GEO-ENVIRONMENTAL SOLUTIONS

LANDSLIP RISK ASSESSMENT

PROJECT:

Proposed Subdivision

Site Address:

471 Cambridge Road and
528 & 540 Pass Road
Cambridge,
TAS
7170

CLIENT:

Matt Brown Property Management & Investment

DATE:

13/01/2025

DOCUMENT CONTROL

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CONTENT

FIGURES

TABLES

1 INTRODUCTION

Geo-Environmental Solutions Pty Ltd (GES) were contracted by Matt Brown Property Management & Investment to provide a geotechnical assessment to assess landslip risk for the proposed subdivision at Rokeby, which lays within the Tasmanian Planning Scheme – Clarence City Council mapped low landslip zone.

The proposed development is located at cadastral title (CT 184647/1,2,3) at 471 Cambridge Road and 528 & 540 Pass Road Cambridge, TAS 7170 (Figure 1). GES are to undertake this geotechnical assessment relating to the proposed works in conjunction with the requirements of the Landslip Hazard Code, part of the Tasmanian Planning Scheme. GES have written this report with reference to the Australian Geomechanics Guidelines (AGS 2007).

GES have undertaken this assessment using previous site observations and investigation, photographs and publicly available datasets in the construction of this report. Estimations are determined by approximation with regional information applied where appropriate to site specific information.

Figure 1 - Location of the site

2 OBJECTIVES

The objective of the site investigation is to:

- Identify the requirements of the Landslip Hazard Code;
- Conduct a Landslip risk assessment of the proposed development excavations with reference to the Australian Geomechanics Society (AGS) *Landslip Risk Management (2007) guidelines';*
- Identify which planning scheme codes need to be addressed in terms of landslip and identify the relevant performance criteria relevant to the project which need addressing;
- Conduct a site risk assessment for the proposed development ensuring relevant performance criteria are addressed.
- Where applicable, provide preliminary recommendations on earthworks to ensure safe slope management.

3 SITE DETAILS

3.1 Project Area Land Title

The land studied in this report is defined by the following title reference:

- CT 184647/1, 184647/2, 184647/3

the 'Site' and/or the 'Project Area' in this report.

3.2 Australian Building Code Board

This report presents a summary of the overall site risk to Landslip hazards. This assessment has been conducted for the year 2073 which is representative of a 'normal' 50-year building design life category.

Per the Australian Building Code Board (ABCB 2015), when addressing building minimum design life:

'The design life of buildings should be taken as 'Normal" for all building importance categories unless otherwise stated.'

As per Table 3-1, the building design life is 50 years for a normal building.

Table 3-1 Design life of building and plumbing installations and their components

Building Design Life Category	***Building Design Life (years)***	***Design life for components or sub systems readily accessible and economical to replace or repair (years)***	***Design life for components or sub systems with moderate ease of access but difficult or costly to replace or repair (years)***	***Design life for components or sub systems not accessible or not economical to replace or repair (years)***
Short	1 < dl < 15	5 or dl (if dl<5)	dl	dl
Normal	50	5	15	50
Long	100 or more	10	25	100

Note: Design Life (dl) in years

3.3 The Tasmanian Building Regulations 2016

Building in hazardous areas

As outlined in the Department of Justice web site:

http://www.justice.tas.gov.au/building/building-and-plumbing/building_in_hazardous

Hazardous areas include areas which are bushfire prone, comprise reactive soils or substances, or are subject to coastal erosion, coastal flooding, riverine flooding, and landslip.

Division 5 - - Landslip. Section 59. Landslip hazard areas

- For the purposes of the Act, land is a landslip hazard area if –
  - the land is shown on a planning scheme overlay map as being land that is within a landslip hazard area; and
  - the land is classified as land within a hazard band of a landslip hazard area.
- For the purposes of the definition of *hazardous area* in section 4(1) of the Act –
  - classification under a landslip determination as being land that is within a hazard band of a landslip hazard area is a prescribed attribute; and
  - a landslip hazard area is a hazardous area.

3.4 Tasmanian Planning Scheme Landslip Overlay – Clarence City Council

The proposed subdivision development lays approx. 15% within the low landslip hazard overlay. The areas with the low landslip hazard overlay, consists of slope angles between 11° and 20° within the low landslip overlay as defined by the Tasmanian Planning Scheme – Clarence City Council Overlay Mapping (Figure 2).

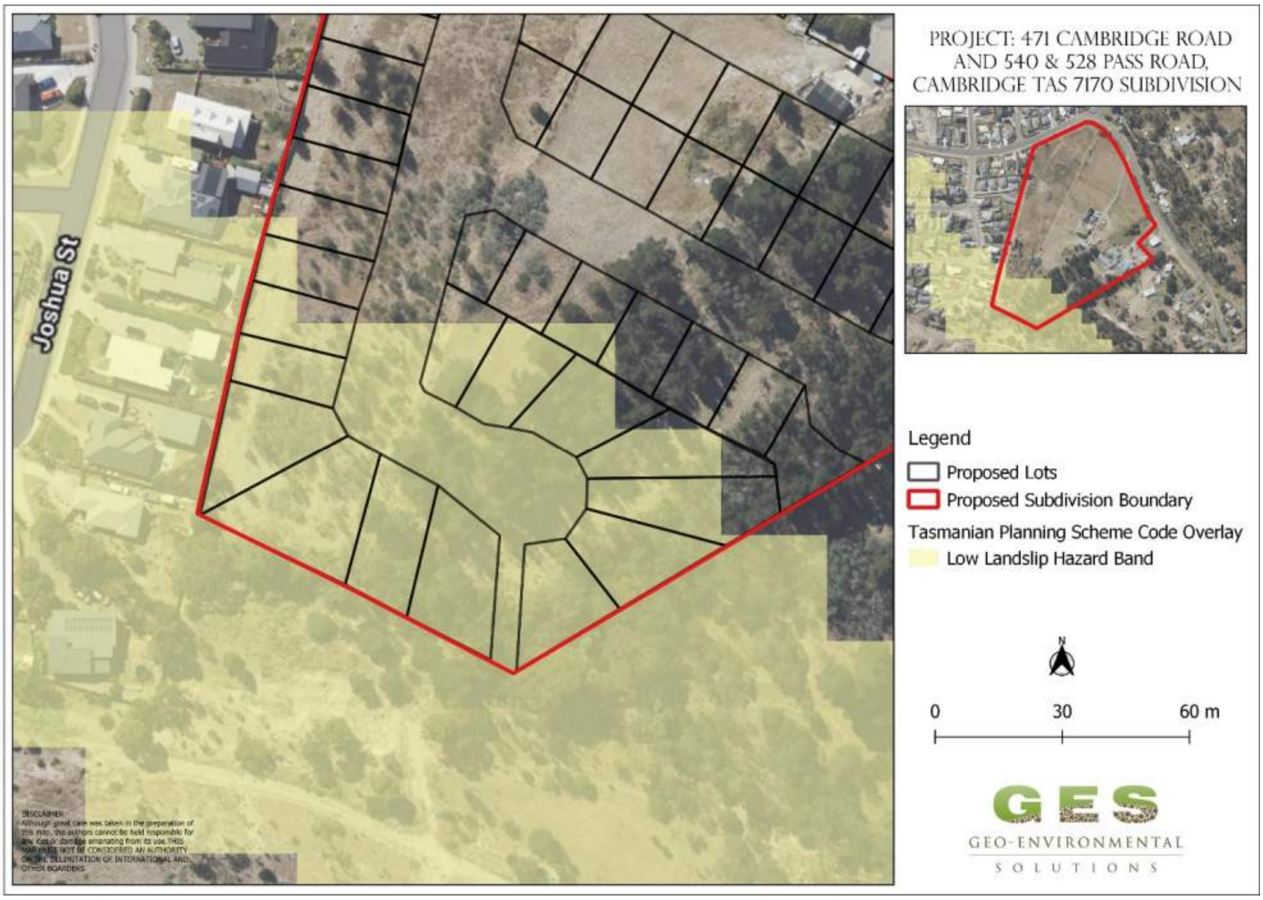

Figure 2 – Landslip Overlay near the Site (The List)

3.5 Site and Proposed Works

The project encompasses an area of approximately 6.0 hectares. Currently the site is occupied with two dwellings and a multiple number of sheds. The existing buildings will be demolished prior the proposed works. The proposed subdivision will have a different size residential lot, four-unit development areas and commercial development area. The lots will vary in size, ranging from 100 square meters to 450 square meters.

Access driveways to the proposed subdivision will be facilitated through Pass Road and Cambridge Road.

Plans for the proposed works have been provided to GES from JMG Engineers & Planners (Project No. J220646PL, Dated: 07/10/2024). The plans are presented in Figure 3.

Figure 3 - Site Plan showing proposed works.

3.5.1 Development & Works Acceptable Solutions

Where applicable, the need for further performance criteria compliance is outlined in Appendix 1.

3.5.2 Landslip Hazard Code (LHC)

Given that the proposed subdivision development resides in Landslip Hazard Areas, the code C15.7.1 performance criteria will need to be addressed.

4 SITE MAPPING

4.1 Geological Mapping

The geological map for the site has been presented in Figure 4. Based on the MRT 1:25,000 scale geology map 'Hobart' (Sheet No. 5225), indicates subdivision is underlain by the following geological unit:

- Permian – Triassic (Map Unit: Rqph) - Freshwater predominantly cross-bedded quartzose to feldspathic sandstone commonly with overturned cross-bedding, subordinate siltstone with sparse plant and vertebrate fossils (Knocklofty Formation).
- Quaternary (Map Unt: Qa) - Alluvial gravel, sand and clay.
- Permian (Map Unit: Pux) - Undifferentiated generally unfossiliferous glaciomarine fissile and non-fissile siltstone and silty sandstone with lonestones (Abels Bay Formation, Malbina Formation, Risdon Sandstone).
- Permian (Map Unit: Pua) – Generally unfossiliferous glaciomarine interbedded non-fissile and fissile siltstone and silty sandstone, with common bioturbation and lonestones; uppermost beds of laminated to massive siltstone with some beds of well sorted sandstone (Abels Bay Formation).
- Permian (Map Until: Pum) - Generally poorly fossiliferous interbedded glaciomarine fine- to medium-grained sandstone, fissile and non-fissile siltstone, lonestones and pebble-rich patches, productid bed at top, basal interval commonly with thick beds of coarse-grained sandstone.

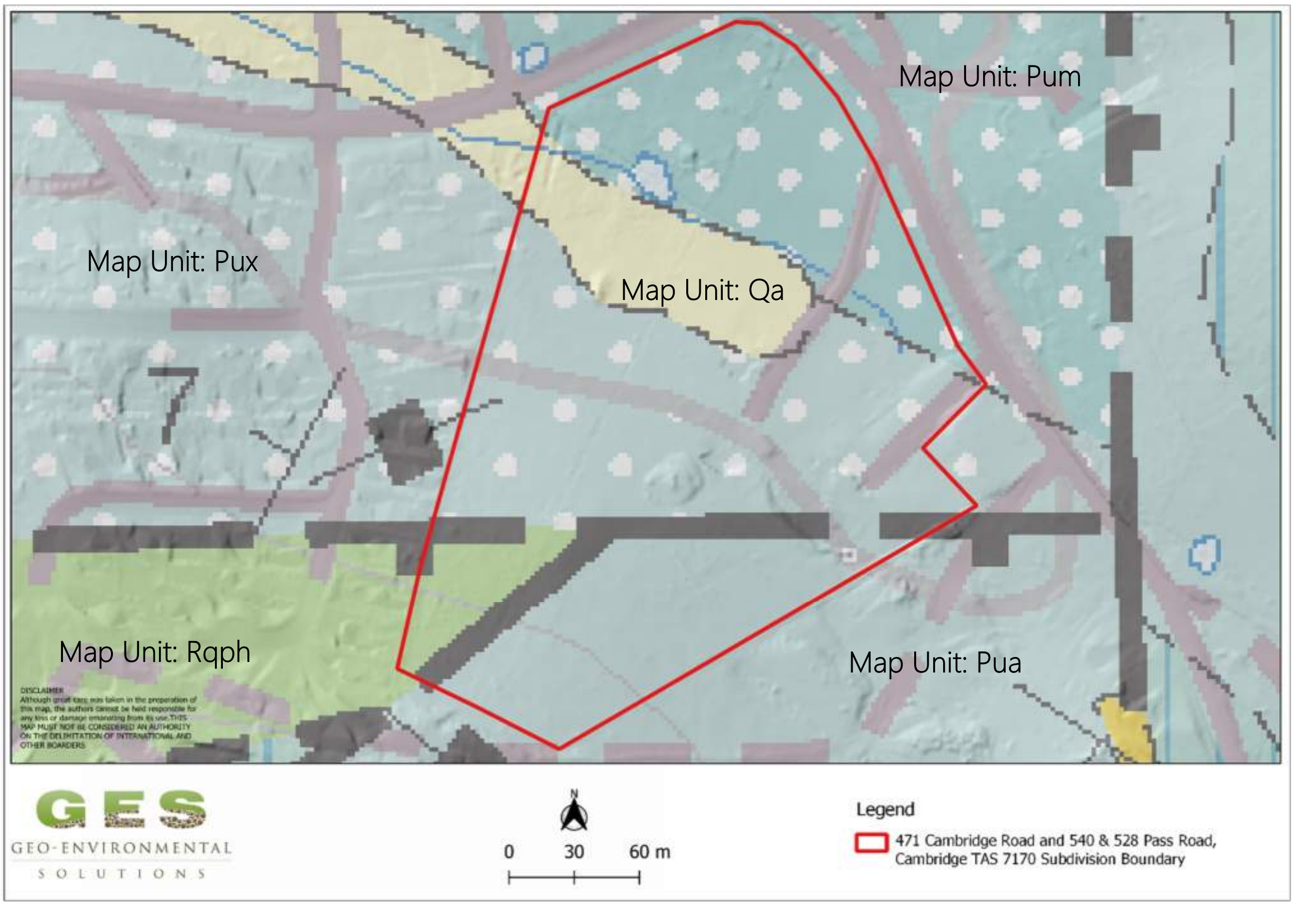

Figure 4 - Mapped Geology (Source: MRT Mapping 'Hobart' 1:25,000)

4.2 Site Geomorphology

The proposed subdivision is situated on the northeast-facing slopes. In terms of elevation, the southwest area spans from approximately 128 meters AHD (Australian Height Datum) along the southwest boundary to 95 meters AHD at the northeast corner of the site. Only southwest end of the proposed subdivision is located within a low landslip overlay at the end of Road 1 cul de sac. The development area covered by a landslip overlay encompasses elevations ranging approx. from 127 meters AHD to 113 meters AHD. The topography of the site exhibits a variety of slopes, ranging from gentle to moderate. The proposed subdivision dwellings, including those situated within the landslip area, are positioned on slopes with inclinations of approximately 10-15 degrees on the southwest side of the subdivision. Some parts of the slope angle exceeding 14 degrees to up to 20 degrees. To visualize and analyse the slope angles on-site, a slope angle map was generated using QGIS software, utilizing LiDAR data from Clarence in 2019. This map, depicted in Figure 5, illustrates the distribution of slope angles across the area.

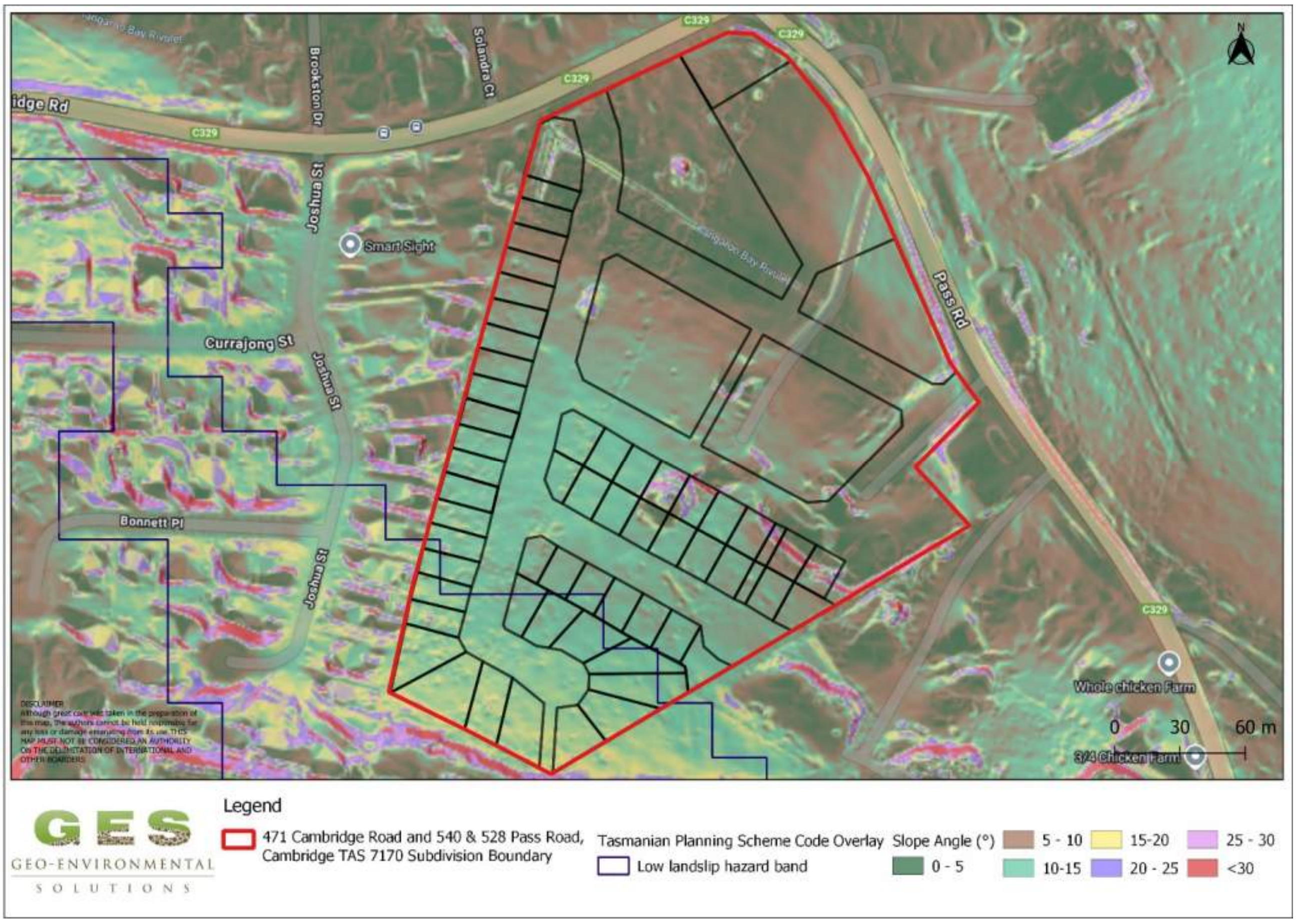

Figure 5 Slope angle with a hill shade model developed from East Coast 2020 LiDAR data.

4.2 Site Investigation

A site investigation was conducted by GES for the purpose of collecting data and observing the site for this report. Summary of soil profile within the proposed site presented in Table 1. A number of test holes were conducted over the location within a landslip hazard zone area to identify the distribution of, and variation in soil materials. Soil depth in the proposed building area is highly variable to approximately 1.10m containing a significant amount rock floater. Given the sand and gravel content the soil is likely to only experience moderate ground surface movement from moisture fluctuations. It is also recommended that foundations be placed onto siltstone bedrock wherever possible. The soils on site consist of moderately reactive silt/clay mixture. Refusal was encountered on upper sequences of siltstone bedrock in all test locations at depth ranging from 0.6mbgs to 1.50mgbs. Given the variable nature and of depth to rock on site, and the presence of amounts of rocks/floaters in the soil, careful attention may be required during excavation for the preparation of a consistent footing surface.

Table 1 Soil Profiles

BH 1 Depth (m)	BH 2 Depth (m)	BH 3 Depth (m)	Description
0.00 – 0.60	0.00 -0.50		Brown Gravelly SAND (GS), weak polyhedral structure, dry weak cohesion, abundant siltstone rocks and gravels, disturbed appearance, gradual boundary to
0.60 – 1.10	0.50 – 0.60		Mixed Brown) and Black Gravelly CLAY (CI), approx 40% fine gravels, moderate polyhedral structure, slightly moist firm consistency, medium plasticity, charcoal fragments, disturbed appearance, abrupt boundary to slightly weathered siltstone
		0.00 – 0.30	Yellowish Dark Brown Clayey SAND (SC), loam fabric, weakly developed polyhedral structure, approx 5% 1-5mm angular siltstone gravels, trace of clay, visible fine-medium silt and sand grains, few fine roots, dry loose consistency, clear smooth boundary to
		0.30 – 0.45	Yellowish Dark Brown Silty and Sandy Medium CLAY (CH), moderately developed subangular blocky structure, approx 40% fine sand and silt, medium plasticity, visible fine-medium sand grains, dry firm consistency, parting to
		0.45 -1.00	Dark Greyish Brown Sandy Medium CLAY (CH), well developed subangular blocky structure, approx 50% fine sand, approx 10% 2-10mm angular gravels and rocks increasing with depth, medium plasticity, visible fine-medium sand grains, dry hard consistency, parting to
		1.00 – 1.30	Dark Yellowish Brown Silty and Sandy CLAY (CL), moderately developed polyhedral structure, approx 60% fine sand and silt, approx 10-15%, 2-10mm angular gravels and rocks increasing with depth, low plasticity, visible fine-medium sand grains, slightly moist hard consistency, gradual boundary to
		1.30 – 1.50+	Olive Yellow Silty Sand (SP), dry hard consistency, massive structure, extremely hard at 1.5m, refusal on slightly weathered siltstone

5 LANDSLIP HAZARD ANALYSIS

5.1 Landslip Characteristics

Based on the slope characteristics including site geology, slope geometry and slope angles, MRT Landslip mapping/inventory and site observations, the following scenarios have been identified as potential slope failure mechanisms for the site:

- Scenario 1 – Shallow translational slide failure within shallow residual soils immediately below the estimated dwellings from removal of vegetation with potential for regression;

- Scenario 2 – Shallow translational slide within shallow residual soils in cuttings above development, caused by oversteepening of natural soil slopes, with no allowance for drainage;

- Scenario 3 - Shallow translational slide within natural soils and fill materials caused by loading of natural soil slopes and unstable batter angles, with no allowance for drainage;

5.1.1 Frequency Analysis

Table 2 presents the frequency analysis for the identified slope failure mechanisms. Terminology used is in accordance with the Australian Geomechanics Society (AGS) guidelines for Landslip risk management (2007a,b,c,d). (Table 2).

Table 2 Frequency analysis for Landslip hazards 1 & 2

Scenario	Failure Mechanism	Unit Affected	Observed in the field	Potential Size	Potential Speed	Water Content	Current Likelihood	Treated Likelihood
Scenario 1	Shallow translational slide - residual soils from removal of vegetation with potential regression	Surficial residual soils	No	Small with potential regression upslope towards dwelling	Slow to moderate	Wet/ saturated	Possible	Unlikely
Scenario 2	Shallow translational slide - cut	Over-steepened surficial residual soils	No	Small	Slow to moderate velocities	Wet/ saturated	Possible	Unlikely
Scenario 3	Shallow translational slide - fill	Potential fil	No	Small	Slow to moderate	Wet/ Saturated	Possible	Unlikely

5.2 Risk Analysis

5.2.1 Risk to Property

Risk has been considered for the proposed subdivision pre and post construction. Without suitable management of foundation depths, safe batter angles, fill compaction, the site is considered moderate risk from uncontrolled excavation. Treated risk may be reduced to low with the implementation of safe cut batter angles, limited use of fill and foundations being socketed into the underlying bedrock. Alternatively, potential cut and fill may be supported by suitably designed drained retaining walls. Site stormwater should be diverted away from the building platform and not outlet to ground below proposed dwelling. For the ongoing stability of any proposed cutting, cut-off v-drains should be implemented above all cutting and a graded toe drain immediately below the cutting faces to prevent water ponding near foundations (Table 3). Indicative soil classification for lots at southwest of the subdivision (end of Road 1 Cul de sac area) is Class P due to landslip risk. As such, specific assessment for site soil class and landslip risk will need to be conducted at the development application stage for each lot, once house plans are produced.

Table 3 Consequence analysis for Landslip hazards – Property

Scenario	Issue	Current Risks			Recommended risk treatment	Post Treatment Risk
		Likelihood of occurrence	Consequence to property	Level of risk to property		
Scenario 1	Shallow Slide Failure	Possible	Medium	Moderate	All proposed development to have site soil class assessment for residential dwellings as per AS2870-2011 foundations for all residential dwellings. Foundations of the proposed dwellings should be extended into underlying bedrock and designed in accordance with good hillside construction practices should be adopted as per Australian Geoguide LR8. Lots within a landslip area should be assessed for specific landslip risk during the development application stage for each proposed dwelling.	Low
Scenario 2	Shallow Slide Failure	Possible	Minor	Moderate	Cut slopes for the construction of titles should be constructed using the following slope angles: • Residual Soils – 1V: 2H; and • Siltstone Bedrock – 1.2V: 1H. Alternatively, slopes can be retained using suitably engineered retaining walls. All cutting should include a cut-off v-drain above the cutting and a graded toe drain immediately below the cutting face. Cutting for the lots within a landslip area should be assessed at the development application stage.	Low
Scenario 3	Shallow Slide Failure	Possible	Minor	Moderate	Prior to placement of proposed fill all topsoil should be stripped from the fill pad footprint and benches should be keyed into the slope (preferably onto underlying bedrock). The fill material should be granular and be placed in lifts of maximum 0.2m in height and adequately compacted in accordance with AS3798-2007; Fill batter angles should not exceed 1V: 3H and fill heights should not exceed 2.0m without prior assess that should be conducted from specific plans/volumes. Good hillside construction practices should be adopted as per Australian Geoguide LR8.	Low

5.2.2 Risk to Life

The risk to life is generally considered acceptable for Scenarios 1 and 3 after implementing the recommended risk treatments. (Table 4). Societal risk has not been assessed as part of this report.

Table 4 Consequence analysis for Landslip hazards – Life

Hazard	Scenario 1	Scenario 2	Scenario 3
Factor	Shallow Translational Slide - Residual Soils from Removal of Vegetation with Potential Regression	Shallow Slope Failure – Cut	Shallow Slope Failure - Fill
Likelihood	Unlikely	Unlikely	Unlikely
Indicative Annual Probability	0.001	0.001	0.001
Use of Affected Structure/Site	Residential Property – Assumed 50%	Residential Property – Assumed 10%	Residential Property – Assumed 10%
Probability of Spatial Impact	0.5	0.1	0.1
Probability of Not Evacuating	Residual soils should exhibit signs of stress (tension cracking prior to failure), resulting in time for evacuation and/or remediation. 0.3	Anticipated failure volumes <20m^3 0.2	Fill batters and residual soils should exhibit signs of stress (tension cracking prior to failure), resulting in time for evacuation and/or remediation. 0.3
Vulnerability	Structure unlikely to collapse 0.3	Expected volumes unlikely to cause death. 0.3	Structure unlikely to collapse
Risk for Person Most at Risk	$4.5x10^{-5}$	$6.0\ x10^{-6}$	$3X10^{-5}$

Note 1: It has been assumed that each person has an equal probability of death for each of the hazards. This is a conservative estimate of the risk to life.

5.2.3 Societal Risk

The Societal Risk Graph plot presented in Figure 6. showing the estimated individual risks for scenarios 1 2 and 3 as presented in Figure 6 (outlined in the AGS 'Landslide Risk Management Concepts and Guidelines', 2000). The risks are estimated based on people in the structure spending up to 12 hours per day in internal areas the property.

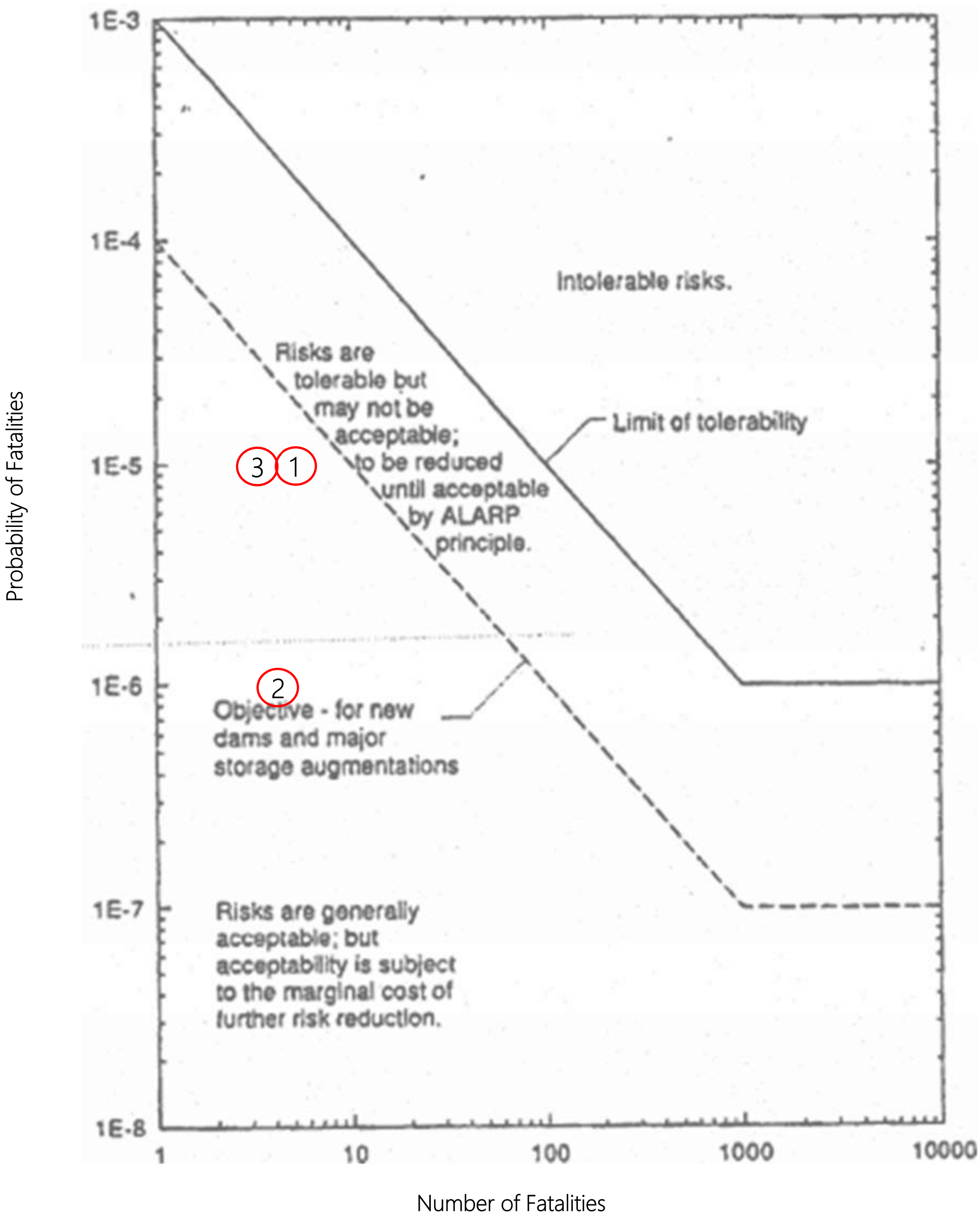

Figure 6 Societal Risk Graph of Probability of Fatalities vs Number of Fatalities (ANCOLD 1998)

6 CONCLUSIONS AND RECOMMENDATIONS

Based on the observations made during the site visit and the outcome of the investigation, landslip risk assessment, the following conclusions are made:

- Only the lots on the southwest portion of the subdivision (end of Road 1 cul de sac area) consists of slope angles between 11° and 20° and lie within the low landslip overlay as defined by the Tasmanian Planning Scheme – Clarence City Council Mapping.
- The soils on site consist of moderately reactive silt/clay mixture. Refusal was encountered on upper sequences of siltstone bedrock in all test locations at depth ranging from 0.6mbgs to 1.50mgbs. Given the variable nature and of depth to rock on site, and the presence of amounts of rocks/floaters in the soil, careful attention may be required during excavation for the preparation of a consistent footing surface.
- Foundations of the future dwellings should be extended into underlying bedrock and designed in accordance with good hillside construction practices should be adopted as per Australian Geoguide LR8.
- According to "AS2870-2011 Residential slabs & footings" indicative soil classification for lots within a landslip area (end of Road 1 cul de sac) are Class P due to landslip risk. As such, specific assessment for site soil class and landslip risk will need to be conducted at the development application stage for each lot, once house plans are produced.
- Cutting for the lots within a landslip area should be assessed at the development application stage.
- Cut slopes (up to a maximum height of 1.5m) for the construction of titles should be constructed using the following slope angles:
  - Residual Soils – 1V: 2H; and
  - Siltstone Bedrock – 1.2V: 1H.
  - Alternatively, slopes can be retained using suitably engineered retaining walls (or where slope height exceeds 1.5m).
- All cutting must include adequate drainage.
- Prior to placement of proposed fill all topsoil should be stripped from the fill pad footprint and benches should be keyed into the slope (preferably onto underlying bedrock). The fill material should be granular and be placed in lifts of maximum 0.2m in height and adequately compacted in accordance with AS3798-2007;
- Fill batter angles should not exceed 1V: 3H and fill heights should not exceed 2.0m without prior assessment that should be conducted from specific plans/volumes.
- All earthworks should be conducted in accordance with AS3798-2007 and a sediment erosion plan should be implemented on site during and after construction.
- The proposed works will not cause or contribute to landslide on the site, adjacent land, or on public infrastructure the recommendations are followed.
- The proposed subdivision within a landslip overlay is compliant with section C15.7.1 of the Planning Scheme as it represents a tolerable risk for the life of use and development.

GES should be contacted immediately should conditions greatly differ to that which are stated in this report.

7 LIMITATIONS STATEMENT

This Assessment Report has been prepared in accordance with the scope of services between Geo-Environmental Solutions Pty. Ltd. (GES) and 'the Client'. To the best of GES's knowledge, the information presented herein represents the Client's requirements at the time of printing of the Report. However, the passage of time, manifestation of latent conditions or impacts of future events may result in findings differing from that discussed in this Report. In preparing this Report, GES has relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations referenced herein. Except as otherwise stated in this Report, GES has not verified the accuracy or completeness of such data, surveys, analyses, designs, plans and other information.

REFERENCES

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APPENDIX 1 – Acceptable Solutions

Landslip Code Areas

C15.7.1 Subdivision within a landslip hazard area

Objective:	
That subdivision within a landslip hazard area does not create an opportunity for use or development that cannot achieve a tolerable risk from a landslip.	
Acceptable Solutions	**Performance Criteria**
A1 Each lot, or a lot proposed in a plan of subdivision, within a landslip hazard area, must: (a) be able to contain a building area, vehicle access, and services, that are wholly located outside a landslip hazard area; (b) be for the creation of separate lots for existing buildings; (c) be required for public use by the Crown, a council or a State authority; or (d) be required for the provision of Utilities.	**P1** Each lot, or a lot proposed in a plan of subdivision, within a landslip hazard area must not create an opportunity for use or development that cannot achieve a tolerable risk from landslip, having regard to: (a) any increase in risk from a landslip for adjacent land; (b) the level of risk to use or development arising from an increased reliance on public infrastructure; (c) the need to minimise future remediation works; (d) any loss or substantial compromise, by a landslip, of access to the lot on or off site; (e) the need to locate building areas outside the landslip hazard area; (f) any advice from a State authority, regulated entity or a council; and (g) the advice contained in a landslip hazard report.

APPENDIX 2 – Qualitative Risk Assessment Tables

Likelihood & Consequence Index

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.
(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.
(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

Qualitative Risk Matrix

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

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

APPENDIX 3 – Qualitative Risk Assessment

Performance Criteria C15.7.1 That subdivision within a landslip hazard area does not create an opportunity for use or development that cannot achieve a tolerable risk from a landslip:	Relevance	Management Options	Managed (treated) Risk Assessment			Further Assessment Required
			Consequence	Likelihood	Risk	
P1 Each lot, or a lot proposed in a plan of subdivision, within a landslip hazard area must not create an opportunity for use or development that cannot achieve a tolerable risk from landslip, having regard to: (a) any increase in risk from a landslip for adjacent land; (b) the level of risk to use or development arising from an increased reliance on public infrastructure; (c) the need to minimise future remediation works; (d) any loss or substantial compromise, by a landslip, of access to the lot on or off site; (e) the need to locate building areas outside the landslip hazard area; (f) any advice from a State authority, regulated entity or a council; (g) the advice contained in a landslip hazard report.		Refer to recommendations.	Medium Minor Minor	Unlikely	Low	All proposed development to have site soil class assessment for residential dwellings as per AS2870-2011 foundations for all residential dwellings. Lots within a landslip overlay (end of Road 1 Cul de sac) should be assessed for specific landslip risk during the development application stage for each proposed dwelling.

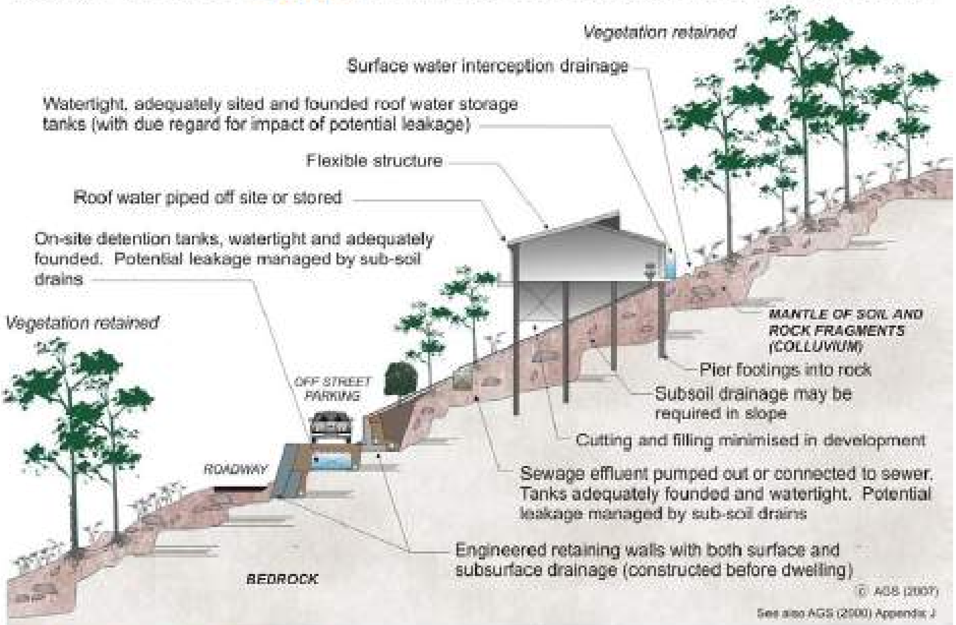
APPENDIX 4 - Australian Geomechanics Society (AGS) Landslip Risk

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

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

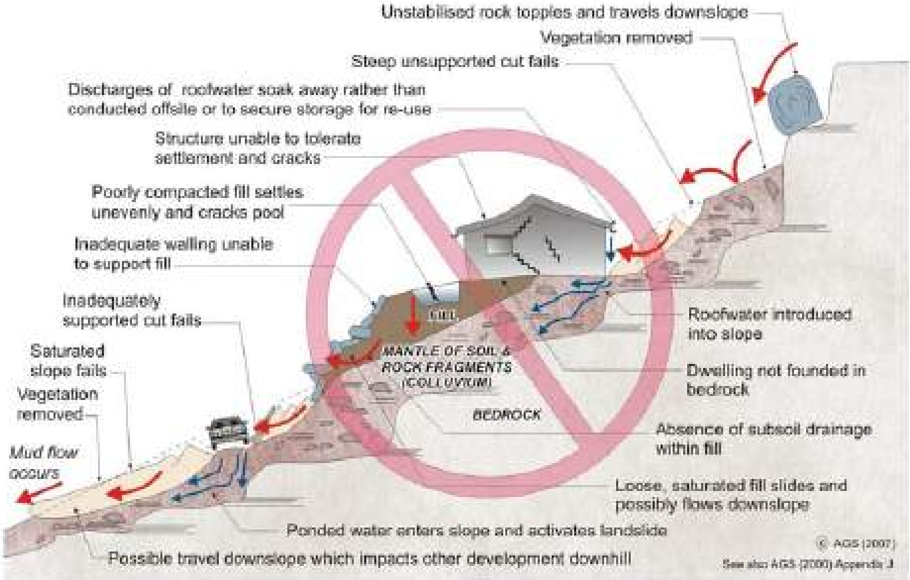
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

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

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

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

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

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

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

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

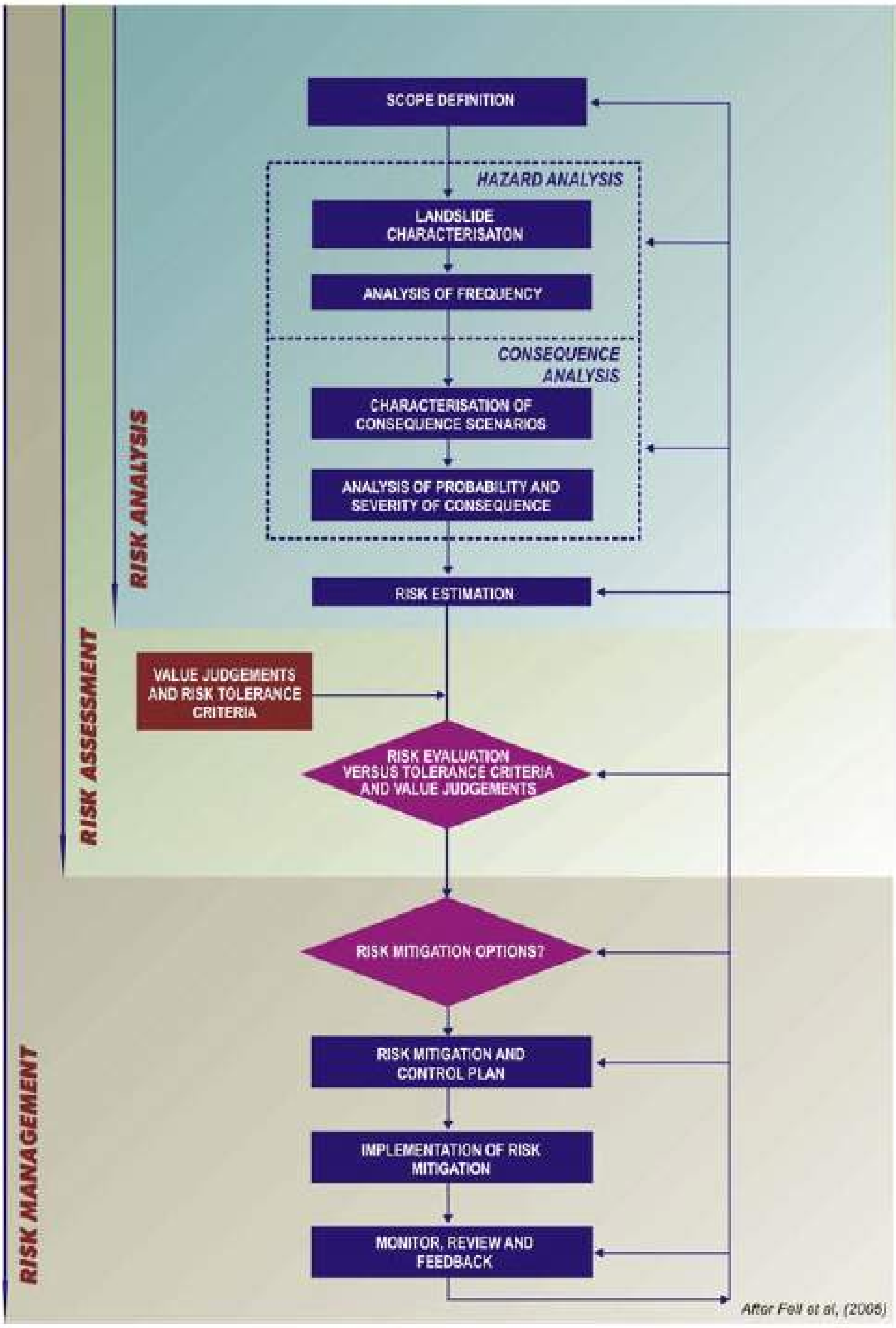
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to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

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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

FRAMEWORK FOR LANDSLIDE RISK MANAGEMENT



APPENDIX B - LANDSLIDE TERMINOLOGY

The following provides a summary of landslide terminology which should (for uniformity of practice) be adopted when classifying and describing a landslide. It has been based on Cruden & Varnes (1996) and the reader is recommended to refer to the original documents for a more detailed discussion, other terminology and further examples of landslide types and processes.

Landslide

The term *landslide* denotes "the movement of a mass of rock, debris or earth down a slope". The phenomena described as landslides are not limited to either the "land" or to "sliding", and usage of the word has implied a much more extensive meaning than its component parts suggest. Ground subsidence and collapse are excluded.

Classification of Landslides

Landslide classification is based on Varnes (1978) system which has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are ***Rock***, ***Earth*** and ***Debris***, being classified as follows:-

The material is either rock or soil.

Rock: is "a hard or firm mass that was intact and in its natural place before the initiation of movement."

Soil: is "an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil."

Earth: "describes material in which 80% or more of the particles are smaller than 2 mm, the upper limit of sand sized particles."

Debris: "contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2 mm and the remainder are less than 2 mm."

The terms used should describe the displaced material in the landslide before it was displaced.

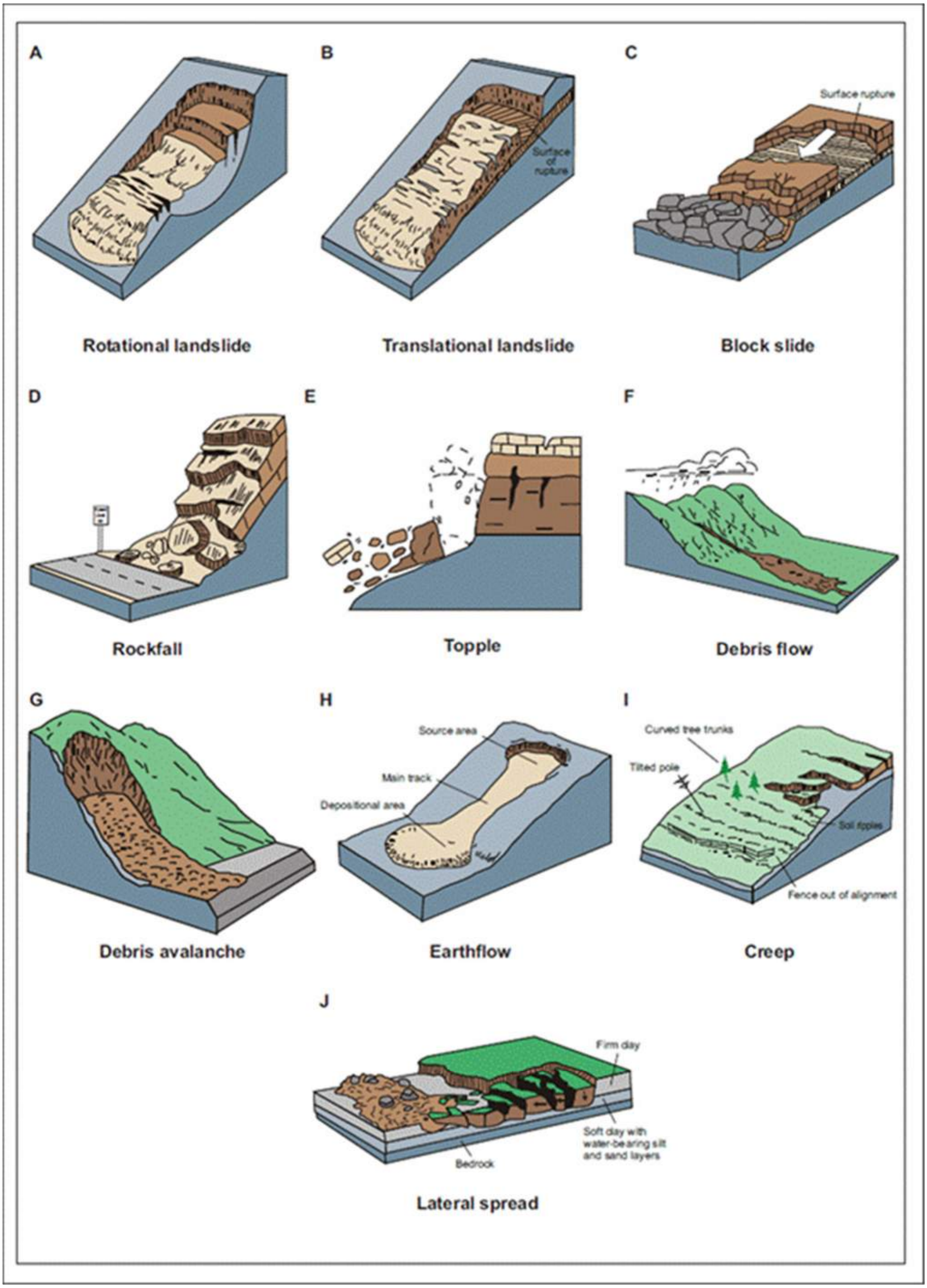
The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence *fall*, *topple*, *slide*, *spread* and *flow*.

The following table shows how the two terms are combined to give the landslide type:

Table B1: Major types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

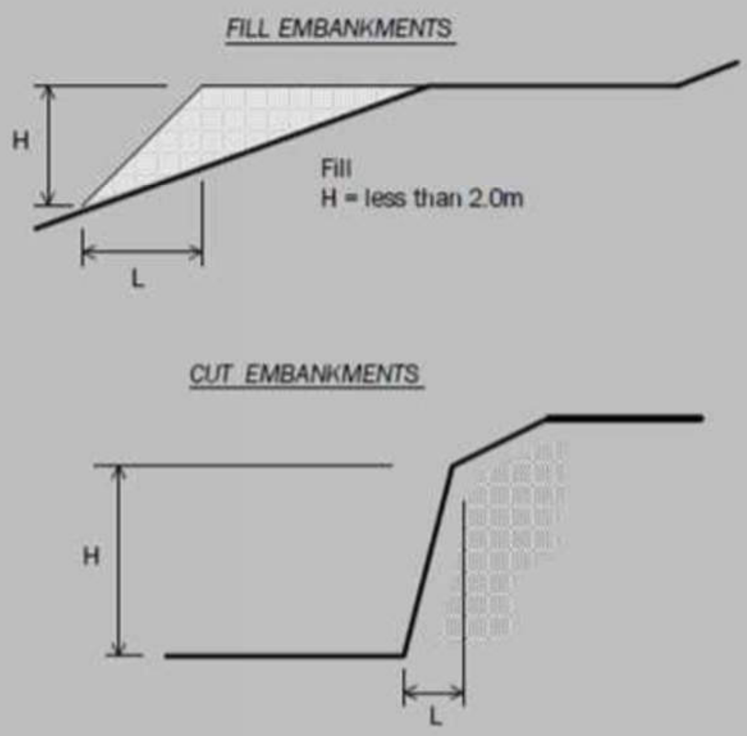
<table>
<tr><th colspan="2" rowspan="3">TYPE OF MOVEMENT</th><th colspan="3">TYPE OF MATERIAL</th></tr>
<tr><th rowspan="2">BEDROCK</th><th colspan="2">ENGINEERING SOILS</th></tr>
<tr><th>Predominantly Coarse</th><th>Predominantly Fine</th></tr>
<tr><td colspan="2">FALLS</td><td>Rock fall</td><td>Debris fall</td><td>Earth fall</td></tr>
<tr><td colspan="2">TOPPLES</td><td>Rock topple</td><td>Debris topple</td><td>Earth topple</td></tr>
<tr><td rowspan="2">SLIDES</td><td>ROTATIONAL</td><td rowspan="2">Rock slide</td><td rowspan="2">Debris slide</td><td rowspan="2">Earth slide</td></tr>
<tr><td>TRANSLATIONAL</td></tr>
<tr><td colspan="2">LATERAL SPREADS</td><td>Rock spread</td><td>Debris spread</td><td>Earth spread</td></tr>
<tr><td colspan="2" rowspan="2">FLOWS</td><td>Rock flow</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><td>(Deep creep)</td><td colspan="2">(Soil creep)</td></tr>
<tr><td colspan="2">COMPLEX</td><td colspan="3">Combination of two or more principle types of movement</td></tr>
</table>

Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at http://landslides.usgs.gov.


A
Rotational landslide
B
Surface of rupture
Translational landslide
C
Surface rupture
Block slide
D
Rockfall
E
Topple
F
Debris flow
G
Debris avalanche
H
Source area
Main track
Depositional area
Earthflow
I
Curved tree trunks
Tilted pole
Soil ripples
Fence out of alignment
Creep
J
Firm clay
Soft clay with water-bearing silt and sand layers
Bedrock
Lateral spread

APPENDIX 5 – Batter Angles for Embarkments

Note : Retaining walls or other form of soil retaining methods must be adopted where the slope ratio is greater than that indicated in the table below :-



MATERIAL TYPE (refer soils report)		EMBANKMENT SLOPES (Height : Length)	
		Compacted Fill	Cutting
Stable Rock (A*)		2 : 3	6 : 1
Sand (A*)		1 : 2	2 : 3
Silt (P*)		1 : 4	1 : 4
Clay	Firm Clay	1 : 2	1 : 1
	Soft Clay	Not Suitable	2 : 3
Soft Soils (P*)		Not Suitable	Not Suitable