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Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

GEOTECHNICAL ASSESSMENT

for

PROPOSED ALTERATIONS AND ADDITIONS

at

76 ALAMEDA WAY WARRIEWOOD, NSW

Prepared For

Eva Bartoll

Project No.: 2019-137

August, 2019

Document Revision Record

Issue No	Date	Details of Revisions
0	27th August 2019	Draft issue

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for	Eva Bartoll
	Name of Applicant
Address of site	76 Alameda Way, Warriewood

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

I, ***Troy Crozier*** *on behalf of* ***Crozier Geotechnical Consultants*** on this the 27th August 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 prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ☐ am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- ☐ have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ☐ have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ☐ have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Geotechnical Assessment for Proposed Alterations and Additions

Report Date: 26th August 2019 **Project No.:** 2019-137

Author: T. Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Design Drawings by Alinea Dzine, Drawing No.: 19035-1 to 11, Revision: , Dated: June 2019
Site Survey Plan by Michael Fairweather, Reference: 16-114, Dated: 14th November 2016

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

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

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

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

Company... **Crozier Geotechnical Consultants**

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

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

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

Development Application for Eva Bartoll
Name of Applicant

Address of site ____76 Alameda Way, Warriewood ____

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Geotechnical Assessment for Proposed Alterations and Additions
Report Date: 26th August 2019 **Project No.:** 2019-137
Author: T. Crozier
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted __22nd August 2019______ (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 ....very minor ground works proposed in development......
  - □ 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 ...50 years .... (specify)
- ■ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ■ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- □ Risk assessment within Bushfire Asset Protection Zone.

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

Signature ....

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

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

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

Company... **Crozier Geotechnical Consultants**

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Date: 26th August 2019
Project No: 2019-137

GEOTECHNICAL ASSESSMENT FOR PROPOSED ALTERATIONS AND ADDITIONS
76 ALAMEDA WAY, WARRIEWOOD, NSW.

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for proposed alterations and additions at 76 Alameda Way, Warriewood, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the request of the client Eva Bartoll.

The site is located on the high east side of Alameda Way with Iramir Place along the southern boundary. It is situated within gently to moderately west dipping topography and contains a one and two storey residential house with gardens, terraces, swimming pool and timber decks.

Reference to Northern Beaches (Pittwater) Council's LEP 2014 Geotechnical Risk Management Map (GTH_012), the site has been classified as being within the H2 landslip hazard zone therefore the site requires a Geotechnical Landslip Assessment to be conducted in support of a Development Application. This report therefore includes a detailed description of the site and limited description of adjacent properties, assessment of proposed works, site specific risk assessment where landslip hazards are identified and recommendations for construction to maintain the 'Acceptable Risk Management' criteria.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Principal Engineering Geologist.
b) Review of Ortho Photomaps and Aerial Photography of the site.

The following plans and diagrams were supplied for the work:

- Design drawings by Alinea Dzine, Drawing No.: 19035-1 to 11, Revision: , Dated: June 2019.
- Site survey plan by Michael Fairweather, Reference: 16-114, Dated: 14/11/2016.

2. PROPOSED DEVELOPMENT

It is understood that the proposed works involve alterations and additions to the existing house which will involve replacement of the existing deck at the western end of the house, at Ground Floor level, with a new larger timber deck that will extend slightly further west and will then wrap around the house and extend along the southern side, adjacent to the existing swimming pool. The existing deck at the eastern end of the First Floor level will also be replaced by a similar deck however a new roof will be formed over this deck. Minor alterations to the internal portions of the existing house are also proposed.

The proposed works require no bulk excavation or significant geotechnical component however minor new footings will be required for the Ground Floor level deck.

3. SITE FEATURES:

3.1. Description:

The site is an irregular shaped block located on the high east side of Alameda Way with Iramir Place extending up slope along the sites southern side boundary. It is situated at mid-slope level on the western face of a low north striking ridgeline within gently to moderate west dipping topography. It has a front west boundary of 17.38m, rear east boundary of 28.59m, side north boundary of 29.05m and side south boundary of 20.73m, as referenced from the provided survey plan.

The site contains a one and two storey residential house located across the centre of the block with landscaped gardens and a swimming pool along with various decks and terraces. A view of the site taken from the NSW SIX-maps spatial data service is shown below:

Photograph: 1 – View of site and surrounds

3.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by the Newport Formation (Rnn) of the Upper Narrabeen Group. Newport Formation (Upper Narrabeen Group) is of middle Triassic Age and typically comprises inter-bedded laminite, shale, quartz to lithic quartz sandstones and pink clay pellet sandstones.

4. FIELD WORK:

4.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and limited inspection of adjacent properties on the 22nd August 2019 by a Principal Engineering Geologist. It included a photographic record of the site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of ground levels, vegetation and existing structures.

4.2. Field Observations:

The Alameda Way road reserve is gently south dipping where it passes the site and is formed with a bitumen pavement and concrete kerb or guttering with gently west dipping lawn road reserve extending up to the sites western boundary. The Iramir Place Road reserve is also formed with a bitumen pavement and concrete kerb and guttering with grassed reserve extending to the site's boundary. There were no signs of excess movement or deterioration within the road pavement or reserve to indicate any deep seated landslip or geotechnical hazards which may impact the site.

Photograph: 1 – Alameda Way, 'site' to right

Photograph: 2 – Iramir Place, 'site' to left

The north-east corner of the site contains gently sloping terraces with garden surrounds that are stepped down to the west and retained by low timber, concrete block and sandstone rock retaining walls along the rear northern side of the house. A garage structure is formed at the eastern end of the house, at Ground Floor level, with a timber deck above at First Floor level. The garage is considered to be an addition to the original house and appears to have involved excavation into the hill slope, which is now retained by a 3.0m high concrete retaining wall. The low garden support walls show some cracking and deterioration however there were no indications of instability in garden beds or terraces whilst the garage's concrete retaining wall is in good condition with no signs of movement, excess cracking or deterioration.

Photograph: 3 - Gardens, terrace north-east corner

Photograph: 4 – Garage at east end of site

The western end of the site contains a narrow, gently sloping garden bed that rises up from the crest of a series of vertical 100mm diameter timber posts that have been formed along the sites western boundary and retain the garden bed approximately 1.0m above the road reserve level. These posts are separated by approximately 50mm gaps and are interpreted to provide support via a cantilever method. At the crest of the garden slope is a steel fence line with a narrow garden on its eastern side that is retained approximately 400mm above a concrete terrace formed at the western end of the house. The timber log retaining wall system shows deterioration of the timber material due to age and is also rotated by approximately 10 deg, likely due to soil creep pressures and deterioration of the buried cantilever support portion.

Photograph: 5 – Timber log retaining wall west bdy.

Photograph: 6 – Concrete terrace west end of house

The existing house on site is a two storey brick and timber structure that contains a small ‘rumpus room’ at the western end below the Ground Floor level. This lower level appears partially excavated into the hill slope with brick retaining walls around most sides and a slight drop at the western end down from the existing open concrete terrace. The original house structure was of brick construction with a timber First Floor level added at a later date. Timber decks extend from the eastern end of the house at First Floor level and also at the western end of the house at Ground Floor level. The house appears of 1960’s construction and in good condition no significant cracks or evidence of foundation movement identified. The roof is guttered with down pipes connected to a sub-surface stormwater system. The existing decks show signs of deterioration due to age.

A concrete part inground swimming pool is located to the south of the house with narrow garden beds and concrete paved pathways around its perimeter. A narrow gently sloping garden bed is formed along the southern side boundary, supported by another low (<1.0m) vertical timber log retaining wall. The pool and pathway appear in good condition whilst the timber log wall shows deterioration with age but only very minor rotation to the south.

The neighbouring property to the north (No. 78) contains a single storey timber cottage style residential house which has visible sandstone block footing walls below its western end due to the natural ground surface slope. This property contains concrete pathways and gardens around its perimeter and is at similar ground surface levels as the site along the common boundary. The house is located approximately 2.0m from the common boundary.

The neighbouring property to the east (No. 1 Iramir Place) is a rear ‘battle-axe’ style block with concrete access driveway extending upslope along the site’s eastern boundary. This neighbouring block then extends to the north-east and also partly down the site’s northern boundary. It contains a two storey brick residential house in the north-east portion with a concrete swimming pool downslope to the west and a raised cabana at the southern end of the pool, adjacent to the common boundary with the site. The ground surface level of this property is similar to the site at the common boundary with gardens sloping down into the site.

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

5. COMMENTS:

5.1. Geotechnical Assessment:

The inspection and assessment identified no significant landslip hazards within the site or adjacent properties. The existing residence is at least 20 years old and is in good condition, with no signs of excess cracking or settlement on external walls to indicate foundation movement. Minor cracking was identified in the existing concrete terraces, and low retaining walls however none of these cracks indicate significant underlying geotechnical issues. The existing garage concrete retaining wall is in very good condition and shows no signs of instability or excess deterioration. Surface stormwater appears to be well controlled with no signs of surface flow or erosion over the slope within the site.

The existing timber post retaining walls supporting garden beds at the sites western and southern boundaries are deteriorating with age whilst the western wall shows signs of moderate rotation. This wall will be expected to continue to rotate with eventual collapse, however the resultant slope movement is considered to be limited to the adjacent garden area and is not considered to be a significant landslip hazard.

The proposed works are limited from a geotechnical perspective and are considered to create no new landslip hazards to the site or adjacent properties.

It is recommended that the footings for the new deck at the western end of the house be extended to found within residual soils to reduce any impact from movement in the soils retained by the log wall on the western boundary. It is also recommended that these log retaining walls be replaced before further significant deterioration or rotation occurs. This should be considered within a time line of approximately 10 years.

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

5.2. Slope Stability & Risk Assessment:

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

A. Landslip (earth slide <$3m^3$) due to collapse of timber log retaining wall at western boundary
B. Landslip (earth slide <$3m^3$) due to collapse of timber log retaining wall at southern boundary

A qualitative assessment of risk to life and property related to these hazards is presented in Table A and B, Appendix: 2, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

Hazard A was estimated to have a **Risk to Life** of up to **5.21 x 10^{-8} for a single person,** while the **Risk to Property** was considered to be **'Low'**.

Hazard B was estimated to have a **Risk to Life** of up to **6.51 x 10^{-8} for a single person,** while the **Risk to Property** was considered to be **'Very Low'**.

The risk related to these existing hazards is considered to achieve the □Acceptable□risk level and where the recommendations of this report are followed the probability of failure reduces in all situations and as such the risk will remain within the □Acceptable□risk management criteria of Councils policy for the design life of the existing development, taken as 50 years. Therefore, the project is considered suitable for the site provided the recommendations of this report are implemented.

5.3. Design Life of Development:

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

- Stormwater and subsoil drainage systems,
- Retaining walls and soil slope erosion and instability,
- Maintenance of trees/vegetation on this and adjacent properties.

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 □2011 (50 years)). In order to attain an □Acceptable Risk Management Criteria□ for a design life of 100 years as detailed by the Councils Risk Management Policy, it will be necessary for the property owner to adopt and implement a maintenance and inspection program. It is considered that the existing house will have a design life of no more than 50 years from its upgrade following the proposed works.

If a maintenance and inspection schedule are not implemented the □Acceptable□risk levels for the design life of the property may not be attained.

A recommended program is given in Table: 1 below and should also include the following guidelines:

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

Table 1: Recommended Maintenance and Inspection Program for Future Developments

Structure	**Maintenance/ Inspection Item**	**Frequency**
Stormwater Drains.	Owner to inspect to ensure that the drains and pipes are free of debris & sediment build-up. Clear surface grates and litter.	Every year or following each major rainfall event
Retaining Walls or remedial measures	Owner to inspect walls for deviation from as constructed condition or for excess deterioration/rotation or signs of soil settlement/erosion or significant cracking adjacent to crest.	Every two years or following major rainfall events. Replace existing non-engineered timber log walls prior to their failure

<u>N.B.</u> Provided the above schedule is maintained the design life of the property should conform AS2870 and Councils stability criteria

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

6. CONCLUSION:

The inspection and assessment identified no obvious significant slope movement, excess surface stormwater flow or seepage, erosion or instability within the site or adjacent properties. The entire site and surrounding slopes have been assessed as per the Northern Beaches (Pittwater) Council Geotechnical Risk Management Policy 2009 and two minor existing landslip hazards were identified.

The proposed works involve alterations and additions to the existing house and landscaping that involve no bulk excavation, filling or retention and require some new footings. The works are therefore considered ‘Minor’ from a geotechnical perspective and will not create any new landslip hazards.

The existing potential landslip hazards were assessed to present risks within the ‘Acceptable’ risk management criteria and therefore require no further assessment or stabilising measures.

It is recommended that all new footings be founded within residual soils of similar strength to reduce the potential differential settlement and soil creep impact. New footings will require inspection to verify their bearing capacity and the in-situ nature if they are to be ‘certified’ at the end of the project. The timber log retaining walls along the west and south boundaries should also be replaced in the near future.

The risks associated with the site and proposed development achieve and can be maintained within ‘Acceptable’ levels provided the recommendations of this report, including maintenance are implemented. As such the site is considered suitable for the proposed construction works provided that the recommendations outlined in this report are followed.

Prepared by:

Troy Crozier
Principal
MAIG. RPGeo: Geotechnical and Engineering
Registration No.: 10197

7. REFERENCES:

1. Australian Geomechanics Society 2007, Landslide Risk Assessment and Management, Australian Geomechanics Journal Vol 42, No 1, March 2007.
2. Geotechnical Risk Management Policy for Northern Beaches (Pittwater), 2009.

CROZIER
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Appendix 1

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NOTES RELATING TO THIS REPORT

Introduction

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

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and classification Methods

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

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

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

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

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

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

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

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

Sampling

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

Disturbed samples taken during drilling to allow information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

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

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

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

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

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

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

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

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

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

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

Cone Penetrometer Testing and Interpretation

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

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

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

The information provided on the plotted results comprises: -

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

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

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

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

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

Qc = (12 to 18) Cu

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

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

Dynamic Penetrometers

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

Two relatively similar tests are used.

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

Laboratory Testing

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

Borehole Logs

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

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

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

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

Ground Water

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

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

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

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

Site Anomalies

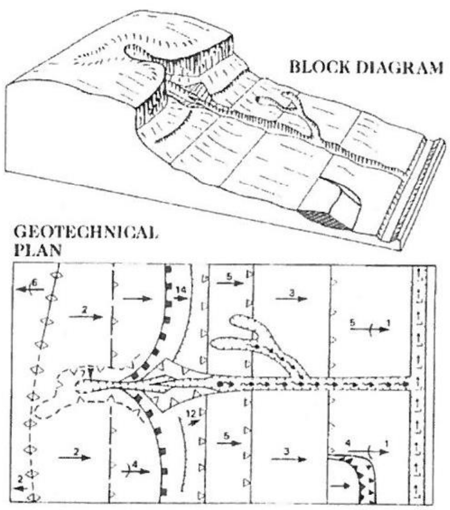
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

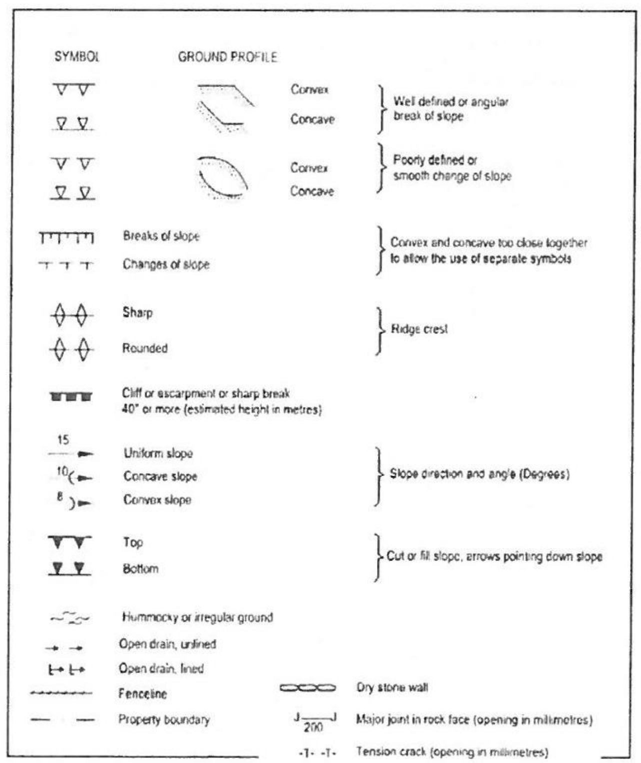
Reproduction of Information for Contractual Purposes

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

Site Inspection

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

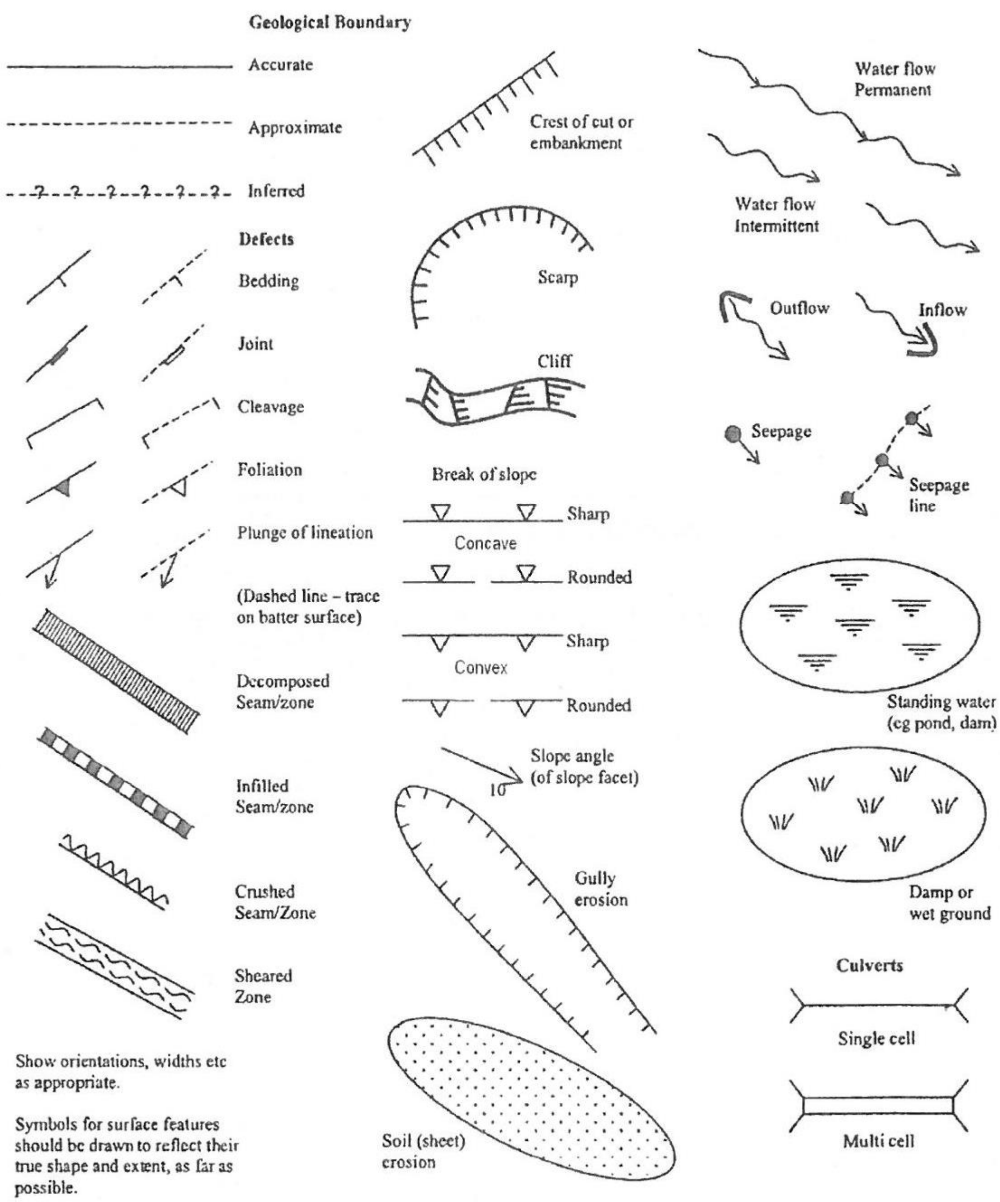




Example of Mapping Symbols

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

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



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

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Appendix 2

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide $<3m^3$) from garden at west end of site due to collapse of timber log retaingn wall		Log wall is low (<1.20m) but is rotated and deteriorated. May only slowly rotate without forming landslip instability.	a) Terrace located upslope several metres, regression possible impact to outer western edge only b) reserve at base of wall, may impact 10% of length adjacent to site		a) Person in terrace 2hrs/day avge. b) Person in reserve (no pathway) 0.5hrs/day avge	a) Possible to not evacuate b) Possible to not evacuate	a) Person in open space, not buried b) Person in open space, not buried	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Terrace	0.001	0.10	0.05	0.0833	0.5	0.05	**1.04E-08**
		b) Road reserve	0.001	1.00	0.10	0.0208	0.5	0.05	**5.21E-08**
B	Landslip (boulder slide $<3m^3$) from buried boulder in slope above house		Log wall is low (<1.20m) but is only very slightly rotated and deteriorated. May only slowly rotate without forming landslip instability.	a) reserve at base of wall, may impact 10% of length adjacent to site		a) Person in reserve (no pathway) 0.25hrs/day avge	a) Unlikely to not evacuate	a) Person in open space, not buried	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Road reserve	0.0001	1.00	0.05	0.0104	0.3	0.05	**6.51E-10**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
  Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)
* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.
* considered for person most at risk, where multiple people occupy area then increased risk levels
* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide <3m^3) from garden at west end of site due to collapse of timber log retaingn wall	a) Terrace	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		b) Road reserve	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
B	Landslip (boulder slide <3m^3) from buried boulder in slope above house	a) Road reserve	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Very Low

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

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Appendix 3

APPENDIX A

DEFINITION OF TERMS

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

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

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

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

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

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

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

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

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

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

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

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

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

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

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

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

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes:

(2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

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