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PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT

for

PROPOSED SUBDIVISION

at

337 LOWER PLATEAU ROAD, BILGOLA PLATEAU, NSW

Prepared For

Ray and Mary Trevisan

Project No.: 2022-214

October 2022

Document Revision Record

Issue No	Date	Details of Revisions
0	11th October 2022	Original issue

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GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for____________________Ray and Mary Trevisan________________________

Name of Applicant

Address of site ___ 337 Lower Plateau Road, Bilgola Plateau, NSW

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

I, __***Troy Crozier***__________ *on behalf of* ___***Crozier Geotechnical Consultants*** *11* October 2022 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 $2million.

I:

☐ 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 Report for Proposed Subdivision

Report Date: 11 October 2022 **Project No.:** 2022-214

Author: Ben Taylor

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Architectural Drawings – Gartner Trovato Architects, Proposed Sub-division, Project no.: 2133, Drawing No.: 01 to 08, Dated: 30th August 2022
Survey Drawing – Stutchbury Jacques, Reference: 11342/21, Dated: 17/01/2022

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 ....

Name ...**Troy Crozier**..

Chartered Professional Status...**RPGeo (AIG)** ....

Membership No.: ...**10197**..

Company... **Crozier Geotechnical Consultants**

REGISTERED PROFESSIONAL GEOSCIENTIST
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TROY CROZIER
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GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for Ray and Mary Trevisan
Name of Applicant
Address of site 337 Lower Plateau Road, Bilgola Plateau, NSW

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 Report for Proposed New Subdivision
Report Date: 11 October 2022 **Project No.:** 2022-214
Author: Ben Taylor
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

■ Comprehensive site mapping conducted 23 September 2022

■ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
■ Subsurface investigation required
 ☐ No Justification ...... minor works only.
 ■ Yes Date conducted ......23 September 2022...

■ 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 ...**Troy Crozier**..

Chartered Professional Status...**RPGeo (AIG)** ....

Membership No. ...**10197**..

Company... **Crozier Geotechnical Consultants**

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PRELIMINARY GEOTECHNICAL INVESTIGATION FOR PROPOSED SUBDIVISION
337 LOWER PLATEAU ROAD, BILGOLA PLATEAU, NSW

1. INTRODUCTION:

This report details the results of a preliminary geotechnical investigation carried out for proposed works at 337 Lower Plateau Road, Bilgola Plateau. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the written request of Gartner Trovato Architects on behalf of the owners, Ray and Mary Trevisan.

It is understood that the proposed works involve demolition of the existing dwelling, sub-division of the property into three lots, and subsequent construction of individual dwellings. This report is supplied for subdivision only, however it addresses preliminary dwelling designs supplied.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils precinct (Geotechnical Risk Management Policy for Pittwater – 2009). To meet the Councils Policy requirements for land classified as H1 a detailed Geotechnical Report is required which meets the requirements of Paragraph 6.5 of that policy, including a landslide risk assessment to the methods of AGS 2007 for the site and proposed works.

This preliminary geotechnical report details the existing conditions and how development may be achieved to ensure geotechnical stability and good engineering practice for the three new subdivided lots as well as a landslide hazard assessment as per the AGS March 2007 publication.

The field investigation was limited by access issues across the site however it comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Senior Geotechnical Engineer,
a) The drilling of one borehole using hand tools along with Dynamic Cone Penetrometer (DCP) testing adjacent to the borehole to investigate the subsurface conditions.

The following documents have been supplied and relied upon for the proposal, investigation and reporting:

- Architectural Drawings – Gartner Trovato Architects, Proposed Sub-division, Project no.: 2133, Drawing No.: 01 to 08, Dated: 30th August 2022
- Survey Drawing – Stutchbury Jacques, Reference: 11342/21, Dated: 17/01/2022

1.1 Proposed Development:

It is understood that the proposed works involve the demolition of the existing dwelling and sub-division of the property into three lots, with the subsequent construction of separate dwellings. The initial works involve the sub-division with geotechnical reporting to assess the conditions against the Council policy and the proposed preliminary dwelling designs to provide advice on reducing excavation

2. SITE FEATURES:

2.1. Site Description:

The site is an irregular near "battle-axe" shaped block which covers an area of approximately 3,410m^2 in plan. It is located on the low western side of Lower Plateau Road within a gully which drains down from the plateau to Pittwater to the west. An aerial photograph of the site and surrounds with boundary designations is provided below (Photograph 1), as sourced from Six Maps Spatial Data.

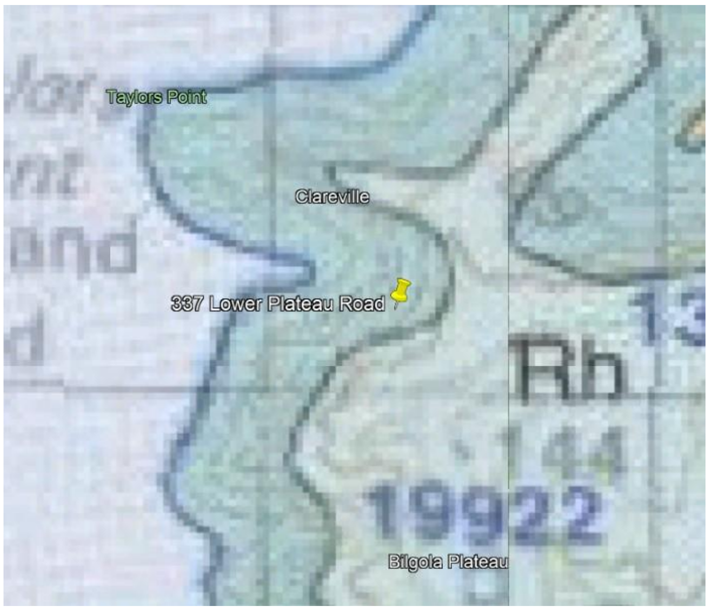
Photograph 1: Aerial photo of site (outlined red) and surrounds

2.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet (9130) indicates that the site is located near the boundary between the Hawkesbury Sandstone (Rh) and underlying Upper Narrabeen Group (Rnn). Site inspection confirmed that the site is underlain by Newport Formation (Upper Narrabeen Group) rock which is of middle Triassic Age. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones.

Narrabeen Group rocks are dominated by shales and thin siltstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise shale beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases large space convex joints. The shale often forms deeply weathered silty clay soil profiles (medium to high plasticity) with thin silty colluvial cover.

An extract of the relevant geological sheet is provided as Extract 1.



Extract 1: Sydney (9130 Geology Series Map): 1: 100000 – Geology underlying the site

3. FIELD WORK:

3.1. Methods:

The field investigation comprised geotechnical inspection/mapping and a subsurface investigation which were both undertaken/supervised by a Senior Geotechnical Engineer on 23rd September 2022.

The geotechnical mapping comprised a visual inspection/photographic record of observations and geological/geomorphological mapping of the site and adjacent land with examination of soil slopes, rock outcrops, vegetation and existing structures.

The sub-surface investigation comprised the drilling of one hand auger borehole (BH1) to investigate sub-surface geology in a location expected to provide a deep soil profile. Dynamic Cone Penetrometer (DCP) testing was carried out adjacent to the borehole in accordance with AS1289.6.3.2 – 1997, "Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer Test" to estimate near surface soil conditions and assist in determining depth to bedrock.

Soil samples were also recovered from the auger for geotechnical logging purposes which was undertaken in accordance with AS1726:2017 'Geotechnical Site Investigations'.

Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed Borehole Log Sheets and Dynamic Penetrometer Test Sheet in Appendix: 2. A geological model/section is provided as Figure: 2, Appendix: 1.

3.2 Field Observations

The site is situated on the western side of Lower Plateau Road within moderate to steep west dipping topography. Lower Plateau Road comprises a bituminous sealed pavement and is separated from the site and neighbouring properties by a concrete kerb and undeveloped reserve. There were no any signs of excessive cracking or settlement in the road or kerb to indicate underlying geological movement, while extensive sandstone outcropping was identified in the vicinity of the site.

The site is accessed via a concrete driveway which is moderately sloping (~13^{o}) down to the west between adjacent neighbouring properties (No. 335 and No. 339 Lower Plateau Road) and which has been partially cut through outcropping medium strength sandstone to 1.0m depth. As the driveway enters the main section of the site a carpark space branches off to the north while the driveway continues down to the south. This curved portion of the driveway is bounded on the upper, east side by a mortared, sandstone block retaining wall up to 1.30m high which appears in generally good condition with the exception of some minor cracking in one location. A near level lawn and garden area separates the driveway from the front of the site dwelling.

The site dwelling structure is a two and three storey brick and timber house positioned towards the east of the block at the base of the driveway, with a garage attached to the southern end and a concrete swimming pool to the north. Due to the sloping topography of the site the ground levels on the front, eastern side of the house are one level higher than the levels on the rear, western side. The structures appeared to be founded directly on sandstone bedrock which was outcropping adjacent and there were no indications of excessive settlement or deflection in visible walls. Photograph 2 below shows the front of the house from the driveway.

Photograph 2: View of the front of the site dwelling structure from the driveway, looking roughly west

Two creeks flow through the site, one on either side of the site house, from the east before converging to the west of the house, with a timber pedestrian bridge extending from the concrete driveway across the southern creek. Both creeks are flanked by outcropping medium strength sandstone bedrock and boulders which form a terraced morphology which steps down to the lower, western portions of the site. The western half of the site is undeveloped and heavily vegetated, with slopes which were generally steep (~20º to 23º) with some extremely steep (~60º) to subvertical outcropping. Several partially buried boulders were observed across the site, however none appeared to present a current hazard to life or property.

There are thirteen separate properties around Lower Plateau Road, Yarrabee Place and Stromboli Place whose rear boundaries back on to the site. Due to the heavy vegetation and topography it was not possible to undertake a thorough investigation of all of these neighbouring properties, however the majority of them appeared to contain two storey brick and/or fibro cement residential structures generally set back >10m from the common boundaries with the site. The visible portions of these structures indicated that footings are founded on sandstone bedrock with significant outcropping across the properties on Lower Plateau Road.

The exceptions to this were the properties adjacent to the site driveway (No. 335 and No. 339 Lower Plateau Road) which contained brick dwelling and garage structures within approximately 1.0m from the common boundary, and No. 285 Stromboli Place which contains a fibro cement clad dwelling within approximately 1.0m from the rear site boundary. The property at No. 10 Yarrabee Place also contains a swimming pool set within approximately 2.0m from the southern site boundary.

The levels in neighbouring properties matched those within the site across the common boundary with no retaining walls marking site boundaries except along a portion of the southern side of the driveway, which contains a mortared sandstone block retaining wall which is in good condition and up to 1.0m high.

The neighbouring buildings and properties were only inspected from within the site or from the road reserve however the visible aspects did not show any significant signs of large-scale slope instability or other major geotechnical concerns which would impact the site.

3.3 Field Testing

For a description of the subsurface conditions, the Borehole log and Dynamic Penetrometer Test Sheet should be consulted in Appendix 2, however a very broad description is provided below:

- **TOPSOIL/FILL –** Topsoil and fill comprising firm to hard, low plasticity, moist gravelly clay with fine to coarse grained crushed sandstone gravels and sandstone cobbles. This material was inferred to extend to approximately 0.80m below ground level and is anticipated to be encountered in limited areas of the site around the existing dwelling.
- **COLLUVIUM –** This unit was identified visually at the surface during the site visit and interpreted from previous experience in the area. It is anticipated to comprise gravels, sands and clays of variable density/consistency with the potential for cobbles and boulders. The unit is anticipated to extend up to 1.0m in thickness.
- **RESIDUAL SOIL** – This unit was inferred from DCP results and is expected based on previous experience in the area. This unit is expected to comprise stiff to hard, medium plasticity, moist sandy clay and clayey sand soils and is anticipated to be limited to <0.50m thickness.
- **SANDSTONE BEDROCK –** This material was found in outcropping areas to generally comprise **s**lightly to moderately weathered, low to medium strength sandstone of the Narrabeen Group formation encountered across much of the site at the ground surface and is expected to be encountered at shallow depth (<2.0m) elsewhere. The unit may be encountered in particularly

weathered areas as extremely to highly weathered and extremely low to very low strength, but generally anticipated to comprise moderately to slightly weathered, low to medium strength sandstone with the potential for high strength sandstone in some locations.

Seepage was not encountered in the boreholes however it was seen over outcrop surfaces in the vicinity of the site and is expected on defects in bedrock excavation and at soil/bedrock interface.

4. COMMENTS:

4.1 Ground Model

Based on the investigation results and observations, it is anticipated that the ground conditions underlying the site consist of variable topsoil, fill soils and colluvium containing boulders, with residual soils (sandy clay and clayey sand) possible in some areas. Sandstone bedrock was found to be outcropping across much of the site and comprised low to medium strength sandstone of the Narrabeen Group formation, which is expected to be encountered across the site at depths of <2.0m below the existing ground surface. There is also the potential for minor weathered siltstone/shale bands to be encountered within the sandstone. Several partially buried sandstone boulders were identified estimated at up to approximately $6m^3$. Groundwater is anticipated at shallow depths in the vicinity of the existing dwelling structure due to the presence of the two creeks flowing on either side, however in the elevated portions of the site the groundwater table may extend to depths >5m. Seepage is also anticipated especially at the soil/bedrock interface and following periods of heavy rainfall.

4.2. Preliminary Geotechnical Assessment:

The site investigation did not identify any significant or deep-seated landslip instability hazards or signs of previous instability, or unstable boulders.

The proposed works are expected to involve the demolition of existing site structures, the subdivision of the site and the construction of three new separate residential dwellings. Preliminary drawings for the proposed residential structures indicate minimal fill and excavation required with structures supported on posts founded on competent bedrock or reusing existing footings founded on bedrock where approved by the structural engineer.

All new footings should be founded within competent sandstone bedrock of at least low strength in order to minimise the risk of differential settlement and creep movement in the slope along with erosion at creeks unless otherwise accounted for in the structural engineering design. Ancillary structures may be founded to residual soils. Footings should not be founded in fill or colluvial soils.

Excavation is understood to be limited to the proposed dwelling in the southern portion of the site and is not expected to encounter bedrock. Therefore, vibration monitoring is not expected to be required.

All footings must be inspected by an experienced geotechnical professional during construction and/or before concrete/steel are placed to verify the expected geology and depth for confirmation of assumed load capacity. These inspections are mandatory if the project requires 'certification' upon completion.

4.3. Site Specific Risk Assessment:

Based on our site investigation and review of the proposed works we have identified the following credible geological/geotechnical hazards which need to be considered in relation to the existing site and the proposed works. The hazards are:

A. Landslide (<20m^3) due to poor construction and maintenance methods for new residence in steeply sloping topography
B. Boulder dislodgement, boulder up to 3.0m across

The hazards have been assessed in accordance with the methods of the Australian Geomechanics Society (Landslide Risk Management, AGS Subcommittee, May 2002 and March 2007), see Tables: A and B, Appendix: 3 The Australian Geomechanics Society Qualitative Risk Analysis Matrix is enclosed in Appendix: 4 along with relevant AGS notes and figures. The frequency of failure was interpreted from existing site conditions and previous experience in these geological units.

The **Risk to Life** from **Hazard A** was estimated to be **4.17 x 10^{-3}** for a single person, whilst the **Risk to Property** from the hazards were considered to be **'Very High'**.

The assessments were based on poor construction and maintenance with shallow footings and poor drainage. Provided the recommendations of this report are implemented including the installation of the recommended engineered support the likelihood of any failure becomes 'Rare' and as such the consequences reduce and risk becomes within 'Acceptable' levels when assessed against the criteria of the AGS 2007. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

4.4. Design & Construction Recommendations:

Preliminary design and construction recommendations are tabulated below:

4.4.1. New Footings:	
Site Classification as per AS2870 – 2011 for new footing design	Class P due to the landslide rating
Type of Footing	Posts founded within competent bedrock
Maximum Allowable Bearing Capacity* (Shallow Footings)	Low strength sandstone bedrock: 1,000kPa Medium strength sandstone bedrock: 2,000kPa
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e – Rock site
Remarks: Final design drawings for each house will need to be assessed prior to construction and all new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata. This is mandatory to allow them to be ‘certified’ at the end of the project. Individual footings should be founded within/on material of similar bearing and settlement characteristics to reduce the potential for differential settlement.	

4.4.2. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		Groundwater expected at shallow depth around the vicinity of existing dwelling structure Seepage over rock surface only
Excavation likely to intersect	Water Table	Yes
	Seepage	Possible in soils above bedrock and in defects within the bedrock, potentially higher following periods of rainfall.
Site Location and Topography		Western side of road within moderately to steeply west dipping topography
Impact of development on local hydrogeology		Negligible provided limited excavation/fill undertaken in areas of shallow groundwater as proposed
Onsite Stormwater Disposal		Collect and discharge off-site into Council stormwater system preferred.
Remarks: Any trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which preferably discharges to the Council’s stormwater system off site. The existing drainage pathways may be used.		

4.5. Conditions Relating to Design and Construction Monitoring:

To allow certification at the completion of the project it will be necessary for Crozier Geotechnical Consultants to:

1. Conduct additional geotechnical assessment of each new dwelling as part of its DA assessment.
2. Inspect and test all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness, and the stability prior to the placement of steel or concrete,
3. Inspect the completed development to ensure all retention and stormwater systems are complete and connected and that construction activity has not created any new landslip hazards.

4.6. Design Life of Structure:

We have interpreted the design life requirements specified within Council's Risk Management Policy to refer to structural elements designed to support the existing structures, control stormwater and maintain the risk of instability within acceptable limits. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and instability,
- maintenance of trees/vegetation on this and adjacent properties.

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 2011 (100 years)). It will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period. Additionally, the property owner should adopt and implement a maintenance and inspection program.

If this maintenance and inspection schedule are not maintained the design life of the property cannot be attained. A recommended program is given in Table: C in Appendix: 3 and should also include the following guidelines.

- The conditions on the block don't change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site
- The property is maintained in good order and in accordance with the guidelines set out in;
    a) CSIRO sheet BTF 18
    b) Australian Geomechanics "Landslide Risk Management" Volume 42, March 2007.
    c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component. It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site.

Also, individual Government Departments will maintain public utilities in the form of power lines, water, and sewer mains to ensure they don't leak and increase either the local groundwater level or landslide potential.

5. CONCLUSION:

The investigation found the subsurface conditions at the site consist of variable topsoil/fill to depths up to 0.80m below ground level, with colluvial and residual soils inferred across the site based on topography and previous experience in the area. Low to medium strength sandstone was observed across much of the site as outcropping bedrock as well as in several partially buried boulders. It is anticipated that particularly exposed sections of the bedrock may present as highly weathered and very low strength, while the bedrock is expected to grade to medium strength within 1.50m depth. Groundwater is likely to be encountered in the vicinity of the creeks which flow across the site, including around the existing site dwelling structure.

The proposed works involve the demolition of existing site structures, the subdivision of the site and construction of three new separate dwelling structures, with two at the front, eastern end of the site and one near the southern boundary. It is understood that minimal excavation is required for the proposed works and that the structures are to be supported on posts founded on competent bedrock, or reutilising existing footings where approved by the structural engineer which are founded on sandstone bedrock.

It is recommended that all new footings for all structures be founded on sandstone of at least low strength to avoid variable settlement within the new structure.

Based on preliminary design drawings it is expected that hard rock excavation will not be required and therefore significant ground vibrations which could damage neighbouring structures will not be produced during the works.

This preliminary geotechnical investigation involved a walkover of the site with limited subsurface investigation. However, an assessment has been made only for subdivision, and an assessment of each individual completed house design will be required for their subsequent DA.

The risks associated with proposed development on the site can be maintained within 'Acceptable' levels with negligible impact to the neighbouring properties or structures provided the recommendations of this report and any future geotechnical directive are implemented, including the recommendations of the Australian Geomechanics Hillside Construction Guidelines. As such the site is considered suitable for the proposed subdivision and residential development construction works provided that the recommendations outlined in this report and future development specific reports are followed.

Prepared by:	Reviewed by:
Ben Taylor	Troy Crozier
Senior Geotechnical Engineer	Principal
	MIEAust,
	MAIG. RPGeo; 10197

6. REFERENCES:

1. Australian Geomechanics Society 2007, "Landslide Risk Assessment and Management", Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, "The preparation of maps and plans in terms of engineering geology" Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. E. Hoek & J.W. Bray 1981, "Rock Slope Engineering" By The Institution of Mining and Metallurgy, London.
4. C. W. Fetter 1995, "Applied Hydrology" by Prentice Hall. V. Gardiner & R. Dackombe 1983, "Geomorphological Field Manual" by George Allen & Unwin.

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Appendix 1

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring 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.

Description and classification Methods

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

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination.
The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling to allow 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 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. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water 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 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures 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 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm 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 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -

Qc (MPa) = (0.4 to 0.6) N blows (blows per 300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -

Qc = (12 to 18) Cu

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 “Methods of Testing Soil for Engineering Purposes”. Details of the test procedure used are given on the individual report forms.

Borehole Logs

The bore logs presented herein 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. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

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

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm “ “ “ “ “	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it 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.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations 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 interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company 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 condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

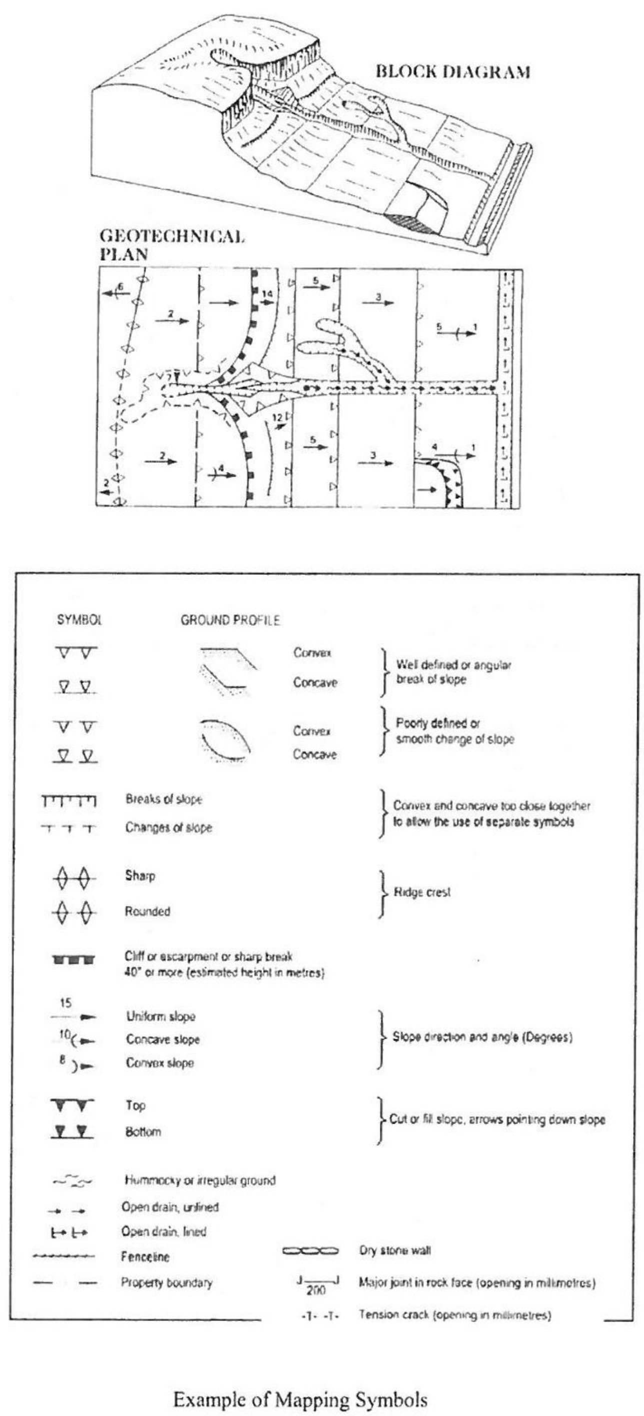
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

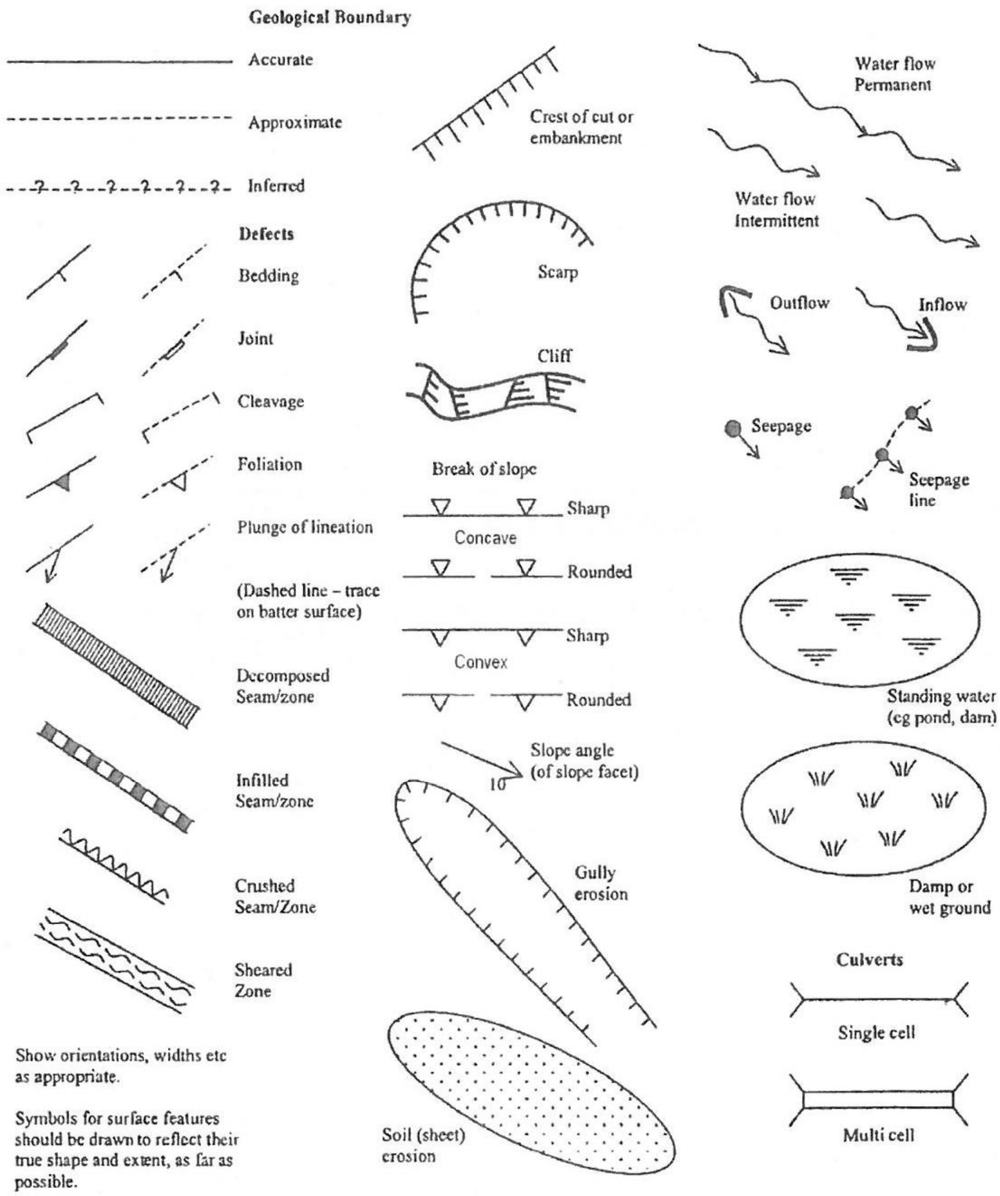
Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Show orientations, widths etc as appropriate.

Symbols for surface features should be drawn to reflect their true shape and extent, as far as possible.

Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

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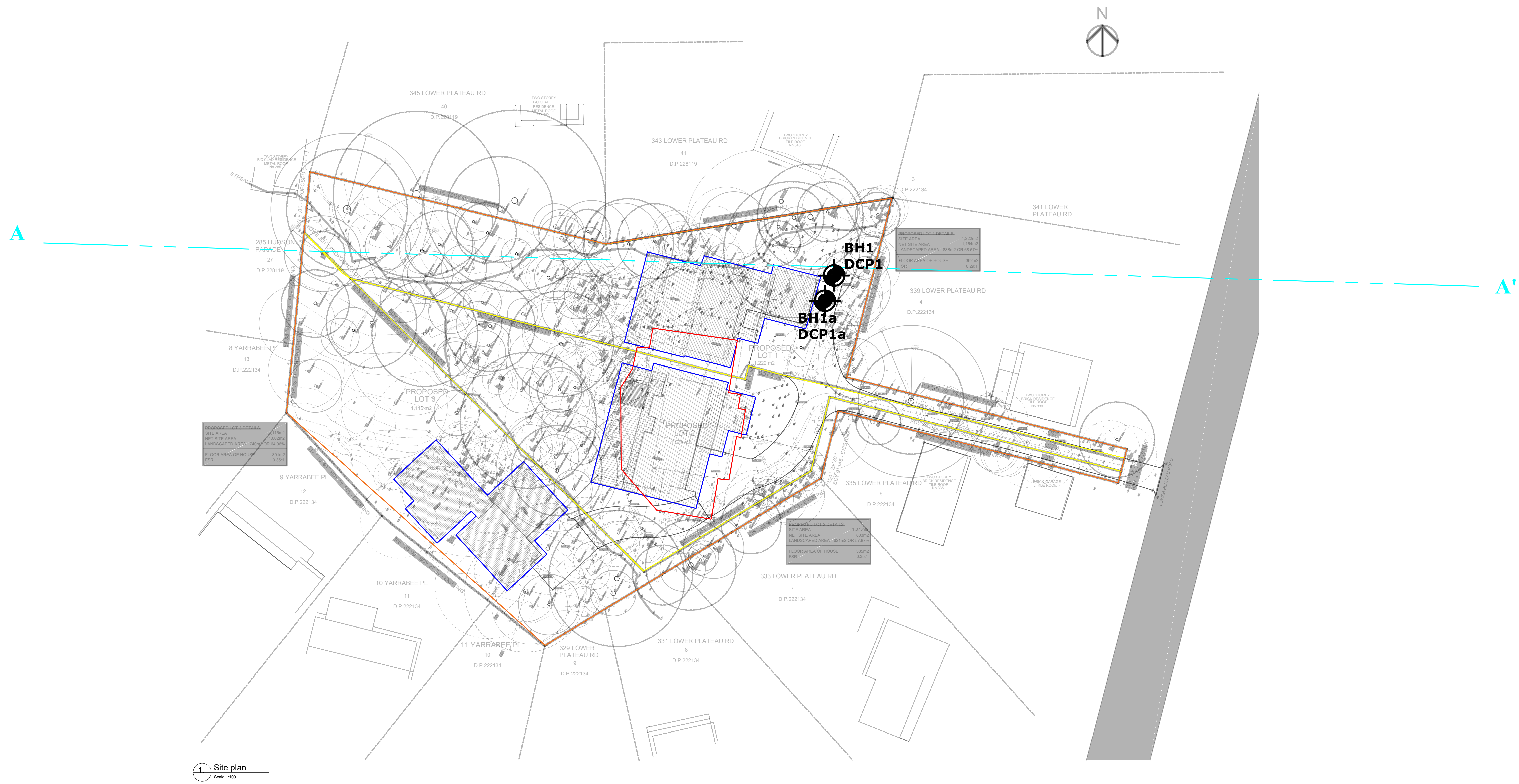
Appendix 2



SITE PLAN & TEST LOCATIONS FIGURE 1.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

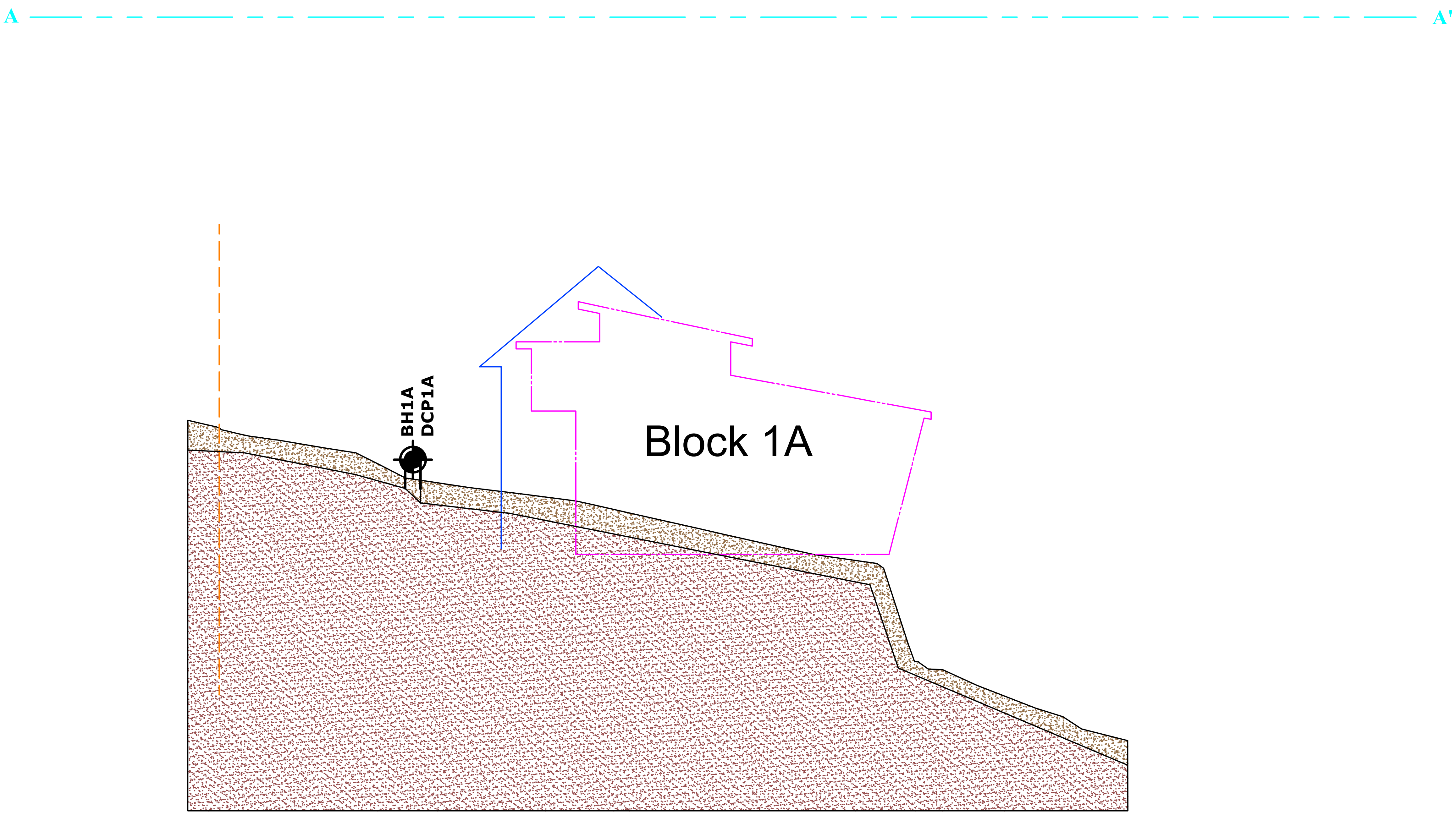
LEGEND

- PROPERTY BOUNDARY
- PROPOSED DWELLINGS
- EXISTING DWELLING
- PROPOSED BOUNDARY
- BH DCP — AUGER / DYNAMIC CONE PENETROMETER LOCATION
- A — A' — CROSS-SECTION REFERENCE LINE

SCALE:	1:100 @ A1
DRAWING:	FIGURE 1
DATE:	10/2022
APPROVED BY:	TMC
DRAWN BY:	PS
PROJECT:	2022-214

PREPARED FOR:
Ray and Mary Trevisan

ADDRESS:
337 Lower Plateau Road, Bilgola Plateau



0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:200

SECTION A FIGURE 2.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

BH DCP AUGER / DYNAMIC CONE PENETROMETER LOCATION	EXISTING STRUCTURES	PROPOSED WORKS	PROPERTY BOUNDARY	SANDSTONE BEDROCK	FILL/ COLLUVIUM	A — A' SECTION LINE

SCALE: 1:200 @ A2	PREPARED FOR: Ray and Mary Trevisan
DRAWING: FIGURE 2	
DATE: 10/2022	
APPROVED BY: TMC	ADDRESS: 337 Lower Plateau Road, Bilgola Plateau
DRAWN BY: PS	
PROJECT: 2022-214	

BOREHOLE LOG

CLIENT: Ray and Mary Trevisan | **DATE:** 23/09/2022 | **BORE No.:** 1

PROJECT: Subdivision | **PROJECT No.:** 2022-214 | **SHEET:** 1 of 1

LOCATION: 337 Lower Plateau Road, Bilgola Plateau | **SURFACE LEVEL:** RL79.3

Depth (m) 0.00	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling: Type	Sampling: Tests	In Situ Testing: Type	In Situ Testing: Results
		FILL: Brown, low plasticity, moist gravelly clay fill, fine to coarse grained sub-angular sandstone gravels, with some cobbles				
		Hand auger refusal at 0.25m on sandstone cobbles in fill				

RIG: --

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Nil

REMARKS:

DRILLER: PS

LOGGED: BT

CHECKED: TMC

BOREHOLE LOG

CLIENT: Ray and Mary Trevisan | **DATE:** 23/09/2022 | **BORE No.:** 1A

PROJECT: Subdivision | **PROJECT No.:** 2022-214 | **SHEET:** 1 of 1

LOCATION: 337 Lower Plateau Road, Bilgola Plateau | **SURFACE LEVEL:** RL79.3

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
0.00			Type	Tests	Type	Results
		FILL: Brown, low plasticity, moist gravelly clay fill, fine to coarse grained sub-angular sandstone gravels, with some cobbles				
		Hand auger refusal at 0.42m on sandstone cobble in fill				

RIG: --

DRILLER: PS

METHOD: Hand Auger

LOGGED: BT

GROUND WATER OBSERVATIONS: Nil

REMARKS:

CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Ray and Mary Trevisan | **DATE:** 23/09/2022

PROJECT: Subdivision | **PROJECT No.:** 2022-214

LOCATION: 337 Lower Plateau Road, Bilgola Plateau | **SHEET:** 1 of 1

	Test Location									
Depth (m)	1	1A								
0.00 - 0.10	1	2								
0.10 - 0.20	8	1								
0.20 - 0.30	27	4								
0.30 - 0.40	30R	7								
0.40 - 0.50		5								
0.50 - 0.60		7								
0.60 - 0.70		6								
0.70 - 0.80		4								
0.80 - 0.90		9								
0.90 - 1.00		12B								
1.00 - 1.10		Bouncing at 0.95m								
1.10 - 1.20										
1.20 - 1.30										
1.30 - 1.40										
1.40 - 1.50										
1.50 - 1.60										
1.60 - 1.70										
1.70 - 1.80										
1.80 - 1.90										
1.90 - 2.00										
2.00 - 2.10										
2.10 - 2.20										
2.20 - 2.30										
2.30 - 2.40										
2.40 - 2.50										
2.50 - 2.60										
2.60 - 2.70										
2.70 - 2.80										
2.80 - 2.90										
2.90 - 3.00										
3.00 - 3.10										
3.10 - 3.20										
3.20 - 3.30										
3.30 - 3.40										
3.40 - 3.50										
3.50 - 3.60										
3.60 - 3.70										
3.70 - 3.80										
3.80 - 3.90										
3.90 - 4.00										

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

(B) Test hammer bouncing upon refusal on solid object

-- No test undertaken at this level due to prior excavation of soils

Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslide (<20m^3) due to poor construction and maintenance methods for new residence in steeply sloping topography		Assuming poor drainage, footings, vegetation etc. Slope is steep (approx. 23^o) with colluvium over sandstone	Landslide expected to extend to creek bed downslope, expected to impact up to half of structure		Person in site and neighbouring dwellings 16hr/day average	a) Possible to not evacuate b) Unlikely to not evacuate	Person possibly buried	
			Almost Certain	**Prob. of Impact**	**Impacted**				
		a) Site dwelling structure	0.1	1.00	0.50	0.6667	0.50	0.25	**4.17E-03**
		b) Neighbourning property downslope (No. 285 Hudson Parade)	0.1	0.25	0.50	0.6667	0.25	0.25	**5.21E-04**
B	Boulder dislodgement, boulder up to 6m^2		Assuming poor earthworks, no geotechnical inspections	Boulder likely to topple and come to rest at low, western end of creek		Person in a) lower creek area 1hr/week ave b) neighbouring dwelling 16hr/day	a) Likely to not evacuate b) Possible to not evacuate	a) person likely to be buried b) person possibly buried	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Creek, low vegetated area of the site	0.001	1.00	0.10	0.0030	0.75	0.95	**2.12E-07**
		b) Neighbourning property downslope (No. 285 Hudson Parade)	0.001	0.25	0.10	0.6667	0.50	0.50	**4.17E-06**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems
* likelihood of occurrence for design life of 100 years

* Spatial Impact - Probaility of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)

* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.
* considered for person most at risk, where multiple people occupy area then increased risk levels
* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslide (<20m3) due to poor construction and maintenance methods for new residence in steeply sloping topography	a) Site dwelling structure	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		b) Neighbourning property downslope (No. 285 Hudson Parade)	Almost Certain	Event is expected to occur over design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Very High
B	Boulder dislodgement, boulder up to 6m2	a) Creek, low vegetated area of the site	Possible	The event could occur under adverse conditions over the design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Very Low
		b) Neighbourning property downslope (No. 285 Hudson Parade)	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.
* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.
* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.
* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.

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Appendix 4

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

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.

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.

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

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

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

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

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

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.

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.

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

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

Individual Risk – 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.

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.

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.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

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.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

APPENDIX C: 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}		10 years		The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-2}$	100 years	20 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 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%		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%	100%	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%	40%	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%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	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

APPENDIX C: – 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

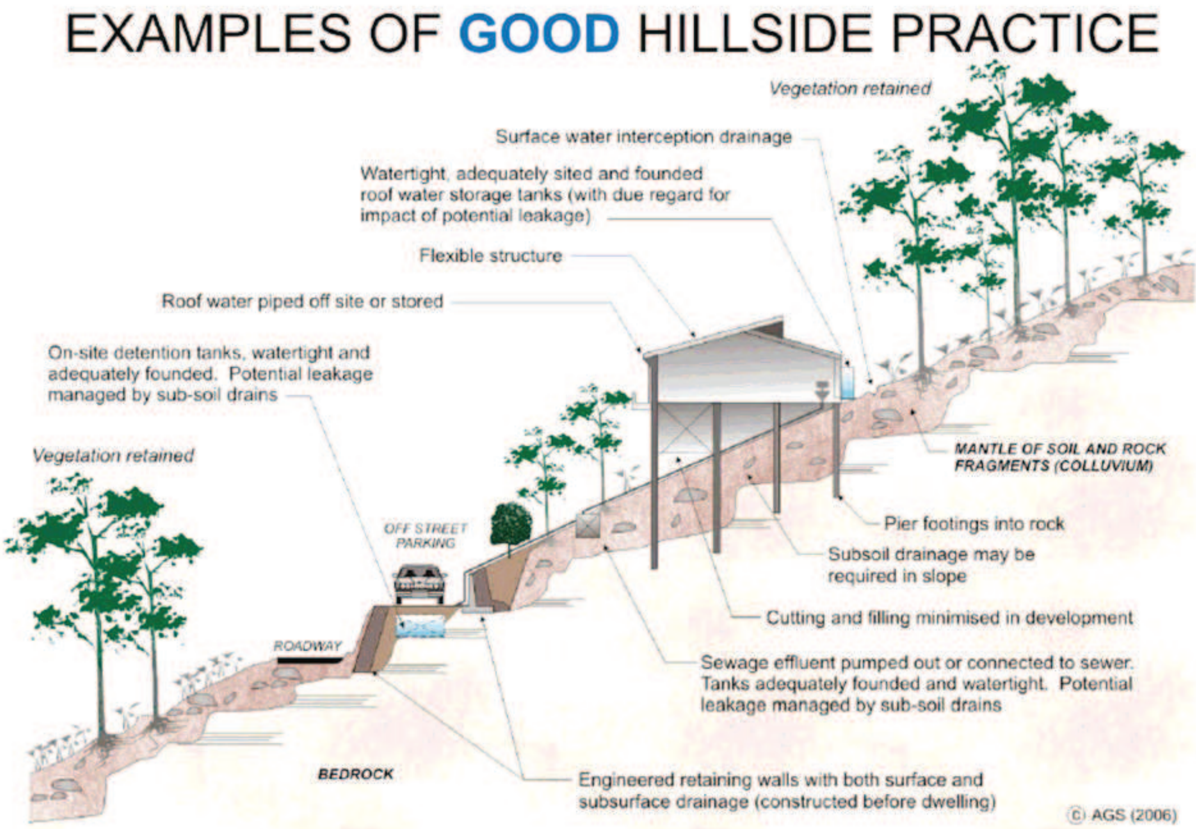
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
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.

Appendix 5

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner 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.	Indiscriminatory 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
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
OFF STREET PARKING
ROADWAY
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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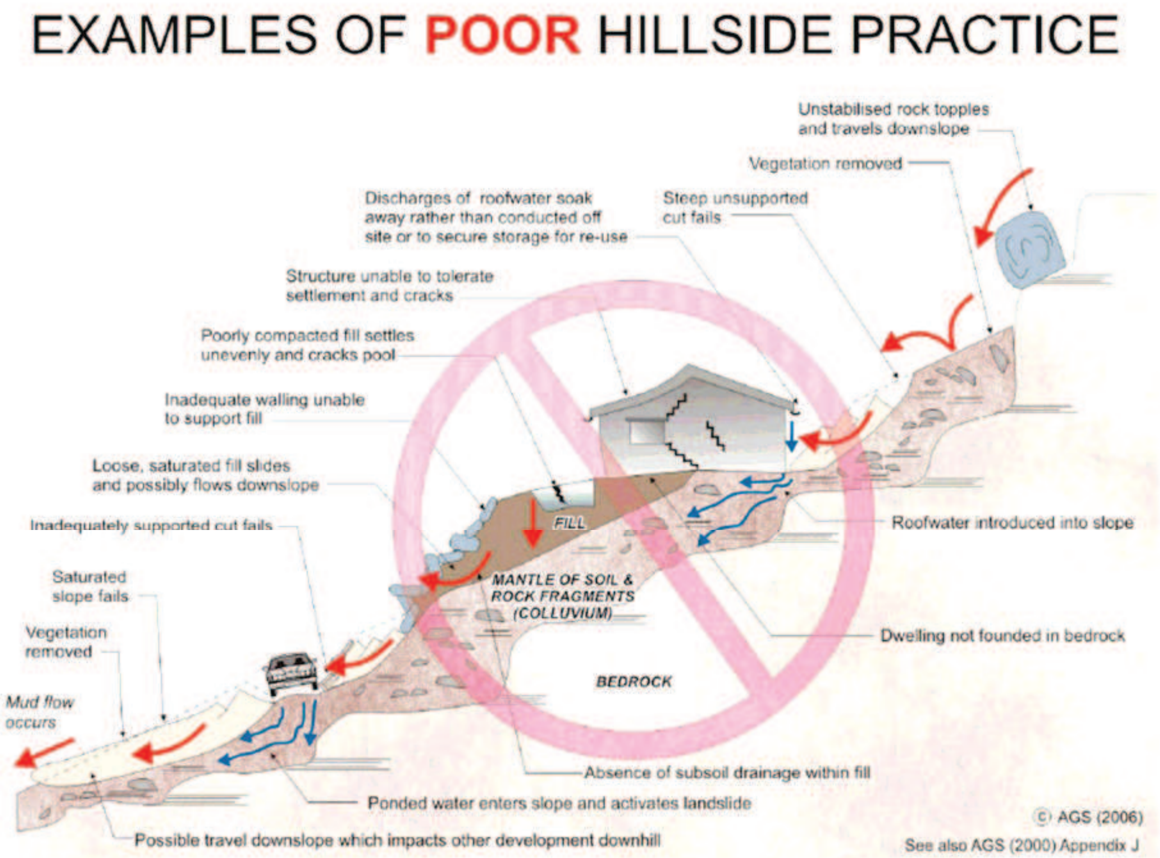
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
Mud flow occurs
BEDROCK
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J