KEIGHRAN GEOTECHNICS
Geotechnical • Pavements • Materials • Consulting Engineers

Greg D. Keighran Pty Ltd (Inc NSW)

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Principal
G.D. Keighran BE MIE(Aust)

Date: 30th November 2020 Your Ref: 01416 Our Ref: 17100/GK/7

J & J Shanahan
Suite 1 , Level 1
55 Grandview Street
PYMBLE N.S.W. 2073

Attention: Mr J. Shanahan

Dear Sir,

Re: Geotechnical Assessment
New Double Garage and Dwelling
145A Crescent Road - Newport

1. Introduction

At your request, Keighran Geotechnics has undertaken a geotechnical inspection and investigation at the above property on the 26th September 2017.

The inspection was undertaken in order to assess:

- the stability of the subject property
- provide geotechnical recommendations for new Double Garage and Dwelling construction.

Our inspection is based on visual assessment and incorporates judgement based on experience with other sites within the Pittwater and Sydney Basin Region. The surface features, rock outcrops and vegetation of the property and adjoining land were carefully inspected and interpreted to assess the geological profile and natural stability of the land in relation to the new double garage and dwelling proposed in the Architectural Drawings 01416H Rev 05 by Midcoast Design and Drafting Pty Ltd.

2. Method of Investigation

The fieldwork for this investigation was carried out under the supervision of our principal geotechnical engineer on 26th September 2017 and comprised:

a) Detailed site inspection and geotechnical assessment.
b) Hand Auger / DCP and Logging of the subsurface conditions.

A single hand augered borehole was drilled on the subject property to a depth of up to 1.5 metres and a DCP test undertaken next to the borehole to determine the depth to weathered bedrock. The borehole was logged by the supervisor who provided the borehole logs presented Section 4 . The method of soil classification adopted is explained in Appendix A. An engineering classification of sedimentary rocks in the Sydney area is presented in Appendix B.

The locations of the borehole and other site features noted are indicated on the Drawing No. 17100/4A presented in this Report.

3. Site Conditions

The subject property is located on the northern side of Crescent Road about 100 metres south east of the intersection with Beaconsfield Road at Newport and in the middle slopes in the local terrain. The property rises up from Crescent Road via a concrete driveway. The northern half of the property is open and grassed slope at about 1V:3H rising up from a series of terraced concrete retaining walls along the northern side of the driveway.

Western Side of Property Above Retaining Wall

Western Side of Property from front of Dwelling

4. Site Geology and Subsurface Conditions

The subject is indicated on the Sydney 1:100,000 Geological Series Map as being underlain by either of the bordering Rn - Newport Formation of sandstone with interbedded shale or the overlying Rh - Hawkesbury Sandstones both from the Triassic Geological Period.

We note that large straight mature turpentine trees are present on the subject and adjoining properties which generally indicate that stable / sandy residual soils are present.

The subsurface conditions are fully described in the Engineering Logs and are summarised below:-

FILL / Topsoil: sandy clay, brown and yellow, moist to firm. Encountered to a depth of 0.4 metres.

RESIDUAL: sandy clay, yellow brown, trace orange and grey, moist and firm to stiff. Encountered below the FILL to depths ranging from 0.4 to 1.5 metres.

BEDROCK: Weathered sandstone with interbedded shale lenses, fine grained, light grey / yellow brown some red , dry to moist and stiff to hard. Commencing from 1.5 metres below the surface.

No groundwater was detected in the borehole.

5. Site Stability

The subject property has been assessed with reference to the Australian Geomechanics Society subcommittee on "Landslide Risk Management Concepts and Guidelines" March 2000 (Reference 2) and has included consideration of observed surface slope, exposure of the subsurface conditions and assessment of existing retaining and dwelling structures on the subject and adjoining properties.

The natural sandy clay soils on the property overlying sandstone bedrock with interbedded shale. The existing cemented rock retaining walls along the driveway supporting the slope shows no signs of movement or cracking,

In regard to the risk of instability of the subject property, it is considered that:-

a) The subject property has been assessed in accordance with AGS "Landslide Risk Management Concepts and Guidelines" May 2007 as follows:-

Landslide Risk Assessment – Risk to Property

Hazard or Mode of Instability	Likelihood	Consequence to Existing or Proposed Development	Risk to Proposed Development	Remarks
Soil Creep	Unlikely	Minor	Very Low to Low	None Observed
Active or Deep seated Slide	Unlikely	Minor	Very Low to Low	Existing Dwelling is well Supported
Rock Fall	Not Credible	Major	Very Low	No significant escarpment close to the property.
Retaining Wall Distress	Unlikely	Major	Low	Existing Block Wall appears to be well built and supported with no signs of distress
Temporary Excavation for Double Garage Under Dwelling	Unlikely	Major	Low	Excavation up to 4.0 metres required and will exposed weathered rock in face below 1.5 metres. Prompt construction of supporting retaining walls will be required to maintain stability for the short term

Landslide Risk Assessment - Risk to Life

The above potential hazards are considered to be Unlikely to Not Credible resulting in a very low to low risk to property which would also result in a very low risk to life and well below the acceptable limit of 10^{-6}.

b) the subject property is currently in a stable condition with the existing dwelling well supported and the open yards are uniformly graded with no signs of land instability.

c) Existing / proposed dwelling development of the subject property is considered to be a very low risk and can be managed by normal slope maintenance procedures, as outlined in the Appendices and as recommended in Section 5 – "Development Recommendations" below.

d) the property is suitable for construction of the new double garage and dwelling construction detailed in the architectural and structural drawings provided that the various recommendations of this report are implemented and the assessed risks of landslide are reduced to acceptable levels as detailed in Section 6 – Development Recommendations;

6. Review of Architectural Drawing Details

The Architectural Drawings 01416H Rev 05 by Midcoast Design and Drafting Pty Ltd indicates:-

- The new Double Garage and Dwelling is to be located in the slope just past the entrance rising up to the north east into the property with the slope. The initial excavation will be to demolish portion of the existing retaining wall at the about 9.0 metres from start of the driveway for about 8 metres in length.

- The excavation for the garage will extend about 6 metres into the hillside and typical stepping or battering the excavation to temporary stable slopes detailed below, prior to the installation of the block or brick retaining walls around three (3) sides of the garage.

- The excavation will exposed weathered sandstone bedrock midway down the rear of the excavation and a major portion of the garage floor. The Retaining wall and garage floor slab will be supported close to or on the sandstone bedrock.

- The dwelling footings outside the garage footprint will need to be taken to similar bearing materials.

- The backyard is proposed to be terraced by two (2) retaining walls up to 0.8 metres in height running across the contours with excavation and placement of compacted filling behind the walls.

- On completion of the new double garage and dwelling construction the disturbed areas will need to be suitably landscaped or retained with small terraced landscape type retaining structures.

7. Development Recommendations

Attention is drawn to the general guidelines to hillside construction and drainage provided in the Appendix B and C to this report. The relevant sections of these guidelines should be regarded as 'recommendations' in addition to the specific recommendations which follow:-

The above proposed works will not affect the inherent stability of the subject property in the long term and are considered suitable for the subject property. The following recommendations are provided for the design and construction of the new new double garage and dwelling and underlying garage construction :-

- All new retaining structures greater than 0.9 metres in height are to be designed by the structural engineer and suitably founded in the residual sandy clay soils or weathered bedrock if encountered which will be confirmed by the geotechnical engineer during construction.

- Some propping of the existing retaining wall on either side of the new double garage and dwelling construction to maintain support to the existing wall during construction.

- The dwelling and garage construction will comprise some excavation up to about 4.0 metres into the existing surface and we recommend that the existing retaining wall and garage entrance is excavated first then progressing towards the rear of the garage. This will provide an exposure of the soil and rock profile supporting the existing block retaining wall and allow the determination the support / batter requirements.

  We expect that the sandstone bedrock will be exposed in the proposed excavation and excavation of the sandstone bedrock may require the use of hydraulic hammers. Excavations of sandstone bedrock within 6 metres of existing residential dwellings adjoining the property are to be undertaken with care and should the use of hydraulic hammers be required the Contractor is to ensure that vibrations resulting from such excavation work are minimised and limited to a maximum peak particle velocity of about 5 mm / second at the subject property boundaries .

  We recommend the operation of hydraulic hammers up to Krupp 300 or equivalent generally operated on 5 tonne excavators should adopted due to the size of the garage excavation and the proximity to the existing dwelling

- An allowable bearing pressure of 700 kPa may be adopted for footings of the garage founded in the weathered sandstone bedrock.

- All footing should be inspected by a suitably qualified structural or geotechnical engineer prior to placing concrete, to confirm that the base of the footing is suitable founded to the design requirements.

- The retaining walls are to be suitably founded in the cut face which will comprise a mix of weathered rock and residual soils and should adopt a minimum design bearing pressure of 150 kPa in residual soils and 700 kPa in weathered bedrock.

- All exposed surfaces are to be retained by landscape type retaining walls or landscaped and planted on completion of the new double garage and dwelling construction.

8. General

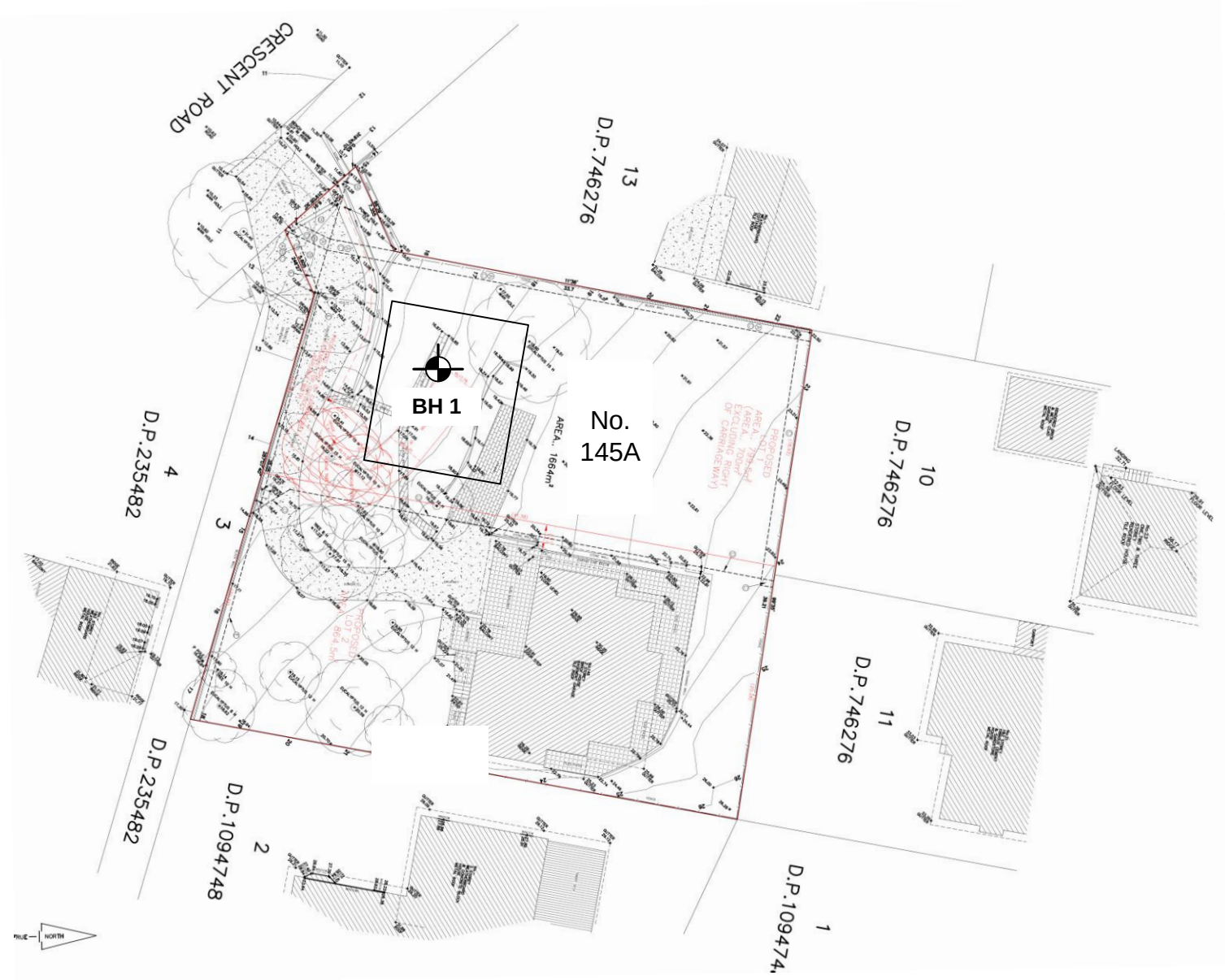
It is to be noted that the recommendations, comments and opinions expressed in this Report are based on visual assessment and experience on similar sites within the Pittwater Area.

Should subsurface conditions be encountered which differ markedly from those inferred in the Report, or should the scope of the development works planned vary significantly from the landscape details and proposed double garage and dwelling details provided in the noted drawings, then further geotechnical advice should be obtained.

Yours faithfully,
KEIGHRAN GEOTECHNICS
per:

_____
G.D. KEIGHRAN B.E. MIE(Aust)
Director - Principal Engineer

Drawing No 17100/4A
Appendix A Pittwater Council - Forms 1 and 1A
Appendix B Landslide Risk Assessment – LR7
Appendix C GeoGuides LR 1, LR2 and LR 8



BH BH / DCP TEST LOCATIONS

GEOTECHNICAL ASSESSMENT

GDK
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Scale	
Plan	
Section	
Drawn	
Checked	

J & J SHANAHAN

NEW DOUBLE GARAGE AND DWELLING
145A CRESCENT ROAD
NEWPORT

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
0	ISSUED TO CLIENT IN REPORT	17 OCT 2018	

Drawing No.

17100/4A

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

Development Application for	J & J Shanahan
	Name of Applicant
Address of site	145A Crescent Road - Newport

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

I, *Greg Keighran* (Insert Name) *on behalf of* *Keighran Geotechnics* (Trading or Company Name)

on this the 18th July 2019 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

✓ 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

✓ I 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 am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

✓ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: 17100 /GK/7- Geotechnical Assessment and Recommendations – New Double Garage and Dwelling – 145A Crescent Road - Newport

Report Date: 30th November 2020
:
Author: Greg Keighran

Author's Company/Organisation: Keighran Geotechnics

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

Architectural / Landscape Drawings 01416H Rev 05 by Midcoast Design and Drafting Pty Ltd

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 Greg D Keighran .
Chartered Professional Status BE MIE(Aust)
Membership No. 286467
Company Greg D Keighran Pty Ltd T/AS Keighran Geotechnics

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

Development Application for J & J Shanahan
Name of Applicant
Address of site 145A Crescent Road - Newport

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: 17100/GK/7 – Geotechnical Assessment – New Double Garage and Dwelling – 145A Crescent Road - Newport
Report Date: 30th November 2020
Author: **Greg Keighran**
Author's Company/Organisation: Keighran Geotechnics

Please mark appropriate box

Comprehensive site mapping conducted _____
(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 Existing Investigation by Brink in 1997 and alterations within 5 metres of dwelling with known subsurface conditions
Yes Date conducted ……

- ✓ 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 Greg D Keighran .
Chartered Professional Status BE MIE (Aust)
Membership No. 286467
Company Greg D Keighran Pty Ltd T/AS Keighran Geotechnics

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips

AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

LR1 - Introduction	LR2 - Landslides	LR3 - Landslides in Soil
LR4 - Landslides in Rock	LR5 - Water & Drainage	LR6 - Retaining Walls
LR7 - Landslide Risk	LR8 - Hillside Construction	LR9 - Effluent & Surface Water Disposal
LR10 - Coastal Landslides	LR11 - Record Keeping	

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

Consequence	the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life.
Discontinuity	in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground.
Equilibrium	the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite.
Factor of safety (FOS)	theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one.
Failure	when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function.
Geotechnical practitioner	when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner.
Hazard	a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time.
Landslide	the movement, or the potential movement, of a mass of rock, debris, or earth down a slope.
Likelihood	a qualitative description of probability, or frequency, of occurrence.
Partial saturation	the condition in the ground above the water table where both air and water are present as well as soil, or rock.
Perched water table	a water table above the true water table supported by a low permeability stratum.
Permeability	a measure of the ability of the ground to allow water to flow through it.
Risk	a measure of the probability and severity of an adverse effect to life, health, property or the environment.
Slip failure	landslide.
Stable	the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure.
Retaining structure	anything built by humans which is intended to support the ground and inhibit failure.
Structure	in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location.
Tension crack	a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent , failure.
Water table	the level in the ground below which it is saturated and the voids are filled with water.

Photograph courtesy of Phil Flentje

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

LANDSLIDES

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a “landslide”. Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au .

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 - Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10°- 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18°- 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27°- 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45°- 64°	1 on 0.5	Need rope access to climb slope
Cliff	64°- 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

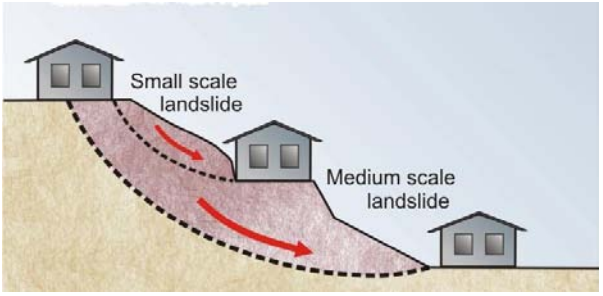

Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

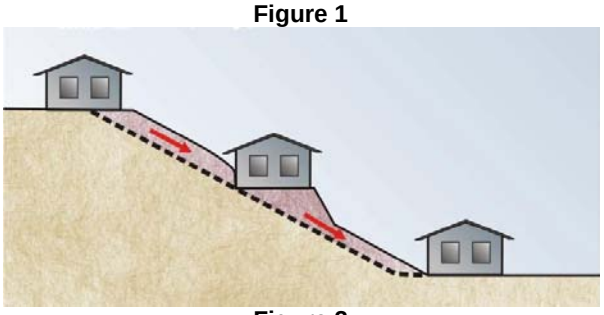

Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

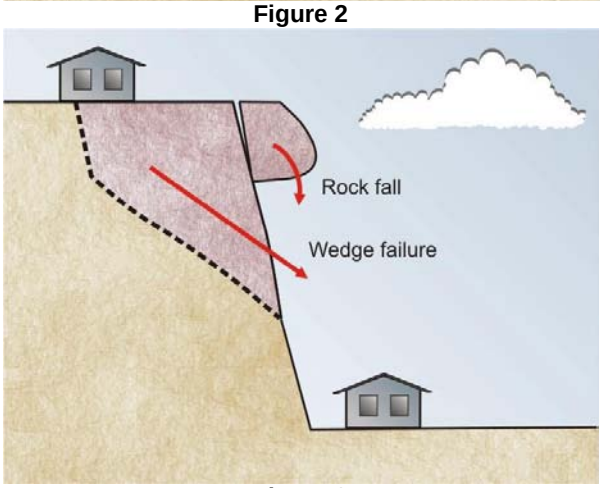

Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

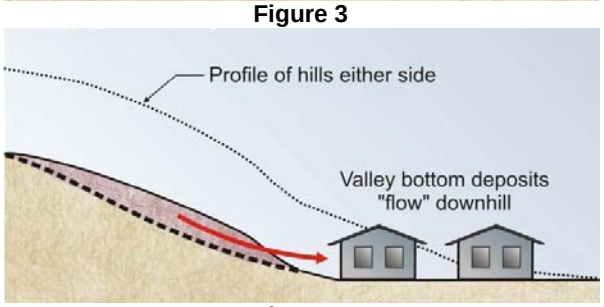

Figure 4

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- 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.

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
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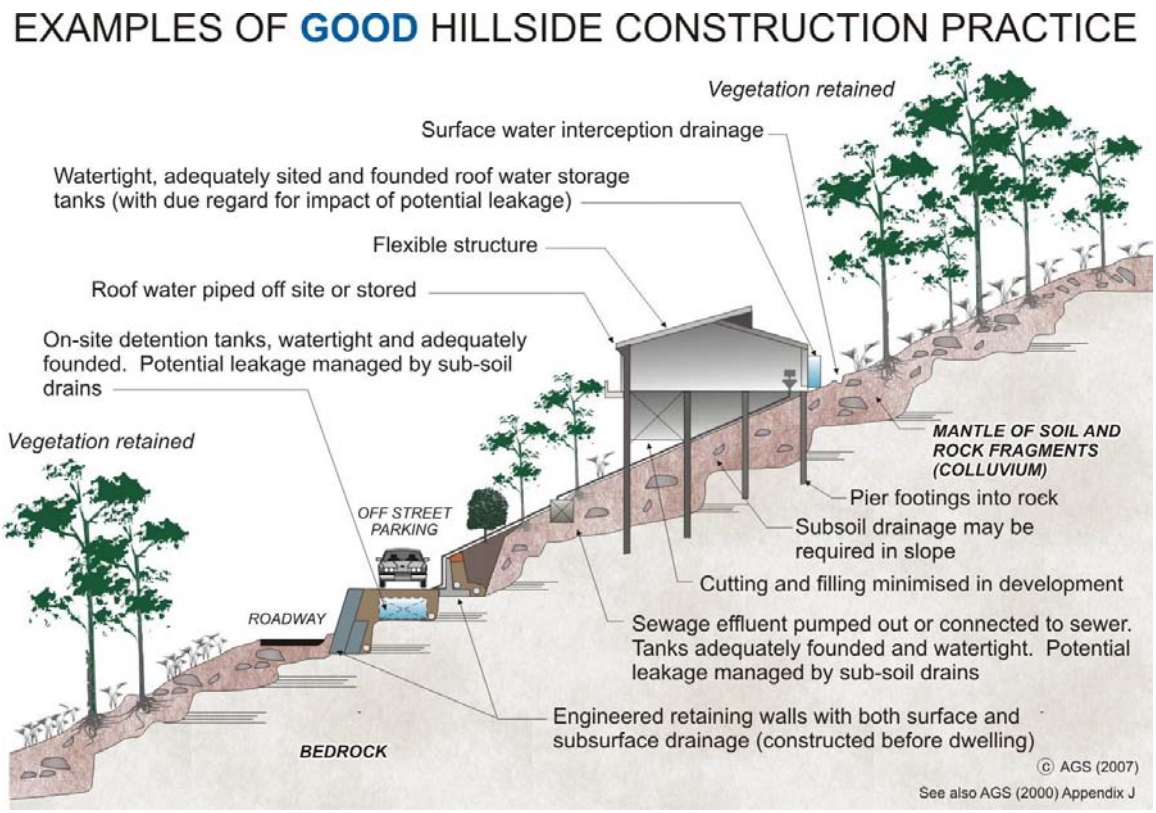
AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

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