10 April 2015
BH Ref: 5702

Bruce McConochie
1B The Serpentine
Bilgola Beach NSW 2107

Dear Sir,

RE: Comments on Slope Instability Risk & Site Development
Proposed Additions, Lot 1 DP 232164
No 1B The Serpentine, Bilgola Beach

1. Introduction

As requested, Barker Harle has prepared this report with comments on slope instability risk for the above property. Proposed development of the site is understood to involve the construction of additions to the northern and southern ends of the existing dwelling, and a two vehicle carport and turning bay.

The purpose of this report is to provide comment on:

- The assessed risk of slope instability on the property, in accordance with the methodology set out in guidelines prepared by the Australian Geomechanics Society Sub-committee on Landslide Risk Management, in 'Australian Geomechanics', Vol 37 No 2 (Ref 1); and
- Geotechnical guidelines for development on the site.

For the purpose of the investigation, the client provided Barker Harle with a set of draft design drawings by Matthew Woodward Architecture, in 14 sheets dated 9 April 2015, showing the layout and extent of proposed development.

The scope of this investigation included a desktop review of available published information, field work and the preparation of this report. The following sections give the results of the investigation and the slope stability assessment.

For the purpose of a qualitative assessment of the risk of slope instability on the site, this report makes reference to the terms defined in the Australian Geomechanics Society Landslide Taskforce paper, *Practice note guidelines for landslide risk management*, in 'Australian Geomechanics' Vol 42 No 1 (Ref 2).

2. Site Description

The property, identified as Lot 1 in DP 232164, occupies an irregular shaped allotment of some 1,132 m^2 located on the western side of The Serpentine at Bilgola Beach. The site is bounded by existing residential development to the north-east, east and south, and by vacant land and Barrenjoey Road to the north-west and west.

The property is situated on the east-facing lower slopes of the Bilgola Plateau. Average ground slopes on the property are in the order of 18° towards the east.

At the time of investigation, existing development on the property comprised a one- to two-storey timber clad dwelling. Access to the property from The Serpentine is gained by a driveway shared with Nos 1 and 1A. Vegetation comprises established lawn cover, landscaped gardens and young to mature trees up to 10 m high. Numerous weathered sandstone boulders were observed within the surface soils across the property and adjacent areas. Views of the site are given in Photographs P1 to P5, below.

Photograph P1 – View towards west from near south-eastern corner of property

Photograph P2 – View towards south taken from near northern corner of property

Photograph P3 – View towards west; showing southern end of dwelling

Photograph P4 – View towards north along western side of dwelling

Photograph P5 – Sandstone boulders exposed in cut area at lower ground floor level of existing dwelling; view towards north-west

3. Geological Setting and Soil Landscape

Reference to the Sydney 1:100000 geological series sheet published by the NSW Department of Mineral Resources (Ref 3) indicates that the site is underlain by undifferentiated rocks belonging to the Clifton Subgroup of the Narrabeen Group of Triassic age. Rock types within the Clifton Subgroup typically comprise sandstone, shale and tuff.

The site is lies within the Watagan colluvial landscape as identified on the ‘Sydney 1:100000 soil landscape series sheet 9130’ published by the Department of Environment, Climate Change and Water (Ref 4). The Watagan colluvial landscape is characterised by rolling to very steep hills on fine grained sediments of the Narrabeen Group. Slope gradients are typically more than 25 % on local relief of 60 m to 120 m. Limitations of the Watagan colluvial landscape include mass movement hazard, steep slopes, severe soil erosion hazard and occasional rock outcrop.

4. Field Work

4.1 Methods

The field work undertaken on 9 April 2015 consisted of a walkover visual assessment of the property and the surrounding area, three dynamic cone penetrometer (DCP) probe tests and the excavation of one borehole by hand auger methods.

Drawing 5702/GEO1 shows the approximate locations of the boreholes and DCP tests.

4.2 Results

Borehole BH1 encountered clay soils varying in consistency from stiff to hard, typically very stiff, to the limit of investigation at 1.1 m depth where refusal of the hand auger was encountered.

The DCP probe was driven to refusal at depths ranging from 1.2 m at test location DCP1 to 2.4 m at test location DCP3.

No ground water inflow was encountered in the borehole or at the DCP test probes and no surface water seepage was observed on site on the day of the field work.

The DCP probe test results and an engineering log of the borehole are given in the attachments to this report.

5. Data Interpretation

5.1 Proposed Development

The draft design plans indicate that the proposed dwelling additions will be supported on isolated footings and will require no bulk earthworks to accommodate them on site.

The draft design plans show that the proposed carport will require excavations to about 1.5 m depth in order to accommodate it at the proposed location just east of the dwelling.

5.2 Subsurface Conditions

The proposed development areas of the property are underlain by very stiff clayey soils. It is interpreted that the soils overlie weathered sandstone bedrock at depths in the order of 1 m to 2.5 m.

In places on site, it is anticipated that boulders of weathered sandstone will be present within the clay soils present as colluvium on site as observed in the cut adjacent to southern side of the lower ground floor area of the existing dwelling.

6. Assessment of Slope Instability Risk

An assessment of the risk to both property and life as a result of failure mechanisms on the site has been undertaken with reference to the Australian Geomechanics Society Landslide Taskforce paper, 'Practice note guidelines for landslide risk management' [Ref 2]. Risk analysis can be broken up into four components, namely:

- Hazard identification;
- Frequency analysis, or estimation of likelihood of occurrence;
- Consequence analysis; and
- Risk estimation.

No obvious movement of surface soils or bedrock was observed on site. Based on the field observations and interpretations the following slope instability hazards have been identified on this site:

- Creep of surface soils;
- Failure of retaining walls; and
- Mass movement of surface soils due to deep seated slope failure.

The assessment of slope instability risk was based on the following semi-quantitative interpretations of likelihood and consequence for each of the above hazards, in line with the terminology of Ref 2:

- Creep of surface soils – "Likely" and "Minor";
- Failure of retaining walls – "Likely" and "Insignificant"; and
- Soil mass movement – "Unlikely" and "Medium".

The risk rating for each of the above hazards is assessed to be "Moderate", "Low" and "Low", respectively.

Ref 2 indicates that sites which have been deemed to have a "Low" risk level or lower are usually acceptable to regulators, and that hazards with a "Moderate" risk level are usually acceptable provided measures are undertaken to ensure ongoing monitoring and maintenance of the hazard.

The assessed risk to loss of life due to the hazards identified above is estimated to be in the order of 5×10^{-5} to 4×10^{-6}, which is less than the risk level deemed in Ref 2 as "tolerable" for existing development. There are no established individual or societal risk acceptance criteria for the loss of life due to a hazardous event such as a landslide or rock fall. Australian Geoguide LR7 (attached) discusses "acceptable" and "tolerable" levels of risk which have been proposed by several authorities including the ANCOLD Guidelines for Risks from Large Dams.

It is considered that the proposed development of the site would be feasible subject to engineering input during detailed design and construction. This would necessarily include geotechnical inspections during site works to assess subsurface conditions exposed in bulk excavations and to confirm founding conditions for the proposed structures.

7. Comments – Geotechnical Guidelines for Site Development

7.1 General

Effective risk management on the site would be achieved by including in the proposed development design features which either reduce the likelihood of occurrence of a potential slope movement hazard or ameliorate the consequences of a landslip event. Examples of such risk management measures are given in the following sections.

7.2 Geotechnical Guidelines for Site Development

7.2.1 Footings

It is recommended that all proposed footing systems be designed in accordance with AS2870–2011 (Ref 5). Consideration will need to be given to the required extent of excavation and filling of the site, including removal of the existing trees and site regrading, when selecting and designing the footing system.

For the proposed development on this site, it is recommended all structures be supported on footings which are founded on or within weathered bedrock.

7.2.2 Excavations

Unsupported cuts in soil must be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 2H:1V and must be protected from erosion. All excavations greater than 0.8 m deep should be supported by properly designed and constructed retaining walls.

Where applicable, the excavation design should incorporate surcharge loads from slopes, retaining walls, structures and other improvements within the vicinity of the excavation.

Depending on the degree of weathering and fracturing exposed during excavations for the proposed development, rock faces may be battered as steep as 1H:8V. This suggested batter slope should be confirmed by geotechnical inspection at the time of excavation.

Drainage measures should be implemented above and behind all excavations to intercept both surface and subsurface water movement.

Figure 1 shows diagrammatically the excavation guidelines given above.

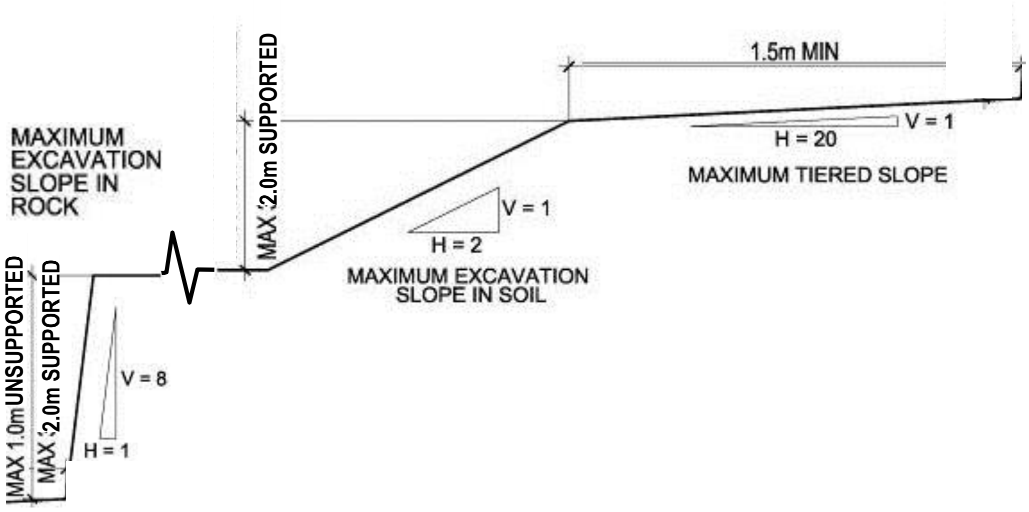


Figure 1 – Guidelines for Excavations in Soil and Rock

7.2.3 Filling

It is recommended that no filling additional to that existing on the property should be added to the development site.

7.2.4 Earthworks in General

Council's development guidelines should be reviewed during site planning as development guidelines may impose height limitations or support requirements on site cuts and fills.

7.2.5 Retaining Walls

All retaining walls on this site should be engineer-designed in accordance with the requirements of AS 4678–2002, 'Earth-retaining structures' (Ref 6).

All retaining structures should be designed to support, where appropriate, surcharge loading due to any sloping ground surface above the retaining walls.

All retaining walls should be constructed with adequate surface and subsurface drainage to the Engineer's and Council's requirements.

7.2.6 Site Drainage

The effective drainage from the site of surface and subsurface water is important to ensure the stability of the surface soil and the long term performance of footing systems and retaining walls.

The property should be developed and maintained in accordance with the guidelines set out in Section 3 of the BCA and Appendix B of AS 2870–2011 (Ref 5).

In particular the following measures are recommended:

- Catch/dish drains formed at the top and dish and rubble drains installed at the toe of all batters;
- Subsoil drains installed behind new retaining walls;
- Cut areas sloped to fall away from proposed building areas and water not be allowed to pond around buildings;
- The site be graded to prevent water from ponding on all areas of compacted fill;
- Surface stormwater and subsoil water collected and disposed of in accordance with Council's requirements – a possible means of stormwater disposal would be to the gully and small dam to the south-west of the proposed development area;
- Erosion control measures to be undertaken during construction to Council's requirements; and
- Disposal of collected stormwater by on-site infiltration is not suitable for this site.

8. Report Limitations

Barker Harle has prepared this report on a geotechnical investigation for proposed residential redevelopment at No 1B The Serpentine, Bilgola Beach, in accordance with Barker Harle's proposal by email of 10 March 2015. The following is a guide as to the intended scope and use of this report.

- This report is provided for the exclusive use of Mr Bruce McConochie for the purposes as described in the report. It may not be used or relied upon for other purposes or by a third party. Barker Harle can accept no responsibility for loss or damage arising out of the use of this report beyond its purpose as stated above, or incurred by any third party relying on the report without the express written consent of Barker Harle. In preparing this report Barker Harle has necessarily relied upon information provided by the client and/or their agents.
- The extent of testing associated with this assessment is limited to the borehole and DCP test probe locations and variations in ground conditions may occur. The data from the test locations have been used to provide an interpretation of the likely subsurface profile at the site of the proposed development. Barker Harle should be contacted immediately if subsurface conditions are subsequently encountered that differ from those described in this report so that we can review and re-interpret the geotechnical model on the basis of the additional data.
- The scope of this investigation does not include any comment on the potential excavatability of the subsurface materials on site.
- Neither this report, nor sections from this report, should be used as part of a specification for a project without review and agreement by Barker Harle. This is because this report has been written as advice and opinion rather than instructions for construction.
- This report must be read in conjunction with all of the attachments.
- The recommendations provided in this report represent a summary of our technical advice. Please discuss the recommendations with the undersigned if you require any clarification.

Please feel free to contact the undersigned if you have any questions regarding this matter.

Yours faithfully
Barker Harle

Adam Hawkes
Professional Engineer

Reviewed

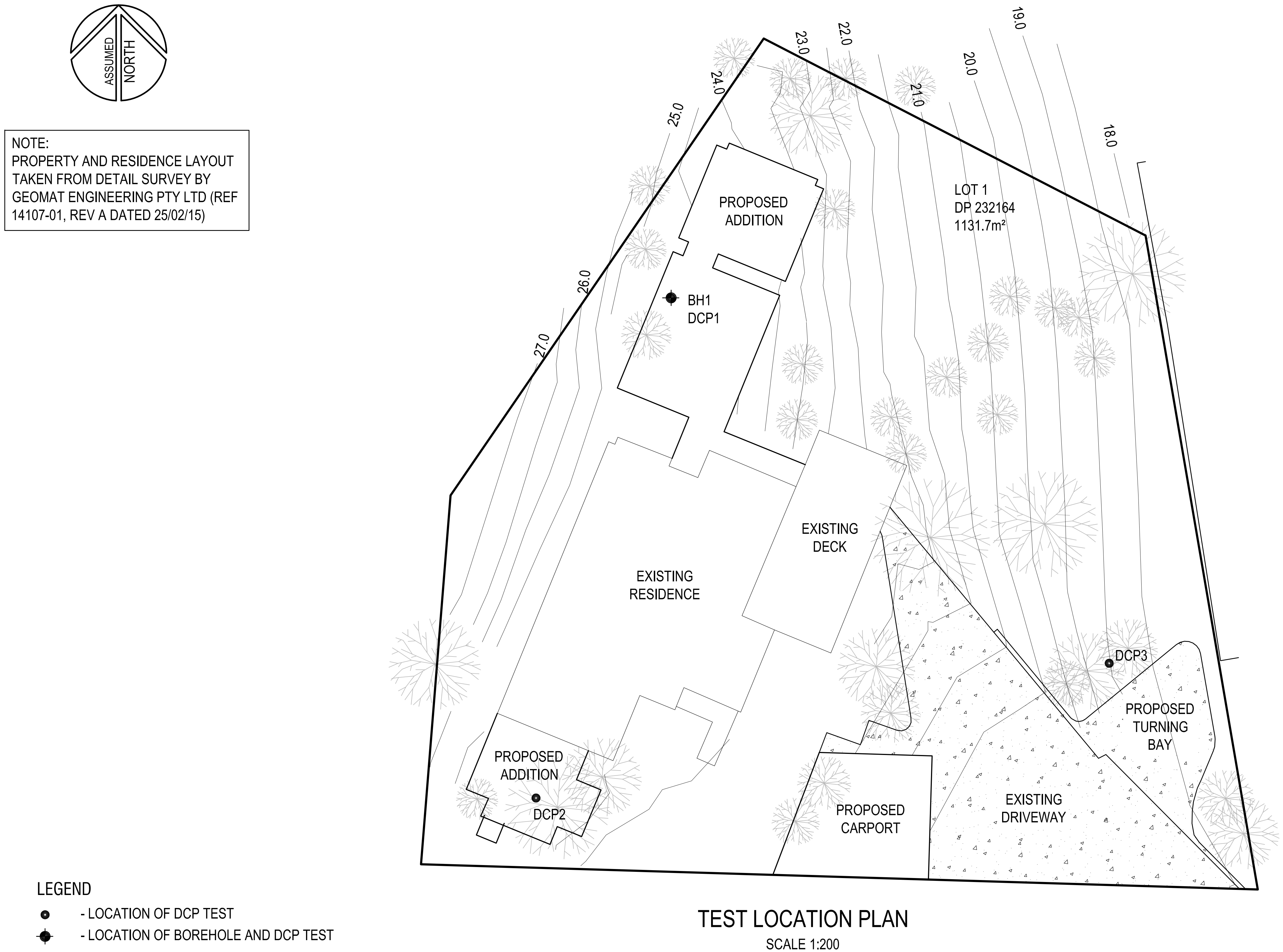
Peter Fennell
MIE Aust

9. References

1. Landslide risk management concepts and guidelines, in ‘Australian Geomechanics’, Vol 37 No 2 (May 2002)
2. Practice note guidelines for landslide risk management, in ‘Australian Geomechanics’, Vol 42, No 1 (March 2007)
3. ‘Sydney 1:100000 geological series sheet, 9130 (Edition 1)’, Geological Survey of NSW, Department of Mineral Resources (1983)
4. ‘Sydney 1:100000 soil landscape series sheet 9130’ and associated report, NSW Department of Environment, Climate Change and Water (2009)
5. Australian Standard AS 2870–2011, ‘Residential slabs and footings’, Standards Australia (January 2011)
6. Australian Standard AS 4678–2002, ‘Earth-retaining structures’, Standards Australia (February 2002)

Attachments:

1. Drawing 5702/GEO1
2. Dynamic Cone Penetrometer test results
3. Engineering Log
4. General Notes
5. Australian Geoguides LR7 (Landslide Risk) and LR8 (Hillside Construction Practice)



TEST LOCATION PLAN

SCALE 1:200

REV.	DATE	ISSUE DESCRIPTION	DESIGN	DRAWN	CHECKED
-	10.04.15	Report Issue	-	AH	-

Approved:

barker harle
consulting engineers

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TEST LOCATION PLAN
PROPOSED ADDITIONS
LOT 1 DP 232164
1B THE SERPENTINE, BILGOLA BEACH
MR B. MCONOCHIE

Drawing: 5702
Sheet: GEO1
Revision: -
Original Sheet Size: A3

Dynamic Cone

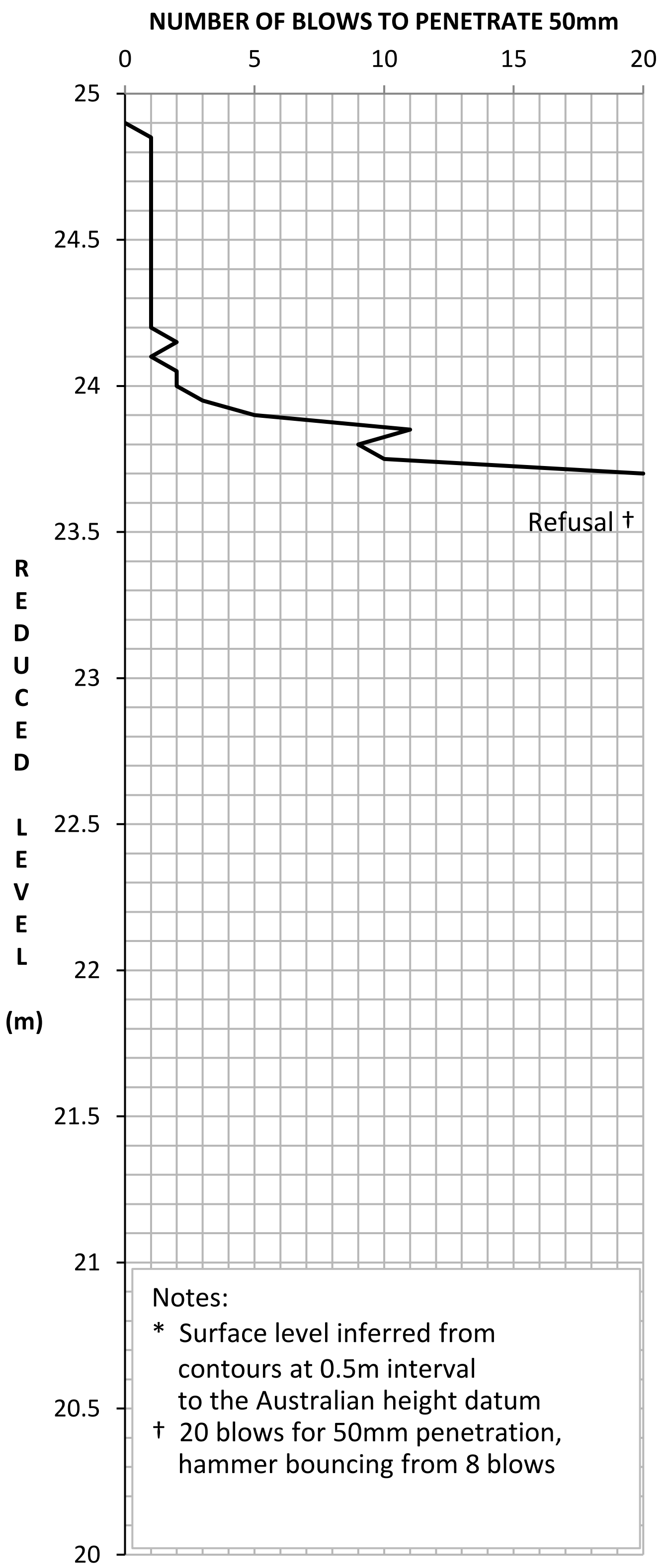
Penetrometer log

barker harle consulting engineers

Location:	1B The Serpentine, Bilgola Beach		
Client:	B. McConochie	**BH Ref:**	5702
Position:	See Site Plan	**Date:**	09-Apr-15
GroundWater:	Nil Encountered	**Logged By:**	AH/PF

*** Surface RL:** 24.9 AHD

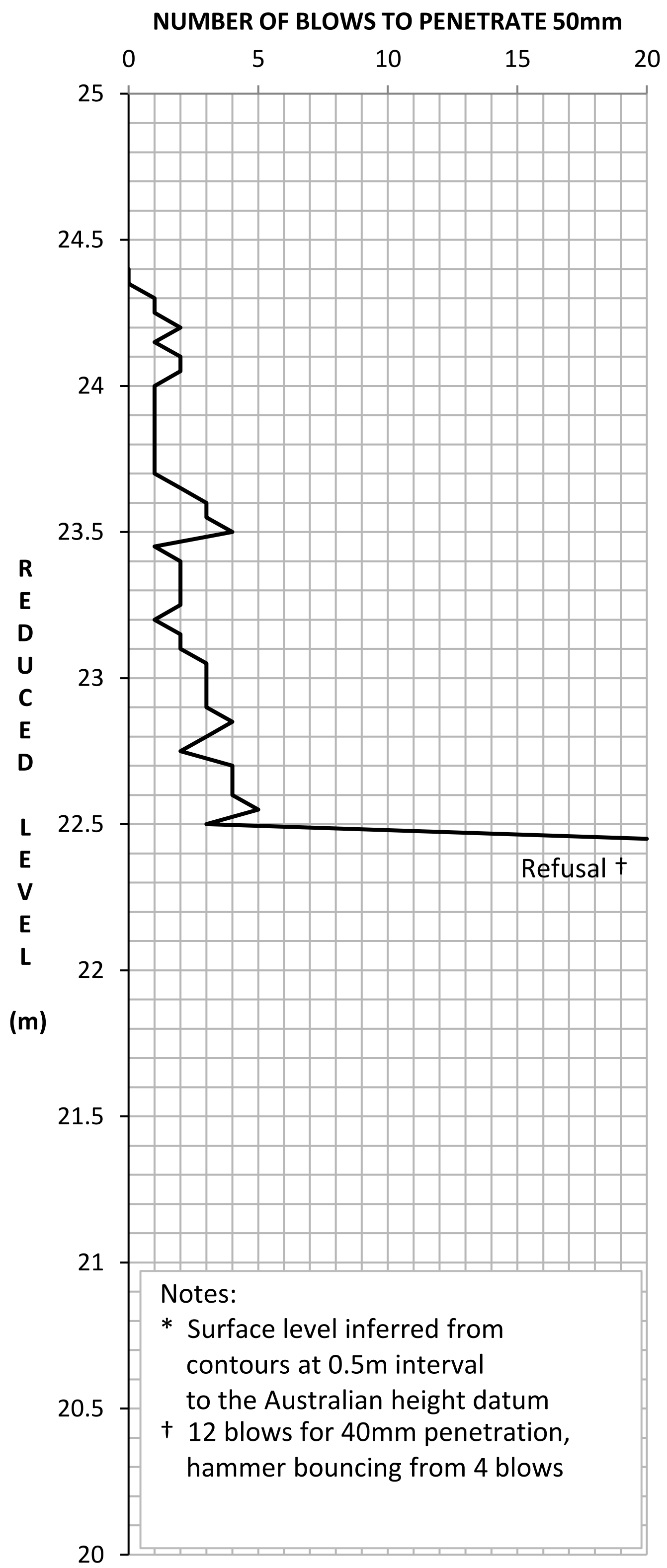
DCP1



Notes:
* Surface level inferred from contours at 0.5m interval to the Australian height datum
† 20 blows for 50mm penetration, hammer bouncing from 8 blows

*** Surface RL:** 24.4 AHD

DCP2

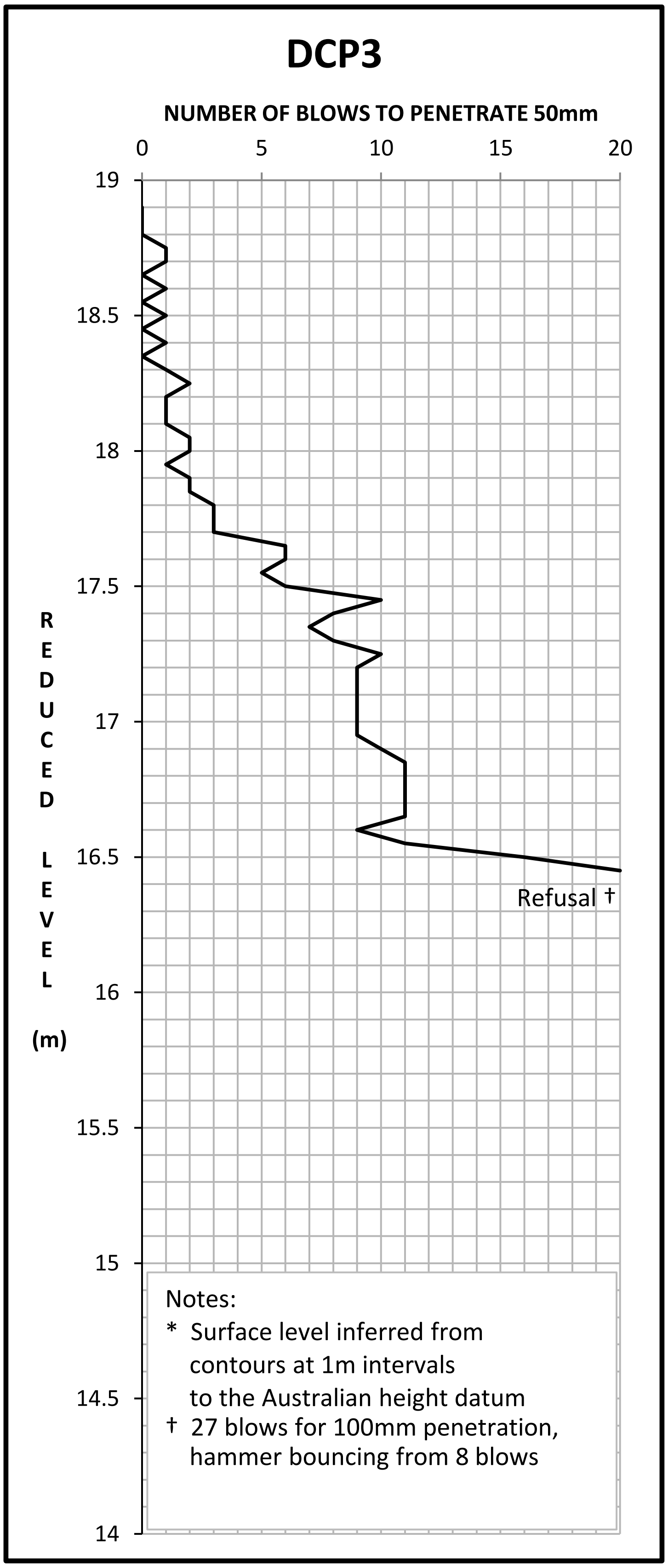


Notes:
* Surface level inferred from contours at 0.5m interval to the Australian height datum
† 12 blows for 40mm penetration, hammer bouncing from 4 blows

Dynamic Cone Penetrometer log

Location:	1B The Serpentine, Bilgola Beach		
Client:	B. McConochie	**BH Ref:**	5702
Position:	See Site Plan	**Date:**	09-Apr-15
GroundWater:	Nil Encountered	**Logged By:**	AH/PF

*** Surface RL:** 18.9 AHD



ENGINEERING LOG

barker harle consulting engineers

Location:	1B The Serpentine, Bilgola Beach	**Borehole No:**	BH1
Client:	B. McConochie	**Equipment:**	Hand Augers *
Position:	SEE SITE PLAN	**Logged By:**	PF
Surface RL:	24.9 AHD	**Job No:**	5702
Groundwater:	NIL ENCOUNTERED	**Date:**	9-Apr-15

Depth in metres	Water	USCS	Material/Strata	Consistency / Rel. Density	Moisture	Plasticity	Structure and Additional Comments
0 – 0.10	NIL	CL	TOPSOIL - Sandy CLAY, stiff, dark brown, roots to 3mm diameter throughout, M ~ Wp	St	M	L	PP = 160 kPa
0.10 – 0.25	NIL	CL	CLAY - very stiff, brown yellow mottled, some sand, fine to coarse grained, trace fragments of weathered sandstone to 5mm size, M ~ Wp	VSt	M	L	PP = 380 kPa
0.25 – 0.60	NIL	CL	CLAY - very stiff to hard, orange brown yellow mottled, some fine to coarse sand, trace weathered sandstone fragments to 30mm size, M ~ Wp	VSt–H	M	M	PP > 600 kPa PP = 320 kPa PP > 600 kPa
0.60 – 1.0	NIL	CL	CLAY - very stiff, grey orange mottled, some fine to coarse sand, M > Wp	VSt	M–W	L	PP = 280 kPa
1.0 – 1.1	NIL	CL	Silty CLAY - very stiff, pale grey orange mottled, trace fine to medium sand, M ~ Wp	VSt	M	M	PP = 320 kPa

Key

Water
- seeping
- free standing

Moisture
- D dry
- M moist
- W wet

Plasticity
- NP Non Plastic
- L Low
- M Medium
- H High

Sampling Data
- U50 undisturbed sample 50mm diameter
- D disturbed sample
- NC cone penetrometer
- B bulk sample

Consistency / Relative Density

VS	very soft		
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VD	very dense

USCS Summary

GW	GRAVEL, well graded
GP	GRAVEL, poorly graded
GM	Silty GRAVEL
GC	Clayey GRAVEL
SW	SAND, well graded
SP	SAND, poorly graded
SM	Silty SAND
SC	Clayey SAND
ML	Low plasticity SILT
CL	Low plasticity CLAY
MH	High plasticity SILT
CH	High plasticity CLAY
OL, OH, Pt	Organic soils

Site Plan N.T.S / Comments

End BH1 at 1.1m, refusal of hand auger.

* 175mm diameter clay cutter to 0.5m depth, then 75mm diameter hand auger to 1.1m depth.

Refer to explanation sheet for description of terms and symbols used

TERMS & SYMBOLS

barker harle consulting engineers

Unified Soil Classification System

COARSE-GRAINED SOILS More than half the material (by weight) is individual grains visible to the naked eye	GRAVELLY SOIL More than half of coarse fraction is larger than 4.75mm	CLEAN GRAVEL Will not leave a stain on wet palm	Substantial amounts of all grain particle sizes	GW
			Predominantly one size or range of sizes with some intermediate sizes missing	GP
		DIRTY GRAVEL Will leave a stain on a wet palm	Non-plastic fines (to identify, see ML below)	GM
			Plastic fines (to identify, see CL below)	GC
	SANDY SOIL More than half of coarse fraction is smaller than 4.75mm	CLEAN SAND Will not leave a stain on a wet palm	Wide range in grain size and substantial amounts of all grain particle sizes	SW
			Predominantly one size or range of sizes with some intermediate sizes missing	SP
		DIRTY SAND Will leave a stain on a wet palm	Non-plastic fines (to identify, see ML below)	SM
			Plastic fines (to identify, see CL below)	SC

	Ribbon	Liquid Limit	Dry crushing strength	Dilatancty reaction	Toughness	Stickiness	
FINE-GRAINED SOILS More than half the material (by weight) is individual grains not visible to the naked eye (< 0.074mm)	None	<50	None to slight	Rapid	Low	None	ML
	Weak	<50	Medium to high	None to very slow	Medium to high	Medium	CL
	Strong	>50	Slight to medium	Slow to none	Medium	Low	MH
	Very strong	>50	High to very high	None	High	Very high	CH
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture						OL, OH, Pt

Description and classification of soils and rocks in accordance with AS1726 'Geotechnical Site Investigations'

Plasticity A2.4(b)

Symbol	Descriptive term	Liquid limit (%)
NP	Non plastic	-
L	of low plasticity	<= 35
M	of medium plasticity	> 35 <= 50
H	of high plasticity	> 50

Moisture Condition A2.5(a)

'Dry' (D)	Cohesive soils; hard and friable or powdery, well dry of plastic limit. Granular soils; cohesionless and free-running.
'Moist' (M)	Soil feels cool, darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
'Wet' (W)	Soil feels cool, darkened in colour. Cohesive soils usually weakened and free water forms on hands when handling. Granular soils tend to cohere.

Consistency terms - Cohessive soils TA4

Term	USS (kPa)	Field guide to consistency
Very soft	<=12	Exudes between fingers when squeezed in hand
Soft	12-25	Can be moulded by light finder pressure
Firm	25-50	Can be moulded by strong finger pressure
Stiff	50-100	Cannont be moulded by fingers, can be indented by thumb
Very stiff	100-200	Can be indented by thumb nail
Hard	>200	Can be indented with difficulty by thumb nail

Consistency terms - Non-Cohessive soils TA5

Term	Density index (%)
Very loose	<= 15
Loose	15 - 35
Medium dense	35 - 65
Dense	65 - 85
Very Dense	> 85

TERMS & SYMBOLS

Symbols

Soil	Rock
Asphaltic Concrete or Hotmix	Claystone (massive)
Concrete	Siltstone (massive)
Topsoil	Shale (laminated)
Fill	Sandstone (undifferentiated)
Peat, Organic Clays and Silts (Pt, OL, OH)	Sandstone, fine grained
Clay (CL, CH)	Sandstone, coarse grained
Silt (ML, MH)	Conglomerate
Sandy Clay (CL, CH)	Limestone
Silty Clay (CL, CH)	Coal
Gravelly Clay (CL, CH)	Dolerite, Basalt
Sandy Silt (ML)	Tuff
Clayey Sand (SC)	Porphyry
Silty Sand (SM)	Granite
Sand (SP, SW)	Pegmatite
Clayey Gravel (GC)	Schist
Silty Gravel (GM)	Gneiss
Gravel (GP, GW)	Quartzite
Loam	Talus
	Alluvium

Inclusions	Seams
Rock Fragments	Seam >0.1m thick
Organic Material	Seam 0.01m to 0.1m thick
Ironstone Gravel, Laterite	
Shale Breccia in Sandstone	

General Notes

Introduction

These notes are supplied with all geotechnical reports from **Barker Harle** and therefore may contain information not necessarily relevant to this report.

The purpose of the report is set out in the introduction section of this report. It should not be used by any other party, or for any other purpose, as it may not contain adequate or appropriate information in these events.

Engineering Reports

Barker Harle engineering reports are prepared by qualified personnel and are based on information obtained, and on modern engineering standards of interpretation and analysis of that information. Where the report has been prepared for a specific design proposal the information and interpretation may not be relevant if the design proposal is changed. If the design proposal or construction methods do change, **Barker Harle** request that it be notified and will be pleased to review the report and the sufficiency of the investigation work.

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, the report must be regarded as interpretative, rather than a factual document, limited, to some extent, by the scope of information on which it relies.

***Barker Harle** cannot accept responsibility for problems which may develop if it is not consulted after factors considered in the report's development have changed.*

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, **Barker Harle** 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.
- The actions of contractors responding to commercial pressures.

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

A Geotechnical Engineering Report May Be Subject To Misinterpretation

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a geotechnical engineering report. To help avoid these problems, **Barker Harle** should be retained to review the adequacy of plans and specifications relative to geotechnical issues.

Engineering Logs Should Not Be Separated From The Engineering Report.

Final engineering logs are developed by the Geotechnical Engineer based upon interpretation of field logs and laboratory evaluation of field samples. Only final engineering logs are included in geotechnical engineering reports. To minimize the likelihood of engineering log misinterpretation, *give contractors ready access to the complete geotechnical engineering report*.

Site Inspection

Barker Harle will always be pleased to provide inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit, to full time engineering presence on site.

Change In Conditions

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions, which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.*

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and thus, the continuing adequacy of a geotechnical report. **Barker Harle** should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

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, **Barker Harle** requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed during construction, than at some later stage, well after the event.

Ground Water

Unless otherwise indicated the water levels given on the engineering logs are levels of free water or seepage in the test hole recorded at the given time of measuring. This may not accurately represent actual ground water levels, due to one or more of the following:

- 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 prior weather changes. They may not be the same at the time of construction as indicated at the time of investigation.

Accurate confirmation of levels can only be made by appropriate instrumentation techniques and monitoring programs.

General Notes – Continued

Foundation Depth

Where referred to in the report, the recommended depth of any foundation, (piles, caissons, footings etc) is an engineering estimate of the depth to which they should be constructed. The estimate is influenced and perhaps limited by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications based upon this report should provide for variations in the final depth depending upon the ground conditions at each point of support.

Engineering Logs

Engineering logs presented in the report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify economically. In any case, the boreholes or test pits represent only a very small sample of the subsurface profile.

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

Drilling Methods

The following is a summary of drilling methods currently used by **Barker Harle**, and some comments on their use and application.

Continuous Sample Drilling: The soil sample is obtained by screwing a 75 or 100mm auger into the ground and withdrawing it periodically to remove the soil. This is the most reliable method of drilling in soils as the moisture content is unchanged and soil structure, strength, appearance etc. is only partially affected.

Test Pits: These are excavated using a backhoe or tracked excavator, allowing close examination of insitu soil if it is safe to descend into the pit. The depth of digging is limited to about 3 metres for a backhoe, and about 5 metres for an excavator. A potential disadvantage is the disturbance of the site caused by the excavation.

Hand Auger: The soil sample is obtained by screwing a 75mm Auger into the ground. This method is usually restricted to approximately 1.5 to 2 metres in depth, and the soil structure and strength is significantly disturbed.

Continuous Spiral Flight Augers: The soil sample is obtained by using a 90 – 115mm diameter continuous spiral flight auger which is 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, returned to the surface, are very disturbed and may be contaminated. Information from the drilling is of relatively lower reliability. SPT's or undisturbed sampling may be combined with this method of drilling for reasonably satisfactory sampling.

Hand Penetrometers

Hand Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and recording the number of blows for successive 50mm increments of penetration.

Two, relatively similar tests are used:

1. Perth Sand Penetrometer (AS 1289.5.3.3) – A 16mm flat ended rod is driven with a 9kg hammer, dropping 600mm. This test was developed for testing the density of sands and is mainly used in granular soils and loose fill.

2. Cone Penetrometer/Scala Penetrometer (AS 1289.5.3.2) – A 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm. The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio (CBR) have been published by various road authorities.

Sampling

Sampling is carried out during drilling to allow engineering examination, and laboratory testing of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending on the amount of disturbance during drilling, some information on strength and structure.

Undisturbed samples are taken by pushing a think walled sample tube into the soils and withdrawing this with a sample of soil in a relatively undisturbed state contained inside. 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. Details of the type and method of sampling are given in the report.

Laboratory Testing

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

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**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 the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**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 possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

Risk (deaths per participant per year)	**Activity/Event Leading to Death** (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding , ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

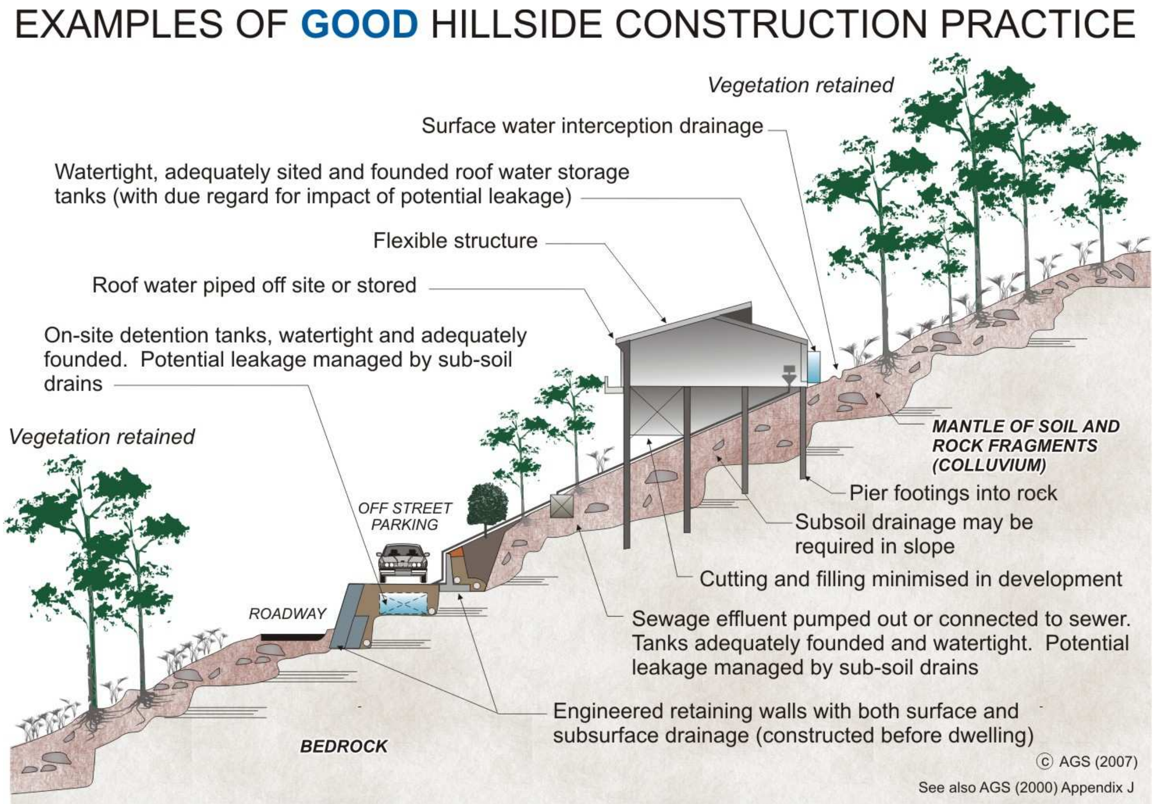
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
  GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

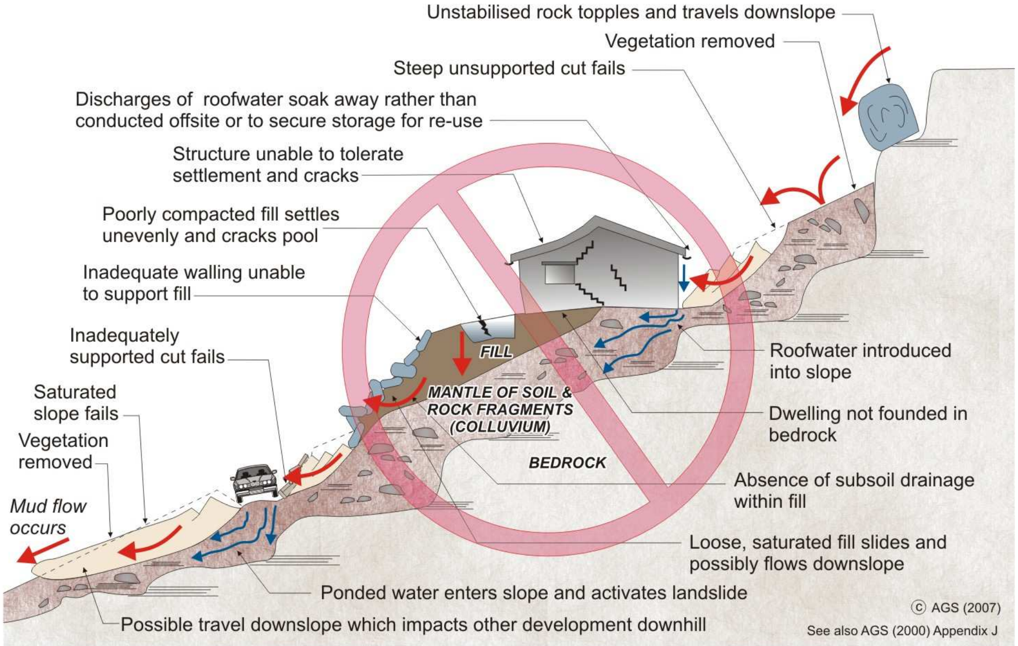
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

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- GeoGuide LR3 - Landslides in Soil
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