

## LANDSLIDE RISK ASSESSMENT



### **PROPOSED DRIVEWAY 14 BATCHELORS ROAD - SANDFLY**

**Client:** Lachlan Joyce  
**Certificate of Title:** 134464/1  
**Investigation Date:** Monday, 20 January 2025

**Refer to this Report As**

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**Limitations of this geotechnical report**

In some cases, variations in actual Site conditions may exist between subsurface investigation boreholes. This report only applies to the tested parts of the Site, and if not specifically stated otherwise, results should not be interpreted beyond the tested areas.

The Site investigation is based on the observed and tested soil conditions relevant to the inspection date. Subsurface conditions may change laterally and vertically between test sites, so discrepancies may occur between what is described in the reports and what is exposed by subsequent excavations. No responsibility is therefore accepted for any difference in what is reported, and actual site and soil conditions for parts of the investigation site which were not assessed at the time of inspection.

No responsibility is accepted for subsequent activities onsite by owners and/or climate variability including but not limited to placement of fill, uncontrolled earthworks, altered drainage conditions or changes in groundwater levels.

The pages that form the last six pages of this report are an integral part of this report. The notes contain advice and recommendations for all stakeholders in this project (i.e. the structural engineer, builder, owner and future owners) and should be read and followed by all concerned.

This report has been prepared based on provided plans detailed herein. Should there be any significant changes to these plans, then this report should not be used without further consultation. This report should not be applied to any project other than indicated herein.

## Executive Summary

Enviro-Tech Consultants Pty. Ltd. (Envirotech) were contracted by Lachlan Joyce to prepare a landslide risk assessment for a property at 14 Batchelors, Road Sandfly.

This report will assess the existing driveway access to a proposed dwelling (herein referred to as the Site) which falls within the Low and Medium Landslide Hazard Code Overlay (Attachment 1)

Based on the Kingborough LIDAR (2022) the Project Area ranges in elevation from approximately 195 to 330 m AHD with a strong slope (~30%) to the east towards Cooke Rivulet.

The geology of the Site is consistent with MRT mapping and comprises of Jurassic dolerite. The soil ranges in depth from 0.5 through to 2.0 m thickness and comprises of soil and cobble colluvium overlying Sandy SILT and Silty CLAY layers. This layer transitions to extremely weathered and highly weathered dolerite, which is found at the base of the entire length of the existing driveway cut.

The existing cut batter reaches up to 50° in some parts of the driveway with an average slope angle of 40°.

Localised rockfall of cobbles and small boulders are observed at the base of the road cut. Most of the soil layers tested at the Site are severely dispersive and susceptible to riling erosion with wash out exposing cobbles and boulders within the cut and fill batters.

The existing driveway fill batter has angles up to 40° observed.

The fill in the driveway is observed to be highly compacted with no evidence of slope instability in the models and in the field. The margins of the driveway are vulnerable to slope instability with slip scenario modelled on the outside edge of the road 0.5m from the cut. The slope instability is confirmed in the field, with tension cracks and DCP free falling through the FILL batter at locations where filled slopes exceed 35°.

The following risk scenarios have been established for the proposed building, works and use:

### Scenario 1

Within the lifetime of the proposed development, the probability of Scenario 1 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

### Scenario 2

Within the lifetime of the proposed development, the probability of Scenario 2 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

### Scenario 3

Within the lifetime of the proposed works, it LIKELY that the margins of the road near cross Section A and Test Pit TP2 will become unstable and slide. The probability that road will be damaged is inferred to be reduced to POSSIBLE through measures such as preventing water from draining into the FILL (including into tension cracks). Other options may be considered such as road stabilisation works to further reduce the probability, but given to road can be widened into the cut, then the overall consequences (as a proportion of the overall area of the road impacted) may be reduced instead.

### Scenario 4

Same scenario as above, with a lower probability given the POSSIBLE probability is assigned as it is dependent on the vehicle intercepting the collapsed road section. With the treatment measures, this probability may be reduced to UNLIKELY. Treatment involving widening of the road into the cut and putting guideposts in to prevent vehicles from travelling over the more vulnerable filled areas at risk of slope failure.

Provided the treatment measures are put in place, the following is concluded:

- The type, form and scale are suitable for the intended duration of the development.
- The buildings and works do not cause or contribute to landslip on the site, on adjacent land or public infrastructure.
- Landslip reduction or protection measures are not required beyond the boundary of the Site

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# 1 Introduction

## 1.1 Background

Enviro-Tech Consultants Pty. Ltd. (Envirotech) were contracted by Lachlan Joyce to prepare a landslide risk assessment for a property at 14 Batchelors, Road Sandfly.

This report will assess the existing driveway access to a proposed dwelling (herein referred to as the Site) which falls within the Low and Medium Landslide Hazard Code Overlay (Attachment 1).

This Landslide Risk Assessment (LRA)<sup>1</sup> is for the Site and immediate surrounds (herein referred to as the Project Area) is based on the Australian Geomechanics Society (AGS) LRM guidelines (2007)<sup>2</sup>.

Envirotech have assessed risk to life and property based on the supplied site plans for the proposed development and the identified hazards<sup>3</sup>.

## 1.2 Scope

The scope of the Site investigation is to:

- Overview any MRT landslide mapping, databases and historical studies relevant to the Site.
- Determine Project Area geology, geomorphology, geometry, hydrology and slope forming processes to determine Site specific landslide hazards
- Prepare a geotechnical site investigation (GSI) comprising a detailed analysis of Site soil and rock conditions including soil and rock testing and analysis to obtain material geotechnical properties.
- Geomorphic mapping of any slope forming process and landslide features which may impact on the proposed development.
- Develop slope stability models and prepare a landslide risk assessment based on existing and potential landslide scenarios which may occur from the proposed development.
- Identify if the landslide hazards associated with the proposal can achieve and maintain an acceptable risk<sup>4</sup>
- Where any associated risks are deemed as not being acceptable, then treatment options are recommended to ensure a tolerable risk<sup>5</sup>.

## 1.3 Cadastral Title

The land studied in this report is defined by the title 134464/1

1 This landslide risk assessment has been written in accordance with Australian Geomechanics Society Guidelines for landslide risk management by an engineering geologist with appropriate skills, training, insurances and qualifications as specified in the Director of Building Control's determination.

2 This framework, definitions and terminology adopted in this report are applied directly from the AGS LRM guideline reports (AGS 2007a to 2007e).

3 As well as a Site-specific LRA field investigation conducted by Envirotech, hazards identified within this report are based on open-source scientific documents, spatial remote sensing data, Site specific and local area soil test reports and LRA reports where available. Some of the spatial data used in this assessment is by its nature approximate and may contain errors introduced by the data provider(s).

4 Tolerable risk means the lowest level of likely risk from landslide to secure the benefits of a use or development in a landslide hazard area, and which can be managed through routine regulatory measures or by specific hazard management measures for the intended life of each use or development.

5 Treatment measures where applicable are to ensure that the proposed use and development are appropriately designed, located, serviced, constructed, or managed to reduce risk to within tolerable limits for protecting human life and property and the cost to the community. In which case, prepare the following risk assessments for the proposal using the AGS risk-based framework:

- quantitative risk assessment approach for assessment of life loss risk
- qualitative or semi-quantitative assessment of property risk

## 1.4 Site Setting

The local Hillshade model for the project area and Site is presented in Attachment 1 (Map 1).

# 2 Planning

## 2.1 Proposed Development

This report will assess the existing driveway access to a proposed dwelling (herein referred to as the Site) which falls within the Low and Medium Landslide Hazard Code Overlay (Attachment 1).

## 2.2 Planning

Details on relevant code objectives, acceptable solutions, and performance criteria to be addressed are presented in Attachment 2.

### 2.2.1 Overlay Extent

Landslide hazard overlay mapping (Map 2) illustrates that the existing driveway, fall within the low and medium landslide hazard band. The interim planning scheme code E3 needs to be addressed.

### 2.2.2 Components

Landslide hazard overlay mapping (Map 2) illustrates the following components:

- Remaining areas slopes 11-20 degrees (low hazard overlay)
- Remaining areas slopes >20deg (medium hazard overlay)

### 2.2.3 Landslide Code

Major works codes are triggered given the following are proposed:

- Excavation of 100 m<sup>3</sup> or more in cut volume
- Excavation or soil disturbance of an area of 1,000 m<sup>2</sup> or more
- Felling or removal of vegetation over a contiguous area greater than 1,000m<sup>2</sup>;

As there are no acceptable solutions to the proposed works, the following performance criteria are to be addressed:

- E3.7.1 P1 Buildings and Works, other than Minor Extensions
- E3.7.3 P1 Major Works

# 3 Project Area Description

## 3.1 Topography

Based on the Kingborough LIDAR (2022) the Project Area ranges in elevation from approximately 195 to 330 m AHD with a strong slope (~30%) to the east towards Cooke Rivulet.

## 3.2 Published Geology

According to the 1:250,000 geological mapping by Mineral Resources Tasmania (MRT), geology of the Site comprises:

- Jurassic dolerite

## 4 Investigation Findings

### 4.1 Walkover

Site photos are presented in Attachment 3. The following were observed in the Site walkover:

- The existing cut batter reaches up to 50° in some parts of the driveway with an average slope angle of 40°.
- Localised rockfall of cobbles and small boulders at the base of the road cut were observed.
- Steep angles are also used for the existing driveway fill where batter angles up to 40° are observed.
- There is evidence of localise slope instability (tension cracks) in some parts of the existing driveway fill (Photo 6, Photo 7).

### 4.2 Observed Geology

Soil investigation points are presented in Map 4.

Findings from the Soil assessment, engineering logs, and core/test pit photographs are presented in the attached GSI report (Attachment 13)

Findings indicate that the underlying geology is consistent with MRT mapping and comprises Jurassic dolerite. The soil ranges in depth from 0.5 through to 2.0 m thickness and comprises of soil and cobble colluvium overlying Sandy SILT and Silty CLAY layers. This layer transitions to distinctly weathered and slightly weathered dolerite, which is found at the base of the entire length of the existing driveway cut.

### 4.3 Geotechnical Observations

Geotechnical testing results are presented in Attachment 13.

Results indicate colluvial deposits are medium firm to hard. The underlying SILT and CLAY layers are stiff to very stiff across the soil testing locations.

## 5 Hazard Assessment

### 5.1 Hazard Scenarios

The site geotechnical model is presented in Attachment 4 which illustrates three slope instability scenarios for the Project Area:

- **Scenario 1.** Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide
- **Scenario 2.** Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple
- **Scenario 3.** Slope instability in existing driveway uncompacted fill edges with road damage: Earth Slide
- **Scenario 4.** Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide

### 5.2 Geotechnical Model

Cross sections have been prepared for the Site to capture all four scenarios. The model has been developed by inferring intersecting soil profiled observed within the test holes (Attachment 4). Soil geotechnical properties for all soil layers are inferred based on soil testing results including from dynamic cone penetrometer testing, undrained shear strength from the field vane, Atterberg limits and particle size analysis as well as general experience and field observations. Material properties are presented in Attachment 4.

The fill material is inferred to comprise of similar soils observed in the road cutting. The filled road margins have significantly reduced soil strengths as observed in the field testing and observations.

### 5.3 Slope Stability Analysis

Geo 5 Slope Stability model has been used for the analysis. The slope stability analysis has been prepared for Scenario 3 and 4 within the Project Area with findings presented in Attachment 5. The specific location of these scenarios is near Test Pit TP2 and near cross section A.

The following geotechnical constraints have been applied to the model:

- A deep water table scenario has been adopted within the Project Area.
- A road loading of 20 kN/m<sup>2</sup> is applied
- Analysis using the Bishop method
- A safety factor of 1.3

The following is concluded from the modelling:

- Based on present conditions, a safety factor of 1.3 is not met (1.26) with rotational failure predicted on the margin of the road.
- The cut is projected to have a safety factor exceeding 1.3.
- If the road margins are loaded as indicated above, a factor of safety of 1.05 is modelled which is below the acceptable limits
- Management is recommended for Scenario 3 and required for Scenario 4.

### 5.4 Landslide Probability Analysis

A landslide hazard assessment is presented in Attachment 6 which is based on landslide terminology presented in Attachment 8:

#### Scenario 1

Within the lifetime of the proposed development, the probability of Scenario 1 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

#### Scenario 2

Within the lifetime of the proposed development, the probability of Scenario 2 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

#### Scenario 3

Within the lifetime of the proposed works, it LIKELY that the margins of the road near cross Section A and Test Pit TP2 will become unstable and slide. The probability that road will be damaged is inferred to be reduced to POSSIBLE through measures such as preventing water from draining into the FILL (including into tension cracks). Other options may be considered such as road stabilisation works to further reduce the probability, but given to road can be widened into the cut, then the overall consequences (as a proportion of the overall area of the road impacted) may be reduced instead.

#### Scenario 4

Same scenario as above, with a lower probability given the POSSIBLE probability is assigned as it is dependent on the vehicle intercepting the collapsed road section. With the treatment measures, this probability may be reduced to UNLIKELY. Treatment involving widening of the road into the cut and putting guideposts in to prevent vehicles from travelling over the more vulnerable filled areas at risk of slope failure.

## 6 Risk Assessment

### 6.1 Risk to Life

Given proposed treatment measures presented within this report, risk to life is considered tolerable with consideration for the elements most at risk.

### 6.2 Risk to Property

Given proposed treatment measures, risk to property is considered LOW within the building design life.

## 7 Concluding Statement

Landslide risk associated with buildings and works is:

- capable of feasible and effective treatment through hazard management measures, to be tolerable risk

## 8 Recommendations

### 8.1 General

The outcomes of this assessment for landslide risk to property and risk to life only apply if building design and Site use is in accordance with the following guidelines presented in Attachment 11 & Attachment 12:

- Some Guidance's for Hillside Construction adapted from the Journal of the Australian Geomechanics Society - Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007 (AGS 2007c).
- CSIRO 2003b. A builder's guide to preventing damage to dwellings. Part 2 - sound construction methods. Building Technology File. Distributed by CSIRO Publishing Number 22 August 2003.

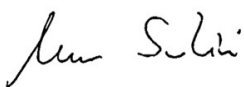
### 8.2 Geotechnical Site Investigation Report

Key slope stability management measures along with recommendations presented in the GSI report must be followed for successful management of site slope stability.

### 8.3 Key Slope Stability Management Measures

For Scenario 3 the attached Geotechnical Site Investigation address management measures which will need to be followed with key recommendations including:

- Road widening by 0.5 m in the cut near Section A and test pit TP2 (Map 5) but not in the fill (fill must not be used).
- Provision of roadside guideposts 1.0m from the crest of the widened sections
- Ensuring the cuts do not exceed 1H:1V.
- Fill management including preventing water infiltration and slope stabilisation if not cost prohibitive



Marco Scalisi BSc Msc | Environmental & Engineering Geologist

Project manager

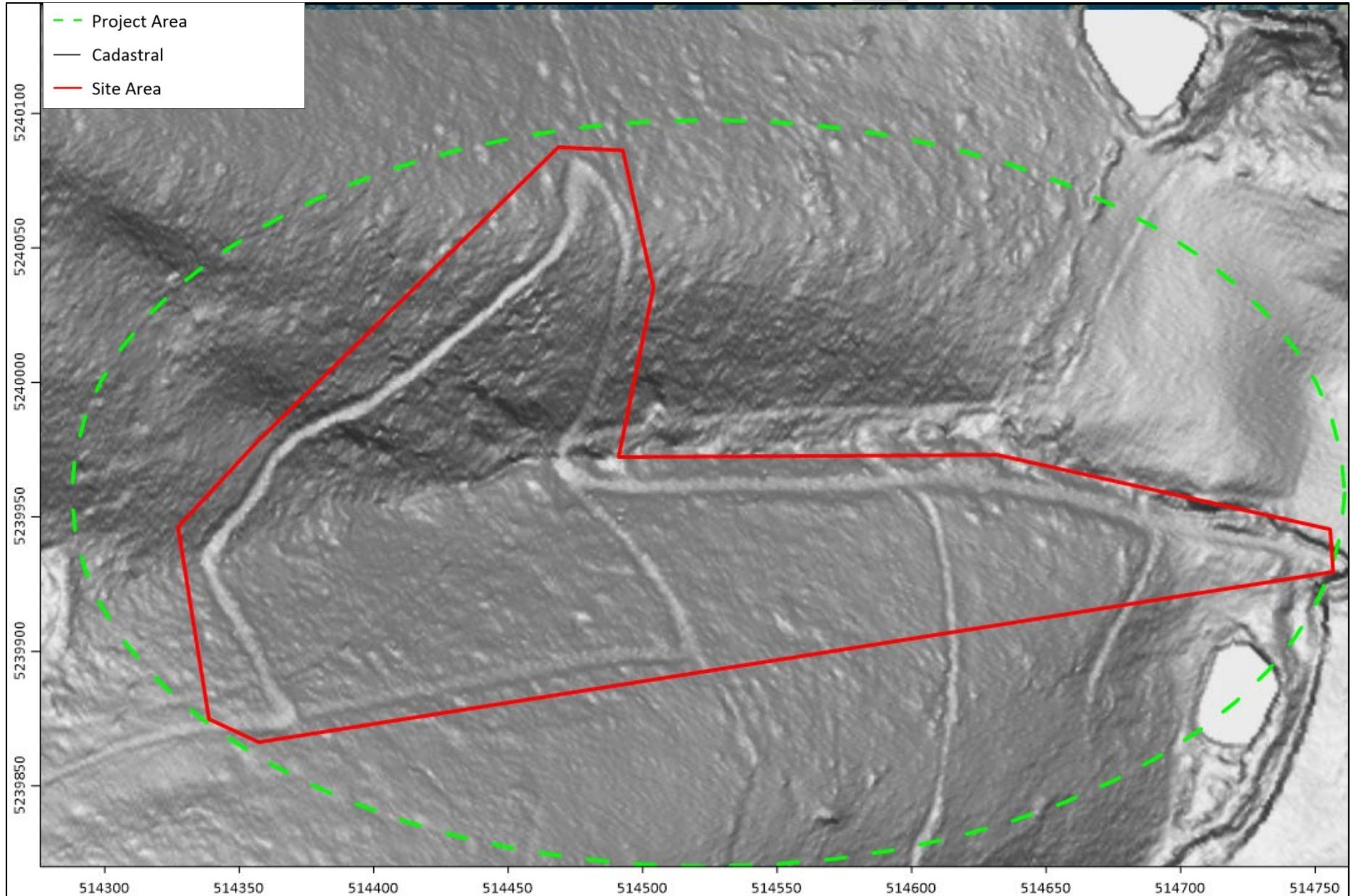
Enviro-Tech Consultants Pty. Ltd.

## 9 References

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- AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
- AGS (2007b). Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007
- AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
- AGS (2007d). Commentary on Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007
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- CSIRO 2003a. Foundation Maintenance and Footing Performance: A Homeowners Guide. CSIRO BFT 18 replaces information sheet 10/91. CSIRO document, BTF 18 – "Foundation Maintenance and Footing Performance: A Homeowner's Guide
- CSIRO 2003b. A builders guide to preventing damage to dwellings. Part 2 - sound construction methods. Building Technology File. Distributed by CSIRO Publishing Number 22 August 2003.
- Stewart, I.E., Baynes, F.J. and Lee, I.K. (2002) "The RTA Guide to Slope Risk Analysis Version 3.1" Australian Geomechanics Vol 37 No 2 May pp115 – 147.

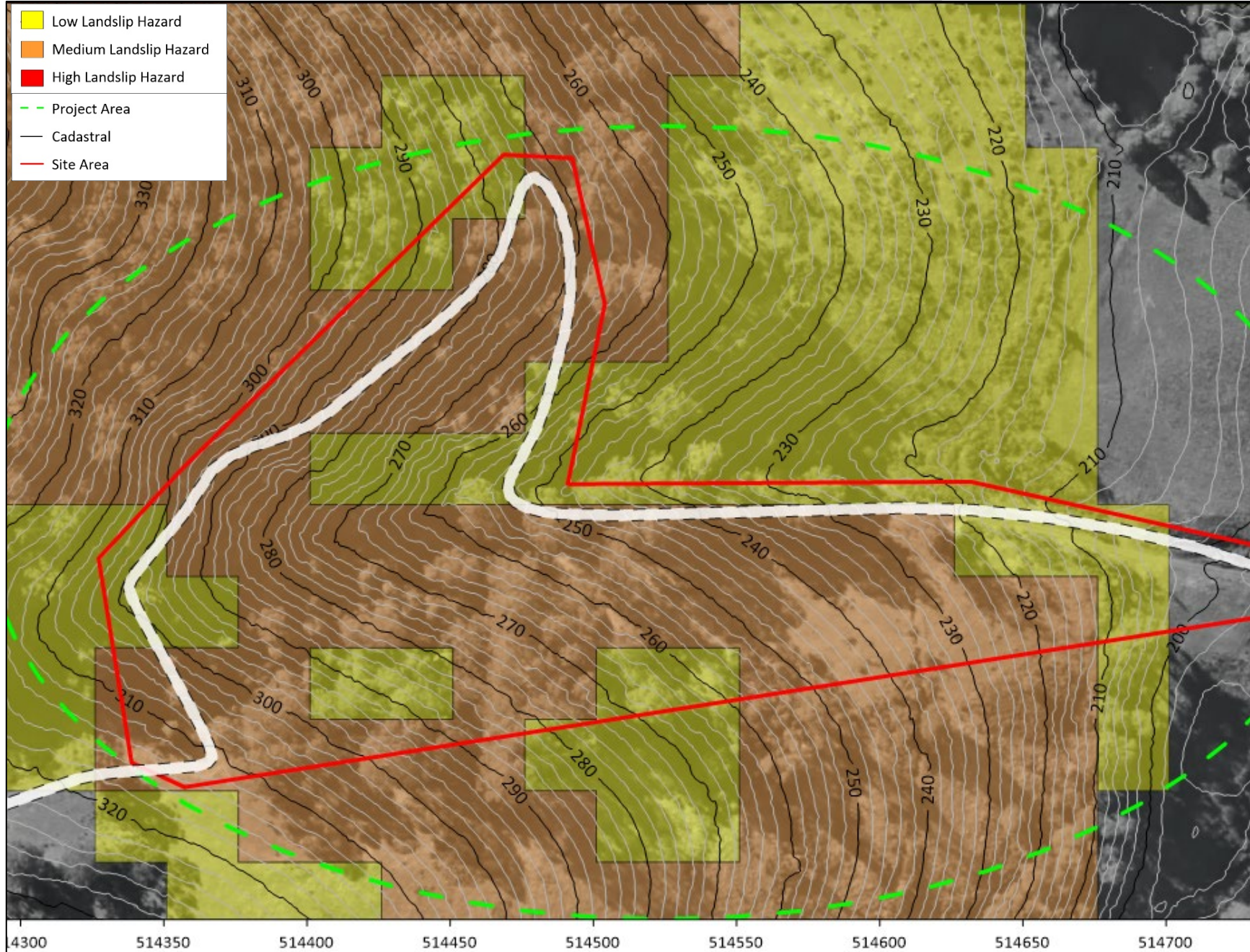
## Attachment 1 Maps

### Map 1



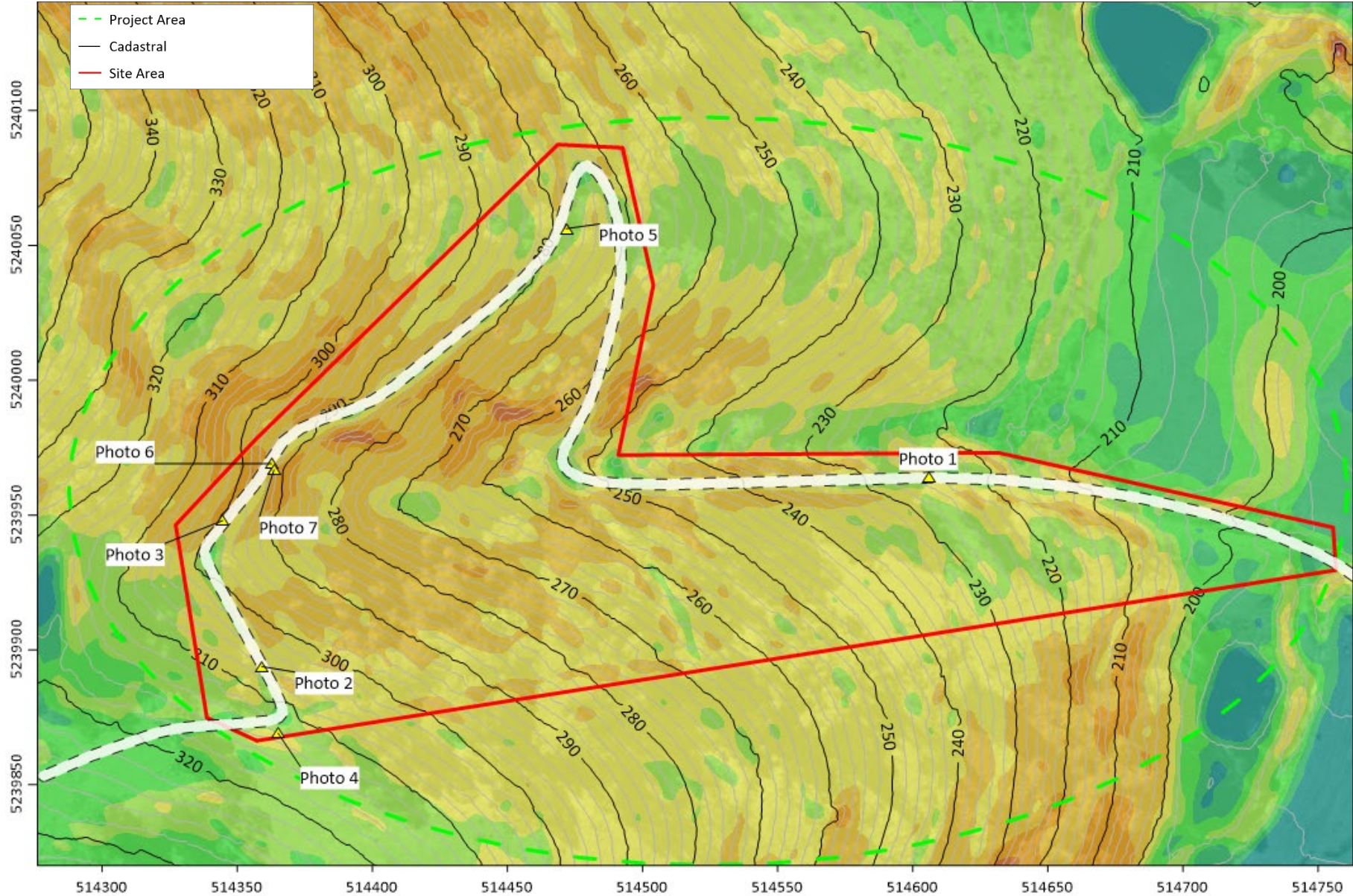
Map 1 Site local setting (Hillshade)

## Map 2



Map 2 Landslide hazard area code overlay. See Attachment 2 for details of hazard planning code definitions.

### Map 3



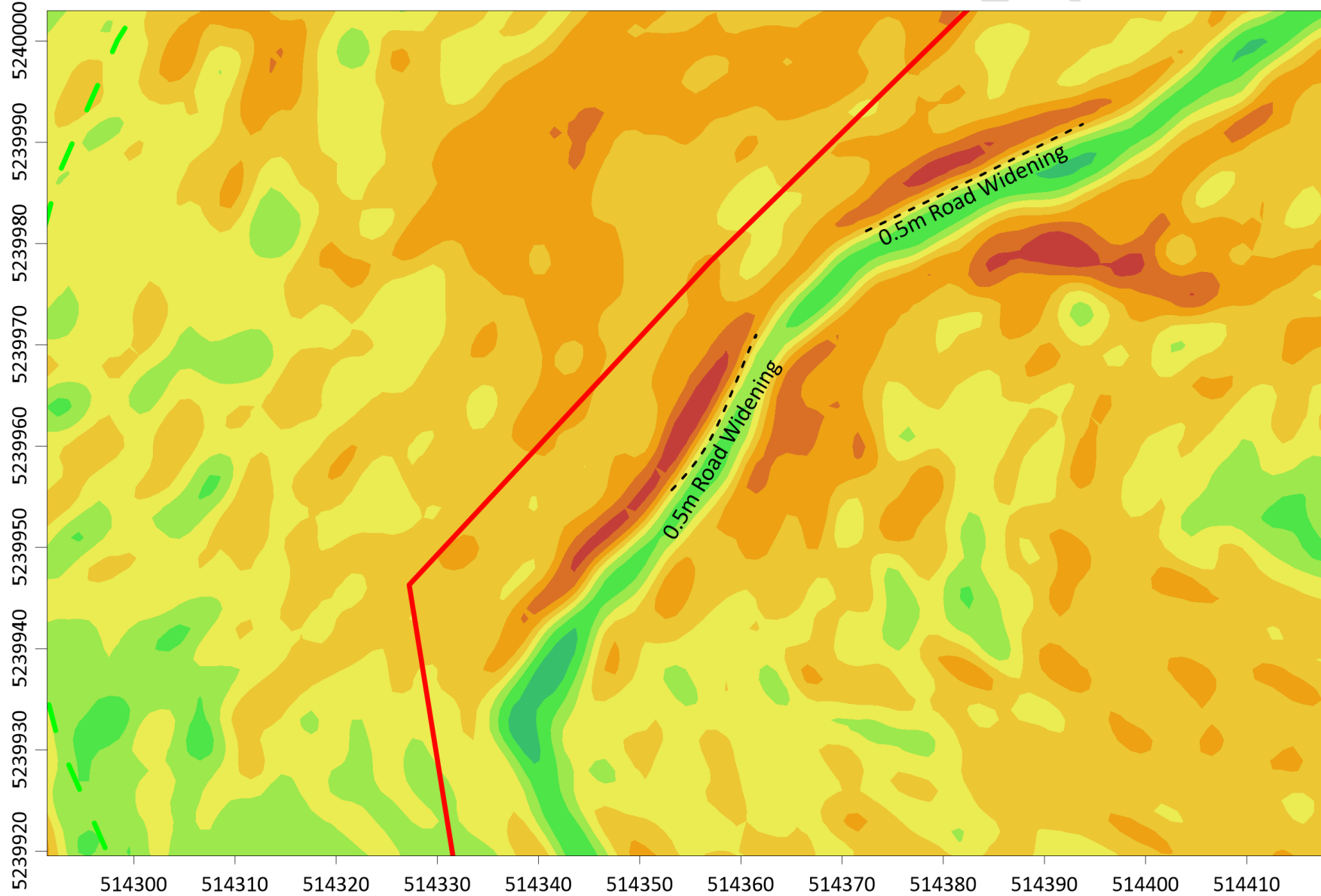
Map 3 Local slope model and Site photos location.

### Map 4



Map 4 Soil testing locations and geotechnical model cross section

### Map 5



Map 5 Road widening locations

## Attachment 2 Planning & Building Regulations

### Landslide Hazard Overlay

#### Code Overlay Reporting Requirements

The proposed building and works fall within The LIST Landslide Hazard Overlay (low hazard band) as presented in Attachment 1 - Map 2.

The proposed development reporting requirements are summarised in Table 1

**Table 1 Landslide Hazard Reporting Requirements Framework**

<b>Council</b>	Kingborough
<b>Planning Scheme</b>	Interim Planning Scheme
<b>Planning Scheme Code</b>	E3.0 Landslide Code
<b>Landslip Hazard Band</b>	Medium and Low
<b>Landslip Planning Map Component</b>	Remaining areas slopes >20deg (Medium Hazard ) and Remaining areas slopes 11-20 degrees (Low Hazard )
<b>Proposed Development Is Exempt From Planning</b>	NOT EXEMPT
<b>Major Works Code to be Addressed</b>	Yes*
<b>Critical Use, Vulnerable Use or Hazardous Use</b>	No
<b>Subdivision that creates a new road or extends an existing road in a medium landslip overlay</b>	No
<b>Development Code to Be Addressed</b>	E3.7.1 Buildings and Works, other than Minor Extensions E3.7.3 Major Works
<b>Additional Information Required for Footing System</b>	NO
<b>Planning Report Requirements</b>	Landslide Hazard Assessment
<b>Modelling Timeframe</b>	Building design life
<b>Directors Determination Reporting Requirements</b>	Preliminary to any Building Works
<b>Certificate of Likely Compliance</b>	Preliminary to any Building Works
<b>Site Classification Requirements</b>	As determined in a Site Classification report
<b>Reporting Guideline Requirement</b>	Report identifying tolerable or acceptable risk

\* Major works as defined in the Interim Planning Scheme Code E3.0, with the following major works proposed at the Site within the Landslip Hazard Overlay:

Excavation of 100 m<sup>3</sup> or more in cut volume

Excavation or soil disturbance of an area of 1,000 m<sup>2</sup> or more

Felling or removal of vegetation over a contiguous area greater than 1,000m<sup>2</sup>;

## **E3.7 Development Standards for Buildings and Works**

### **E3.7.1 Buildings and Works, other than Minor Extensions**

#### **E3.7.1 Objective**

To ensure that landslide risk associated with buildings and works for buildings and works, other than minor extensions, in Landslide Hazard Areas, is:

- (a) acceptable risk; or
- (b) tolerable risk, having regard to the feasibility and effectiveness of measures required to manage the landslide hazard.

#### **E3.7.1 A1 Acceptable Solutions**

For Building and Works within a Landslide Hazard Area there are no acceptable solutions and therefore performance criteria need to be addressed.

#### **E3.7.1 P1 Performance Criteria**

Performance criteria E3.7.1 P1 are addressed in Attachment 10.

#### **Code Overlay – Major Works**

The proposed development is to be assessed according to Major Works Code given the following proposed at the site:

- Felling or removal of vegetation over a contiguous area greater than 1,000m<sup>2</sup>;
- Excavation of 100 m<sup>3</sup> or more in cut volume
- Excavation or soil disturbance of an area of 1,000 m<sup>2</sup> or more

#### **E3.7.3 A1 Objective**

To ensure that landslide risk associated with major works in Landslide Hazard Areas, is:

- (a) acceptable risk; or
- (b) tolerable risk, having regard to the feasibility and effectiveness of measures required to manage the landslide hazard.

#### **E3.7.3 A1 Acceptable Solutions**

As there are no acceptable solutions to Major Works within a landslide hazard overlay, performance criteria need to be addressed.

#### **E3.7.3 P1 Performance Criteria**

Performance criteria E3.7.3 P1 are addressed in Attachment 10.

## Attachment 3 Site Photos



**Photo 1 Evidence of exposed dolerite bedrock on the lower section of the driveway**



**Photo 2 Colluvium deposits in the existing road cut.**



**Photo 3 Colluvium deposits in the existing road cut.**



**Photo 4 Evidence of exposed slightly weathered dolerite bedrock on the upper section of the driveway**



**Photo 5 Evidence of exposed slightly weathered dolerite bedrock on the northern section of the driveway**



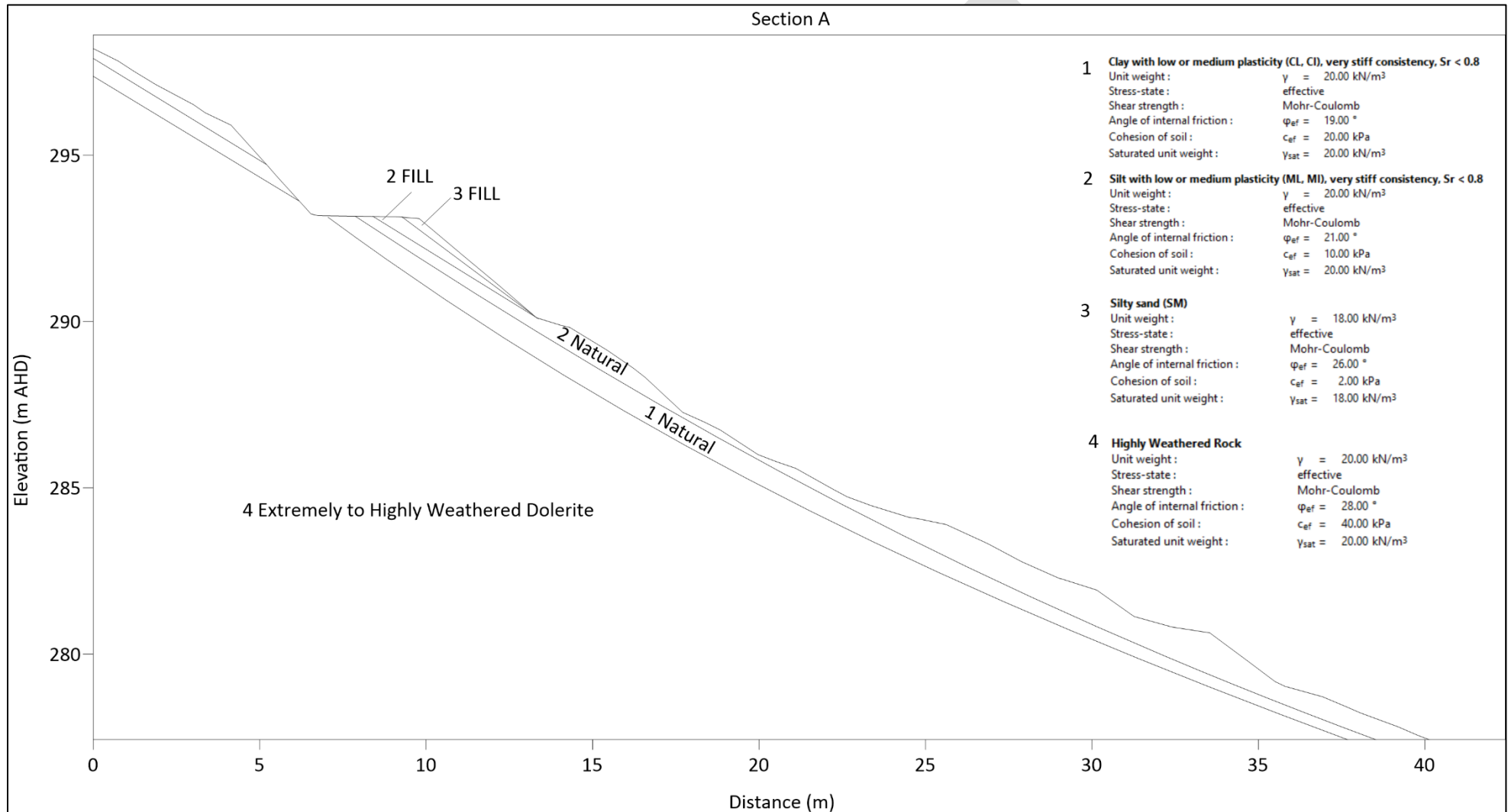
**Photo 6 Evidence of tension cracks within the road fill in this section of the driveway.**



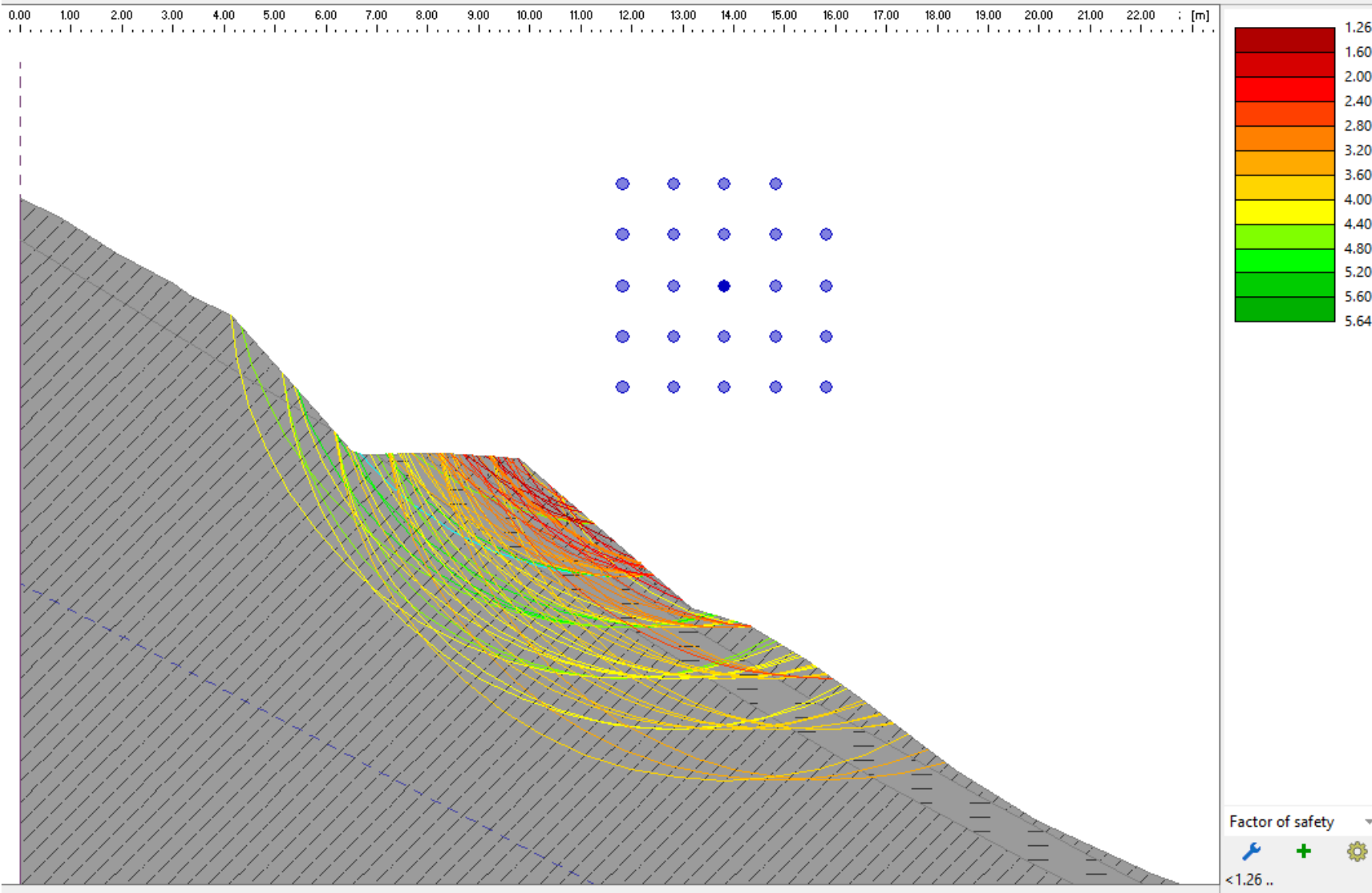
Photo 7 Overview of road fill area

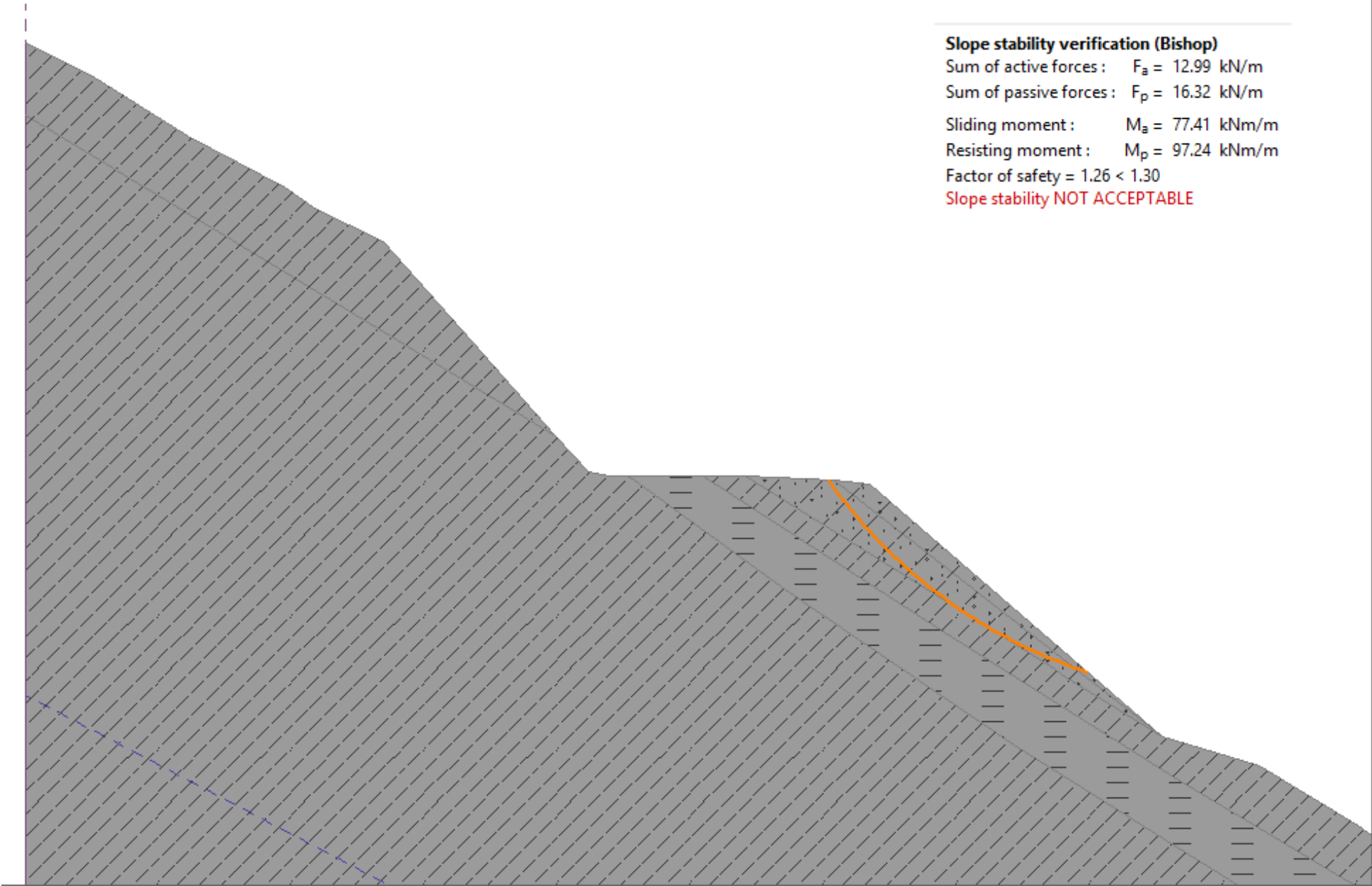
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## Attachment 4 Geotechnical Site Investigation Model



# Attachment 5 Slope Stability Assessment





**Slope stability verification (Bishop)**

Sum of active forces :  $F_a = 12.99$  kN/m

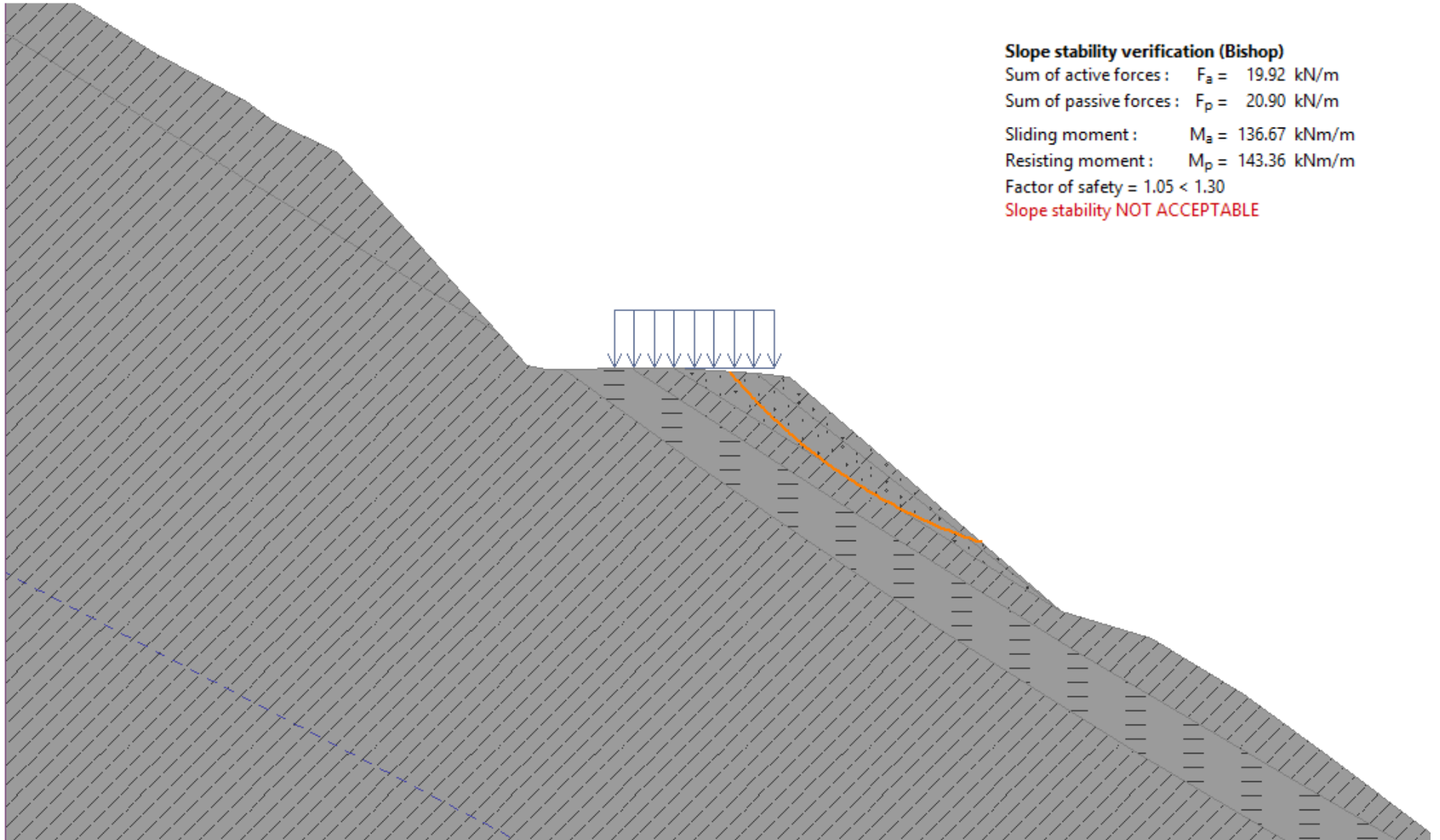
Sum of passive forces :  $F_p = 16.32$  kN/m

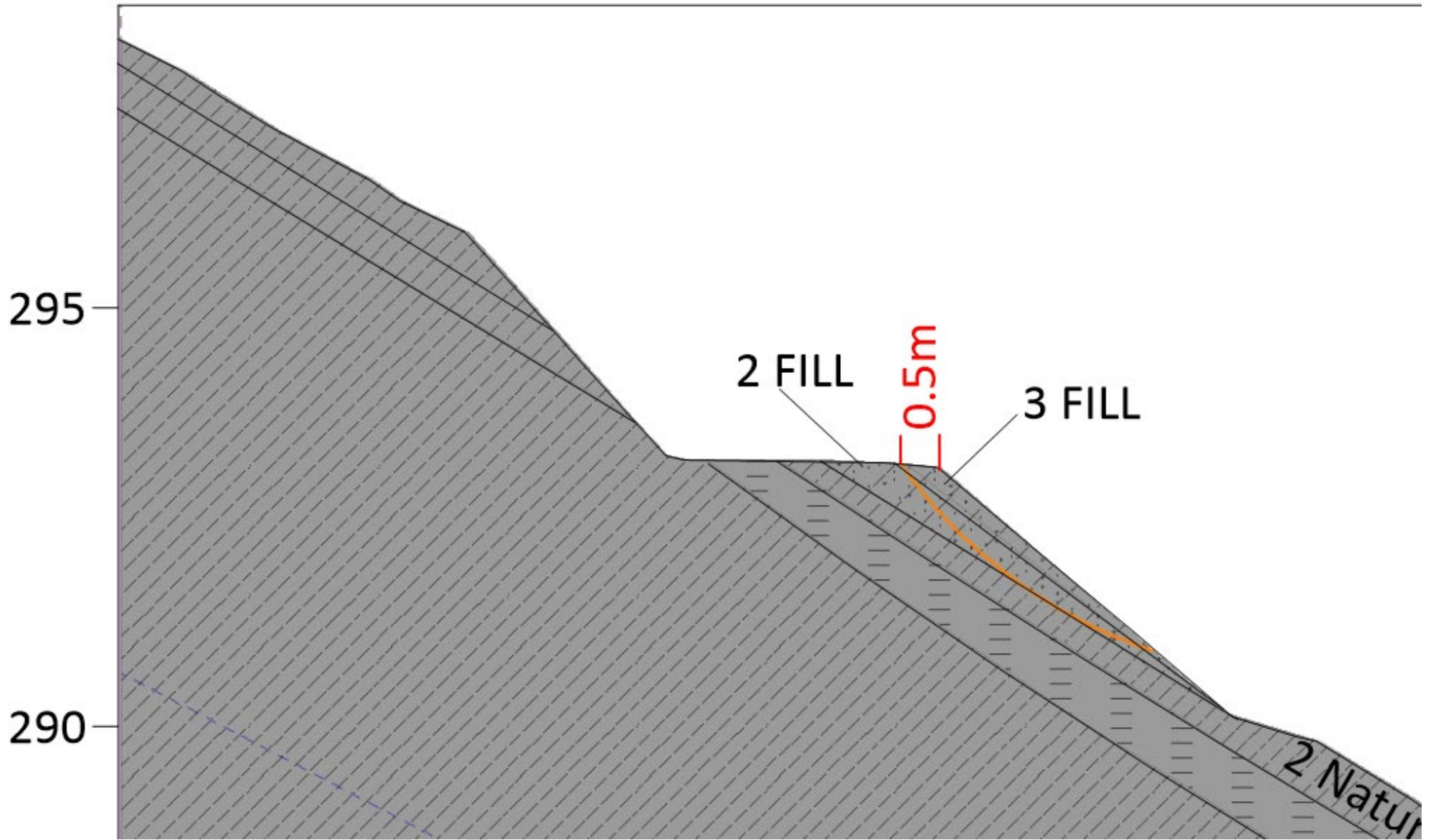
Sliding moment :  $M_a = 77.41$  kNm/m

Resisting moment :  $M_p = 97.24$  kNm/m

Factor of safety =  $1.26 < 1.30$

**Slope stability NOT ACCEPTABLE**





## Attachment 6 Landslide Hazard Assessment

### Potential Landslide Scenarios

Based on the geomorphological setting, the following possible landslide scenarios are identified:

**Scenario 1.** Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide

Shallow seated rotation or translational failure through colluvium layers overlaying the dolerite bedrock.

**Scenario 2.** Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple

Rockfall susceptibility around section of the driveway with batters over 30 degrees for boulders and cobbles sticking off existing cut surfaces. The subsoil soil in the Project Area is severely dispersive, and the matrix of the colluvial deposits is expected to be continually washed-out exposing rocks within the face.

**Scenario 3.** Slope instability in existing driveway uncompacted fill edges with road damage: Earth Slide

Shallow seated rotation or translational failure through road fill in section with steep fill batter angles (40°) near cross Section A and near test pit TP2. Assessed risk to the driveway.

**Scenario 4.** Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide

Shallow seated rotation or translational failure through road fill in section with steep fill batter angles (40°) near cross Section A and near test pit TP2. Assessed risk to vehicles including loss of life.

### Landslide Hazard Analysis

#### Landslide Classification

Potential landslide scenarios presented in Table 2 are based on physical Site characteristics including Site geology, geometry and slope forming processes. The scenarios are classified according to AGS Practice Note Guidelines for Landslide Risk Management (2007 c) with some terminology presented in Attachment 8.

**Table 2 Landslide classification (AGS 2007 c)**

Scenario	Material, Affect & Receptor	Material Class	Water Content	Type of Movement	Failure Mechanism	Observed in the field
1	Debris flow through colluvium soils along driveway cuts hitting vehicles	Fine	Wet	Translational	Earth Slide	No
2	Small scale rockfall/rotation of cobbles and boulders hitting vehicles	Coarse	Dry	Topple	Debris Topple	No
3	Slope instability in existing driveway uncompacted fill edges with road damage	Fine	Wet	Translational	Earth Slide	Yes
4	Slope instability in existing driveway uncompacted fill edges with vehicle damage	Fine	Wet	Translational	Earth Slide	Yes

## Landslide Susceptibility

The susceptibility analysis presented in Table 3 is based on landslide terminology, from the AGS Practice Note Guidelines for Landslide Risk Management (2007 c).

**Table 3 Landslide susceptibility**

Scenario	Material & Mechanism	Trigger	Potential Size	Potential Rate	Travel Distance
1	Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide	Rainfall (wet natural colluvium soils)	10 m <sup>3</sup>	Rapid	2
2	Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple	Unstable boulders on cut surfaces (dry)	1 m <sup>3</sup>	Very Rapid	2
3	Slope instability in existing driveway uncompacted fill edges with road damage: Earth Slide	Precipitation	20 m <sup>3</sup>	Moderate	15
4	Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide	Precipitation	20 m <sup>3</sup>	Moderate	15

## Landslide Hazard Probability & Treatment Measures

Probabilities are based on quantitative terminology presented in Attachment 9.

### Scenario 1

Within the lifetime of the proposed development, the probability of Scenario 1 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

### Scenario 2

Within the lifetime of the proposed development, the probability of Scenario 2 causing damage to a vehicle is UNLIKELY (Table 4) and therefore will not require treatment.

### Scenario 3

Within the lifetime of the proposed works, it LIKELY that the margins of the road near cross Section A and Test Pit TP2 will become unstable and slide. The probability that road will be damaged is inferred to be reduced to POSSIBLE through measures such as preventing water from draining into the FILL (including into tension cracks). Other options may be considered such as road stabilisation works to further reduce the probability, but given to road can be widened into the cut, then the overall consequences (as a proportion of the overall area of the road impacted) may be reduced instead.

### Scenario 4

Same scenario as above, with a lower probability given the POSSIBLE probability is assigned as it is dependent on the vehicle intercepting the collapsed road section. With the treatment measures, this probability may be reduced to UNLIKELY. Treatment involving widening of the road into the cut and putting guideposts in to prevent vehicles from travelling over the more vulnerable filled areas at risk of slope failure.

**Table 4 Likelihood that identified landslide scenarios will encroach the proposed building & works**

Scenario	Material & Mechanism	Likelihood of Occurrence			Treatment
		Present	During/After Development	With Treatment	
1	Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide	Unlikely	Unlikely		No treatment required
2	Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple	Unlikely	Unlikely		No treatment required
3	Slope instability in existing driveway uncompacted fill edges with road damage: Earth Slide	Likely	Likely	Possible	Preventing water moving into fill
4	Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide	Possible	Possible	Unlikely	Road widening with barrier

## Attachment 7 Landslide Risk Assessment

### Risk to Property

Overall risk to property is considered LOW to HIGH. HIGH risks are associated with Scenario 3, and MODERATE risks associated with Scenario 4. Through application of the treatment measures presented in Attachment 6 risk to property can be reduced to:

- MODERATE for Scenario 3 by reducing the area of road impacted by the event through works (the consequence as a proportion of usable road area).
- LOW for Scenario 4 by shifting the vehicles away from the at-risk area (likelihood reduction).

Risks presented in Table 5 are based on quantitative terminology presented in Attachment 9.

**Table 5 Qualitative risk assessment for determining level of risk to proposed building and works**

Scenario	Material & Mechanism	Risks to Property			Residual (Treated) Risks to Property		
		Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
1	Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide	Unlikely	Minor	Low			
2	Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple	Unlikely	Minor	Low			
3	Slope instability in existing driveway uncompacted fill edges with road damage: Earth Slide	Likely	Medium	High	Possible	Minor	Moderate
4	Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide	Possible	Medium	Moderate	Unlikely	Medium	Low

## Risk to Life

Overall risks to life are considered acceptable for Scenarios 1 and 2 (no treatment required) and tolerable for Scenario 4 given the recommended treatment measures (Table 6) and based on public most at risk for an existing slope.

**Table 6 Risk to life – consequence analysis for landslide hazards –post-treatment**

Hazard	Scenario 1	Scenario 2	Scenario 4
Lithology & Mechanism	Debris flow through colluvium soils along driveway cuts hitting vehicles: Earth Slide	Small scale rockfall/rotation of cobbles and boulders hitting vehicles: Debris Topple	Slope instability in existing driveway uncompacted fill edges with vehicle damage: Earth Slide
Risk assessment based on	No Treatment	No Treatment	Treatment
Likelihood	Unlikely	Unlikely	Unlikely
Indicative Annual Probability	0.0001	0.0001	0.0001
Use of Affected Structure or Site, and person most at risk	Driveway	Driveway	Driveway
Portion of Hours Per Day	1	1	10
Proportion days per year	330	330	330
Daily Probability	0.038	0.038	0.377
Rate	Rapid	Very Rapid	Moderate
Temporal spatial probability allowing for the possibility of evacuation given there is warning of the landslide occurrence.	Minimal opportunity to escape in time. Potentially very little warning	Minimal opportunity to escape in time. Potentially very little warning	Moderate chance of escaping in time
Probability of Not Evacuating Value	1	1	0.2
Location	Person In Vehicle	Person In Vehicle	Person In Vehicle
Vulnerability (probability of loss of life of the individual given the impact)	If the vehicle is buried/crushed	If the vehicle is buried/crushed	If the vehicle is buried/crushed
Vulnerability Value	0.6	0.1	0.1
Risk for Person Most at Risk	2.26E-06	3.77E-07	7.53E-07
Occupancy Number of People	3	3	2
Total Risk	6.78E-06	1.13E-06	1.51E-06
Tolerable Risk Category	public most at risk, new slope	public most at risk, new slope	public most at risk, new slope
Tolerable Risk Value	5.00E-05	5.00E-05	5.00E-05
<b>Risk Evaluation</b>	<b>Acceptable</b>	<b>Acceptable</b>	<b>Tolerable</b>

## Attachment 8 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>.

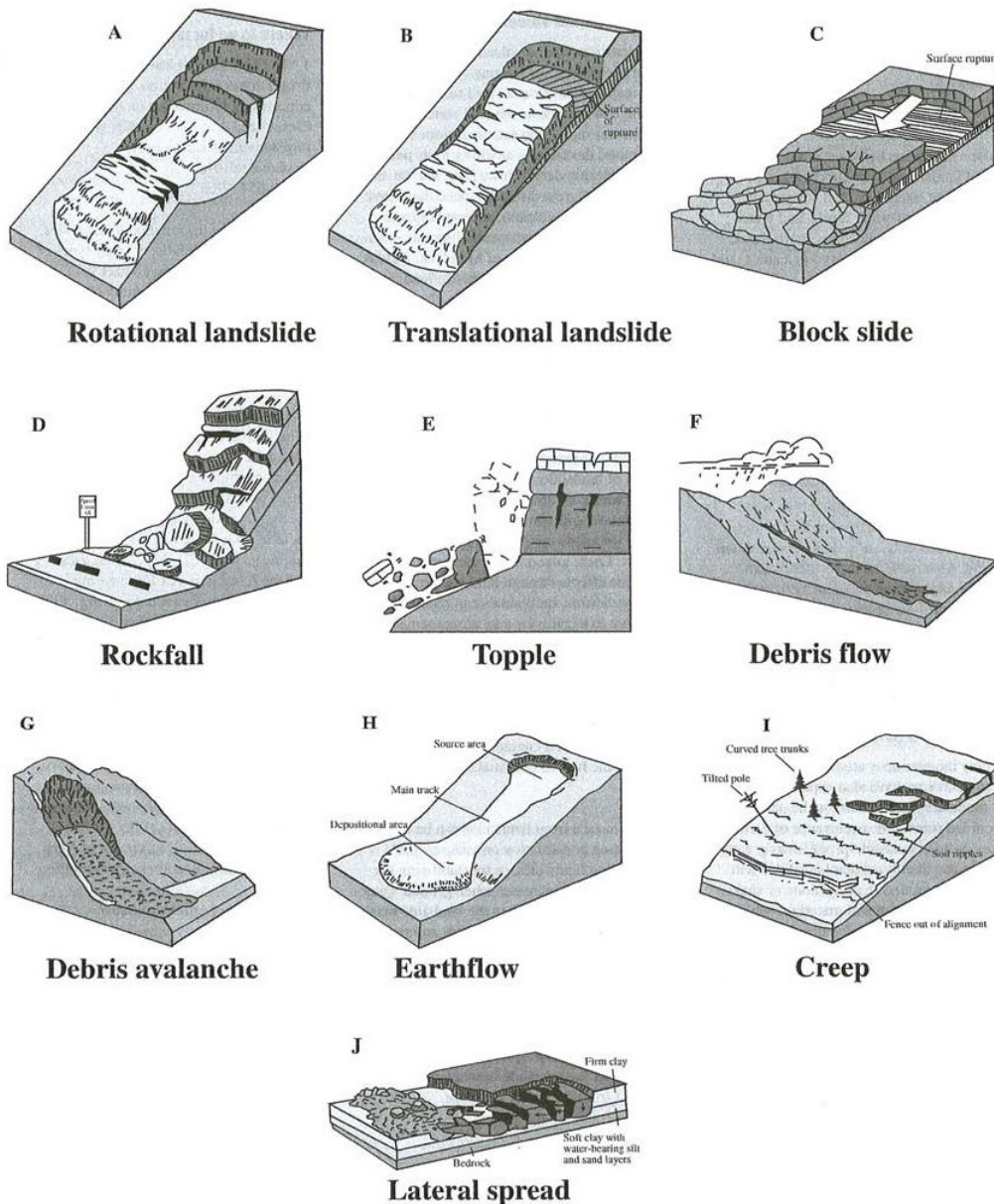


Figure B1: These schematics illustrate the major types of landslide movement.  
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

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).

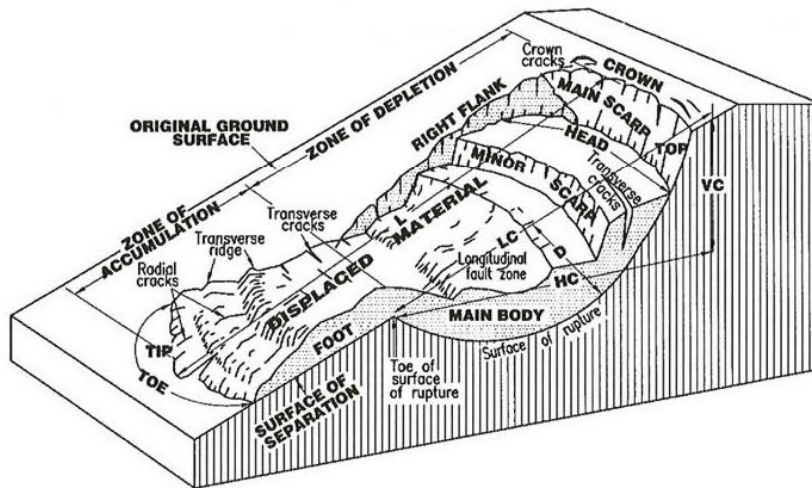


Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(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
		$5 \times 10^3$	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		$5 \times 10^1$	3 m/min	
5	Rapid			Escape evaluation possible; structures, possessions, and equipment destroyed
		$5 \times 10^{-1}$	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		$5 \times 10^{-3}$	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
		$5 \times 10^{-5}$	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		$5 \times 10^{-7}$	15 mm/year	
	Extremely SLOW			Imperceptible without instruments; construction <b>POSSIBLE WITH PRECAUTIONS</b>

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

**REFERENCES AND ACKNOWLEDGEMENT**

Cruden, D.M., & Varnes, D.J. (1996), “Landslide Types and Processes”, Ch.3 in “Landslides. Investigation and Mitigation”, Eds Turner, A.K. and Schuster, R.L. Special Report 247, Transport Research Board, National Research Council, Washington D.C. Extracts reprinted above by kind permission of the authors and publishers. Copies of the publication can be obtained from “Transport Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington D.C. 20418, USA.

IAEG (International Association of Engineering Geology) Commission on Landslides, (1990). Suggested nomenclature for landslides, Bulletin IAEG, No. 41, pp.13-16.

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

WP/WLI (International Geotechnical Societies’ UNESCO Working Party on World Landslide Inventory) (1990). A suggested method for reporting a landslide. Bulletin IAEG, 41, pp.5-12

WP/WLI (International Geotechnical Societies’ UNESCO Working Party on World Landslide Inventory) (1993). A suggested method for describing the activity of a landslide. Bulletin International Association of Engineering Geology, 47: 53-57.

WP/WLI (International Geotechnical Societies’ UENSCO Working Party on World Landslide Inventory) (1994). Multilingual Glossary for Landslides, Bitech Press, Vancouver, in press.

## Attachment 9 Qualitative Terminology Adopted for Assessing Risk to Property (after AGS 2007c)

### QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10 <sup>-1</sup>	5x10 <sup>-2</sup>	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 <sup>-2</sup>		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10 <sup>-3</sup>	5x10 <sup>-3</sup>	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10 <sup>-4</sup>	5x10 <sup>-4</sup>	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10 <sup>-5</sup>	5x10 <sup>-5</sup>	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10 <sup>-6</sup>	5x10 <sup>-6</sup>	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%		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%	40%	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%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	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 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 <sup>-1</sup>	VH	VH	VH	H	M or L (5)
B – LIKELY	10 <sup>-2</sup>	VH	VH	H	M	L
C – POSSIBLE	10 <sup>-3</sup>	VH	H	M	M	VL
D – UNLIKELY	10 <sup>-4</sup>	H	M	L	L	VL
E – RARE	10 <sup>-5</sup>	M	L	L	VL	VL
F – BARELY CREDIBLE	10 <sup>-6</sup>	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.



## Attachment 10 Performance Criteria

### Landslide CODE – 3.7.1 Buildings and Works, other than Minor Extensions

Objective:

To ensure that landslide risk associated with buildings and works for buildings and works, other than minor extensions, in LHA's, is:

- (a) acceptable risk; or
- (b) tolerable risk, having regard to the feasibility and effectiveness of measures required to manage the landslide hazard.

Performance Criteria E3.7.1 P1 Buildings and works must satisfy all of the following:	Relevance	Management Options <sup>6</sup>	Loss of Life Analysis (treated)	Risk to Property (with treatment)			Further Assessment Required
				Consequence	Likelihood	Risk	
(a) no part of the buildings and works is in a High Landslide Hazard Area;	NA						No
(b) the landslide risk associated with the buildings and works is either: <ul style="list-style-type: none"> <li>(i) <i>acceptable risk</i> (means a risk society is prepared to accept as it is. That is; without management or treatment); or</li> <li>(ii) capable of feasible and effective treatment through hazard management measures, so as to be <i>tolerable risk</i>.</li> </ul> The following <i>tolerable risk</i> definition is adopted in this case: A tolerable risk means the <i>residual tolerable risk</i> after the hazard has been satisfactorily treated. The <i>residual tolerable risk</i> may be assessed using either qualitative or qualitative methods in the landslide risk assessment either: <ul style="list-style-type: none"> <li>(a) if using the AGS qualitative risk assessment method apply the "As Low As Reasonably Possible (ALARP)" principle with the residual tolerable risk level no higher than a "moderate" risk level under the AGS 2007(c) risk method; or</li> <li>(b) if using the AGS quantitative risk assessment method then the tolerable loss of life for the person most at risk as suggested by the AGS 2007(c) to be:                             <ul style="list-style-type: none"> <li>(i) if existing slope / existing development: 10-4 / annum;</li> <li>(ii) if new constructed slope / new development / existing landslide: 10-5 / annum.</li> </ul> </li> </ul>	Applying the AGS quantitative risk assessment method, the landslide risk associated with the buildings and works is considered tolerable and in effect, capable of feasible and effective treatment through hazard management measures	No treatment required	6.8E-06				No
		No treatment required	1.1E-06				
		Preventing water moving into fill	2.3E-04	Minor	Possible	Moderate	
		Road widening with barrier	1.5E-06	Medium	Unlikely	Low	

<sup>6</sup> For specific detail of management measures, the recommendations section of this report is to be read in conjunction. The proposed development should be constructed in accordance with the Australian Geomechanics Society (2007) guidelines for Good Hillside Construction Practices.

### Landslide CODE – E3.7.3 Major Works

Objective:

To ensure that landslide risk associated with buildings and works for buildings and works, other than minor extensions, in Landslide Hazard Areas, is:

- (a) acceptable risk; or
- (b) tolerable risk, having regard to the feasibility and effectiveness of measures required to manage the landslide hazard.

Performance Criteria E3.7.3 P1 Major works must satisfy all of the following:	Relevance	Management Options <sup>7</sup>	Loss of Life Analysis (treated)	Risk to Property (with treatment)			Further Assessment Required
				Consequence	Likelihood	Risk	
(a) no part of the buildings and works is in a High Landslide Hazard Area;	NA						No
(b) the landslide risk associated with the buildings and works is either: <ul style="list-style-type: none"> <li>(i) <i>acceptable risk</i> (means a risk society is prepared to accept as it is. That is; without management or treatment); or</li> <li>(ii) capable of feasible and effective treatment through hazard management measures, so as to be <i>tolerable risk</i>.</li> </ul> The following <i>tolerable risk</i> definition is adopted in this case: A tolerable risk means the <i>residual tolerable risk</i> after the hazard has been satisfactorily treated. The <i>residual tolerable risk</i> may be assessed using either qualitative or qualitative methods in the landslide risk assessment either: <ul style="list-style-type: none"> <li>(a) if using the AGS qualitative risk assessment method apply the "As Low As Reasonably Possible (ALARP)" principle with the residual tolerable risk level no higher than a "moderate" risk level under the AGS 2007(c) risk method; or</li> <li>(b) if using the AGS quantitative risk assessment method then the tolerable loss of life for the person most at risk as suggested by the AGS 2007(c) to be:                             <ul style="list-style-type: none"> <li>(i) if existing slope / existing development: 10-4 / annum;</li> <li>(ii) if new constructed slope / new development / existing landslide: 10-5 / annum.</li> </ul> </li> </ul>	The landslide risk associated with the buildings and works is capable of feasible and effective treatment through hazard management measures, so as to be tolerable risk.	No treatment required	6.8E-06				No
		No treatment required	1.1E-06				
		Preventing water moving into fill	2.3E-04	Minor	Possible	Moderate	
		Road widening with barrier	1.5E-06	Medium	Unlikely	Low	

<sup>7</sup> For specific detail of management measures, the recommendations section of this report is to be read in conjunction. The proposed development should be constructed in accordance with the Australian Geomechanics Society (2007) guidelines for Good Hillside Construction Practices.

## Attachment 11 Guidelines for Hillside Construction

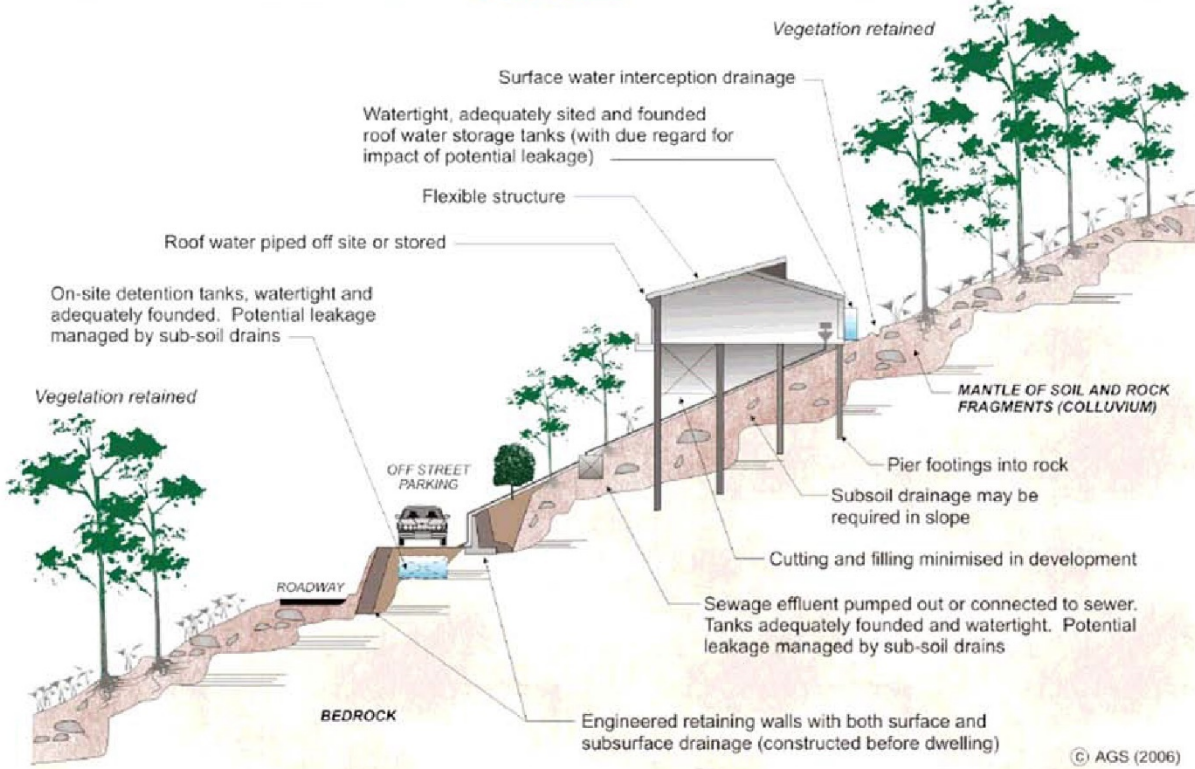
### PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

#### APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

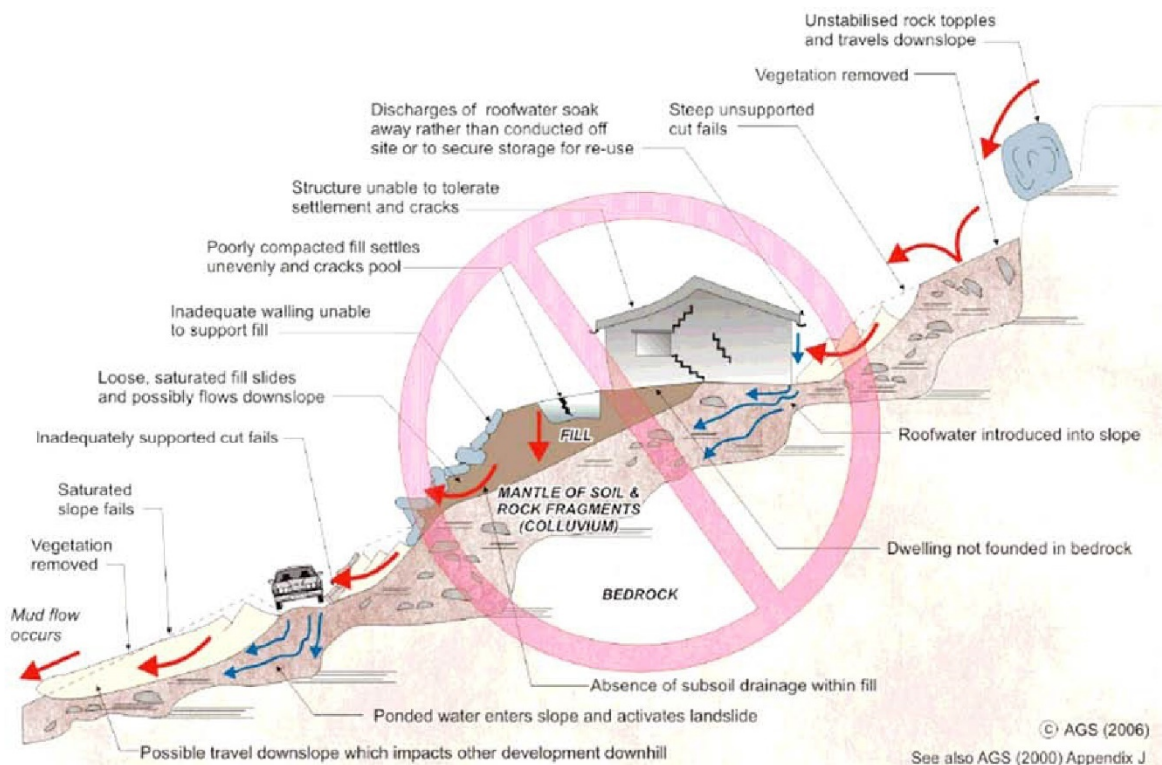
ADVICE	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
<b>GEOTECHNICAL ASSESSMENT</b>	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
<b>PLANNING</b>		
<b>SITE PLANNING</b>	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.
<b>DESIGN AND CONSTRUCTION</b>		
<b>HOUSE DESIGN</b>	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.
<b>SITE CLEARING</b>	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
<b>ACCESS &amp; DRIVEWAYS</b>	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.
<b>EARTHWORKS</b>	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
<b>CUTS</b>	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
<b>FILLS</b>	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.
<b>ROCK OUTCROPS &amp; BOULDERS</b>	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
<b>RETAINING WALLS</b>	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.
<b>FOOTINGS</b>	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.
<b>SWIMMING POOLS</b>	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.	
<b>DRAINAGE</b>	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.
<b>SURFACE</b>	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.
<b>SUBSURFACE</b>	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 sillage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
<b>SEPTIC &amp; SULLAGE</b>	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
<b>EROSION CONTROL &amp; LANDSCAPING</b>		
<b>DRAWINGS AND SITE VISITS DURING CONSTRUCTION</b>		
<b>DRAWINGS</b>	Building Application drawings should be viewed by geotechnical consultant	
<b>SITE VISITS</b>	Site Visits by consultant may be appropriate during construction/	
<b>INSPECTION AND MAINTENANCE BY OWNER</b>		
<b>OWNER'S RESPONSIBILITY</b>	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.	

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



# Attachment 12 A builder's guide to preventing damage to dwellings Part 2



## A builder's guide to preventing damage to dwellings

### Part 2 – Sound construction methods

#### THE PROBLEMS

##### Site water problem identification

It is essential to investigate the site and prepare it in such a way that ground and surface water are prevented from entering the building footprint, whether the building has suspended floors or is footed on a ground slab. Site investigation methods are dealt with in BTF 19, which should be read prior to reading this BTF. It is also recommended that BTF 18 be read as additional information on this subject.

##### Legal considerations

Good site drainage always addresses both surface and ground water flows. Lack of attention to potential building movement caused by moisture migration can be a costly oversight for the builder, who may be found liable for damage long after any statutory warranty has expired. The Building Code of Australia (BCA) has not made site drainage mandatory, although it does set out acceptable construction practice in Volume 2, Clause 3.1.2, to be used where a local drainage authority deems it necessary. This makes for uncertainty in the minds of builders as to their responsibilities, but the courts tend to view the builder as the expert and, where some foreseeable damage occurs, it is usually found that the builder should have used methods that would have prevented the damage.

Where site investigation has revealed that there is existing or potential erosion problem, or where reactive clay subsoil is present, the builder is wise to give written advice to the owner and strongly recommend that ground drainage be installed. Where the owner declines in writing, some jurisdictions are known to have accepted that it is within the contractor's rights to continue the project. However, ground drainage is an area where contractors ignore or try to side-step at their own peril.

As to water entering a building, the BCA is quite clear. It is the task of the builder to prevent rainwater from entering a building, even when the rainwater is propelled by a storm of a magnitude that would only be expected to occur, on average, once in a hundred years. What is not so obvious to many is that water should not be allowed to enter the cavity, which is there not as a drain or repository for water that enters through openings, but as a break between the outer and inner leaves of exterior walls to prevent water from permeating through as it used to do when buildings were constructed of 230 mm solid brick-work. When water enters the cavity in volume, a wet, dark and enclosed environment is set up that can result in serious consequences for the health and amenity of the occupants.

Water problems in buildings are usually cumulative, resulting from several oversights rather than from a single source. This BTF is designed as a general checklist of commonly occurring flaws in construction methods, to help the builder deliver a product that will be durable, weatherproof and provide a healthy environment.

#### SURFACE AND GROUND WATER PREVENTION

It is no longer acceptable for a builder to claim that building movement is outside his or her power to prevent. The subsoil of

land that is available for building development normally has an allowable bearing capacity well in excess of the loads imposed by class 1a buildings. The movement problems that are experienced by buildings are very often brought about by the failure of the builder and designers to deal with site water.

Surface and ground water that is allowed within the footprint of the building causes erosion and foundation soil movement, which in turn causes an exacerbation of cracking in slabs; cracking and failure in masonry and finishes; doming and dishing of floors; cupping and lifting of timber flooring; decay to timber members; degradation of metals and mortar; doming and dishing of roofs, leading to breakage of tiles and degradation of mortar beds.

##### Surface drainage methods

The basis of good surface water drainage is to:

- Have the finished exterior ground level at the building perimeter a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- In the finished ground, provide a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

The above requirements mean that thought may need to be given to finished floor level etc. before the plans go to council.

Where there is natural topography that leads to surface water being encouraged toward the building, a dish or other surface drain should be installed and connected to the stormwater system through a pit.

##### Ground water drainage methods

If it is desired to keep the soil dry in areas other than the building footprint, it should be realised that this other drainage may not be sufficient to prevent water entering the footprint, and additional drainage for the building may be necessary. It should be understood that ground drainage is a complex subject, often requiring the expertise of an engineer who is suitably competent in hydrology and geotechnics. For anything other than straightforward problems, even drainers or builders experienced in installing ground drainage should engage a consultant to assist in the design. This section is therefore intended to give reminders to already competent people, and to assist others toward a rudimentary understanding to help them discuss the issues with a consultant. In addition, it is essential for a builder or drainer to comply with the minimum requirements of BCA Volume 2, Clause 3.1.2, and AS 3500.3.2, Sections 6-8, unless installing a system certified by an engineer.

The first step is to investigate the depth and volume of the subsoil flow of water. Test pits, particularly on the uphill perimeter of the footprint should be dug as outlined in BTF 19. It is, however, important to remember that ground drainage problems are not restricted to sloping sites. Some of the most susceptible sites are on flat land, particularly where the area is ringed by

higher ground. In addition, as explained in BTF 18, where warm, wet summers and colder, dry winters are experienced, the building itself will tend to cause inward water migration.

In any case, the minimum depth of drainage should comply with BCA Volume 2, Clause 3.1.2.4, that the top of the drain be a minimum of 400 mm below ground and 100 mm below the adjacent footing. This means that the trench should be dug at a safe distance from the footing to ensure that the foundation is not affected. If this is not practicable, temporary measures to support the trench walls may be needed and/or the strength of the pipe material may need to be increased. It is important to remember that in clay the allowable angle between the external bottom corner of the footing and the nearest part of the bottom of the trench is usually 45°, whereas the normally applicable angle for compact granular soil is 30°. These may be exceeded where the trench fill is well compacted and the piping is non-compressible, but supervision by a competent engineer is normally necessary for soil classification and strength issues. A good working arrangement is to locate the trench toward the edge of the area that is graded away from the building to allow run-off of surface water.

Having discovered the required depth, the next step is to establish whether it is above the depth of the local authority's stormwater system, to determine the method of dispersal of the captured water. It must be borne in mind that the BCA's minimum fall for ground drainage is 1:300, and a silt arrestor requires a minimum drop of 50 mm from the invert of the inlet to the inner roof of the outlet. If the depth of the ground drainage is too low for the council system, councils may allow a soakage pit for any naturally occurring ground water, so that the drainage can divert the water from the uphill side of the building to the downhill side. The builder should confirm this with the council.

Next, the type of drainage should be determined. For general purposes, a geocomposite system using 90 mm slotted stormwater pipe with fabric sock and geofabric perimeter material is adequate, however suppliers can advise on other systems. It is desirable in any ground drainage system and essential where the fall is shallower than 1:100 to install inspection openings to enable the system to be flushed out. These should be at changes of direction greater than 45° and at the connection to the stormwater system. Where practicable, pits make the ideal inspection opening, particularly when configured as silt arrestors.

#### **Drainage to rock substrates**

BTF 19 discusses the special drainage problems with rock foundations. While a solid rock foundation remains stable regardless of water flows, water damage to building elements and high subfloor relative humidity can have potentially serious consequences. When the ground floor is to be suspended, and particularly when using timber framing and/or flooring, drains should be cut around the perimeter where water can otherwise enter the subfloor. Totally preventing water entering the subfloor area can be impracticable because of faults and interstrata gaps. Where water flows on rock foundations cannot be prevented, the design should allow for an open subfloor and an increased minimum clearance between the floor and the ground, commensurate with the volume of water experienced. If a completely open subfloor is impracticable, openings should be as large as possible, particularly where subfloor walls would otherwise dam water. Watercourses should be cut out to divert water if this is beneficial to the aim of removing water as soon as possible. A mechanical ventilation system may need to be installed as an augmentation to the measures discussed above, but when relied upon without sufficient other precautions, such a system may be inadequate.

#### **Subfloor ponding**

When constructing dwellings with suspended floors, it is essential to grade the subfloor area so that no depressions remain that can allow water to pond. With rock foundations it may be necessary to use concrete to fill depressions.

#### **Dampproof courses**

Ground moisture usually carries salts and other chemicals. When moisture migrates through masonry by capillary action, some chemicals may be transported. It is often these chemicals that attack the building elements. Different dampproof course (DPC) materials are susceptible to different chemicals.

It is not always possible to predict the nature of pollutants to which the underside of a DPC will be exposed. This is one of the reasons that moisture should be kept away from the building. DPCs that have poor plasticity or develop poor plasticity through exposure to water and chemicals, are unsuited for use where building movement cannot be totally prevented, because they tend to break. When a DPC is discontinuous it allows water to penetrate the gap. This is one common way that rising damp occurs in buildings constructed in the modern era.

The safest suggestion for overcoming the problem of lack of durability in DPCs for applications where high moisture content is expected, is to double up, perhaps using two different types, one on top of the other.

#### **Antcapping**

Antcapping should never be used as a DPC unless it has been tested and designed for this purpose. Galvanising will break down over time when in constant contact with moisture, particularly when salts are present. It is essential to isolate the antcapping from any water in the masonry by using a DPC between. The galvanising should also be checked for quality and any cuts or damage should be coated with cold galvanising, because even when the antcapping is isolated from direct contact with water, constant high humidity in the air will tend to attack the steel. Once corrosion has eaten through the metal, termites are given a path of entry to the building. This is not a rare condition.

### **RAINWATER PREVENTION**

In addition to surface and ground water considerations, there are several issues of construction that builders must address in order to prevent rainwater from entering the building.

Rainwater is not only a problem when it enters the living area as water, but also when it is allowed into the cavities and voids and onto building members that can degrade or decay. In addition, rainwater has a more insidious danger in that it gives life to fungus and promotes pests like dust mites – these conditions are conducive to illness in people who are abnormally susceptible to breathing disorders.

Builders and tradespeople often attempt to make a building weatherproof by the use of sealants. It should be realised that sealants cannot be regarded as a durable solution to most weatherproofing problems. Durability can only be attained by sound construction method.

#### **Ridge capping**

Mortar bedding to ridge capping is permeable, even with flexible pointing applied over it. Water can migrate through the bedding and pond on the tile above the bedding. Any condensation tends to perpetuate the moisture and, in addition, where summers are warm and wet and winters are cold and dry the tendency is for moisture to be drawn in. The above factors tend to create an overflow of water that may drip into the roof space or run down the soffit of the tiling, decaying battening or framing and/or eventually damaging fastenings. This flow adds to flows caused by the natural absorption of water through tiles and any wind-driven rain that penetrates the gaps between tiles. These are the flows that lead to inundation of the roof. Weepholes should be created in the beds at the depressions in tiles to allow water to flow to the top surface of the tiles.

Where footing movement occurs, usually due to the action of water on the foundation soil, the roof moves. Cut and pitched roofs will dome and dish in the same way that floors do, because of the uneven rise and fall of reactive clay soils. This movement causes a stress on rigid members of the roof structure such as mortar beds to hips, ridges and verges, which hog and sag, tending to crack the mortar and/or the tiles. When 1:2 cement: sand mortar pointing is used, this will retard the cracking, but it will eventually crack and when it does, the water entry will increase accordingly. On truss roofs the effect is less but still sufficient to cause cracking. If there is no footing movement, the pointing tends to last many years. Where some movement is expected, it is recommended that flexible pointing be used.

#### **Sarking**

In general, roof tiles are of marginal suitability for installing on a roof slope of less than 18° and should never be used where the pitch is lower than 15°. For other roof slopes below 25°, the manufacturer's recommendations should be checked before



### Weepholes

AS 3700, Clause 12.7.2.3, requires that weepholes are formed immediately above the cavity flashing and that mortar is removed from the joint so that the opening is clean and the flashing is exposed. This is to ensure the free flow of water from the cavity. It is not uncommon to find blocked weepholes, recessed DPCs and fouled cavity flashings all on the same job.

### Window and door openings

The popularity of unevenly faced bricks has led to a problem at openings. The problem arises where brickwork reveals do not present a straight line against windows, and is exacerbated by the fact that these bricks are generally not suited to flush mortar bedding. Consequently, it is common to see gaps at window/reveal interfaces caused by brick unevenness and raked joints. Such gaps mean that the building envelope is not weatherproof within the requirements of the BCA.

It should be realised that the cavity is not envisaged as a part of a water removal system, but is there to prevent moisture permeation from the outer skin to the inner skin. It may also act as a last line of defence in the event of an extraordinary event, however the idea that a builder should leave gaps in the building envelope through which water can penetrate into the cavity is in direct conflict with the objectives and requirements of the BCA. An external wall that routinely allows water to enter the cavity, turns that cavity into a hazard to the building elements, and to the health and amenity of the occupants. It is the job of the builder to make the envelope weatherproof. The construction system must prevent significant volumes of water entering the cavity.

In the case of window and door reveals, the bricklayer, while being mindful of the danger of ceramic growth, should not rake or iron the joint past the leading edge of the frame. In some cases where gaps must be left because long walls make ceramic growth a hazard, or where the brick profile is badly uneven, storm moulds should be installed, and bedding should be left flush with the leading edge of the storm mould.

It is also common to see cases where an overwide cavity creates insufficient overlap between the window and the brickwork reveal. Where this occurs, storm moulds are also called for.

### Window gaskets

When fitted to brick veneer construction, windows need to be clear of the brickwork sill so as to allow for timber shrinkage in the frame. The usual allowance is 5–10 mm clearance to ground floor windows and a minimum of 15 mm on the second storey. For this purpose, aluminium window assemblies are fitted with neoprene gaskets to bridge the gap between the window frame and the brickwork sill. As with reveals, the brickwork sill should have joints left flush from the leading edge of the gasket to the rear edge of the sill. Commonly, little attention is paid to seating the gasket to provide a waterproof surface. Mortar is left on top of sill bricks which, when timber shrinkage reduces or closes the gap, pushes the gasket up and away from the brick and allows water to enter the cavity. Mortar should be cleaned off the top of bricks while laying. In addition, bricklayers commonly turn the ends of gaskets down into the perpend at the sill/ reveal joints. This is poor practice, as it leaves a gap above the gasket where water can gain entry to the cavity and which also encourages water into the mortar where the gasket turns down. These gaskets should be cleanly cut off flush with the reveal and the mortar should be flush with the sill brickwork. If the reveal bed aligns with the gasket there is no reason that the gasket cannot be bedded into it.

### Sills and thresholds

Where brickwork sills are significantly sloped, it is common to find that the bricks are cut to have a minimal overlap with the gasket. These gaskets need a minimum 15 mm overlap with

the sill bricks where the sill is at 30° to the horizontal. For lesser angles the necessary overlap increases.

Brickwork patio and other door thresholds are often laid without any fall away from the building. This will always result in water entering the cavity. Some bricklayers fill the cavity in at the doorway to prevent water incursion, but this does not work and only inhibits the operation of the flashing. The builder must provide the bricklayer with sufficient height to allow for weepholes to be continued across the doorway as necessary, and for either a soldier course sill with sufficient fall or room to lay a sloped tiling threshold.

### Subfloor vents

In dwellings having suspended ground floors, particularly where timber floor framing is used, adequate cross-flow ventilation must be installed to counteract condensation. BCA Volume 2, Section 3.4.1, gives minimum ventilation standards that are deemed to satisfy the performance requirements. The required ventilation area is based on the perimeter length of the building and differs depending on:

- The zone in which the dwelling is located.
- The moisture content of the foundation soil.

It is also important to realise that where the floor is lower to the ground, there is less volume of air to dissipate the moisture that is transferred to it from the ground.

### Landscaping

Two important aspects of landscaping that relate to water entry were introduced in the surface drainage section above, viz.:

- The finished exterior ground level at the building perimeter should be a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, if paving is to be used around the building perimeter, the clearance may be 50 mm. Where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- The finished ground should have a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

In addition, the landscaper should only install automatic watering systems where the beds that they service are lower than the base of the footings or where they are separated from the building by a properly engineered surface and ground water drainage system.

## FURTHER READING/REFERENCED DOCUMENTS

- AS 2050, *Installation of Roof Tiles*, Standards Australia, Sydney, 2002.
- AS 3500.3.2, *Stormwater Drainage – Acceptable Solutions*, Standards Australia, Sydney, 1998.
- AS 3700, *Masonry Structures*, Standards Australia, Sydney, 2001.
- BTF 18, *Foundation Maintenance and Footing Performance – A Homeowner’s Guide*, CSIRO, Highett, Victoria, 2001.
- BTF 19, *A Builder’s Guide to Preventing Damage to Dwellings: Part 1 – Site Investigation and Preparation*, CSIRO, Highett, Victoria, 2003.
- Building Code of Australia (BCA) Volume 2*, Australian Building Codes Board, Canberra, 1996.

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Further professional advice needs to be obtained before taking any action based on the information provided.

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## **Attachment 13 Geotechnical Site Investigation**

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## GEOTECHNICAL SITE INVESTIGATION



### **14 BATCHELORS ROAD - SANDFLY PROPOSED DRIVEWAY AND BRIDGE**

**Client: Lachlan Joyce**

**Certificate of Title: 134464/1**

**Investigation Date: 20/01/2025**

**Refer to this Report As**

Enviro-Tech Consultants Pty. Ltd. 2025. Geotechnical Site Investigation for a Proposed Driveway and Bridge, 14 Batchelors Road - Sandfly. Unpublished report for Lachlan Joyce by Envirotech Pty. Ltd., 20/01/2025.

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**Limitations of this report**

Advice herein is general, and advice provided in the associated report must be read in conjunction with this report:

Enviro-Tech Consultants Pty. Ltd. 2025. Landslide Risk Assessment Report for a Proposed Driveway And Bridge, 14 Batchelor's Road - Sandfly. Unpublished report for Lachlan Joyce by Envirotech Pty. Ltd., 20/01/2025.

In some cases, variations in actual Site conditions may exist between subsurface investigation boreholes. This report only applies to the tested parts of the Site at the Site of testing, and if not specifically stated otherwise, results should not be interpreted beyond the tested areas.

The Site investigation is based on the observed and tested soil conditions relevant to the inspection date and provided design plans (building footprints presented in Attachment A). Any site works which has been conducted which is not in line with the Site plans will not be assessed. Subsurface conditions may change laterally and vertically between test Sites, so discrepancies may occur between what is described in the reports and what is exposed by subsequent excavations. No responsibility is therefore accepted for any difference in what is reported, and actual Site and soil conditions for parts of the investigation Site which were not assessed at the time of inspection.

This report has been prepared based on provided plans detailed herein. Should there be any significant changes to these plans, then this report should not be used without further consultation which may include drilling new investigation holes to cover the revised building footprint. This report should not be applied to any project other than indicated herein.

No responsibility is accepted for subsequent works carried out which deviate from the Site plans provided or activities onsite or through climate variability including but not limited to placement of fill, uncontrolled earthworks, altered drainage conditions or changes in groundwater levels.

## Site Investigation

The Site investigation is summarised in Table 1.

*Table 1 Summary of Site Investigation*

<b>Client</b>	Lachlan Joyce
<b>Project Address</b>	14 Batchelors Road - Sandfly
<b>Council</b>	Kingborough
<b>Planning Scheme</b>	Interim Planning Scheme
<b>Inundation, Erosion or Landslip Overlays</b>	Low & Medium Landslide Hazard Area
<b>Proposed</b>	Driveway And Bridge
<b>Investigation</b>	Fieldwork was carried out by an Engineering Geologist on the 20/1/2025
<b>Site Topography</b>	The building site has a very strong slope of approximately 35% (19°) to the east
<b>Site Drainage</b>	The site receives overland flow run off directly from the west.
<b>Soil Profiling</b>	A total of 3 test pits, 1 cut, and 1 Boreholes were investigated at the Site.
<b>Investigation Depths</b>	The target excavation depth was estimated at 2.3 m. Borehole logs and photos are presented in Appendix B & C.
<b>Soil moisture and groundwater</b>	All recovered soil at the site ranged from slightly moist to wet. Groundwater was encountered at 0.1 to 1 m below ground surface.
<b>Geology</b>	According to 1:250,000 Mineral Resources Tasmania geological mapping (accessed through The LIST), the geology comprises of: Jurassic Dolerite and related rocks

## Soil Profiles

The geology of the site has been documented and described according to Australian Standard AS1726 for Geotechnical Site Investigations, which includes the Unified Soil Classification System (USCS). Soil layers, and where applicable, bedrock layers, are summarized in Table 2.

Table 2 Soil Summary Table

#	Layer	Details	USCS	TP01	TP02	TP03	CT04	BH05
1	Sandy SILT	FILL: Sandy SILT trace gravel, brown, well sorted, low plasticity, fine to medium grained sand, H	ML					0-0.1
2	Sandy SILT	Sandy SILT, strong brown, well sorted, low plasticity, S-H	ML					0.1-1.2 DS@0.6
3	Sandy SILT	SOIL & BOULDERS/COBBLES: Sandy SILT, dark greyish brown, well sorted, low plasticity, fine to medium grained sand, trace leaf litter, 5 % leaf litter and roots; 60% DOLERITE boulders/cobbles, F-H	ML	0-0.5 DS@0.3	0-1		0-1	
4	Sandy SILT	SOIL & BOULDERS/COBBLES: Sandy SILT, olive brown, well sorted, low plasticity, trace organics, 5 % ; angular gravel; 80% DOLERITE boulders/cobbles, F-H	ML	0.5-1.4 DS@1.1		0-0.4		
5	Silty CLAY	Silty CLAY with sand, olive brown, medium plasticity, St-VSt	CI				1-3.5 DS@1.5	
6	Clayey Sandy SILT	Clayey Sandy SILT trace gravel, light olive brown, low plasticity, fine to medium grained sand, St-VSt	ML		1-3.4 DS@3.1	0.4-0.8		
7	Clayey SILT	Clayey SILT with gravel/sand, brownish yellow, well sorted, low plasticity; angular gravel, F-H	ML					1.2-1.9 DS@1.7 REF
8	DOLERITE	Extremely Weathered DOLERITE Bedrock					3.5-3.6 REF	
9	DOLERITE	Distinctly Weathered DOLERITE Bedrock		1.4-1.5 REF	3.4-4.5 REF	0.8-0.9 REF		

**Consistency<sup>1</sup>** VS Very soft; S Soft; F Firm; St Stiff; Vst Very Stiff; H Hard. Consistency values are based on soil strengths AT THE TIME OF TESTING and is subject to variability based on field moisture condition

**Density<sup>2</sup>** VL Very loose; L Loose; MD Medium dense; D Dense; VD Very Dense

**Rock Strength** EL Extremely Low; VL Very Low; L Low; M Medium; H High; VH Very High; EH Extremely High

**PL** Point load test (lump)

**DS** Disturbed sample

**PV** Pocket vane shear test

**FV** Downhole field vane shear test

**U50** Undisturbed 48mm diameter core sample collected for laboratory testing.

**REF** Borehole refusal

**INF** DCP has continued through this layer and the geology has been inferred.

<sup>1</sup> Soil consistencies are derived from a combination of field index, DCP and shear vane readings.

<sup>2</sup> Soil density descriptions presented in engineering logs are derived from the DCP testing.

## Recommendations

### *Dispersive soils*

#### Findings

The results presented in Appendix D indicate:

- Most of the samples collected from the Site were either not dispersive (Emerson Class 4 or greater) or were slightly dispersive (Emerson Class 3).

#### Site specific recommendations

- No specific recommendations apply to manage soil dispersion.
- The soils at the Site are only slightly dispersive with a low risk of soil/tunnel erosion.

### *Site Drainage*

The existing driveway has been designed without table drains which is an effective way to reducing the risk of water pooling and accumulating in the residual clay soils surfacing the extremely weathered dolerite at the toe of the cut. There is no signs of erosion on the road surface and the stormwater management is effective. The probability of landslip occurring in the fill along the road margins is maintained as likely and this probability may be reduced by measures to prevent the input of water into the fill including feeding into observed tension cracks.

There is evidence of erosion of the colluvial soil in the cuts, but given the soil is not dispersive, this erosion is not significant but should ideally be managed.

### *Permanent Cut Batters*

It is recommended that unretained cuts in colluvial soil do not exceed 1V: 1H.

### *Permanent Fill Batters*

The margins of the road are exceptionally loose with tension cracks observed. Preventing water from moving into the fill will reduce the risk of slope failure but will not prevent it. Considerations need to be given to measures to stabilise the slope. Namely, through compaction control.

### *Road Crossing*

Soft soil near the proposed creek crossing should be removed and replaced with more suitable material which will resist erosion.

### ***Long-term erosion management***

Fine soils are washing out of the colluvium matrix exposing cobbles and boulders. Although the landslide risk assessment indicates risks of damage to vehicles and loss of life is low, consideration needs to be given to cost benefits of installing a

The following measures are generally recommended for maintaining long-term erosion stability of soil slopes, road cuts through colluvium will require erosion control blankets.

### ***Foundation Maintenance***

Australian Geoguide (LR8) Hillside Construction Practice (Appendix F) will need to be followed.



Kris Taylor, BSc (hons)

Environmental & Engineering Geologist

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# Appendix A Mapping



Figure 1 Site Borehole Locations

# Appendix B Borehole Logs

		<b>ASSESSMENT:</b> Geotechnical Site Investigation <b>STRUCTURE:</b> Driveway And Bridge				<b>Test Pit : TP01</b> <b>DATE TESTED:</b> 20/01/2025								
		<b>EASTING:</b> 514352 <b>NORTHING:</b> 5239894		<b>ACCURACY</b> <b>HORIZ:</b> 1m <b>VERT:</b> ~0.1m		<b>LOGGED BY:</b> M. Scalisi <b>ELEVATION:</b> 308.6								
<b>LOCATION:</b> 14 Batchelors Road - Sandfly <b>CLIENT:</b> Lachlan Joyce					<b>EQUIPMENT:</b> 5 tone excavator <b>ESTIMATED GROUND m (m AHD):</b>									
DEPTH (m)	GRAPHIC	DESCRIPTION	DENSITY CONSIST. STRENGTH	LAYER	ELEVATION (mAHD)	MOISTURE		SAMPLE TEST	Cu (kPa)	UCS (kg/cm <sup>2</sup> )	(IS <sub>50</sub> MPa)			
						Index	%				Well	NSPT	NDCP/100mm	
0.0	ML	SOIL & BOULDERS/COBBLES: Sandy SILT, dark greyish brown, well sorted, low plasticity, fine to medium grained sand, trace leaf litter, 5 % leaf litter and roots, roots; 60% DOLERITE boulders/cobbles	firm to hard	3	308.5	Slightly Moist	20	DS					2.0	
308.3					12.0									
308.1														7.0
0.5	ML	SOIL & BOULDERS/COBBLES: Sandy SILT, olive brown, well sorted, low plasticity, trace organics, 5 % , gravel 15%, fine to medium grained, angular; 80% DOLERITE boulders/cobbles	very stiff to hard	4	307.9	Wet	15	DS					5.0	
307.7					10.0									
307.5														REF
307.3														
307.1														
1.5		Distinctly Weathered DOLERITE Bedrock olive yellow		9										
GP Bucket Refusal on Distinctly Weathered DOLERITE Bedrock End of Test Pit at 1.5m depth.														
<b>GROUNDWATER:</b> Encountered at 0.5 m Below Ground Surface											<b>PAGE 1 of 1</b>			
<b>TESTING:</b> DS: disturbed sample; PV: pocket vane; PP: pocket penetrometer; FV: downhole field vane; U50: undisturbed 50mm sample; REF: DCP refusal														

**LOCATION:** 14 Batchelors Road - Sandfly

**CLIENT:** Lachlan Joyce

**EQUIPMENT:** 5 tone excavator

**ESTIMATED GROUND m (m AHD):**

DEPTH (m)	GRAPHIC	DESCRIPTION	DENSITY CONSIST. STRENGTH	LAYER	ELEVATION (mAHD)	MOISTURE		SAMPLE	TEST	Cu (kPa)	UCS (kg/cm <sup>2</sup> )	(IS <sub>50</sub> MPa)		NDCP/100mm
						Index %	Well					NsPT		
0.0		SOIL & BOULDERS/COBBLES: Sandy SILT, dark greyish brown, well sorted, low plasticity, fine to medium grained sand, trace leaf litter, 5 % leaf litter and roots, roots; 60% DOLERITE boulders/cobbles	stiff to hard	3	289.4	Slightly Moist								4.0
	289.2				11.0									
	289.0													
0.5	288.8													
	288.6													
	288.4													
1.0		Clayey Sandy SILT trace gravel, light olive brown, low plasticity, fine to medium grained sand	stiff to very stiff	6		288.4	Wet							4.0
	288.2													
	288.0													
1.5					4.0									
	287.8													
	287.6													
2.0						5.0								
	287.4													
	287.2													
2.5														
	287.0													
	286.8													
3.0		30												
	286.6													
	286.4													
	286.2													
3.5			DS											
	286.0													
	285.8													
	285.6													
4.0				Distinctly Weathered DOLERITE Bedrock olive yellow										
	285.4													
	285.2													
	285.0													
4.5		GP Bucket Refusal on Distinctly Weathered DOLERITE Bedrock End of Test Pit at 4.5m depth.												
	284.8													

**GROUNDWATER:** Encountered at 1 m Below Ground Surface

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**TESTING:**

DS: disturbed sample; PV: pocket vane; PP: pocket penetrometer; FV: downhole field vane; U50: undisturbed 50mm sample; REF: DCP refusal

**LOCATION:** 14 Batchelors Road - Sandfly

**CLIENT:** Lachlan Joyce

**EQUIPMENT:** 5 tone excavator

**ESTIMATED GROUND m (m AHD):**

DEPTH (m)	GRAPHIC	DESCRIPTION	DENSITY CONSIST. STRENGTH	LAYER	ELEVATION (mAHD)	MOISTURE		SAMPLE	TEST	Cu (kPa)	UCS (kg/cm <sup>2</sup> )	(IS <sub>50</sub> MPa)		NDCP/100mm
						Index %	Well					NsPT		
0.0	ML	SOIL & BOULDERS/COBBLES: Sandy SILT, olive brown, well sorted, low plasticity, trace organics, 5 % , gravel 15%, fine to medium grained, angular; 80% DOLERITE boulders/cobbles	firm to hard	4	285.3	Wet								3.0
					285.1									17.0
0.5	ML	Clayey Sandy SILT trace gravel, light olive brown, low plasticity, fine to medium grained sand		6	284.9									12.0
					284.7									
		Distinctly Weathered DOLERITE Bedrock olive yellow		9	284.5									REF

GP Bucket Refusal on Distinctly Weathered  
DOLERITE Bedrock  
End of Test Pit at 0.9m depth.

**GROUNDWATER:** Not Encountered

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**TESTING:**

DS: disturbed sample; PV: pocket vane; PP: pocket penetrometer; FV: downhole field vane; U50: undisturbed 50mm sample; REF: DCP refusal



**LOCATION:** 14 Batchelors Road - Sandfly

**CLIENT:** Lachlan Joyce

**EQUIPMENT:** AMS Powerprobe 9120 RAP

**ESTIMATED GROUND m (m AHD):**

DEPTH (m)	GRAPHIC	DESCRIPTION	DENSITY CONSIST. STRENGTH	LAYER	ELEVATION (mAHD)	MOISTURE		SAMPLE TEST	Cu (kPa)	UCS (kg/cm <sup>2</sup> )	(IS <sub>50</sub> MPa)		NDCP/100mm
						Index %	Well				NsPT		
0.0	ML	FILL: Sandy SILT trace gravel, brown, well sorted, low plasticity, fine to medium grained sand	hard	1	194.1	Dry							15.0
0.5	ML	Sandy SILT, strong brown, well sorted, low plasticity	soft to hard	2	193.9 193.7 193.5	Wet	21	DS					4.0 1.9 4.0 4.0 2.7
1.0	ML	Clayey SILT with gravel/sand, brownish yellow, well sorted, low plasticity, gravel 25%, coarse grained, angular	firm to hard	7	193.3 193.1 192.9 192.7 192.5 192.3	Moist	23	DS					1.7 1.7 0.8 0.8 1.6 2.4 4.0 5.0 8.0 10.0 8.0
Direct Push Sampler Refusal on Clayey SILT with gravel/sand End of borehole at 1.9m depth.													

**GROUNDWATER:** Encountered at 0.1 m Below Ground Surface

**PAGE 1 of 1**

**TESTING:**

DS: disturbed sample; PV: pocket vane; PP: pocket penetrometer; FV: downhole field vane; U50: undisturbed 50mm sample; REF: DCP refusal

# Appendix C Core Photographs

TP01









**BH05**



**\* 1 metre core tray length**

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## Appendix D Geotechnical Testing

### Soil Dispersion (Emerson aggregate test)

Select soil samples were tested for sodicity using the Emerson Class number method according to AS1289.3.8.1. The results presented in Table 3 demonstrate that:

- Most of the samples collected from the Site were either not dispersive (Emerson Class 4 or greater) or were slightly dispersive (Emerson Class 3).

Table 3 Summary of the Emerson class results.

Layer	Soil	Depth	Sample ID	Emerson Class	Date Tested	Water	pH
3	Sandy SILT	0.3	TP01 0.3	Class >4	22/01/2025	DI 24°C	
2	Sandy SILT	0.6	BH05 0.6	Class 3	22/01/2025	DI 24°C	6.38
4	Sandy SILT	1.1	TP01 1.1	Class 3	22/01/2025	DI 24°C	6.21
5	Silty CLAY	1.5	CT04 1.5	Class 3	22/01/2025	DI 24°C	6.36
7	Clayey SILT	1.7	BH05 1.7	Class >4	22/01/2025	DI 24°C	
6	Clayey Sandy SILT	3.1	TP02 3.1	Class 3	22/01/2025	DI 24°C	5.62

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## Appendix E Geotechnical Interpretation

### Footing Minimum Target Depths

Footing design for the proposed structures are to consider the depths of limiting layers at the base of Class P soils where present. Where practical/allowable, thickened beams may be deepened through problematic soil layers according to engineering specifications (Table 4). Table 5 should be referred to where only 50kPa allowable bearing capacity is required.

Table 4 also presents a summary of the estimated soil depths and associated layers where less than 5mm of vertical soil movement can be expected due to soil moisture fluctuations from normal seasonal wetting and drying cycles. Where 5mm tolerances are required, loads shall be supported at minimum target layer depths presented in Table 4, with considerations given to required bearing capacities in accordance with Table 5. Two scenarios are presented with groundwater at surface and groundwater at 1.0m depth.

Table 4 Soil characteristic surface movements and recommended footing minimum target depths

Footing design parameters	Water Table At Surface	Water Table 1.0m
	BH05	BH05
Iss Calculation Depth <sup>^</sup>	0.00	0.00
Surface movement Ys (mm)	0	15
Soil class	A	S
Base of problem soil layer (m)*	-	-
Layer at base of problem soil*	-	-
Pier/Footing recommended target depth (m)#	1.3	1.3
Pier/footing recommended target layer#	7	7

- No problem layers encountered

\*Base of problematic soil layer depth at test location below top of borehole surface to achieve 100 kPa allowable bearing capacity or greater.

# Target soil layer depth below top of borehole surface where Ys values from normal wetting and drying cycles are estimated at less than 5mm vertical movement

<sup>^</sup> Calculated based on depth below cut (with negative value) or above fill (with positive value) borehole drilling depth. Inferred fill reactivity will be conservatively assessed unless requested otherwise.

## Soil and Rock Allowable Bearing Capacity

Soil allowable bearing capacity was calculated from correlations with DCP blow counts. Where high clay and silt content is observed in the soil, soil allowable bearing capacity is determined from undrained shear strengths using field vane correlated DCP values. Interpretive bearing capacity values are presented in Table 5.

Table 5 Soil allowable bearing capacities and problematic ground conditions.

Depth from (m)	Allowable Bearing Capacity (kPa)				
	TP01	TP02	TP03	CT04	BH05
0	80*	120*	100*	270*	FILL*
0.1	150	160	400	280	530
0.2	340	310	580	300	340
0.3	380	400	>800	230	150
0.4	360		REF	220	150
0.5	310			330	160
0.6	360			300	130
0.7	REF			270	100
0.8			DOLERITE	170	70~
0.9				150	60~
1				140	40~
1.1				140	50~
1.2				160	80~
1.3				170	120
1.4	DOLERITE			190	160
1.5				210	230
1.6		170			340
1.7		180			380
1.8		190			410
1.9		200			REF
2		200			
2.1					
2.2					
2.3					
2.4					
2.5					
2.6					
2.7					
2.8					
2.9					
3					
3.1					
3.2					
3.3					
3.4		DOLERITE			
3.5		DOLERITE		DOLERITE	

Correlations drawn from DCP and vane shear testing.

REF - Penetrometer Refusal

^ Footings to be founded through the FILL

~ Problematic soil layer attributed to loose, soft, or low allowable bearing capacity soil (<100 kPa)

\*Soil layer expected at the base of problematic soil layers at test location (or at surface where problematic soils not encountered) to achieve 100 kPa allowable bearing capacity or greater.

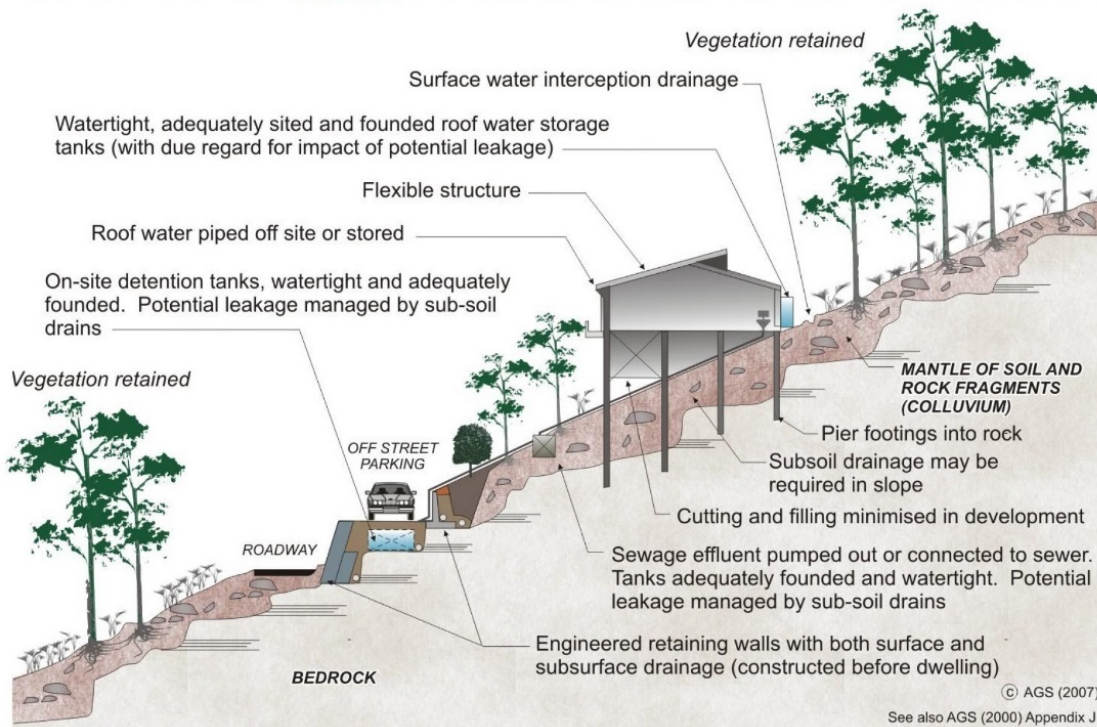
## Appendix F Examples of Good Hillside Construction (AGS LRM LR8)

### 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.

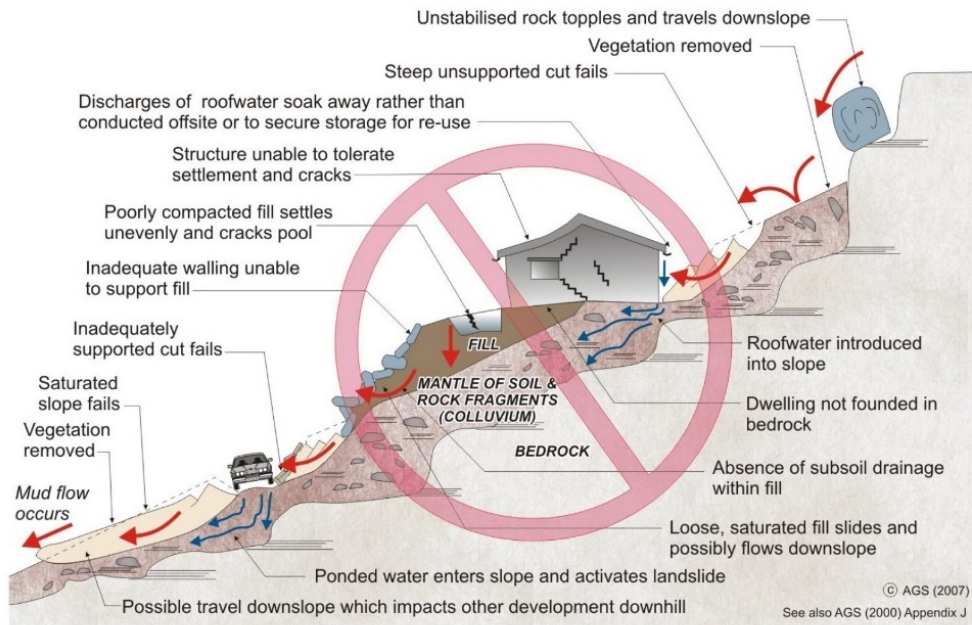
**Vegetation clearance** - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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.