REPORT TO

ROYAL HASKONINGDHV

ON

GEOTECHNICAL ASSESSMENT

OF

EXISTING FORESHORE CLIFF FACES

AT

VARIOUS LOCATIONS BETWEEN CULBURRA BEACH AND RACECOURSE BEACH, SHOALHAVEN CITY COUNCIL LOCAL GOVERNMENT AREA, NSW

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JKGeotechnics
www.jkgeotechnics.com.au

T: +61 2 9888 5000
Jeffery and Katauskas Pty Ltd trading as JK Geotechnics
ABN 17 003 550 801

Report prepared by:

Paul Roberts
Principal Associate | Engineering Geologist

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

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Table A1 to A6: Summary of Risk Assessment to Property Under Existing Conditions

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Figure 1: Site Location Plan

Appendix A: Landslide Risk Management Terminology

1 INTRODUCTION

This report presents the results of a geotechnical assessment of the selected sections of foreshore cliff lines within the Shoalhaven City Council Local Government Area (LGA). The geotechnical assessment was commissioned by Richard Plain (Royal HaskoningDHV [RH]) in an email dated 15 November 2016. The commission was on the basis of our fee proposal (Ref. P43342ZRlet) dated 20 September 2016.

We have been provided with the following documents:

1. A Coastal Slope Instability Study for the Shoalhaven City Council Coastal Zone Management Study and Plan (Ref. 3001209-020, dated August 2008, prepared on behalf of Shoalhaven City Council (SCC) by SMEC Australia (SMEC).
2. A Shoalhaven Coastal Hazard Study Summary Report for the Shoalhaven Coastal Zone Management Plan (Ref. 3001209-019 Rev. 3, dated 20 July 2009) prepared on behalf of SCC by SMEC.
3. A Draft Shoalhaven Coastal Emergency Response Management Plan (Ref. 2239/R04/V2, dated March 2009) prepared on behalf of SCC by Umwelt (Australia) Pty Ltd (Umwelt).
4. Site Specific Emergency Action Plans (Ref. 3001721 Rev. 2, dated 16 May 2011) prepared on behalf of SCC by SMEC.
5. Shoalhaven Public Asset Coastal Risk Management Review (Ref. RN1961.001.00 Rev. 2, dated July 2012) prepared on behalf of SCC by BMT WBM Pty Ltd.
6. Coastal Zone Management Plan (Ref. 2239/RO4_V3, dated October 2012) prepared on behalf of SCC by Umwelt.
7. Shoalhaven Development Control Plan 2014, Chapter G6: Coastal Management Areas (Version 2, dated 1 July 2015) prepared by SCC.
8. Supplementary Geotechnical Observations - Coastal Slope Instability Hazard Study Various Sites Shoalhaven City Council LGA (Project 72051-1, dated 12 July 2011) prepared on behalf of SCC by Douglas Partners (DP)
9. Peer Review - Coastal Slope Instability Hazard Study Various Sites in Shoalhaven City Council LGA (Project 72051-1, dated 12 July 2011) prepared on behalf of SCC by DP.
10. Geotechnical Assessment of stability of Cliffs Line, Bannister Point (Project 12436B, 10 June 1992) prepared on behalf of SCC by DP.
11. Scoping Study and Stability Assessment on Various Lots Surfers Ave, Tallwood Ave and Bannister Head Rd Narrawallee (Project 78319, dated December 2011) prepared on behalf of SCC by DP.
12. Geotechnical assessment of Impact of landslide event at 65 Sunset Strip, Manyana, (Ref. GEOTWOLL038866AA-AArev3, dated 10 December 2015) prepared on behalf of Ms E Orr by Coffey Geotechnics Pty Ltd (Coffey).
13. Geotechnical report on ‘Slope Failures Two Sites within the Shoalhaven City Council LGA’ at 65 Sunset Strip, Manyana, and 168 Mitchell Parade, Mollymook (Project 78771.00, dated 8 September 2015) prepared on behalf of Mills Oakley Lawyers by DP.
14. Coastal Erosion: stormwater impact assessment (Ref. 1340 Rev. 2, dated 18 June 2015) prepared by Footprint Sustainable Engineering.
15. Geotechnical assessment of ‘Landslip at Lot 219, No. 168 Mitchell Parade, Mollymook’ (Ref. 2015117:amw, dated 15 September 2015) prepared by Southern Geotechnics.

16. Landslide risk assessment, Public Reserve Areas below 27 Sunset Strip, Manyana and 231 Mitchell Parade, Mollymook Beach (Ref. GEOTWOLL03799AD-AB (Rev.1), dated 4 August 2016) prepared by Coffey.
17. Geotechnical assessment at 'No. 20 Myrniong Grove, Berrara' (Ref. GEOTWOLL03902AB-AA, dated 14 March 2016) prepared on behalf of John Drew by Coffey.
18. Geotechnical assessment of 'Landslide Mitigation Options 65 Sunset Strip, Manyana' (Ref. 85484.R.001.Rev0, dated 25 May 2016) prepared on behalf of Fiona McGinley by DP.

The geotechnical assessment included site inspections at various locations along the foreshore and a desk top review of the provided information. Based on the results of our assessment, we provide our comments on the current stability of the cliff lines, factors affecting the stability of the cliff lines, current levels of risk to life and property and landslide risk management measures that can be implemented by Council.

We note that RH will cover the coastal engineering aspects of the commission, including:
1. Additional advice with regard to the contents of this report, as necessary.
2. Modifications to Councils LEP and DCP.
3. Owner Notification.
4. Education and Awareness.
5. Program of Works.
6. Emergency Action Subplan.

JK Geotechnics will provide additional advice in relation to items 2, 3, 4, 5 and 6 in a subsequent report.

2 ASSESSMENT PROCEDURE

The assessment was completed by a Senior Associate level engineering geologist on 30 November, 1 and 2 December 2016. The walkover inspection was completed from publicly accessible safe vantage points along the crest and base of the cliff lines at the following locations (see Figure 1):
- Penguin Head and Culburra Beach.
- Plantation Point.
- Hyams Point.
- Berrara Point.
- Inyadda Point.
- Narrawallee.
- Bannisters Point.
- Collers Beach.
- Rennies Beach.
- Racecourse Beach.

We note that at Bannisters Point, the presence of a deep gully in the wave cut platform over the eastern side of the headland and high tidal levels over the south-eastern portion of the headland prevented access between these locations.

The site was compared to similar nearby sites in order to provide a comparative basis for assessing the risk of further instability affecting the site. The attached Appendix A1 defines the terminology adopted for the risk assessment together with a flow chart illustrating the Risk Management Process based on the guidelines given in AGS 2007(c) (Reference 1).

A summary of our observations is presented in Section 3 below. Our specific recommendations regarding landslide risk management are discussed in Section 5, following our risk assessment.

The features described in the following Section 3 are based on hand held tape measure, inclinometer and compass techniques. Should any of the described features be critical to the future maintenance of the site then we recommend they be more accurately located using optical survey techniques.

3 SUMMARY OF OBSERVATIONS

The observations presented below are based on our recent site inspections and have been compared to the site conditions described in Document 1 (prepared by SMEC) and Documents 8 and 10 (prepared by DP). In addition, the foreshore area at Narrawallee, which was not included in Document 1, was described in Document 11 (prepared by DP). To avoid repetition, where site conditions have not changed, no further comments have been provided and the reader should refer to the previous documents for more details.

3.1 Penguin Head and Culburra Beach

The 'boulder armour' described by DP to be 5m to 10m wide and covering the base of the cliff around the north-western portion of the Penguin Head site. Over the western end of the northern cliff face the 'boulder armour' was generally missing or a maximum width of about 4m in places. Localised erosion of the fill batter slope over this area was evident (see Plate 1).

Plate 1

Localised less than 0.5m^3 soil slumps in the vicinity of DP Photo 37 with 'ag' pipes extending down the cliff face from the yard area above (see Plate 2).

Plate 2

The 'armour zone' 5m to 8m wide described by DP over the base of the central eastern portion of the northern cliff face was intermittently present and a maximum width of about 4m (see Plate 3).

Plate 3

The timber lookout at the crest of the cliff at the eastern end of the headland was set-back between about 1m and 1.5m from the crest of the cliff. The base of the cliff face below south-eastern side of the lookout was undercut (maximum height 3.5m and 'depth' 1.8m). The sub-vertical joints in the sandstone above the undercut were open a maximum width of about 0.1m.

Plate 4

The ‘dense cover of rock armour’ described by DP over the base of the eastern end of the southern cliff face was intermittently present and a maximum width of about 4m (see Plate 5).

Plate 5

A recent soil slump (about $8m^3$) had impacted the rear yard area at the crest of the cliff (assessed to be 203 Penguin Head Road). Sections of the damaged brick fence were located on the wave cut platform (see Plate 6).

Plate 6

3.2 Plantation Point

Over the north-westerly facing cliff face, the isolated 0.2m to 0.4m blocks on the beach surface were not observed.

Over the western portion of the north facing cliff face, there were signs of run-off erosion impacting the soil profile. Some trees were leaning over for vertical or had curved bases, suggesting creep of the soil profile (see Plate 7).

Plate 7

Over the eastern portion of the north facing cliff face, there were signs of fretting and spalling of the upper residual clay soil profile (see Plate 8).

Plate 8

A concrete man hole cover was present at the crest of the north-eastern portion of the cliff and an erosion gully (maximum 2m wide and 1.5m deep) was present down the cliff face with traces of concrete on the cliff face and at the toe of the cliff (see Plates 9 and 10).

Plate 9

Plate 10

3.3 Hyams Point

The toe of the vegetated slope at the northern end of the site had been eroded to form a maximum 1m high sub-vertical face (see Plate 11).

Plate 11

The area described by DP as 'concrete faced slope, cracked and spalling' appears to have been remediated and now comprises a concrete block seawall founded on the bedrock wave cut platform. The terraced rear yard above the seawall has been formed using timber landscape retaining walls (see Plate 12).

Plate 12

The discharge area of the stormwater pipe within the east-west orientated easement over the central portion of the site was overgrown (seer Plate 13).

Plate 13

At the southern end of the site there appeared to be arcuate area within the overgrown soil slope that probably represents and old landslip, maximum size about 40m^3 (see Plate 14).

Plate 14

To the south of the old landslip, two 90mm diameter PVC stormwater pipes discharge at the toe of the soil slope. The ends of the pipe have been orientated to the north and south and the discharge of the pipes appears to have eroded the toe of the soil slope. The sub-vertical erosion face was about 0.5m high and the erosion had caused the toe to recede landward about 3m (see Plate 15).

Plate 15

3.4 Berrara Point

A timber deck was located close to the crest of the cliff within the rear yard of 16 Myrniong Grove. The upper section of the cliff comprised an uneven overgrown surface inferred to represent colluvial soils (see Plate 16).

Plate 16

The recent landslip area over the upper portion of the cliff face at 20 Myrniong Grove had been remediated with gabion retaining wall supporting a steep (50°) slope (3m high) which had been provided with erosion control matting that incorporated cells for soil (see Plates 18 and 19).

Plate 17

Plate 18

A number of the gabion baskets forming the top row of the retaining wall were not full of rock. A PVC stormwater pipe discharged part way down the cliff face (see Plates 17 and 18).

The soil slope at the crest of the cliff below 28 Myrniong Grove was concave and sloped down to the south-west at a maximum of about 50^{o}. Patches of residual clay soils and extremely weathered bedrock were evident through the vegetative cover which are assumed to be the result of run-off erosion. This area has been interpreted to represent an old landslip feature (see Plate 19).

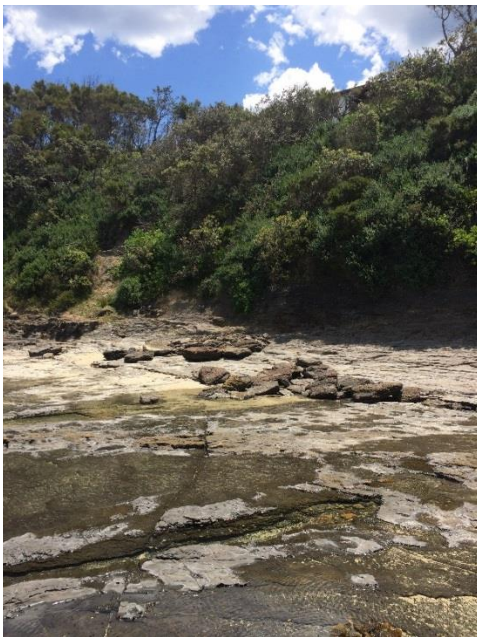


Plate 19

Plate 20

The gully, orientated approximately north-west to south-east, at the southern end of the site appeared to be at the location of a stormwater easement discharge point. An igneous dyke (orientated approximately north-west to south-east) was exposed in the wave cut platform and cliff face immediately to the south west of the gully. We have inferred that fractured and altered bedrock at the margin of the dyke has been preferentially eroded by both wave action and run-off from the stormwater easement and/or run-off from the road above. A similarly orientated gully in the wave cut platform seaward of the gully was also noted.

3.5 Inyadda Point, Manyana

At the northern end of the site (below the northern end of Sunset Strip) the cliff face (maximum height about 7m) exposed a steep soil slope overlying an intermittent vertical sandstone cliff face. There was evidence of near surface slumping of the soil profile and erosion of the sandstone. Some soil erosion debris was present at the toe of the cliff (see Plate 21). The four northernmost properties (1, 3, 5 and 7 Sunset Strip) were identified by DP as 'most at risk from cliff erosion' (DP Photo 20).

Plate 21

The east facing vegetated foreshore slope was inferred to comprise colluvial soils and was typically a maximum of about 30^o. There was evidence of traces of old landslip features and what appeared to be a more recent landslip below 27 Sunset Strip (see Plate 22).

Plate 22

To the west of Inyadda Point, DP previously described a 5m to 10m wide rock armour covering the wave cut platform. The rock armour lining the south facing foreshore slope was either absent or was a maximum width of about 4m (see Plate 23).

Plate 23

The south facing foreshore slope was a maximum of about 35° and a number of erosion gullies were evident and colluvium was exposed in the gully sides. The recent landslip that impacted 65 Sunset Strip in August 2015 was evident (see Plate 24).

Plate 24

There appeared to be an erosion gully on the western boundary of 69 Sunset Strip. The section of Sunset Strip above had been provided with a kerb and gutter but the catchment area included the slope above (see Plate 25).

Plate 25

At the south-western end of the site,' erosion/slump chutes' described by DP were evident but overgrown. The kerb and gutter lining the seaward side of Sunset Strip above (adjacent to 113 Sunset Strip) ended at the property boundary (see Plate 26).

Plate 26

3.6 Narrawallee

The seaward side of Surfers Avenue was lined by a concave slope with a sub-vertical lower portion (maximum overall height about 2.5m high) which generally exposed colluvial clayey soils with gravel and cobbles of sandstone. A localised area of fill appears to have been placed to form the car parking area which was set-back 2m from the crest of the slope (see Plate 27). The seaward side of the road was set-back at least 7m from the crest of the slope.

Plate 27

The wave cut platform was generally covered by rounded sandstone gravels, cobbles and boulders and the platform surface either exposed residual clays, extremely weathered claystone or, locally, high strength silcrete overlying the clays and claystone. Boulders of silcrete were 'blocky' and angular in shape and appeared to have been eroded in-situ by wave action.

To the south of the car park area, the colluvial soils have been eroded to form sub-vertical faces (maximum 2m high) and the tree root systems formed overhangs. Some trees had collapsed onto the wave cut platform. The trees covering the old landslip in the reserve area above were leaning over or had curved bases (see Plate 28).

Plate 28

The tree covered slope at the southern end of the site sloped down to the east at a maximum of about 35°. The slope surface was uneven and the trees were leaning over or had curved bases. The slope appears to have been previously impacted by a number of landslips (see Plate 29).

Plate 29

To the north-west of the car park area, the colluvial soils have been eroded to form sub-vertical faces (maximum 2m high) and the tree root systems formed overhangs. Some trees had collapsed onto the wave cut platform (see Plate 30).

Plate 30

The roadside stormwater drain inlets were typically infilled with leaf debris (see Plate 31).

Plate 31

3.7 Bannisters Point

Over the western portion of the south facing cliff face, the toe erosion of the overgrown colluvium soil profile was intermittent.

At the crest of the cliff, the rear yard of what was inferred to be 168 Mitchell Parade, there appeared to be a gabion retaining wall at the crest of the cliff face and a newly planted soil slope below (see Plate 32).

Plate 32

Some toe erosion of the old rock fall has exposed colluvium over the area of the old rock fall indicated on DP Photo 15 and to the west and east typically forming 1m high sub-vertical faces (see Plate 33).

Plate 33

At the north-eastern end of the Mollymook Beach, at crest of the slope affected by the 'large ancient slump' identified by DP, a timber lookout was set-back about 2m from the crest of the cliff face (see Plate 34).

Plate 34

The section of Mitchell Parade above the eroded back scarp described by DP (DP Photo 16), was not provided with kerb and guttering. This supports the DP inference that the erosion was associated with 'uncontrolled discharge' (see Plate 35).

Plate 35

Where access to the crest of the cliff face was possible between 199 and 215 Mitchell Parade, the profile (in plan) was undulating with steep, uneven, overgrown slopes and a number of trees with curved bases (see Plate 36).

Plate 36

The northern end of the headland comprised an uneven vegetated slope and colluvium had been exposed by erosion at the toe of the slop at the interface with the sandstone bedrock wave cut platform. The sub-vertical erosion faces were a maximum height of about 3m (see Plate 37).

Plate 37

The north-east facing portion of the cliff face (below the car park area to the north of Bannisters) exposed sandstone (maximum height about 6m) below the vegetated colluvium slope. Occasional joint controlled wedge failures were evident (see Plate 38).

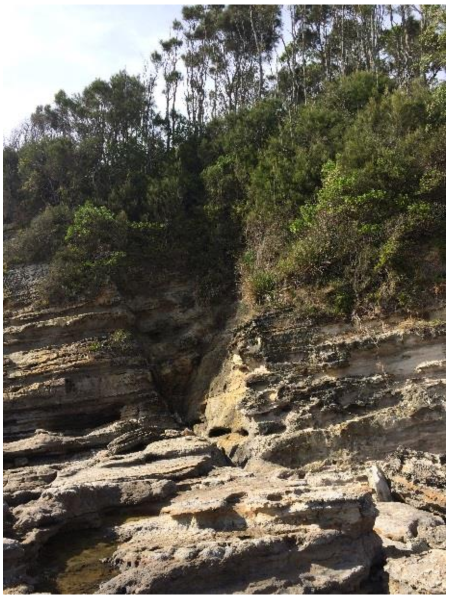


Plate 38

To the south, the cliff face appeared to have a stepped profile comprising; a gently dipping stepped wave cut platform, a lower vertical sandstone bedrock face with a limited soil cover, a vegetated bench area, then a further steep colluvial slope above that sloped back up to the rear yards of the property on Mitchell Parade (see Plate 39).

Plate 39

The wide gully in the wave cut platform (orientated approximately 100°) was lined by sub-vertical joints and what appeared to be a recent rock fall (approximately 100m^3) had impacted the southern side of the gully (see Plate 40).

Plate 40

The cliff face that extended north-west form the northern end of the headland exposed sub-vertical basalt overlying extremely weathered claystone with numerous angular and 'blocky' basalt blocks (maximum 1m dimension) and rounded sandstone gravels and cobbles covering the shoreline (see Plate 41).

Plate 41

The upper steep slope was tree covered; leaning trees and curved tree bases indicating creep was impacting the upper soil profile. The claystone at the base of the cliff was being eroded, resulting in undercutting of the basalt and block collapses (see Plate 42).

Plate 42

3.8 Collers Beach Headland

At the north-western end of the site, the house identified by DP as being '2m to 3m above the wave cut platform' corresponded to 17 Shipton Crescent (see Plate 43).

Plate 43

Immediately to the south-east of the house, the vegetated slope there was a gully that corresponded to the discharge of a stormwater outlet inferred to be present upslope.

To the south-east of Plate 43, there were signs of recent slumping of the lower colluvial soil slopes (maximum about 5m^3) and some sub-vertical toe erosion faces (maximum height about 2m). A sandstone cliff face that was unravelling and spalling was evident landward of the lower colluvial soil slope (see Plate 44).

Plate 44

A new plastic stormwater pipe extended down the full height of the cliff adjacent to an area of fractured and undercut sandstone (see Plate 45). This area was inferred to be below about 61 to 65 Nurrawallee Street.

Plate 45

The cliff face at the south-western end of the site continues to erode and spall along the face and toe with potentially unstable blocks of sandstone evident on the cliff face (see Plates 46 and 47).

Plate 46

Plate 47

3.9 Rennies Beach

The landslip area adjacent to the eastern boundary of 7 Rennies Beach Close and downslope of the adjacent public car park has been remediated using a gabion retaining wall (maximum 4m high) with a maximum 27^{o} vegetated sloping backfill surface above. The stormwater pipe discharged onto a concrete base and a reno mattress had been provided over the majority of the base of the remediated area (see Plate 48).

Plate 48

A creek line was flowing below the remediated area. Sandstone was exposed in the creek bed and extremely weathered claystone was exposed in the sub-vertical creek bank sides (maximum 3m high). Undercut erosion of the claystone was evident (maximum height about 0.5m and 'depth' about 1m) and small slumps had also occurred (maximum size about $0.5m^3$).

The debris from the rock falls identified by DP was missing. There were overhanging sandstone blocks at the locations of DP Photos 7 and 8.

Plate 49

Plate 50

The upper portion of the cliff face over the area of DP photo 7 was unravelling and spalling with small blocks caught on ledges of the cliff face. The sandstone was fractured and maximum 1m x 1m x 1m potentially unstable blocks were evident (see Plates 49 and 50).

The upper section of the cliff face within the gully to the east of DP Photo 8 had been impacted by a small slump, about $5m^3$ (see Plate 51). The area of detachment appeared to be controlled by a 45^o joint sloping down to the south and seepage was evident. There was no kerb and gutter at the eastern end of Rennies Beach Close above and there were signs of run-off erosion (see Plate 52).

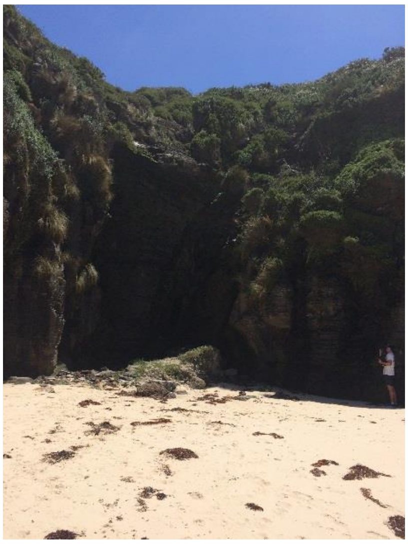


Plate 51

Plate 52

3.10 Racecourse Beach

The cliff face undercut below the south-western side of the car park was a maximum height of 4m and 'depth' of 1.5m (see Plate 53). There was occasional small rocks (less than 0.1m 3) at the base of the cliff. The car park was set-back at least 3m from the crest of the cliff face.

Plate 53

North of the cliff face a marine sand and colluvial soil area sloped down to the south at a maximum of about 20^{o}. A number of erosion gullies were evident and the slope extended landward up to the rear yards of 43 to 49 South Pacific Crescent (see Plate 54).

Plate 54

The uneven surfaced, vegetated colluvial soil slope contained a number of erosion gullies with very little toe erosion evident (see Plate 55).

Plate 55

Some erosion of the toe of the landslip debris lobe (DP Photo 3) was evident and formed sub-vertical faces (maximum about 0.3m high) eroding at the toe (see Plate 56).

Plate 56

4 GEOTECHNICAL ASSESSMENT

4.1 Geological Setting

Reference to the 1:250,000 Geological Maps of Wollongong and Ulladulla indicates that the geological units present at the various sites are as follows:

Permian age Wandrawandian Siltstone; comprising siltstone and silty sandstone, pebbly in parts:

- Culburra Beach and Penguin Head
- Berrara

Permian age Conjola Formation; comprising conglomerate, sandstone and silty sandstone:

- Plantation Point
- Hyams Point
- Inyadda Point, Manyana
- Narrawallee
- Bannisters Point, Mollymook
- Collers Beach Headland, Ulladulla
- Rennies Beach, Ulladulla
- Racecourse Beach, Ulladulla

Tertiary age undifferentiated sediments comprising gravel, sand, clay, quartzite, sandstone and conglomerate and Tertiary age basalt:

- Inyadda Point, Manyana
- Narrawallee
- Bannisters Point, Mollymook
- Collers Beach Headland, Ulladulla

- Rennies Beach, Ulladulla
- Racecourse Beach, Ulladulla

The principal joint sets within the above bedrock units were sub-vertical (at least 60°) and generally orientated between approximately north south (350° and 010°) and east west (090° and 100°), i.e. perpendicular to each other (orthogonal). The lateral spacings typically ranged between about 0.5m and 6m. The bedding in the bedrock was typically sub-horizontal; the maximum dip recorded was about 10° down to the east or west.

Some recent (Quaternary age) marine sands formed dune areas over selected areas of the sites.

Over upper sections of some of the cliff faces, residual soils, derived from in-situ weathering of the bedrock are also likely to be present and would typically contain bands of weathered bedrock. This process can also lead to steep soil slopes often with relic joints from the rock mass that can form planes of weakness or open fissures that allow water to enter the soil profile.

Colluvial soil slopes comprising moderately steep or steep bushland slopes were identified at the various sites. Colluvial soils represent relic landslip deposits and typically contain numerous cobble and boulder sized bedrock inclusions within a sandy or clayey soil matrix.

4.2 Factors Affecting Cliff Face Stability

4.2.1 Bedrock Cliff Faces

At the base of the bedrock cliff faces there were varying quantities of rock debris from previous rock falls and landslips. Blocks of rock along the wave cut platform at the base of the cliff were more angular and 'blocky' in shape, over sections of Penguin Head, Narrawallee, Bannisters Point, Collers Beach Headland and Racecourse Beach. This has been interpreted to indicate debris from more recent instability events. The more angular a rock fragment, the less time wave action has had the opportunity to cause erosion of the blocks. Conversely, where more rounded rocks were present, at Narrawallee, Bannisters Point and Collers Beach Headland, this has been interpreted to indicate debris from older instability events and subsequent erosion by wave action to form the rounded rocks.

The cliff faces have revealed a number of relatively weak features:

- Extremely weathered claystone (Tertiary sediments) underlying sub-vertically jointed Tertiary basalt (an old volcanic lava flow) at Bannisters Point and reported by DP at 65 Sunset Strip, Manyana (Document 18).
- Tertiary claystones overlying Conjola Formation sandstone at Rennies Beach.
- Tertiary sediments forming cliff faces at Collers Beach Headland
- Siltstone bands within the sandstone at Penguin Head and Berrara.

- Weaker silty sandstone bands within sandstones and conglomerates at Plantation Point, Hyams Point, Inyadda Point (Manyana), Narrawallee, Bannisters Point (Mollymook), and Collers Beach Headland, Rennies Beach and Racecourse Beach (Ulladulla).

The geological units represent banded sequences of relatively stronger and weaker rocks. The weaker rocks weather (degrade) and erode more readily and result in undercuts forming below bands of stronger rocks.

The differential weathering and erosion of the above relatively weak features in coastal settings is caused by wave action, rocks carried by waves and impacting the cliff face, 'sand blasting' due to wind action, growth of salt within the rocks introduced by sea spray, and regular wetting and drying of the rocks within the tidal zone.

The differential weathering and erosion of relatively weak features below stronger bedrock formations is a typical mechanism of cliff line collapses due to the undercutting, followed by toppling and/or basal shear of the stronger rocks above the undercuts, and was evident at the sites inspected. The angular and 'blocky' shaped blocks observed at many of the sites has been controlled by the two principal orthogonal sub-vertical joint sets, the sub-horizontal bedding and the spacing of the joints and bedding.

Additional triggers to collapse of potentially unstable features such as undercuts, overhangs, blocks and wedges over the cliff faces are:

- Water pressure developed in the sub-vertical open joints behind potentially unstable features. The water could collect:
  - During and following rainfall events from direct rainfall and associated surface water run-off and/or discharges from poorly maintained and/or poorly designed stormwater drainage,
  - Due to leaking water carrying pipelines (sewers, water mains, pool backwash systems, garden irrigation systems etc).
  - Due to the presence of soil infill and/or vegetative matter that in the open defect that traps water.
- Localised tree root 'jacking' where tree roots penetrate sub-vertical open joints at the rear of potentially unstable features over the cliff faces. In addition, the 'jacking' action of tree roots and growth of tree roots would also lead to a further opening of the joint plane thereby allowing greater quantities of water to accumulate in the defect behind the potentially unstable feature.
- Water collecting in open defects and rotting vegetation in the open defects resulting in continued weathering and degradation of the bedrock forming the defect face. This process of weathering and degradation can then lead to weakening of the intact bedrock in and around the defect area, thus increasing the potential for tensile failure of the intact bedrock.
- Expansion and contraction of the bedrock can also be expected as a response to temperature variations. This would lead to lateral expansion and contraction of the bedrock surfaces forming the open and possibly infilled defect, with additional soil entering the open defect during periods of expansion. The increased quantity of soil infill within the defect would then inhibit the contraction of the bedrock resulting in a build-up of stress, which would lead to further propagation of the defect.

4.2.2 Soil Foreshore Slopes

Colluvial and/or residual soil slopes comprising moderately steep or steep slopes were identified at the sites. Instability of such slopes is typically governed by one or more of the following factors:

- Elevated water pressures within the soils and saturation of the soils (thereby increasing the mass of the soil).
- Over-steep slopes caused by erosion or excavations during development.

Elevated water pressures and saturation of the soils can occur:

- During and following rainfall events due to natural increases in the groundwater level.
- Due to elevated groundwater levels resulting from the removal of trees.
- By infiltration of water into the soil profile during and following rainfall events from direct rainfall and associated surface water run-off and/or discharges from poorly maintained and/or poorly designed stormwater drainage.
- Due to leaking water carrying pipelines (sewers, water mains, pool backwash systems, garden irrigation systems etc).

Over steep slopes are typically formed in the following situations:

- Immediately following landslips; generally the back scarp area at the head of the landslip.
- Erosion due to surface water run-off, particularly where concentrated discharges occur from water carrying pipe lines, other drainage features (soakaway drains) and paved areas (roads, driveways etc.
- Erosion of the toe of the slopes by wave action.

On-going creep of soils is typical over moderate and steeply sloping sites. Creep would be indicated by uneven slope surfaces, localised small scale sub-vertical back scarp features over the slope surface, leaning trees on the slope and/or trees on the slope with curved bases

4.2.3 Conclusions

Based on the above, our site observations and a review of the provided documents, it is evident that the majority of instability affecting the foreshore areas at the ten sites has impacted soil slopes. Bedrock has occasionally been impacted where the lower portion of the soil profile impacted by the land slip represents a residual profile. The principal trigger for the landslips was rainfall, with an increased likelihood of instability associated with a number of the other factors described in Section 4.2.2, above, i.e.:

- The areas of erosion over the upper portions of soil slopes described at various sites.
- The older instabilities that have impacted the slopes lining the north-eastern side of Mollymook Beach below Mitchell Parade and Cliff Avenue.
- The landslip at 20 Myrniong Grove, Berrara.
- The landslip at 65 Sunset Strip, Manyana.
- The landslip at 168 Mitchell Parade, Mollymook.
- The landslip at 231 Mitchell Parade, Mollymook.

- The area of recent and older instability at Surfers Avenue, Tallwood Avenue and Bannister Head Road, Narrawallee. Elevated groundwater levels (possibly artesian) are believed to be the most significant factor impacting stability.

In addition, in our opinion, the recent areas of instability identified during this assessment at the sites listed below were also likely to have been triggered during rainfall events:

- 27 Sunset Strip, Manyana.
- The rear yard area on the southern side of Penguin Head.
- The upper portion of the cliff face at the eastern end of Rennies Beach Close, Ulladulla.

Erosion of the cliff face is occurring, but the instability is relatively localised and typically of relatively small scale. Larger scale instabilities were noted at:

- The eastern end of Racecourse Beach, Ulladulla, which has been assessed to be an old landslip.
- Bannister Head Road, Narrawallee, which could be exacerbated by coastal erosion at the toe of the slope, and Bannisters Point, Mollymook.

4.3 Risk Assessment

4.3.1 General

The likelihood of coastal erosion impacting property is a function of the rate of recession of the cliff faces. Determination of historical rates of recession is a difficult task requiring care, detailed field observations and research. Since issue of Document 1 (prepared by SMEC) there has been criticism of the basis of their calculation of the cliff recession rate, in particular the assumption that sea levels have remained stable for the last 6500 years during the Holocene. The cliff erosion rate then being a direct function of the width of the wave cut platform. We concur with the discussion in Section 4.1.2 of Document 9 (prepared by DP). It would appear that erosion rates much less than the 10mm to 18mm per year calculated by SMEC are more applicable as sea levels may not have remained stable for the last 6500 years. Therefore, the location and form of the current cliff faces are the product of much reduced rates of erosion. However, careful mapping of relic shoreline features developed during the Holocene period, such as older wave cut platforms, semi fossilised shellfish and tube worms and clastic deposits is required to establish a more accurate erosion rate. On this basis, the erosion rates used by SMEC to establish the 'Recession Risk Lines' presented in the CZMP may be regarded as resulting in very conservative lines.

It is recognised that recession would not occur at a uniform rate with time, but is cyclical, occurring in 'bites' that only occur infrequently and typically influenced by:

- The defect spacing (joints and bedding planes) within the rock mass
- Erosion of the softer siltstone/claystone beds leading to undercutting.
- Eventual toppling of the overlying sandstone/conglomerate/basalt with detachment along sub-vertical joint planes.

Looking at the loss of bedrock in another way, it would require an 'unusual' storm event to trigger a loss given the above mechanism. Our site observations have indicated that toppling over extensive lengths of cliff face does not occur immediately undercutting occurs, but more typically manifests as blocks falling from the undercut section or localised sections of collapse. Therefore, there needs to be a process of progressive undercutting combined with a trigger event to cause the failure.

However, the scale of the failure needs to be sufficiently extensive along the cliff face so that it extends upslope as well as along the cliff face in order to affect a considerable portion of the foreshore. That is, in other words, a localised failure is less likely to affect a site landward of the existing cliff face than a larger scale failure. There has been no direct evidence of such a mechanism impacting any of the sites.

However, relatively large scale landslip have impacted sections of the study area, but their principal triggers have been inferred or assessed to be associated with rainfall, elevated groundwater levels and other exacerbating factors such as those described in Section 4.2.2, with possible exacerbation by erosion at the toe of the slope. Put simply, these large scale landslips are not the product of coastal erosion. In this regard, we note that extensive assessment of the area of recent and older instability at Surfers Avenue and Tallwood Avenue, Narrawallee has been undertaken by DP (Documents 10 and 11). DP have recommended installation of instrumentation in order to provide a better understanding of groundwater levels and ground movements.

4.3.2 Potential Geotechnical Hazards

Based on the results of our inspections and review of the provide documents, the potential geotechnical hazards for the sites are summarised and outlined below:

1. Instability of overhang/undercut features, blocks and/or wedges of rock over the cliff face.
2. Instability of foreshore colluvial/residual soil slopes, small scale (less than $5m^3$) and impacting the full width of a residential lot (at least $200m^3$).
3. Large scale cliff face instability.
4. Instability of landslip remediation measures.
5. Creep of steep soil slopes

In our opinion, the persons and property most at risk are:

- Persons on the beach, wave cut platforms, lookouts and in rear yards.
- Site personnel working on landslip remediation measures.
- The lookout structures.
- Landscape structures and houses.
- Utility infrastructure.

It is important to be mindful that rock falls etc can occur at anytime and it would be difficult to impossible to predict when the identified potential hazards will occur. Also, we cannot predict when an extreme or unusual event may occur (such as an earthquake or 1 in 100 year rainfall event etc) and what impact it would have on the stability of the identified potential hazards.

4.3.3 Risk To Property

We provide below our qualitative assessment of risk to property, which has been carried out in accordance with the guidance provided in Reference 1. The terminology adopted is in accordance with Table A1 given in Appendix A.

Our assessment of the risk to property under existing conditions is presented in the attached Tables A1 to A6 and is summarised below.

Tables A1 to A3 apply to the general site areas.

Tables A4 to A6 apply to specific site locations where landslip remediation measures have been installed (Potential Geotechnical Hazard 4), previous instability has occurred recently and/or areas where existing structures are located close to the crest of cliff faces and slopes. The specific locations assessed were:

- Penguin Head Lookout, Culburra Beach,
- 191, 195 and 209 Penguin Head Road, Culburra Beach,
- Deck at 16 Myrniong Grove, Berrara,
- 20 Myrniong Grove, Berrara,
- 28 Myrniong Grove, Berrara,
- 1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana,
- 1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana,
- 27 Sunset Strip Inyadda Point, Manyana,
- 25 and 29 Sunset Strip Inyadda Point, Manyana,
- 65 Sunset Strip Inyadda Point, Manyana,
- 63 and 67 Sunset Strip Inyadda Point, Manyana,
- 63 and 67 Sunset Strip Inyadda Point, Manyana
- 168 Mitchells Parade, Bannisters Point, Mollymook,
- 199 to 215 Mitchell Parade, Bannisters Point, Mollymook,
- Timber Lookout, Bannisters Point, Mollymook,
- 17 Shipton Crescent, Collers Beach, Ulladulla,
- 61 - 65 Nurrawallee Street, Collers Beach, Ulladulla
- Adjacent to 7 Rennies Beach Close, Ulladulla and
- Racecourse Beach Car Park, Ulladulla.

Table A1 indicates that for Potential Geotechnical Hazard 1 (Instability of overhang/undercut features, blocks and/or wedges of rock over the cliff face) the assessed risk to property is Low, which would be considered to be ‘acceptable’, in accordance with the criteria given in Reference 1.

Table A2 indicates that for Potential Geotechnical Hazard 2 (Instability of foreshore colluvial/residual soil slopes, small scale (less than 5m^3) and a larger scale instability impacting the full width of a residential lot (at least 200m^3), the assessed risk to property is Very Low (small scale instability) and Low (larger scale instability), would be considered to be 'acceptable', in accordance with the criteria given in Reference 1.

Table A3 indicates that for Potential Geotechnical Hazard 3 (Large scale cliff face instability.) the assessed risk to property is Very Low or Low, would be considered to be 'acceptable', in accordance with the criteria given in Reference 1.

With regard to Tables A4 to A6 we note the following:

- For the landslip remediation measures (Potential Geotechnical Hazard 4) identified at 20 Myrniong Grove, Berrara, 168 Mitchells Parade, Bannisters Point, and adjacent to 7 Rennies Beach Close, Rennies Beach, the assessed risk to property is Low, would be considered to be 'acceptable', in accordance with the criteria given in Reference 1. This assumes that the landslip remediation measures have been engineer designed.

- Levels of risk to property were assessed to be 'acceptable' at the following locations:
  - Penguin Head Lookout, Culburra Beach,
  - 1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana,
  - 1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana,
  - 199 to 215 Mitchell Parade, Bannisters Point, Mollymook,
  - Timber Lookout, Mollymook Beach, Bannisters Point, Mollymook, and
  - 61 - 65 Nurrawallee Street, Collers Beach, Ulladulla.

- Levels of risk to property were assessed to be Moderate (which would be considered to be 'tolerable', in accordance with the criteria given in Reference 1), at the following locations:
  - 191, 195 and 209 Penguin Head Road, Culburra Beach,
  - Deck at 16 Myrniong Grove, Berrara,
  - 28 Myrniong Grove, Berrara,
  - 27 Sunset Strip Inyadda Point, Manyana,
  - 25 and 29 Sunset Strip Inyadda Point, Manyana,
  - 231 Mitchell Parade, Bannisters Point, Mollymook, and
  - 17 Shipton Crescent, Collers Beach, Ulladulla.

- Levels of risk to property were assessed to be High or Very High (which would be considered to be 'unacceptable', in accordance with the criteria given in Reference 1), at the following locations:
  - 65 Sunset Strip Inyadda Point, Manyana, and
  - 63 and 67 Sunset Strip Inyadda Point, Manyana.

We note that the DP risk assessment (carried out in accordance with the guidance provided in Reference 1) for the Surfers Avenue and Tallwood Avenue general area indicated 'acceptable' risk levels for all identified slope failure modes, with the exception of a deep seated rotational failure, where risk levels were assessed to be at 'tolerable' levels.

With regard to creep of soil slopes, this mechanism has not been presented in the attached Tables. Whilst creep is occurring (Almost Certain likelihood), the consequences to property have been assessed as insignificant and so risk levels are at 'acceptable' (Low) levels, in relation to the criteria given in Reference 1.

4.3.4 Risk To Life

On the basis of the above, and using the information obtained from our site observations, we provide below our qualitative assessment of risk to property and semi quantitative assessment of risk to life. The terminology adopted is in accordance with Table A1 given in Appendix A.

We have used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life. The temporal, vulnerability and evacuation factors that have been adopted are given in the attached Tables B1 to B6 together with the resulting risk calculation. We note that we have assumed that the affected person or persons is immediately above the specific hazard when it occurs (i.e. spatial probability of 1), which may be regarded as conservative.

Our assessed total risk to life for an individual person most at risk, under existing conditions, typically ranges between about 10^{-5} and 10^{-10}. These would be considered to be 'acceptable', in relation to the criteria given in Reference 1. However, we note that with regard to:

- Persons in the rear yard of 191, 195 and 209 Penguin Head Road, Culburra Beach, 199 to 215 Mitchell Parade, Bannisters Point, Mollymook, our assessed risk to life is $5x10^{-5}$ for an individual but increases to 1×10^{-4} for two people, which are 'tolerable', in relation to the criteria given in Reference 1.
- Site personnel required to complete the landslip remediation measure at 65 Sunset Strip, Inyadda Point, Manyana, our assessed risk to life is $9x10^{-4}$ for an individual but increases to 1.8×10^{-3} for two workers, which are 'unacceptable', in relation to the criteria given in Reference 1.

With regard to creep of soil slopes, based on an Almost Certain likelihood and using the appropriate temporal, vulnerability and evacuation factors given in the attached Tables B1 to B6, the assessed risk to life would be less than 10^{-5}. This would be considered to be 'acceptable', in relation to the criteria given in Reference 1.

4.3.5 Additional Comments

A member of the public may have some difficulty grappling with the concept of risk and deciding whether, or not, they 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. Table 3 of Appendix A includes data from NSW for the years 1998 to 2002. A risk of 1 in 100,000 (equivalent to $1x10^{-5}$ which is regarded as 'acceptable' in in relation to the criteria given in Reference 1) 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, falling, drowning, a motor vehicle accident, choking on our food, etc. The reported risks are as follows:

- Motor vehicle accident: 1 in 23,000; equivalent to about 4.3 $x10^{-5}$ ('acceptable' in in relation to the criteria given in Reference 1).
- Falling: 1 in 30,000; equivalent to about 3.3 $x10^{-5}$ ('acceptable' in in relation to the criteria given in Reference 1).
- Drowning: 1 in 70,000; equivalent to about 1.4 $x10^{-5}$ ('acceptable' in in relation to the criteria given in Reference 1).
- Fire: 1 in 180,000; equivalent to about 5.6 $x10^{-6}$ ('acceptable' in in relation to the criteria given in Reference 1).
- Choking on food: 1 in 660,000; equivalent to about 1.5 $x10^{-6}$ ('acceptable' in in relation to the criteria given in Reference 1).

It can be seen that the risks of dying as a result of all of the incidents are greater than 1:100,000 and yet few people actively avoid situations where these risks are present. This should be kept in mind when considering the results of the above risk analysis. Further discussion is presented in Appendix A.

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 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 be made aware of reasonable and practical measures available to reduce risk as far as possible. Hence, risk cannot be completely removed, only reduced, as removing risk is not currently scientifically achievable.

In preparing our recommendations given below we have assumed that no activities on surrounding land which may affect the risk on the subject sites would be carried out. We have further assumed that all Council, buried services and other buried services within, and adjacent to the site are, and will be regularly maintained to remain, in good condition.

With the recommendations outlined in Section 5 below implemented, the assessed risk to life and property would remain at, or be reduced to, 'acceptable' levels, in accordance with the criteria given in Reference 1.

We provide below recommendations regarding landslide risk management measures. These recommendations form an integral part of the Landslide Risk Management (LRM) Process. However, it is a matter for Council and other property owners how they wish to implement the advice provided in Section 5, below.

5 LANDSLIDE RISK MANAGEMENT

We provide below a range of landslide risk management (LRM) measures which we recommend be implemented by Council, private property owners and utility owners. Their purpose, apart from assisting in risk management, is to provide a sense that the LRM process is a matter for all of the community to participate in, and to share in the responsibility for its implementation.

The advice provided below, and its impact on current levels of risk to property, has been summarised on the attached Table C. We note that with the advice below implemented, it can be assumed that the likelihood of a hazard occurring would be reduced by at least one order of magnitude and this would also reduce levels of risk to life in a similar manner. That is for a specific situation, a 'tolerable' risk level would reduce to an 'acceptable' risk level, assuming all other factors remain the same (e.g. occupancy levels etc).

5.1 Water Carrying Services and Stormwater Drainage

All water carrying pipe lines discharging on the slopes and cliff faces should be piped to the base of the slope/cliff and discharged such that the flow is directed away from the slope, i.e. not as implemented at the Hyams Point property, where Plate 15 was taken.

All existing surface (including roof) and subsurface drains, pool backwash systems, septic tanks, water tanks etc, must be subject to ongoing and regular maintenance by the property owners. Within the next 12 months following issue of this report, we recommend that property owners (private property, Council and utility owners) within the coastal area check all water carry pipelines/water storing systems for leaks and/or other damage and repair as necessary. The checks should be undertaken by a registered plumber or other similarly experienced professional. The property owners should be provided with a written report confirming the scope of work completed including any repairs undertaken. This may assist property owners should there be future slope instability within or adjacent to their property and poorly maintained water carrying pipe lines are suspected as a trigger for the instability.

In addition, following this initial maintenance, similar checks should also be carried out at no more than ten yearly intervals with a similar report also prepared.

Abandoned absorption trenches (soakaway drains) and disused service trenches close to the crests of foreshore slopes and cliffs should be excavated and backfilled with cement stabilised sand. This will prevent these areas introducing additional run-off into the slopes and possible increasing the likelihood of instability. Such features should also be checked for during the maintenance inspections described above and confirmation of the works being carried out, where necessary.

For any new developments in the coastal area, it should be a Council requirement that all existing and proposed surface (including roof) and subsurface drains are subject to ongoing and regular maintenance by the property owners as described above. In addition, any proposed pool backwash systems should be piped and discharged to the main sewer system.

The existing Council stormwater drainage adjacent to coastal areas should also be checked by a hydraulic engineer with regard to the design of the system and its capacity. Where necessary, improvements should be made to prevent uncontrolled discharge of stormwater through properties and over slopes, which has the potential to cause instability. This work may well need to be prioritised, with the ten sites identified in this report initially being assessed.

5.2 On-Going Monitoring

In the coastal areas, private property owners and Council should monitor their individual properties or general site area, as appropriate, on an annual basis and after periods of prolonged or heavy rainfall and/or predicted high tidal levels (particularly where they correspond with storm events). The purpose of the monitoring is to assess existing conditions and any indications of deterioration such as cracking of the crest areas of slopes and cliff faces, deformed fence posts, evidence of rock falls and/or soil slumps at the base of the slopes, cracked/leaning/deformed retaining walls lookout structures etc..

It is imperative that such monitoring be formally documented and that the required frequency of reporting (and to whom) is clearly defined. Where incidents of instability have occurred within the monitoring period then, where possible, we suggest that private property owners and Council provide relevant details within the monitoring reports. These details would include the date of the incident, the weather conditions on the day and leading up to the incident, a location plan/sketch, photographs and dimensions of the specific features (block sizes, crack widths etc would also need to be recorded). Where new incidents have occurred, the monitoring reports should be provided to the geotechnical engineer so that if there are any causes for concern, further advice can be provided. The need for site specific stabilisation measures can then be better assessed.

In addition, on a 10 yearly basis, a detailed assessment of all the site areas in this report should be undertaken by experienced geotechnical and coastal engineers to assess current conditions with regard to the contents of this report and the on-going inspection monitoring reports.

Based on previous studies of available rainfall data in relationship to landslide events, in particular a study carried out for the Pittwater area (Walker 2007, Reference 2), we provide the following tentative definition of heavy rainfall and prolonged rainfall:

- Heavy Rainfall: at least 100mm of rainfall in one day, and
- Prolonged Rainfall: at least 150mm of rainfall over a 5 day period.

These amounts of rainfall represent 2 year ARI occurrences for the Pittwater area and are considered reasonable for the Shoalhaven City Council area, unless more specific advice is available to Council.

5.3 Existing Landslip Remediation Measures

At some site locations, landslip remediation measures have recently been installed. We have no information regarding the design or construction details of these remediation measures, or the assessed impact on risk levels as a result of the remediation measures. We recommend that Council request details of the design and construction of the remediation measures, details of the improvement in risk levels and geotechnical certification of the remediation measures. If such information is not available, then the risk assessments presented in Tables A4, A6, B4 and B6 will need to be reassessed.

5.4 Existing Landslips

We note the landslips at 27 and 65 Sunset Strip, Inyadda Point, Manyana have yet to be remediated and should instability of the steep back scarp occur, this could impact the neighbouring properties. With regard to 65 Sunset Strip, Inyadda Point, Manyana, we recommend that the recommendations present in Document 18 (prepared by DP) in relation to modifications to the landslip remediation measures presented in Document 12 (prepared by Coffey) be expedited. However, we note that for at least two site workers, the assessed risk to life was at 'unacceptable' levels. Consequently, appropriate geotechnical advice will be required and close liaison with the contractor to detail safe working procedures.

With regard to 27 Sunset Strip, Inyadda Point, Manyana, the landslip remediation measures proposed in Document 16 (prepared by Coffey) should be implemented.

With regard to 231 Mitchell Parade, Mollymook (also described in Document 16, prepared by Coffey), the landslip remediation measures proposed in Document 16 should be implemented.

With regard to the area of recent and older instability at Surfers Avenue and Tallwood Avenue, Narrawallee assessed by DP (Documents 10 and 11), as noted in Section 4.3.1 above, we recommend that the DP advice to install instrumentation in order to provide a better understanding of groundwater levels and ground movements be implemented. Based on this monitoring, it would be expected that a more appropriate range of landslip remediation measures could be designed and implemented.

5.5 Additional Geotechnical and Coastal Engineering Assessment

Levels of risk to property were assessed to be 'tolerable' at the following locations:

- 191, 195 and 209 Penguin Head Road, Culburra Beach,
- Deck at 16 Myrniong Grove, Berrara,
- 28 Myrniong Grove, Berrara,
- 17 Shipton Crescent, Collers Beach, Ulladulla.

Levels of risk to life for people in the rear yards of 191, 195 and 209 Penguin Head Road, Culburra, and 199 to 215 Mitchell Parade, Bannisters Point, Mollymook, were assessed to be 'acceptable' to 'tolerable' depending on the number of people in the rear yard.

We recommend that Council advise the property owners at 191, 195 and 209 Penguin Head Road, Culburra Beach, 199 to 215 Mitchell Parade, Bannisters Point, Mollymook and 16 and 28 Myrniong Grove, Berrara, that they should seek further geotechnical advice with regard stability of the coastal portions of their sites.

We recommend that Council advise the property owners at 17 Shipton Crescent, Collers Beach, Ulladulla, that they should seek further coastal engineering advice with regard to coastal erosion and the locations of hazards lines that may impact their property. Details of the design and construction of the property should also be required as this will inform the coastal engineering assessment.

We expect that as development continues along the foreshore area, there will be critical appraisal of the current hazard lines presented in the CZMP. Based on our comments on cliff face recession rates presented in Section 4.3.1 above, and the comments presented in Document 9 (prepared by DP), we expect that future developments will propose building footprints that encroach seaward of the current hazard lines. These developments are likely to be supported by geotechnical and coastal engineering reports, providing opinion on why the hazard lines are conservative, and requesting reassessment. This will impose significant cost on land owners and Council. We expect that a future reappraisal of the hazard lines will be warranted and will be better informed by the on-going geotechnical assessment of foreshore sites that has been undertaken to date (including this report). A reappraisal within the next ten years should be considered.

5.6 Additional Advice

With regard to potential instability impacting the lookouts at Penguin Head and Bannisters Point and the car park at Racecourse Beach, the following actions may be taken by Council in the event of instability occurring:

- Immediately close the lookouts.
- Immediately prevent access to the car parking bays at the crest of the cliff.
- Commission a geotechnical assessment then implement the LRM recommendations. For the lookouts this would probably require their re-locations and for the car park, re-location of the fence line landward of its current location.

6 GENERAL COMMENTS

It is possible that the subsurface soil, rock or groundwater conditions encountered during implementation of the landslide risk management measures 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 Council 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.

REFERENCES

1. Australian Geomechanics Society (2007c) *'Practice Note Guidelines for Landslide Risk Management'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp63-114.
2. Walker B.F (2007), *'Rainfall Data Analysis and relation to the landsliding at Newport'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp197-212.

TABLE A1
SUMMARY OF RISK ASSESSMENT TO PROPERTY

General Location	Penguin Head and Culburra Beach	Plantation Point	Hyams Point	Berrara Point	Inyadda Point, Manyana	Narrawallee	Bannisters Point, Mollymook	Collers Beach, Ulladulla	Rennies Beach, Ulladulla	Racecourse Beach, Ulladulla
POTENTIAL GEOTECHNICAL HAZARD 1	**Instability of overhang/undercut features, blocks and/or wedges of rock over the cliff face**									
Assessed Likelihood	Almost Certain									
Assessed Consequences	Insignificant									
Risk	Low									
Comments	Localised failure, does not impact structures at the crest of the cliff face. Larger scale cliff face failures addressed in Table A3. Specific site locations addressed in Tables A4 to A6.									

TABLE A2
SUMMARY OF RISK ASSESSMENT TO PROPERTY

General Location	Penguin Head and Culburra Beach	Plantation Point	Hyams Point	Berrara Point	Inyadda Point, Manyana	Narrawallee	Bannisters Point, Mollymook	Collers Beach, Ulladulla	Rennies Beach, Ulladulla	Racecourse Beach, Ulladulla
POTENTIAL GEOTECHNICAL HAZARD 2	**Instability of foreshore colluvial/residual soil slopes, small scale (less than 5m^3) and large scale (impacting the full width of a residential lot [at least 200m^3]).**									
	Small					Large				
Assessed Likelihood	Likely					Possible				
Assessed Consequences	Insignificant					Insignificant (Assumes only landscape structures impacted, houses set well back from edge of cliff)				
Risk	Low					Very Low				
Comments	Specific site locations addressed in Tables A4 to A6.									

TABLE A3
SUMMARY OF RISK ASSESSMENT TO PROPERTY

General Location	Penguin Head and Culburra Beach	Plantation Point	Hyams Point	Berrara Point	Inyadda Point, Manyana	Narrawallee	Bannisters Point, Mollymook	Collers Beach, Ulladulla	Rennies Beach, Ulladulla	Racecourse Beach, Ulladulla
POTENTIAL GEOTECHNICALHAZARD 3	**Large scale cliff face instability.**									
Assessed Likelihood	Rare	Rare	Rare	Rare	Rare	Rare	Rare	Rare	Rare	Rare
Assessed Consequences	Major	Minor	Major	Major	Major	Major	Major	Major	Major	Major
Risk	Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low
Comments	Failure impacts seaward portion of house	Failure impacts utility infrastructure	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house	Failure impacts seaward portion of house

TABLE A4
SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	Penguin Head Lookout	191, 195 and 209 Penguin Head Road	Deck at 16 Myrniong Grove, Berrara	20 Myrniong Grove, Berrara	28 Myrniong Grove, Berrara	1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana	1, 3, 5 and 7 Sunset Strip Inyadda Point, Manyana
POTENTIAL LANDSLIDE HAZARD	**1** **Instability of cliff face overhang**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**4** **Instability of landslip remediation measures**	**2** **Large scale soil slope instability**	**1** **Instability of blocks and/or wedges of rock over the cliff face**	**2** **Small scale soil slope instability**
Assessed Likelihood	Possible	Likely	Likely	Unlikely	Possible	Likely	Likely
Assessed Consequences	Insignificant	Minor	Minor	Minor	Minor	Insignificant	Insignificant
Risk	Very Low	Moderate	Moderate	Low	Moderate	Low	Low
Comments		Instability assumed to impact the slope and the seaward end of the rear yards.		Assumes remediation measures engineer designed.	Instability assumed to impact the slope and possibly the rear yard.	Assumes localised instability with little, if any, impact on rear yard. Houses set-back from crest of slope.	

TABLE A5
SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	27 Sunset Strip Inyadda Point, Manyana	25 and 29 Sunset Strip Inyadda Point, Manyana	65 Sunset Strip Inyadda Point, Manyana	63 and 67 Sunset Strip Inyadda Point, Manyana	63 and 67 Sunset Strip Inyadda Point, Manyana	168 Mitchells Parade, Bannisters Point, Mollymook	199 to 215 Mitchell Parade, Bannisters Point, Mollymook
POTENTIAL LANDSLIDE HAZARD	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**4** **Instability of landslip remediation measures (Gabion wall)**	**2** **Large scale instability of soil slope**
Assessed Likelihood	Likely	Likely	Almost Certain	Almost Certain	Likely	Unlikely	Likely
Assessed Consequences	Minor	Minor	Medium/Major	Medium	Medium	Minor	Insignificant
Risk	Moderate	Moderate	Very High	Very High	High	Low	Very Low
Comments	Regression of current steep back scarp. Back scarp assessed to be at least 10 seaward of the house.	Assumes any instability would impact a similar section of the slope, i.e. rear yard would not be impacted.	Regression of current steep back scarp assumed to impact the house.	Regression of current steep back scarp assumed to impact the neighbouring houses.	Assumes any instability would impact a similar section of the slope, i.e. extend to the seaward side of the house.	Assumes remediation measures engineer designed.	Houses assessed to be set-back at least 10m from the edge of the cliff

TABLE A6
SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	**231 Mitchells Parade, Bannisters Point, Mollymook**	**231 Mitchell Parade, Bannisters Point, Mollymook**	**Timber Lookout, Bannisters Point, Mollymook**	**17 Shipton Crescent, Collers Beach, Ulladulla**	**61 - 65 Nurrawallee Street, Collers Beach, Ulladulla**	**7 Rennies Beach Close, Ulladulla**	**Racecourse Beach Car Park, Ulladulla**
POTENTIAL LANDSLIDE HAZARD	**2** **Large scale soil slope instability**	**2** **Large scale instability of soil slope**	**2** **Large scale instability of soil slope**	**2** **Large scale instability of soil slope**	**1** **Instability of blocks and/or wedges of rock over the cliff face**	**4** **Instability of landslip remediation measures (Gabion wall)**	**1** **Instability of cliff face overhang**
Assessed Likelihood	Almost Certain	Possible	Possible	Possible	Almost Certain	Unlikely	Possible
Assessed Consequences	Insignificant	Medium	Insignificant	Medium	Insignificant	Medium	Insignificant
Risk	Low	Moderate	Very Low	Moderate	Low	Low	Very Low
Comments	Regression of current steep back scarp assumed to reserve area only.	Assumes further landslip movement results in back scarp regressing landward at least 10m and impacting seaward margin of existing house.	Relatively low cost repairs to lookout, or re-location.	Trigger would be coastal erosion. House assumed to be founded on bedrock. Coastal engineer should assess potential for coast erosion to extend back to the house to confirm risk levels.	Houses assessed to be set-back at least 10m from the edge of the cliff	Assumes remediation measures engineer designed.	Assumes localised instability with fence line and possibly seaward margin of car park.

TABLE B1

SUMMARY OF RISK ASSESSMENT TO LIFE UNDER EXISTING CONDITIONS

General Location	**Penguin Head and Culburra Beach**	**Plantation Point**	**Hyams Point**	**Berrara Point**	**Inyadda Point, Manyana**	**Narrawallee**	**Bannisters Point, Mollymook**	**Collers Beach, Ulladulla**	**Rennies Beach, Ulladulla**	**Racecourse Beach, Ulladulla**
POTENTIAL GEOTECHNICAL HAZARD 1	**Instability of overhang/undercut features, blocks and/or wedges of rock over the cliff face**									
Assessed Likelihood	Almost Certain									
Indicative Annual Probability	$1x10^{-1}$									
Persons at Risk	In rear yard On beach or platform at the toe of the slope/cliff face In reserve area at the crest of the slope									
Number of Persons Considered	2									
Duration of Use of Area Affected (Temporal Probability)	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff, or in reserve (Plantation Point); 4×10^{-5}									
Probability of Not Evacuating Area Affected	0.01									
Spatial Probability	1									
Vulnerability to Life if Failure Occurs Whilst Person Present	0.01 (rear yard) 0.5 (beach, platform at the base of the cliff and reserve at the crest of the slope)									
Risk for Person Most at Risk	2×10^{-7} (rear yard) 2×10^{-8} (beach, platform at the base of the cliff and reserve at the crest of the slope)									
Total Risk	4×10^{-7} (rear yard) 4×10^{-8} (beach, platform at the base of the cliff and reserve at the crest of the slope)									

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.

Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.

Specific site locations addressed in Tables B4 to B6.

TABLE B2

SUMMARY OF RISK ASSESSMENT TO LIFE UNDER EXISTING CONDITIONS

General Location	Penguin Head and Culburra Beach	Plantation Point	Hyams Point	Berrara Point	Inyadda Point, Manyana	Narrawallee	Bannisters Point, Mollymook	Collers Beach, Ulladulla	Rennies Beach, Ulladulla	Racecourse Beach, Ulladulla
POTENTIAL GEOTECHNICAL HAZARD 2	**Instability of foreshore colluvial/residual soil slopes, small scale (less than 5m^3) and large scale (impacting the full width of a residential lot [at least 200m^3]).**									
	Small Scale					Large Scale				
Assessed Likelihood	Likely					Possible				
Indicative Annual Probability	1×10^{-2}					1×10^{-3}				
Persons at Risk	In rear yard On beach or platform at the toe of the slope/cliff face In reserve area at the crest of the slope									
Number of Persons Considered	2									
Duration of Use of Area Affected (Temporal Probability)	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff, or in reserve (Plantation Point); 4×10^{-5}									
Probability of Not Evacuating Area Affected	0.01					0.1				
Spatial Probability	1									
Vulnerability to Life if Failure Occurs Whilst Person Present	0.1					0.5				
Risk for Person Most at Risk	2×10^{-7} (rear yard) 4×10^{-10} (beach, platform at the base of the cliff and reserve at the crest of the slope)					1×10^{-6} (rear yard) 2×10^{-9} (beach, platform at the base of the cliff and reserve at the crest of the slope)				
Total Risk	4×10^{-7} (rear yard) 8×10^{-10} (beach, platform at the base of the cliff and reserve at the crest of the slope)					2×10^{-6} (rear yard) 4×10^{-9} (beach, platform at the base of the cliff and reserve at the crest of the slope)				

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.
Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.
Large scale instability assumes only landscape structures impacted, houses set well back from edge of cliff.
Specific site locations addressed in Tables B4 to B6.

TABLE B3

SUMMARY OF RISK ASSESSMENT TO PROPERTY

General Location	Penguin Head and Culburra Beach	Plantation Point	Hyams Point	Berrara Point	Inyadda Point, Manyana	Narrawallee	Bannisters Point, Mollymook	Collers Beach, Ulladulla	Rennies Beach, Ulladulla	Racecourse Beach, Ulladulla
POTENTIAL GEOTECHNICAL HAZARD 3	**Large scale cliff face instability.**									
Assessed Likelihood	Rare									
Indicative Annual Probability	1×10^{-5}									
Persons at Risk	In rear yard On beach or platform at the toe of the slope/cliff face In reserve area at the crest of the slope In the house									
Number of Persons Considered	2									
Duration of Use of Area Affected (Temporal Probability)	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff, or in reserve (Plantation Point); 4×10^{-5} Person in house; 0.3									
Probability of Not Evacuating Area Affected	0.5									
Spatial Probability	1									
Vulnerability to Life if Failure Occurs Whilst Person Present	1									
Risk for Person Most at Risk	1×10^{-7} (rear yard and reserve) 2×10^{-10} (beach, platform at the base of the cliff and reserve at the crest of the slope) 1.5×10^{-6} (in house)									
Total Risk	2×10^{-7} (rear yard and reserve) 4×10^{-10} (beach, platform at the base of the cliff and reserve at the crest of the slope) 3×10^{-6} (in house)									

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.

Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.

Person in house, occupancy based on 8hrs per day: about 0.3.

Specific site locations addressed in Tables B4 to B6.

TABLE B4

SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	**Penguin Head Lookout**	**191, 195 and 209 Penguin Head Road**	**Deck at 16 Myrniong Grove, Berrara**	**20 Myrniong Grove, Berrara**	**28 Myrniong Grove, Berrara**	**1, 3, 5 and 7 Sunset Strip Inyadda Point**	**1, 3, 5 and 7 Sunset Strip Inyadda Point**
POTENTIAL LANDSLIDE HAZARD	**1** **Instability of cliff face overhang**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**4** **Instability of landslip remediation measures**	**2** **Large scale soil slope instability**	**1** **Instability of blocks and/or wedges of rock over the cliff face**	**2** **Small scale soil slope instability**
Assessed Likelihood	Possible	Likely	Likely	Unlikely	Possible	Likely	Likely
Indicative Annual Probability	$1x10^{-3}$	$1x10^{-2}$	$1x10^{-2}$	$1x10^{-4}$	$1x10^{-3}$	$1x10^{-2}$	$1x10^{-2}$
Persons at Risk	Person in lookout Person on platform below	In rear yard On beach or platform at the toe of the slope					
Number of Persons Considered	2						
Duration of Use of Area Affected (Temporal Probability)	Person in lookout; 2.6×10^{-3} Person on beach, platform at the base of the cliff; 4×10^{-5}	Person in rear yard; 0.02 Person on beach or platform at the base of the cliff; 4×10^{-5}					
Probability of Not Evacuating Area Affected	0.5	0.5	0.5	0.5	0.01 (rear yard) 0.5 (beach or platform at the base of the cliff)		
Spatial Probability	1						
Vulnerability to Life if Failure Occurs Whilst Person Present	0.5	0.5	0.5	0.5	0.1 (rear yard) 0.5 (beach or platform at the base of the cliff)		
Risk for Person Most at Risk	6.5×10^{-7} (lookout) 1×10^{-8} (platform at the base of the cliff)	5×10^{-5} (rear yard) 1×10^{-7} (beach or platform at the base of the cliff)		5×10^{-7} (rear yard) 1×10^{-9} (beach or platform at the base of the cliff)	5×10^{-6} (rear yard) 1×10^{-8} (beach or platform at the base of the cliff)	2×10^{-7} (rear yard) 1×10^{-7} (beach or platform at the base of the cliff)	
Total Risk	1.3×10^{-6} (lookout) 2×10^{-8} (platform at the base of the cliff)	1×10^{-4} (rear yard) 2×10^{-7} (beach or platform at the base of the cliff)		1×10^{-6} (rear yard) 2×10^{-9} (beach or platform at the base of the cliff)	1×10^{-5} (rear yard) 2×10^{-8} (beach or platform at the base of the cliff)	4×10^{-7} (rear yard) 2×10^{-7} (beach or platform at the base of the cliff)	
Comments		Instability assumed to impact the slope and the seaward end of the rear yards.		Instability assumed to impact the rear yard.	Instability assumed to impact the slope and possibly the rear yard.	Assumes localised instability with little, if any, impact on rear yard. Houses set-back from crest of slope.	

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.

Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.

Person in lookout; occupancy based on 5 mins per day, 9 months of the year, i.e. 2.6×10^{-3}

Reduced probability of not evacuating locations compared to Table B2 due to restricted size of lookout or reduced width of rear yard between slope crest and rear of house.

TABLE B5

SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	**27 Sunset Strip Inyadda Point, Manyana**	**25 and 29 Sunset Strip Inyadda Point, Manyana**	**65 Sunset Strip Inyadda Point, Manyana**	**63 and 67 Sunset Strip Inyadda Point, Manyana**	**63 and 67 Sunset Strip Inyadda Point, Manyana**	**168 Mitchells Parade, Bannisters Point, Mollymook**	**199 to 215 Mitchell Parade, Bannisters Point, Mollymook**
POTENTIAL LANDSLIDE HAZARD	**2** **Small scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**2** **Large scale soil slope instability**	**4** **Instability of landslip remediation measures (Gabion wall)**	**2** **Large scale instability of soil slope**
Assessed Likelihood	Likely	Likely	Almost Certain	Almost Certain	Likely	Unlikely	Likely
Indicative Annual Probability	$1x10^{-2}$	$1x10^{-2}$	$1x10^{-1}$	$1x10^{-1}$	$1x10^{-2}$	$1x10^{-4}$	$1x10^{-2}$
Persons at Risk	In rear yard On beach or platform at the toe of the slope/cliff face		Workers on site On beach or platform at the toe of the slope/cliff face	In rear yard On beach or platform at the toe of the slope/cliff face In the house	In rear yard On beach or platform at the toe of the slope/cliff face		
Number of Persons Considered	2						
Duration of Use of Area Affected (Temporal Probability)	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff; 4×10^{-5}		Workers completing remediation works; 0.06 Person on beach, platform at the base of the cliff; 4×10^{-5}	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff; 4×10^{-5} Person in house; 0.3	Person in rear yard; 0.02 Person on beach, platform at the base of the cliff; 4×10^{-5}		
Probability of Not Evacuating Area Affected	0.1	0.01	0.5 (site area) 0.01 (beach)	0.1	0.1	0.5	0.5
Spatial Probability	1						
Vulnerability to Life if Failure Occurs Whilst Person Present	0.1	0.01	0.3 (site area) 0.1 (beach)	0.1	0.1	0.5	0.5
Risk for Person Most at Risk	2×10^{-6} (rear yard) 4×10^{-9} (beach, platform at the base of the cliff)	2×10^{-8} (rear yard) 4×10^{-11} (beach, platform at the base of the cliff)	9×10^{-4} (workers) 4×10^{-9} (beach, platform at the base of the cliff)	2×10^{-5} (rear yard) 4×10^{-8} (beach) 3×10^{-4} (house)	2×10^{-6} (rear yard) 4×10^{-9} (beach)	5×10^{-7} (rear yard) 1×10^{-9} (beach or platform at the base of the cliff)	5×10^{-5}(rear yard) 1×10^{-7} (beach or platform at the base of the cliff)
Total Risk	4×10^{-6} (rear yard) 8×10^{-9} (beach, platform at the base of the cliff)	4×10^{-8} (rear yard) 8×10^{-11} (beach, platform at the base of the cliff)	1.8×10^{-3} (workers) 8×10^{-9} (beach, platform at the base of the cliff)	4×10^{-5} (rear yard) 8×10^{-8} (beach) 6×10^{-4} (house)	4×10^{-6} (rear yard) 8×10^{-9} (beach)	1×10^{-6} (rear yard) 2×10^{-9} (beach or platform at the base of the cliff)	1×10^{-4} (rear yard) 2×10^{-7} (beach or platform at the base of the cliff)
Comments	Regression of current steep back scarp. Back scarp assessed to be at least 10m seaward of the house.	Assumes any instability would impact a similar section of the slope, i.e. rear yard would not be impacted.		Regression of current steep back scarp. Back scarp assessed to be at least 10m seaward of the house.	Assumes any instability would impact a similar section of the slope, i.e. rear yard would not be impacted.	Assumes remediation measures engineer designed.	Houses assessed to be set-back at least 10m from the edge of the cliff

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.
Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.
Person in house, occupancy based on 8hrs per day: about 0.3.
Person on site completing remediation, occupancy based on 8hrs per day, 5 days per week, over 3 month period: about 0.06.

TABLE B6

SUMMARY OF RISK ASSESSMENT TO PROPERTY FOR SPECIFIC LOCATIONS

SPECIFIC LOCATION	**231 Mitchells Parade, Bannisters Point, Mollymook**	**231 Mitchell Parade, Bannisters Point, Mollymook**	**Timber Lookout, Bannisters Point, Mollymook**	**17 Shipton Crescent, Collers Beach, Ulladulla**	**61 - 65 Nurrawallee Street, Collers Beach, Ulladulla**	**7 Rennies Beach Close, Ulladulla**	**Racecourse Beach Car Park, Ulladulla**
POTENTIAL LANDSLIDE HAZARD	**2** **Large scale instability of soil slope**	**2** **Large scale instability of soil slope**	**2** **Large scale instability of soil slope**	**2** **Large scale instability of soil slope**	**1** **Instability of blocks and/or wedges of rock over the cliff face**	**4** **Instability of landslip remediation measures (Gabion wall)**	**1** **Instability of cliff face overhang**
Assessed Likelihood	Almost Certain	Possible	Possible	Possible	Almost Certain	Unlikely	Possible
Indicative Annual Probability	$1x10^{-1}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-1}$	$1x10^{-4}$	$1x10^{-3}$
Persons at Risk	In rear yard On beach or platform at the toe of the slope	In rear yard On beach or platform at the toe of the slope In the house	Person in lookout Person on platform below	In rear yard On beach or platform at the toe of the slope			In car park On beach or platform at the toe of the slope
Number of Persons Considered	2						
Duration of Use of Area Affected (Temporal Probability)	Person in rear yard; 0.02 Person on beach or platform at the base of the cliff; 4×10^{-5}	Person in rear yard; 0.02 Person on beach or platform at the base of the cliff; 4×10^{-5} In the house; 0.3	Person in lookout; 2.6×10^{-3} Person on platform at the base of the cliff; 4×10^{-5}	Person in rear yard; 0.02 Person on beach or platform at the base of the cliff; 4×10^{-5}			In car park; 0.01 Person on beach or platform at the base of the cliff; 4×10^{-5}
Probability of Not Evacuating Area Affected	0.1	0.1	0.5 (lookout) 0.1 (platform below)	0.1	0.1	0.5	0.1 (car park) 0.5 (platform below)
Spatial Probability	1						
Vulnerability to Life if Failure Occurs Whilst Person Present	0.01	0.1	0.5 (lookout) 0.1 (platform below)	0.1	0.01 (rear yard) 0.5 (platform below)	0.5	0.1 (car park) 0.5 (platform below)
Risk for Person Most at Risk	2×10^{-6} (rear yard) 4×10^{-9} (beach or platform at the base of the cliff)	2×10^{-7} (rear yard) 4×10^{-10} (beach or platform at the base of the cliff) 3×10^{-6} (in house)	6.5×10^{-7} (lookout) 4×10^{-10} (beach or platform at the base of the cliff)	2×10^{-7} (rear yard) 4×10^{-10} (beach or platform at the base of the cliff)	2×10^{-6} (rear yard) 2×10^{-7} (beach or platform at the base of the cliff)	5×10^{-7} (rear yard) 1×10^{-9} (beach or platform at the base of the cliff)	1×10^{-6} (car park) 1×10^{-8} (beach or platform at the base of the cliff)
Total Risk	4×10^{-6} (rear yard) 8×10^{-9} (beach or platform at the base of the cliff)	4×10^{-7} (rear yard) 8×10^{-10} (beach or platform at the base of the cliff) 6×10^{-6} (in house)	1.3×10^{-6} (lookout) 8×10^{-10} (beach or platform at the base of the cliff)	4×10^{-7} (rear yard) 8×10^{-10} (beach or platform at the base of the cliff)	4×10^{-6} (rear yard) 4×10^{-7} (beach or platform at the base of the cliff)	1×10^{-6} (rear yard) 2×10^{-9} (beach or platform at the base of the cliff)	2×10^{-6} (car park) 2×10^{-8} (beach or platform at the base of the cliff)
Comments	Regression of current steep back scarp assumed to reserve area only.	Assumes further landslip movement results in back scarp regressing landward at least 10m and impacting seaward margin of existing house.	Relatively low cost repairs to lookout, or re-location.	Trigger would be coastal erosion. House assumed to be founded on bedrock. Coastal engineer should assess potential for coast erosion to extend back to the house to confirm risk levels.	Houses assessed to be set-back at least 10m from the edge of the cliff	Assumes remediation measures engineer designed.	Assumes localised instability with fence line and possibly seaward margin of car park.

Notes

Person in rear yard, occupancy based on 0.5hrs per day: about 0.02.
Person in car park, occupancy based on 0.25hrs per day: 0.01
Person walking on track or access path; occupancy based on average walking rate of 4 seconds per 5m length per day for 9 months of year: about 4×10^{-5}.
Person in house, occupancy based on 8hrs per day: about 0.3.
Person on site completing remediation, occupancy based on 8hrs per day, 5 days per week, over 3 month period: about 0.06.
Person in lookout; occupancy based on 5 mins per day, 9 months of the year, i.e. 2.6×10^{-3}

TABLE C

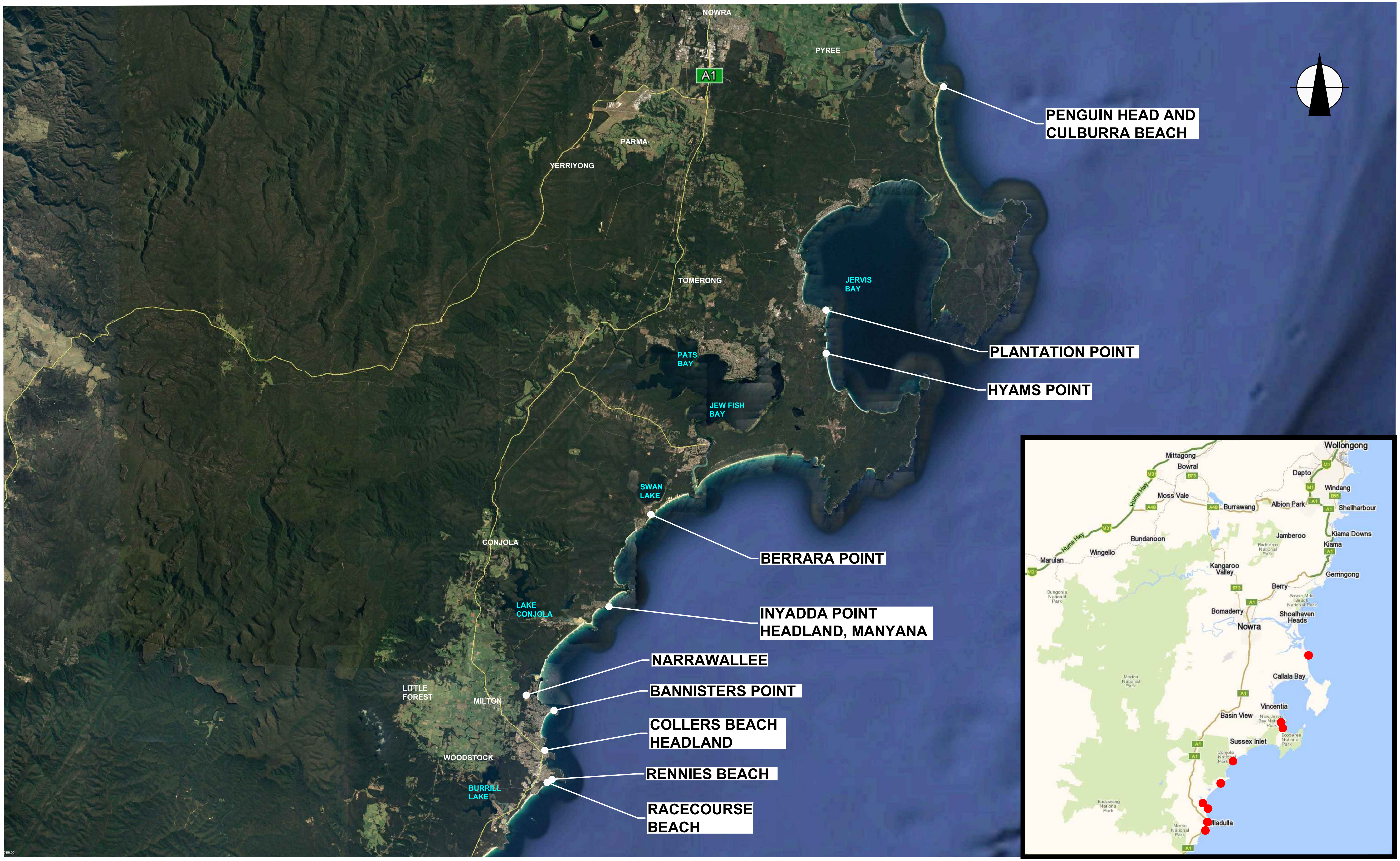
CURRENT RISK LEVELS (TO PROPERTY) AND IMPACT OF LANDSLIDE RISK MANAGEMENT (LRM) MEASURES ON RISK LEVELS

LOCATION	CURRENT RISK LEVEL	LRM								RISK LEVEL FOLLOWING LRM (see Note 1)
		Monitoring by Council and/or property owner, as applicable	Council assess current stormwater drainage, check for leaks and repair/ upgrade as required	Property owners to check drainage, water mains, sewer system, pool backwash systems and any other water carrying services for leaks/damage and repair as necessary.	Council to request geotechnical certification of installed landslip remediation measures including confirmation that risk has been reduced to 'acceptable' levels	Utility companies to check water carrying pipelines for leaks and repair as necessary	Existing landslips to be remediated in accordance with geotechnical advice	Assessment by coastal engineer	Assessment by geotechnical engineer	
Penguin Head and Culburra Beach; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Penguin Head Lookout.	LOW & VERY LOW	✓								LOW & VERY LOW
191, 195 and 209 Penguin Head Road	MODERATE	✓	✓	✓		✓			✓	LOW
Plantation Point; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Hyams Point; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Berrara Point; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Deck at 16 Myrniong Grove, Berrara.	MODERATE	✓	✓	✓		✓			✓	LOW
20 Myrniong Grove, Berrara.	LOW	✓	✓	✓	✓	✓				LOW
28 Myrniong Grove, Berrara.	MODERATE	✓	✓	✓		✓	✓		✓	LOW
Inyadda Point; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
1, 3, 5 and 7 Sunset Strip Inyadda Point.	LOW	✓	✓	✓		✓				LOW
27 Sunset Strip Inyadda Point.	MODERATE	✓	✓	✓		✓	✓			LOW
25 and 29 Sunset Strip Inyadda Point.	MODERATE	✓	✓	✓		✓	✓			LOW
65 Sunset Strip Inyadda Point.	VERY HIGH	✓	✓	✓		✓	✓			LOW
63 and 67 Sunset Strip Inyadda Point.	HIGH AND VERY HIGH	✓	✓	✓		✓	✓			LOW
Narrawallee; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Bannisters Point; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
168 Mitchells Parade, Bannisters Point.	LOW	✓	✓	✓	✓	✓				LOW
231 Mitchells Parade, Bannisters Point.	LOW & MODERATE	✓	✓	✓		✓	✓			LOW
199 to 215 Mitchell Parade, Bannisters Point.	VERY LOW	✓	✓	✓		✓				VERY LOW
Timber Lookout, Mollymook Beach, Bannisters Point.	VERY LOW	✓	✓	✓		✓				VERY LOW

LOCATION	CURRENT RISK LEVEL	LRM								RISK LEVEL FOLLOWING LRM (see Note 1)
		Monitoring by Council and/or property owner, as applicable	Council assess current stormwater drainage, check for leaks and repair/ upgrade as required	Property owners to check drainage, water mains, sewer system, pool backwash systems and any other water carrying services for leaks/damage and repair as necessary.	Council to request geotechnical certification of installed landslip remediation measures including confirmation that risk has been reduced to 'acceptable' levels	Utility companies to check water carrying pipelines for leaks and repair as necessary	Existing landslips to be remediated in accordance with geotechnical advice	Assessment by coastal engineer	Assessment by geotechnical engineer	
Collers Beach; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
17 Shipton Crescent, Collers Beach.	MODERATE	✓	✓	✓		✓		✓		LOW
61 - 65 Nurrawallee Street, Collers Beach.	LOW	✓	✓	✓		✓				LOW
Rennies Beach; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
7 Rennies Beach Close gabion wall.	LOW	✓	✓	✓	✓	✓				LOW
Racecourse Beach; General Site Area.	LOW & VERY LOW	✓	✓	✓		✓				LOW & VERY LOW
Racecourse Beach Car Park.	VERY LOW	✓	✓	✓		✓				VERY LOW

<u>Note</u>

1. The risk level assumes that all of the LRM measures and the necessary actions are implemented.



AERIAL IMAGE SOURCE: GOOGLE EARTH PRO, 7.1.5.1557, 2015.

0 2,500 5,000 7,500 10,000 12,500

SCALE 1:250000@A3 METRES

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

Title: **SITE LOCATION PLAN**

Location: BETWEEN CULBURRA BEACH & RACECOURSE BEACH SHOALHAVEN, NSW

Report No: 30016ZR

Figure No: 1

JK Geotechnics

PLOT DATE: 13/12/2016 11:53:27 AM DWG FILE: S:\6 GEOTECHNICAL JOBS\30000'S\30016ZR SHOALHAVEN\CAD\30016ZR.DWG

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.

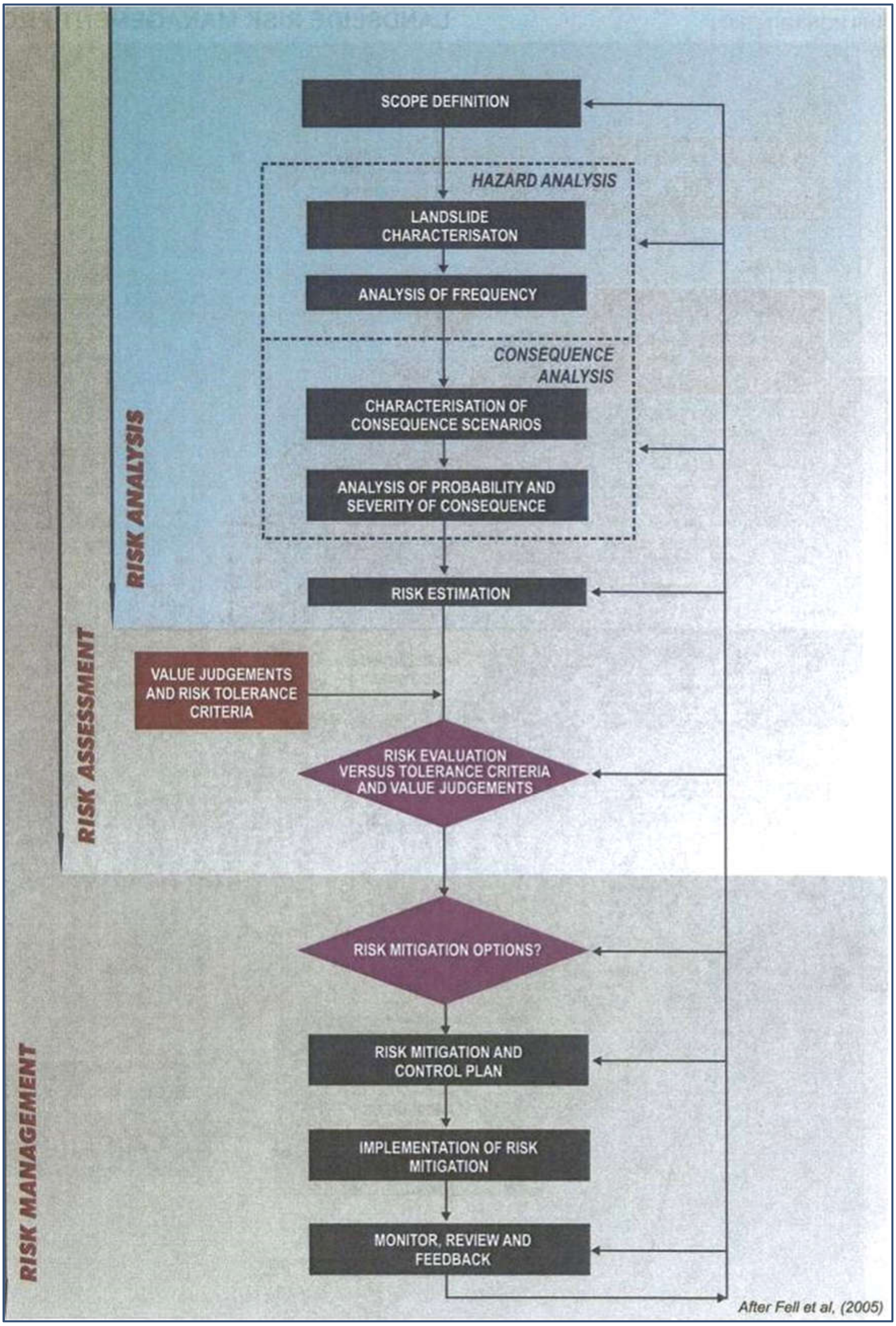


FIGURE A1: Flowchart for Landslide Risk Management.

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.

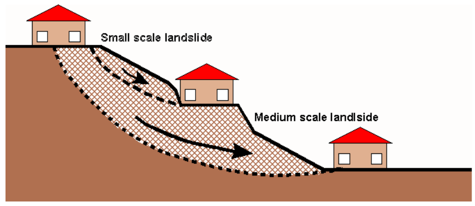


Figure 1

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.

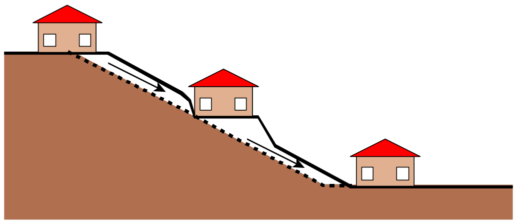


Figure 2

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.

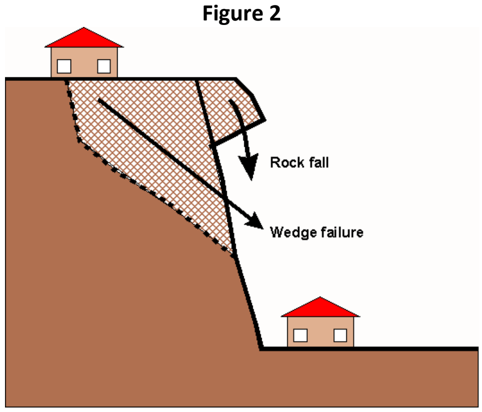


Figure 3

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.

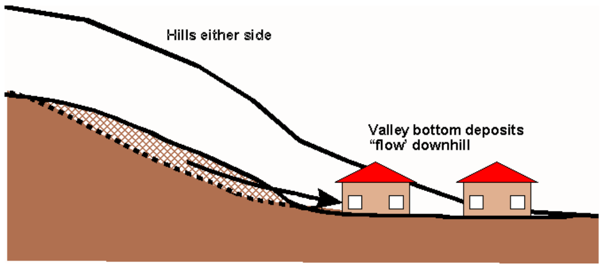


Figure 4

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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