REPORT TO

MELINE NAZLOOMIAN

ON

GEOTECHNICAL ASSESSMENT

FOR

PROPOSED ALTERATIONS AND ADDITIONS

AT

5 BARRABOOKA STREET, CLONTARF, NSW

Date: 30 September 2024
Ref: 37023PHErpt

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1 INTRODUCTION

This report presents the results of our geotechnical assessment of the site at 5 Barrabooka Street, Clontarf, NSW. The location of the site is shown in Figure 1. The assessment was commissioned by Meline Nazloomian by return of a signed 'Acceptance of Proposal' form and was carried out in accordance with our proposal, Ref. 'P60797PE' dated 12 June 2024.

Based on the supplied undated architectural drawings (Job No. BAT-2309, Drawing Nos. DA-001, DA-011, DA-050 to DA-053, DA-100 to DA-104, DA-200, DA-201, DA-300, DA-500 to DA-502, DA-530, DA-531, DA-540, DA-550, DA-551, and DA-700) prepared by Squillace, we understand the proposed development will comprise the construction of a two storey addition within the central and eastern portions of the site and internal alterations within the western portion of the building which will remain. The finished floor level of the proposed upper ground addition at approximately RL47.73m is a maximum of approximately 1.1m above current surface levels. A footbridge linking the Level 1 dining/living area at RL51.302 with the Barrabooka Street footpath is also proposed, as well as external landscaping.

The purpose of the geotechnical assessment was to carry out a walkover inspection to identify potential geotechnical hazards, assess the risk of instability to both life and property, and to provide our comments and recommendations on landslide risk management measures, site preparation, and footing design.

This report has been prepared in accordance with the Australian Geomechanics Society 'Practice Note Guidelines for Landslide Risk Management' (AGS2007c) risk classification system (Reference 1).

2 ASSESSMENT METHODOLOGY

The walkover assessment was carried out by our Associate Geotechnical Engineer, Michael Egan, on 3 September 2024 and comprised 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 Reference 1. A summary of our observations is presented in Section 3 below.

The attached Figure 2 presents a geotechnical site plan with the various features identified on site during our walkover assessment. These features were measured by hand held clinometer and tape measure techniques and hence are only approximate. Should any of these features be critical to the proposed development, we recommend they be located more accurately using instrument survey techniques. Figure 2 is based on the survey plan prepared C & A Surveyors NSW Pty Ltd (Reference No. 30921-23, dated 3 November 2023) and Figure 3 defines the mapping symbols used.

3 SUMMARY OF OBSERVATIONS

For ease of reference, the following site description should be read with reference to the attached Figure 2 and photographic plates presented below.

The site is located on the side of a west facing hillside which steps and slopes down at an average of approximately 15° toward Middle Harbour. The site is rectangular in plan being approximately 45m deep (east to west) by 10m wide (north to south) and has a maximum elevation relief of approximately 10m between the eastern and western side boundaries. Barrabooka Street bounds the site to the east.

At the time of the walkover inspection, the central portion of the site comprised a three storey brick house which had been partially cut into the hillside to a maximum depth of approximately 4.5m at its north-eastern corner. A sandstone bedrock exposure was present beside the south-eastern corner of the house and appeared to be part of a relatively persistent cliff line which extended through the site, as outlined further below.

A timber deck partially suspended over the above mentioned cliff line was located between the eastern side of the house and a single storey carport. The carport was accessible via an on-grade concrete driveway that was flanked by garden areas. A rendered retaining wall (maximum 0.9m high) supported an elevated garden area on the northern (i.e. high) side of the driveway, whereas the garden area on the southern (i.e. low) side of the driveway was supported by a mortared and dry stacked sandstone boulder wall (maximum 1.2m high). The latter wall was partially leaning over a maximum of approximately 3° in a southerly direction. Another mortared sandstone block retaining wall (maximum 1.8m high) along the central portion of the southern site boundary appeared to support a former garden bed on the southern side of the carport, although observations of the wall were limited due to the existing vegetation in this area.

The western portion of the site contained a terraced yard supported by a low height brick retaining wall, below which the natural hillside sloped down to the west at a maximum of approximately 28°.

The sandstone cliff line within the subject site was located below the aforementioned timber deck and was orientated in an approximately north-south direction. The sandstone cliff line was up to a maximum height of approximately 3.5m beside the south-eastern corner of the house. In this area, the sandstone cliff face exposed several near horizontal bedding partings and sub-vertical joints orientated (i.e. striking) to the north-east and south-east at approximately 022° and 126°, respectively. The identified discontinuities had formed a localised overhang that was a maximum horizontal depth of approximately 1.4m and isolated several detached blocks which were between 0.5m and 1.8m thick. One of the detached blocks had shifted between approximately 0.2m and 0.5m away from the cliff line in a south-westerly direction; see Plate 1 below. Observations were somewhat limited due to the existing vegetation surrounding the southern end of the cliff line.

It is possible that a portion of the eastern brick wall of the house had been founded on a large detached block within the cliff line, although this could not be confirmed due to an existing drainage channel and previous waterproofing of the wall; see Plate 2 below.

Plate 1: Overhang and detached block located beside the south-eastern corner of the house

Plate 2: Detached block located against (or possible below) the eastern brick wall of the house

The neighbouring property to the north (7 Barrabooka Street) contained a three storey brick house set back approximately 0.9m from the common boundary. The house was located within the eastern portion of the site and behind (i.e. to the east of) the above mentioned cliff line which was exposed below a deck on the western side of the house. The southern end of the deck was supported by sandstone bedrock and/or detached blocks within the cliff line, although the central and northern portions appeared to be supported on clayey fill (maximum 1.2m thick) above the bedrock surface. Below the cliff line, the rear yard of the neighbouring site was terraced over three levels and supported by blockwork retaining walls (maximum height of approximately 1.2m). Sandstone bedrock was observed outcropping beyond the western site boundary.

The neighbouring property to the south (3 Barrabooka Street) contained a three storey house set back approximately 1m from the common boundary and comprised a three level brick house located in the western portion of the site. The eastern (i.e. front) portion of the property contained a driveway and a garden area which comprised outcropping sandstone bedrock, detached sandstone blocks, a lawn and low height retaining walls. The rear of the property contained a grass yard that gently sloped down to the west away from the house. Sandstone bedrock was observed outcropping beyond the western site boundary.

4 SUBSURFACE CONDITIONS

The 1:100,000 series geotechnical map of Sydney (Geological Survey of NSW, Geological Series Sheet 9130) indicates the site to be underlain by Hawkesbury Sandstone and this was confirmed by several sandstone exposures both within the subject site and the neighbouring properties. Where bedrock is not exposed at the ground surface, we anticipate the subsurface conditions would comprise a limited depth of fill and/or residual soils overlying weathered sandstone bedrock at shallow depth.

Groundwater would be expected well below ground surface level, though minor ephemeral seepage may occur over and through the bedrock particularly during and following heavy and prolonged rainfall.

5 GEOTECHNICAL ASSESSMENT

The hillside within and surrounding the site generally grades down to the west at an average slope of approximately 15° with a near vertical sandstone cliff line located within the central portion of the site below the exiting timber deck.

The north-eastern portion of the house had been excavated a maximum vertical depth of approximately 4.5m into the sandstone cliff line, whereas the south-eastern portion of the house is set back between approximately 1m and 2m from the cliff. Several detached blocks were exposed within the cliff line beside the house. The sandstone bedrock within and surrounding the subject site was generally assessed as being slightly weathered and of medium strength.

There are a number of retaining walls within the site including adjacent to the front driveway and carport, rear terraced garden, and the north-eastern portion of the house. Where observations were possible, these walls were in fair condition with the exception of the mortared and dry stacked sandstone boulder wall along the eastern portion of the southern site boundary which was leaning over (i.e. to the south) a maximum of approximately 3°. We note that the condition of the mortared sandstone block retaining wall along the central portion of the southern boundary could not be assessed due to the existing vegetation in that area.

5.1 Potential Geotechnical Hazards

Based on our walkover inspection, we consider the potential geotechnical hazards associated with the site to be the following:

A Stability of existing retaining walls:

(i) On the northern side of the driveway;
(ii) On the southern side of the driveway;
(iii) On the southern side of the existing carport;
(iv) On the eastern side of the existing house; and
(v) Within the terraced garden area on the western side of the house.

B Stability of the existing sandstone cliff line:

(i) Instability of the cliff face which impacts the proposed addition; and
(ii) Instability of the cliff face which impacts the existing house.

Whilst on site, our observations did not reveal any obvious signs of both near surface and/or deep seated soil instability such as tension cracks, bulging slopes, leaning trees etc. Furthermore, considering the presence of a sandstone cliff line and several sandstone outcrops within and surrounding the subject site, we consider the likelihood of a shallow soil slump or deep seated instability through the bedrock to be barely credible.

5.2 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. 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 is either Low or Very Low, which would be considered 'Acceptable' in accordance with the criteria given in Reference 1.

We have also used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life. The temporal and vulnerability factors that have been adopted are given in the attached Table B together with the resulting risk calculation. Our assessed risk to life for the person most at risk is about 2.4×10^{-7}. This would also be considered to be 'Acceptable' in relation to the criteria given in Reference 1.

5.3 Risk Assessment

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.

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, these walls must be inspected by a structural engineer to confirm whether the walls will be suitable for the design life of the building (i.e. expected to be 100 years) or if replacement/strengthening is required.

We have 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.

6 COMMENTS AND RECOMMENDATIONS

We consider that the proposed development may proceed provided the following 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.

6.1 Landslide Risk Management Measures

The proposed two storey addition will be constructed within the central and eastern portions of the site and will extend over the existing sandstone cliff line and adjoin the portion of the house that will remain. We understand that several existing retaining walls will also be retained as part of the proposed development. Whilst risk levels have been assessed to be at 'Acceptable' levels, the existing sandstone cliff line is partly covered by the existing timber deck and although the current retaining walls are generally in fair condition, the following measures must be taken:

- Prior to the commencement of construction, a structural engineer must assess the existing retaining walls that will remain. The purpose of the structural assessment is to advise whether the existing retaining walls are suitable for the design life of the building (i.e. assumed to be 100 years), or to provide advice on strengthening or replacement, as necessary.
- Based on the results of our walkover inspection, the detached block shown in Plate 1 may need to be stabilised using rock bolts or removed from the cliff face subject to the additional geotechnical inspection. The cliff face overhang may also need to be either removed or underpinned. It is not clear what impact removal of the detached block/overhang will have on the stability of the overlying/adjacent portions of the cliff line and JK Geotechnics must inspect the cliff face immediately following demolition of the carport and timber deck. Following the inspection, it is possible that additional potentially unstable blocks of rock may be identified and JK Geotechnics will need to provide further advice on appropriate stabilisation measures shortly thereafter. The stabilisation of any hazards that extend across the common boundary will need to be discussed with the adjoining property owner.

6.2 Site Preparation and Demolition

Bulk excavation for construction of the proposed two storey addition is not expected, as the proposed upper ground floor, Level 1 and footbridge will be suspended above current surface levels. As such, dilapidation surveys on the neighbouring properties to the north and south are not recommended. However, where hydraulic rock hammers are used such as for footings excavations, dilapidation surveys should be completed on the neighbouring structures and can be used as a benchmark against which to set vibration limits for rock excavation and for assessing possible future claims for damage arising from the works. The owners of the adjoining properties should be asked to confirm in writing that the dilapidation survey report on their property presents a fair assessment of the existing conditions. As dilapidation survey reports are relied upon for the assessment of potential future damage claims, they must be carried out thoroughly with all defects rigorously described (ie. defect type, defect location, crack width, crack length etc) and defects photographed where practical.

Internal alterations and additions are proposed within the western portion of the house that will remain. At this stage, additional structural loads are also not anticipated for the proposed works. Where this is not the case, we expect the existing footings are founded on weathered sandstone bedrock and consider an allowable bearing pressure of 1,000kPa for sandstone bedrock of at least low strength can be adopted to check the capacity of the existing footings to support any new structural loads. If existing footings will be subjected to additional loads, then test pits must be excavated so that a geotechnical engineer can assess the foundation materials, and advise of any underpinning, if appropriate. Where an existing footing is founded on a detached sandstone block, regardless of whether additional structural loads will be applied, further advice must be sought from JK Geotechnics.

Demolition of any existing walls, footings, concrete slabs etc. must be carried out with care and necessary bracing (i.e. vertical and lateral support) of existing walls that are to remain must be designed by the structural engineer, so as not to destabilise or remove support from the existing house.

Prior to the commencement of the removal of the concrete surfaces and/or footings etc, we recommend that a saw cut be provided at the interface with sections of any paved surfaces that will remain. This will assist in controlling potential damage associated with removal of the adjacent paved surface and/or footings. We expect the saw cut pieces will be removed using a ripping tyne and bucket attachments to tracked excavators.

6.3 Footings

For uniformity of support, the proposed two storey addition must be founded in the underlying weathered sandstone bedrock of at least low strength which is anticipated at shallow depth. All footings located within a theoretical line drawn up from the base of the cliff line at 1 Vertical (V) in 1 Horizontal (H) must be designed based on an allowable bearing pressure of 500kPa. Following the additional cliff line inspection outlined in Section 6.1 above, the allowable bearing pressure may potentially be upgraded provided that no adversely orientated joints, overhangs, undercuts etc. which may potentially impact the stability of the cliff line, are present. All other high level footings founded on sandstone bedrock of at least low strength and set well back from the cliff face may be designed based on an allowable bearing pressure of 1,000kPa, subject to geotechnical inspection.

All high level footing excavations must be excavated, cleaned out, inspected by JK Geotechnics, and poured with minimal delay. All footings must be free from all loose or softened materials prior to pouring concrete.

7 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. If there is any change in the proposed development described in this report then all recommendations should be reviewed. 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.

TABLE A

SUMMARY OF RISK ASSESSMENT TO PROPERTY

POTENTIAL GEOTECHNICAL HAZARD	**A – Stability of Existing Retaining Walls**					**B – Stability of Existing Sandstone Cliff Line**	
	(i) On the northern side of the driveway	(ii) On the southern side of the driveway	(iii) On the southern side of the existing carport	(iv) On the eastern side of the existing house	(v) Within the terraced garden area on the western side of the house	(i) Instability of the cliff face impacting the proposed addition	(ii) Instability of the cliff face impacting the existing house
Assessed Likelihood	Rare	Rare	Rare	Rare	Rare	Unlikely	Unlikely
Assessed Consequence	Insignificant	Insignificant	Minor	Medium	Insignificant	Minor	Minor
Risk	Very Low	Very Low	Very Low	Low	Very Low	Low	Low
Comments	A (i to v): Assumes localised instability. All retaining walls that will be kept must be inspected by a structural engineer who must advise whether the walls are to be strengthened or replaced, if required. A (iii): The condition of the retaining wall is based on a visual appraisal of the adjacent retaining wall to the east. B (i & ii): The hazard comprises detachment of a potentially loose block or overhang. The assessed likelihood assumes that following demolition of the existing carport and timber deck, the sandstone cliff line is reinspected by JK Geotechnics to further assess its stability and to direct all necessary stabilisation measures, such as installing rock bolts, shotcrete, drainage, underpins etc.						

TABLE B

SUMMARY OF RISK ASSESSMENT TO LIFE

POTENTIAL LANDSLIDE HAZARD	A – Stability of Existing Retaining Walls[1]					B – Stability of Existing Sandstone Cliff Line[2]	
	(i) On the northern side of the driveway	(ii) On the southern side of the driveway	(iii) On the southern side of the existing carport	(iv) On the eastern side of the existing house	(v) Within the terraced garden area on the western side of the house	(i) Instability of the cliff face impacting the proposed addition	(ii) Instability of the cliff face impacting the existing house
Assessed Likelihood	Rare	Rare	Rare	Rare	Rare	Unlikely	Unlikely
Indicative Annual Probability	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-5}	10^{-4}	10^{-4}
Persons at risk	(i) Person walking on driveway (ii) Person gardening	Person gardening	Person driving into or walking through the carport	Person within the house	Person within the terraced garden area	Person within the house	Person within the house
Duration of Use of area Affected (Temporal Probability)	(i) 1.39×10^{-3} (i.e. 2mins per day) (ii) 5.95×10^{-3} (i.e. 1hr per week)	5.95×10^{-3} (i.e. 1hr per week)	1.39×10^{-3} (i.e. 2mins per day)	0.5 (i.e. 12hrs per day)	4.17×10^{-2} (i.e. 1hr per day)	0.5 (i.e. 12hrs per day)	0.5 (i.e. 12hrs per day)
Probability of not Evacuating Area Affected	0.1 (i.e. prior warning likely)	0.1 (i.e. prior warning likely)	0.7 (i.e. prior warning unlikely)	0.3 (i.e. some warning likely)	0.1 (i.e. prior warning likely)	0.8 (i.e. prior warning unlikely)	0.8 (i.e. prior warning unlikely)
Spatial Probability	1.15×10^{-1} (i.e. 2m wide collapse across a 13m long wall)	1.14×10^{-1} (i.e. a 2m wide collapse across a 13m long wall)	5×10^{-1} (i.e. a 2m wide collapse across a 4m long wall)	3.75×10^{-1} (i.e. a 3m wide collapse across a 8m long wall)	1.25×10^{-1} (i.e. a 2m wide collapse across a 16m long wall)	3.33×10^{-1} (i.e. a 2m long detached block impacting the eastern portion of the proposed building which is 6m long)	2.50×10^{-1} (i.e. a 2m long detached block impacting the eastern portion of the building which is 8m long)
Vulnerability to Life if Failure Occurs Whilst Person Present	0.01 (i.e very unlikely to be buried)	0.01 (i.e very unlikely to be buried)	0.01 (i.e very unlikely to be buried)	0.01 (i.e house very unlikely to collapse)	0.01 (i.e very unlikely to be buried)	0.01 (i.e. proposed two storey addition very unlikely to collapse)	0.01 (i.e. unlikely to have significant debris penetrating the wall of the existing house)
Risk for Person most at Risk	(i) 1.60×10^{-12} (ii) 6.84×10^{-12}	6.78×10^{-12}	4.87×10^{-11}	5.63×10^{-9}	5.21×10^{-11}	1.33×10^{-7}	1×10^{-7}
Total Risk	2.4×10^{-7}						
Comments	1. All retaining walls that will be kept must be inspected by a structural engineer who must advise whether the walls are to be strengthened or replaced, if required. 2. The hazard comprises detachment of a potentially loose block or overhang. Assumes that any instability will impact the south-eastern corner of the existing house/proposed addition. The assessed likelihood assumes that following demolition of the existing carport and timber deck, the sandstone cliff line is reinspected by JK Geotechnics to further assess its stability and to direct all necessary stabilisation measures, such as installing rock bolts, shotcrete, drainage, underpins etc.						

AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

This plan should be read in conjunction with the JK Geotechnics report.

Title:	**SITE LOCATION PLAN**
Location:	5 BARRABOOKA STREET, CLONTARF, NSW
Report No: 37023PHE	Figure No: 1

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PLOT DATE: 30/09/2024 10:50:15 AM DWG FILE: J:\6F GEOTECHNICAL JOBS\37000'S\37023PE CLONTARF\CAD\37023PHE.DWG

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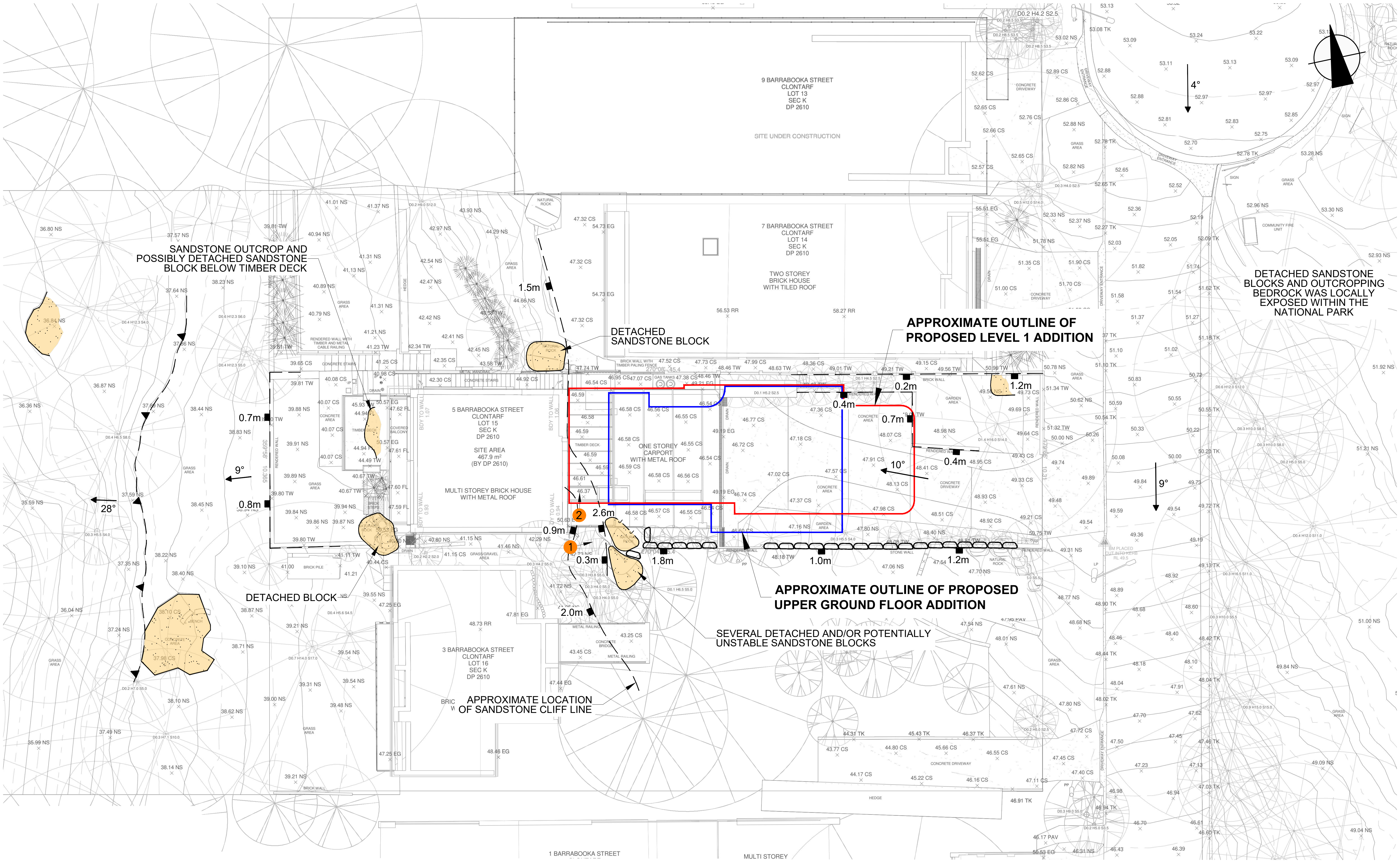

LEGEND

① PHOTOGRAPHIC PLATE NUMBER, LOCATION AND DIRECTION

NOTE:
REFER TO FIGURE 3 FOR GEOTECHNICAL MAPPING SYMBOLS.

0 2 4 6 8 10

SCALE 1:200 @A3 METRES

This plan should be read in conjunction with the JK Geotechnics report.

Title:	GEOTECHNICAL SITE PLAN
Location:	5 BARRABOOKA STREET, CLONTARF, NSW
Report No: 37023PHE	Figure No: 2

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PLOT DATE: 30/09/2024 2:31:18 PM DWG FILE: J:\6F GEOTECHNICAL JOBS\37000'S\37023PE CLONTARF\CAD\37023PHE.DWG

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TOPOGRAPHY

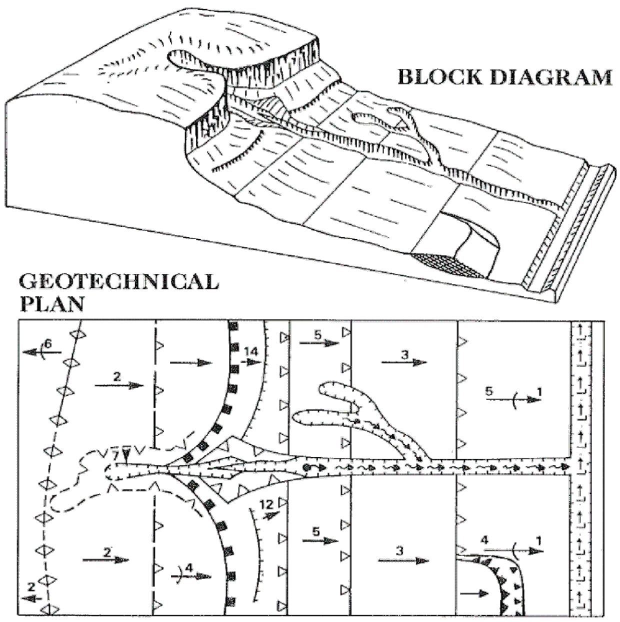
Symbol	*Ground Profile*		
		convex concave	well defined or angular break of slope
		convex concave	poorly defined or smooth change of slope
breaks of slope changes of slope			convex and concave too close together to allow the use of separate symbols
sharp rounded			ridge crest
3	Cliff or escarpment or 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).



Title:	**GEOTECHNICAL MAPPING SYMBOLS**
Location:	5 BARRABOOKA STREET, CLONTARF, NSW
Report No: 37023PHE	Figure No: 3

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This plan should be read in conjunction with the JK Geotechnics report.

PLOT DATE: 30/09/2024 10:50:39 AM DWG FILE: J:\6F GEOTECHNICAL JOBS\37000'S\37023PE CLONTARF\CAD\37023PHE.DWG

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APPENDIX A

LANDSLIDE RISK

MANAGEMENT

TERMINOLOGY

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.

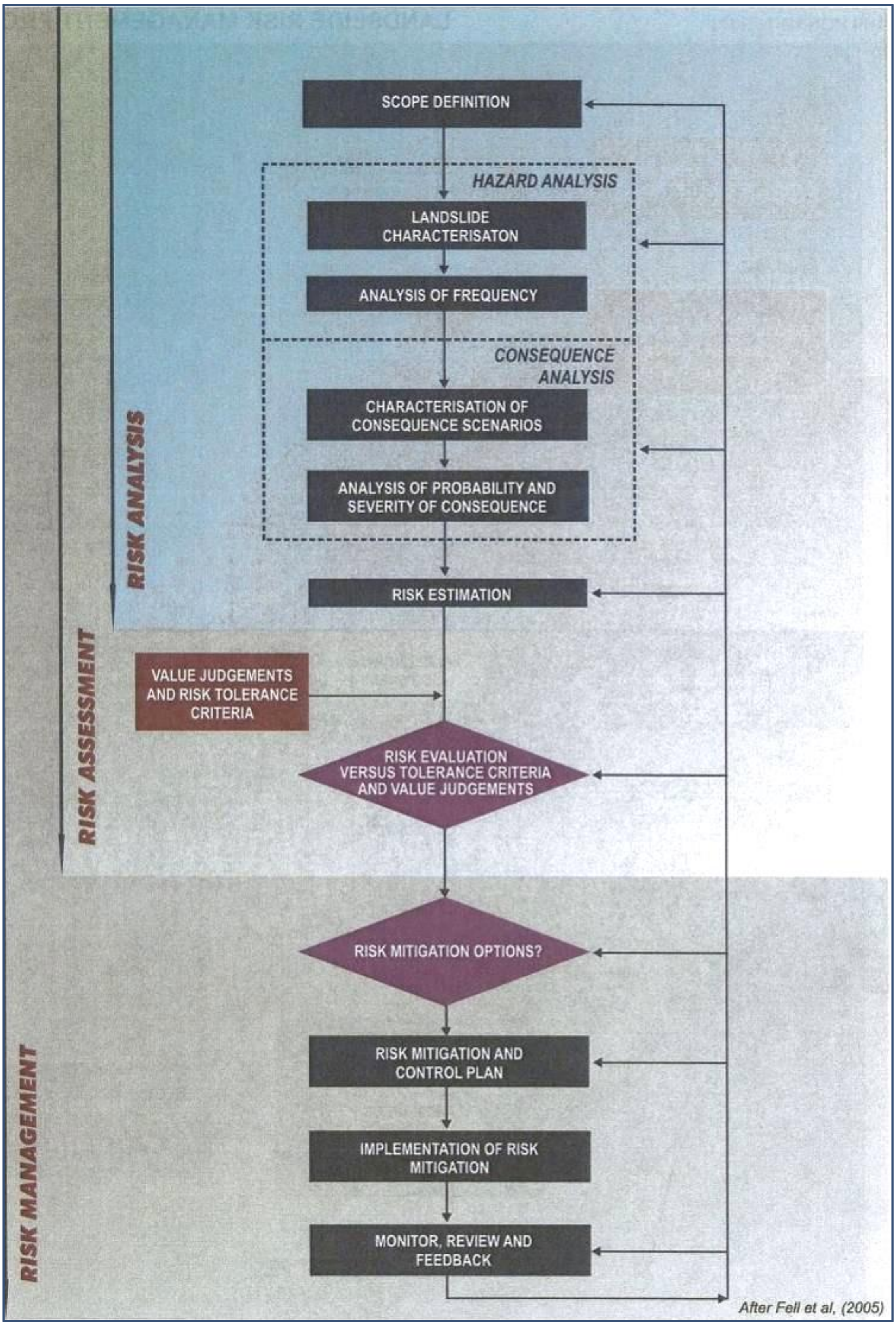

FIGURE A1: Flowchart for Landslide Risk Management.

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}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-2}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
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%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

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

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

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

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.

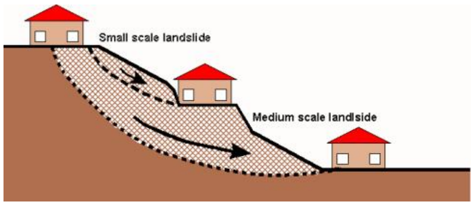

Figure 1

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.

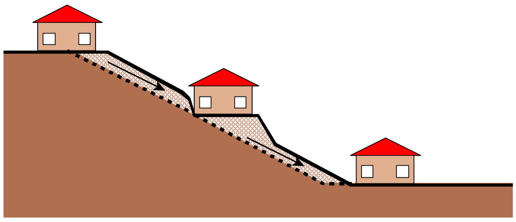

Figure 2

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.

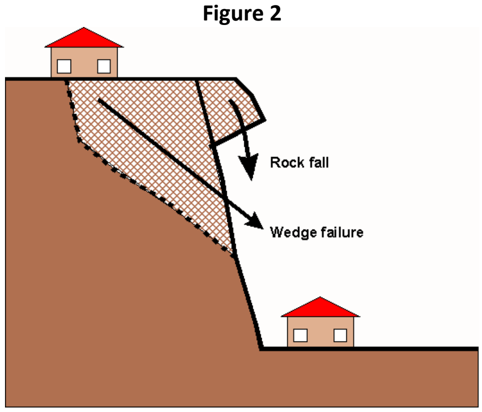

Figure 3

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.

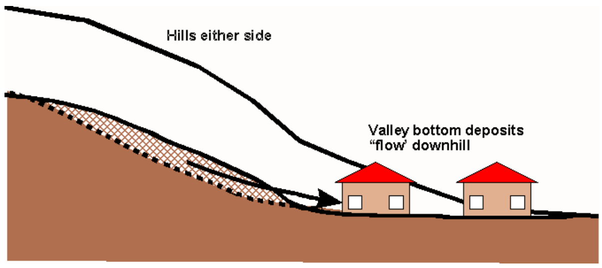

Figure 4

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.

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

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

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

Risk to Property

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

TABLE 2 – LIKELIHOOD

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

The terms "unacceptable", "may be 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 of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1 – RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

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:

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APPENDIX B

SOME GUIDELINES

FOR

HILLSIDE CONSTRUCTION

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

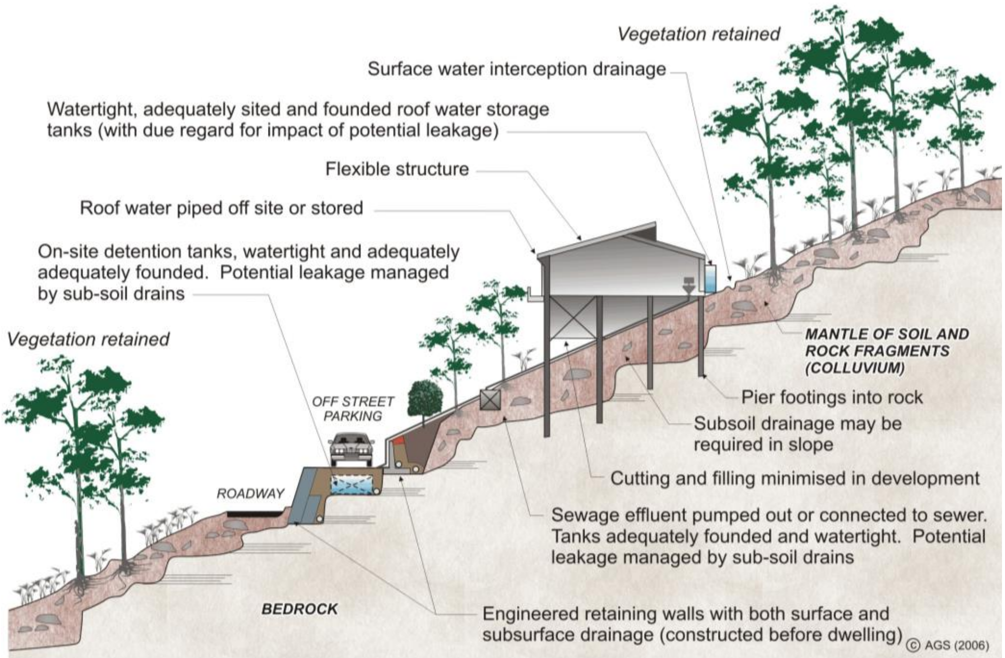
	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having 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 extracted 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)

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.

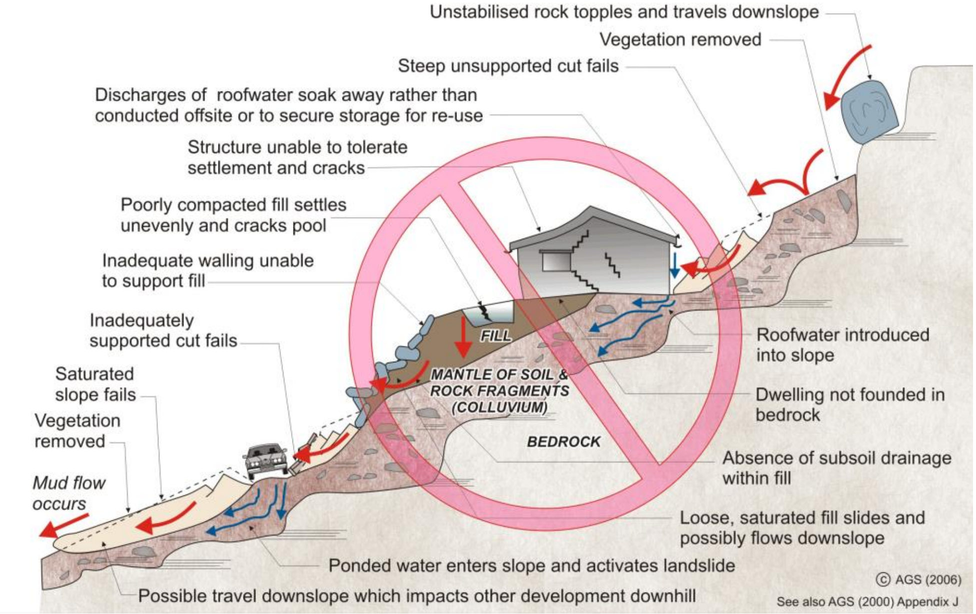
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

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 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.