GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for ____________________   Name of Applicant   **Address of site** ____________________

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

I, PAUL ROBERTS *on behalf of* JK Geotechnics
(Insert Name) (Trading or Company Name)

on this the 7TH DECEMBER 2015 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.

We/I:

Please mark appropriate box

- [x] 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~~ Are 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~~ We 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~~ are 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~~ our 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 NEW HOUSE
Report Date: 7/12/15 Report Ref No: 28960ZRpt
Author: PAUL ROBERTS
Author's Company/Organisation: JK Geotechnics

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

ARCHITECTURAL DRAWINGS (Drg. No 1501-P-00 to P-10 Rev. B & 1501-
E-00 to E-9 Rev. B, dated 1/12/15) prepared by Benn&Penna. Survey
Plan (Drg. No. 16288-02, dated 2/9/14) prepared by Bee + Lethbridge P/L

~~I am~~ We are 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~~ reviewing 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. *as discussed in the Report.*

Signature .... Paul Roberts

Name .... PAUL ROBERTS

Chartered Professional Status .... C.P.Eng

Membership No. 2307698

Company .... JK 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 ______________________________
Name of Applicant

Address of site ______________________________

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 NEW HOUSE
Report Date: 7/12/15 Report Ref. No: 28960ZRrpt
Author: PAUL ROBERTS
Author's Company/Organisation: JK Geotechnics

Please mark appropriate box

- [x] Comprehensive site mapping conducted 27/11/15 (date)
- [x] Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- [x] Subsurface investigation required
  - [x] No Justification USED RESULTS FROM PREVIOUS INVESTIGATION FOR GARAGE & SITE INSPECTIONS. INVESTIGATION RECOMMENDED FOR C.C. STAGE
  - [ ] Yes Date conducted ....
- [x] Geotechnical model developed and reported as an inferred subsurface type-section
- [x] Geotechnical hazards identified
  - [x] Above the site
  - [x] On the site
  - [x] Below the site
  - [x] Beside the site
- [x] Geotechnical hazards described and reported
- [x] Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - [x] Consequence analysis
  - [x] Frequency analysis
- [x] Risk calculation
- [x] Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified ~~conditions are achieved~~. *recommendations presented in the Report are adopted*
- [x] Design Life Adopted:
  - [x] 100 years
  - [ ] Other .... specify
- [x] Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- [x] Additional action to remove risk where reasonable and practical have been identified and included in the report.
- [x] Risk assessment within Bushfire Asset Protection Zone.

We are ~~I am~~ aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ~~ensuring~~ *confirming* 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. *as discussed in the Report.*

Signature ....Paul Roberts....
Name ....PAUL ROBERTS....
Chartered Professional Status....C.P. Eng....
Membership No. ....2307698....
Company....JK Geotechnics....

REPORT

TO

RICHARD BENN

ON

GEOTECHNICAL ASSESSMENT

(In Accordance with Pittwater Council Risk Management Policy)

FOR

PROPOSED NEW HOUSE

AT

1156 BARRENJOEY ROAD, PALM BEACH, NSW

7 December 2015

Ref: 28960ZRrpt

JK Geotechnics

GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

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Date: 7 December 2015
Report No: 28960ZRrpt
Revision No: 0

Report prepared by:

Paul Roberts
Senior Associate

Report reviewed by:

Agi Zenon
Principal Geotechnical Engineer

For and on behalf of
JK GEOTECHNICS
PO Box 976
NORTH RYDE BC NSW 1670

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1 INTRODUCTION

This report presents the results of our geotechnical assessment of the site at 1156 Barrenjoey Road, Palm Beach, NSW. The assessment was commissioned on behalf of Richard Benn by Andrew Benn in an email dated 21 November 2015. The commission was on the basis of our fee proposal (Ref. P40684ZR) dated 17 June 2015. The site was inspected by the undersigned on 27 November 2015, in order to assess the existing stability of the site and the effect on stability of the proposed development.

Details of the proposed development are presented in Section 5 below. In summary, however, it is proposed to demolish the existing house over the upper (northern) end of the site and construct a new two storey house over a partial storage level located below the western side of the new house. A new stair access will be provided to connect the storage level to the existing (recently completed) garage level below. Localised excavations to a maximum depth of about 3m will be required over selected eastern (upslope) sections of the site.

We note that JK Geotechnics were involved during the Construction Certificate, Construction and the Occupation Certificate stages of the recently completed driveway access and garage over the western and south-western portions of the site. We completed a geotechnical investigation (including cored boreholes) and attended numerous site inspections during the course of the works.

This report has been prepared in accordance with the requirements of the Geotechnical Risk Management Policy for Pittwater (2009), as amended in Appendix 5 of Pittwater 21 DCP Appendices, Amendment 15, dated 20 December 2014, and as discussed in Section 6 below. Based on the information provided on Geotechnical Hazard Map – Sheet GTH_01 (part of the Pittwater Local Environment Plan 2014) presented on the Council website, the site lies within an 'H1' Geotechnical Hazard zone. It is understood that the report will be submitted to Council as part of the DA documentation. Our report is preceded by the completed Council Forms 1 and 1a.

2 ASSESSMENT METHODOLOGY

This stability assessment is based upon a detailed inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs. These features were compared to those of other similar lots in neighbouring locations to provide a comparative basis for assessing the risk of instability affecting the proposed development. The attached Appendix A defines the terminology adopted for the risk assessment together with a flowchart illustrating the Risk Management Process based on the guidelines given in AGS 2007c (Reference 1).

A summary of our observations is presented in Section 3 below. Our specific recommendations regarding the proposed development are discussed in Section 7 following our geotechnical assessment.

The attached Figure 1 presents a geotechnical sketch plan showing the principal geotechnical features present at the site. Figure 1 is based on the 'Proposed Site Plan' architectural drawing (Drawing Number 1501-P-00 Rev. B, dated 1 December 2015) prepared by Benn & Penna Architecture. The architectural drawing also includes survey information sourced from the survey plan (Drawing Number 16288-02, dated 2 September 2014) prepared by Bee & Lethbridge Pty Ltd. Additional features on Figure 1 have been measured by hand held inclinometer and tape measure techniques and hence are only approximate. Should any of the features be critical to the proposed development, we recommend they be located more accurately using instrument survey techniques. Figure 2 presents a typical cross-section through the site based on the survey data augmented by our mapping observations. An explanation of the geotechnical mapping symbols used on Figure 1 are presented on the attached Figure 3.

3 SUMMARY OF OBSERVATIONS

We recommend that the summary of observations which follows be read in conjunction with the attached Figure 1. We have also included relevant information from our involvement in the design and construction of recently completed driveway access and garage outlined in Section 1, above.

- The site is located on a hillside that slopes and steps down to the north and west.
- The site is battle axe shaped in plan and has northern and western frontages onto Barrenjoey Road, which curves around the base of the slopes within the site. The northern portion of the street frontage was lined by a sub-vertical rock cut face which was a maximum of about 6m height. Barrenjoey Road sloped down to the south at a maximum of about 8^{o} and was paved with asphaltic concrete (AC); the AC surface was generally in reasonable condition.
- The battle axe handle of the site comprised a recently constructed on-grade and suspended concrete driveway which extended north up to a new garage level and was founded in bedrock. The southern section of the driveway and the garage had been excavated back into the hillside maximum depths of about 5m and 6m, respectively. The driveway excavation had been permanently retained by an anchored contiguous and soldier pile wall retention

system which had been provided with a concrete and sandstone clad facing. The upper portion of the garage excavation had been permanently supported by reinforced shotcrete and rock bolts.

- Below the driveway, the landscaped area sloped down to the west typically at between about 30^o and 40^o (locally 25^o). Sandstone boulders had been intermittently placed along the toe of the landscape slope above the sandstone kerbing lining the eastern side of the road.

- The northern end of the driveway was lined by a stepped landscaped slope and concrete paved stepped access. The steps were supported by concrete retaining walls between about 1m and 2m height.

- The existing one and two storey weatherboard and sandstone masonry house was located over the south-eastern section of the battle axe portion of the site. The house appeared to have been constructed on a flat building platform cut back into the sandstone cliff line which lined the rear (eastern) side of the house and ranged between about 2m and 4m height. A short section of dilapidated sandstone masonry wall (about 2m high) was located about midway along the cliff line behind the house. The cliff line extended south and at an east-west return in the face a steeply sloping joint (open 0.6m and soil infilled) defined a potentially unstable wedge of sandstone. The cliff line extended south and stepped down to the south-west into the neighbouring site to the south (No. 60 Palm Beach Road).

- Based on a cursory inspection, the existing house appeared to be in reasonable internal and external condition. We note that as part of the garage excavation works a steel frame (supported on piles founded in sandstone and an underpinned detached block of sandstone) was constructed to provide temporary support to the western side of the house. Based on a cursory inspection through an opening in the southern end of the sub-floor space wall, it appeared that the sandstone cliff face to the south of the house extended north below the house.

- The cliff line behind the house extended north and lined the eastern side of a sandstone paved terrace area and also stepped up to the east about 3m into the neighbouring site (No. 1158 Barrenjoey Road). The northern end of the cliff line was orientated approximately north-east to south-west and stepped down to the north-west to the aforementioned sandstone cut face which lined the south-eastern side of Barrenjoey Road. The north-eastern end of the cliff face (adjacent to the eastern site boundary) contained an undercut feature which was about 0.8m high and extended back a ‘depth’ of at least 3m.

- The north-western portion of the paved area terrace was founded on a sandstone bedrock outcrop (maximum height about 2.5m). The eastern side of the terrace area was lined by a dilapidated stacked sandstone wall (maximum height about 1m). Above the retaining wall the cliff face was characterised by open sub-vertical joints orientated approximately 020^{o} and 110^{o}. The joints were open a maximum of about 0.3m with soil infill and some loose blocks (maximum 0.5m dimension) were also noted. The western side of the terrace area was supported by a sandstone masonry wall (maximum height about 1.2m) which was founded on the bedrock outcrop. Below the northern and western sides of this upper paved area the natural thickly vegetated convex hillside sloped down to the north and west typically at about 30^{o} to 35^{o} to the crest area of the rock cut face which lined the street frontage below.

- The southern end of the house was lined by a dilapidated stepped sandstone paved area and stepped sandstone bedrock surface. The southern end of this area was supported by stacked sandstone retaining wall (about 1.2m high) which returned to the north into the site. A concrete septic tank was also located at the return in the retaining wall return.
- The north-eastern portion of the site included a number of large detached sandstone blocks ('floaters') up to about 2m x 2m x 4m size which extended north-east across the site boundary.
- The neighbouring house to the south (No. 60 Palm Beach Road) was set-back at least 10m from the south-eastern corner of the battle axe section of the site boundary. The neighbouring house comprised a one and two storey rendered and timber house constructed over the upper portion of the hillside. The upslope side of the building platform had been cut into the hillside and the cuts were supported by rendered and sandstone masonry walls. Sandstone bedrock cliff lines were evident over the upper portion of the neighbouring site and the northern end of the cliff lines appeared to extend into the subject site (as noted above). The downslope (western) side of the residence was suspended over the hillside. The stepped landscaped rear yard was supported by timber retaining walls (maximum height about 1.2m) and extended down to the west to the sandstone cliff (maximum 4.5m high) lining the eastern side of the driveway described above. Based on an inspection of the internal and exterior of the building and structures completed as part of the dilapidation survey the residence was assessed to be in good condition. Further details on the condition of the residence were presented in a dilapidation survey report completed following construction of the driveway (Ref. 24024ZRlet11, dated 3 August 2015).
- The neighbouring split level timber pole house uphill to the east of the existing house was set-back at least about 1m from the south-eastern corner of the battle axe section of the site boundary. Based on a cursory inspection from within the site the neighbouring house appeared to be founded on bedrock and to be in good external condition. The front yard stepped down to the north and a cliff line (about 3m high) was observed over the upper portion

of the front yard. Sandstone paved steps lined the northern portion of the eastern site boundary.

4 SUBSURFACE CONDITIONS

The 1:100,000 geological map of Sydney indicates that the site is underlain by Hawkesbury Sandstone close to the contact with the underlying Newport Formation of the Narrabeen Group, which generally comprises interbedded laminite (thinly interbedded sandstones and siltstone), sandstone and shale. The Hawkesbury Sandstone forms a cap to the hillsides in the area. The outcrops over the upper portion of the site, the neighbouring upslope properties and the road cut face lining the northern site boundary are interpreted to represent the Hawkesbury Sandstone. The roadside rock cut faces lining the toe of the slope adjacent to the southern and central portion of the western site boundary are interpreted to represent the underlying Newport Formation. The numerous inspections during construction confirmed that the Newport Formation was present immediately below the base of the cliff lines now lining the eastern side of the southern end of the driveway.

Based on our experience in this area (which was confirmed by our site inspections during construction of the driveway and garage), the subsurface conditions over the footprint of the proposed new house will comprise a stepped bedrock surface with a cover of colluvial soils. The colluvial soils, which are derived from previous slope instability that has occurred in the recent geological past, will contain numerous inclusions of sandstone ranging up to boulder size.

The pertinent aspects of the subsurface investigations and site inspections for the driveway and garage works and our recent site observations are summarised below:

Fill

Sandy or clayey fill with varying gravel content (less than 1m thick) is expected to be locally encountered across the footprint of the proposed house. We would expect the fill to be poorly compacted.

Natural Clays

Typically, we expect natural sandy clays of medium plasticity and variable strength (typically stiff) to be encountered beneath the paved surfaces and from the base of the fill and hard. The natural clays represent colluvial deposits with gravel, cobble and boulder sized sandstone inclusions. The colluvial soils are expected to be about 2m to 2.5m maximum thickness. Locally, the colluvial soils will predominantly comprise sandstone boulders which may exceed 1.5m x 1m x 1m dimension.

Weathered Sandstone Bedrock

Weathered bedrock representing the Hawkesbury Sandstone was encountered and was previously assessed to be distinctly weathered and of low to medium strength, improving with depth to slightly weathered and of medium to high strength.

We note that the bedrock faces lining a portion of Barrenjoey Road below the northern site boundary contained a number of sub-parallel defects which were orientated at between about 295^o and 330^o (sloping down to the south-west at between about 70^o and 85^o) and between 055^o and 060^o (sloping down to the north-west or south-east at between about 50^o and 85^o).

5 PROPOSED DEVELOPMENT

We understand from the provided architectural drawings (Drawing Numbers 1501-P-00 to P-10 Rev. B and 1501-E-00 to E-9 Rev. B, dated 1 December 2015) prepared by Benn & Penna Architecture, the proposed development will comprise the following:

- A new two storey house constructed over a partial storage area below the western side of the proposed house. The proposed finished floor reduced level (RL) of the ground floor level will be at RL35.2m and RL35.1m (over the terrace area). Nominal excavations are envisaged as the house will be located at a similar surface levels as the existing house and will essentially line the cliff face behind the existing house. The dilapidated section of sandstone masonry wall behind the house will be removed.
- The proposed finished floor RL of the storage area will be at RL32.54m and will connect via a stairway to the rear (western) end of the garage. The ground floor terrace level will extend over the storage area.

The footprint of the proposed development is indicated on Figure 1.

6 GEOTECHNICAL ASSESSMENT

The subject site is characterised by a moderately to steeply sloping cover to a stepped sandstone bedrock hillside. Whilst there are no obvious signs of deep seated slope instability, the colluvial soils have the potential to be subject to downslope creep or, under particularly adverse conditions, deeper seated instability. Detached blocks of sandstone ('floaters') were also recorded.

The site appeared to be relatively well drained.

Over the majority of the site, bedrock is expected at surface or at shallow depth and deeper over the south-western portion of the subject site where colluvial soils were encountered in the garage excavations. The colluvial soils represent old landslide deposits that have accumulated over geological time. Such deposits are expected at a site such as this, which is underlain by bedrock at the interface between the more competent Hawkesbury Sandstone and the weaker underlying Newport Formation. Over time the weaker Newport Formation degrades (due to weathering), erodes and landslides occur. Undercuts form at the base of the more competent Hawkesbury Sandstone eventually leading to toppling and collapse of large sandstone blocks ('floaters'). In addition, stress relief effects due to erosion of the landscape to form the current hillsides leads to opening of the defects within the Hawkesbury Sandstone and sliding along sub-horizontal defects. The sandstone bedrock outcrops were typified by open sub-vertical joints.

As a consequence of the above processes, blocks have fallen and toppled from cliff lines over the upper portion of the hillside. The detached blocks over the northern portion of the site represent blocks associated with such hillside processes and which are expected to continue over geological time.

There were a number of stacked sandstone walls located across the site that were in variable condition. Under existing conditions, localised collapse of poor condition walls can be expected over time as their condition continues to deteriorate. However, their collapse is expected to be relatively localised. However, the garage cut faces have been supported by engineer designed reinforced shotcrete and rock bolts.

6.1 Potential Landslide Hazards

We consider that the potential landslide hazards associated with the site to be the following:

A Instability of existing stacked sandstone retaining walls:

- (i) Poor condition retaining walls.
- (ii) Sandstone masonry walls.
- (iii) New concrete walls supporting the stepped access.

B Instability of the hillside slopes:

(i) Existing cliff line behind the existing house and the neighbouring upslope site to the east.

(ii) Existing cliff line in the neighbouring site to the south.

(iii) Detached sandstone blocks below the existing house.

(iv) The outcrops and soil slopes over the northern end of the site.

C Instability of existing excavation support measures

D Instability of temporary excavation batters.

E Instability of proposed retaining walls.

These potential hazards are indicated in schematic form on the attached Figure 2.

6.2 Risk Analysis

The attached Table A summarises our qualitative assessment of each potential landslide hazard and of the consequences to property should the landslide hazard occur. Use has been made of data in MacGregor *et al* (2007), and the Corrigendum, to assist with our assessment of the likelihood of a potential hazard occurring. Based on the above, the qualitative risks to property have been determined. The terminology adopted for this qualitative assessment is in accordance with Table A1 given in Appendix A. Table A indicates that the assessed risk to property varies between 'Moderate' and 'Low' or 'Very Low' under existing conditions, which would be considered 'Tolerable' and 'Acceptable', respectively in accordance with the criteria given in Reference 1 and the Pittwater Council Risk Management Policy. Following implementation of the recommendations outlined in Section 7, below risk levels would reduce to 'Acceptable' levels within the site.

We have also used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life during and after completion of the proposed development and implementation of the recommendations outlined in Section 7, below. The temporal, spatial, evacuation and vulnerability factors that have been adopted are given in the attached Table B together with the resulting risk calculation. Following implementation of the recommendations outlined in Section 7, our assessed risk to life for the person most at risk is less than 10^{-6}. This would be considered to be 'Acceptable' in relation to the criteria given in Reference 1 and the Pittwater Council Risk Management Policy.

Based on a review of the Pittwater Council Bush Fire Prone Land Map, dated 13 June 2013 provided on Councils website, we note that the subject site is not designated as bush fire prone.

On this basis, we have assessed that there will be negligible impact on slope stability as a result of any potential bushfire under existing conditions. Furthermore, we have assumed that the new residence will be designed and constructed in accordance with best practice for bushfire management. Consequently we have assessed the levels of risk to life and property due to landslides associated with bushfire to be at 'Acceptable' levels in relation to the criteria given in Reference 1 and the Pittwater Council Risk Management Policy. However, if the site or neighbouring sites along, up or downslope of the site are affected by bushfire then as soon as is practicable after the bushfire, an experienced geotechnical engineer or engineering geologist should inspect the subject site and the adjoining slopes to assess site stability and confirm the scope and extent of any stabilisation measures.

We note that an assessment of risk to life and property due to bushfire is outside our area of expertise and in accordance with Council guidelines, a Bushfire Consultant should complete such an assessment, if required.

6.3 Risk Assessment

The Pittwater Risk Management Policy requires suitable measures 'to remove risk'. It is recognised that, due to the many complex factors that can affect a site, the subjective nature of a risk analysis, and the imprecise nature of the science of geotechnical engineering, the risk of instability for a site and/or development cannot be completely removed. It is, however, essential that risk be reduced to at least that which could be reasonably anticipated by the community in everyday life and that landowners are made aware of reasonable and practical measures available to reduce risk as far as possible. Hence, where the policy requires that 'reasonable and practical measures have been identified to remove risk', it means that there has been an active process of reducing risk, but it does not require the geotechnical engineer to warrant that risk has been completely removed, only reduced, as removing risk is not currently scientifically achievable.

Similarly, the Pittwater Risk Management Policy requires that the design project life be taken as 100 years unless otherwise justified by the applicant. This requirement provides the context within which the geotechnical risk assessment should be made. The required 100 years baseline broadly reflects the expectations of the community for the anticipated life of a residential structure and hence the timeframe to be considered when undertaking the geotechnical risk assessment and making recommendations as to the appropriateness of a development, and its design and remedial measures that should be taken to control risk. It is recognised that in a 100 year period external factors that cannot reasonably be foreseen may affect the geotechnical risks associated with a site. Hence, the Policy does not seek the geotechnical engineer to warrant the development for a

100 year period, rather to provide a professional opinion that foreseeable geotechnical risks to which the development may be subjected in that timeframe have been reasonably considered.

Our assessment of the probability of failure of existing structural elements such as retaining walls (where applicable) is based upon a visual appraisal of their type and condition at the time of our inspection. Where existing structural elements such as retaining walls will not be replaced as part of the proposed development, where appropriate we identify the time period at which reassessment of their longevity seems warranted.

In preparing our recommendations given below we have adopted the above interpretations of the Risk Management Policy requirements. We have also assumed that no activities on surrounding land which may affect the risk on the subject site would be carried out. We have further assumed that all Council's buried services are, and will be regularly maintained to remain, in good condition.

We consider that our risk analysis has shown that the site and existing and proposed development can achieve the 'Acceptable Risk Management' criteria in the Pittwater Risk Management Policy provided that the recommendations given in Section 7 below are adopted. These recommendations form an integral part of the Landslide Risk Management Process.

7 COMMENTS AND RECOMMENDATIONS

We consider that the proposed development may proceed provided the following specific design, construction and maintenance recommendations are adopted to maintain and reduce the present risk of instability of the site and to control future risks. These recommendations address geotechnical issues only and other conditions may be required to address other aspects.

7.1 Conditions Recommended to Establish the Design Parameters

7.1.1 The existing dilapidated stacked sandstone wall lining the eastern side of the terrace area requires strengthening or replacing. Retaining wall design parameters are provided in Section 7.1.7, below. The removal of the short section of dilapidated sandstone masonry wall located behind the house will need to be carefully completed during demolition. Geotechnical inspection of the exposed rock face behind the wall will be required to assess the need and extent of stabilisation measures such as rock bolts, reinforced shotcrete, underpins etc.

7.1.2 All proposed footings must be founded in sandstone bedrock. However, over the southern side of the existing house there is little available information on bedrock depths and so we recommend that two cored boreholes be drilled to confirm bedrock depths and quality. The footings should be tentatively designed for an allowable bearing pressure of 1000kPa, subject to the results of the cored borehole investigation and inspection by a geotechnical engineer prior to pouring. Footings close to the crests of natural or cut rock faces should be designed for an allowable bearing pressure of 600kPa on condition that the bedrock faces below the footings are inspected by a geotechnical engineer to check for the presence of potentially unstable wedges or seams etc which may require support using rock bolts, reinforced shotcrete etc.

7.1.3 The existing cliff line behind the existing house will require geotechnical inspection once the adjacent sections of existing house have been removed to assess the need and extent of stabilisation measures as outlined in Section 7.1.1, above. In addition, the potentially unstable wedge towards the southern end of the cliff line behind the existing house will require stabilisation. A combination of rock bolts and permanent reinforced shotcrete (with a decorative sandstone cladding) to support the soil joint infill will be required. Weepholes or must be provided to drain the soil infill. The embedded end of the weep holes must be wrapped with a geotextile fabric to control subsoil erosion. The stabilisation of the wedge will need to be completed prior to any rock excavation in this area.

7.1.4 Subject to inspection by a geotechnical engineer temporary batters for the proposed excavations should be no steeper than 1 Vertical (V) in 1 Horizontal (H) within the clayey soil profile, extremely weathered and/or fractured sandstone bedrock. Competent sandstone bedrock may be cut to a vertical face, subject to geotechnical inspection. The excavation batters are expected to be accommodated within the site. All surcharge loads must be kept well clear of the excavation perimeter. Sandstone bedrock is expected to stand unsupported subject to the geotechnical inspections. Any bands of extremely weathered and/or fractured bedrock, potentially unstable wedges of sandstone etc may require localised support as described as outlined in Sections 7.1.1 and 7.1.3, above.

7.1.5 Where rock bolts are to run below adjoining properties, then the permission of the owners must be obtained before installation.

7.1.6 The surface water discharging from the new roof and paved areas must be diverted to outlets for controlled discharge to the existing stormwater system which appears to drain to the road.

7.1.7 The proposed new retaining walls and any existing walls that require strengthening should be designed using the following parameters should be designed using the following parameters:

– For cantilever walls that will be propped by the proposed structure and any underpins supporting a soil profile, adopt a triangular lateral earth pressure distribution and an 'at rest' earth pressure coefficient (k_o) of 0.55 for the retained soils and extremely weathered bedrock profile, assuming a horizontal backfill surface.

– For cantilever walls where movement is of little concern (say landscape walls), adopt a triangular lateral earth pressure distribution and an 'active' earth pressure coefficient, K_a, of 0.35 for the retained height, assuming a horizontal backfill surface.

– A bulk unit weight of $20kN/m^3$ should be adopted for the soil profile.

– Any surcharge affecting the walls (e.g. traffic loading, live loading, footings, compaction stresses, etc) should be taken into account in the design using the appropriate earth pressure coefficient from above.

– The retaining walls should be provided with complete and permanent drainage of the ground behind the walls. The subsoil drains should incorporate a non-woven geotextile fabric (eg. Bidim A34), to act as a filter against subsoil erosion.

– Toe resistance of the wall may be achieved by keying the footing into bedrock. An allowable lateral stress of 200kPa may be adopted for key design assuming horizontal ground in front of the toe. However the presence of a step down in the bedrock in front of the key cannot be discounted and geotechnical inspections are recommended.

– Toe restraint for low height (say <1m) landscape walls founded in the soil profile may be provided by the passive pressure of the soil below bulk adjacent surface levels. A 'passive' earth pressure coefficient, K_p, of 3 may be adopted, provided a Factor of Safety of 2 is used in order to reduce deflections. Localised excavations in front of the walls e.g. for buried services etc should also be taken into account in the design.

– Retaining walls supporting a soil profile may be founded on sandstone bedrock at the crest of excavation faces, provided the bedrock below the toes of the retaining walls are inspected by the geotechnical engineer. Lateral restraint may be provided by starter bars drilled and grouted to a depth of at least 0.5m into the sandstone bedrock. The starter bars should be installed at a downward angle into the rock face and be provided with a vertical cogged length. If cross bedded units within the sandstone bedrock are identified during geotechnical inspections and slope down into the excavation, then the starter bars may have to be extended to stabilise the potentially unstable cross bedded units. .

– Rock bolts installed within the weathered bedrock of at least low strength should be designed for an allowable bond strength of 200kPa. Where appropriate, the bolt heads should be engaged with the reinforcement mesh and encapsulated in the shotcrete with sufficient cover to achieve corrosion protection.

7.1.8 Over any soil subgrade areas beneath proposed on-grade floor slabs, after completion of any bulk excavations to achieve design subgrade levels, the subgrade must be proof rolled. The proof rolling should be carried out using a small (say 2 tonne) smooth drum vibratory roller or, where access is restricted, a hand held vibrating plate compactor. During proof rolling, adjoining structures must be closely monitored by the site supervisor and if there are causes for concern then the static (no-vibration) mode should be used or work immediately stop and this office be contacted for further advice. The aim of the proof rolling is to identify any soft or unstable areas, which if detected should be excavated down to a sound base and backfilled with thoroughly compacted engineered fill. Alternatively, floor slabs may be suspended, in which case no subgrade preparation would be required.

7.1.9 Engineered fill must be free of organic materials, other contaminants and deleterious substances and have a maximum particle size not exceeding 40mm. Engineered fill should be placed in layers of maximum 100mm loose thickness and compacted to achieve at least 98% of Standard Maximum Dry Density (clayey fill materials and excavated bedrock). For any fill over landscaped areas, where movements are expected to be of little concern, the above compaction criteria may be reduced to at least 95% of SMDD (clayey fill materials and excavated bedrock). Backfill to conventional retaining walls should also comprise engineered fill. Well graded granular materials such as ripped or crushed sandstone and demolition rubble would be suitable for this purpose. Compaction of backfill behind retaining walls is likely to require the use of hand held vibrating plate (or “wacker packers”) compactors. Confirmatory in-situ density testing should be undertaken to assess compaction. Any areas of insufficient compaction will require reworking.

7.1.10 The effluent system should be piped and discharged to the main sewer system.

7.1.11 The guidelines for Hillside Construction given in Appendix B should also be adopted.

7.2 Conditions Recommended to the Detailed Design to be Undertaken for the Construction Certificate

7.2.1 The additional geotechnical investigation referred to in the preceding Section 7.1.2 is to be completed prior to finalisation of design drawings.

7.2.2 All structural design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.3 All hydraulic design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.4 All landscape design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.5 Dilapidation surveys must be carried out on the neighbouring buildings and structures to the east and south. A copy of the dilapidation report must be provided to the neighbours and Council or the Principle Certifying Authority.

7.3 Conditions Recommended During the Construction Period

7.3.1 An excavation/retention methodology must be prepared prior to bulk excavation commencing. The methodology must include but not be limited to proposed excavation techniques, the proposed excavation equipment, excavation sequencing, geotechnical inspection intervals or hold points, vibration monitoring procedures, monitor locations, monitor types, contingency plans in case of exceedances.

7.3.2 The excavation/retention methodology must be reviewed and approved by the geotechnical engineer.

7.3.3 The approved excavation/retention methodology must be followed.

7.3.4. Periodic vibration monitoring must be carried out during rock excavations using rock breakers. The ground vibration measured as peak particle velocity (PPV) must not exceed 5mm/sec at the northern, southern and eastern site boundaries. The PPV will need to be confirmed following review of the dilapidation survey reports recommended in Section 7.2.4, above.

7.3.5 To reduce the potential to de-stabilise any sandstone boulders below the house within the proposed storage area excavation, we recommend that they be carefully excavated using a rock saw attachment supplemented with the use of a ripping tyne and/or rock breaker attachment to the tracked excavator. In some instances, say to assist in preventing debris rolling down the hill and impacting the downslope section of the site it may be preferable to use hand held rock splitting techniques. The use of rock saws and/or rock splitting techniques will provide a neat sub-vertical cut face and reduce vibrations which may otherwise potentially de-stabilise the boulders.

The stability of the portions of boulders that will remain will need to be assessed by geotechnical inspection. It is likely that underpins, rock bolts supporting reinforced shotcrete (with strip drains) and rock bolts will be required to support the remaining sections of sandstone boulders. The stabilisation measures should be designed as permanent and incorporated into the retention system. The sandstone bedrock below the boulders may then be cut vertically.

Where boulders are located just above the top surface of bedrock, have been underpinned and the underpins are located along the perimeter of the excavation they must be laterally restrained, particularly as they may be retaining the soil profile outside the excavation. For permanent restraint we recommend that starter bars be drilled and grouted to a depth of about 0.5m into the sandstone. Design parameters are presented in Section 7.1.7, above.

The above sequence of excavations would need to be completed in maximum 1.8m depth intervals together with frequent geotechnical inspections.

7.3.6 The localised stabilisation measures to the rock cut faces and sandstone boulders exposed in cut faces must be witnessed by the geotechnical engineer.

7.3.7 The geotechnical engineer must inspect all footing excavations prior to placing reinforcement or pouring the concrete.

7.3.8 Bulk excavations must be progressively inspected by the geotechnical engineer as excavation proceeds. We recommend inspections at 1.8m vertical depth intervals and on completion.

7.3.9 Proposed material to be used for backfilling behind retaining walls in critical areas (e.g. backfill that will be supporting paved areas etc) must be approved by the geotechnical engineer prior to placement.

7.3.10 Compaction density of the backfill material must be checked by a NATA registered laboratory to at least Level 2 in accordance with, and to the frequency outlined in, AS3798, and the results submitted to the geotechnical engineer.

7.3.11 If they are to be retained, the existing stormwater system, sewer and water mains must be checked for leaks by using static head and pressure tests under the direction of the hydraulic engineer or architect, and repaired if found to be leaking.

7.3.12 The geotechnical engineer must inspect all subsurface drains prior to backfilling.

7.3.13 An ‘as-built’ drawing of all buried services at the site must be prepared (including all pipe diameters, pipe depths, pipe types, inlet pits, inspection pits, etc).

7.3.14 The geotechnical engineer must confirm that the proposed house has been completed in accordance with the geotechnical reports.

We note that all above Conditions must be complied with. Where this has not been done, it may not be possible for Form 3, which is required for the Occupation Certificate to be signed.

7.4 Conditions Recommended for Ongoing Management of the Site/Structure(s)

The following recommendations have been included so that the current and future owners of the subject property are aware of their responsibilities:

7.4.1 All existing and proposed surface (including roof) and subsurface drains must be subject to ongoing and regular maintenance by the property owners. In addition, such maintenance must also be carried out by a plumber at no more than ten yearly intervals; including provision of a written report confirming scope of work completed (with reference to the ‘as-built’ drawing) and identifying any required remedial measures.

7.4.2 All existing rock faces and detached sandstone blocks remaining across the site must be inspected by an experienced engineer/engineering geologist at no more than ten yearly intervals; including provision of a written report confirming scope of work completed and identifying any required remedial measures.

7.4.3 Any existing retaining walls that are to be remain over the site must be inspected by a structural engineer at no more than ten yearly intervals; including the provision of a written report confirming scope of work completed and identifying any required remedial measures.

7.4.4 No cut or fill in excess of 0.5m (e.g. for landscaping, buried pipes, retaining walls, etc), is to be carried out on site without prior consent from Pittwater Council.

7.4.5 Where the structural engineer has indicated a design life of less than 100 years then the structure and/or structural elements must be inspected by a structural engineer at the end of their design life; including a written report confirming scope of work completed and identifying the required remedial measures to extend the design life over the remaining 100 year period.

8 OVERVIEW

It is possible that the subsurface soil, rock or groundwater conditions encountered during construction may be found to be different (or may be interpreted to be different) from those inferred from our surface observations in preparing this report. Also, we have not had the opportunity to observe surface run-off patterns during heavy rainfall and cannot comment directly on this aspect. If conditions appear to be at variance or cause concern for any reason, then we recommend that you immediately contact this office.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

Reference 1: Australian Geomechanics Society (2007c) *'Practice Note Guidelines for Landslide Risk Management'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp63-114.

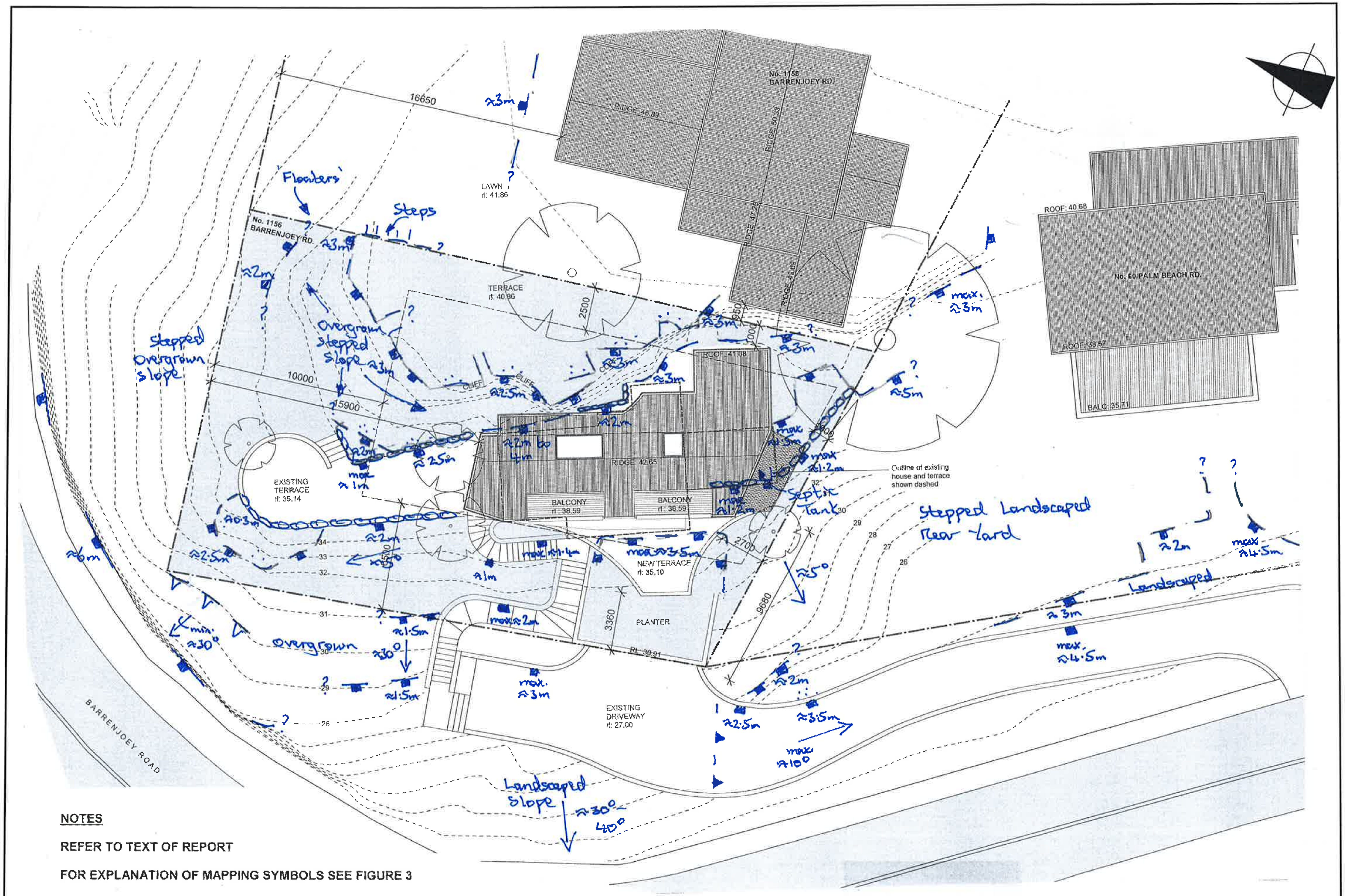
Reference 2: MacGregor, P, Walker, B, Fell, R, and Leventhal, A (2007) *'Assessment of Landslide Likelihood in the Pittwater Local Government Area'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp183-196.

TABLE A
SUMMARY OF RISK ASSESSMENT TO PROPERTY

Potential Landslide Hazard	EXISTING CONDITIONS								DURING AND AFTER COMPLETION OF PROPOSED DEVELOPMENT AND IMPLEMENTATION OF RECOMMENDATIONS OUTLINED IN SECTION 7									
	A: Instability of existing retaining walls			**B: Instability of the hillside slopes**				**C: Instability of Existing Excavation Support measures**	**A: Instability of existing retaining walls**			**B: Instability of the hillside slopes**				**C: Instability of Existing Excavation Support measures**	**D: Instability of Temporary Excavation Batters**	**E: Instability of Proposed Retaining Walls**
	(i) Poor condition retaining walls	**(ii) Sandstone masonry retaining walls**	**(iii) New concrete retaining walls**	**(i) Existing cliff line behind the existing site and upslope to the east**	**(ii) Existing cliff line to the south**	**(iii) Sandstone blocks below the existing house**	**(iv) The outcrops and soil slopes over the northern end of the site**		**(i) Poor condition retaining walls**	**(ii) Sandstone masonry retaining walls**	**(iii) New concrete retaining walls**	**(i) Existing cliff line behind the existing site and upslope to the east**	**(ii) Existing cliff line to the south**	**(iii) Sandstone blocks below the existing house**	**(iv) The outcrops over the northern end of the site**			
Assessed Likelihood	Likely	Possible	Rare	Possible	Possible	Unlikely	Possible	Rare	Rare	Rare	Rare	Unlikely	Possible	Rare	Unlikely	Rare	Unlikely	Rare
Assessed Consequences	Minor (walls) Insignificant (yard areas/house)			Minor	Insignificant	Minor	Insignificant	Minor	Minor (walls) Insignificant (yard areas/house)			Minor	Insignificant	Minor	Insignificant	Minor	Minor	Minor
Risk	Moderate (walls) Low (yard areas/ house)	Moderate (walls) Very Low (yard areas/ house)	Very Low	Moderate	Very Low	Very Low	Very Low	Very Low	Very Low			Low	Very Low	Very Low	Very Low	Very Low	Low	Low
Comments	A (i) to (iii) and B (i) to (vi): Assumes localised instability. A (iii): Assumes walls have been engineer designed. C: Assumes stabilisation measures were engineer designed.								A (i) and (ii): Assumes walls will be removed as part of works or assessed and repaired as appropriate. A (iii): Assumes walls have been engineer designed. B (i) to (iii): Assumes potential unstable features will be stabilised or removed (as appropriate) following geotechnical assessment. B (v): Assumes detached sandstone blocks will be removed or stabilised (as appropriate). C: Assumes stabilisation measures were engineer designed. D: Assumes recommended batter slopes will be adopted and excavation batters inspected by geotechnical engineer E: Assumes the retaining walls will be properly engineered.									

TABLE B
SUMMARY OF RISK ASSESSMENT TO LIFE
DURING AND AFTER COMPLETION OF PROPOSED DEVELOPMENT AND IMPLEMENTATION OF RECOMMENDATIONS OUTLINED IN SECTION 7

Potential Landslide Hazard	**A: Instability of existing retaining walls**			**B: Instability of the hillside slopes**				**C: Instability of Existing Excavation Support Measures**	**D: Instability of Temporary Excavation Batters**	**E: Instability of Proposed Retaining Walls**
	(i) Poor condition retaining walls	**(ii) Sandstone masonry retaining walls**	**(iii) New concrete retaining walls**	**(i) Existing cliff line behind the existing house and upslope to the east**	**(ii) Existing cliff line to the south**	**(iii) Sandstone blocks below the existing house**	**(iv) The outcrops and soil slopes over the northern end of the site**			
Assessed Likelihood	Rare	Rare	Rare	Rare	Possible	Rare	Unlikely	Rare	Unlikely	Rare
Indicative Annual Probability	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-3}	10^{-5}	10^{-4}	10^{-5}	10^{-4}	10^{-5}
Persons at Risk	Persons in yard area within the site and on the driveway			Persons in house and yard areas within and neighbouring the site	Persons in yard area within the neighbouring site, the site and on the driveway	Persons in house and yard areas within and neighbouring the site	Persons in yard area within the site	Persons in house, yard areas, garage and driveway within the site and the neighbouring site	Persons at crest Workers within excavation	Persons in house and yard area
Number of Persons Considered	2									
Duration of Use of Area Affected (Temporal Probability)	1hr/day each i.e. 0.04			1hr/day each i.e. 0.04 (yard areas) 20hr/day each i.e. 0.8 (living areas) 6hrs/day each i.e. 0.25 (bedroom)	1hr/day each i.e. 0.04	1hr/day each i.e. 0.04 (yard areas) 20hr/day each i.e. 0.8 (living areas) 6hrs/day each i.e. 0.25 (bedroom)	1hr/day each i.e. 0.04	1hr/day each i.e. 0.04 (yard areas) 20hr/day each i.e. 0.8 (living areas) 6hrs/day each i.e. 0.25 (bedroom)	1hr/day each over say 6 weeks i.e. 4.6 x 10^{-3} 6hrs/day each over say 6 weeks i.e. 0.03	1hr/day each i.e. 0.04 (yard areas) 20hr/day each i.e. 0.8 (living areas) 6hrs/day each i.e. 0.25 (bedroom)
Probability of Not Evacuating Area Affected	0.2			0.2 (yard areas) 0.4(house)	0.2	0.2 (yard areas) 0.4(house)	0.2	0.2 (yard areas) 0.4(house)	0.4	0.2 (yard areas) 0.4(house)
Spatial Probability	1m failure over 5m length of wall i.e. 0.2			2m failure over 10m length of slope i.e. 0.2				1m failure over 5m length of stabilised face i.e. 0.2	1m failure over 5m length of excavation i.e. 0.2	1m failure over 5m length of wall i.e. 0.2
Vulnerability to Life if Failure Occurs Whilst Person Present	0.1			0.4 (house) 0.1 (yard areas)	0.1	0.4 (house) 0.1 (yard areas)	0.1	0.4 (house) 0.1 (yard areas)	0.1	0.4 (house) 0.1 (yard areas)
Risk for Person Most at Risk	8 x 10^{-9}			1.6 x 10^{-9} (yard areas) 2.6x 10^{-7} (living areas 8 x 10^{-8} (bedroom)	1.6 x 10^{-8}	1.6 x 10^{-9} (yard areas) 2.6 x 10^{-7} (living areas 8 x 10^{-8} (bedroom)	1.6 x 10^{-9}	1.6 x 10^{-9} (yard areas) 2.6 x 10^{-7} (living areas 8 x 10^{-8} (bedroom)	3.7x 10^{-9} 2.4x 10^{-8}	1.6 x 10^{-9} (yard areas) 2.6 x 10^{-7} (living areas 8 x 10^{-8} (bedroom)
Total Risk	1.6 x 10^{-8}			3.2x 10^{-8} (yard areas) 5.2x 10^{-7} (living areas 1.6 x 10^{-8} (bedroom)	3.2 x 10^{-8}	3.2x 10^{-8} (yard areas) 5.2x 10^{-7} (living areas 1.6 x 10^{-8} (bedroom)	3.2 x 10^{-9}	3.2x 10^{-8} (yard areas) 5.2x 10^{-7} (living areas 1.6 x 10^{-8} (bedroom)	7.4x 10^{-9} 4.8x 10^{-8}	3.2x 10^{-8} (yard areas) 5.2x 10^{-7} (living areas 1.6 x 10^{-8} (bedroom)



NOTES

REFER TO TEXT OF REPORT

FOR EXPLANATION OF MAPPING SYMBOLS SEE FIGURE 3

SCALE (m)

0 10

GEOTECHNICAL SKETCH PLAN

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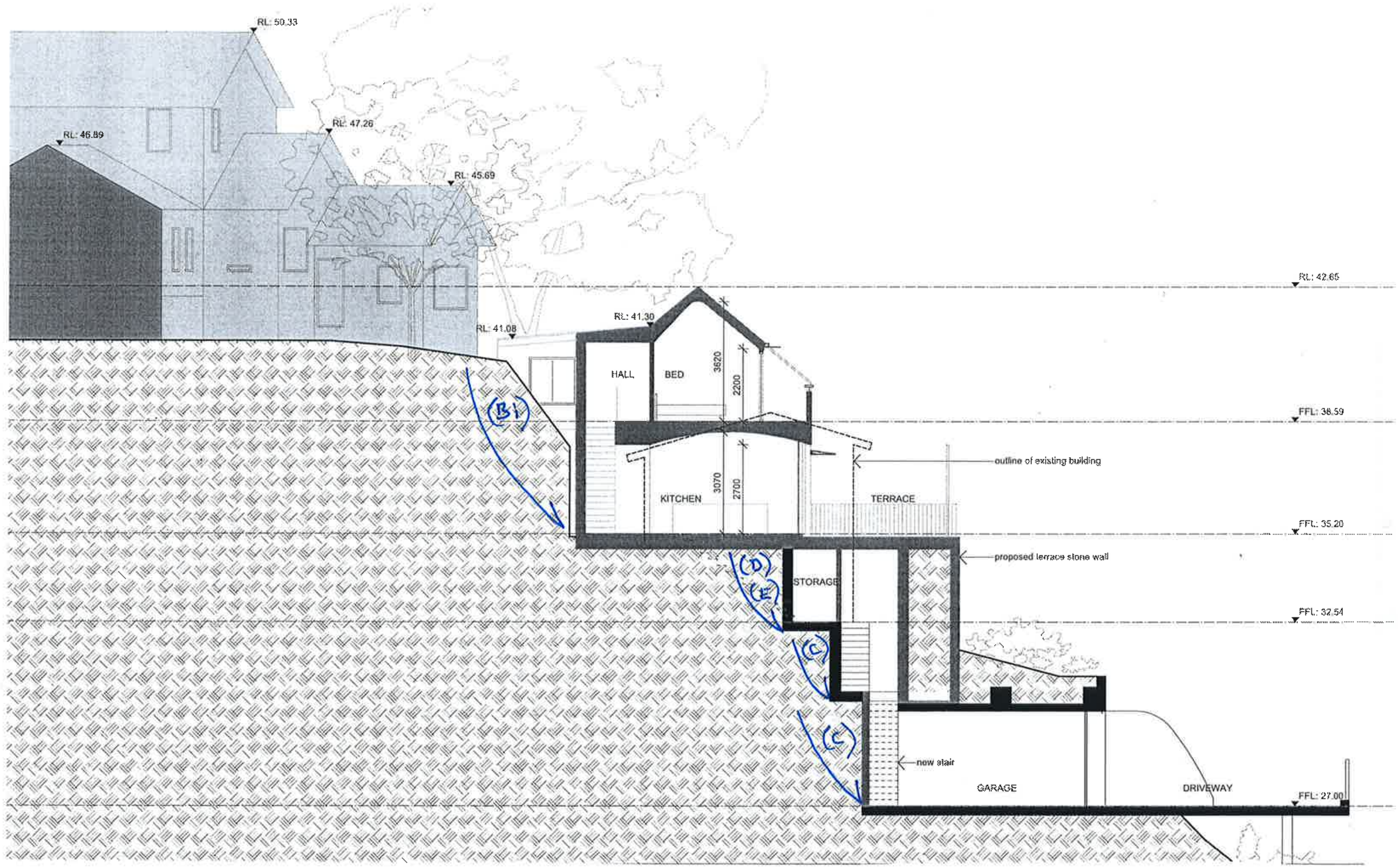
Report No 28960ZR Figure No. 1



NOTES

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SCALE (m)
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SECTION A-A SHOWING POTENTIAL LANDSLIDE HAZARDS

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Report No 28960ZR Figure No. 2

TOPOGRAPHY

Symbol *Ground Profile*

convex / concave — well defined or angular break of slope

convex / concave — poorly defined or smooth change of slope

breaks of slope / changes of slope — convex and concave too close together to allow the use of separate symbols

sharp / rounded — ridge crest

3 — Cliff or escarpment or sharp break 40° or more (estimated height in metres)

15 Uniform Slope / 10 Concave Slope / 8 Convex Slope — Slope direction and angle (Degrees)

Top / Bottom — Cut or fill slope, arrows pointing down slope

Hummocky or irregular ground

OTHER FEATURES

Boulder

Seepage/spring

Swallow hole for runoff

Natural water course

Open drain, unlined

Open drain, lined

Fenceline

Property boundary

Dry Stone Wall

J —— J 200 — Major joint in rock face (opening in millimetres)

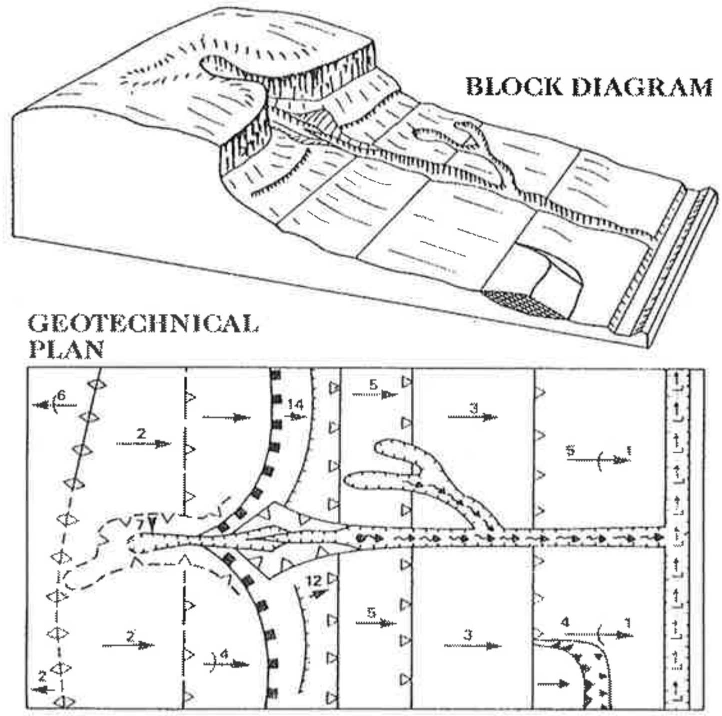
- T - T - 10 — Tension crack (opening in millimetres)

Masonry or concrete wall

Ponding water

Boggy or swampy area

EXAMPLE OF USE OF TOPOGRAPHIC SYMBOLS:



(After Gardiner, V & Dackombe, R.V. (1983), Geomorphological Field Manual; George Allen & Unwin).

GEOTECHNICAL MAPPING SYMBOLS

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Report No. 28960ZR Figure No. 3

APPENDIX A

LANDSLIDE RISK

MANAGEMENT

TERMINOLOGY

APPENDIX A
LANDSLIDE RISK MANAGEMENT

Definition of Terms and Landslide Risk

Risk Terminology	Description
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.
Annual Exceedance Probability (AEP)	The estimated probability that an event of specified magnitude will be exceeded in any year.
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.
Elements at Risk	The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.
Frequency	A measure of likelihood expressed as the number of occurrences of an event in a given time. See also 'Likelihood' and 'Probability'.
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.
Individual Risk to Life	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.
Landslide Activity	The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg. seasonal) or continuous (in which case the slide is 'active').
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, or kinetic energy per unit area.
Landslide Risk	The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.
Landslide Susceptibility	The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
Likelihood	Used as a qualitative description of probability or frequency.
Probability	A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event. These are two main interpretations: (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an 'objective' or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

Risk Terminology	Description
Probability *(continued)*	(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.
Qualitative Risk Analysis	An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.
Quantitative Risk Analysis	An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.
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.
Risk Analysis	The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification and risk estimation.
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 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 judgments 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 Management	The complete process of risk assessment and risk control (or risk treatment).
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.
Susceptibility	See 'Landslide Susceptibility'.
Temporal Spatial Probability	The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.
Tolerable Risk	A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.
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.

NOTE: Reference should be made to Figure A1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

Reference should also be made to the paper referenced below for Landslide Terminology and more detailed discussion of the above terminology.

This appendix is an extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

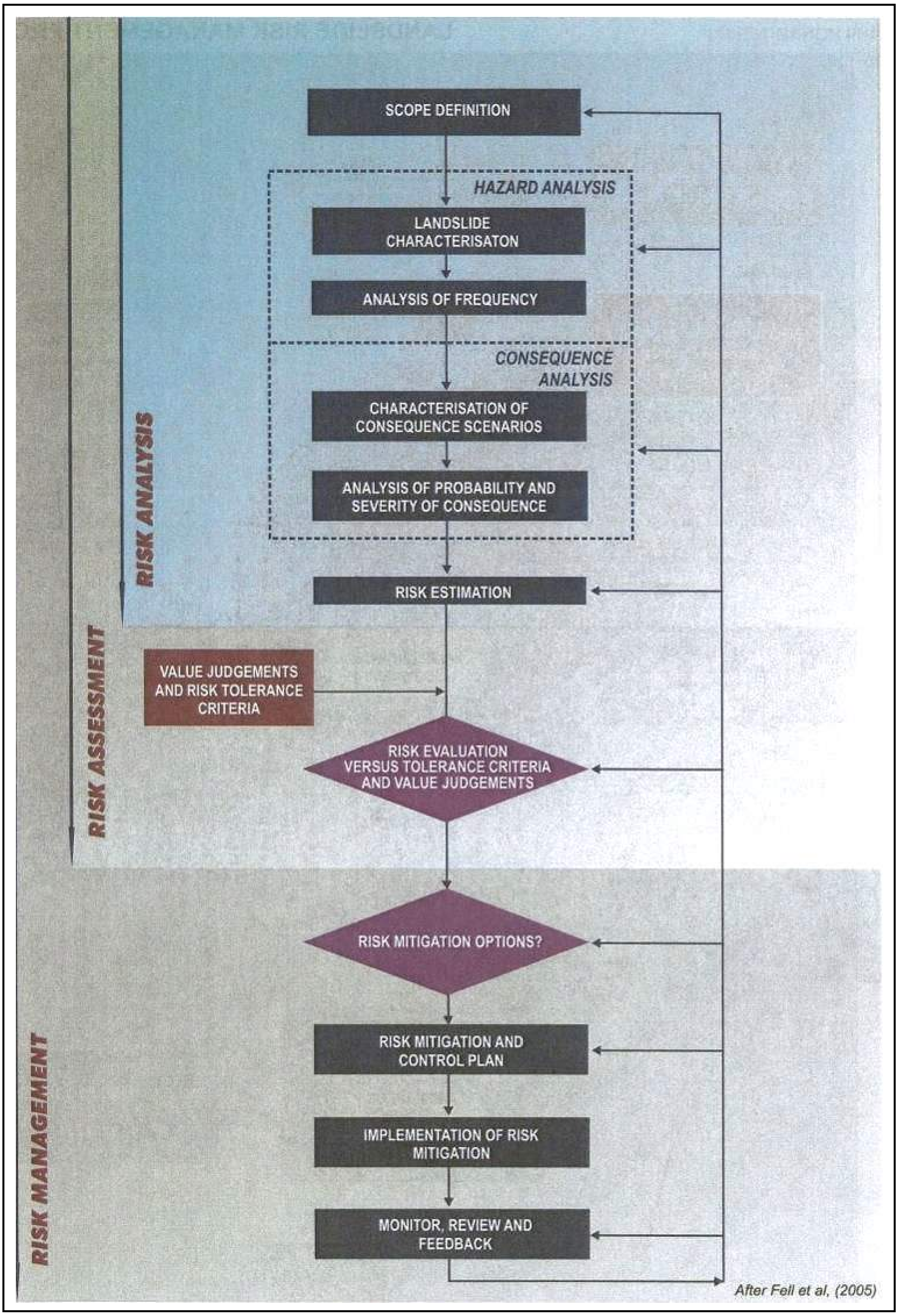


FIGURE A1: Flowchart for Landslide Risk Management.

This figure is an extract from GUIDELINE FOR LANDSLIDE SUSCEPTIBILITY, HAZARD AND RISK ZONING FOR LAND USE PLANNING, as presented in Australian Geomechanics Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: 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}		10 years		The event is expected to occur over the design life.	ALMOST CERTAIN	A
	5×10^{-2}		20 years			
10^{-2}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
	5×10^{-3}		200 years			
10^{-3}		1000 years		The event could occur under adverse conditions over the design life.	POSSIBLE	C
	5×10^{-4}		2000 years			
10^{-4}		10,000 years		The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
	5×10^{-5}		20,000 years			
10^{-5}		100,000 years		The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
	5×10^{-6}		200,000 years			
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%		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
	100%			
60%		Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
	40%			
20%		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
	10%			
5%		Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
	1%			
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.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: LANDSLIDE RISK ASSESSMENT
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) 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.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

AUSTRALIAN GEOGUIDE LR2 (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 fall 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. The 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 series consequences. Wetting up of the ground (which may involve a rise in groundwater 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
- Groundwater 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:

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.

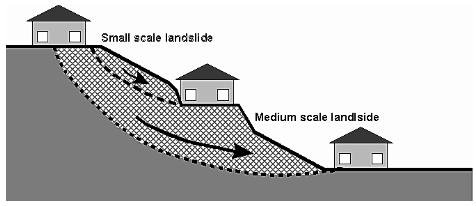


Figure 1

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.

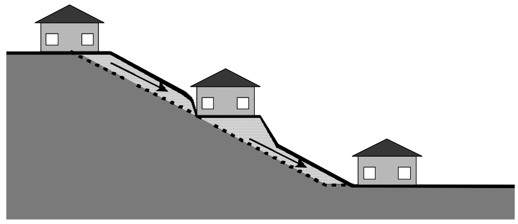


Figure 2

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.

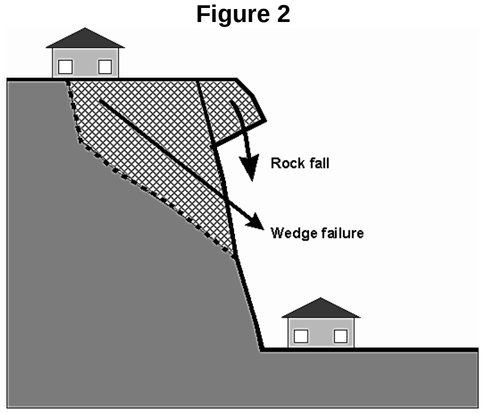


Figure 3

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.

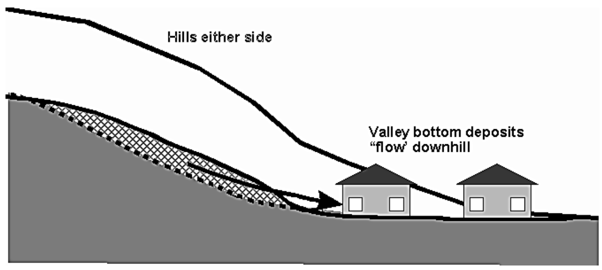


Figure 4

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.

AUSTRALIAN GEOGUIDE LR7 (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 (see 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 normally covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, then go first for information to your local council. If you have any concern that you could be dealing with a landslide hazard that your local council is not aware of you should seek advice from a geotechnical practitioner.

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 inevitably lacks 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 the repairs and perhaps temporary loss of use. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

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.

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", "tolerable" 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 risk level. This may be lower than you feel is reasonable for your block but it is, nonetheless, a pre-requisite for development. Reasons for this include the fact that a landslide on your block may pose a risk to neighbours and passers-by and that , should you sell, subsequent owners of the block may be more risk averse than you.

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. 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 today. If this were not so, there would be no risk at all and clearly that is not the case.

In NSW, the planning authorities consider that 1:1,000,000 is the maximum tolerable risk for domestic housing built near an obvious hazard, such as a chemical factory. Although not specifically considered in the NSW guidelines there is little difference between the hazard presented by a neighbouring factory and a landslide: both have the capacity to destroy life and property and both are always present.

TABLE 3 – RISK TO LIFE

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

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

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

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

APPENDIX B

SOME GUIDELINES

FOR

HILLSIDE CONSTRUCTION

APPENDIX B – SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements.
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance (including onto properties below). Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc. in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on bedrock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within bedrock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide generous falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge of roof run-off into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use of absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by a geotechnical consultant.	
SITE VISITS	Site visits by consultant may be appropriate during construction.	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident seek advice. If seepage observed, determine cause or seek advice on consequences.	

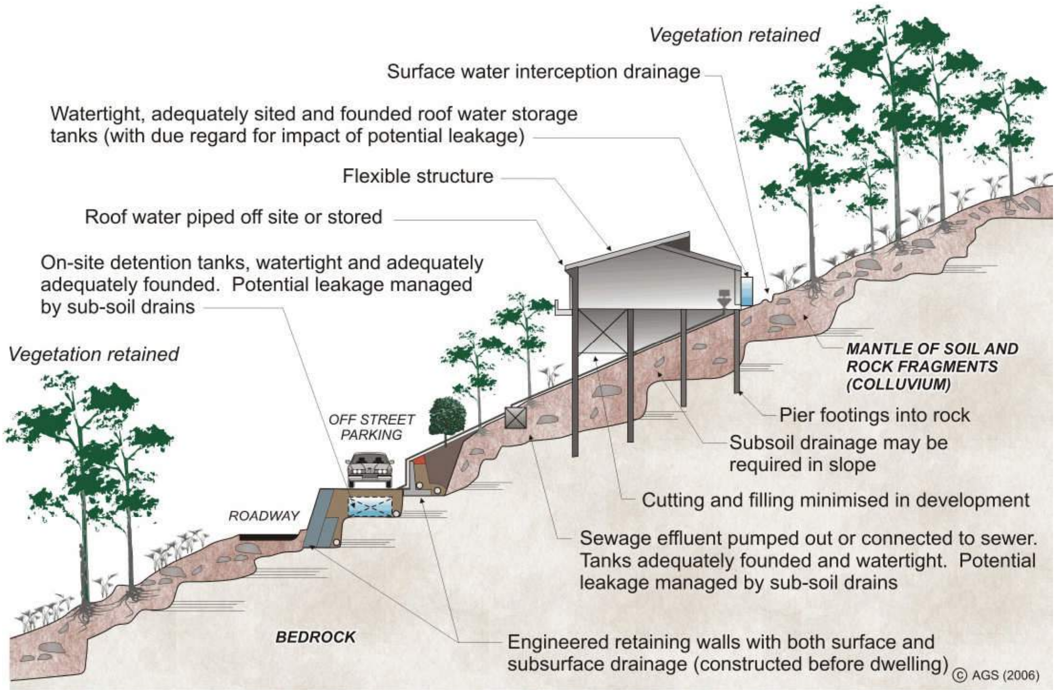
This table is an extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in *Australian Geomechanics*, Vol 42, No 1, March 2007 which discusses the matter more fully.

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.

EXAMPLES FOR **GOOD** HILLSIDE CONSTRUCTION PRACTICE



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 due to 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 fulfill 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.

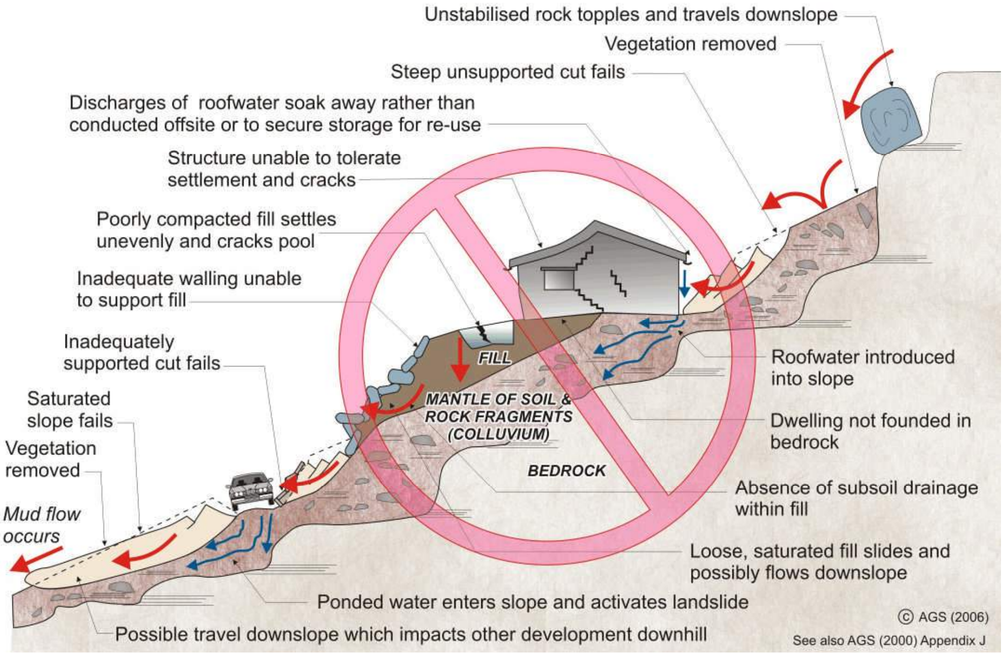
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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
Extract from Geoguide LR8 – Hillside Construction Practice

EXAMPLES FOR **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

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

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

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

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

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

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 LR7 - Landslide Risk
- 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.

Extract from Geoguide LR8 – Hillside Construction Practice.