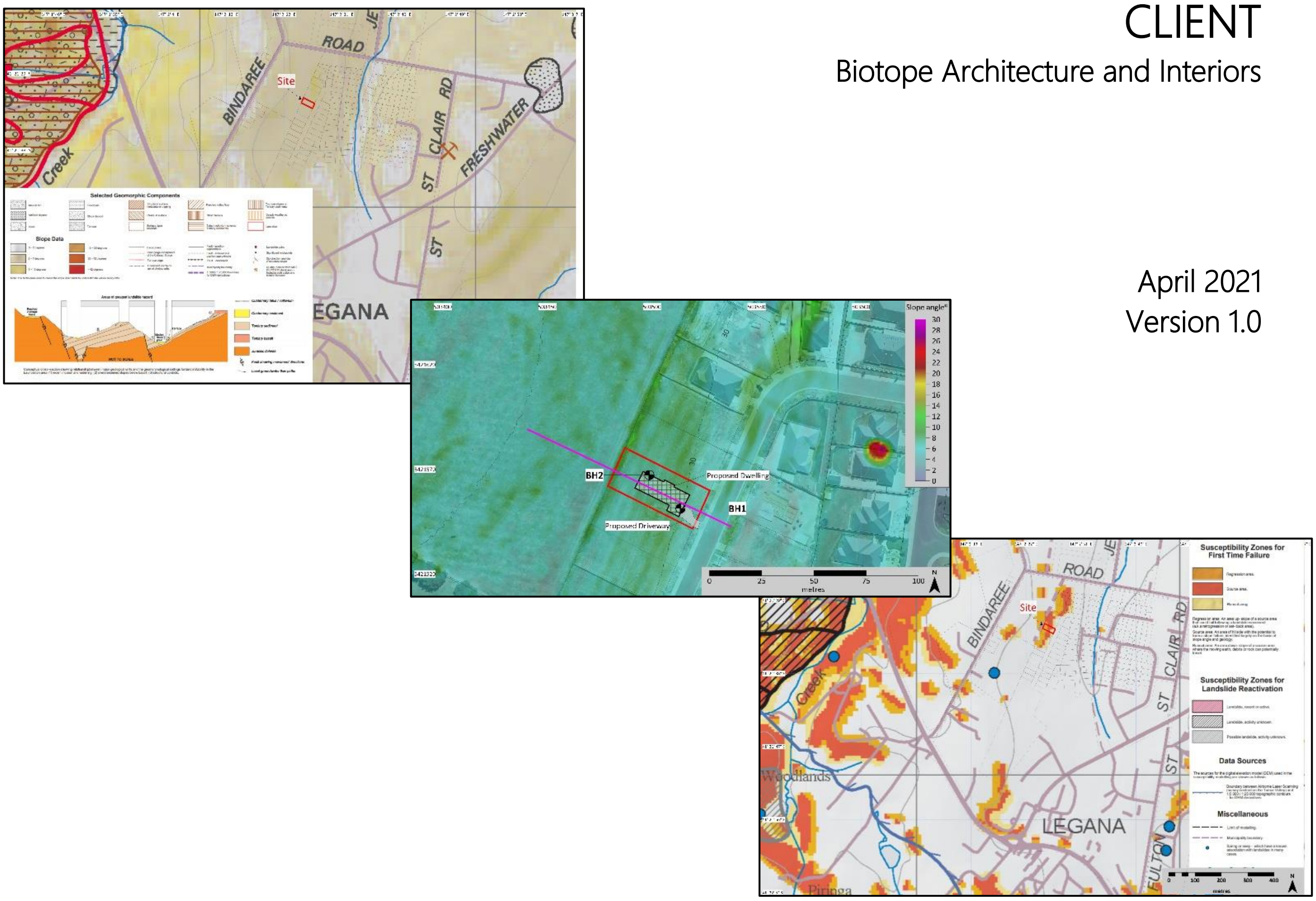
LANDSLIDE RISK ASSESSMENT

Proposed Residential and Visitor Accommodation
4101 Channel Highway, Flowerpot

CLIENT

Biotope Architecture and Interiors



April 2021
Version 1.0

Geo-Environmental Solutions P/L 29 Kirksway Place, Battery Point. Ph 6223 1839 Fax 6223 4539

Refer to this report as

GES (2021). *Landslide Risk Assessment, Proposed Dwelling, 4101 Channel Highway, Flowerpot, Version 1.0.* (Unpublished report for Biotope Architecture and Interiors by Geo-Environmental Solutions Pty. Ltd., 17 August 2021; 39 pages)

Geo-Environmental Solutions may submit hard or electronic copies of this report to Mineral Resources Tasmania to enhance the geotechnical database of Tasmania.

Important Note

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1 Summary

A geotechnical investigation has been conducted for a proposed dwelling at 4101 Channel Highway, Flowerpot. The proposed development site comprises the title land: CT 20339/1. Significant portions of the site have been identified by Mineral Resources Tasmania landslip hazard mapping as being in low hazard band overlays.

1.1 Main findings and conclusions

Following the field assessment, desktop investigations and the outcome of the landslide hazard analysis and risk assessment, the following can be concluded:

- There is a VERY LOW to MODERATE risk at the site should the recommended hazard treatments not be met.
- Following the recommended hazard treatments listed in Table 2 and Section 7 the risk profile for landslide hazard at the site is Very Low to Low. In our experience, authorities generally allow developments to proceed with Low to Moderate risk.
- The proposed development is to comprise a one storey dwelling (Main House), two visitor accommodation dwellings, a caretaker dwelling, a sauna and a boat shed and jetty. The development will also include multiple driveway areas and other paved surfaces. An existing shed is to be kept in the northern portion of the site and an existing concrete water tank is to be repurposed into a plunge pool near the proposed sauna structure.
- The underlying geology typically consists of sandy topsoils overtop of CLAY to a depth of at least 2.0 -3.0 m. Refusal was encountered within TH3 on a dark brown pan layer at 1.7 mbgs.
- Ground conditions below 3.0 m have not been observed/ assessed and are therefore inferred from local experience.
- The natural sub soils identified on site are moderate to highly plastic and reactive and are likely to exhibit significant ground surface movement with an indicative (Ys) range of 40-60mm.
- Review of Middleton LiDAR 2017 data shows slope angles vary across the site with slope angles near the development between approx. 5° and 25° although typically 5° to 12°
- With the implementation of all the following recommendations the development satisfies the performance criteria and is considered acceptable risk in terms of the Kingborough Interim Planning Scheme 2015 performance solutions E3.7.1 P1 and E3.7.3 P1.

GES should be contacted immediately should ground conditions be different from what is described in this report.

2 Introduction

2.1 Background

This assessment is required as part of the application for proposed development works at the site. This landslide assessment is required in accordance with the Tasmanian Planning Scheme (TPS) 2020 and the Tasmanian Building Regulations (2016) (Attachment 1 & Attachment 3).

Geo-Environmental Solutions Pty Ltd (GES) were contracted by Biotope Architecture and Interiors to prepare a Landslide Hazard Assessment for a proposed dwelling at 4101 Channel Highway, Flowerpot (Attachment 2).

GES have undertaken this assessment using available scientific literature and datasets. Estimations are determined by approximation with appropriate regional information applied where appropriate to site specific information.

2.2 Site Title

The land studied in this report is a portion of the central and eastern extent of the cadastral parcel defined by the following title reference:

- CT 20339/1

This parcel of land is approx. 2.64 ha in size and accessed from Channel Highway. Herein, it will be referred to as the 'Site' and/or the 'Project Area'.

2.3 Guidelines and Standards

Where applicable, this report is in general accordance with the following guidelines and Australian/New Zealand Standards:

- Tasmanian Local Government guidelines for site and soil evaluations (wastewater) and geotechnical (slope stability) investigations (including Tasmanian Geological Survey Record UR2017/03)
- Tasmanian Chapter, AGS 1998. Guidelines for geotechnical assessment of subdivisions. Australian Geomechanics Society. Australian Geomechanics 33(3): 53–57.
- Australian Geomechanics Society guidelines (2007) – See Attachment 1
- AS1726 – 2017 Geotechnical Site Investigations
- AS2870 – 2011 Residential Slabs and Footings – construction
- AS1289 (2000). Australian Standard. Methods of Testing of Soils for Engineering Purposes.
- AS4133 (2000). Australian Standard. Methods of Testing of Rocks for Engineering Purposes.
- AS/NZS4360 – 2004 Risk Management

2.4 Scope of Works

The scope of the site investigation is to:

- Conduct a review of site geology, groundwater, geomorphology, recent and historical landslides, from publicly available datasets.
- Undertake a number of borehole investigations.
- Assess potential landslide risk at the site.

- Where applicable, provide recommendations on methods and design approach to manage landslide hazards for the proposed development.

2.5 Methodologies, Dates & Personnel

The fieldwork was performed on 14/08/2020 in the presence of a geotechnician from GES who located the boreholes, nominated sampling and testing, recovered samples and prepared engineering logs.

3 Desktop Investigation

3.1 Interim Planning Scheme Hazard Bands

Interim planning scheme hazards band mapping, codes, and acceptable solutions are presented in Attachment 3. The site is partially within the low hazard band.

3.2 Unpublished MRT Correspondence and Reports

No MRT correspondence or unpublished reports are available for the site.

4 Site Description

4.1 Site Location

The site is located on an east trending spur with gentle to moderate slopes. The site is situated between Channel Highway to the west and D'Entrecasteaux Channel to the east. The proposed development is to be accessed from Channel Highway (refer to Attachment 2).

4.2 Site Rainfall

Site rainfall statistics near the site (Middleton Post Office) show mean annual rainfall of approx. 915.3 mm (data since 1910). On average, the wettest month is August with 92.9mm. On average, the driest month is January with 56.0mm (0).

4.3 Topography and Relief

4.3.1 Present Site Conditions

At the time of investigation, the site vegetation comprised grass species as well as native and ornamental tree species. The ground surface at the site is undulating with has slope angles ranging between approx. 5° and 25° across the site trending north, east and south. There are two existing dams; one in the north of the site and one in the south. Multiple site buildings are mostly situated in the centre of the site (most of which, are to be demolished). Beyond the eastern site boundary is a steep slope that descends to the coast of the D'Entrecasteaux Channel. Photographs are presented in Attachment 5.

4.3.2 Proposed Site Development

Plans constructed by Biotope Architecture Interiors (dated: 25/05/2021) have been provided to GES detailing the proposed development. The proposed development is to comprise a one storey dwelling (Main House), two visitor accommodation dwellings, a caretaker dwelling, a sauna and a boat shed and jetty. The development will also include multiple driveway areas and other paved surfaces. An existing shed is to be kept in the northern portion of the site and an existing concrete water tank is to be repurposed into a plunge pool near the proposed sauna structure (Attachment 6).

4.4 Geomorphology

The site is located on an east trending spur with gentle to moderate slopes. The site is situated between Channel Highway to the west and D'Entrecasteaux Channel to the east. Beyond the eastern site boundary is a steep slope that descends to the coast of the wave cut shore platform and beach of the D'Entrecasteaux Channel . Review of Middleton LiDAR 2017 data shows slope angles vary across the site with slope angles near the development between approx. 5° and 25° although typically 5° to 12°. Elevations range from approx. 30 m AHD on the western boundary of the site to approx. 0 m AHD near the proposed boat shed.

4.5 Geology & Soils

4.5.1 Published Geology

Based on the 1:250,000 scale series Geological Mapping – Sheet: SE the site geology comprises of the following geological units:

- Upper Parmeener Supergroup – Triassic Aged (Map Unit: Rq) – Dominantly Quartz Sandstone.

4.5.2 Observed Geology

The field inspection carried out on 14/08/20 and six boreholes were completed using a GeoProbe 540UD rig. The underlying geology typically consists of sandy topsoils overtop of CLAY to a depth of at least 2.0 - 3.0 m. Refusal was encountered within TH3 on a dark brown pan layer at 1.7 mbgs (Attachment 8).

The CLAYS encountered were of moderate to high plasticity and are thought to be highly reactive with estimated Ys values of 40-60mm (Class H1) Attachment 9.

4.6 Surface Drainage

The surface of the site comprises a mantle of sandy soils over top of moderate to high plasticity CLAY soils on gentle to moderate slopes. The site soils are thought to be imperfectly drained. As such, it is anticipated that stormwater may infiltrate it the sandy soils relatively freely but not into the silty CLAY sub-soils. Stormwater is expected to flow predominantly overland flow to the east north and south dependent on the location across the site.

4.7 Hydrogeology

No seeps have been mapped upslope of the site in public data sources. A defined water course runs along the northern boundary of the site. Two dams are in the north and south of the site, which are not considered to be spring fed.

4.8 Site Classification – AS2870 – 2011

According to "AS2870-2011 Residential slabs & footings" the site has been classified as Class H1.

The natural sub soils identified on site are medium to highly plastic and reactive and are likely to exhibit moderate and variable ground surface movement with an indicative (Ys) range of 40-60mm.

5 Landslide Risk Analysis

5.1 Historical Slope Stability

No historic slope instability has been noted near the proposed development. There is likely to be past evidence of instability on the southeast facing coastal cliff beyond the site boundary. However, this is far enough removed from the proposed development.

5.2 Current Slope Stability

No evidence of current slope instability was observed during site investigations.

5.2.1 Landslide Characteristics

Based on the slope characteristics including site geology, slope geometry and the existing cut slope angles, the following scenarios have been identified as potential slope failure mechanisms for the site:

- Scenario 1 – Shallow slide failure of cuts slopes above the proposed developments;
- Scenario 2 – Medium scale slide failure (up to 4.0m deep) within the fill and natural clay soils below the proposed developments; and
- Scenario 3 – Deep-seated slide failure of the site slopes into the D'Entrecasteaux Channel.

5.2.2 Frequency Analysis

Table 1 presents the frequency analysis for the identified slope failure mechanisms. Terminology used is in accordance with the Australian Geomechanics Society (AGS) guidelines for landslide risk management (2007a,b,c,d).

Table 1 Frequency analysis for landslide hazards 1 - 3

Scenario	Failure Mechanism	Unit Affected	Observed in the field	Potential Size	Potential Speed	Water Content	Current Likelihood	Consequence	Action Required
1	Shallow Slide Failure	CLAY rich soils	No	Very Small to Small	Very Slow to Rapid	Moist to Saturated	Likely	Minor	Yes
2	Medium Scale Slide Failure	Fill and clay soils	No	Very Small to Medium	Very Slow to Moderate	Wet to Saturated	Possible	Major	Yes
3	Deep-Seated Slide Failure	CLAY soils	Yes	Medium to large	Very slow to slow	Wet to Saturated	Barely Credible	Minor	No

5.3 Risk Analysis

5.3.1 Risk to Property

There is a **VERY LOW to MODERATE** risk at the site should the recommended hazard treatments not be met. From experience most councils accept Low to Moderate risk as determined by a landslide management report as acceptable to tolerable risk.

Table 2 Consequence analysis for landslide hazards 1 – 3 – Property

Scenario		Current Risks			Recommended Hazard Treatment	Residual Risks following implementation of risk treatment		
	Issue	Likelihood of occurrence	Consequence to property	Level of risk to property		Likelihood of occurrence	Consequence to property	Level of risk to property
Scenario 1	Shallow Slide Failure	Likely	Minor	Moderate	Unretained cuts must not exceed 1.5m **and** not exceed 1V : 2H gradient. Cuts in exceedance of 1.5m **and** 1V : 2H gradient should be retained with suitably engineered retaining walls. Aggregate toe drains should be included into the design along the base of all cuttings. A cut-off v-drain should be incorporated above any cutting/retaining wall faces. Foundations of retaining walls should be seated into competent ground with bearing capacities in exceedance of 100kPa. This should be checked by a geotechnical professional or the site engineer prior to construction of foundations. No cuts should be made below the proposed dwelling.	Unlikely	Minor	Low
Scenario 2	Medium Scale Slide Failure	Possible	Medium	Moderate	Use of fill should be limited to 1.0 m height across the site. Fill should be placed in suitably compacted layers not exceeding 150 mm in height. Fill batters should not exceed gradients of 1V: 2H. Fill should be sculpted so that water does not pool on the fill surface. Foundations must be founded within good ground (allowable bearing capacities ≥100kPa) The identified sub soils are moderate to highly plastic clay rich soils, are reactive and are likely to exhibit significant ground surface movement. As such, foundations should be designed to accommodate the (Ys) range of 40-60mm.	Unlikely	Medium	Low
Scenario 3	Deep-Seated Slide Failure	Barely Credible	Medium	Very Low	Point loading of water should be avoided. Wastewater should be applied near ground surface and over an appropriate area. Earthworks for the proposed development should be conducted during dry periods to avoid water infiltration into the clay rich soils. Stormwater from impervious surfaces should be connected as soon as possible. All construction and earthworks on site should be adequately designed in accordance with the good hillside construction practices as outlined in the Australian Geomechanics Society (AGS) Geoguide LR8.	Barely Credible	Medium	Very Low

5.3.2 Risk to Life

Risk to life has been considered for Scenarios 1 – 3 following the recommended hazard treatments (Table 3)

Table 3 Consequence analysis for landslide hazards 1 – 3 – Life – Post Treatment

Hazard	Scenario 1	Scenario 2	Scenario 3
Factor	Shallow Slide Failure	Medium Scale Slide Failure	Deep-seated Slide Failure
Likelihood	Unlikely	Unlikely	Barely Credible
Indicative Annual Probability	0.001	0.001	0.00001
Use of Affected Structure/Site	CLAY rich soils	Fill and CLAY soils	CLAY soils
Probability of Spatial Impact	Cut upslope of the driveway or any of the proposed structures that is not proposed to be retained. = 0.2	Dwelling foundations. = 0.4	Southern boundary of site. = 0.2
Proportion of Time	Estimated 12 hours a day. = 0.5	Estimated 12 hours a day. = 0.5	Estimated 12 hours a day. = 0.5
Probability of Not Evacuating	Cut batters and retaining walls should exhibit signs of stress (cracking or rotation) allowing time to evacuate. = 0.2	Fill must be benched into natural ground. Foundations must be founded within good ground (allowable bearing capacities ≥100kPa) and designed to accommodate Ys values of 40-60 mm. Clay rich fill and soils should exhibit signs of stress (cracking) allowing time to evacuate. = 0.2	Clay rich soils should exhibit signs of stress (cracking) and the expected slow movement of a failure of this type should allow time to evacuate. = 0.1
Vulnerability	Retaining wall/s and cuts may require remediation. = 0.2	Dwelling unlikely to collapse. = 0.2	Failure will not likely occur near the proposed development. =0.05
Risk for Person Most at Risk	4.0×10^{-6}	8.0×10^{-6}	5.0×10^{-9}

Note 1 It has been assumed that each person has an equal probability of death for each of the hazards. Societal risk has not been assessed.

6 Conclusions

Following the field assessment, desktop investigations and the outcome of the landslide hazard analysis and risk assessment, the following can be concluded:

- There is a VERY LOW to MODERATE risk at the site should the recommended hazard treatments not be met.
- Following the recommended hazard treatments listed in Table 2 and Section 7 the risk profile for landslide hazard at the site is Very Low to Low. In our experience, authorities generally allow developments to proceed with Low to Moderate risk.
- The proposed development is to comprise a one storey dwelling (Main House), two visitor accommodation dwellings, a caretaker dwelling, a sauna and a boat shed and jetty. The development will also include multiple driveway areas and other paved surfaces. An existing shed is to be kept in the northern portion of the site and an existing concrete water tank is to be repurposed into a plunge pool near the proposed sauna structure.
- The underlying geology typically consists of sandy topsoils overtop of CLAY to a depth of at least 2.0 -3.0 m. Refusal was encountered within TH3 on a dark brown pan layer at 1.7 mbgs.
- Ground conditions below 3.0 m have not been observed/ assessed and are therefore inferred from local experience.
- The natural sub soils identified on site are moderate to highly plastic and reactive and are likely to exhibit significant ground surface movement with an indicative (Ys) range of 40-60mm.
- Review of Middleton LiDAR 2017 data shows slope angles vary across the site with slope angles near the development between approx. 5° and 25° although typically 5° to 12°
- With the implementation of all the following recommendations the development satisfies the performance criteria and is considered acceptable risk in terms of the Kingborough Interim Planning Scheme 2015 performance solutions E3.7.1 P1 and E3.7.3 P1.

7 Recommendations

Based on the outcome of the landslide hazard analysis and risk assessment, the following recommendations are made:

7.1 Construction Recommendations

- Unretained cuts must not exceed 1.5m **and** not exceed 1V : 2H gradient.
- Cuts in exceedance of 1.5m **and** 1V : 2H gradient should be retained with suitably engineered retaining walls.
- Aggregate toe drains should be included into the design along the base of all cuttings. A cut-off v-drain should be incorporated above any cutting/retaining wall faces.
- Foundations of retaining walls should be seated into competent ground with bearing capacities in exceedance of 100kPa. This should be checked by a geotechnical professional or the site engineer prior to construction of foundations.
- No cuts should be made below the proposed dwelling.

- Use of fill should be limited to 1.0 m height across the site.
- Fill should be placed in suitably compacted layers not exceeding 150 mm in height.
- Fill batters should not exceed gradients of 1V: 2H.
- Fill should be sculpted so that water does not pool on the fill surface.
- Foundations must be founded within good ground (allowable bearing capacities ≥100kPa)
- The identified sub soils are moderate to highly plastic clay rich soils, are reactive and are likely to exhibit significant ground surface movement. As such, foundations should be designed to accommodate the (Ys) range of 40-60mm.
- Point loading of water should be avoided.
- Wastewater should be applied near ground surface and over an appropriate area.

7.2 General Recommendations

- Stormwater from impervious surfaces should be connected as soon as possible.
- Earthworks for the proposed development should be conducted during dry periods to avoid water infiltration into the high plasticity clay rich soils.
- Stormwater form new impervious surfaces should be connected to public reticulated systems as soon as possible.
- All site construction and earthworks should be adequately designed in accordance with good hillside construction practices as outlined in the Australian Geomechanics Society (AGS) Geoguide LR8.

GES should be contacted immediately should ground conditions be different from what is described in this report.

David Lee BSc
Environmental & Engineering Geologist

8 References

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

AGS (2007e). The Australian Geoguides for Slope Management and Maintenance. Australian Geomechanics Vol 42 No 1 March 2007

AS1289 (2000). Australian Standard. Various methods as Prepared by Committee CE/9, Testing of Soils for Engineering Purposes. Approved on behalf of the Council of Standards Australia on 3 December 1999 and published on 28 February 2000.

AS1726 (2017). Australian Standard. Geotechnical Site Investigations. Approved on behalf of the Council of Standards Australia on 7 April 2017 and published on 2nd May 2017.

AS4133 (2000). Australian Standard. Prepared by Committee CE/9, Testing of Soils for Engineering Purposes. Approved on behalf of the Council of Standards Australia on 3 December 1999 and published on 28 February 2000.

Attachments

This report must be accompanied by the following Attachments:

Attachment 1. Planning, Standards and Guidelines

1.1 *Interim Planning Scheme*

As detailed in Attachment 3, parts of the site reside within the interim planning scheme (IPS) Landslide Hazard Area Overlay

- The site falls within a Medium Landslide Hazard Area overlay
- The proposed development does not meet E3.7.1 A1 or E3.7.3 A1 acceptable solutions as there are no acceptable solutions to "Buildings and Works, other than Minor Extensions" E3.7.1 A1 or "Major Works" (E3.7.3 A1). As such Performance Criteria E3.7.1 P1 and E3.7.3 P1 are required to be assessed.

1.2 *Reporting Guidelines*

This landslide hazard report has been prepared considering the following guide:
"Building on Tasmanian Landscapes: Guidance for Geotechnical Reporting in Tasmania" (Mineral Resources Tasmania, 2018).
The following five AGS documents followed in this assessment are:

- 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
- AGS (2007e). The Australian Geoguides for Slope Management and Maintenance. Australian Geomechanics Vol 42 No 1 March 2007

Attachment 2. Site Locality Maps

The site is located on gentle to moderate east facing slopes in Flowerpot, Tasmania. The proposed development is to be accessed from Channel Highway.

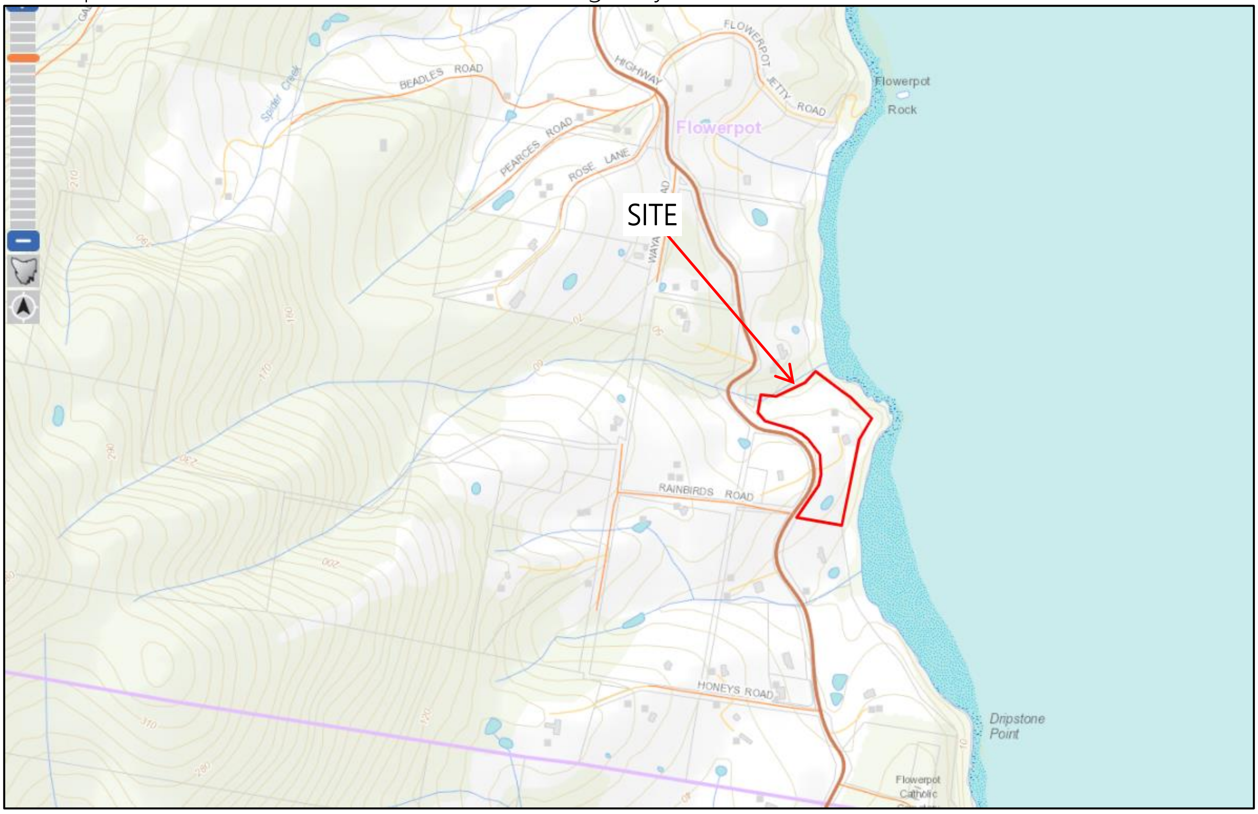


Figure 1. Regional Location of Project Area - The Land and Information System, Tasmania (LIST).

Figure 2 Site Location - The Land and Information System, Tasmania (LIST).

Attachment 3. Interim Planning Scheme Overlays

3.1 *Landslide Code*

Majority of the site falls within the Interim Planning Scheme (IPS) Low Landslide Hazard Area overlay (yellow = low) (Figure 3).

3.2 *Acceptable Solutions*

E3.6.1 Development on Land Subject to Risk of Landslip

The proposed development does not meet E3.7.1 A1 and E3.7.3 A1 acceptable solutions as there are no acceptable solutions to "Buildings and Works, other than Minor Extensions" E3.7.1 A1 or "Major Works" (E3.7.3 A1). As such Performance Criteria E3.7.1 P1 and E3.7.3 P1 are required to be assessed.

Standard	Code	Acceptable Solution		Performance Criteria
Use	E3.6.1 Hazardous Use	A1	Hazardous use relates to an alteration or intensification of an approved use.	P1
		A2	No acceptable solution.	P2
	E3.6.2 Vulnerable Use	A1	Vulnerable use is for visitor accommodation.	A1
		A2	No acceptable solution.	A2
Development	E3.7.1 Buildings and Works, other than Minor Extensions	A1	No Acceptable solution	P1
	E3.7.2 Minor Extensions	A1	Buildings and works for minor extensions must comply with the following: (a) be in a Medium Landslide Hazard Area.	P1
	E3.7.3 Major Works	A1	No acceptable solution.	P1
Subdivision	E3.8.1 Subdivision	A1	No Acceptable solution	P1
		A2	Subdivision is not prohibited by the relevant zone standards.	P2

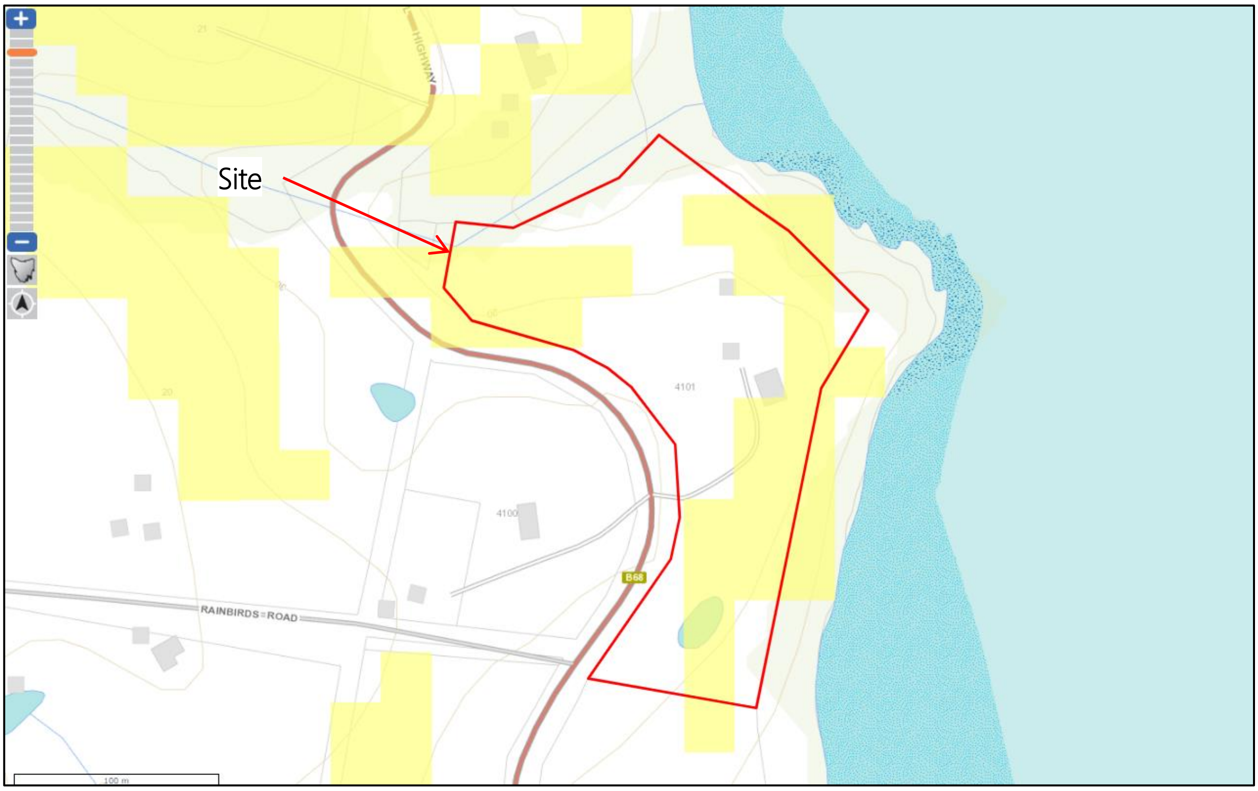


Figure 3 Interim Planning Scheme Landslide Hazard Area Overlay

Attachment 4. Rainfall Data

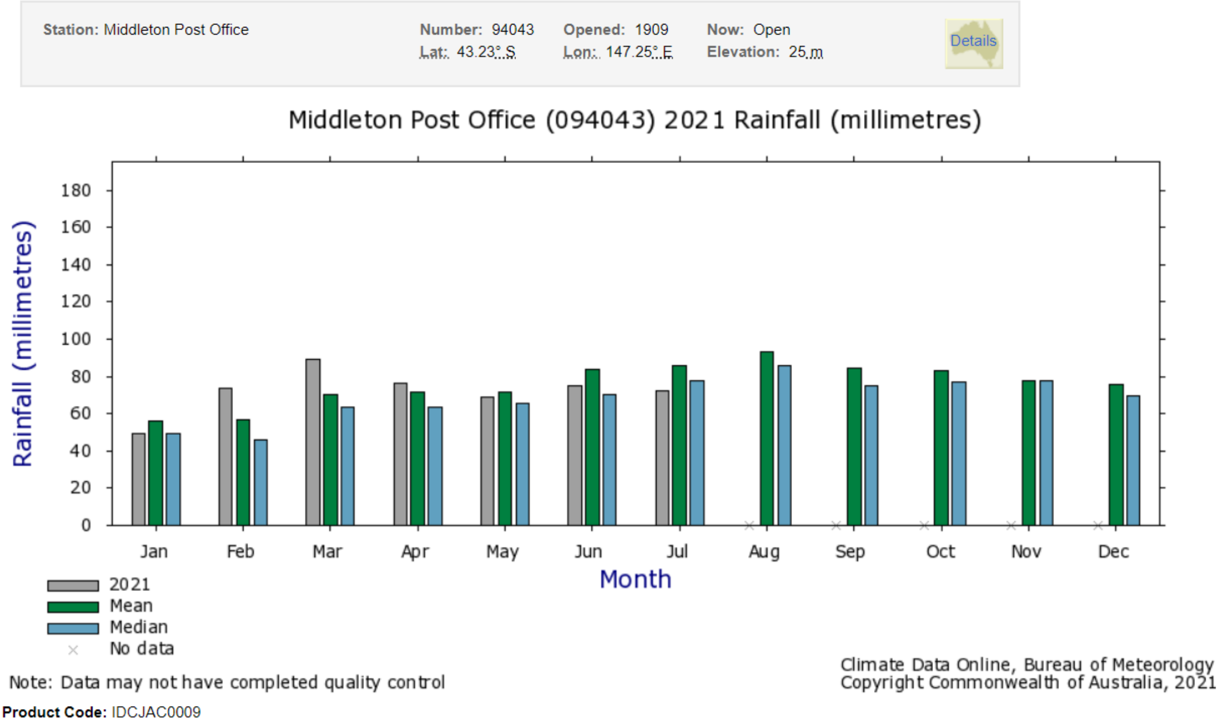


Figure 4 Monthly Rainfall Trends near the Site

Attachment 5. Site Photos

Figure 5 Looking SE at The existing dwelling.

Figure 6 Looking N across site at the proposed sauna location.

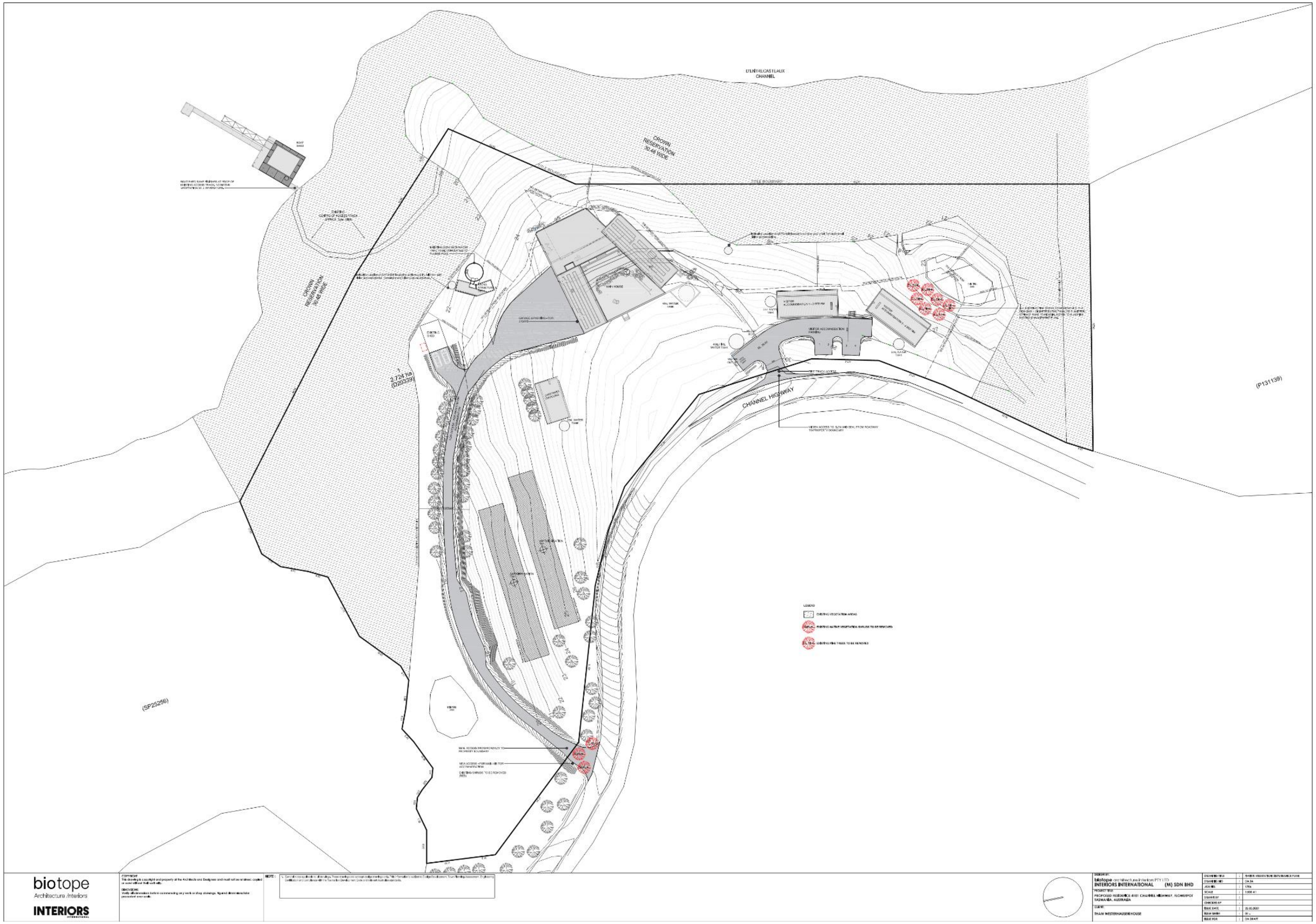
Figure 7 Looking NE across eastern part of the site.

Figure 8 Looking N showing the site slopes immediately below the existing dwelling.

Figure 9 Looking SE down the coastal cliff.

Attachment 6. Site Plan

Figure 10 Site plan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CROWN RESERVATION 30.48 WIDE
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(D20339)
CHANNEL HIGHWAY
(P131139)
(SP25256)
biotope
Architecture Interiors
INTERIORS
DESIGN BY:
biotope architecture interiors PTY LTD
INTERIORS INTERNATIONAL (M) SDN BHD
PROJECT TITLE
PROPOSED RESIDENCE 4101 CHANNEL HIGHWAY, FLOWERPOT
TASMANIA, AUSTRALIA
CLIENT:
THAM WESTERHAUSEN HOUSE
ISSUE FOR : DA DRAFT

Attachment 7. Geomorphology

The site is situated on steep southeast facing slopes approx. 7 - 9° with slopes decreasing towards the eastern site boundary.

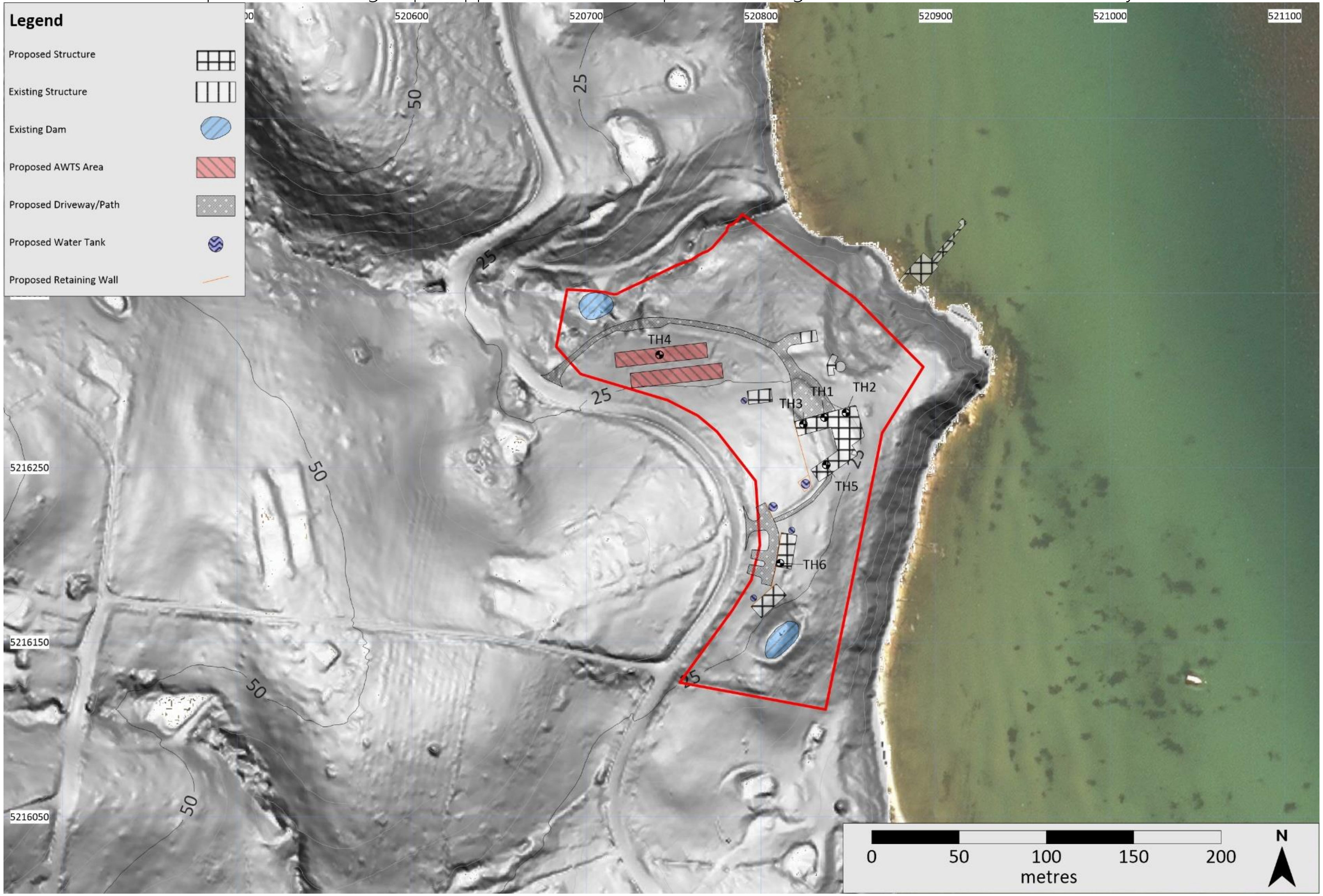

Figure 11 Hillshade Model Developed from Middleton 2017 LiDAR

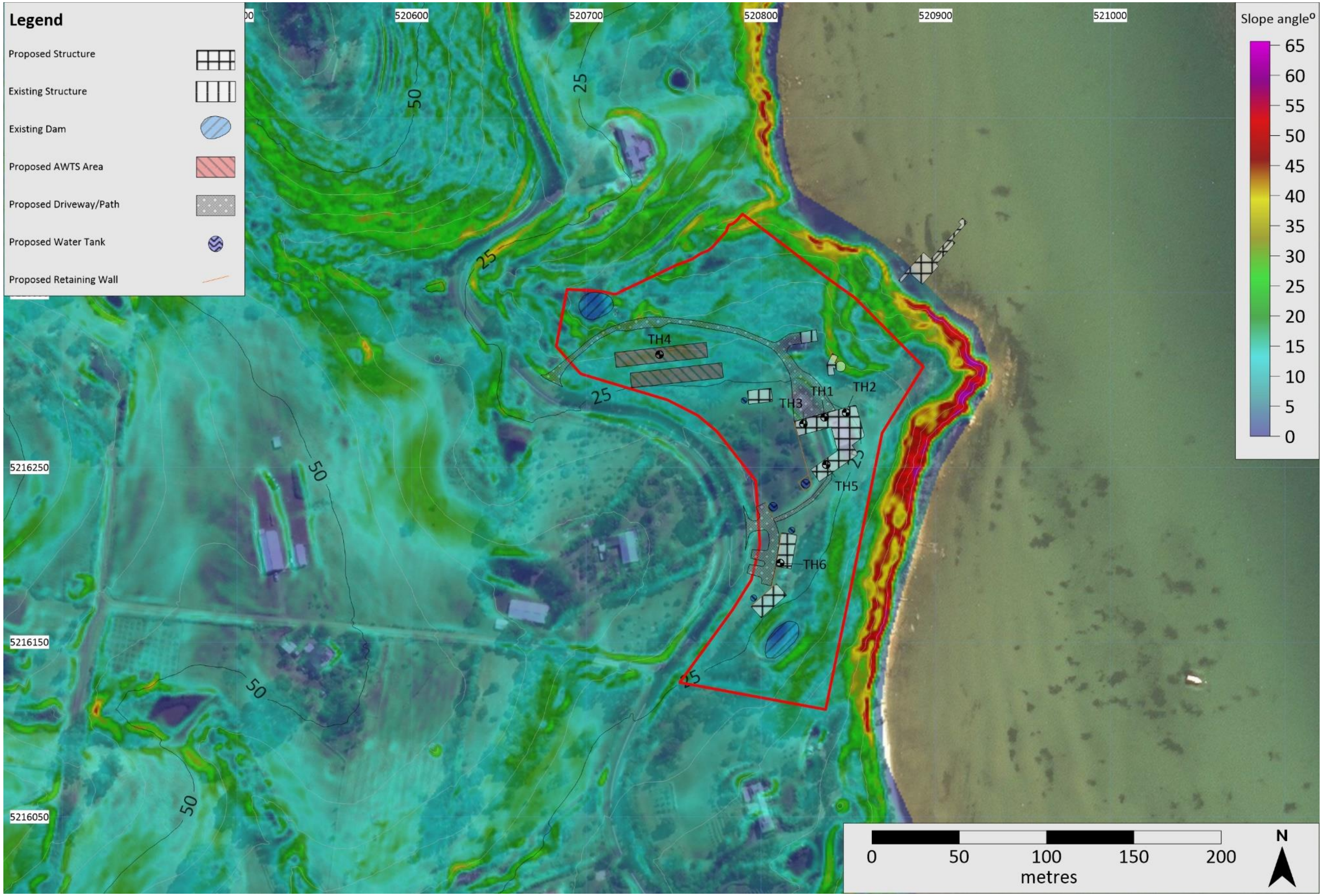

Figure 12 Slope Angle Map Developed from Middleton 2017 LiDAR data.

Attachment 8. Published Geology

Based on the 1:250,000 scale series Geological Mapping – Sheet: SE the site geology comprises of the following geological units (Figure 13):

- Upper Parmeener Supergroup – Triassic Aged (Map Unit: Rq) – Dominantly Quartz Sandstone.
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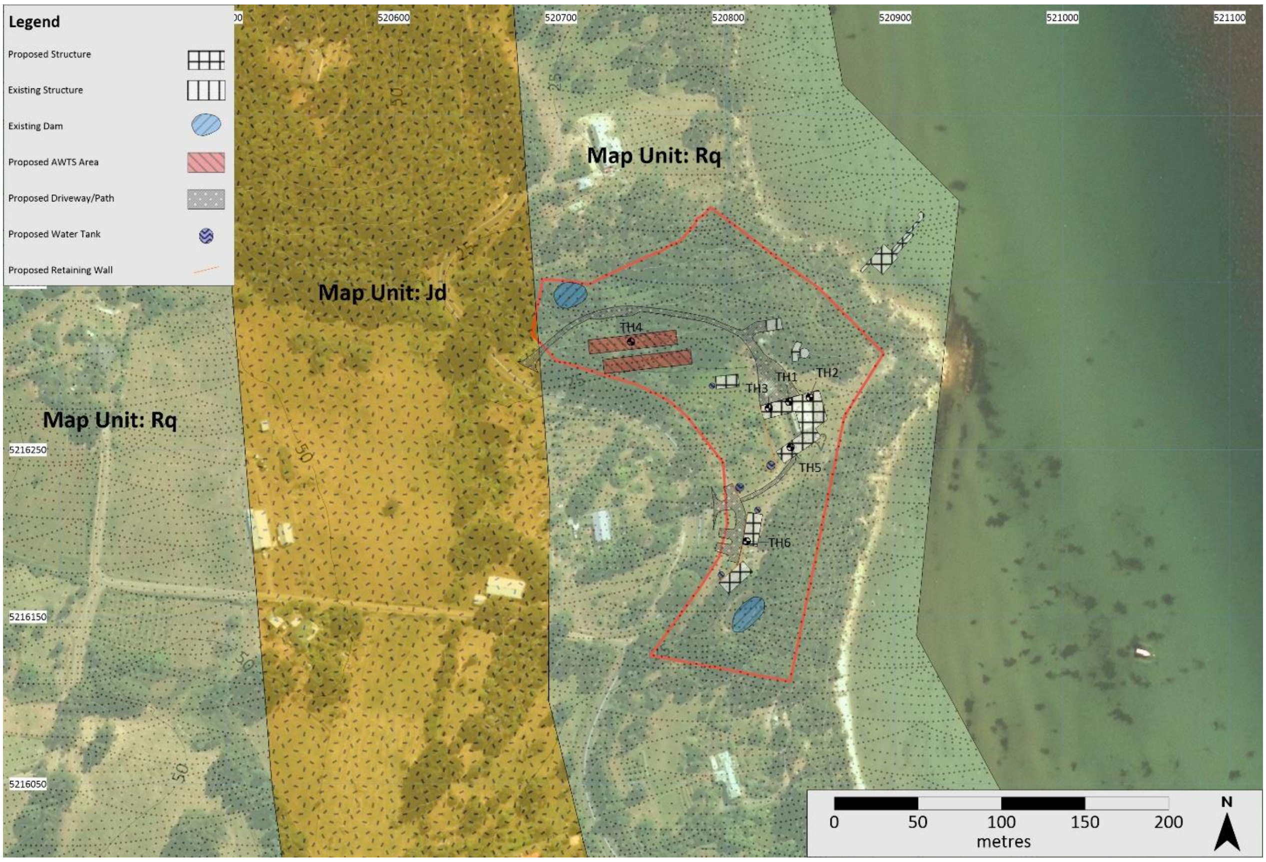


Figure 13 Regional Geology

Attachment 9. Field Assessment

Hole 1 Depth (m)	Hole 2 Depth (m)	Horizon	Description
0.00 – 0.10	0.00 – 0.30	A1	Brown **SAND (SW)**, single grain, slightly moist, medium dense consistency, trace of gravels, gradual boundary to
0.10 – 0.50		B1	Light Grey **SAND (SP)**, single grain, slightly moist, medium dense consistency, clear smooth boundary to
0.50 – 1.60	0.30 – 2.0+	B21	Brownish Yellow and Light Grey **CLAY (CH)**, moderate polyhedral structure, slightly moist, very stiff consistency, high plasticity, gradual boundary to
1.60 – 3.0+		B22	Light Grey and Red **CLAY (CL)**, moderate polyhedral structure, slightly moist hard consistency, medium plasticity, approx. 30% gravels, lower boundary undefined.

Hole 3 Depth (m)	Hole 4 Depth (m)	Horizon	Description
0.00 – 0.30	0.00 – 0.20	A1	Grey **SAND (SP)**, single grain, slightly moist loose consistency, clear boundary to
0.30 – 1.30	0.20 – 0.50	A2	Light Grey **SAND (SP)**, single grain, slightly moist very dense consistency, clear boundary to
1.30 – 1.60	0.50 – 2.0+	B21	Light Grey **CLAY (CL)**, moderate polyhedral structure, slightly moist very stiff consistency, medium plasticity, gradual boundary to
1.60 – 1.7+		PAN	Dark Brown **SAND (SW)**, trace of clay, weak polyhedral structure, slightly moist hard consistency, refusal on cemented sand

Hole 5 Depth (m)	**Hole 6 Depth (m)**	**Horizon**	**Description**
0.00 – 0.20	0.00 – 0.10	A1	Brown **SAND (SW)**, single grain, slightly moist, medium dense consistency, trace of gravels, gradual boundary to
	0.10 – 0.50	A3	Pale Brown **CLAYEY SAND (SC)**, weak polyhedral structure, slightly moist very dense consistency, approx. 10% clay, gradual boundary to
0.20 – 0.60		B1	Light Grey **SAND (SP)**, single grain, slightly moist, medium dense consistency, clear smooth boundary to
0.60 – 1.90	0.30 – 2.0+	B21	Brownish Yellow and Light Grey **CLAY (CH)**, moderate polyhedral structure, slightly moist, very stiff consistency, high plasticity, gradual boundary to
1.90 – 2.0+		B22	Light Grey and Red **CLAY (CL)**, moderate polyhedral structure, slightly moist hard consistency, medium plasticity, approx. 30% gravels, lower boundary undefined.

Attachment 10. Landslide Risk Framework

This Attachment addresses slope stability (landslide) issues for the proposal in accordance with Australian Geomechanics Society (AGS) Landslide Risk Management (2007) . The process is depicted in Figure 14.

The main types of landslide movement are shown in Figure 15 and Table 4.

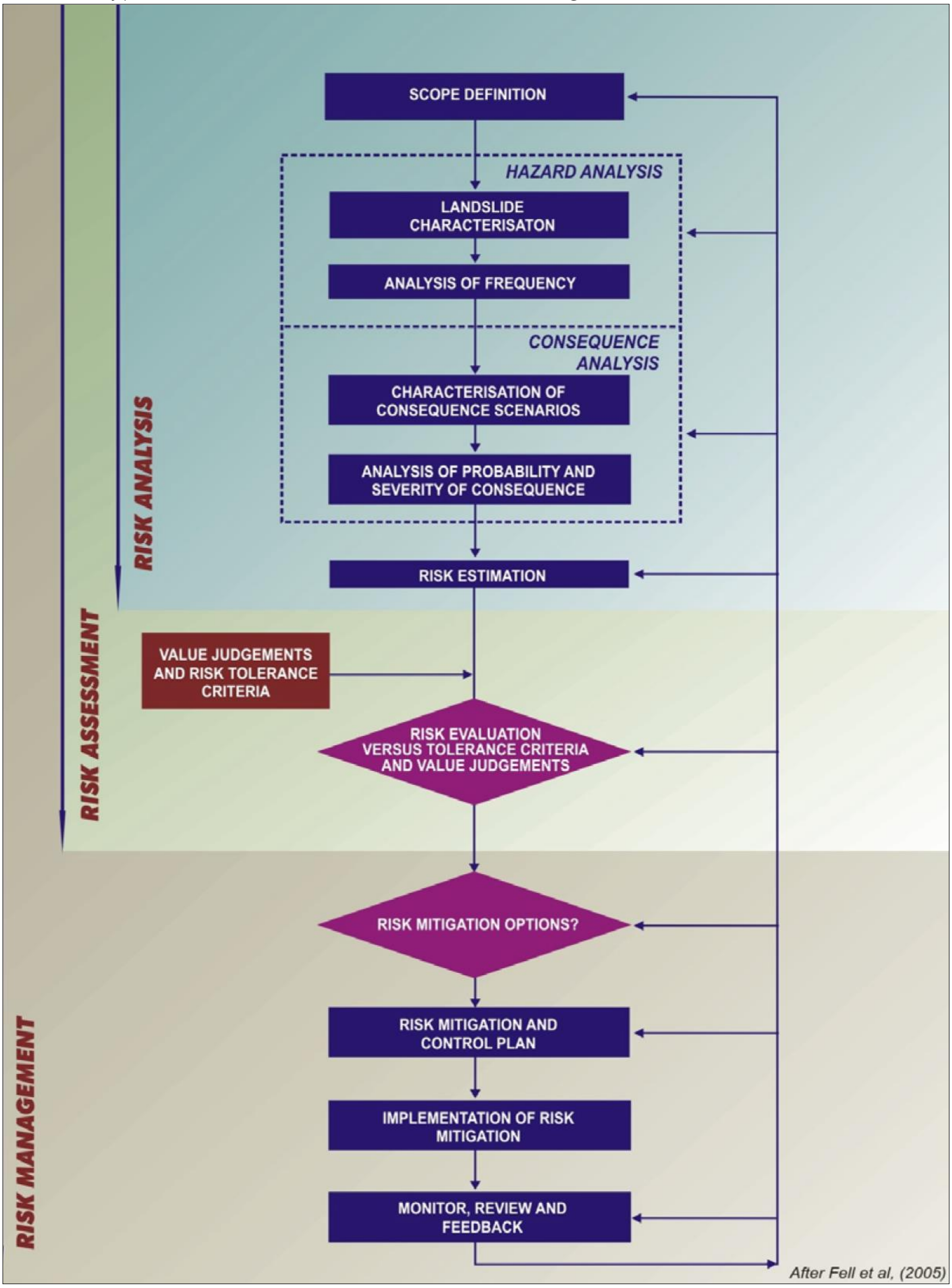


Figure 14 Framework for Landslide Risk Management

Source: Reproduced without amendment from AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007

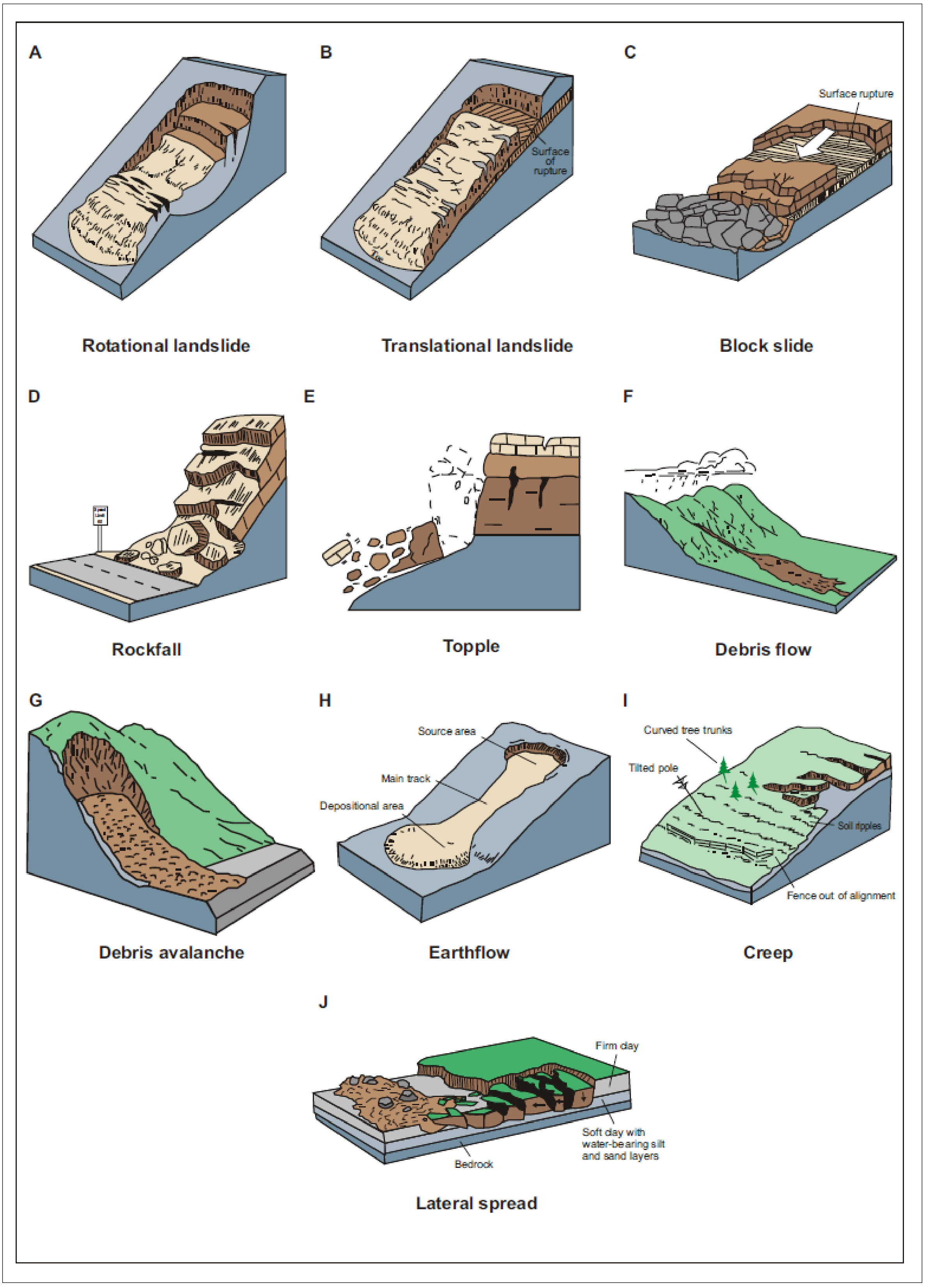


Figure 15 Main Types of Landslide Movement

Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

Table 4 Main Types of Landslide Movement

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		

Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

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

Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

Description	Size (m^2)
	0.01
Very small	
	10
Small	
	1,000
Medium	
	100,000
Large	
	1,000,000
Very large	

Size is areal extent of failure zone
After: van Schalkwyk, A and Thomas, M.A. (1991). Slope failures associated with the floods of September 1987 and February 1988 in Natal and Kwa-Zulu, Republic of South Africa. Geotechnics in the African Environment, Blight et al. (Eds), pp. 57-63

Attachment 11. Qualitative Terminology for Use in Assessing Risk

Likelihood & Consequence Index

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-6}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

Qualitative Risk Matrix

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

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

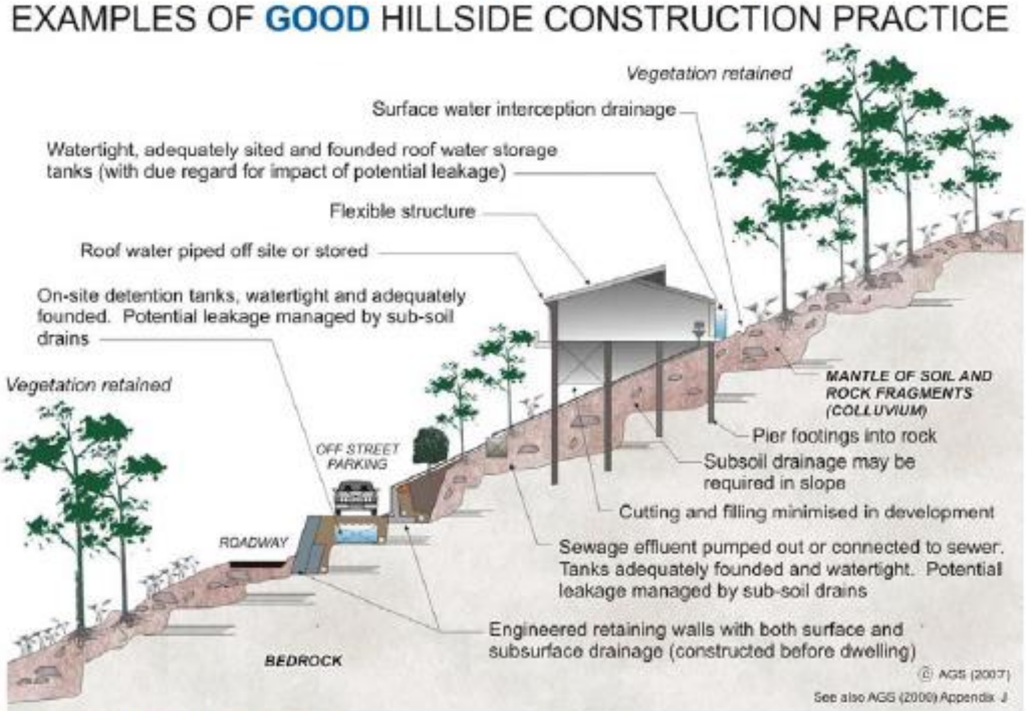
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Attachment 12. Examples of Good Hillside Construction Practice

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.



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.

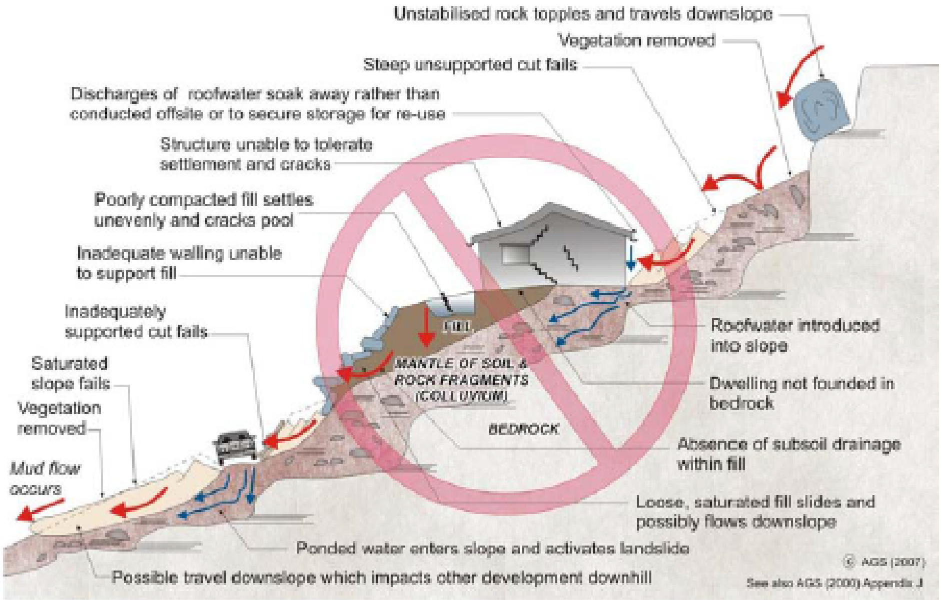
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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