

REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED NEW RESIDENTIAL HOUSE

at

1168 BARRENJOEY ROAD, PALM BEACH, NSW

Prepared For

Lisa and Martin Cork

Project No.: 2022-210

Document Revision Record

Issue No	Date	Details of Revisions
0	14 March 2023	Original issue

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GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for _____

Name of Applicant _____

Address of site 1168 Barrenjoey Road, Palm Beach

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 March 2023 certify that I am a engineering geologist as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above company to issue this document and to certify that the company has a current professional indemnity policy of at least \$2million.

- ☐ 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: Proposed New Residential House at 1168 Barrenjoey Road, Palm Beach

Report Date: 14 March 2023

Project No.: 2022-210

Author: K. Nicholson

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Architectural: Luigi Rosselli, Job No.: 2041, Drawing: DA00-DA12, Dated: 28/02/2023.

Survey: CMS Surveyors, Drawing Name: 10248Adetail, Date of Survey: 15/12/2020

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.

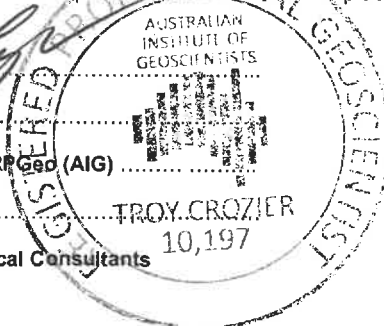
Signature _____

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

Chartered Professional Status...**RP Geo (AIG)**...

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

Company... **Crozier Geotechnical Consultants**



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

Development Application for _____
 Name of Applicant _____
 Address of site _____ 1168 Barrenjoey Road, Palm Beach _____

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: Proposed New Residential House at 1168 Barrenjoey Road, Palm Beach
Report Date: 14 March 2023 **Project No.:** 2022-210
Author: K. Nicholson
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ☒ Comprehensive site mapping conducted _____ 14 September 2022 _____
 (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 conducted14 September 2022.....
- ☒ Geotechnical model developed and reported as an inferred subsurface type-section
- ☒ Geotechnical hazards identified
☒ Above the site
☐ On the site
☐ Below the site
☐ Beside the site
- ☒ Geotechnical hazards described and reported
- ☒ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
☒ Consequence analysis
☒ Frequency analysis
- ☒ Risk calculation
- ☒ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☒ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☒ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ☒ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- ☒ Design Life Adopted:
☒ 100 years
☐ Other specify
- ☒ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ☐ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☐ Risk assessment within Bushfire Asset Protection Zone.

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

Signature _____
 Name ...Troy Crozier...
 Chartered Professional Status: RPGeo (AIG) _____
 Membership No. ...10197...
 Company... Crozier Geotechnical Consultants

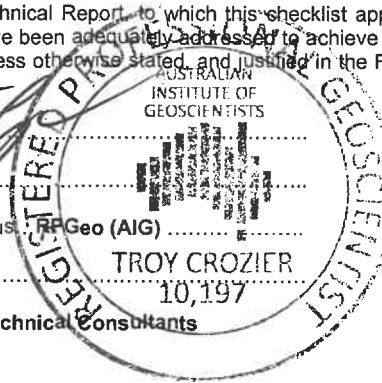


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Date: 14 March 2023

Project No: 2022-210

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**GEOTECHNICAL REPORT FOR NEW RESIDENCE AT
1168 BARRENJOEY ROAD, PALM BEACH, NSW**

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out for a proposed new residence at 1168 Barrenjoey Road, Palm Beach, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the written request of Luigi Rosselli Architects on behalf of the client Lisa and Martin Cork.

It is understood that the proposed works involve demolition of the existing structure and construction of a new five storey dwelling with a basement garage and a lift within the rear. It is also understood that the proposed development will require a bulk excavation to approximately 13.0m depth towards the rear of the new dwelling to allow the construction of the lift/garage. However, the majority of the excavation will be less than 10.0m in depth to achieve the garage finished floor level of RL13.84m. Excavation and re-landscaping/re-construction of the easement adjacent to Barrenjoey Road is also proposed to allow the construction of the basement garage with street level access.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils precinct (Geotechnical Risk Management Policy for Pittwater – 2009). To meet the Councils Policy requirements for works which trigger the landslip policy a detailed Geotechnical Report which meets the requirements of Paragraph 6.5 of that policy is required. This report must include a landslide risk assessment of the site and proposed works, a plan, a geological section and provide recommendations for construction and to ensure stability is maintained for a design life of 100 years. It is recommended that the client make themselves aware of the Policy and its requirements.

This report includes a description of site and sub-surface conditions, borehole logs and in-situ test results, site mapping/plan, geological cross sections, a geotechnical assessment of the development and provides recommendations for design and construction.

The investigation was undertaken as per the Proposal No: P22-401, Dated: 12 August 2022 which was based on the requested scope of work and comprised:

- a) On site service clearance by a specialist underground service location subcontractor
- b) Full time site supervision and geotechnical inspection and mapping of the site and adjacent properties by a Senior Engineering Geologist.
- c) Drilling of six boreholes using hand tools along with six Dynamic Cone Penetrometer (DCP) tests

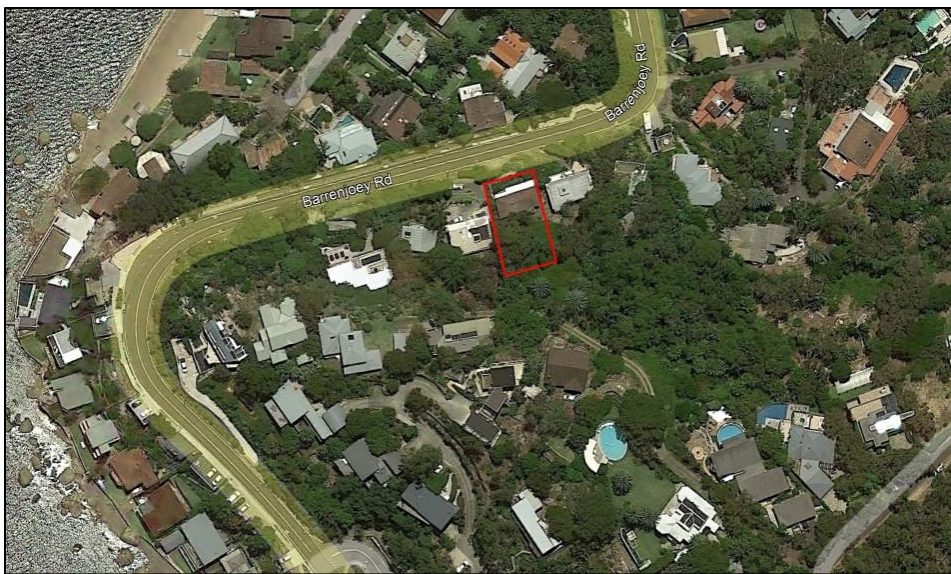
The following plans and drawings were supplied and relied on for the work:

- Architectural Drawings – Luigi Rosselli, Job No.: 2041, Drawing: DA00-DA12, Dated: 28/02/2023.
- Survey Drawing – CMS Surveyors, Drawing Name: 10248Adetail, Date of Survey: 15/12/2020.

2. SITE FEATURES:

2.1. Description:

The site is rectangular in shape and covers an area of approximately 921m² in plan as referenced from the provided survey drawing. It is located on the high south side of the road within steeply north dipping topography and the elevation varies between a high of RL45.5m adjacent to the southwest corner and a low of RL18.5m near the north side of the site. It has north/south and east/west boundaries of 20.2m and 45.8m respectively as determined from the survey plan provided. An aerial photograph of the site and its surrounds is provided below (Photograph 1), as sourced from Google Earth.



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

The site contains the main site dwelling, terraced front gardens, a small deck to the rear of the residence, an access path/gardens and side access pathways and planter beds. The majority of the rear of the site was inaccessible at the time of investigation however appears to comprise a steeply north dipping vegetated slope.

The main site dwelling comprises a one and two storey brick and clad rendered structure that appears >50 years of age and is accessed via a concrete pathway which is partially situated within the site and partially within Barrenjoey Road easement.

The front garden and pathway are partially supported by a low (<1.0m high) sandstone block retaining wall. Access to the rear of the property is via concrete paths to the east and west of the existing residence. A general view of the site is provided in Photograph 2.



Photograph 2: View of the site looking south from Barrenjoey Road

The site is bordered to the north, east, south and west by Barrenjoey Road and easement, No.1170 Barrenjoey Road, No.50 Sunrise Road and No. 1166 Barrenjoey Road respectively.

Barrenjoey Road comprises an asphalt carriageway which was gently east dipping where it passed the site. The road easement comprises a concrete parking bay adjacent to an approximately 2.0m high timber retaining wall which supports landscaped gardens and the access pathway to the site, a portion of which also partially lies within the easement.

No.1170 Barrenjoey Road contains a two and three storey sandstone block and clad house with a vegetated slope to the rear of the dwelling and sloping concrete driveway accessed from Barrenjoey Road. The house structure is approximately 2.0m from the shared boundary and the property is at similar level to the site immediately adjacent to the shared boundary and shares similar north dipping topography.

No.50 Sunrise Road was inaccessible at the time of fieldwork however appears to contain a two storey sandstone block house with front and rear gardens and driveway. The house structure is approximately 16m from the shared boundary and the property is at similar level to the site immediately adjacent to the shared boundary.

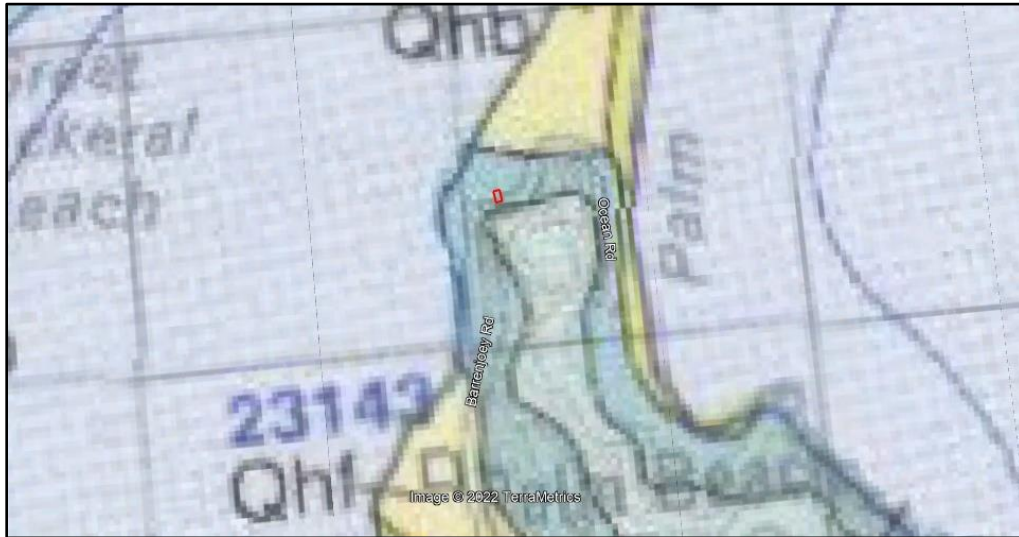
No.1166 Barrenjoey Road contains a two and three storey brick house with a vegetated slope to the rear of the dwelling with sloping concrete driveway and parking area accessed from Barrenjoey Road. The house structure is approximately 3.0m from the shared boundary and the property is at similar level to the site immediately adjacent to the shared boundary and shares similar north dipping topography.

2.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet indicates that the site is underlain by Newport Formation (Upper Narrabeen Group) rock which is of middle Triassic Age. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones. Narrabeen Group rocks are dominated by shales and thin siltstone beds and often form rounded convex ridge tops with moderate angle ($<20^\circ$) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise 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 silty clay soil profiles (medium to high plasticity) with thin silty colluvial cover.

Deposits of the overlying Hawkesbury Sandstone are shown near the upslope south boundary of the site which typically comprise medium to coarse grained quartz sandstone with minor lenses of shale and laminite. Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes. These slopes often consist of sandstone terraces and cliffs with steep colluvial slopes below. The terraced areas above these cliffs often contain thin sandy (low plasticity) soil profiles with intervening rock (ledge) outcrops. The outline of the cliff areas are often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint pattern, many cliff areas are undercut by differential weathering. Slopes below these cliffs are often steep 15 to 23° with moderately thick sandy colluvial soil profile that are randomly covered by sandstone boulders.

It should be noted that the geological boundaries indicated at 1:100,000 scale should be considered approximate. An extract of the relevant Geology Series Sheet is provided below with the site (in red) indicated.



Extract 1: Extract of Geology Series sheet 9130 with the site outlined red.

3. FIELD WORK:

3.1. Methods:

The field work comprised a walkover inspection of the site and a subsurface investigation, both of which were undertaken/supervised by a Senior Engineering Geologist on the 14 September 2022. The subsurface investigation comprised the drilling of six boreholes (BH1 to BH6) and six DCP tests (DCP1 to DCP6). The boreholes were undertaken using hand auger techniques due to access restrictions.

DCP testing was carried out from the ground surface adjacent to the boreholes in accordance with AS1289.6.3.2 – 1997, “Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer”.

The borehole locations were determined on site by CGC and disturbed soil samples were recovered from the auger for geotechnical logging purposes which was undertaken in accordance with AS1726:2017 ‘Geotechnical Site Investigations’.

Prior to commencement of the intrusive works the test locations were cleared by an accredited underground services location contractor.

The ground surface elevation at the borehole locations (RL m AHD) was determined by interpolation between contours/spot heights included on the survey drawing provided by the client.

Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with a geological cross section (Figure 2). Detailed Borehole Log Report sheets and Dynamic Penetrometer Test Sheet are included in Appendix: 2.

3.2. Field Observations:

Bedrock exposures were observed within the site and within the surrounding area. The most noticeable outcrop was located to the rear of the site dwelling and appeared to comprise medium strength sandstone within a cliff which was up to approximately 7m in height and extended into the properties to the east and west boundaries and is shown in Photograph 3.



Photograph 3: View of a section of the cliff within the site and No.1170 looking south from the rear of the site dwelling.

The cliff appeared to be globally stable displaying widely spaced sub horizontal bedding defects with no significant seams or widespread adverse defects observed. One localised previous wedge failure was observed within the cliff and is shown in Photograph 4.

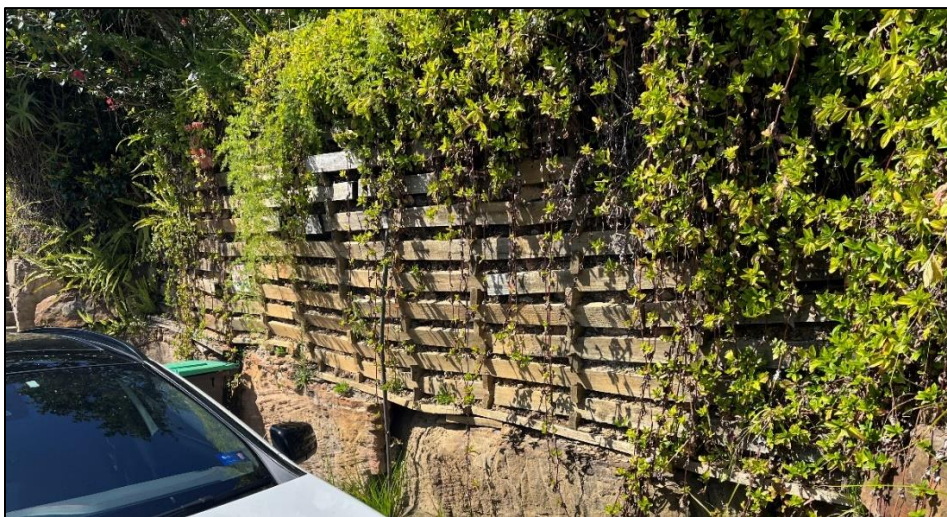


Photograph 4: View of a previous wedge failure (circled red) within the cliff line to the rear of the site house.

Some localised deformation of the access steps to the site and to the residence however this is likely to be a result of settlement of near surface soils and creep rather than representing a geotechnical stability issue.

The timber retaining wall within Barrenjoey easement adjacent to the parking area displayed bulging which is likely due to insufficient original construction, and it is considered likely that the retaining wall is nearing the end of serviceability lifetime. (See Photograph 5)

The retaining wall was founded on a sandstone outcrop approximately 0.7m in height. The outcrop was approximately 0.7m in height and comprised low to medium strength sandstone.



Photograph 5: View of deformation in retaining wall in Barrenjoey Road easement.

To the west of the site, a sandstone outcrop is present adjacent to Barrenjoey Road. Defects within this face appeared to vary from perpendicular (trending north-south to northwest-south east). A view of the defects is shown in Photograph 6.



Photograph 6: View of defects within exposure to the west of the site

Inspection of the existing structures within the site did not indicate any significant geotechnical issues which may have an impact on the proposed development (e.g. back scars, cracking in brickwork etc.) in excess of what would be anticipated based on the age, type of structures and anticipated ground conditions.

Previous work undertaken for the adjacent property to the east (No.1170) indicated that boulders were present near the crest of the cliff line and could be anticipated near the crest of the cliff above the site residence.

No indications of significant distress were observed within the structures within the properties to the east and west of the site and Barrenjoey Road appeared in good condition.

Except where noted, the neighbouring properties and structures were inspected from the site or road reserves, however visible aspects showed no indications of geotechnical hazards which may impact the site.

3.3. Ground Conditions:

For a detailed description of the ground conditions encountered underlying the site, the individual borehole logs should be referred to however, the sub-surface conditions at the project site can be broadly classified as follows:

- **Fill/Possible Colluvium** – this layer was encountered at all borehole locations to a maximum depth of 1.3m in BH3 and comprised either sandy clay (within BH1 to BH3) or silty sand (within BH4 to BH6) with varying proportions of gravel.
- **Silty/Sandy Clay** – Natural soils comprising firm to hard sandy/silty clay were encountered in all boreholes underlying the fill and extended to a maximum depth of 1.9m (BH4) within the rear of the site. Based on the results of the DCP testing it is considered that soil extends to a maximum depth of around 2.5m with the possible exception of DCP3 which extended to 2.9m depth and was apparently (although not conclusively) within soils at this depth.
- **Sandstone** – What has been interpreted as representing weathered bedrock of at least very low strength was encountered at all DCP test locations except DCP6 which extended to 2.9m. It was noticeable that interpreted bedrock was encountered within the sidewall within BH5 at a depth of 0.9m compared with DCP refusal at 1.3m depth indicating a steeply dipping cliff line is present underlying the area to the rear of the site house. It may also indicate that DCP6 encountered the cliff face between approximately 1.6m and 2.9m with the DCP tip/rod deflecting off the interpreted steeply dipping bedrock face resulting in high blow counts below 1.6m depth, however this is unconfirmed.

A free-standing ground water table or significant water seepage were not identified within any of the boreholes. No signs of ground water were observed after the retrieval of the DCP rods.

4.0 COMMENTS:

4.1. Geotechnical Assessment:

The proposed works involve construction of a new residence requiring excavation up to an approximate maximum of 13.0m depth in a narrow section at the rear of the residence to allow the construction of the proposed garage level/lift at FFL13.84m. The majority of the proposed works require bulk excavation to a maximum of approximately 10.0m depth.

Based on the investigation results, the proposed excavation will be through a layer of fill (possible colluvium) to a maximum of 1.0m depth then firm to hard silty/sandy clay, typically to a maximum of 2.5m depth however in the vicinity of BH6/DCP6, this depth may increase to in excess of 2.9m. Competent bedrock (low to medium strength) will then be encountered within the proposed excavation along with minor seepages on

the bedrock surface. It is anticipated the bedrock may contain defects, possibly trending north-south and northwest-southeast. A groundwater table is not anticipated within the proposed excavation however seepage at bedrock/soil interface and within bedrock defects could be expected.

Considering the proposed depth of the excavations to be undertaken along with the separation distances from the site boundaries, safe temporary batter slopes of 1.0H: 1.0V (for the sandy clay/clayey sand) appear to be generally achievable the north, east and south sides of the excavation. The west side of the excavation appears to be within approximately 1.6m of the adjacent shared boundary. Within BH6/DCP6, soils/weathered bedrock were encountered to a depth of 2.9m (and potentially deeper), therefore safe temporary batter slopes may not be feasible within this area.

Prior to bulk excavation within this area, the depth to bedrock should be confirmed to allow design of suitable support systems. The construction of safe batter slopes adjacent to boundaries will be subject to the strength of the bedrock encountered below DCP refusal depths. Where bedrock is weaker than at least low strength, it will be necessary to provide support to bedrock prior to bulk excavation.

Defects in the bedrock can result in sliding movement which has the potential to undermine or impact adjacent properties. The potential to identify these defects is increased through core drilling investigation however it cannot always be confirmed. As such, whilst generally rare a risk of damage exists where deep excavation adjacent to any boundary or structure is proposed. This risk can only be completely mitigated by construction of a full excavation height pile wall prior to excavation, however this will be difficult and expensive to implement within the site and through medium to high strength sandstone bedrock.

The strength of the bedrock underlying the site is unconfirmed therefore there is a potential for the bedrock to be more deeply weathered and/or of lesser or higher strength than interpreted. For confirmation of bedrock strength underlying the site, an investigation utilizing cored boreholes is required and it is envisaged that (due to the depth of proposed excavation) additional boreholes to below the full depth of excavation will likely be a condition of the DA approval (if successful) prior to issue of the Construction Certificate.

Based on the 'hard' bedrock outcrops observed within and adjacent to the site, it is considered (although unconfirmed) that most of the excavation will likely be through at least low to medium strength bedrock. The excavation of low to medium strength (and stronger) sandstone requires the use of rock excavation equipment (see Section 4.1.2).

It is considered that due to the proximity of the neighbouring structures and anticipated volume of hard rock excavation, vibration calibration and full-time monitoring are required during bulk excavation to prevent damage to residential dwelling structures. The requirement for vibration calibration/monitoring could be avoided where hammer weights are restricted to less than approximately 250kg however this may result in considerably slower excavation rates. It is probable the most cost-effective excavation methodology will be dependent on confirmation of bedrock strength (via cored boreholes) within proposed bulk excavation depths. CGC should be consulted by excavation contractor prior to works commencing to assess methodology/equipment size to reduce the potential for the creation of potentially damaging vibrations.

It is recommended that all new footings for 'main' structures extend through the fill, any clay soils and be founded onto/within at least very low strength bedrock. The majority of the footings will likely comprise shallow strips/pads within the base of the excavation where medium strength bedrock is anticipated, however in areas where bulk excavation is not proposed and located below proposed new settlement sensitive structures, piers may be required to extend through soils and found within bedrock. Preliminary allowable bearing capacities for the range of foundation conditions anticipated are provided in Section 6.3.1.

Where any existing services (e.g. sewer/stormwater) exist within the site, their location should be accurately determined to determine whether additional measures are required to protect the service from the site works. Based on information provided on DBYD plans a ducted iron concrete lined (DACL) sewer is present within the site. Where this sewer is present above the base of the excavation it is considered support will be required as well as consultation with Sydney Water to determine any required protection measures.

The proposed works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or on neighbouring properties provided the recommendations of this report are implemented in the design and construction phases.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and hand tools and auger drilling. This test equipment provides limited data from small, isolated test points across the entire site, therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations. However, the results of the investigation provide a reasonable basis for the DA assessment and preliminary structural design of the proposed works. It is recommended that additional cored boreholes are undertaken prior to commencement of siteworks to avoid potential delays on site.

4.2. Site Specific Risk Assessment:

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

- A. Landslip (earth slide $<3\text{m}^3$) of soils at the crest of the proposed excavation
- B. Landslip (wedge failure $<3\text{m}^3$) within bedrock excavation due to adverse defects
- C. Landslip (wedge failure $<10\text{m}^3$) within bedrock excavation due to adverse defects
- D. Boulder roll (1m^3) from above cliff line at rear of house.

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

The risks have been assessed assuming no (or inadequate) support is provided prior to bulk excavation, post excavation or maintenance is not implemented.

The **Risk to Life** from **Hazard A** was estimated to be **up to 4.69×10^{-6}** for persons, while the **Risk to Property** was considered to be up to **‘Moderate’**.

The **Risk to Life** from **Hazard B** was estimated to be up to **3.52×10^{-7}** for persons, while the **Risk to Property** was considered to be **‘Moderate’**.

The **Risk to Life** from **Hazard C** was estimated to be up to **1.13×10^{-5}** for persons within the site residence adjacent to the excavation, while the **Risk to Property** was considered to be up to **‘Moderate’**.

The **Risk to Life** from **Hazard D** was estimated to be **6.25×10^{-8}** for persons within the site residence adjacent to the excavation, while the **Risk to Property** was considered to be **‘Low’**.

The risks associated with landslide hazards potentially generated by the development have been assessed as reaching up to “Unacceptable” levels. However, provided the recommendations of this report are implemented including installation of support measures pre-excavation and regular geotechnical inspection during works, then the likelihood of any failure becomes ‘Unlikely to Rare’ and as the risks reduce to within the “Acceptable” risk management criteria. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

4.3. Design & Construction Recommendations:

Design and construction recommendations are tabulated below:

4.3.1. New Footings:	
Site Classification as per AS2870 – 2011 for new footing design	Class ‘A’ footings found in base of excavation, otherwise ‘P’ due to landslip potential/fill thickness.
Type of Footing	Strip/Pad or Slab at base of excavation, piers external to excavation if required.
Allowable Bearing Pressures for shallow footings.	- Stiff Sandy Clay/Clay: 150kPa* - Very Stiff Sandy Clay/Clay: 250kPa* - Hard Sandy Clay/Clay: 400kPa* - Very low Strength bedrock: 650kPa - Low Strength bedrock: 1,000kPa** - Medium Strength bedrock: 3,000kPa**
Site sub-soil classification as per <i>Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia</i>	B _e – Rock Site
*For lightweight ancillary structures only **Requires cored boreholes to confirm Remarks: All new footings must be inspected and tested by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity against the structural engineers design requirements. This is mandatory to allow them to be ‘certified’ at the end of the project.	

4.3.2. Excavation:

Depth of Excavation	Up to 13.0m for the proposed lift/garage excavation
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Table 1 below shows the properties potentially affected by the proposed excavation and the separation distances to the shared property boundary and structure.

Table 1: Property Separation Distances – Garage Excavation

Boundary	Adjacent Property	Excavation	Bulk Excavation Depth (m bgl)	Separation Distances (m)	
				Boundary	Building
North	Barrenjoey Road easement	Garage	5.0 reducing to 0.0 at road	0.0	Not Applicable
East	1170 Barrenjoey Road	Garage	≤ 7.5	3.5	+ 2.0
East	1170 Barrenjoey Road	Ground Floor	≥ 1.50	3.0	+ 2.0
South	50 Palm Beach Road	Garage/Lift	13.5	≈ 30.0	≈ 60.0

West	1166 Barrenjoey Road	Garage	13.50	1.80	+ 3.0
West	1166 Barrenjoey Road	Ground Floor	3.50	1.6	- 3.0
	Sewer	Ground Floor	3.50	Possibly within excavation	-

Type of Material to be Excavated	Fill/residual soils to maximum 3.0m in thickness underlain by minor sandy clay/silty clay then weathered bedrock likely grading quickly to at least low to medium strength.
----------------------------------	---

Guidelines for un-surcharged batter slopes are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/Temporary	Long Term/Permanent
Uncontrolled fill**	2:1	2.5:1
Sandy Clay- Stiff or ‘stronger’	1:1	2:1
Bedrock-Very low strength or fractured	0.5:1	1:1
Bedrock – Low strength, unfractured	Vertical	0.25:1.0
Bedrock – Medium strength, unfractured	Vertical	Vertical

*Subject to geotechnical inspection **May be highly variable

Remarks: Seepage through the soils can 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. Geotechnical inspection of batters will be required at regular intervals during construction to assess their stability, especially for permanent batters. Groundwater seepages can reduce batter slope stability and ponded water must be prevented from accumulating at the base or crest of any batter slope. It is expected temporary/permanent support will be required pre-excavation to sides of excavation unless additional investigation can prove otherwise.

Equipment for Excavation	Fill/Natural clay soils	Excavator with Bucket
	Very low strength bedrock	Assisted with ripper
	Low strength (or better)	Rock excavation equipment (rock hammer, saw, grinder)

Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	5mm/s for any structure within 10m of excavation 3mm/s for sensitive services. Consultation will be required to determine vibration limits to protect SW assets
Vibration Calibration Tests Required	Likely necessary unless rock excavation hammers limited to <250kg
Full time vibration Monitoring Required	Subject to calibration results
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • For assessment any unsupported excavations • During installation of pre-excavation support • Where unexpected ground conditions are identified, or any other concerns are held. • Following footing excavations to confirm founding material strength • If competent bedrock exposed in excavation
Dilapidation Surveys Requirement	Recommended on all structure within 10m of excavation perimeters.

4.3.3. Retaining Structures:

Required	New retaining structures will be required as part of the proposed development to support the excavation perimeters
Types	Steel reinforced concrete/concrete block walls post excavation, where space permits. Bored soldier piers pre-excavation where safe batter slopes cannot be constructed. Designed in accordance with Australian Standards AS46782002 Earth Retaining Structures.
Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:	

Material	Unit Weight (kN/m3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K0)	
Fill soil	18	ϕ' = 29°	0.35	0.52	N/A
Clay (very stiff to hard)	22	ϕ' = 35°	0.27	0.40	N/A
VLS or fractured bedrock	23	ϕ' = 38°	0.10	0.15	200kPa
LS or better unfractured bedrock	24	ϕ' = 40°	0.01	0.05	400 kPa

Remarks:

In suggesting these parameters, it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. 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.

Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilize active earth pressure coefficients (K_a).

4.3.4. Drainage and Hydrogeology

Groundwater Table or Seepage identified in Investigation		No
Excavation likely to intersect	Water Table	No
	Seepage	Yes (possible over clay soils and over bedrock surface and within bedrock along defects)
Site Location and Topography		Low north side of the road, within moderately/steeply north dipping topography
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Not considered feasible
Remarks: As the excavation faces are expected to encounter some seepage, an excavation trench should be installed at the base of excavation cuts to below floor slab levels to reduce the risk of resulting dampness issues. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Council's stormwater system off site.		

4.4 Conditions Relating to Design and Construction Monitoring:

To allow certification as part of construction, building and post-construction activity for this project, it will be necessary for geotechnical:

1. Review structural design drawings for implementation of the recommendations of this report (Form 2B) and to confirm inspection/testing required to maintain site stability.
2. Inspect installation of pre-excavation support systems and all excavation in rock and batter slopes in soils at 1.50 – 2.00m depth intervals.
3. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure and stability prior to the placement of steel or concrete.
4. Where ground conditions vary from those anticipated and outlined in this report are encountered.

The client and builder should make themselves familiar with the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

4.5. 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 acceptable limits. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and 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 – 1996 (50 years)). In order to attain a design life of 100 years as required by the Councils Risk Management Policy, 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.

It should be noted that timber log/sleeper retaining walls will not remain stable for 100 years and therefore should not be utilized for boundary or critical support systems.

If this maintenance and inspection schedule are not maintained the design life of the property cannot be attained.

A recommended program is given in Table: 2 and should also include the following guidelines.

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

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). It is assumed that Pittwater Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site. Also individual Government Departments will maintain public utilities in the form of power lines, water and sewer mains to ensure they don't leak and increase either the local groundwater level or landslide potential.

5. CONCLUSION:

Ground conditions likely to be encountered in excavation comprise up to around 1.3m of fill under which firm to hard sandy clay/clay is likely to be encountered to be encountered within around 2.5m depth with localised deeper areas of soil underlain by bedrock of at least very low strength and likely stronger. Significant groundwater is not anticipated however seepage the soil/bedrock interface and along defects in the rock mass is expected within the excavation.

Temporary batters appear feasible on the north, east and south of the excavation perimeters however pre-excavation support may be required for sections of the west side of the excavation and almost certainly adjacent to the existing sewer (subject to location confirmation).

Subject to the rock strength within the depth of excavation, it is expected that vibration monitoring will be required unless lightweight hammers (<250kg) are used. It is recommended that dilapidation surveys are undertaken on neighbouring properties to the east and west prior to any site works being started (including demolition).

A deep excavation is proposed therefore landslide hazards were identified. The landslip risk was assessed as achieving 'Unacceptable' levels where poor design and construction practices are implemented. However, where the recommendations of this report are implemented in full, the risk from all hazards will reduce to within the 'Acceptable' risk management criteria of the Councils policy.

It is therefore considered that the site and proposed works are suitable and can meet the 'Acceptable' risk management criteria for the design life of development taken as 100 years. Additional cored boreholes are recommended to determine bedrock strength and quality within the full depth of excavation to allow design prior to the Construction certificate application.

Prepared by:



Kieron Nicholson
Senior Engineering Geologist

Reviewed by:



Troy Crozier
Principal
MIE Aust.
MAIG. RPGeo; 10197

6. REFERENCES:

1. Australian Geomechanics Society 2007, "Landslide Risk Assessment and Management", Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, "The preparation of maps and plans in terms of engineering geology" Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. C. W. Fetter 1995, "Applied Hydrology" by Prentice Hall. V. Gardiner & R. Dackombe 1983, "Geomorphological Field Manual" by George Allen & Unwin
4. Australian Standard AS 3798 – 2007, Guidelines on Earthworks for Commercial and Residential Developments.
5. Australian Standard AS 2870 – 1996, Residential Slabs and Footings – Construction
6. Australian Standard AS1170.4 – 2007, Part 4: Earthquake actions in Australia

Appendix 1

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:

<u>Soil Classification</u>	<u>Particle Size</u>
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:

<u>Classification</u>	<u>Undrained Shear Strength kPa</u>
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:

<u>Relative Density</u>	<u>SPT</u> "N" Value (blows/300mm)	<u>CPT</u> 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 separate 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by 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: -

$$Q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) N \text{ blows (blows per 300mm)}$$

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

$$Q_c = (12 \text{ to } 18) C_u$$

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.

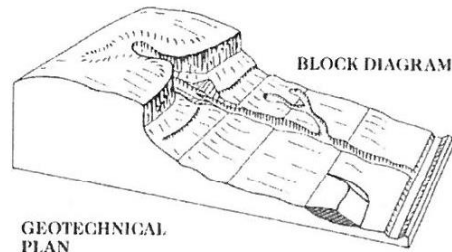
Reproduction of Information for Contractual Purposes

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.

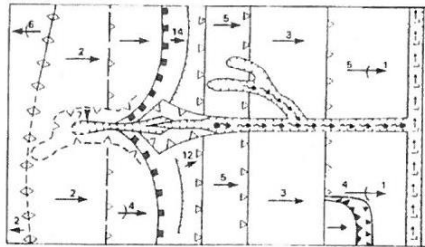
Site Inspection

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.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007



GEOTECHNICAL
PLAN



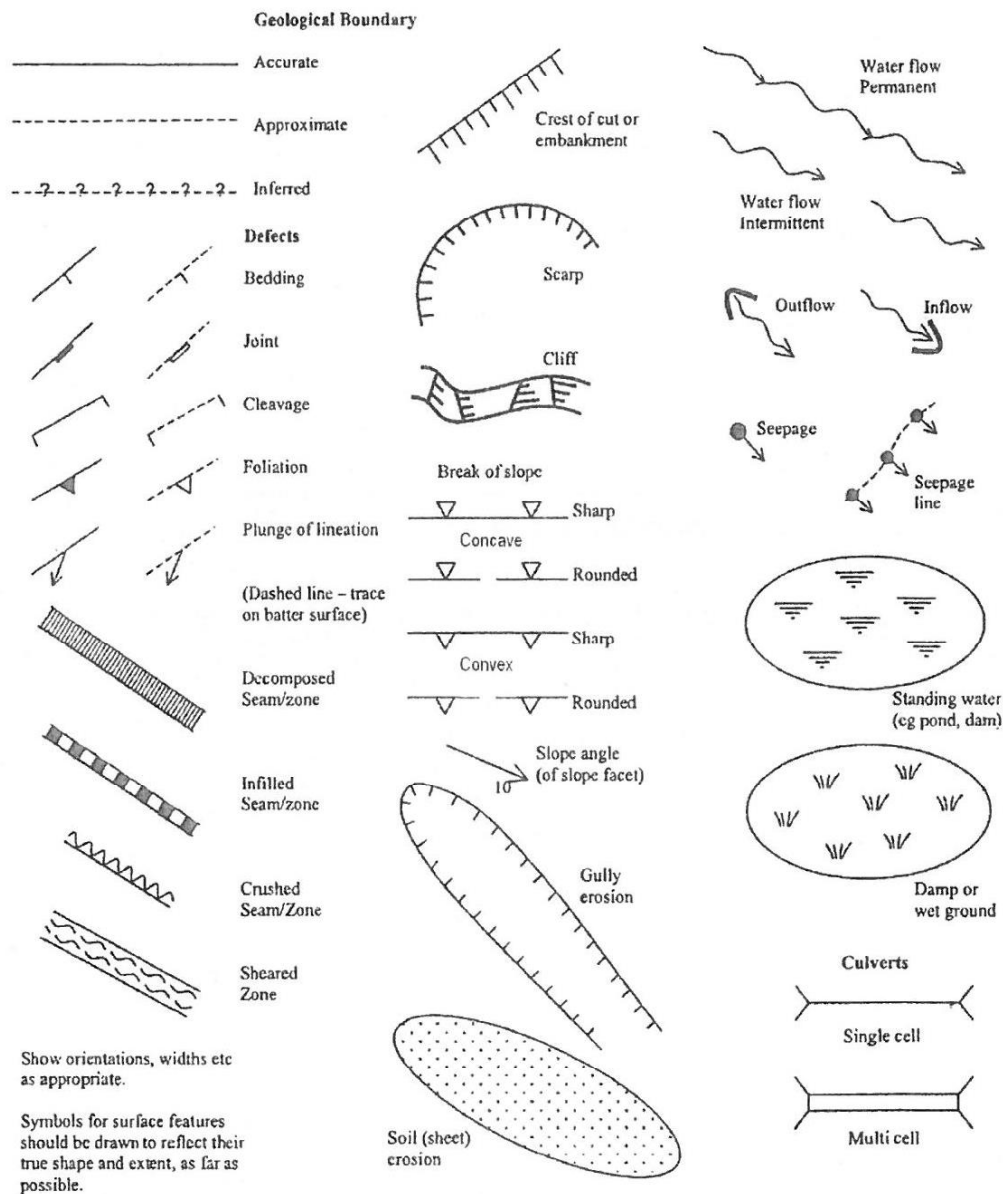
SYMBOL	GROUND PROFILE	
		Convex
		Concave
		Convex
		Concave
	Breaks of slope	} Convex and concave too close together to allow the use of separate symbols
	Changes of slope	
	Sharp	} Ridge crest
	Rounded	
	Cliff or escarpment or sharp break 40° or more (estimated height in metres)	
	Uniform slope	} Slope direction and angle (Degrees)
	Concave slope	
	Convex slope	
	Top	} Cut or fill slope, arrows pointing down slope
	Bottom	
	Hummocky or irregular ground	
	Open drain, unfilled	
	Open drain, lined	
	Fence line	
	Property boundary	
	Dry stone wall	
	Major joint in rock face (opening in millimetres)	
	Tension crack (opening in millimetres)	

Example of Mapping Symbols

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

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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).

Appendix 2



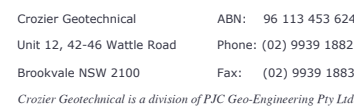
FIGURE 1.

PROPOSED EXCAVATION OUTLINES	BH DCP	AUGER / DYNAMIC CONE PENETROMETER LOCATION
------------------------------------	---	---

A—A' CROSS-SECTION
REFERENCE LINE

APPROVED BY:	TMC
DRAWN BY:	JD
PROJECT:	2022-210

ADDRESS:
1168 Barrenjoey Road, Palm Beach

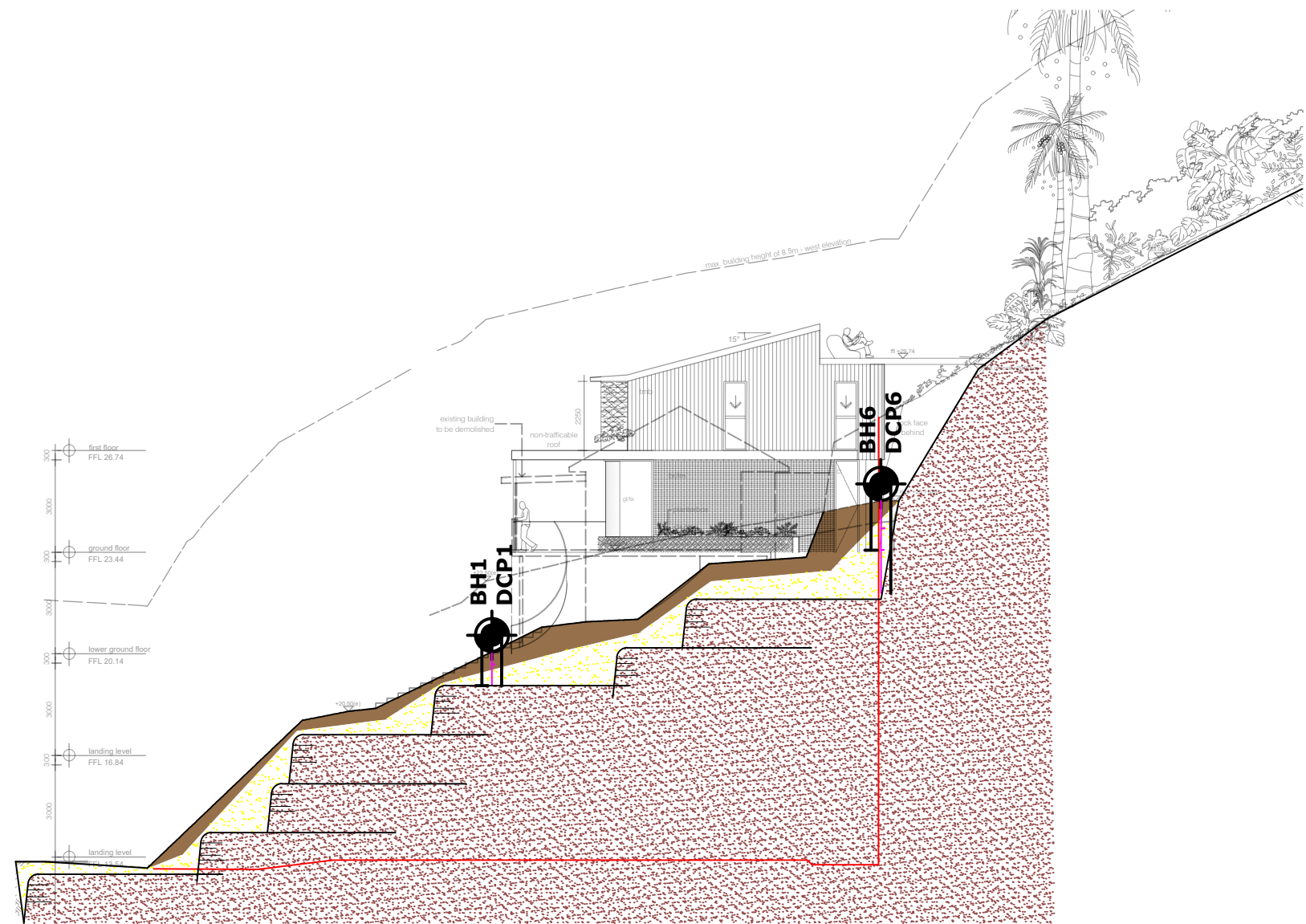
 PROPERTY
BOUNDARY

EXISTING
STRUCTURE



PROPOSED
EXCAVATION
OUTLINES

A ----- A'



SITE SECTION FIGURE 2.



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

ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

LEGEND



AUGER /
DYNAMIC CONE
PENETROMETER
LOCATION



PROPOSED
EXCAVATION
OUTLINE



SANDSTONE
BEDROCK



RESIDUAL SOILS



FILL A ----- A' SECTION LINE

SCALE: 1:200 @ A3
DRAWING: FIGURE 2
DATE: 09/2022

APPROVED BY: TMC
DRAWN BY: JD
PROJECT: 2022-210

PREPARED FOR:
Martin Cork

ADDRESS:
1168 Barrenjoey Road, Palm Beach

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 1

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL20.3m

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		FILL: Dark brown, fine to medium grained, moist sandy clay with fine to medium sandstone gravel				
0.40	CH	Silty CLAY: Firm, yellow brown mottled grey silty clay, moist with trace of fine sand				
0.80		... soft, mottled red				
0.90		... stiff, trace of medium to coarse subangular tabular gravel of sandstone				
1.00						
1.10		Hand auger refusal at 1.2m depth on interpreted very low strength sandstone				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: --

CHECKED: T.M.C

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 2

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL19.8

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
0.30		FILL: Grey mottled brown, sandy clay, trace fine grained sand ... brown mottled grey silty clay				
0.50						
	CI	Sandy CLAY: Firm grey brown, moist sandy clay, fine to medium grained sand				
0.80						
0.90	CH	Silty CLAY: Stiff, brown mottled grey silty clay ... locally mottled red				
1.00						
1.30		... trace rounded ironstone gravel				
1.60		... hard				
1.80		Hand auger refusal at 1.8m depth within interpreted very low strength sandstone.				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: --

CHECKED: T.M.C

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 3

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL20.2

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
0.30		FILL: Brown, fine to medium grained, moist, sandy clay fill with subangular gravel of sandstone, rootlets ... brown grey silty clay with trace of gravel				
0.50						
0.75		... grey, moist to wet, with zones of fine to medium grained gravelly sand				
1.00						
1.30	CI	Sandy CLAY: Very stiff, brown mottled grey, moist silty clay, fine grained sand				
1.50						
1.70		Auger refusal at 1.7m within hard clay				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: --

CHECKED: T.M.C

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 4

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL23.2

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
0.30		FILL: Brown silty sand with rootlets ... clayey sand				
0.50						
0.75	CI	Sandy CLAY: Stiff, brown mottled grey, moist, fine grained sandy clay				
	CH	Silty CLAY: Very stiff, pale brown mottled grey, moist silty clay with trace fine gravel sand				
1.00						
1.50						
1.90		... red mottled below 1.5m depth				
2.00		Hand auger refusal at 1.9m depth within hard clay				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: --

CHECKED: T.M.C

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 5

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL23.3

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
		FILL: Brown, fine grained moist silty sand with rootlets				
0.20						
	CH	Silty CLAY: Firm, pale brown grey, moist silty clay				
0.40		... orange brown				
0.70		... ironstone gravel				
0.90						
		Hand auger refusal at 0.9m depth. Interpreted bedrock encountered on southern side of borehole				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: --

CHECKED: T.M.C

BOREHOLE LOG

CLIENT: Martin Cork

DATE: 14/09/2022

BORE No.: 6

PROJECT: New Dwelling

PROJECT No.: 2022-210

SHEET: 1 of 1

LOCATION: 1168 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL24.7

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		FILL: Dark brown fine grained, moist silty sand trace subangular gravel, roots 0.4m				
0.50						
0.60		.. clayey sand				
0.90		... sandy clay				
1.00						
1.20	CI	Sandy CLAY: Stiff, brown mottled orange, fine to medium grained moist sandy clay				
1.40		... grey brown mottled				
1.60		... pale grey				
		Hand auger refusal at 1.6m depth within hard clay				

RIG: Not applicable

DRILLER: A.C

METHOD: Hand auger

LOGGED: K.N

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: Strong odour from 1.0m depth (sulphurous)

CHECKED: T.M.C

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Martin Cork
PROJECT: New Dwelling
LOCATION: 1168 Barrenjoey Road, Palm Beach

DATE: 14/09/2022
PROJECT No.: 2022-210
SHEET: 1 of 1

Depth (m)	Test Location									
	1	2	3	4	5	6				
0.00 - 0.10	0	0	1	0	0	--				
0.10 - 0.20	2	0	1	1	1	1				
0.20 - 0.30	2	1	1	1	2	1				
0.30 - 0.40	2	4	1	1	2	4				
0.40 - 0.50	2	2	2	4	3	5				
0.50 - 0.60	2	2	1	3	2	5				
0.60 - 0.70	2	3	2	3	2	4				
0.70 - 0.80	2	3	2	3	9	4				
0.80 - 0.90	1	3	2	3	7	3				
0.90 - 1.00	4	3	9	2	5	3				
1.00 - 1.10	3	4	2	2	6	4				
1.10 - 1.20	20 (B) @ 1.2m	3	4	2	5	3				
1.20 - 1.30		3	4	3	5	3				
1.30 - 1.40		3	4	3	10 (B) @ 1.3m	3				
1.40 - 1.50		3	4	4		3				
1.50 - 1.60		3	5	3		3				
1.60 - 1.70		5	4	4		10				
1.70 - 1.80		8	6	5		12				
1.80 - 1.90		8 (B) @ 1.85m	7	9		10				
1.90 - 2.00			9	5		11				
2.00 - 2.10			9 (B) @ 2.1m	14		15				
2.10 - 2.20				6		13				
2.20 - 2.30				11		17				
2.30 - 2.40				23		18				
2.40 - 2.50				12 (B) @ 2.5m		12				
2.50 - 2.60						16				
2.60 - 2.70						14				
2.70 - 2.80						17				
2.80 - 2.90						15				
2.90 - 3.00						END				
3.00 - 3.10										
3.10 - 3.20										
3.20 - 3.30										
3.30 - 3.40										
3.40 - 3.50										
3.50 - 3.60										
3.60 - 3.70										
3.70 - 3.80										
3.80 - 3.90										
3.90 - 4.00										

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

REMARKS: (B) Test hammer bouncing upon refusal on solid object
 -- No test undertaken at this level due to prior excavation of soils

Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide <3m ³) from soils at crest of excavation		Appears up to in excess of 2.9m of soil present above bedrock of unconfirmed strength	a) Deck approximately 2.5m from 3.0m deep soil excavation, impact most of deck b) Garden 2.8m from adjacent to excavation, impact 10% c) Driveway 2.8m from excavation d) Rear wall <1.0m from 13.5m deep excavation e) House approximately 4.0m from excavation, limited soil at crest		a) Person on deck 1hrs/day ave. b) Person in garden 1hr/day ave. c) Person in driveway 1hrs/day ave. d) Person in house 20 hrs/day ave. e) Person in house 20 hrs/day avg.	a) Possible to not evacuate b) Possible to not evacuate c) Possible to not evacuate d) Likely to not evacuate e) Likely to not evacuate	a) Person in open, engulfed b) Person in open space, engulfed c) Person on driveway, structure impact only d) Person in house, house damaged only e) Person in house, house damaged only	
			Possible	Prob. of Impact	Impacted				
		a) Timber Deck of No.1170 Barrenjoey Road	0.001	0.25	0.90	0.0417	0.5	1.00	4.69E-06
		b) Garden of No.1166 Barrenjoey Road	0.001	0.30	0.10	0.0417	0.5	1.00	6.25E-07
		c) Driveway No.1166 Barrenjoey Road	0.001	0.10	0.05	0.0417	0.5	0.05	5.21E-09
		d) Rear wall of new site residence	0.001	0.75	0.01	0.8333	0.75	0.10	4.69E-07
		e) House No.1170	0.001	0.10	0.01	0.8333	0.75	0.10	6.25E-08
B	Landslip (wedge failure <3m ³) within rock excavation		Rock excavations up to 13m depth expected, possible unfavourable defects in some portion	a) Small slide/topple could impact up to 3% of site house b) May impact edge of driveway		a) Person in site house 20hrs/day b) Person in driveway 0.5 hrs/day ave.	a) Likely to not evacuate b) Likely to not evacuate	a) Person in house, house only damaged b) Person in car, pavement only damaged	
			Possible	Prob. of Impact	Impacted				
		a) Rear wall of new site residence	0.001	0.75	0.03	0.4167	0.75	0.05	3.52E-07
		b) Driveway No.1166 Barrenjoey Road	0.001	0.10	0.10	0.0208	0.75	0.05	7.81E-09
C	Landslip (wedge failure <10m ³) within rock excavation		Rock excavations up to 13m depth expected, possible unfavourable defects in some portion	a) Could impact up to 5% of site house b) Could impact 25% of driveway c) Could impact 5% of house d) Could impact 5% of house		a) Person in site house 20hrs/day b) Person in driveway 0.5 hrs/day c) Person in site house 20hrs/day d) Person in site house 20hrs/day	a) Likely to not evacuate b) Likely to not evacuate c) Likely to not evacuate d) Likely to not evacuate	a) Person in house, minor to moderate impact b) Person in car, pavement only damaged c) Person in house, minor impact d) Person in house, minor impact	
			Possible	Prob. of Impact	Impacted				
		a) New site residence	0.001	0.90	0.20	0.8333	0.75	0.10	1.13E-05
		b) Driveway No.1166 Barrenjoey Road	0.001	0.05	0.15	0.0208	0.75	0.05	5.86E-09
		c) House at No. 1170	0.001	0.10	0.05	0.8333	0.75	0.05	1.56E-07
		d) House at No. 1166	0.001	0.10	0.05	0.8333	0.75	0.05	1.56E-07
D	Boulder roll (<1m ³) from above cliff line at rear of residence		No unstable boulders noted in inspection, possible future generation	a) Boulder roll could impact up to 1% of site house		a) Person in site house 20hrs/day	a) Likely to not evacuate	a) Person in house, house only damaged	
			Possible	Prob. of Impact	Impacted				
		a) Rear wall of new site residence	0.001	0.10	0.01	0.8333	0.75	0.10	6.25E-08

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems

* likelihood of occurrence for design life of 100 years

* Spatial Impact - Probability of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).

Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)

* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.

* considered for person most at risk, where multiple people occupy area then increased risk levels

* for excavation induced landslide then considered for adjacent premises/buildings founded off shallow footings, unless indicated

* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.

* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B**Landslide risk assessment for Risk to Property**

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide <3m³) from soils at crest of excavation	a) Timber Deck of No.1170 Barrenjoey Road	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
		b) Garden of No.1166 Barrenjoey Road	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
		c) Driveway No.1166 Barrenjoey Road	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Low
		d) Rear wall of new site residence	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
		e) House No.1170	Unlikely	The event might occur under very adverse circumstances over the design life.	Insignificant	Little Damage or no impact to neighbouring properties, no significant stabilising required .	Very Low
B	Landslip (wedge failure <3m³) within rock excavation	a) Rear wall of new site residence	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
		b) Driveway No.1166 Barrenjoey Road	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
C	Landslip (wedge failure <10m³) within rock excavation	a) New site residence	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Moderate
		b) Driveway No.1166 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 or MINOR damage to neighbouring property, requires large stabilising works .	Low
		c) House at No. 1170	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 or MINOR damage to neighbouring property, requires large stabilising works .	Low
		d) House at No. 1166	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 or MINOR damage to neighbouring property, requires large stabilising works .	Low
D	Boulder roll (<1m³) from above cliff line at rear of residence	a) Rear wall of new site residence	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	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%.

* Cost of site development estimated at

\$5,000,000

TABLE: 2

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.	Every year or following each major rainfall event.
	Owner to check and flush retaining wall drainage pipes/systems	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.	Every two years or following major rainfall event.
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.

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.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007
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	5x10 ⁻²	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 ⁻²		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10 ⁻³	5x10 ⁻³	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10 ⁻⁴	5x10 ⁻⁴	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10 ⁻⁵	5x10 ⁻⁵	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10 ⁻⁶	5x10 ⁻⁶	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

- Notes:** (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.
- (3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.
- (4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not *vice versa*

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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.

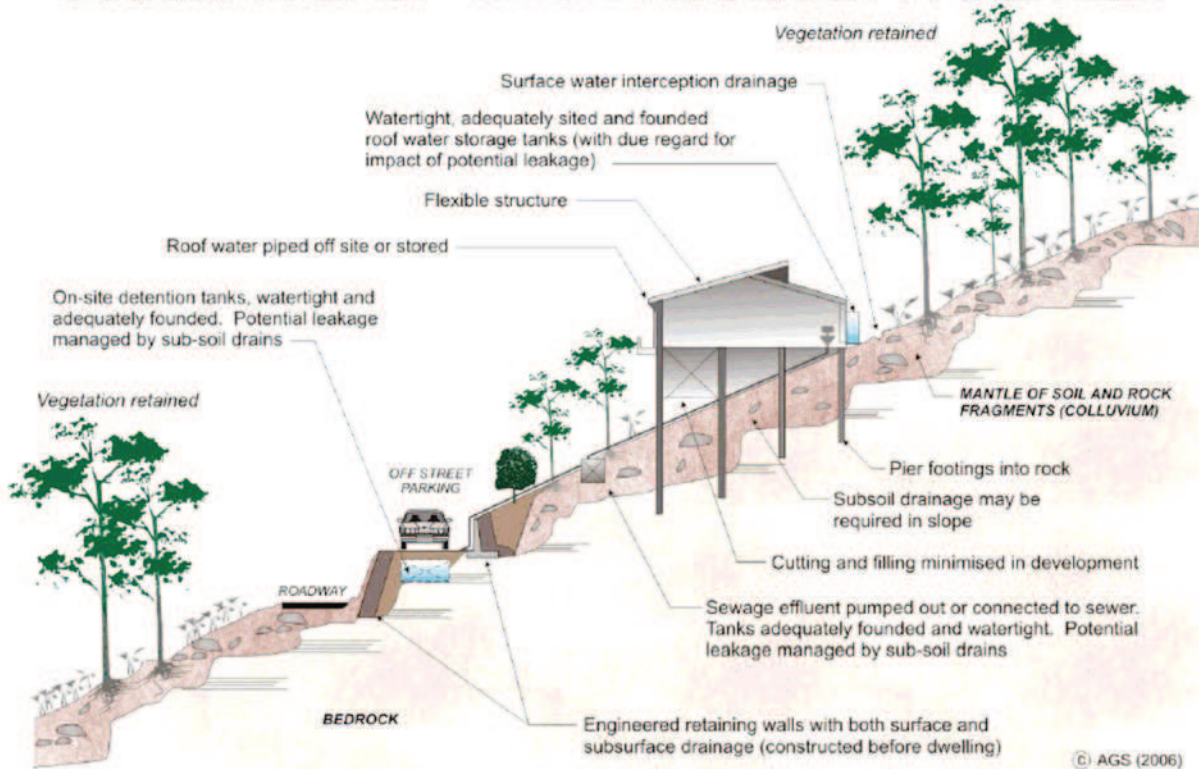
Appendix 5

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

ADVICE		GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
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



EXAMPLES OF **POOR** HILLSIDE PRACTICE

