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LAND STABILITY ASSESSMENT

FOR

SITE 26 FALLS CREEK ROAD FALLS CREEK

Report No: 1230386-1 Issue 2

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REPORT No	:	1230386-1 Issue 2
CLIENT	:	Myrtleford Ski Club Inc PO Box 469 MYRTLEFORD VIC 3737
AUTHORISED BY	:	Mr Kevin Raven
PROJECT LOCATION	:	8-10 Falls Creek Road FALLS CREEK
PROPOSAL	:	It is proposed to develop this site with a pedestrian walkway.
COMMISSION	:	To determine whether the proposed works will be detrimental to the slope stability of the site and surrounding areas.

1. INTRODUCTION:

The investigation for slope stability includes:

- a site inspection of the existing land and topography;
- interpretation of the proposed walkway development and magnitude of the proposed earthworks;
- boreholes to determine the soil profile and to confirm the geology of the site;
- assessment of the implications of the proposed development and recommendations with regard to slope stability.

2. INFORMATION PROVIDED

The table below summarises the documents reviewed before preparing this report:

Document Name/Ref.	Content/Title	Dated	Prepared By
GE2201894-Site 26, Falls Creek Rd, Falls Creek-GE Response-031122 (1)[98]	Council response	November 2022	Department of Environment, Land, Water and Planning
Site Map	Proposed Alterations Drawings	October 2020	Sunjoule Design
07178 SK Issue E 08.02.2024	Updated Plans	February 2024	Sunjoule Design

3. SITE HISTORY

There is no readily available data for landslips in the area. At the time of the investigation, a large landslide had occurred on Bogong High Plains Road between Mount Beauty and Falls Creek. This restricted access to Falls Creek from the West. The landslip is approximately 10km from 10 Falls Creek Road, so is unlikely to have an effect on the stability of the site.

4. SITE GEOLOGY:

Geological maps of the area suggest that the site is in an area of Ordovician Metamorphics. The site investigation confirmed this.

5. SITE INVESTIGATION:

5.1 Topography and Site Walkover

The site of the proposed walkway is located on the North-East side of Myrtleford Ski Club, 10 Falls Creek Road. The slope of the site is moderate to steep, with the slope direction down to the North-West.

The ground cover comprises of crushed rock, natural grasses, native and introduced trees, and an exposed drainage stream constructed with boulders and pebbles running downslope, as shown in site photograph 4.

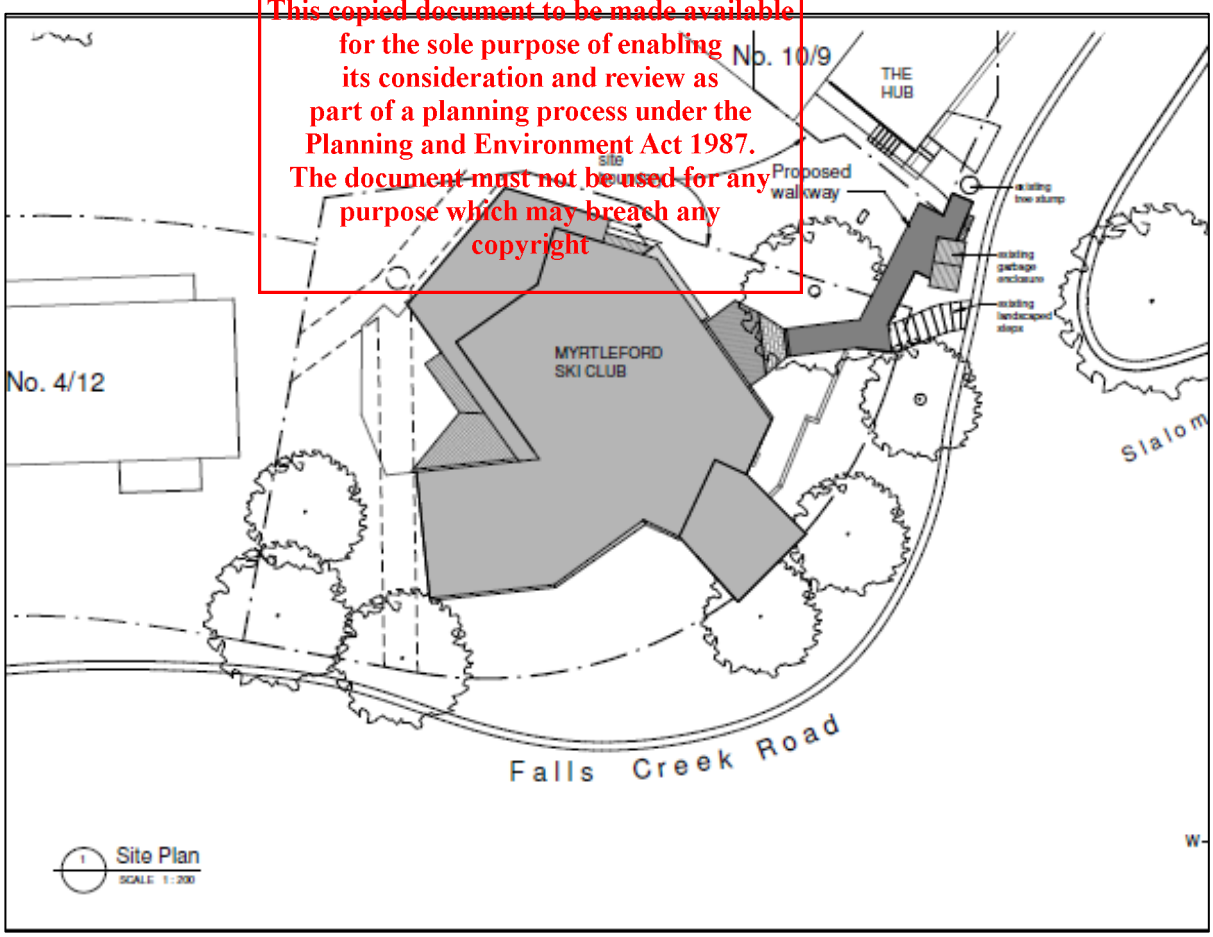
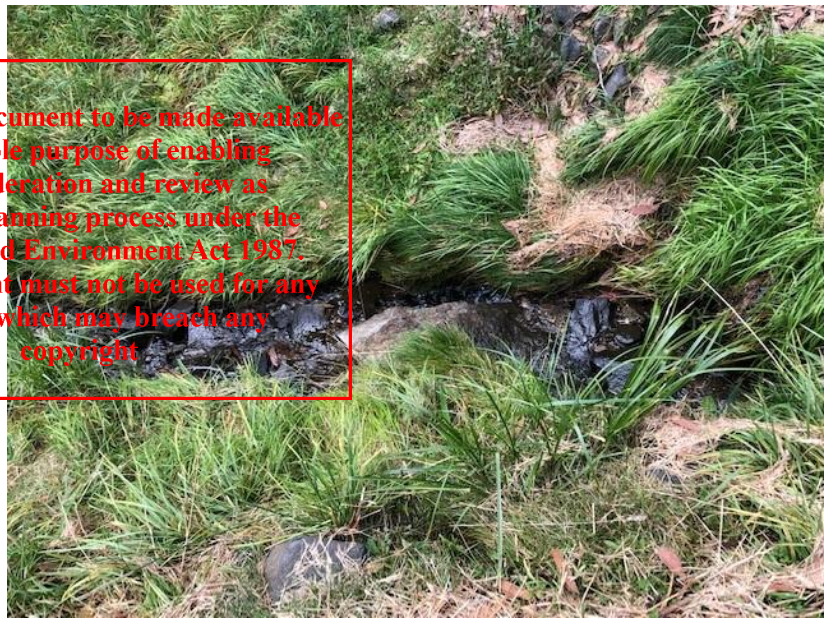


Figure 1: *Plan of proposed walkway location*

Site Photo 1: Proposed walkway location

Site Photo 2: Walkway surrounding area

Site Photo 3: Borehole 4 location downslope



Site Photo 4: Exposed drainage stream

5.2 Soil Profile

Four boreholes (BH) were drilled by hand auger at the approximate locations indicated on the attached plan (aerial map) in Appendix B. The existing soil profile at the proposed location of the walkway consists of silty SAND FILL overlying naturally occurring dense gravelly SAND. Refusal was encountered on weathered ROCK/FLOATER, GNEISS at depths of 400mm and 450mm in boreholes 1 and 2 respectively.

Downslope, the soil profile consists of clayey SILT FILL overlying naturally occurring clayey SILT. Refusal was met on weathered ROCK/FLOATER, GNEISS at depths of 500mm and 700mm below the ground surface level in boreholes 3 and 4 respectively.

6. SLOPE STABILITY MODELLING

The following slope stability models utilise the software program SLIDE 6.0. The resultant factor of safety with respect to the analysis is indicated in the modelling.

As a guide, a factor of safety (FOS) less than 1.0 would indicate that the slope should have failed. A FOS between 1.0 and 1.5 would be indicative of a slope at risk of failure. A FOS between 1.5 and 2.0 would be regarded as tolerable, however, the slope may require some form of remediation to lower the risk. A FOS greater than 2.0 would be regarded as acceptable and safe.

The cross-section drawn in the slope stability model is taken through section A – A, as shown on the attached plan in Appendix B.

The following parameters have been adopted for the units represented in the following models. Some of the values have been assumed based on Civiltest's previous experience and knowledge of similar sites.

Property	Silty SAND FILL	SAND	Silty CLAY	Clayey SAND	Retaining Wall
Color					
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Infinite strength
Unit Weight [kN/m3]	17.5	18	20	20	23
Cohesion [kPa]	1	1	15	5	
Friction Angle [deg]	32	36	26	37	
Water Surface	None	None	None	None	None
Ru Value	0	0	0	0	0

A generalised and simplified geological model (Figure 2) has been constructed based on the local geology type and the contour information provided. The proposed walkway is represented with a 5kN/m distributed load, and the neighbouring structure (8 Falls Creek Road) is represented as a 25kN/m distributed load.

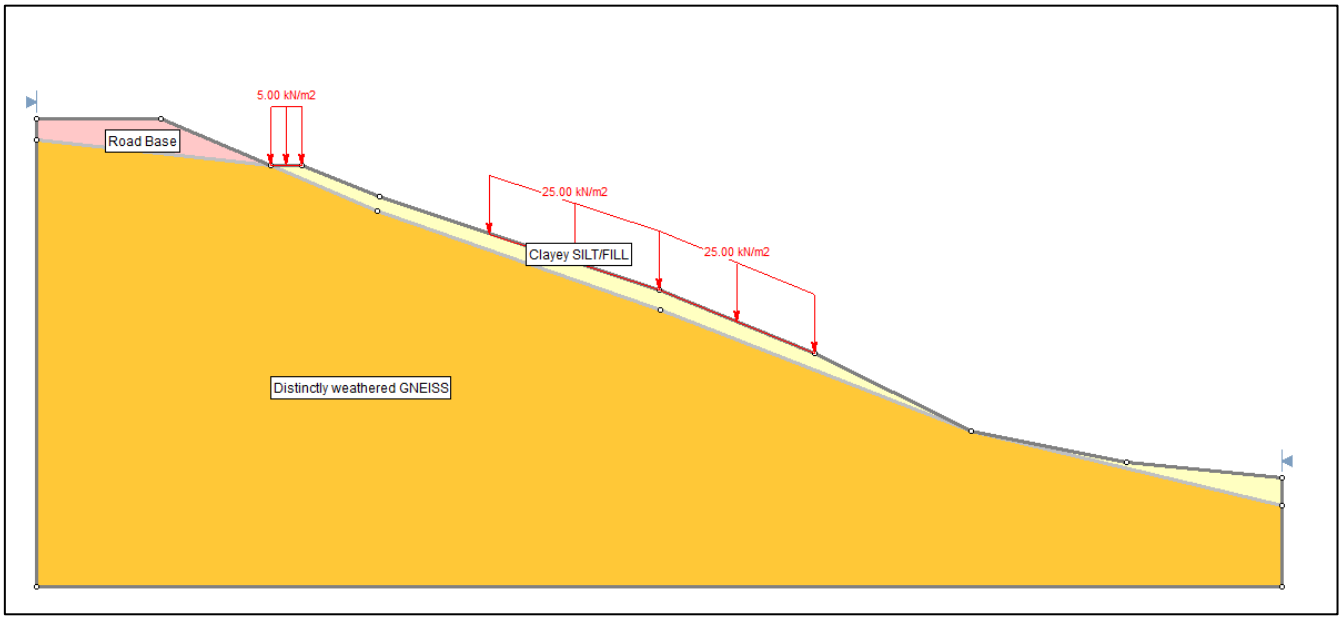
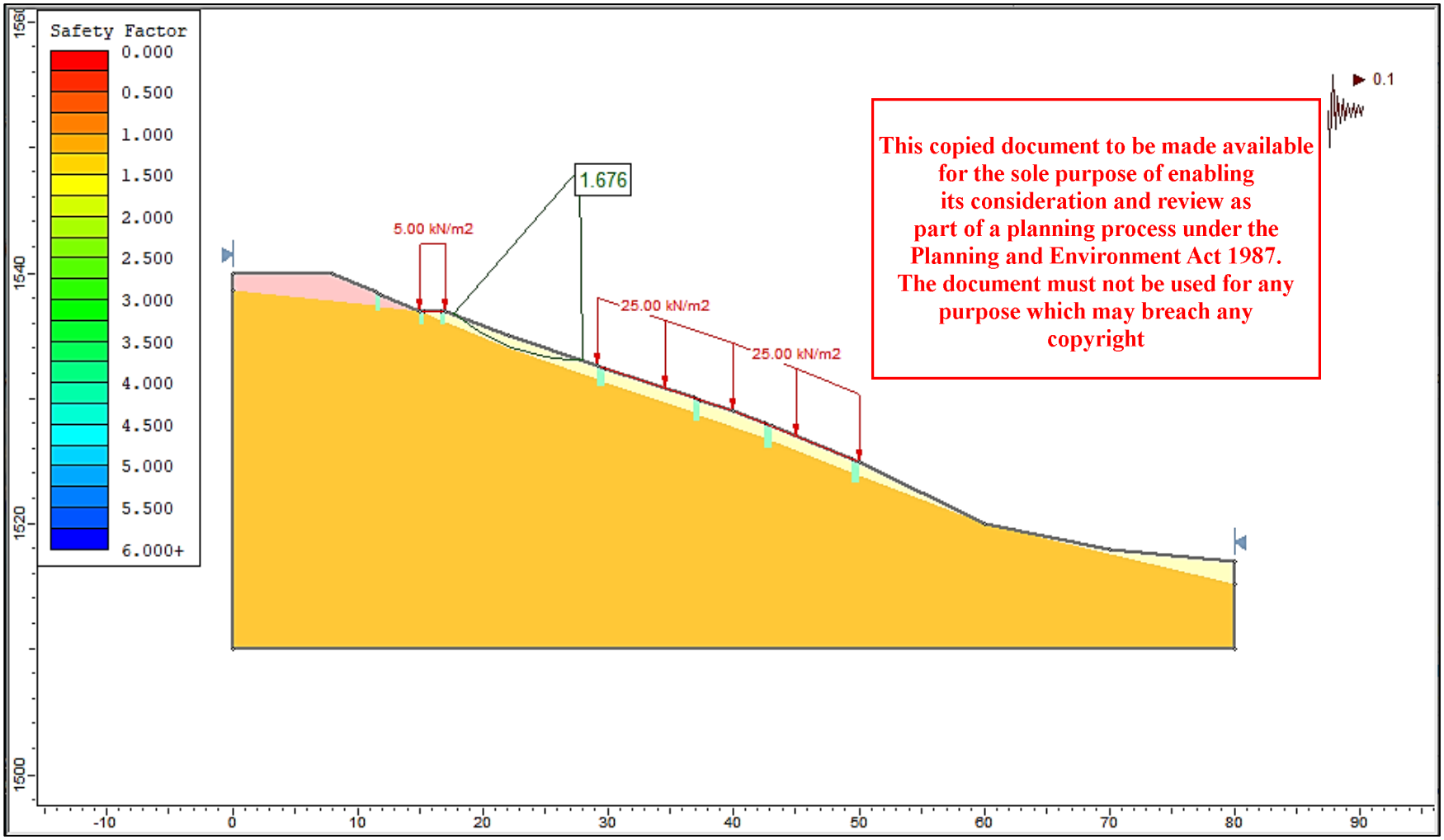


Figure 2: Generalised & Simplified Geological Model

6.1 Findings of the Modelling



The modelling indicates that the existing Factor of Safety for a circular slide at the site is 1.68. If the footings for the walkway are founded in the weathered ROCK, then they would be unaffected by this slip as shown in the model above. Earthquake loading has been incorporated, with an acceleration factor of 0.10.

7. RISK ANALYSIS/ASSESSMENT

7.1 Risk Management Terminology

Risk is defined as a measure of the probability and severity of an adverse effect to health, property or the environment. (Australian Geomechanics Society Landslide Taskforce. 2007).

Risk = the chance of an event times the consequences.

A comprehensive list of terms (AGS Appendices A and B, March 2007) are appended.

7.2 Landslip Terminology

The terms landslip and landslide will have the same meaning. There are five types of landslip: 1. FALL, 2. TOPPLE, 3. SLIDE, 4. SPREAD and 5. FLOW. Figure B1 of AGS Appendix B *Landslide Terminology*, March 2007 describes each type with a diagram.

At present there is one type of slope instability that could potentially occur at this site, which is Shallow Surface Earth FLOW in the FILL or residual soils overlying the bedrock formation.

7.3 Hazard Identification

The identified hazard associated with the site may be summarised as follows:

A. The landslip event of Earth FLOW has the potential to damage the proposed structure. Risk to life is not credible under this event.

7.4 Frequency Analysis

A qualitative assessment has been used to determine specific frequencies of hazards described above. This qualitative assessment uses the terminology as set out in the table *Qualitative Measures of Likelihood* in AGS Appendix C, March 2007. Based on the information provided and the site investigation, the likelihood of Earth FLOW is considered POSSIBLE.

7.5 Consequences to Property

Using the table *Qualitative Measures of Consequences to Property* in AGS Appendix C, March 2007 and taking into account the proposed development, the consequences are assessed as follows

- If damage caused by landslip was to occur, the consequence could be considered MINOR to INSIGNIFICANT for Hazard A.

7.6 Risk Assessment For Property

The *Qualitative Risk Analysis Matrix* in AGS Appendix C, March 2007 has been used to assess the level of risk to property and is represented in the following table.

Hazard		Likelihood	Consequence	Risk
A	Earth FLOW / SPREAD	POSSIBLE	MINOR to INSIGNIFICANT	LOW

Table 7.6.1

Table 7.6.1 shows the identified hazard to have a LOW risk level with respect to the proposed walkway and the practice note guidelines for Landslide Risk Management.

7.7 Risk Assessment for Life

Risk to life is considered not credible at this site.

8. RISK MANAGEMENT AND TREATMENT:

The risk assessment for damage to structures revealed that the identified hazard is considered safe. To maintain a risk rating of LOW for the site, the following measures can be implemented.

- Maintain a good cover of vegetation on slope surfaces. Revegetation using deep-rooted vegetation is also a suitable option for any barren areas post-construction. The aim of this is to prevent the impact of rainfall by utilising the vegetation to take up excess moisture from the surface soils, rather than letting it enter the ground.
- Follow the retention and foundation recommendations outlined in sections 9.4 and 9.6.

The above treatment options will guard against the identified hazards impacting the slope and ramp, and renewed drainage of the site will greatly improve the stability of the existing slope for the long term.

Note, good hillside practices should be adopted at all times when building on sites that may become unstable. AGS Appendix G, March 2007 outlines good hillside practices and can be found attached to this document.

9. RECOMMENDATIONS:

9.1 Site Clearing

All natural vegetation should be retained whenever and wherever possible.

9.2 Earthworks – Cuts

Cut batters (unretained) may be up to 1.0 metre in height on this site with batters not steeper than 1V:2H. This may be impossible to accommodate on-site given the existing slope. Retaining walls may be inevitable where cuts are required for the proposed car parking area.

9.3 Earthworks - Fill

No additional Fill has been allowed for on this site.

9.4 Retaining Walls

Where cut batters are required steeper than 2.0 horizontal to 1.0 vertical, then these should be retained by engineer designed retaining walls to a maximum height of 1.0 metre. These retaining walls should be founded on deep strip footings founded at a minimum depth of 2000mm below the surface level. The retaining walls should be constructed as soon as possible after earthworks have been completed.

Retaining walls must have an agricultural type drain surrounded by a drainage sock placed behind them. Agricultural drains must be surrounded by granular material which extends to the top of the wall. Sufficient weep holes should be made to reduce the pore water pressure on the wall.

The following table can be used for the design of retaining walls:

Material	Unit Weight (kN/m3)	K_a	K_o	c' (kPa)
Clayey SILT FILL	19.0	0.44	0.61	1
Clayey SILT	20.0	0.40	0.57	3
Gravelly SAND	19.5	0.24	0.41	0

Where

K_a = active earth pressure coefficient

K_o = at-rest earth pressure coefficient

c'= effective cohesion

9.5 Drainage

All cuts must have a catch drain constructed at the top to prevent any run-off water flow from running down the batters. The water collected in these drains should ideally be discharged into street drainage and/or a council easement drain.

9.6 Footings for Proposed Walkway

Bored piers or pad footings are a suitable foundation option at this site. They should be founded not less than 100mm into Distinctly Weathered GNEISS as described in the logs of boring, which from the site investigation can be assumed to have an allowable bearing capacity of 200kPa at this depth.

Skin friction between piers and distinctly weathered GNEISS can be assumed to be 50kPa, and should be ignored for all other material.

It is recommended that the founding soils be confirmed by a geotechnical practitioner at the time of excavation to ensure that suitable founding materials have been encountered.

10. CONCLUSION

Based on the site investigation and modelling, the site is suitable for development of a walkway following the recommendations outlined in this report.

11. CONDITIONS OF THE RECOMMENDATIONS:

a) The recommendations made in this report may need to be reviewed should any site works disturb any soil 300mm below the founding depth of the structure.

b) Since the soil horizons and layers can vary in depth and thickness over the site, the depths and bearing capacities given above are given as a guide only. If the footings are founded at the minimum depth, as stated and are in the soil as described in the logs of boring for this site, then the requirements of this report have been met.

c) The recommendations in this report do not consider any effects that climate change may have on the subject property.

d) Any levels referred to in Civiltest reports should be regarded as general and are not to be interpreted as surveyed confirmed levels. All levels should be checked and confirmed by a licensed surveying organisation or qualified personnel.

e) The descriptions of the soils found in the bore holes closely follow those outlined in AS 1726:2017 (Geotechnical Site Investigations). Colour descriptions can vary with soil moisture content. It should be noted therefore, colour and shade descriptions mentioned in this report are made when the soil is in a moist condition.

f) This report has been compiled and recommendations made based on the information supplied in the brief to Civiltest Pty Ltd and from the field investigations and observations made including the extent of if any site filling. Every care has been taken within the terms of the brief to ensure that the field investigation is representative of the site. Therefore, if it is found that for any reason information received by Civiltest Pty Ltd is incorrect or conditions on site vary considerably during construction to those described in this report then the comments and recommendations made in this report may need to be amended.

g) Finally, no responsibility will be taken for this report if it is altered in any way or not reproduced in full.

This report consists of twelve pages. Appendices A (AGS Appendices), B (Plan) and C (Engineering Logs) are attached.

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23 February 2024

AMENDMENT: *The original report was first issued on 19 May 2023. The report was amended on 23 February 2024, and this Issue 2 report now reflects the updated plans as of 8 February 2024. Consequently, this updated revised report supersedes the previous (original) report.*

12. REFERENCES:

Australian Geomechanics Society Landslide Taskforce. (2007). "Practice Note Guidelines For Landslide Risk Management 2007." Journal and News of the Australian Geomechanics Society 42(1): 63-158.

Australian Geomechanics Society, S.C.o.L.R.M. (2002). "Landslide Risk Management Concepts and Guidelines." Australian Geomechanics 35(1): 51-90.

'Slope Movement Types and Processes' David J. Varnes 1978

APPENDIX A

LANDSLIDE RISK MANAGEMENT – AGS SUB-COMMITTEE APPENDICES MARCH 2007

Picarellei, L., Oboni, F., Evans, S.G., Mostyn, G. and Fell, R., (2005) *"Hazard characterization and quantification"* Proc Int Conf on Landslide Risk Management, Vancouver, 31 May-3 June 2005, AA Balkema Publ, O. Hungr, R. Fell, R. Couture and E. Eberhardt eds., pp681

Varnes, D.J. and The International Association of Engineering Geology Commission on Landslides and other Mass Movements (1984). Landslide Hazard Zonation: A review of principles and practice. Natural Hazards, Vol 3, Paris,France. UNESCO, 63p.

Standards Australia (1996) *"Residential Slabs and Footings"* Australian Standard AS2870

Standards Australia (2001) *"Concrete Structures"* Australian Standard AS3600

Standards Australia (2001) *"Steel Structures"* Australian Standard AS4100

Standards Australia (2002) *"Earth Retaining Structures"* Australian Standard AS4678.

APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK

RISK TERMINOLOGY

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, 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.

There 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.

(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.

ASSOCIATED TERMINOLOGY

Importance Level – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason *per se* of the Importance Level.

Authority or **Council** having statutory responsibility for community activities, community safety and development approval or management of development within its defined area/region.

The **Regulator** will be the responsible body/authority for setting Acceptable/Tolerable Risk Criteria to be adopted for the community/region/activity, which will be the basis for setting levels for Acceptable and Tolerable Risk in the application of the risk assessment guidelines.

Importance Level of Structure	Explanation	Examples (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
1	Buildings or structures generally presenting a low risk to life and property (including other property).	Farm buildings. Isolated minor storage facilities. Minor temporary facilities. Towers in rural situations.
2	Buildings and structures not covered by Importance Levels 1, 3 or 4.	Low-rise residential construction. Buildings and facilities below the limits set for Importance Level 3.
3	Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds.	Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250. Buildings and facilities for colleges or adult education facilities with a capacity greater than 500. Health care facilities with a capacity of 50 or more residents but no having surgery or emergency treatment facilities. Jails and detention facilities. Any occupancy with an occupant load greater than 5,000. Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4. Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.
4	Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials.	Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgery facilities. Emergency service facilities: fire, rescue, police station and emergency vehicle garages. Utilities required as back-up for buildings and facilities of Importance Level 4. Designated emergency shelters. Designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries.

(from BCA Guidelines)

Practitioner – A specialist Geotechnical Engineer or Engineering Geologist who is degree qualified, is a member of a professional institute and who has achieved chartered professional status – being either Chartered Professional Engineer (CPEng) within the Institution of Engineers Australia, Chartered Professional Geologist (CPGeo) within the Australasian Institute of Mining & Metallurgy, or Registered Professional Geoscientist (RPGeo) within the Australian Institute of Geoscientists – specifically with Landslide Risk Management as a core competency.

A Practitioner will include persons qualified under the Institution of Engineers Australia NPER – LRM register.

It would normally be required that the Practitioner can demonstrate an appropriate minimum period of experience in the practice of landslide risk assessment and management in the geographic region, or can demonstrate relevant experience in similar geological settings.

Regulator – The regulatory authority [Federal Government/ State Government/ Instrumentality/ Regional/Local.

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).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly Coarse	Predominantly Fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (Deep creep)	Debris flow (Soil creep)	Earth flow
COMPLEX	Combination of two or more principle types of movement			

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.

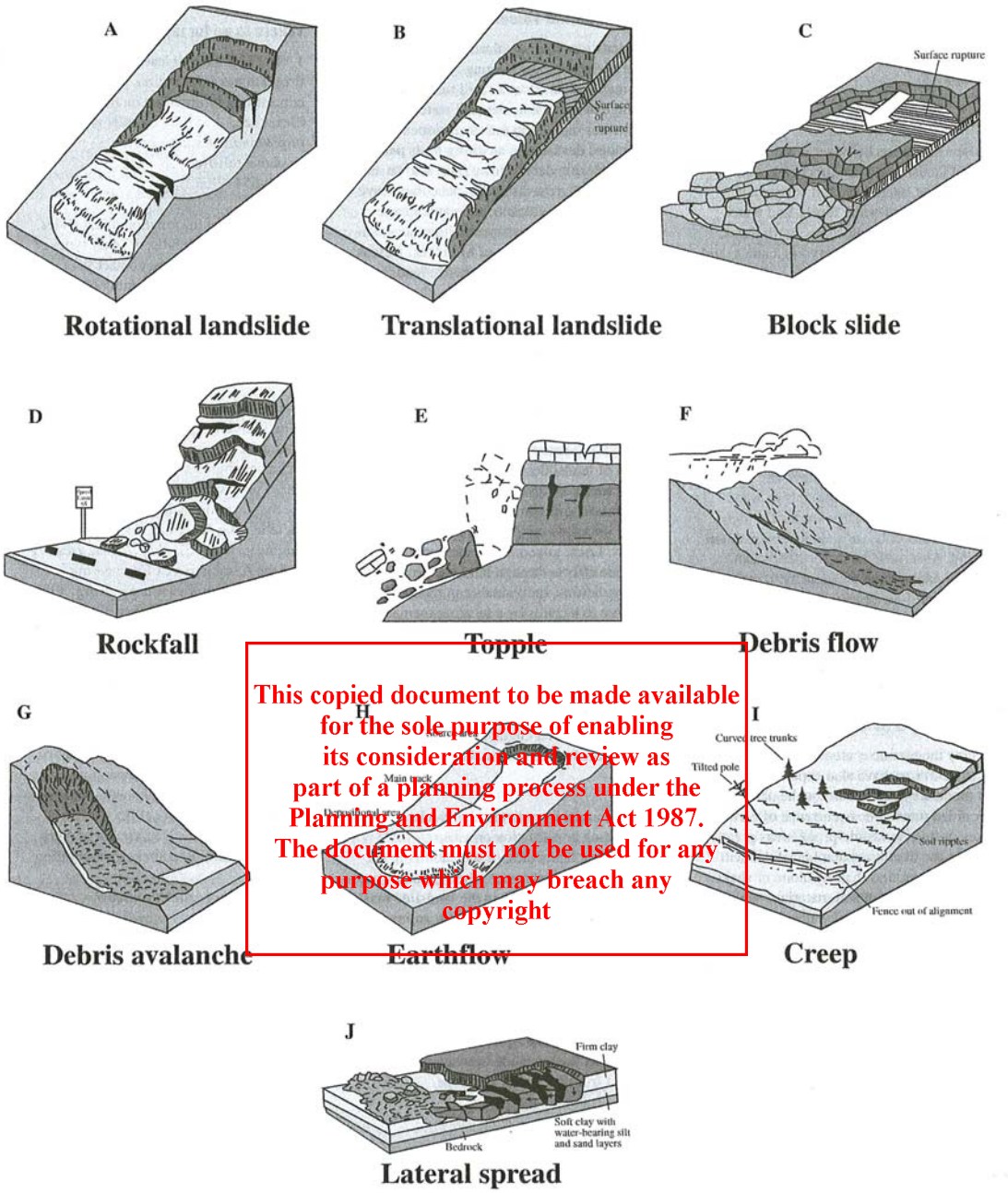

Figure B1: These schematics illustrate the major types of landslide movement.
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Second or subsequent movements in complex or composite landslides can be described by repeating, as many times as necessary, the descriptors used in Table B2. Descriptors that are the same as those for the first movement may then be dropped from the name.

For example, the very large and rapid slope movement that occurred near the town of Frank, Alberta, Canada, in 1903 was a *complex, extremely rapid, dry rock fall – debris flow*. From the full name of this landslide at Frank, one would know that both the debris flow and the rock fall were extremely rapid and dry because no other descriptors are used for the debris flow.

The full name of the landslide need only be given once; subsequent references should then be to the initial material and type of movement; for the above example, "the rock fall" or "the Frank rock fall" for the landslide at Frank, Alberta.

Table B2: Glossary for forming names of landslides.

Activity

State	Distribution	Style
Active	Advancing	Complex
Reactivated	Retrogressive	Composite
Suspended	Widening	Multiple
Inactive	Enlarging	Successive
Dormant	Confined	Single
Abandoned	Diminishing	
Stabilised	Moving	
Relict		

Description of First Movement

Rate	Water Content	Material	Type
Extremely rapid	Dry	Rock	Fall
Very rapid	Moist	Earth	Topple
Rapid	Wet	Debris	Slide
Moderate	Very Wet		Spread
Slow			Flow
Very slow			
Extremely slow			

Note: Subsequent movements may be described by repeating the above descriptors as many times as necessary. These terms are described in more detail in Cruden & Varnes (1996) and examples are given.

Landslide Features

Varnes (1978, Figure 2.1t) provided an idealised diagram showing the features for a *complex earth slide – earth flow*, which has been reproduced here as Figure B2. Definitions of landslide dimensions are given in Cruden & Varnes (1996).

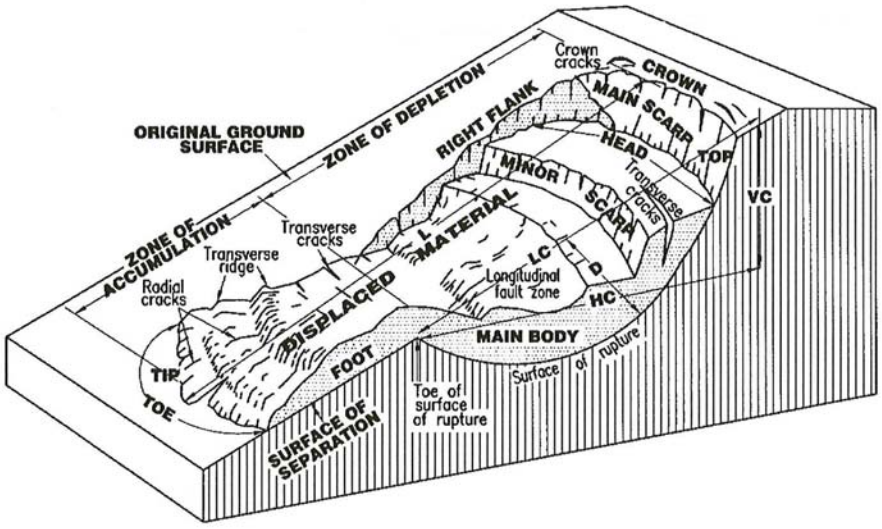

Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(*Varnes, D J (1978,)Slope Movement Types and Processes. In Special Report 176: Landslides: Analysis and Control(R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33).*

Rate of Movement

Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term "creep" has been omitted due to the many definitions and interpretations in the literature.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evaluation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
	Extremely **SLOW**			Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS**

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

REFERENCES AND ACKNOWLEDGEMENT

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PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

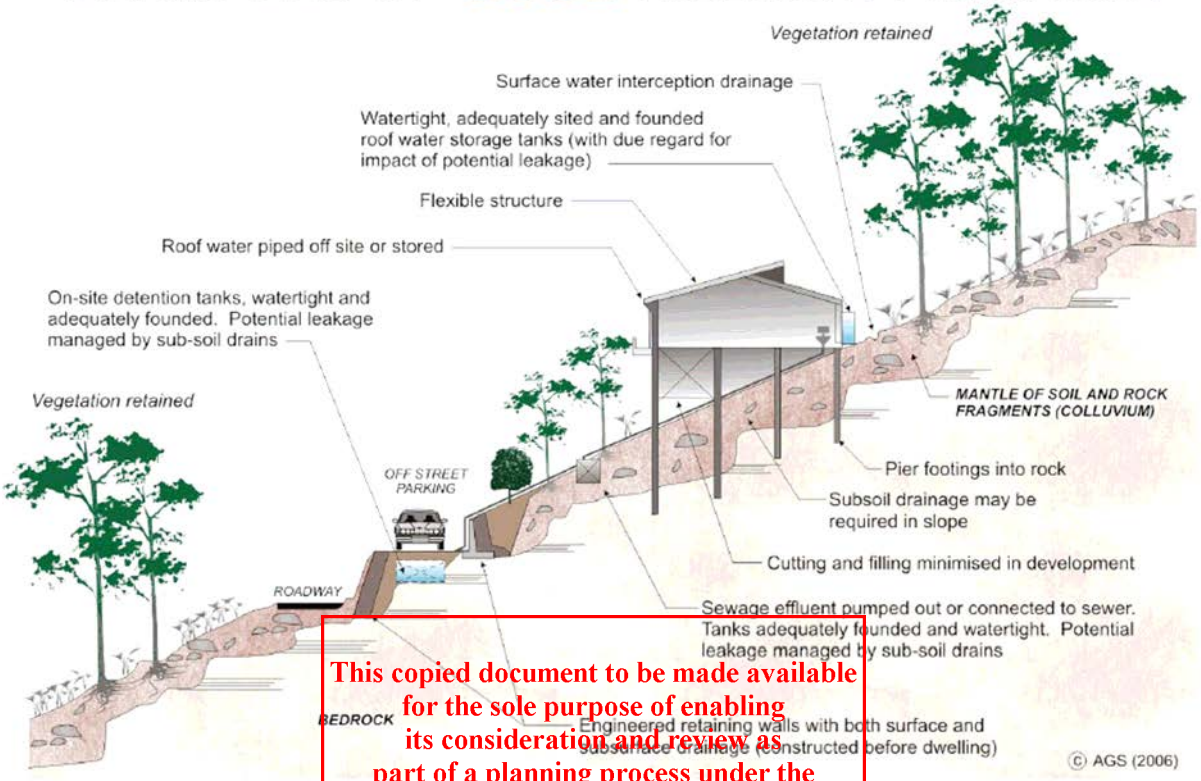
Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the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

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

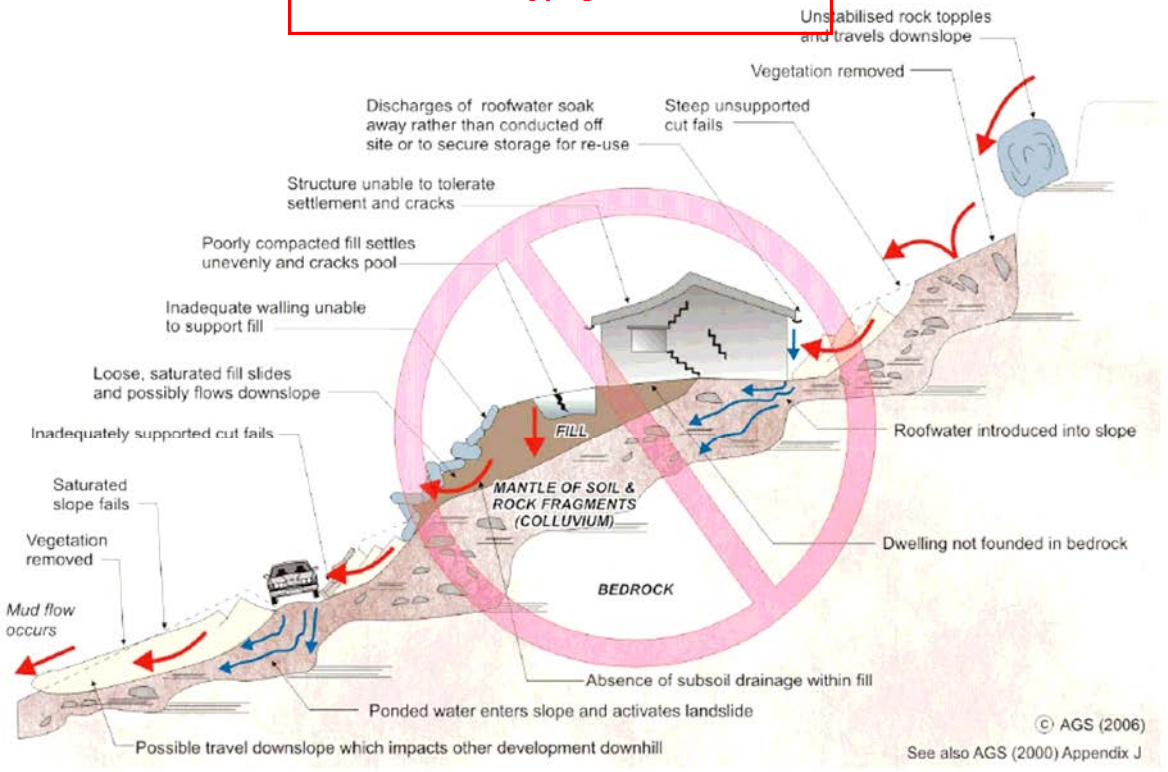
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	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.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE

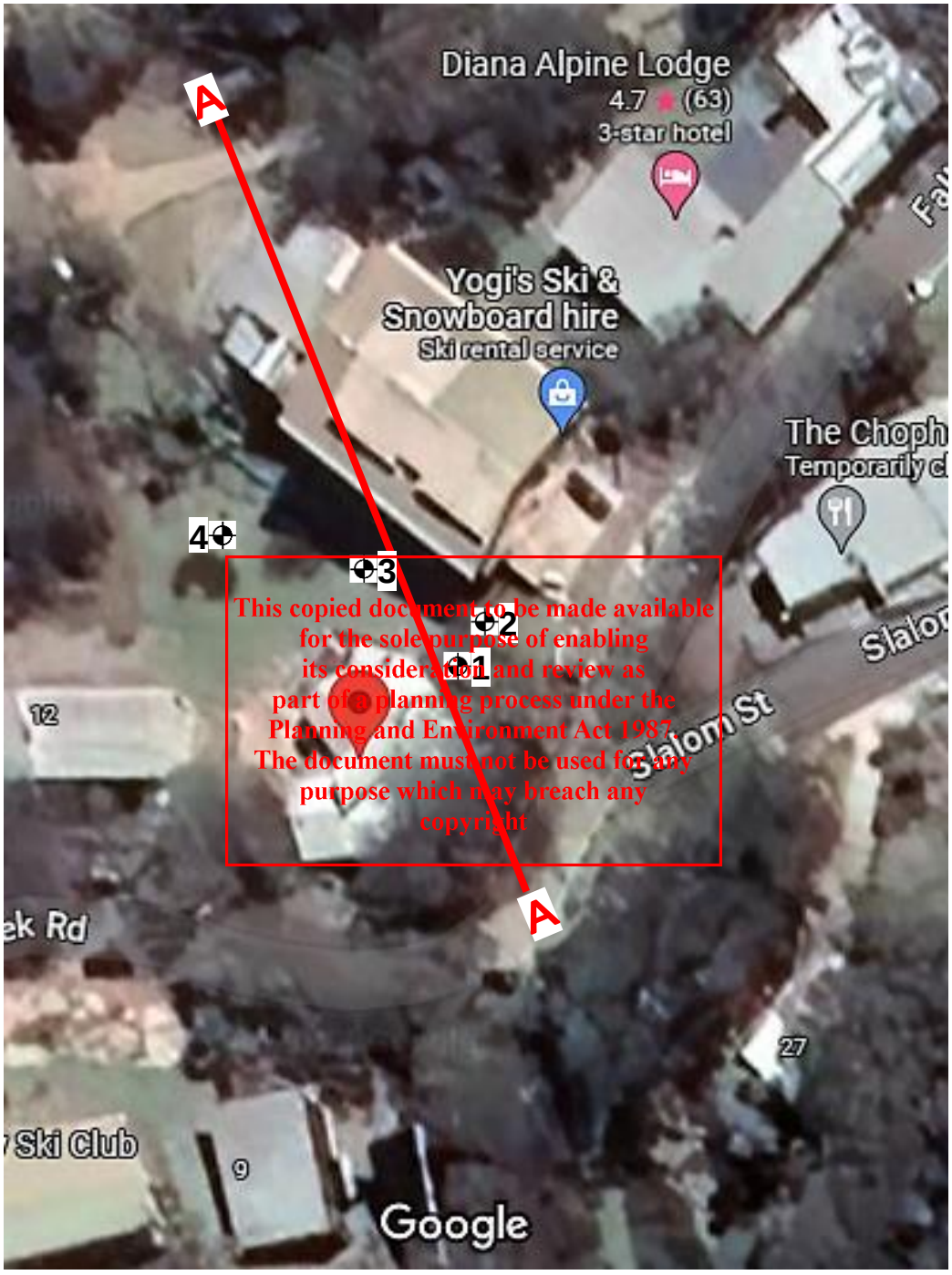


APPENDIX B

PLAN: LOCATION OF TEST SITES & SECTION A – A

PLAN: LOCATION OF TEST SITES & SECTION A – A

8-10 FALLS CREEK ROAD FALLS CREEK



Denotes Borehole

NOT TO SCALE

THIS PLAN IS NOT INTENDED TO PROVIDE AN ACCURATE DEPICTION OF THE NUMBER, SIZE OR LOCATION OF TREES AND/OR SHRUBS

APPENDIX C

ENGINEERING LOGS

ENGINEERING LOG

REPORT NO. 1230386-1 **BOREHOLE NO. 1** **DATE: 20-APR-2023**
FIELD TECHNICIAN: dt **DRILLING METHOD: HA : Hand Auger**
PROJECT LOCATION: Site 26 Falls Creek Road FALLS CREEK

DEPTH (m)	STRATA DESCRIPTION	NOTES	GRAPHIC LOG	TESTING					
				DEPTH (m)	RESULTS				
					DCP Blows/100mm	FIELD CBR (%)	SPT	MC (%)	PP (kg/cm^2)
0	**FILL**, SAND, silty; Grey; Dry; Medium dense								
0.200	SW SAND, gravelly; Grey yellow black; Dry; Dense;								
0.300	Sand is sub-angular, medium grained; Gravel is								
0.400	sub-angular, fine grained								
	Distinctly Weathered ROCK, GNEISS; Grey yellow								
	black; Dry; Medium strength								
	REFUSAL (20-Apr-2023)								
1									
2									
3									
4									

ENGINEERING LOG

REPORT NO. 1230386-1 **BOREHOLE NO. 2** **DATE: 20-APR-2023**
FIELD TECHNICIAN: dt **DRILLING METHOD: HA : Hand Auger**
PROJECT LOCATION: Site 26 Falls Creek Road FALLS CREEK

DEPTH (m)	STRATA DESCRIPTION	NOTES	GRAPHIC LOG	TESTING					
				DEPTH (m)	RESULTS				
					DCP Blows/100mm	FIELD CBR (%)	SPT	MC (%)	PP (kg/cm^2)
0	**FILL**, SAND, silty; Grey; Dry; Medium dense								
0.200	SW SAND, gravelly; Grey yellow black; Dry; Dense;								
0.300	Sand is sub-angular, medium grained; Gravel is sub-angular, fine grained								
0.450	Distinctly Weathered ROCK, GNEISS; Grey yellow black; Dry; Medium strength								
	REFUSAL (20-Apr-2023)								
1									
2									
3									
4									

ENGINEERING LOG

REPORT NO. 1230386-1 **BOREHOLE NO. 3** **DATE: 20-APR-2023**
FIELD TECHNICIAN: dt **DRILLING METHOD: HA : Hand Auger**
PROJECT LOCATION: Site 26 Falls Creek Road FALLS CREEK

DEPTH (m)		STRATA DESCRIPTION	NOTES	GRAPHIC LOG	TESTING					
					DEPTH (m)	RESULTS				
						DCP Blows/100mm	FIELD CBR (%)	SPT	MC (%)	PP (kg/cm^2)
0		**FILL**, SAND, silty, with gravel; Grey; Moist; Medium dense								
	0.500	REFUSAL (20-Apr-2023)								
1										
2										
3										
4										

ENGINEERING LOG

REPORT NO. 1230386-1 **BOREHOLE NO. 4** **DATE: 20-APR-2023**
FIELD TECHNICIAN: dt **DRILLING METHOD: HA : Hand Auger**
PROJECT LOCATION: Site 26 Falls Creek Road FALLS CREEK

DEPTH (m)		STRATA DESCRIPTION	NOTES	GRAPHIC LOG	TESTING					
					DEPTH (m)	RESULTS				
						DCP Blows/100mm	FIELD CBR (%)	SPT	MC (%)	PP (kg/cm^2)
0		**FILL**, SILT, clayey; Grey; Moist; Medium dense								
	0.500	ML SILT, clayey; Brown; Moist(w≈PL); Medium dense								
	0.700	REFUSAL (20-Apr-2023)								
1										
2										
3										
4										