photographs, laboratory strength tests, and inspection of rock core samples, and should not rely solely on the rock classifications presented in geotechnical engineering reports when assessing the suitability of their excavation equipment for the proposed development. Further geotechnical advice must be sought if rock excavation characteristics are critical to the proposed development.

It should be noted that vibrations that are below threshold levels for building damage may be experienced at adjoining developments. Rock excavation methodology should also consider acceptable noise limits as per the "Interim Construction Noise Guideline" (NSW EPA).

The excavated material will also need to be classified for disposal purposes, which will require environmental testing of the various materials.

5.3 Temporary Batter Slopes

Suggested temporary and permanent maximum batter slope angles for dry slopes not exceeding 3 metres in height are presented in Table 5.2 below. These recommendations are provided based on the excavations being carried out above any groundwater table (i.e. dry excavation conditions). Further, no surcharge loads, including construction loads and existing footing loads should be placed within H of the top of the batters, where H is the total batter height.

TABLE 5.2 – Recommended Temporary Batter Slopes

Material	Temporary Batter Slope Ratio (H:V)
Unit 1 and 2 - Topsoil / Fill	1.5:1
Unit 3 - Residual Clays	1:1
Unit 4 – Sandstone bedrock	0.75:1*

*Subject to routine geotechnical inspections during bulk excavation.

5.4 Temporary Excavation Support & Retaining Wall Design

The proposed basement excavation is offset around 1 metre from the southern boundary and 2.5 metres from the northern boundary, therefore there will be insufficient space for temporary batters over sections of the site. The excavations for Level 4 of the dwelling will therefore require temporary lateral support to ensure that excavation stability is maintained. Based on the subsurface conditions encountered during the investigation, you may consider using a conventional shoring system such as reinforced soldier/contiguous piles, or alternately you may also consider installing a soil nail wall type system.

For preliminary design purposes the soil nails would need to have a minimum embedment length equal to the excavation height, and would need a shotcrete facing which typically has a minimum thickness of 120mm. Soil nails are a permanent passive support system, and therefore the nails would need to be designed for a 100 year life.

In addition to the excavations for the main dwelling the development will also include the removal of the sandstone retaining wall on the lower portion of the site together with steepening of the above batter slopes. Construction details for the sandstone wall are not known, and it is possible that the shotcrete facing and vegetation on the upper batter slopes are covering soil nails or other ground support systems which could be destabilised by the excavations. It is therefore imperative that the excavations of these faces be undertaken progressively and under the direct supervision of a geotechnical engineer. Depending on the conditions exposed during excavation it may be necessary to progressively support the faces as the excavation proceeds.

When considering the design of the support system, it will be necessary to allow for the loading from structures in adjoining properties, any ground surface slope and the water table present.

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For the design of temporary structures where some ground movement is acceptable, an active earth pressure coefficient (K_a) may be adopted. However, where adjoining structures are within the zone of influence of the excavation, or it is necessary to limit lateral deflections, it will be necessary to adopt at rest (K_o) conditions. K_o conditions should also be used to design the permanent support system.

A triangular lateral earth pressure distribution should be adopted for cantilevered walls, and a rectangular or trapezoidal lateral earth pressure distribution should be adopted for walls that are progressively propped at their top and base, and/or where two or more rows of anchors/nails are used. A triangular earth pressure distribution should be adopted when determining the load on shotcrete infill panels.

Where required, anchors, nails or internal props can also be considered. Where anchors/nails are used and they extend into the adjoining property, it will be necessary to obtain the permission of the property owners.

Retaining walls may be designed using the parameters provided below in Table 5.3.

TABLE 5.3 – Retaining Wall Design Parameters

Material Unit	Dry Bulk Unit Weight (kN/m³)	Effective Cohesion C' (kPa)	Effective Angle of Friction, ϕ (Deg)	Poisson's Ratio	Elastic Modulus E' (MPa)	Earth Pressure Co-efficients		
						At Rest (K_o)	Active (K_a)	Passive (K_p)
Topsoil / Fill / Soft Clay	18	0	24	0.3	5	0.6	0.4	-
Residual Soils	19	2	26	0.3	20	0.6	0.4	2.5
Sandstone Bedrock	21	35	28	0.25	80	0.5	0.3	3.5

The embedment of retaining walls can be used to achieve passive support. A triangular passive earth pressure distribution (increasing linearly with depth) may be assumed, starting from 0.5 m below excavation toe/base level.

5.5 Drainage

Adequate drainage will need to be provided for any subsurface structures and behind retaining walls to prevent the build-up of hydrostatic forces. The drainage should comprise a strong durable single sized washed aggregate with perforated agricultural drains/pipes installed at the base of wall. Seepage should be gravity drained to Careel Bay.

5.6 Foundation Design

On completion of bulk excavation, a combination of soft silty clays and Class 4/5 sandstone bedrock are expected to be exposed over the footprint of Level 4. The clayey soils over the eastern half of the Level 4 footprint are unlikely to have sufficient capacity to support the building loads, and founding the structure on a combination of clays and bedrock may result in differential settlement. We therefore recommend that the proposed building be uniformly supported on footings founded in the underlying sandstone bedrock.

The lower portion of the site around the existing boatshed has likely been reclaimed, and therefore the ground conditions are expected to comprise poorly compacted uncontrolled fill overlying sandstone bedrock. Sandstone bedrock was also observed outcropping below the existing sea wall. Therefore, foundations over the boatshed section of the site will also need to be transferred to the underlying bedrock.

Foundation design parameters for the various units are provided in Table 5.4 below:

TABLE 5.4 – Foundation Design Parameters

(Unit) Material	Maximum Allowable (Serviceability) Values (kPa)		
	End Bearing Pressure	Shaft Friction in compression#	Shaft Friction in tension*
Topsoil/Fill/Soft clay	-	-	-
Firm to Stiff/Stiff Clay	100	20	10
Very Stiff Clay	300	20	10
Class 5 Sandstone	700	70	35

* Uplift capacity of piles in tension loading should also be checked for inverted cone pull out mechanism.

clean socket of roughness category R2 or better is assumed

Settlements for footings on rock are anticipated to be about 1% of the minimum footing dimension, based on serviceability parameters as per Table 5.4. Settlements for pad footings in clayey soils are anticipated to be up to about 15mm where loading does not exceed the maximum allowable values.

All footings should be poured with minimal delay (i.e. preferably on the same day of excavation) or the base of the footing should be protected by a concrete blinding layer after cleaning of loose spoil and inspection.

Drilling of rock sockets into the sandstone bedrock will require the use of large excavators or piling rigs equipped with rock augers. Some minor groundwater inflow should be anticipated into the bored pile excavations drilled over the upper and central portion of the site, however seepage in these areas is expected to be controllable by conventional pumping methods.

GREEN GEOTECHNICS

Piles drilled from the existing boatshed level are expected to encounter free flowing groundwater below 1 metre depth, therefore conventional bored cast in-situ piles are unlikely to be suitable for this portion of the site. You may therefore wish to consider the use of steel screw piles in this area. The screw piles would however need to be fitted with a cutting face to ensure the helix can fully embed into the underlying bedrock.

Bored pile footings should be drilled, cleaned, inspected and poured with minimal delay, on the same day. Water should be prevented from ponding in the base of footings as this will tend to soften the foundation material, resulting in further excavation and cleaning being required.

The initial stages of footing excavation/drilling, particularly if bored piles are adopted, should be inspected by a geotechnical engineer/engineering geologist to ascertain that the recommended foundation material has been reached and to check initial assumptions about foundation conditions and possible variations that may occur between borehole locations. The need for further inspections can be assessed following the initial visit.

6. FURTHER GEOTECHNICAL INPUT

The following summarises the scope of further geotechnical work recommended within this report. For specific details reference should be made to the relevant sections of this report.

- Complete dilapidation surveys of the adjoining buildings and structures.

- Inspection of the excavation cut faces as they progress, particularly during removal of the lower sandstone wall and steepening of the existing batter slope faces.

- Inspection of footing excavations to ascertain that the recommended foundation has been reached and to check initial assumptions regarding foundation conditions and possible variations that may occur.

- We also recommend that Green Geotechnics view the proposed earthworks and structural drawings in order to confirm they are within the guidelines of this report.

Nevertheless, it will be essential during excavation and construction works that progressive geotechnical inspections be commissioned to check initial assumptions about excavation and foundation conditions and possible variations that may occur between inspected and tested locations and to provide further relevant geotechnical advice.

7. GENERAL RECOMMENDATIONS

Any development on the site should follow good hillside building practices (refer to Attachment 4 for some examples).

Based on the observations made during the site walkover and the risk assessment undertaken, it has been determined that the site has a low risk of slope instability. The site is suitable for residential development provided good hillside building practices are followed. There are no geotechnical constraints for the proposed development of the site; however, Section 5 of this report provides advice and recommendations that should be taken into consideration and applied to any future development.

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and Green Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, the subsurface conditions may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of Green Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

REPORT INFORMATION

Introduction

These notes have been provided to amplify Green Geotechnics report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

Green Geotechnics reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several limitations, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. The borehole must be flushed, and any water must be extracted from the hole if further water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, GG will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, GG cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, Green Geotechnics will be pleased to assist with investigations or advice to resolve the matter.

Site Anomalies

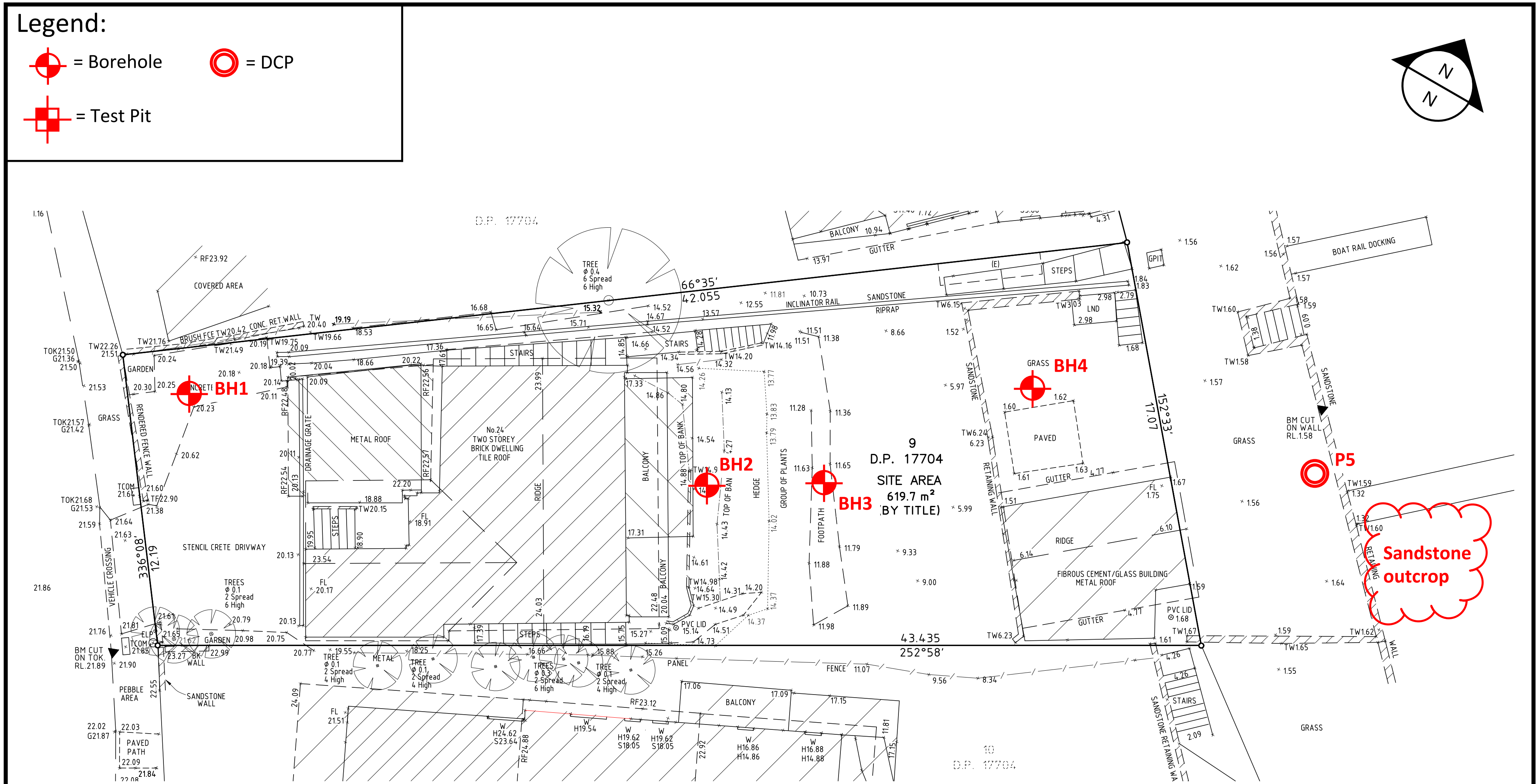
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, GG requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Copyright

FIGURES

Subject Site

GREEN GEOTECHNICS	Project No: GG10371.001A	Geotechnical Investigation 24 Cabarita Road, Avalon	Figure No: GG10371.001A
	Client: Bruce & Elizabeth MacDiarmid		Drawn By: MG
	Date: 6 February 2023	**SITE LOCATION PLAN**	Scale: Unknown



GREEN GEOTECHNICS	Project No: GG10371.001A	Geotechnical Investigation 24 Cabarita Road, Avalon **TEST LOCATION PLAN**	Figure No: GG10371.001B
	Client: Bruce & Elizabeth MacDiarmid		Drawn By: MG
	Date: 6 February 2023		Scale: Unknown

FRONT DRIVEWAY AREA LOOKING TOWARDS BH1

UPPER TERRACE LOOKING TOWARDS BH2

MID TERRACE LOOKING TOWARDS BH3

GREEN GEOTECHNICS	Project No: GG10371.001A	Geotechnical Investigation 24 Cabarita Road, Avalon **SITE PHOTOGRAPHS**	Page 1 of 4
	Client: Bruce & Elizabeth MacDiarmid		
	Date: 6 February 2023		

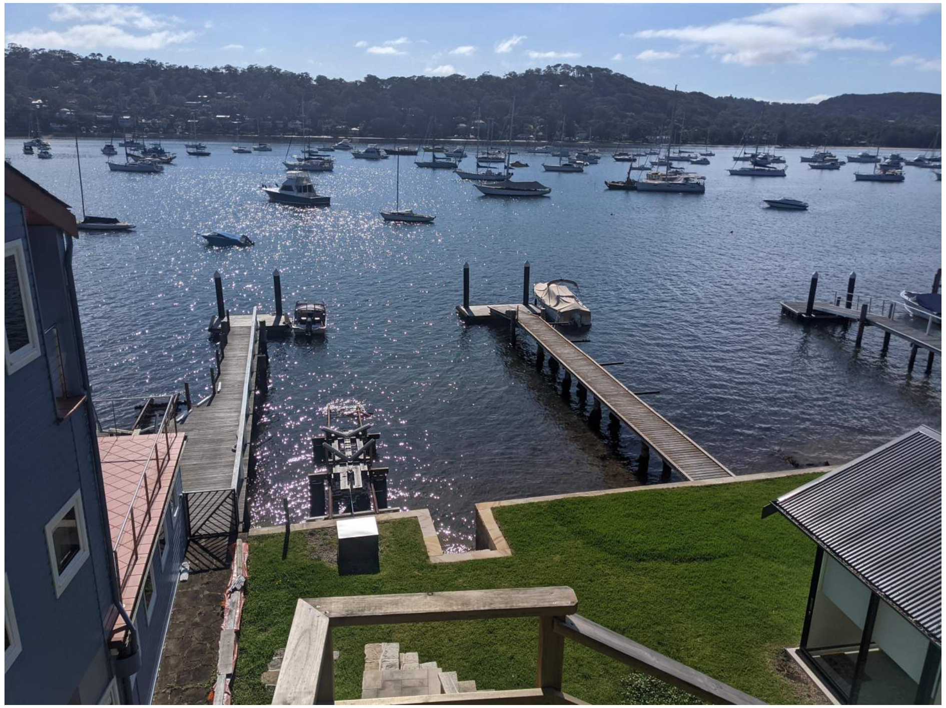
LOWER TERRACE LOOKING AT BH4

VIEW OF EXISTING DWELLING LOOKING UP SLOPE

TILTING STEPS ON NORTHERN SIDE OF DWELLING AJDACENT TO INCLINATOR

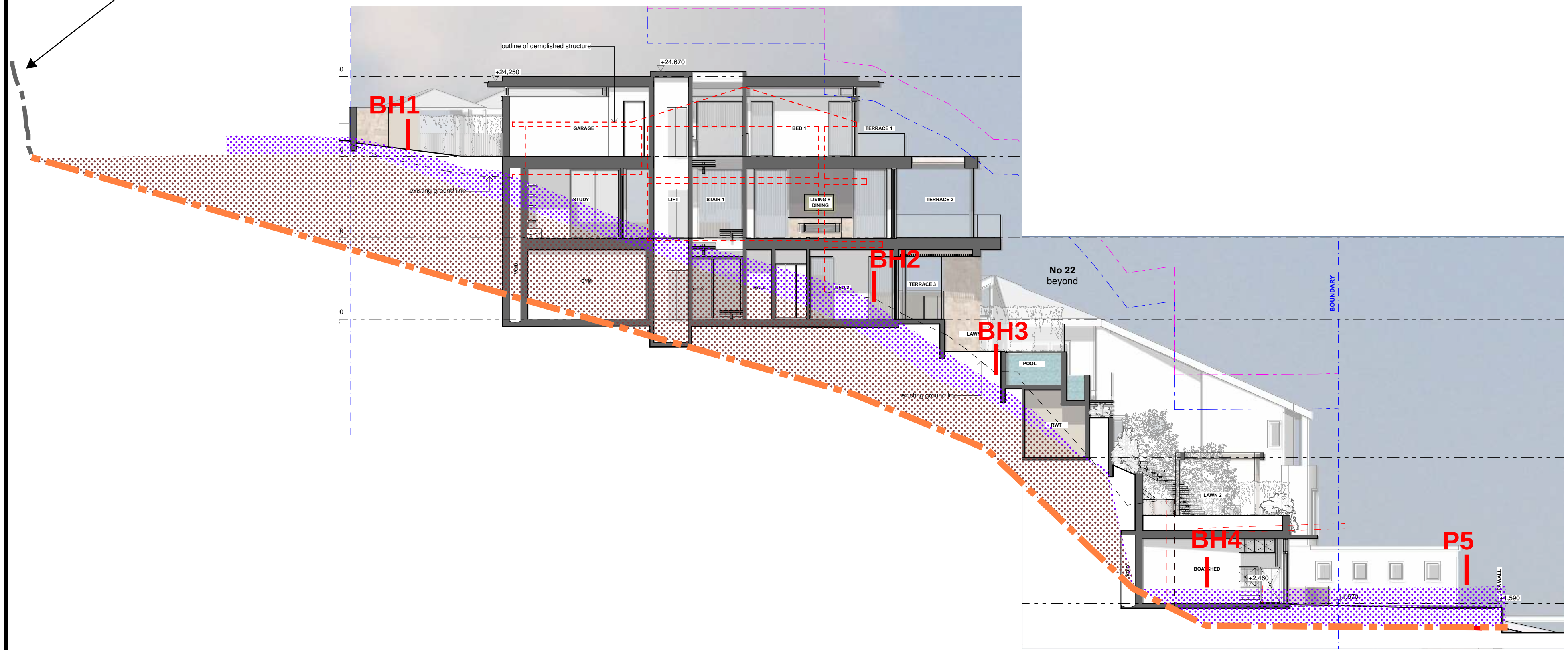
BACK SCARP OF LANDSLIP ON WESTERN SIDE OF AVALON ROAD WITH BEDDING DIPPING INTO THE SLOPE

SHOTCRETE EXPOSED AT LOWER-MID TERRACE ABOVE SANDSTONE MASONRY WALL



VIEW OF THE REAR OF SITE

Rock Cut In Cabarita Road



= Fill

= Colluvial / Residual Soils

= Inferred bedrock profile

GREEN GEOTECHNICS	Project No: GG10371.001A	Geotechnical Investigation 24 Cabarita Road, Avalon	Figure No: GG10371.001D
	Client: Bruce & Elizabeth MacDiarmid		Drawn By: MG
	Date: 6 February 2023	**CROSS SECTION**	Scale: Unknown

APPENDIX A – BOREHOLE LOGS

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10371	Surface RL: 20.2m AHD	Date Logged : 14/10/2021	**BOREHOLE NO.: BH 1**
Address: 24 Cabarita Road, Avalon		Logged By: JK	
Client: Bruce and Elizabeth MacDiarmid		Checked By: MG	Sheet 1 of 1

WATER TABLE	SAMPLES	DEPTH (M)	DESCRIPTION (Soil type, colour, grain size, plasticity, minor components, observations)	USC SYMBOL	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	MOISTURE
			CONCRETE: 100mm thick			
			FILL: Clayey Silty SAND: Dark brown to orange brown, fine grained with occasional sandstone gravel	SM	APPEARS POORLY COMPACTED	M
		1.0	Silty Sandy CLAY: Orange brown, medium plasticity with fine grained sand	CI	STIFF	M
		2.0	Silty CLAY: Orange brown with light grey, medium to high plasticity with a trace of fine sand	CI / CH	STIFF	M
		3.0	Silty Sandy CLAY: Orange brown with light grey, medium to high plasticity with fine grained sand	CI / CH	STIFF	M
		4.0	Silty Sandy CLAY: Light grey with orange, medium to high plasticity with fine grained sand	CI / CH	STIFF VERY STIFF	M
		5.0	SANDSTONE: Orange brown with light grey, fine grained, estimate extremely weathered, very low strength (Class 5)			D
			AUGER REFUSAL AT 5.3m ON WEATHERED SANDSTONE BEDROCK (CLASS 4)			

D - Disturbed sample	U - Undisturbed tube sample	B - Bulk sample	Contractor: Green Geotechnics
S - Chemical Sample	SPT - Standard Penetration Test		Equipment: Christie Utility
WT - Standing Water Table	SP - Water Seepage Level		Hole Diameter (mm): 105
NOTES:	See explanation sheets for meaning of all descriptive terms and symbols		Angle from Vertical (^{o}): 90
			Drill Bit: Spiral TC

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10371 | Surface RL: 14.5m AHD | Date Logged : 14/10/2021

Address: 24 Cabarita Road, Avalon | Logged By: JK

Client: Bruce and Elizabeth MacDiarmid | Checked By: MG

BOREHOLE NO.: BH 2

Sheet 1 of 1

WATER TABLE	SAMPLES	DEPTH (M)	DESCRIPTION (Soil type, colour, grain size, plasticity, minor components, observations)	USC SYMBOL	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	MOISTURE
			FILL: Clayey Silty SAND: Dark brown with dark grey, fine to medium grained with occasional gravel	SM	APPEARS POORLY COMPACTED	D-M
		1.0				
			Silty CLAY: Orange brown with red brown and light grey, high plasticity	CH	SOFT	M
		2.0				
			Silty Sandy CLAY: Orange brown with light grey, medium to high plasticity with fine grained sand	CI / CH	FIRM TO STIFF	M
			HAND AUGER REFUSAL AT 2.5m ON NATURAL CLAY		STIFF	
		3.0	*DCP rods wet 2.5 to 3.0m * Possible bedrock at 3.0m		VERY STIFF TO HARD	
		4.0				
		5.0				

D - Disturbed sample | U - Undisturbed tube sample | B - Bulk sample

S - Chemical Sample | SPT - Standard Penetration Test

WT - Standing Water Table | SP - Water Seepage Level

NOTES: See explanation sheets for meaning of all descriptive terms and symbols

Contractor: Green Geotechnics

Equipment: Hand Auger

Hole Diameter (mm): 62

Angle from Vertical (^{o}): 90

Drill Bit: Mild Steel

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10371	Surface RL: 11.6m AHD	Date Logged : 14/10/2021	**BOREHOLE NO.: BH 3**
Address: 24 Cabarita Road, Avalon		Logged By: JK	
Client: Bruce and Elizabeth MacDiarmid		Checked By: MG	Sheet 1 of 1

WATER TABLE	**SAMPLES**	**DEPTH (M)**	**DESCRIPTION** (Soil type, colour, grain size, plasticity, minor components, observations)	**USCS SYMBOL**	**CONSISTENCY** (cohesive soils) or **RELATIVE DENSITY** (sands and gravels)	**MOISTURE**
			Silty Sandy CLAY: Dark brown to grey, low plasticity, fine grained with a trace of gravel	CL	APPEARS POORLY COMPACTED	M
			HAND AUGER REFUSAL AT 0.3m IN FILL			
		1.0				
		2.0	Possible bedrock at 2.0m			
		3.0				
		4.0				
		5.0				

D - Disturbed sample	U - Undisturbed tube sample	B - Bulk sample	Contractor: Green Geotechnics
S - Chemical Sample	SPT - Standard Penetration Test		Equipment: Hand Auger
WT - Standing Water Table	SP - Water Seepage Level		Hole Diameter (mm): 62
NOTES:	See explanation sheets for meaning of all descriptive terms and symbols		Angle from Vertical (^{o}): 90
			Drill Bit: Mild Steel

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10371	Surface RL: 1.6m AHD	Date Logged : 14/10/2021	
Address: 24 Cabarita Road, Avalon		Logged By: JK	**BOREHOLE NO.: BH 4**
Client: Bruce and Elizabeth MacDiarmid		Checked By: MG	Sheet 1 of 1

WATER TABLE	**SAMPLES**	**DEPTH (M)**	**DESCRIPTION** (Soil type, colour, grain size, plasticity, minor components, observations)	**USC SYMBOL**	**CONSISTENCY** (cohesive soils) or **RELATIVE DENSITY** (sands and gravels)	**MOISTURE**
			FILL: Silty Sandy CLAY: Dark brown, low plasticity with fine grained sand	CL	APPEARS POORLY COMPACTED	M
			FILL: Gravelly Sandy CLAY: Orange brown with light grey, medium plasticity with fine grained sand and some gravel and cobbles of bedrock	CL		M
			HAND AUGER REFUSAL AT 0.6m IN FILL			
		1.0	DCP rods wet at 1.0m			
			Possible bedrock at 1.5m			
		2.0				
		3.0				
		4.0				
		5.0				

D - Disturbed sample	U - Undisturbed tube sample	B - Bulk sample	Contractor: Green Geotechnics
S - Chemical Sample	SPT - Standard Penetration Test		Equipment: Hand Auger
WT - Standing Water Table	SP - Water Seepage Level		Hole Diameter (mm): 62
NOTES:	See explanation sheets for meaning of all descriptive terms and symbols		Angle from Vertical (^{o}): 90
			Drill Bit: Mild Steel

Dynamic Cone Penetrometer Test Report

Project Number: GG10371
Site Address: 24 Cabarita Road, Avalon
Test Date: 14/10/2021

Test Method: **AS 1289.6.3.2**

Technician: JK

Test No	BH1	BH2	BH3	Test No	BH1		
Starting Level	Surface	Surface	Surface	Starting Level	3.0m		
Depth (m)	Penetration Resistance (blows / 150mm)			Depth (m)	Penetration Resistance (blows / 150mm)		
0.00 - 0.15	*	1	1	3.00 - 3.15	4		
0.15 - 0.30	*	2	3	3.15 - 3.30	6		
0.30 - 0.45	1	1	3	3.30 - 3.45	6		
0.45 - 0.60	2	1	2	3.45 - 3.60	5		
0.60 - 0.75	3	1	2	3.60 - 3.75	5		
0.75 - 0.90	6	1	3	3.75 - 3.90	7		
0.90 - 1.05	4	1	4	3.90 - 4.05	8		
1.05 - 1.20	6	1	6	4.05 - 4.20	10		
1.20 - 1.35	9	1	10	4.20 - 4.35	10		
1.35 - 1.50	10	1	10	4.35 - 4.50	11		
1.50 - 1.65	18	1	9	4.50 - 4.65	12		
1.65 - 1.80	22	1	12	4.65 - 4.80	22		
1.80 - 1.95	Refusal	1	22	4.80 - 4.95	Refusal		
1.95 - 2.10	*	2	Refusal	4.95 - 5.10			
2.10 - 2.25	*	2		5.10 - 5.25			
2.25 - 2.40	*	3		5.25 - 5.40			
2.40 - 2.55	*	4		5.40 - 5.55			
2.55 - 2.70	*	6		5.55 - 5.70			
2.70 - 2.85	*	10		5.70 - 5.85			
2.85 - 3.00	*	22 Refusal		5.85 - 6.00			

Remarks: * Pre drilled prior to testing

Dynamic Cone Penetrometer Test Report

Project Number: GG10371

Site Address: 24 Cabarita Road, Avalon

Test Date: 14/10/2021

Test Method: **AS 1289.6.3.2**

Technician: JK

Test No	BH4	P5		Test No			
Starting Level	Surface	Surface		Starting Level			
Depth (m)	Penetration Resistance (blows / 150mm)			Depth (m)	Penetration Resistance (blows / 150mm)		
0.00 - 0.15	1	1		3.00 - 3.15			
0.15 - 0.30	4	2		3.15 - 3.30			
0.30 - 0.45	6	2		3.30 - 3.45			
0.45 - 0.60	8	1		3.45 - 3.60			
0.60 - 0.75	9	1		3.60 - 3.75			
0.75 - 0.90	4	2		3.75 - 3.90			
0.90 - 1.05	19	3		3.90 - 4.05			
1.05 - 1.20	6	3		4.05 - 4.20			
1.20 - 1.35	22	4		4.20 - 4.35			
1.35 - 1.50	Refusal	8		4.35 - 4.50			
1.50 - 1.65		22		4.50 - 4.65			
1.65 - 1.80		Refusal		4.65 - 4.80			
1.80 - 1.95				4.80 - 4.95			
1.95 - 2.10				4.95 - 5.10			
2.10 - 2.25				5.10 - 5.25			
2.25 - 2.40				5.25 - 5.40			
2.40 - 2.55				5.40 - 5.55			
2.55 - 2.70				5.55 - 5.70			
2.70 - 2.85				5.70 - 5.85			
2.85 - 3.00				5.85 - 6.00			

Remarks: * Pre drilled prior to testing

SAMPLING & IN-SITU TESTING

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock. Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure. Undisturbed samples are taken by pushing a thin walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength and are necessary for laboratory determination of shear strength and compressibility.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator.

Large Diameter Augers

Boreholes can be drilled using a large diameter auger, typically up to 300 mm or larger in diameter mounted on a standard drilling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration.

Diamond Core Rock Drilling

A continuous core sample of can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter (NMLC). The borehole is advanced using a water or mud flush to lubricate the bit and removed cuttings.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable, and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as: 15, 30/40 mm.

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.

- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

SOIL DESCRIPTIONS

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle Size (mm)
Boulder >200	Boulder >200
Cobble 63 - 200	Cobble 63 - 200
Gravel 2.36 - 63	Gravel 2.36 - 63
Sand 0.075 - 2.36	Sand 0.075 - 2.36
Silt 0.002 - 0.075	Silt 0.002 - 0.075
Clay <0.002	Clay <0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle Size (mm)
Coarse Gravel	20 – 63
Medium Gravel	6 – 20
Fine Sand	2.36 – 6
Coarse Sand	0.6 – 2.36
Medium Sand	0.2 – 0.6
Fine Sand	0.075 – 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion
And	Specify
Adjective	20 - 35%
Slightly	12 - 20%
With some	5 - 12%
With a trace of	0 - 5%

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained Shear Strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	ST	50 - 100
Very stiff	VST	100 - 200
Hard	H	200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (DCP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N Value	CPT qc value (MPa)
Very loose	VL	<4	<2
Loose	L	4 - 10	2 -5
Medium Dense	MD	10-30	5-15
Dense	D	30-50	15-25
Very Dense	VD	>50	>25

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

ROCK DESCRIPTIONS

GREEN
GEOTECHNICS

Rock Strength

The Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $IS_{(50)}$ MPa	Approximate Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200

* Assumes a ration of 20:1 for UCS to $IS_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable.
Moderately weathered	MW	Staining and discolouration of rock substance has taken Place.
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh stained	FS	Rock substance unaffected by weathering but staining visible along defects.
Fresh	FR	No signs of decomposition or staining.

Degree of Fracturing

The following classification applies to the spacing of natural fractures in core samples (bedding plane partings, joints and other defects, excluding drilling breaks

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured Core	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Unbroken Core lengths mostly > 1000 mm

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	2 m

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100 \text{ mm long}}{\text{total drilled length of section being assessed}}$$

'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling/handling, then the broken pieces are fitted back together and are not included in the calculation of RQD.

ABBREVIATIONS

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

Z	Water seep
V	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
S	Chemical sample
U50	Undisturbed tube sample (50mm)
W	Water sample
PP	Pocket Penetrometer (kPa)
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

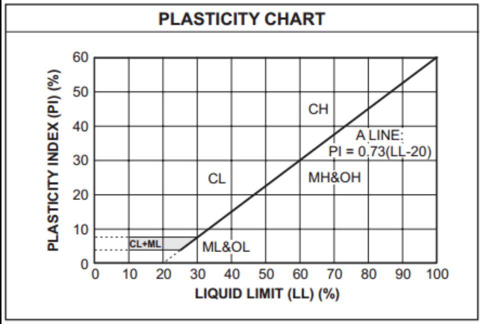
Other

fg	fragmented
bnd	band
qtz	quartz

UNIFIED SOIL CLASSIFICATION TABLE

Field Identification Procedures (Excluding particles larger than 75um and basing fractions on estimated weights)				Group Symbols	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria	
Coarse-grained soils More than half of the material is large that 75um sieve size[b] (The 75um sieve size is about the particle visible to the naked eye)	Gravels More than half of the coarse fraction is larger than a 4mm sieve	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name: indicative approximate percentages of sand and gravel; maximum size; angularity; surface condition, and hardness of the coarse grains; local of geologic name and other pertinent descriptive information; and symbols in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics Example: *Silty Sand*, gravelly; about 20% hard, angular gravel particles 12mm maximum size; rounded and subangular sand grains, coarse to fine, about 15% non-plastic fines low dry strength; well compacted and moist in place; alluvial sand; *(SM)*	Use grain size curve in identifying the fractions as given under field identification Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than 75um sieve size) coarse grained soils are classified as follows Less than 5% GW, GP, SW, SP More than 12% GM, GC, SM, SC 5 to 12% Borderline cases requiring use of dual symbol	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, grave-sand mixtures, little or no fines			Not meeting all graduation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures			Atterberg limits below "A" line or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are borderline cases of requiring use of dual symbols
			Plastic fines (for identification procedures see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures			Atterberg limits above "A" line with *PI* greater than 7
	Sands More than half of the coarse fraction is smaller than a 4mm sieve	Clean sands (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines			$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines			Not meeting all graduation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures			Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are borderline cases of requiring use of dual symbols
			Plastic fines (for identification procedures see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures			Atterberg limits above "A" line with *PI* greater than 7

Find-grained soils More than half of the material is smaller than 75um sieve size	Identification Procedures of Fractions Smaller than 380 um Sieve Size: Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slit plasticity	Give typical name: indicative degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions Example: *Clayey Silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; *(ML)*
	Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
	Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	
Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts	
	High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
	Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils	Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity Chart
For laboratory classification of fine-grained soils

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines

2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity

APPENDIX B – AGS 2007 GUIDELINES

ATTACHMENT 1: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

ATTACHMENT 1: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

ATTACHMENT 2 - DEFINITION OF TERMS AND LANDSLIDE RISK

(Australian Geomechanics Vol 42 No 1 March 2007)

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any year.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Elements at Risk – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Hazard – A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Individual Risk to Life – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Landslide Activity – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (e.g. seasonal) or continuous (in which case the slide is "active").

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Landslide Risk – The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

Landslide Susceptibility – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

Likelihood – Used as a qualitative description of probability or frequency.

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an "objective" or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

Qualitative Risk Analysis – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative Risk Analysis – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Risk Analysis – The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: Scope definition, hazard identification and risk estimation.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Estimation – The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.

Risk Evaluation – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Management – The complete process of risk assessment and risk control (or risk treatment).

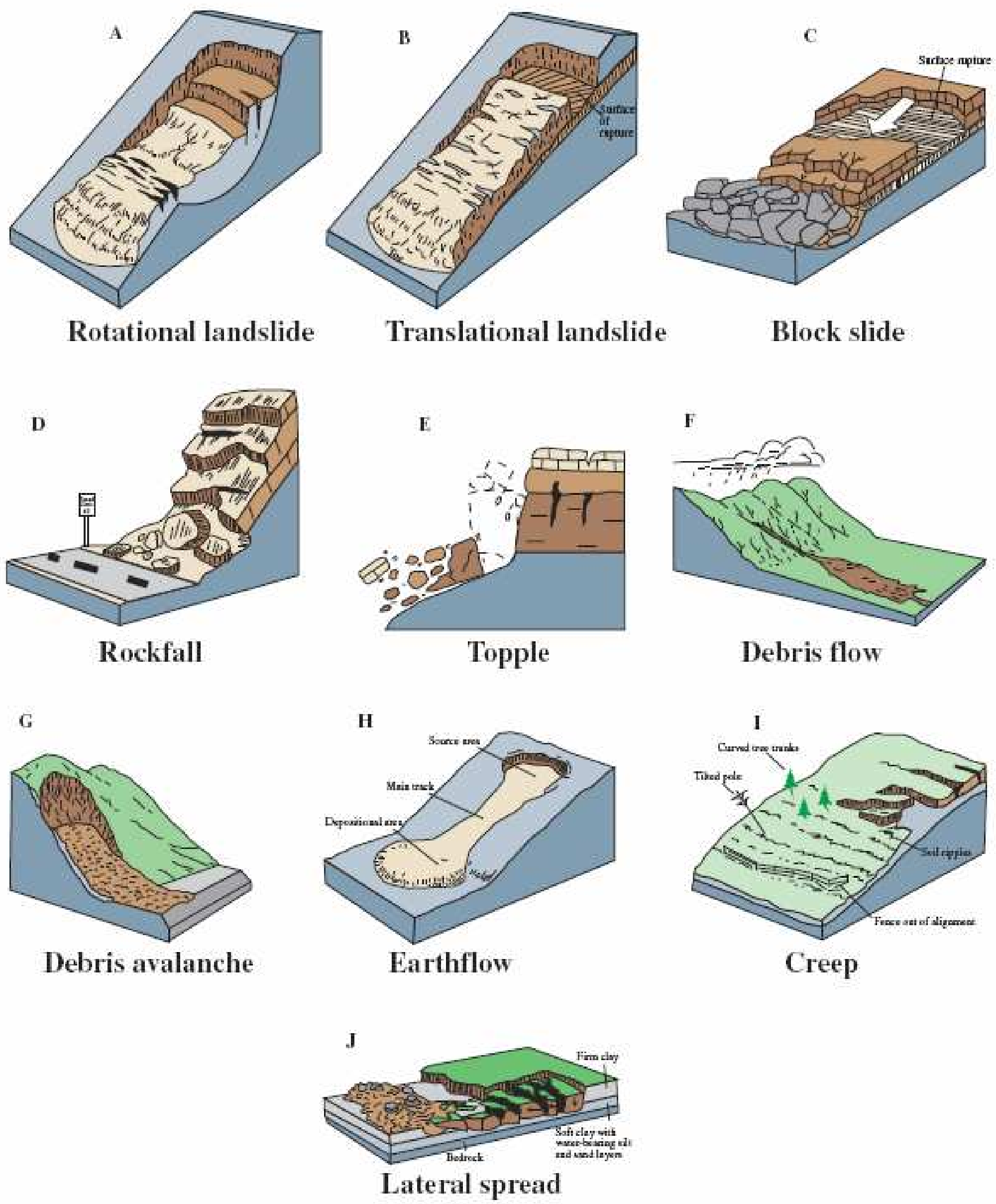
Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

Susceptibility – see Landslide Susceptibility

Temporal Spatial Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.



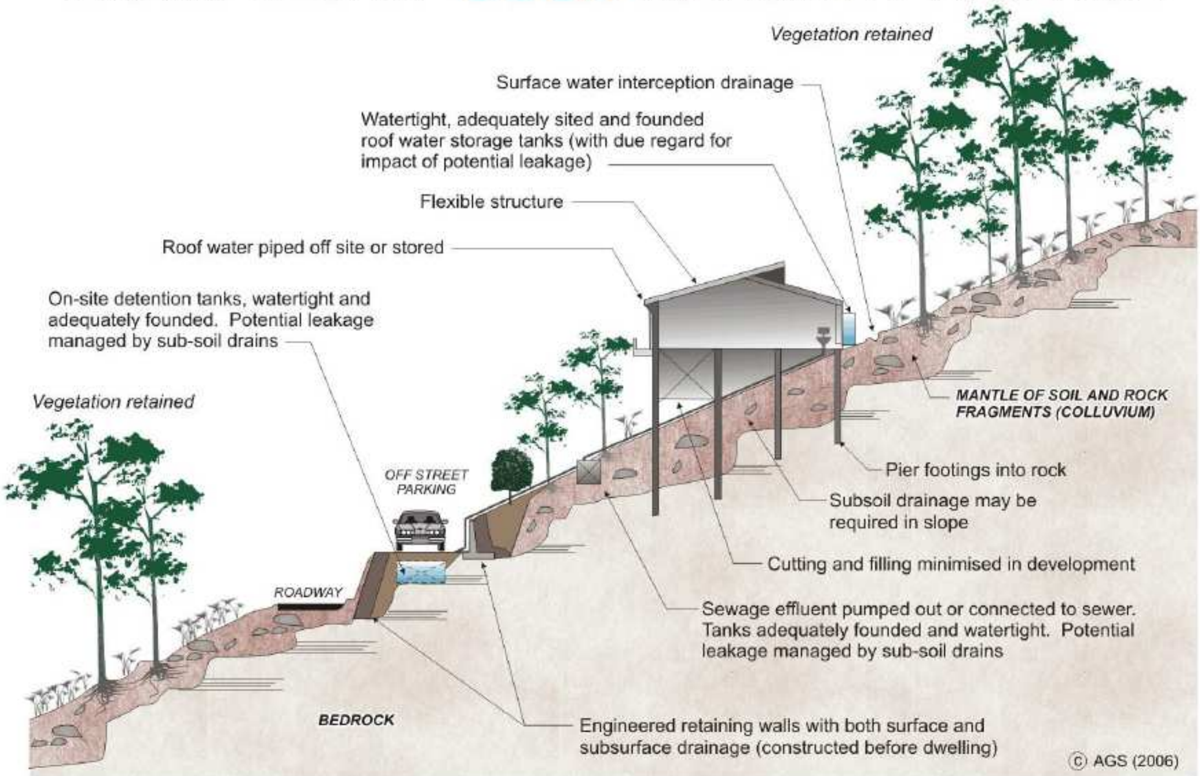
ATTACHMENT 3 MAJOR TYPES OF LANDSLIDES

ATTACHMENT 4

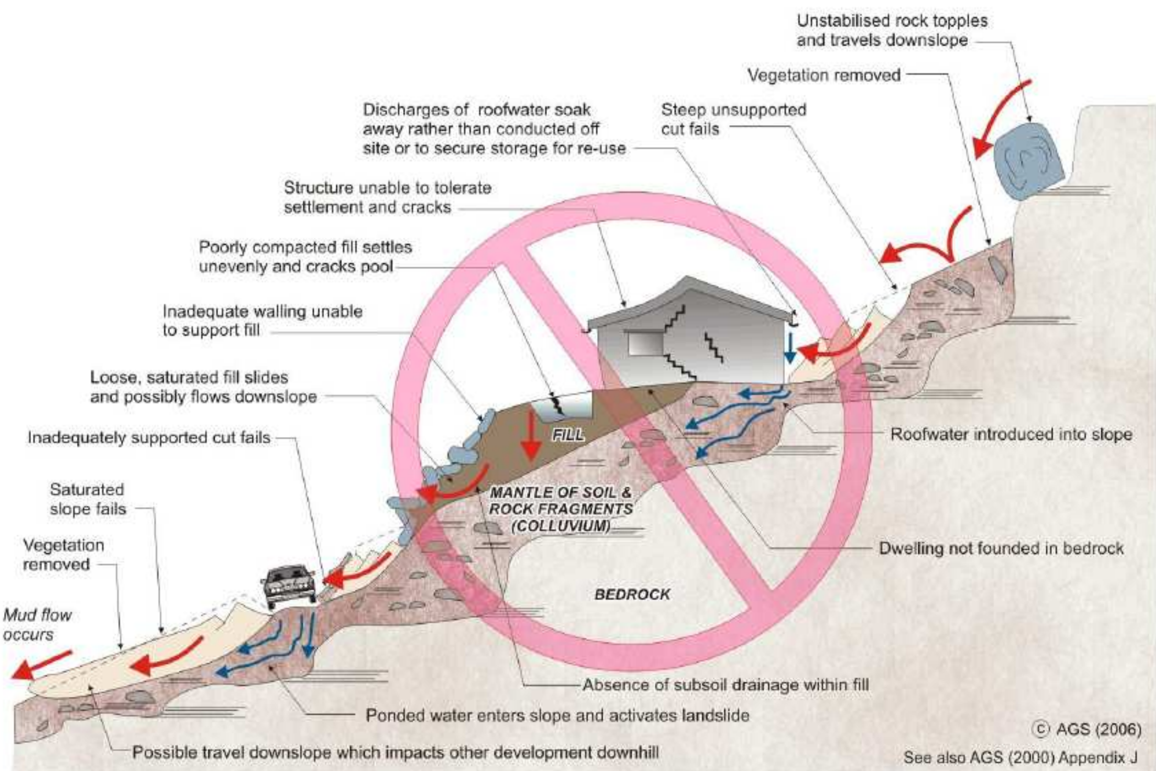
SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



APPENDIX C – COMPLETED FORMS 1 & 1A

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for ______________________________

Name of Applicant

Address of site 24 CABARITA ROAD, AVALON

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, Matthew Green *on behalf of* Green Geotechnics Pty Ltd

(Insert Name) (Trading or Company Name)

on this the 6 February 2023 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least ~~$10million~~. $5,000,000.00

I:

Please mark appropriate box

- ✓ have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ∍ am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ✓ have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- ∍ have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ∍ have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ∍ have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Geotechnical Investigation - 24 Cabarita Road, Avalon

Report Date: Revision A - 6/2/2023

Author: Matthew Green

Author's Company/Organisation: Green Geotechnics Pty Ltd

Documentation which relate to or are relied upon in report preparation:

Architectural Drawings by Corben Architects Revision A (Reference MACA)
Site Survey Drawing Reference 11267-00 Prepared by ATS Land &
Engineering Surveyors

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature . MG ………………………………………………

Name Matthew Green ………………………………………………

Chartered Professional Status MAIG ………………………………

Membership No. 7337 ………………………………………………

Company Green Geotechnics Pty Ltd ……………………………

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for______________________________
Name of Applicant
Address of site 24 CABARITA ROAD, AVALON

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Geotechnical Investigation - 24 Cabarita Road, Avalon
Report Date: Revision A - 6/2/2023
Author: Matthew Green
Author's Company/Organisation: Green Geotechnics Pty Ltd

Please mark appropriate box

✓ Comprehensive site mapping conducted 12/10/21
(date)
✓ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
✓ Subsurface investigation required
- ∍ No Justification ……………………………………………………...
- ∍ Yes Date conducted 14/10/21

✓ Geotechnical model developed and reported as an inferred subsurface type-section
✓ Geotechnical hazards identified
- ✓ Above the site
- ✓ On the site
- ∍ Below the site
- ∍ Beside the site

✓ Geotechnical hazards described and reported
✓ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ∍ Consequence analysis
- ∍ Frequency analysis

✓ Risk calculation
✓ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
✓ Design Life Adopted:
- ✓ 100 years
- ∍ Other ……………………………………………
specify

✓ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
✓ Additional action to remove risk where reasonable and practical have been identified and included in the report.
∍ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ……………………………………………………
Name Matthew Green
Chartered Professional Status MAIG
Membership No. 7337
Company Green Geotechnics Pty Ltd