CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical Consultants
Unit 12/ 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au

REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED DEVELOPMENT

at

LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH

Prepared For

Adam Rytenskild

Project No.: 2020-232

December, 2020

Document Revision Record

Issue No	Date	Details of Revisions
0	15th December 2020	Original issue

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for	Adam Rytenskild (Name of Applicant)	
Address of site	Lot 3, 1110 Barrenjoey Road, Palm Beach, 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***

on this the 15/12/20 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 development at Lot 3, 1110 Barrenjoey Road, Palm Beach, NSW

Report Date: 15/12/2020 **Project No.:** 2020-232

Author: Joshua Cotton

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Architectural Drawings – Jorge Hrdina Architects Pty Ltd, Project No.: 2004, Drawing No.: DA1000, D1001, DA2000 – DA2005, DA2220 – DA2222, DA3000 – DA3003, DA3100 – DA3103, DA4000 – DA4002, Dated: 26/11/2020
Survey Drawing – Hill & Blume Consulting Surveyors, Drawing No.: 61313003A, Sheets: 1-2, Dated: 10/05/2019
Survey Drawing - Adam Clerke Surveyors Pty Ltd, Reference No.: 20688S, Dated: 23/11/2020

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
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
TROY CROZIER
10,197

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

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

Development Application for	Adam Rytenskild (Name of Applicant)
Address of site	Lot 3, 1110 Barrenjoey Road, Palm Beach, 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 development at Lot 3, 1110 Barrenjoey Road, Palm Beach, NSW

Report Date: 15/12/2020 **Project No.:** 2020-232

Author: Joshua Cotton

Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted 19/11/2020 (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 ....19/11/2020...........................
- ■ 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**

REGISTERED PROFESSIONAL GEOSCIENTIST
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
TROY CROZIER
10,197

CROZIER
GEOTECHNICAL CONSULTANTS

TABLE OF CONTENTS

Crozier Geotechnical Consultants
Unit 12/ 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical Consultants a division of PJC Geo-Engineering Pty Ltd
ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au

GEOTECHNICAL REPORT FOR PROPOSED DEVELOPMENT
LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH, NSW

1. INTRODUCTION

This report details the results of a geotechnical investigation and assessment carried out for a proposed development at Lot 3, 1110 Barrenjoey Road, Palm Beach, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Jorge Hrdina Architects on behalf of the client Adam Rytenskild.

It is understood the proposed works involve the construction of a multi-level residential development which will consist of five levels. The development will contain three upper living levels, a First Floor level swimming pool and spa, a lower Cellar level and a Ground Floor garage along with a detached single storey secondary dwelling. The proposed development is to step up the steep terrain of the site, requiring some cuts into the natural surface level. Bulk excavation is anticipated to a maximum of 6.0m depth for the construction of the elevator shaft, Ò3.0m depth for the proposed garage and Ò2.0m for some of the eastern portions of the cellar and upper living levels.

Reference to Northern Beaches Councilôs (Pittwater) LEP (2014) and Landslip Risk Map (GTH_015), the property is within the highest geotechnical hazard zone (H1). To meet the Councils Geotechnical Risk Management Policy requirements for land classified as H1, a detailed Geotechnical Report needs to be provided which will meet the requirements of paragraph 6.5 of that policy. This report therefore includes a landslide risk assessment of the site, plans, geological section and provides recommendations for construction ensuring stability is maintained for a preferred design life of 100 years. The site is also located within Acid Sulphate Soils Class 5 (ASS_015), however due to the elevation of the site there will be no possibility of intersecting these soils.

This report includes a description of site and sub-surface conditions, in-situ test results, site mapping/plan, a geological section, a geotechnical assessment of the proposed works and recommendations for design and construction.

The site assessment and reporting were undertaken as per the Proposal No.:P20-451.1, Dated: 5th November 2020.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer and Principal Engineering Geologist.
b) Dynamic Cone Penetrometer (DCP) testing at four locations to investigate the subsurface conditions.
c) All fieldwork was conducted under the full-time supervision of an experienced Geotechnical Professional.

The following plans and diagrams were supplied by the Architect for the work.

- Architectural Drawings ï Jorge Hrdina Architects Pty Ltd, Project No.: 2004, Drawing No.: DA1000, D1001, DA2000 ï DA2005, DA2220 ï DA2222, DA3000 ï DA3003, DA3100 ï DA3103, DA4000 ï DA4002, Dated: 26/11/2020
- Survey Drawing ï Hill & Blume Consulting Surveyors, Drawing No.: 61313003A, Sheets: 1-2, Dated: 10/05/2019
- Survey Drawing ï Adam Clerke Surveyors Pty Ltd, Reference No.: 20688S, Dated: 23/11/2020

2. PROPOSED DEVELOPMENT

The proposed works involve the construction of a multi-level residential development. The development will include three main living levels, a lower Cellar level and a Ground Floor level comprising a garage with a detached single storey dwelling. The development will also include a swimming pool, spa and decks within the First Floor level and a central elevator connecting the levels of the development. The proposed works will require deep cuts into the natural steep west dipping surface level. Bulk excavation will be required across an estimated area of 113m^2, it is anticipated to extend to 6.0m depth for the elevator shaft, 3.0m depth for the garage and secondary dwelling structure with further excavation required for the eastern ends of the First, Second and Third Floors to Ò2.0m depth. The development will have 0.9m side setbacks from the northern and southern boundaries with an approximate 4.0m side setback from the front western boundary.

3. SITE FEATURES

3.1. Description:

The site (Lot 3) is an irregularly shaped lot at the southern end of No.1110 Barrenjoey Road, with Lot 1 and Lot 2 to the north. The site is situated on the high east side of Barrenjoey Road, located mid slope on the steep western side of a north-south striking ridge line which contains multiple large sandstone boulders.

The site contains a levelled, partially concrete paved terrace within the western portion of the site where a storage container, caravan and shed are located. The tree line located to the west of the near level grassy lawn marks approximately the west site boundary. The eastern portion of the site contains steep west dipping natural terrain with large boulders and trees.

Photograph-1: Aerial photo of site and surrounds

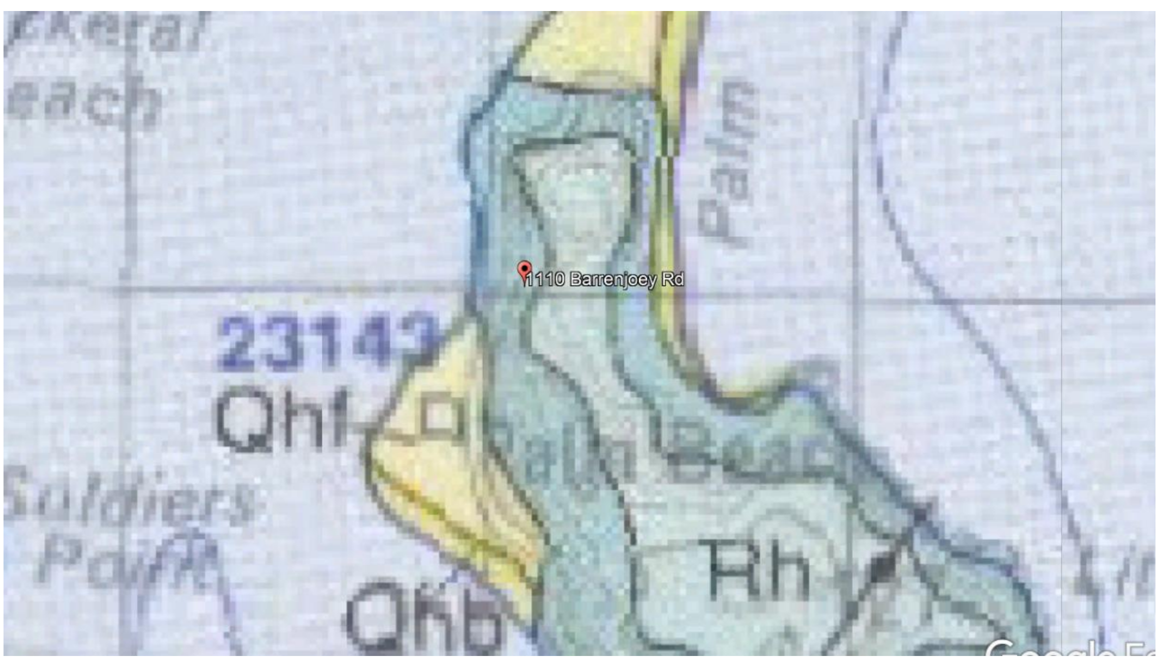
Photograph-2: View of the front of the site, looking south east from Lot 2

An aerial photograph of the entire site including Lot 1 and Lot 2 and its surrounds is provided below (Photograph 1), as sourced from NSW Government Six Map spatial data system whilst the front of the site is shown in Photograph 2.

3.2. Geology

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by weathered bedrock of the Newport Formation (Upper Narrabeen Group) rock (Rnn) 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 and has a tendency to weather to significant depths. To the east of the site the Hawkesbury Sandstone (Rh) which is of Triassic Age is defined. This rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminate that forms a capping to the ridge with boulders from this unit scattered over the slopes below. Sandstone boulders were identified throughout the site and neighbouring properties.

Narrabeen Group rocks are dominated by shales and thin siltstone/sandstone 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 of interbedded shale and siltstone 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 profiles with silty or medium to high plasticity clays and a thin silty colluvial cover. The bedrock may be thinly interbedded with very low to low strength siltstone/shale units and medium to high strength sandstone horizons.



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

4. FIELD WORK

4.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site on the 19th November 2020 by a Geotechnical Engineer and Principal Engineering Geologist. It included a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of rock outcrops, boulders, existing structures and limited inspection of neighbouring properties.

DCP testing was carried out from the ground surface at four nominated locations in accordance with AS1289.6.3.2 ï 1997, ñDetermination of the penetration resistance of a soil ï 9kg Dynamic Cone Penetrometerò to estimate near surface soil conditions and depths to bedrock.

Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed bore log and DCP sheets in Appendix: 2. A Geological model/section is provided as Figure: 2, Appendix: 2.

4.2. Field Observations:

The site comprises the southern third of a largely vacant block of land. Access to the site is provided via a curved, concrete paved driveway from street level to the base of Lot 2. There were no signs of excessive cracking or deformation within the driveway pavement to suggest any movement or underlying geotechnical issues. The slope on the high eastern side of the driveway adjacent to Lot 1 and Lot 2 is retained by a 0.70m to 1.80m high concrete retaining wall which is in good condition with no obvious signs of any cracking or settlement.

The western portion of the site contains a partially paved terrace region with a caravan and shed structure, 3.0m high concrete block and sandstone block retaining walls are located along the eastern side of this front terrace area. These retaining walls appear generally in good condition with no obvious signs of any settlement or movement, except minor cracks within the wall structures. A transition in construction material occurs as the wall extends to the lower face of two large sandstone boulders, where a low concrete block retaining wall (Ò0.60m) appears to be supporting the lower sides or soils below these boulders.

The steep slope (å20°) to the east side of the front terraced area contains open grassy areas with dense vegetation and large trees. There are several large (>5m^3) sandstone boulders lying over the slope which mostly appear to be in a stable position as they are well embedded.

A large palm tree is located approximately 3.0m from the concrete block retaining wall within the front terrace area. The base of this tree shows signs of wash out and erosion, with the large sections of the roots exposed. The tree appears to be positioned partially on top of a large sandstone boulder, this is shown in Photographs 3 and 4.

A middle-terraced level exists just to the east of the front terraced area at approximately R.L. 16.5m, this region is located between large sandstone boulders. A large (å48m^3) angular, north east ï south west striking, west north west dipping (å65°) sandstone boulder is located on the high east side of this middle-terraced level. A dry stack, subvertical sandstone rock retaining wall is located on the northern side of this boulder. This retaining wall appears to be stable, however it is not engineer designed and subject to poor construction methodology. The boulder and retaining wall are shown in Photograph 5 and 6.

Photograph-3: Wash out under roots of palm tree, looking east

Photograph-4: Sandstone boulder and wash out under roots of palm tree, looking north east

Photograph-5: Massive, angular sandstone boulder within the middle-terraced region, looking north east

Photograph-6: Retaining wall to the north of sandstone boulder along the eastern edge of the middle-terraced region, looking east

A series of large sandstone boulders are positioned within the north eastern corner of the site, with one large boulder extending an approximate 12m into the neighbouring property to the north east (No.140 Pacific Road). Within this series of boulders, a detached angular boulder was identified resting on top of another detached unit, both units are orientated down slope bearing onto a largely buried boulder. The upper and possibly lower detached units are interpreted as being susceptible to instability due to sliding or overturning failure. These boulders are shown in Photograph 7.

Photograph-7: Two detached units bearing onto a mostly buried sandstone boulder, looking south

The steep soil slope to the north of the middle terrace extends westwards to the top of the sandstone block retaining wall adjacent to the shed structure. This soil slope is well protected with vegetation cover, there were no signs of excessive surface erosion or any tension crack/deformation over the soil slope to suggest any movement or underlying geotechnical issues. A concrete slurry drain from apparent excess concrete extends along the lower northern boundary; it is understood that this concrete runoff is from the current construction works within the neighbouring lot to the north (Lot 2). The slurry has set within the vegetation cover with excess concrete discharged over the top of the retaining wall, which has set between the eastern side of the shed structure and the retaining wall.

The neighbouring property to the west (No. 1108) contains Barrenjoey House restaurant and Palm Beach Fish and Chips located at street level along Barrenjoey Road with open car parking area at the rear. A vertical cut face exists at the common boundary with the site and is supported by bored concrete piers (600mm diameter) and intermediate concrete panels with a capping beam on top. This wall appears to be in very good condition with no visible signs of any settlement or rotation.

The neighbouring properties to the east (No. 138 ï 140 Pacific Road) are located close to the crest of the ridge with their steeply west sloping backyards extending to the common boundaries with the site. The stepped backyards of these properties are densely vegetated and are retained by dry packed stone walls of variable heights. Only the site visible sections of the backyards of these neighbouring properties were inspected and there were no signs of excessive surface erosion or any tension crack/deformation over the soil slope or within the retaining walls to suggest any movement or underlying geotechnical issues. However, a palm tree orientated sideways and resting on sandstone boulders within No.138 appeared to show signs of previous instability, this is shown in Photograph 8.

Photograph-8: Palm tree within No.138 Pacific Road with horizontally orientated base, looking south east

The neighbouring property to the south (No.1100 Barrenjoey Road) contains a 2 storey timber house located at street level within the front half of the site. The rear half contains a small, dilapidated timber hut surrounded by dense vegetation and tall trees. An above ground sewer pipe runs below this timber hut and intersects the site within the south eastern corner across an unmarked common boundary and continues into No.138 Pacific Road.

The neighbouring lot to the north (Lot 2, 1110 Barrenjoey Road) forms the middle portion of the vacant block and is situated within very similar topography. A very large sandstone boulder (å200m^3) is located within the south western corner of the lot and extends into the site. Resting on top of this boulder is a smaller detached unit, which appears to be stable at present, this is shown in Photograph 9.

Photograph-9: Large sandstone boulder with smaller detached unit on top, within Lot 2, looking south east

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.

4.3. Field Testing:

Dynamic Cone Penetrometer (DCP) tests were undertaken at specific locations across the site with refusal encountered at depths varying from 0.43m (DCP1) to 2.10m (DCP4) on interpreted sandstone bedrock/ boulders. Two of the DCP tests (DCP2 & DCP3) where discontinued at 3.0m depth without encountering refusal.

5. COMMENTS

5.1 Geotechnical Assessment and Recommendations:

The site investigation identified that the site is situated within steep west dipping topography with the soil slope containing several large sandstone boulders. The subsurface geology of the site is interpreted to consist of colluvium/fill underlain by extremely weathered bedrock which grades to siltstone/shale/sandstone bedrock of at least very low strength at depth.

It is understood that the proposed works involve the construction of a multi-level residential development with a basement garage, detached secondary dwelling and swimming pool. Portions of the development will be constructed partially into the existing slope, with maximum excavation required for the elevator shaft and rear of the garage to approximately 6.0m depth, further excavation for the garage, detached secondary dwelling and upper levels are anticipated to extend to Ò3.0m depth. The excavations will extend to 0.9m from the side boundaries and 4.0m from the front boundary, across an estimated area of 113m^2.

The excavations are expected to intersect sandy colluvial soils, potential residual soils along with boulders and bedrock. As such, safe batter slopes may not be achievable along the north, south and east sides of the excavations. Where safe batters cannot be constructed, support prior to excavation will be required to maintain site and boundary stability as per Section 177 of the NSW Conveyancing Act ï 1919. However, at the time of reporting the adjacent properties, with exception of the dilapidated timber hut within No.1100 Barrenjoey Road did not appear to contain structures within the influence zone of the proposed excavations.

The boulders buried across the soil slope are likely creeping with the soil. Excavation adjacent to or into these boulders is likely to disturb and cause instability. Some boulders directly overlie other boulders along unfavourable defects and are considered relatively unstable, as such stabilising measures (i.e. rock bolts/shotcrete) or the removal of these boulders is recommended, whilst stabilising measures to other boulders can be determined based on the proposed development design and excavation footprint.

There is a potential for poorly oriented defects or localized zones of highly weathered bedrock to result in localized rock slide/topple failure in excavation with potential impact to the site or adjacent properties. Therefore, further geotechnical inspection and investigation including core drilling will be required to confirm site conditions, prior to final structural design.

Due to the steep sloping terrain of the site and nature of the proposed works it is recommended that all footings for the proposed development extend through colluvium/fill and extremely weathered material to bear onto bedrock of at least low strength. A flexible pile system appears to be the most suitable footing option for support of the proposed structures, as a flexible layout could minimise the risk of boulder impact or instability with deep pile style footings enabling the development to bear onto competent bedrock.

No groundwater and only indications of minor seepage were encountered during the investigation however, it is likely that minor seepage will be intersected at the soil - rock interface and on defects in the bedrock during excavation, with further surface runoff likely due to the topography of the site. A freestanding water table or Acid Sulfate Soils were not encountered and are not expected within the site due to the elevation and topography of the site within the depths of proposed works and surrounds.

It is recommended that loose soils and small, unstable boulders be removed in the area of the proposed development prior to any construction work. Unstable boulders within a 1.0V:1.5H influence zone of an excavation base are recommended to be removed or secured by way of rock bolts and/or grout underpinning prior to any excavation on site. This will help to prevent potential movement both during and after excavation works. It is also recommended that further investigation including core drilling be undertaken to confirm the depth and nature of bedrock underlying the site.

All footings should be founded off bedrock of similar strength to prevent differential settlement and provide resistance to creep movement in the slope. It is recommended that proposed major structures be supported off pier footings socketed into a minimum of LS bedrock. 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 ćertifiedô at the end of the project. Piers should be socketed at least one diameter into weathered bedrock to provide stability within the slope.

Seepage at the bedrock surface or along defects in the soil/rock can also reduce the stability of batter slopes and invoke the need to implement additional support measures. Where safe batter slopes are not implemented the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions. Batter slopes should not be left unsupported without geotechnical inspection and approval.

Retaining structures will be necessary to support excavations and in part will either need to be installed prior to excavation or in stages during excavation near. It is anticipated that installation of support systems prior to bulk excavation will be very difficult due to the site topography. Retaining structures should be designed with the use of at rest (Ko) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas if located adjacent to existing or proposed footings/structures. Backfilled retaining walls within the site, away from site boundaries or existing structures and/or that may deflect can utilize active earth pressure coefficients (Ka). It is suggested that the retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order to minimize horizontal stresses.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and preliminary hand investigation tools due to access limitations. This test equipment provides limited data from small, isolated test points across the entire site with limited geological data, therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations.

The results of the investigation provide a reasonable basis for the DA analysis, however further investigation is required following DA approval to allow detailed assessment and design prior to Construction Certificate application.

5.2. Stability Risk Assessment:

Based on our site investigation 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. Landslip (Rockslide/topple <5m^3) of unstable angular boulder within north east portion of site due to disturbance
B. Landslip (Rockslide/topple <20m^3) of other boulders due to disturbance
C. Landslip (Soil <3m^3) of earth around perimeter of proposed excavations
D. Landslip (Rock <3m^3) of bedrock around perimeter of excavation for proposed basement garage and elevator

A qualitative assessment of risk to life and property related to this hazard is presented in Table A and B, Appendix: 3, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

The **Risk to Life** from **Hazard A to E** were estimated to be up to **9.38 x 10^{-5}** for a single person, whilst the **Risk to Property** from the hazards were considered to be up to **'High'**.

Although the Risk to Life & Property are considered to be óUnacceptableó, the assessments were based on excavations with no support or planning. Provided the recommendations of this report are implemented the likelihood of any failure becomes óRareô and as such the consequences reduce and risk becomes within óAcceptableô 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.

5.3. Design Life of Structure:

We have interpreted the design life requirements specified within Councils Risk Management Policy to refer to structural elements designed to support the house etc, the adjacent slope, control stormwater and maintain the risk of instability within ñAcceptableò 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 soil slope erosion 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 ï 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 ñAcceptableò risk management criteria for 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 donôt 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 ñLandslide Risk Managementò Volume 42, March 2007.
  c) AS 2870 ï 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 donôt leak and increase either the local groundwater level or landslide potential. Recommendations for construction within hill slopes are also provided in Appendix: 5.

5.4. 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 investigation including core drilling to confirm depth and nature of bedrock along with geological/geotechnical condition,
2. Review and approve the structural design drawings, including the retaining structure design and construction methodology, for compliance with the recommendations of this report prior to construction,
3. Conduct inspections of works as per Section 4.2 of this report, including during installation of retention systems.
4. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and stability prior to the placement of steel or concrete,

Crozier Geotechnical Consultants can not provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

6. CONCLUSION

The investigation identified that the site is situated within steep west dipping topography with several boulders embedded into the colluvial soil slope. It is considered that the detached boulders are generally stable within the soil slopes, however some have potential for instability. Therefore, stabilising measures (i.e. rock bolts/shotcrete) or the removal of unstable boulders is recommended to ensure stability during and after excavation.

It is understood that the proposed works involve the construction of a multi-level residential development with a swimming pool, Ground Floor level garage and detached secondary dwelling. The new house will be constructed partially into the existing slope which will require excavations up to 6.0m depth for the garage and elevator shaft. The excavations will extend to within 0.9m of the north and south boundaries.

Based on the separation distance between the proposed excavation and boundaries, support measures will likely be required, in particularly for significant excavation locations, such as the garage and elevator shaft excavation.

It is interpreted that the subsurface geology of the site consists of colluvium/fill soils, underlain by bedrock grading from extremely low strength to at least low strength, with the potential for residual soils overlying the bedrock surface. However, further geotechnical investigation including core drilling is required to assess bedrock levels/strengths and to provide retention parameters. All footings are recommended to extend through colluvium and residual soils to socket into bedrock of at least low strength to avoid settlement and/or creep movement. All footings should 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.

Provided the recommendations of this report are implemented in the design and construction phases of the development, it is considered that the works can be carried out with negligible impact to the site and neighbouring properties and as such are considered suitable for the site.

It is considered that the site will meet the óAcceptableô risk management criteria for the design life of the development taken as 100 years from the proposed works provided the property is maintained as per the recommendations of this report.

Prepared By:	Reviewed By:
Josh Cotton	Troy Crozier
Engineer	Principal
	MEng, BSc, Dip. Civ. Eng
	MAIG, PRGeo ï Geotechnical and Engineering
	Registration No.: 10197

7. REFERENCES

1. Australian Geomechanics Society 2007, ñLandslide Risk Assessment and Managementò, Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, ñThe preparation of maps and plans in terms of engineering geologyò Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. E. Hoek & J.W. Bray 1981, ñRock Slope Engineeringò By The Institution of Mining and Metallurgy, London.
4. C. W. Fetter 1995, ñApplied Hydrologyò by Prentice Hall. V. Gardiner & R. Dackombe 1983, ñGeomorphological Field Manualò by George Allen & Unwin
5. V. Gardiner & R. Dackombe 1983, ñGeomorphological Field Manualò by George Allen & Unwin.

Appendix 1

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical Consultants ABN: 96 113 453 624
Unit 12/ 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Email: info@croziergeotech.com.au
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

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

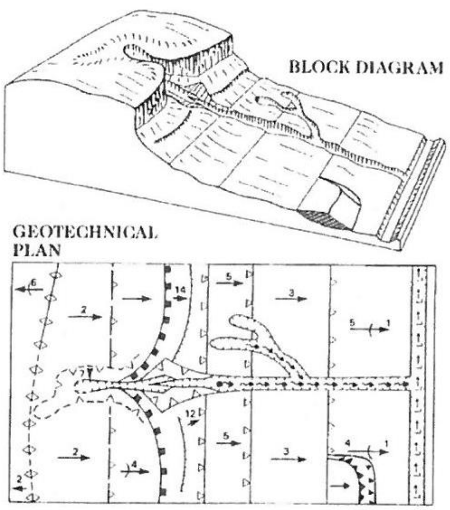
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

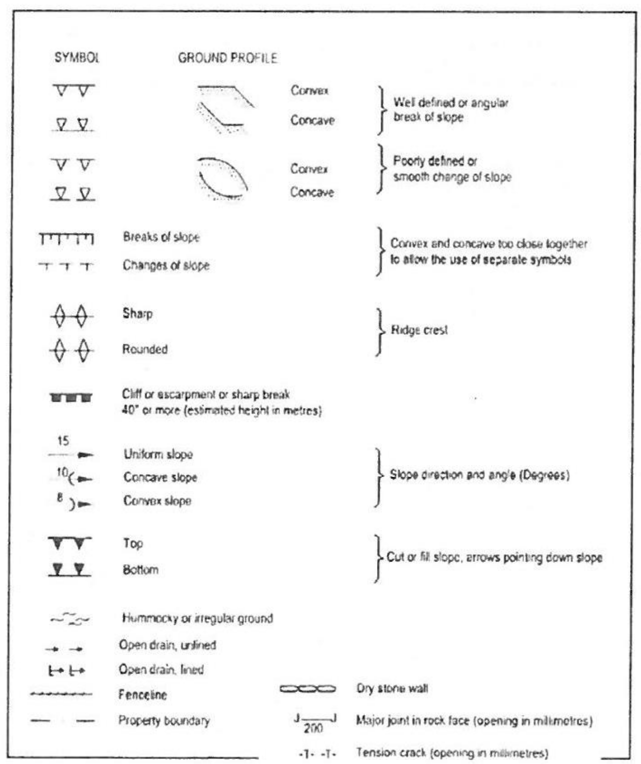
Reproduction of Information for Contractual Purposes

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

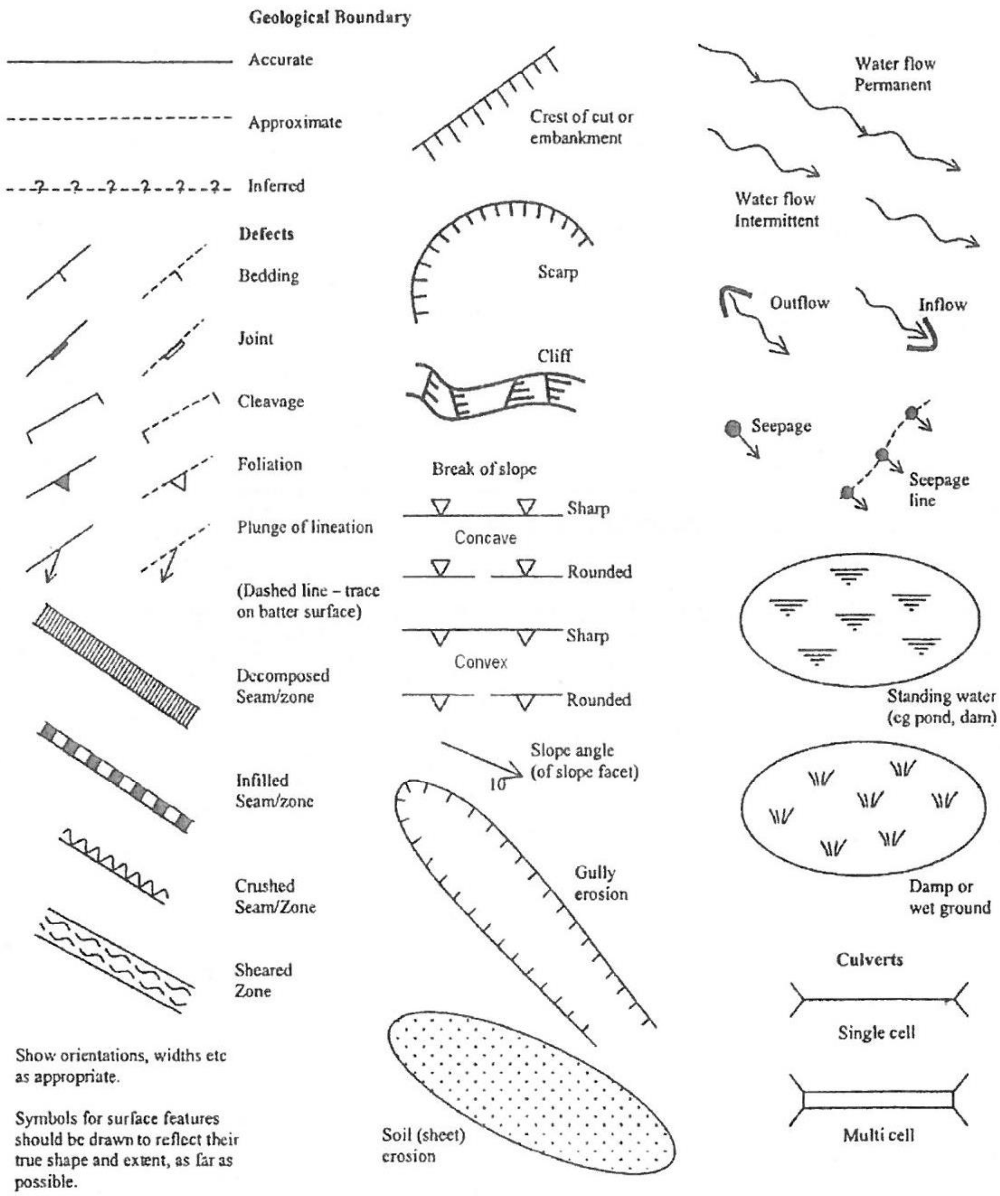
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.





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

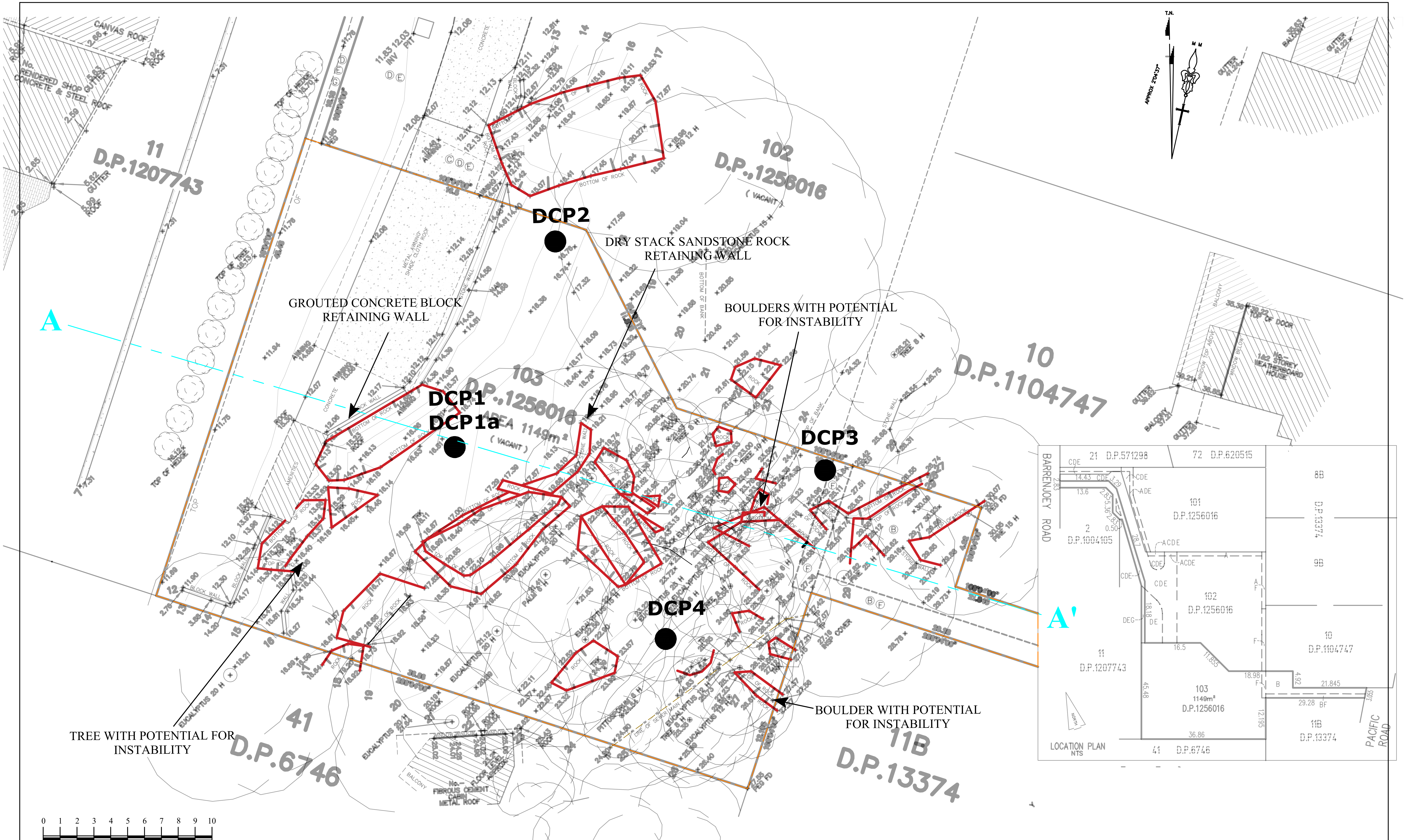
APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



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

CROZIER
GEOTECHNICAL CONSULTANTS

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

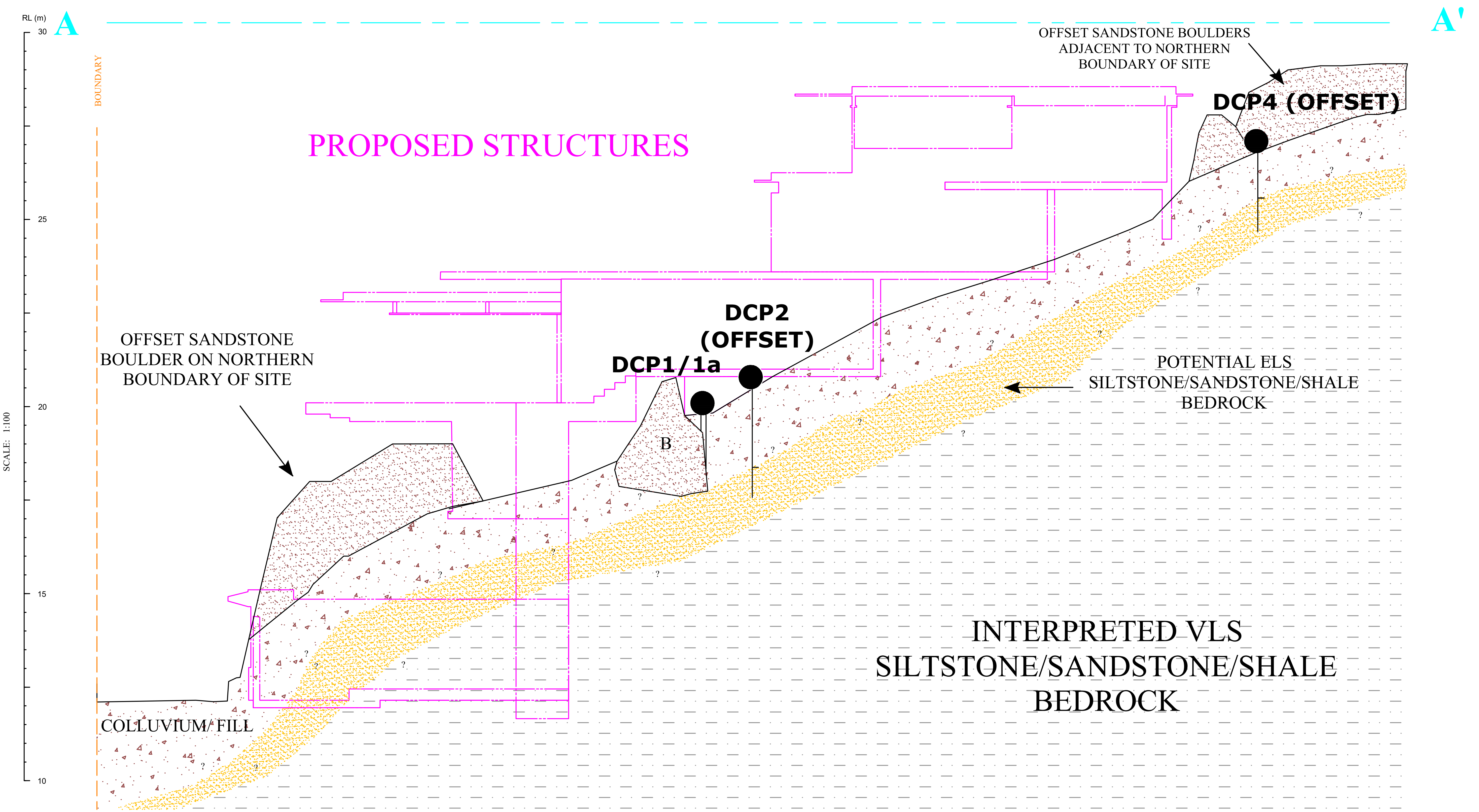
LEGEND

Symbol	Description
● DCP	DYNAMIC CONE PENETROMETER
A ——— A'	CROSS-SECTION REFERENCE LINE
(orange dashed line)	PROPERTY BOUNDARY
(red line)	BOULDERS

SCALE:	1:200 @ A3
DRAWING:	FIGURE 1
DATE:	25/11/2020
APPROVED BY:	TMC
DRAWN BY:	JC
PROJECT:	2020-232

PREPARED FOR:
ADAM RYTENSKILD

ADDRESS:
LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH



0 1 2 3 4 5
SCALE: 1:100

VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

NB. FOR LOCATION OF SECTION A-A', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL 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

- DCP — DYNAMIC CONE PENETROMETER
- A — A' — CROSS-SECTION REFERENCE LINE
- PROPOSED STRUCTURES
- PROPERTY BOUNDARY
- COLLUVIUM/FILL
- POTENTIAL ELS SILTSONE/ SHALE/ SANDSTONE BEDROCK
- INTERPRETED VLS SILTSTONE/ SHALE/ SANDSTONE BEDROCK
- B — APPROXIMATE LOCATION OF SANDSTONE BOULDERS

SCALE:	1:100 @ A3
DRAWING:	FIGURE 2
DATE:	25/11/2020
APPROVED BY:	TMC
DRAWN BY:	JC
PROJECT:	2020-232

PREPARED FOR:
ADAM RYTENSKILD

ADDRESS:
LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Adam Rytenskild **DATE:** 19/11/2020

PROJECT: Construction of multi-level residence with swimming pool **PROJECT No.:** 2020-232

LOCATION: Lot 3, 1110 Barrenjoey Road, Palm Beach **SHEET:** 1 of 1

	Test Location							
Depth (m)	DCP1	DCP1a	DCP2	DCP3	DCP4			
0.00 - 0.15	1	1	1	4	2			
0.15 - 0.30	5	3	3	12	8			
0.30 - 0.45	27*B @ 0.43m	5	4	3	12			
0.45 - 0.60		8	4	4	8			
0.60 - 0.75		5	3	3	7			
0.75 - 0.90		25	4	4	12			
0.90 - 1.05		15	3	5	6			
1.05 - 1.20		7	5	5	7			
1.20 - 1.35		6	5	5	28			
1.35 - 1.50		33*B @ 1.45m	3	8	45			
1.50 - 1.65			4	7	24			
1.65 - 1.80			7	8	20			
1.80 - 1.95			6	6	26			
1.95 - 2.10			12	6	24*disc			
2.10 - 2.25			9	10				
2.25 - 2.40			10	12				
2.40 - 2.55			7	11				
2.55 - 2.70			9	11				
2.70 - 2.85			12	12				
2.85 - 3.00			15	15				
3.00 - 3.15								
3.15 - 3.30								
3.30 - 3.45								
3.45 - 3.60								
3.60 - 3.75								
3.75 - 3.90								
3.90 - 4.05								

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	Landslip (Rockslide/topple <5m³) of unstable angular boulder within north east portion of site due to distubance		a) Detached upper boulder bearing onto other boulder, situated within 1.0m of proposed third floor excavation	a) Boulder topple situated within 1.0m of proposed third level excavation and boulder slides across site, impact 20% b) Boulder situated >50m upslope from area, impact 25% c) Boulder topple situated within 2.0m of common boundary, but across slope from house, impact 1% d) Boulder topple situated >12m across slope, impact 1%		a) Person in studio 12hrs/day b) Person in carpark 4hrs/day c) Person in house 16hrs/day d) Person in gardens 2hrs/day	a) Likely to not evacuate b) Possible to not evacuate c) Likely to not evacuate d)Possible to not evacuate	a) Person in building, crushed b) Person in open space, crushed c) Person in building, crushed d) Person in open space, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	1.00	0.20	0.5000	0.75	1.00	**7.50E-05**
		b) Car parking area in east of neighbouring property to the west (No.1108 Barrenjoey Rd)	0.001	0.10	0.25	0.1667	0.5	1.00	**2.08E-06**
		c) Neighbouring property to the north (Lot 2, No.1110 Barrenjoey Rd - dwelling under construction)	0.001	0.05	0.01	0.6667	0.75	1.00	**2.50E-07**
		d) Neighbouring gardens to the south (No.1100 Barrenjoey Rd)	0.001	0.02	0.01	0.0833	0.5	1.00	**8.33E-09**
B	Landslip (Rockslide/topple <20m³) of other boulders due to distubance		b) Boulders embedded into colluvial soil slope across site	a) Boulder slides/topples of any other boulder within the site, impact 50% b) Boulders situated >20m, impact 10% c) Boulders across slope from common boundary, impact 5% d) Boulders situated within 2.5m of common boundary, impact 5%		a) Person in studio 12hrs/day b) Person in building 20hrs/day c) Person in house 16hrs/day d) Person in house 16hrs/day	a) Likely to not evacuate b) Lkely to not evacuate c) Likely to not evacuate d) Likely to not evacuate	a) Person in building, crushed b) Person in building, crushed c) Person in building, crushed d) Person in building, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	0.50	0.50	0.5000	0.75	1.00	**9.38E-05**
		b) Neighbouring property to the west (No.1108 Barrenjoey Rd)	0.001	0.10	0.10	0.6667	0.75	1.00	**5.00E-06**
		c) Neighbouring property to the north (Lot 2, No.1110 Barrenjoey Rd - dwelling under construction)	0.001	0.05	0.05	0.6667	0.75	1.00	**1.25E-06**
		d) Neighbouring house to the south (No.1100 Barrenjoey Rd)	0.001	0.05	0.05	0.6667	0.75	1.00	**1.25E-06**
C	Landslip (Soil <4m³) of earth around perimeter of excavation for proposed house and garage excavations		Excavation up to 6.0m depth possible, up to 3.0m depth into soils (colluvium) expected	a) Excavation face within 1.0m off the proposed structure, impact 5% b) Excavation within 1.0m of the boundary, impact 10% c) Excavation within 1.0m of the boundary, impact 1% d) House 4.0m from 2.0m excavation, 5% impacted		a) Person in house 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day	a) Possible to not evacuate b) Possible to not evacuate c) Possible to not evacuate d) Possible to not evacuate	a) Person in building, unlikely buried b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, minor damage only	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	0.75	0.05	0.6667	0.5	0.20	**2.50E-06**
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.40	0.10	0.6667	0.5	0.05	**6.67E-07**
		c) Rear gardens (No.1100 Barrenjoey Road)	0.001	0.20	0.01	0.0833	0.5	1.00	**8.33E-08**
		d) Timber hut (No.1100 Barrenjoey Road)	0.001	0.20	0.05	0.0208	0.5	0.05	**5.21E-09**
D	Landslip (Soil <2m³) of earth around perimeter of excavation for proposed single storey secondary dwelling		Excavation up to 6.0m depth possible, up to 3.0m depth into soils (colluvium) expected	a) Excavation face within 0.5m off the proposed structure, impact 50% b) Excavation approximately 10m from the boundary, impact 2% c) Excavation within 1.2m of the boundary, impact 20% d) Excavation approximately 10m from timber hut, 5% impacted e) Excavation approximately 7m from house, 1% impacted		a) Person in structure 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in house 16hrs/day	a) Possible to not evacuate b) Possible to not evacuate c) Possible to not evacuate d) Possible to not evacuate e) Possible to not evacuate	a) Person in building, unlikely buried b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, minor damage only e) Person in building, minor damage only	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site secondary dwelling	0.001	0.75	0.5	0.6667	0.5	0.20	**2.50E-05**
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.01	0.02	0.6667	0.5	0.05	**3.33E-09**
		c) Rear gardens (No.1100 Barrenjoey Road)	0.001	0.50	0.20	0.0833	0.5	1.00	**4.17E-06**
		d) Timber hut (No.1100 Barrenjoey Road)	0.001	0.10	0.10	0.0208	0.5	0.05	**5.21E-09**
		e) House (No.1100 Barrenjoey Road)	0.001	0.03	0.01	0.6667	0.5	0.05	**5.00E-09**
E	Landslip (Rock <3m³) of bedrock around perimeter of excavation for proposed basement garage, single storey secondary dwelling and elevator excavation		Excavation up to 6.0m depth possible into bedrock	a) Excavation face within 1.0m of the proposed structure, impact 10% b) Excavation within 1.0m of the boundary, impact 10% c) Excavation within 1.0m of the boundary, impact 2% d) Timber hut is 4.0m from 2.0m excavation, 20% impacted e) Excavation approximately 7.0m from house, 1% impacted		a) Person in house 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in house 16hrs/day	a) Likely to not evacuate b) Likely to not evacuate c) Possible to not evacuate d) Likely to not evacuate e) Likely to not evacuate	a) Person in building, minor damage only b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, minor damage only e) Person in building, minor damage only	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site structures	0.001	0.5	0.1	0.6667	0.75	0.05	**1.25E-06**
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.10	0.10	0.6667	0.75	0.05	**2.50E-07**
		c) Rear gardens (No.1100 Barrenjoey Road)	0.001	0.10	0.02	0.0833	0.5	1.00	**8.33E-08**
		d) House (Timber hut No.1100 Barrenjoey Road)	0.001	0.10	0.20	0.0208	0.75	0.05	**1.56E-08**
		e) House (No.1100 Barrenjoey Road)	0.001	0.02	0.01	0.6667	0.75	0.05	**5.00E-09**

* hazards considered in current condition and/or without remedial/stabilisation measures or retention
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact referes to slide impacting structure/area expressed as a % (1.00 = 100% probability of slide impacting area if it occurs), Imapcted refers to % of area/strucure impacted if slide occurred
* neighbouring houses considered for bedroom impact unless specified
* considered for person most at risk
* considered for adjacent premises/buildings founded via 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 knwoing of landslide and completely evacuating area prior to landslide impa
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 200

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (Rockslide/topple <20m³) of unstable angular boulder within north east portion of site due to distubance	a) Future site house	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
		b) Car parking area in east of neighbouring property to the west (No.1108 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances 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.	Low
		c) Neighbouring property to the north (Lot 2, No.1110 Barrenjoey Rd - dwelling under construction)	Unlikely	The event might occur under very adverse circumstances 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.	Low
		d) Neighbouring gardens to the south (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
B	Landslip (Rockslide/topple <50m³) of other boulders due to distubance	a) Future site house	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
		b) Neighbouring property to the west (No.1108 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	High
		c) Neighbouring property to the north (Lot 2, No.1110 Barrenjoey Rd - dwelling under construction)	Unlikely	The event might occur under very adverse circumstances 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.	Low
		d) Neighbouring house to the south (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances 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.	Low
C	Landslip (Soil <4m³) of earth around perimeter of excavation for proposed house and garage excavations	a) Future site house	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
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	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
		c) Rear gardens (No.1100 Barrenjoey Road)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		d) Timber hut (No.1100 Barrenjoey Road)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
D	Landslip (Soil <2m³) of earth around perimeter of excavation for proposed excavation of secondary dwelling excavation	a) Future site secondary dwelling	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
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances 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.	Low
		c) Rear gardens (No.1100 Barrenjoey Road)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		d) Timber hut (No.1100 Barrenjoey Road)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		e) House (No.1100 Barrenjoey Road)	Unlikely	The event might occur under very adverse circumstances 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.	Low
E	Landslip (Rock <3m³) of bedrock around perimeter of excavation for proposed basement garage and elevator excavation	a) Future site structures	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
		b) House under construction (Lot 2, No.1110 Barrenjoey Rd)	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
		c) Rear gardens (No.1100 Barrenjoey Road)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		d) House (Timber hut No.1100 Barrenjoey Road)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		e) House (No.1100 Barrenjoey Road)	Unlikely	The event might occur under very adverse circumstances 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.	Low

* 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%.

TABLE: C

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the open drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter. Owner to check and flush retaining wall drainage pipes/systems	Every year or following each major rainfall event. Every 7 years or where dampness/moisture
Retaining Walls. or remedial measures	Owner to inspect walls for deveation from as constructed condition and repair/replace. Replace non engineered rock/timber walls prior to collapse	Every two years or following major rainfall event. As soon as practicable
Large Trees on or adjacent to site	Arborist to check condition of trees and remove as required. Where tree within steep slopes (>18°) or adjacent to structures requires geotechincal inspection prior to removal	Every five years
Slope Stability	Geotechnical Engineering Consultant to check on site stability and maintenance	Five years after construction is completed.

N.B. Provided the above shedule is maintained the design life of the property should conform with Councils Risk Management Policy.

CROZIER
GEOTECHNICAL CONSULTANTS

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}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-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

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

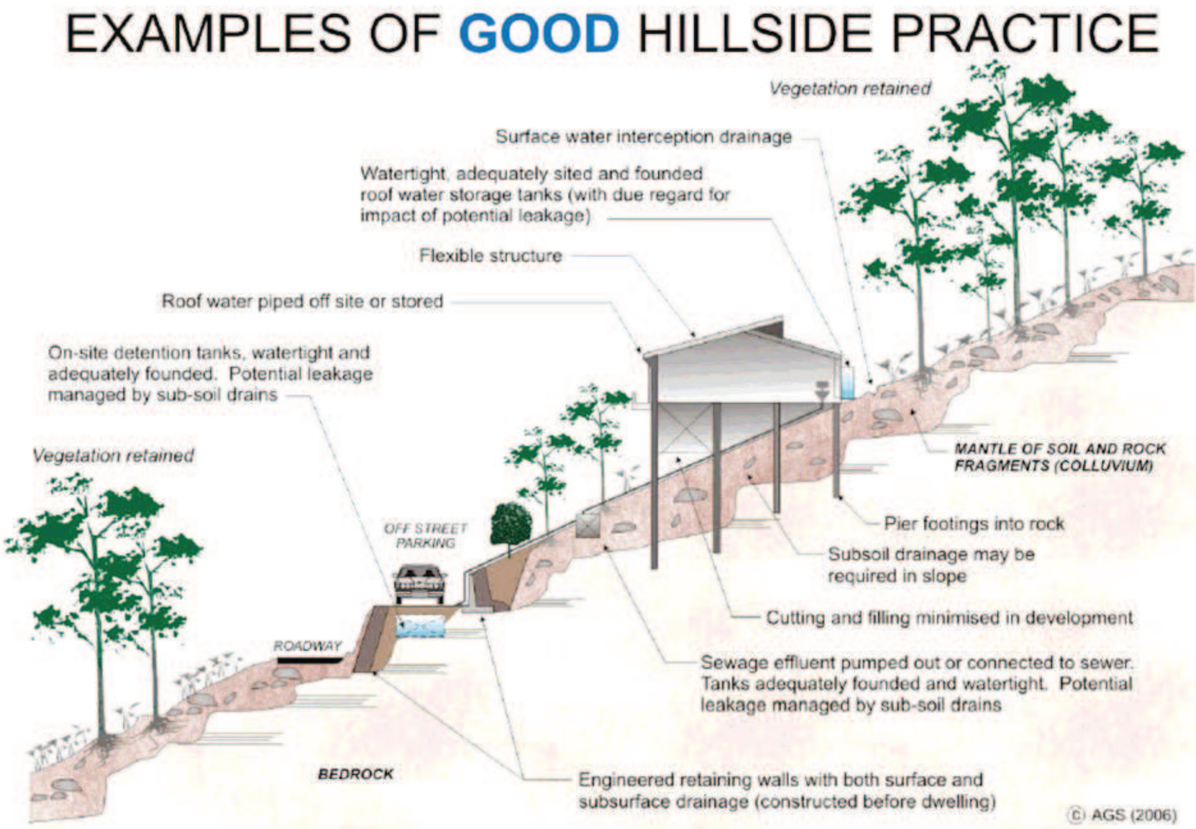
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.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

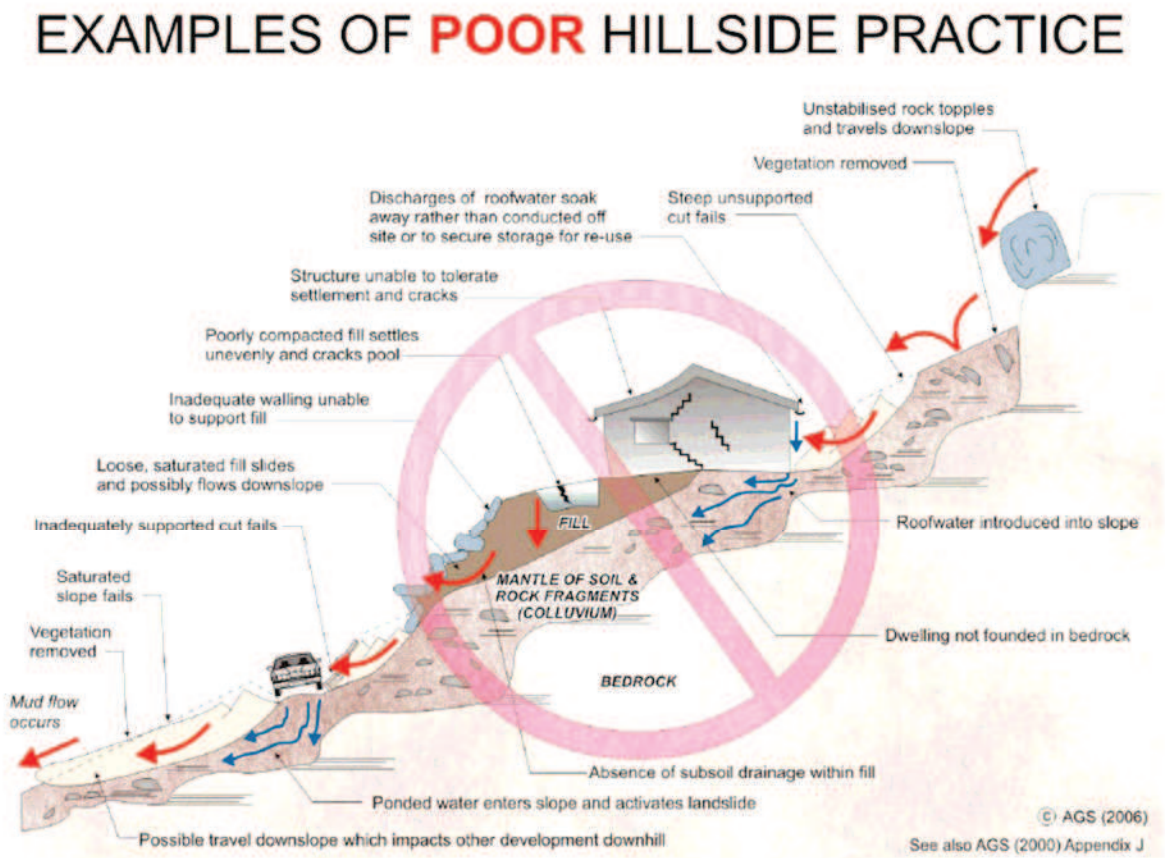
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

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)
© AGS (2006)


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
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Saturated slope fails
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
© AGS (2006)
See also AGS (2000) Appendix J