



Landslide Hazards



2015

SECOND EDITION

Handbook

NON-MANDATORY DOCUMENT



ABCB

LANDSLIDE HAZARDS

HANDBOOK

2015

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Preface

The Inter-Government Agreement (IGA) that governs the ABCBC places a strong emphasis on reducing reliance on regulation, including consideration of non-regulatory alternatives such as non-mandatory guidelines, handbooks and protocols.

This Handbook is one of a series produced by the ABCBC. The series of Handbooks is being developed in response to comments and concerns expressed by government, industry and the community that relate to the built environment. The topics of Handbooks expand on areas of existing regulation or relate to topics which have, for a variety of reasons, been deemed inappropriate for regulation. The aim of the Handbooks is to provide construction industry participants with non-mandatory advice and guidance on specific topics.

Landslide Hazards has been identified as an issue that requires consistent uniform guidance.

Construction on sites prone to potential landslide hazard has been identified as an issue that requires consistent uniform guidance.

This Handbook addresses the issues in generic terms. The Handbook is not a document that sets out preventative measures for landslides, but rather describes the means of estimating and managing the risk to life and property posed by landslides. It is expected that this Handbook will be used to develop solutions relevant to specific situations in accordance with the generic principles and criteria contained herein.

In 2007, the Australian Geomechanics Society (AGS) published a series of Guidelines on Landslide Risk Management including one for landslide zoning, one for slope management and one practice note. This edition of the Handbook on Landslide Hazards is therefore intended to provide an overarching regulatory perspective on the AGS Guidelines taken into account additional States and Territories requirements.

This Handbook was first published in 2006 and was revised in 2015 in accordance with the above objectives.



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- the Australian Geomechanics Society;
- representatives from the Landslide Risk Management Sub-Committee of the Australian Geomechanics Society; and
- Engineers Australia.



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1 Introduction

Reminder:

This Handbook is not mandatory or regulatory in nature and compliance with it will not necessarily discharge a user's legal obligations. The Handbook should only be read and used subject to, and in conjunction with, the general disclaimer at page ii.

The Handbook also needs to be read in conjunction with the building legislation of the relevant State or Territory. It is written in generic terms and it is not intended that the content of the Handbook counteract or conflict with the legislative requirements, any references in legal documents, any handbooks issued by the Administration or any directives by the Building Control Authority.

1.1 Background

It is intended that this Handbook will provide a link between the needs of its intended audience and the NCC provisions relating to landslide.

This Handbook aims to support the provisions of the NCC. It is intended that this Handbook be read in conjunction with the relevant Building Code of Australia (BCA) provisions, including the relevant Objectives, Functional Statements, Performance Requirements and Deemed-to-Satisfy Provisions.

The requirements of the NCC relating to landslides represent the minimum acceptable building standards as determined by wide consultation with the industry and community. Whilst the NCC has no specific requirements relating directly to landslides, its structural Performance Requirements are applicable to landslide issues.

The NCC requires that a building or structure, with appropriate degrees of reliability, must:

- remain stable and not collapse;
- prevent progressive collapse;
- minimise local damage and loss of amenity through excessive deformation, vibration or degradation; and
- avoid causing damage to other properties,

by resisting the actions to which it may reasonably be subjected, including ground movement actions caused by landslide or subsidence.

It is not intended that the content of the Handbook be counteractive to legislative requirements or references in legal documents.

This Handbook does not override or replace the NCC, but rather provides additional information to aid the user in the application of the provisions of the NCC relating to landslide. It is recommended that users of the Handbook seek specialist advice in the application of this Handbook to specific projects.

1.2 Scope

This edition of the Handbook is intended to provide an overarching regulatory perspective on the AGS Guidelines and supporting commentary taking into account additional States and Territories requirements. The AGS Guidelines and Commentary include:

- 'A National Landslide Risk Management Framework for Australia' (AGS 2007f),
- 'Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning' (AGS 2007a),
- 'Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning' (AGS 2007b),
- 'Practice Note Guidelines for Landslide Risk Management 2007' (AGS 2007c),
- 'Commentary on Guideline for Landslide Risk Management 2007' (AGS 2007d), and
- 'The Australian Geoguides for Slope Management and Maintenance' (AGS 2007e).

Consideration of building on sites that are prone to landslide hazard should always be made in conjunction with appropriate consideration of other relevant requirements and issues, including those relating to structure, fire safety, town planning, services and other matters.

Users should interpret the guidance given in this Handbook flexibly and use it as a tool to assist in the design of buildings on sites that are prone to landslide hazard.

Terms used in this Handbook are defined in Chapter 2. A discussion on landslide identification including impacts of landslides on buildings is provided in Chapter 3. General landslide risk management is discussed in Chapter 4. Landslide risk assessment for specific site is discussed in Chapter 5. Design and construction are discussed in Chapter 6 and maintenance issues in Chapter 7. Appendix A provides examples of landslide risk assessment and the associated terminology. Finally, a summary of State and Territory advice is provided as Appendix B.

1.3 Limitations

This Handbook is not intended to:

- override or replace any legal rights, responsibilities or requirements; or
- provide comprehensive or detailed guidance on issues relating to building on sites that are prone to landslide hazard. Specific relevant advice (e.g. geotechnical or engineering geological advice) should be sought if such guidance is required;
- provide specific design solutions for a particular building or site;
- replace available published information; or
- prevent risks relating to building on sites that are prone to landslide hazard.

1.4 Other Handbooks by the ABCBC

The ABCBC has produced a range of Handbooks and other educational material relating to topics associated with the NCC. They can be downloaded from the [ABCBC website](#).

2 Definition of Terms

The following definitions are provided for the purposes of this Handbook:

Consequence: The outcome or potential outcome arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage, damage, injury, or loss of life (AGS 2007a).

Development: Any form of construction activity.

Geotechnical practitioner: A professional geotechnical engineer, or engineering geologist with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management (AGS 2007e).

Hazard: A condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time (AGS 2007e).

Landslide: The movement, or the potential movement, of a mass of rock, debris or earth down a slope (AGS 2007e).

Likelihood: Used as a qualitative description of probability or frequency of occurrence (AGS 2007e).

Risk: A measure of the combined effects of probability and severity of an adverse effect to life, health, property or the environment (AGS 2007e).

Stakeholders: Those people and organisations who may affect, be affected by, or perceive themselves to be affected by, a decision or activity.

3 Landslide Identification

A landslide is a type of soil failure characterised by movement of soils, rocks or debris down a slope, which can cause disturbance to the upper part of the slope, the slope itself and the part below it.

Landslides can range from a small boulder falling from a cliff to millions of tonnes of materials rumbling down a slope. They can move very slowly at a rate of centimetres a year or rapidly at a rate of metres per second.

The most common cause of landslides in Australia is water infiltration. This may be caused by natural phenomena such as heavy rain, or by human activities such as removal of vegetation, interference with natural drainage, leaking water mains, changing of natural slopes by construction and mining activities, or building on steep terrain.

There are also other causes, such as the gradual weakening of the soil or rock masses or destabilisation of the slope due to removal of materials from its lower parts. Removal may occur by natural means, such as sea or river erosion or by human activities such as construction of buildings, highways and other engineering activities.

3.1 Identification of Landslide Hazards

It is often difficult to identify a landslide hazard and assess risk. Knowledge of geology, soil mechanics and experience in the study of land failure and control measures is considered essential and therefore a risk assessment of a site should be undertaken by an appropriately qualified and experienced geotechnical practitioner.

Landslide hazards may be potential or existing. The current landform of a site and its surrounds is a prime indicator of landslide activity, particularly when a past landslide has been contained. However, areas that have had landslides occur may not be easily recognised so it is important to check the history of likely areas.

The presence of relatively flat portions of land within a landslide area can be misleading and research should still be undertaken. For steep sites or rock faces, the landslide hazard may be more apparent.

Landslides do not occur only on sloping sites and may exist uphill of the site, beside the site or down slope of the site. The impact can be upon the site, but also outside of it. The distance between a landslide hazard and a specific site may be significant and therefore beyond the ability of the site's owner to remedy. Scenarios with a potential to impact from a significant distance include rock falls, rock slides and mobile earth flows or debris flows. The effects of landslides can be measured at distances down slope up to hundreds of metres, and potentially up to distances that go on for kilometres.

Identification of landslide hazards requires thorough assessment in order to determine the geomorphology of the site, its regional setting and its geological formation. And it is important that assumptions and conclusions reached during the identification process are reported.

Landslide hazard mapping provides guidance and assistance on the potential for landslide activity for site specific geotechnical assessment.

3.2 Visual Case Studies

Landslides are often difficult to photograph. Often, a landslide will involve the downhill movement of many hundreds of tonnes of soil and rock, but this movement may not be dramatic – it may be apparent only as cracking of the ground surface, shearing along the sides of the landslide or bulging at its toe. Not all landslides are rapid, and do not necessarily involve major travel distances.

The figures presented as Figures 1 through to 8 present views of a number of landslides and landslide mechanisms in an attempt to provide some visual understanding.

Figure 1 illustrates the extent of damage following a landslide in the mountainous Thredbo area. A damaged water main caused a two stage landslide of fill that supported the Alpine Way road. Two lodges were destroyed and 18 lives were lost. The reconstruction of the Alpine Way as seen in Figure 2 involved major engineering works including the installation of reinforced gabion retaining walls.

Figure 1 – Thredbo Landslide (30th July 1997) (Photograph courtesy of NSW Police Constable McLay)

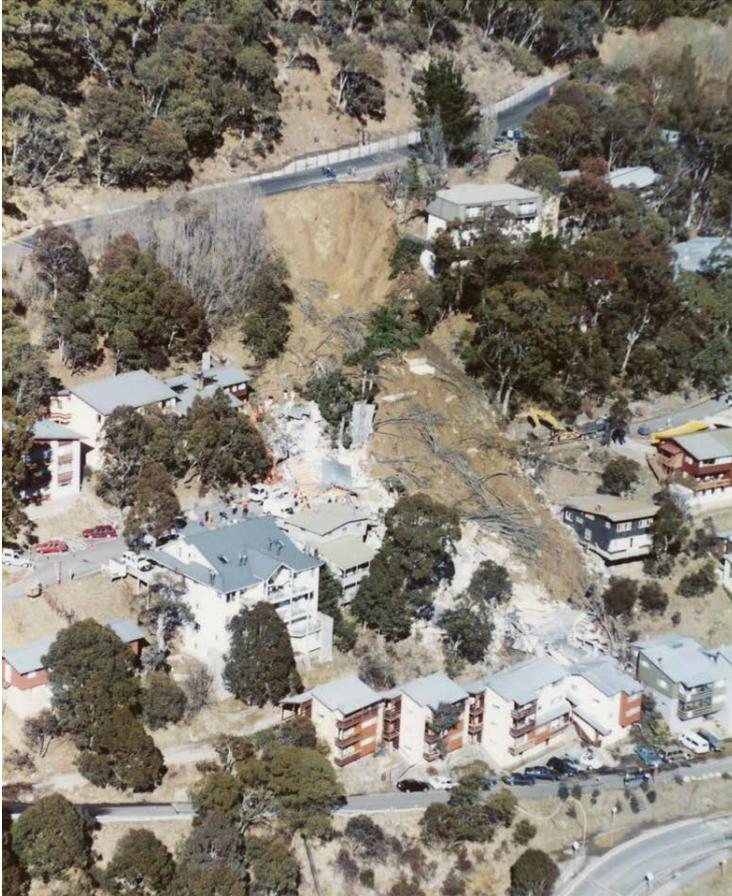


Figure 2 – Reconstruction of Alpine Way, Thredbo (Photograph courtesy of NSW Police Constable McLay)



Figure 3 illustrates a landslide with a large footprint but with a low angle failure. The trigger for the landslide was high water content of the material forming the slope. Elements of the landslide have been recorded as becoming mobile during periods of extended wet weather during the last 10 to 15 years.

Figure 3 – Large scale ancient landslide (Photograph courtesy of Peter Stone (in PolAir2))



Figure 4 illustrates how a very fast moving landslide can move a house off its footings.

Figure 4 - Impact of fast moving landslide (Photograph courtesy of Max Ervin)



Figure 5 shows severe damage to a house which was caused by a landslide.

Figure 5 – House damage following a landslide (Photograph courtesy of Max Ervin)



Figure 6 shows the impact of landslide on a land owner and an impact on an adjoining allotment.

Figure 6 – Landslide impact upon a land owner (Photograph courtesy of Phil Flentje)



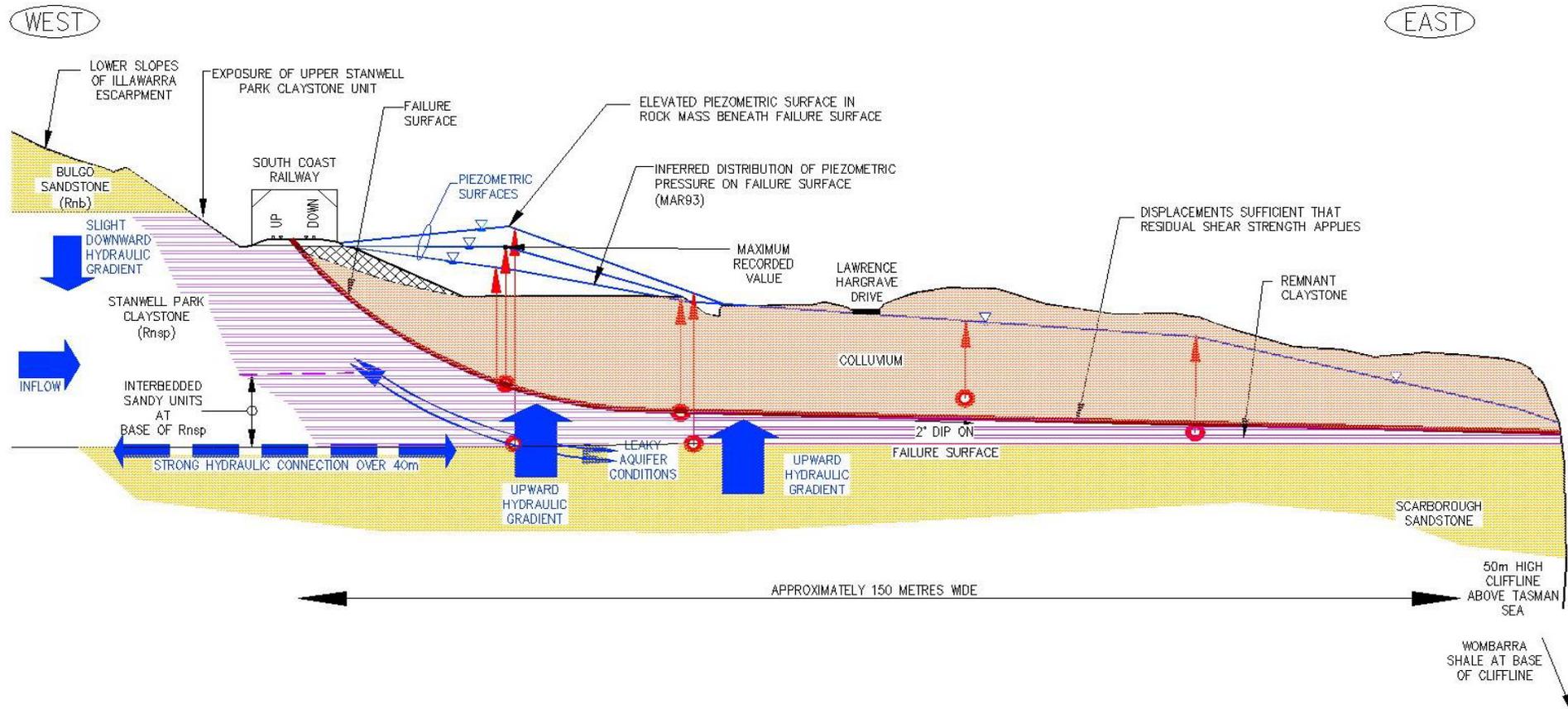
Figure 7 illustrates an area where landslide events have been recognised and selectively treated with engineering works for over a century.

Figure 7 – Geological setting of recurring landslide events (Photograph courtesy of Phil Flentje)



Figure 8 illustrates a generic landslide mechanism on a relatively flat platform area within steep terrain. This type of landslide is described as an earth slide with a 'stick-slip' mode, which is repeated when ground-water levels rise near the railway track. The ocean-side track "rode" upon the landslide whilst the other remained in place. The main cause of instability was high water pressure at the failure surface.

Figure 8 – Earth slide with a stick-slip mode (Source: A. Leventhal (GeoEng 2000))



4 Landslide Risk Management for Land Use and Planning

4.1 General

Landslide problem is treated as a risk management problem involving many stakeholders such as Geoscience Australia (GA), National Disaster Mitigation Program (NDMP), Emergency Management Australia (EMA), Australian Geomechanics Society (AGS), State and Territory Governments (S&T).

The AGS have developed a series of guidelines and supporting commentaries considering landslide risk management. Those relevant to land use and planning include:

- 'A National Landslide Risk Management Framework for Australia' (AGS 2007f),
- 'Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning' (AGS 2007a), and
- 'Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning' (AGS 2007b).

4.2 Risk Management Framework (AGS 2007f)

This document discusses the roles and the interaction between the stakeholders mentioned in 4.1 above. It provides an overall framework for landslide risk management including risk analysis, risk assessment and risk management for the investigation phase and for the design and verification phase.

4.3 Land Use Planning (AGS 2007a & b)

These documents quantify various descriptors used in risk management for 'likelihood' and 'consequence'.

It describes activities required for three types of landslide zoning:

1. 'susceptibility' zoning to determine the spatial distribution of potential landslide.
2. 'hazard' zoning to assess the frequency of rock falls, slides from cuts, fills and retaining walls, small and large landslides.
3. 'risk' zoning to assess the elements at risk includes people and properties that may be affected by potential landslides.

It describes the application of landslide zoning for land use planning.

These activities should be left to geotechnical practitioners.

5 Landslide Risk Management for Building Development

5.1 General

The AGS have developed a series of guidelines and supporting commentaries considering landslide risk management. Those relevant to building development include:

- 'A National Landslide Risk Management Framework for Australia' (AGS 2007f);
- 'Practice Note Guidelines for Landslide Risk Management 2007' (AGS 2007c);
- 'Commentary on Practice Note Guideline for Landslide Risk Management 2007' (AGS 2007d); and
- 'The Australian Geoguides for Slope Management and Maintenance' (AGS 2007e).

5.2 Where and when landslide risk assessment is needed?

Landslide risk assessment should be conducted for:

- any land identified as potentially prone to instability (e.g. as a result of hazard zoning or through identification on planning scheme maps);
- where landslide hazards which impact the site have been identified;
- where a history of landslide activity has been identified;
- where landslide events have been identified or have occurred in a similar geomorphologic setting; or
- where the site, development of the site or construction upon the site may produce landslide hazards which have the ability to impact property or persons outside the site's footprint.

A landslide risk assessment procedure should be applied:

- when planning or designing a proposed development;
- to reduce risk to existing developments; and
- to landslide stabilisation works.

5.3 Guidance for site investigation

Tables 1a to 1d provides guidance for site investigation for construction associated with slopes and should be read in conjunction with the following notes:

- Each situation should be assessed on its merits to decide whether or not the recommended investigation procedures are necessary or if peculiar conditions require further detailed examination.

- While Tables 1a to d provides an indication of the requirements for a site investigation under certain general conditions, more precise information on how the above requirements can be met is given in the original document.
- For slopes on which there are unstable boulders, the services of an experienced geotechnical engineer or engineering geologist is strongly recommended.
- The risk category should be assessed for both present use and potential development of the area.
- A slope classification should be based upon slope height or slope angle, whichever gives the highest risk category.

5.3.1 Requirements for specialist advice

Where Tables 1a to 1d references the need for specialist advice, the following descriptions apply:

- **Specialist Advice A** - Service of an experienced geotechnical engineer or engineering geologist is advisable but may be ‘not necessary’;
- **Specialist Advice B** - Service of an experienced geotechnical engineer or engineering geologist is advisable and may be necessary depend on location relative to the proposed development; and
- **Specialist Advice C** - Service of an experienced geotechnical engineer or engineering geologist is essential.

Tables 1a to 1d –Guidance on site investigation (Adapted from Geotechnical Control Office (2000))

Table 1a – Risk category description based on loss of life and economic loss

<i>Risk category</i>	<i>Negligible</i>	<i>Low</i>	<i>High</i>
Loss of life	None expected (no occupied premises)	Few (only small occupied premises threatened)	More than a few
Economic loss - structural damage	Minimal structural damage.	Appreciable structural damage.	Excessive structural damage

Table 1b – Guidance for site investigation based on ‘Negligible Risk’

Formed Slope Classification (Based on feature, slope height and slope angle)	Angle of Natural Hill Side 0° to 20°	Angle of Natural Hill Side 20° to 40°	Angle of Natural Hill Side Greater than 40°
Soil Fill – < 7.5m slope height, < 50° slope angle Soil Cut – < 5m slope height, < 30° slope angle Rock – < 7.5m slope height Retaining Wall – < 3m slope height	Assessment of surrounding geological and topographical areas to indicate stability. Visual examination of soil and rock formations on the site where it is to be used for embankment	As for 0° to 20°. More detailed geology and topography survey. For steeper slopes information on soil and rock joint strength parameters. Survey of hydrological features affecting the site.	As for 20° to 40°. Area outside confines of site to be examined for instability of soil, rock and boulders above the site.
Specialist Advice	A	B	B

Table 1c – Guidance for site investigation for ‘Low Risk’

Formed Slope Classification (Based on feature, slope height and slope angle)	Angle of Natural Hill Side 0° to 20°	Angle of Natural Hill Side 20° to 40°	Angle of Natural Hill Side Greater than 40°
Soil Fill – < 15m slope height, < 60° slope angle Soil Cut – < 10m slope height, < 30° slope angle Rock – > 7.5m slope height Retaining Wall – > 6m slope height	Carry out geological and topographical survey of site and surrounding area. Check soil and rock joint strength parameters for foundation and site cuts. For embankments steeper than 1 in 3, carry out tests to determine re-compacted strength of fill. For site cuts, obtain information on ground water level.	As for 0° to 20°. Carry out survey of hydrological features affecting the site.	As for 20° to 40°. Extend outside limits of site to permit analyses of slopes above and below the site.
Specialist Advice	B	B	C

Table 1d –Guidance for site investigation for ‘High Risk’

Formed Slope Classification (Based on feature, slope height and slope angle)	Angle of Natural Hill Side 0° to 20°	Angle of Natural Hill Side 20° to 40°	Angle of Natural Hill Side Greater than 40°
Soil Fill – > 15m slope height, > 60° slope angle Soil Cut – > 10m slope height, > 30° slope angle Rock – > 7.5m slope height Retaining Wall – < 6m slope height	Carry out geological and topographic survey of site and the surrounding area. Check soil, and rock joint strength parameters for foundation and site cuts. For embankment steeper than 1 in 3, carry out tests to determine re-compacted strength of fill. For site cuts, obtain information on ground water level.	As for 0° to 20°. Survey of hydrological features affecting the site. Extend investigation locally outside limits of site to permit analyses of slopes above and below the site.	As for 20° to 40°. Extend investigation to include outside limits of site to permit analyses of slopes above and below site.
Specialist Advice	B	C	C

5.4 Classification of Buildings and Structures

Risk assessment of a site should take into account the ‘Importance Level’ of the building proposed for the site. Buildings are classified in accordance with an ‘Importance Level’ in the National Construction Code, in Section B of NCC Volume One as described in Table 2. Importance levels must be assigned on a case-by-case basis.

The placing of buildings of Importance Level 3 or 4 on sites that are prone to landslide hazards requires very careful consideration of the risk involved and should include a risk assessment of the site.

Alert:

NCC Volume One references ‘Importance Levels’ for buildings and structures in **Table B1.2a**, whilst NCC Volume Two references ‘Importance Levels’ for buildings and structures in **Table 3.11.3a**.

Table 2 – Levels of importance assigned to building structures (Source: NCC Volume One and The Guide to NCC Volume One 2015 (Table B1.2a) and NCC Volume Two (Table 3.11.3a))

Importance Level	Building type	Examples of building types (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
L1	Buildings or structures generally presenting a low degree of hazard to life and other property in case of failure	Farm buildings Isolated minor storage facilities Minor temporary facilities Isolated minor Class 10a buildings and Class 10b structures
L2	Buildings or structures not included by L1, L3 or L4	Low-rise residential construction Buildings and facilities below the limits set for L3 Class 1 buildings Class 10a buildings and Class 10b structures associated with a Class 1 building
L3	Buildings or structures that are designed to contain a large number of people	Buildings and facilities where more than 300 people can congregate in one area Buildings and facilities with primary school, secondary school or day care facilities with capacity greater than 250 Buildings and facilities with a capacity greater than 500 for colleges or adult educational facilities Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities Jails and detention facilities Any occupancy with an occupant load greater than 5000 Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance L4 Buildings and facilities not included in L4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries
L4	Buildings or structures that are essential to post-disaster recovery, or associated with hazardous facilities	Buildings and facilities designated as essential facilities Buildings and facilities with special post disaster functions Medical emergency or surgery facilities Emergency service facilities: fire, rescue, police station and emergency vehicle garages Utilities required as backup for buildings and

Importance Level	Building type	Examples of building types (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
		facilities of L4 Designated emergency shelters Designated emergency centres and ancillary facilities Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond property boundaries

5.5 Guide for landslide risk management

The purpose of landslide risk management is to establish that the land, on which the development is proposed, is capable of accommodating the development without posing unacceptable risks to the users, the surrounding area and associated infrastructure and that all stakeholders are aware of the risks involved.

The landslide risk management process can be divided into two phases:

- investigation phase; and
- design and verification phase.

The Practice Note Guidelines for Landslide Risk Management (AGS 2007c) provides guidelines for regulators and practitioners including a framework for landslide risk management. Appendix A contains this framework and also provides terminology and examples of landslide risk assessment from this Practice Note Guideline.

Appendix B provides a summary of advice from State and Territory authorities on how landslide risks should be managed.

5.5.1 Stakeholder roles

The roles of the various stakeholders in landslide risk management are as follows:

Property owner/occupier

The property owner's role may depend on contractual arrangements for development of the property. Generally, the owner should be responsible for engaging the necessary design and construction practitioners, implementing management plans for on-going maintenance of the site, and for monitoring the performance of the structure.

In instances where the property owner is not the occupier, the occupier may be the most appropriate stakeholder to undertake the task of monitoring the performance of the structure.

Geotechnical practitioner

The geotechnical practitioner is the professional with specialist knowledge on landslide risk management. Their role includes:

- identifying potential landslide hazards and conducting an assessment and evaluation of associated risks;
- verifying that geotechnical works are incorporated within the engineered design;
- verifying that the sub-surface conditions exposed during construction are consistent with those included in the risk assessment; and
- providing evidence of conformance of geotechnical works within the construction of the structure.

Structural/civil engineer

The structural/civil engineer's role is to incorporate the geotechnical practitioner's requirements within the design of the structure and to verify that works to manage the landslide risk have been built in accordance with the design.

Constructor/builder

The constructor/builder's role is to plan for the construction, to build the structure in accordance with design documentation and to facilitate assessment of compliance with civil, structural and geotechnical requirements.

Building certifier

The building certifier's role is to certify that the design of the structure conforms to all relevant regulations and that construction conforms to the approved design.

6 Design and Construction

6.1 Principle

The design and construction of a development should ensure that the likelihood of landslide has been managed appropriately and the resulting levels of risk to life and property are acceptable.

6.2 Application

The principle should be applied to all forms of development, including:

- construction of buildings or structures;
- clearing of vegetation;
- slope stabilisation and rehabilitation;
- surface and buried drainage pipelines;
- stormwater, waste disposal and overland flow paths;
- on-site sewage treatment and disposal; and
- on-site works for driveways.

6.3 Risk Management

There are various ways to address and identified the level of risk, including:

- accepting the risk, which is normally possible when the risk is assessed as 'low' or 'moderate' (see AGS 2007c);
- avoiding the risk, which requires either abandonment or modification of the proposed development;
- reducing the likelihood of adverse impacts, which generally involves stabilisation measures to control the contributing factors;
- reducing the consequence of adverse impacts, which generally involves mitigation or relocation to a more favourable position;
- installing monitoring and warning systems, which are most beneficial when a commitment to continuous monitoring is viable; and
- postponing the project, which is appropriate when insufficient information is available to undertake the necessary assessment.

Risk management plans should be developed for each viable option so that the consequences and effectiveness of the various options can be evaluated.

6.4 Design and Construction Options

To ensure that the specific characteristics of the landslide hazard are addressed, the engineered design of the development should be implemented in consultation with the geotechnical practitioner.

There are many typical engineering procedures that can be evaluated by the design and construction team in order to determine the most appropriate means of achieving the accepted level of risk, including:

- removing the landslide hazard through bulk earthworks;
- constructing barriers to deflect landslide debris;
- reducing the slope angle of the landslide hazard;
- improving the strength of the material forming the landslide hazard;
- constructing a toe buttress or retaining wall;
- lowering the water table within the landslide hazard; and
- improving surface and / or sub-surface drainage at the head of the landslide hazard.

During the design and construction process there should be several stages of assessment and verification of compliance with mandatory design requirements or with approved documentation, including:

- at the completion of the structural design. The geotechnical practitioner and the structural engineer should verify that geotechnical constraints have been adequately addressed within the structural design; and
- during the conduct of foundation stabilisation measures and / or construction of footing systems. The geotechnical practitioner and the structural engineer should verify that actual sub-surface conditions were consistent with anticipated conditions, or that modifications were made to accommodate the conditions encountered and the risk profile.

6.5 Guidance to Good Engineering Practice

Appendix G of AGS 2007c provides examples of good practice for hill side construction including site clearing, earthworks, retaining walls, footings, drainage, erosion control etc.

7 Maintenance

7.1 Principles

Developments on sites prone to landslide hazard should be inspected, monitored and maintained in order to retain or reduce the risk of landslides to an acceptable level.

7.2 Application

Owners or occupiers of sites that have been identified as having a landslide hazard should regularly inspect, monitor and maintain the site and all improvements.

For certain developments, the required performance of buildings, structures or ancillary works may rely on their ongoing maintenance so it is essential that these be maintained as required.

When there is evidence of distress, advice should be sought. Such evidence could include:

- significant movement;
- cracking of the ground surface;
- collapse or displacement of retaining walls or cuts;
- presence of mud runs or earth flows;
- downhill movement of the structure;
- distortion of the structure;
- distortion of doorways;
- cracking of walls or partitions;
- cracking of pathways, driveways or pipes; and
- seepage, unusual groundwater presence or groundwater movement.

7.3 Inspecting and Monitoring

On sites where no specific requirements are in place, basic actions include -

- check that all drains are effective;
- check that surface protection and slope support are effective;
- check conditions of retaining structures;
- ground water level should be monitored for changes;
- when movement is suspected, the ground displacement should be monitored; and

- when seepage is observed, causes for it should be determined.

7.4 Maintenance

On sites where no specific requirements are in place, some basic maintenance procedures include:

- regularly clean-out surface and sub-surface drainage systems; and
- repair broken joints and leaks in pipes as soon as damage becomes evident.

8 References

Australian Geomechanics Society see AGS

AGS 2007a, 'Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning', *Journal and News of the Australian Geomechanics Society*, vol. 42, no. 1, March 2007. [Downloadable from [AGS website](#)]

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Appendix A

Landslide Risk Assessment

Terminology - Examples of Qualitative Terminology for Use in Assessing Risk to Property

Table A.1 – Qualitative Measures of Likelihood (Extracted from AGS 2007c)

<i>Indicative value of Approximate Annual Probability</i>	<i>Description</i>	<i>Descriptor</i>	<i>Level</i>
10 ⁻¹	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 ⁻²	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10 ⁻³	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10 ⁻⁴	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10 ⁻⁵	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10 ⁻⁶	The event is almost inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

Table A.2 – Qualitative Measures of Consequences to Property (Extracted from AGS 2007c)

<i>Description</i>	<i>Descriptor</i>	<i>Level</i>
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
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
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
Limited damage to part of structure and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
Little damage.	INSIGNIFICANT	5

Note: The table should be used from left to right; use Description to assign Descriptor, not vice versa.

Table A.3 – Qualitative Risk Analysis Matrix – Level of Risk to Property (Extracted from AGS 2007c)

<i>Likelihood</i>	<i>Consequences to property</i>				
	<i>1: CATASTROPHIC</i>	<i>2: MAJOR</i>	<i>3: MEDIUM</i>	<i>4: MINOR</i>	<i>5: INSIGNIFICANT</i>
A - ALMOST CERTAIN	VH	VH	VH	H	M or L
B - LIKELY	VH	VH	H	M	L
C - POSSIBLE	VH	H	M	M	VL
D - UNLIKELY	H	M	L	L	VL
E - RARE	M	L	L	VL	VL
F - BARELY CREDIBLE	L	VL	VL	VL	VL

Note: See Table A.4 for key and risk level implications.

Table A.4 – Risk Level Implications (Source: AGS 2007c)

<i>Risk level</i>		<i>Example implications</i> *
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; maybe too expensive and unpractical. 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. Treatment options to reduce to Low risk should be implemented as soon as possible.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator’s approval) but requires investigation and planning 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: 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.

Landslide Risk Assessment Process

Figure A.1 – Example 1 - Qualitative landslide risk assessment for property (Source: Walker (2002))

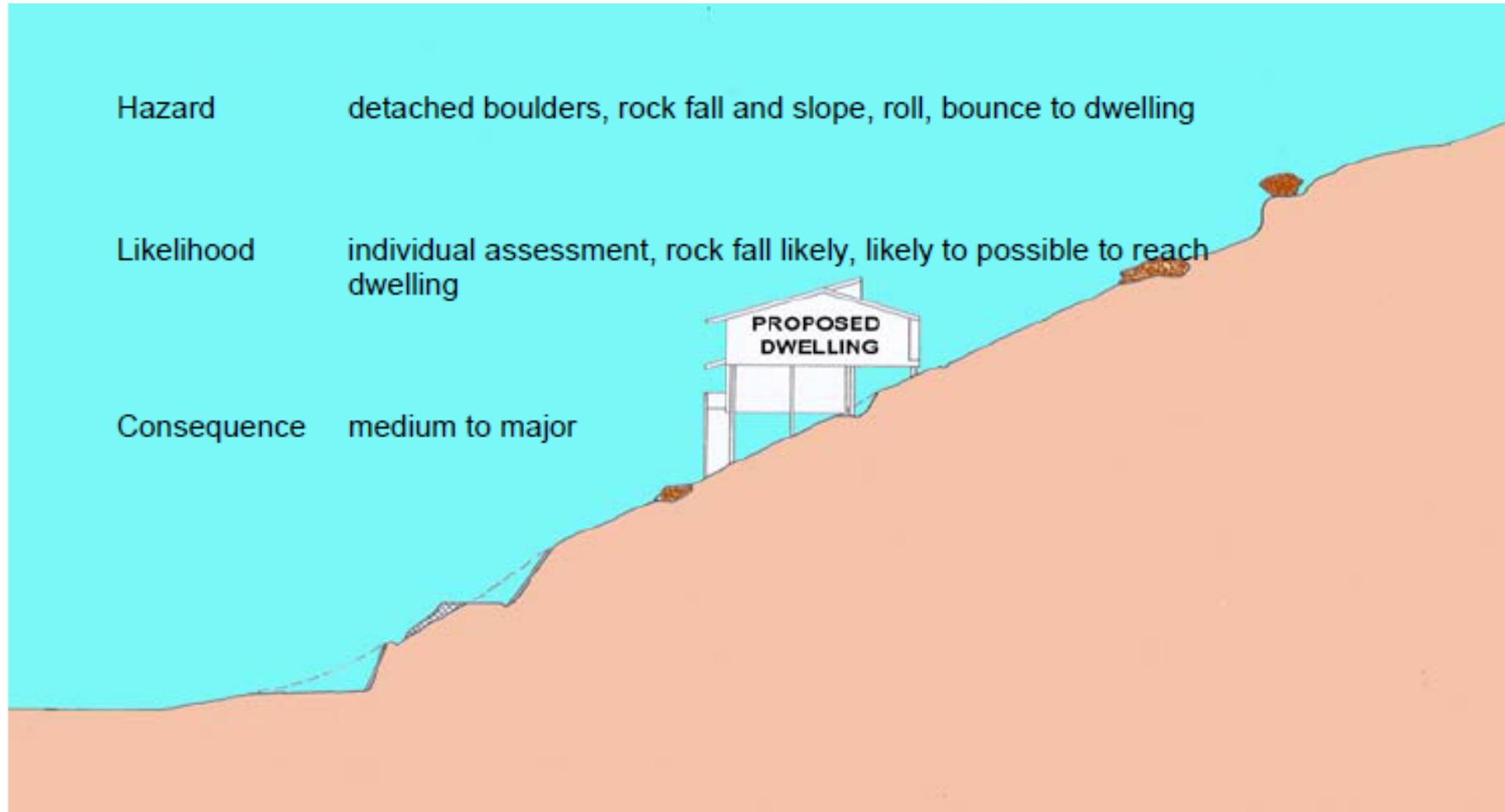


Figure A.2 – Example 2 - Qualitative landslide risk assessment for property (Source: Walker (2002))

Hazard	earth slide from colluvial slope above
Initiation	excessive ground water rise or and / or infiltration
Consequence	impact upon dwelling – minor
Likelihood	unlikely – stick – slip failure without mud run, might occur

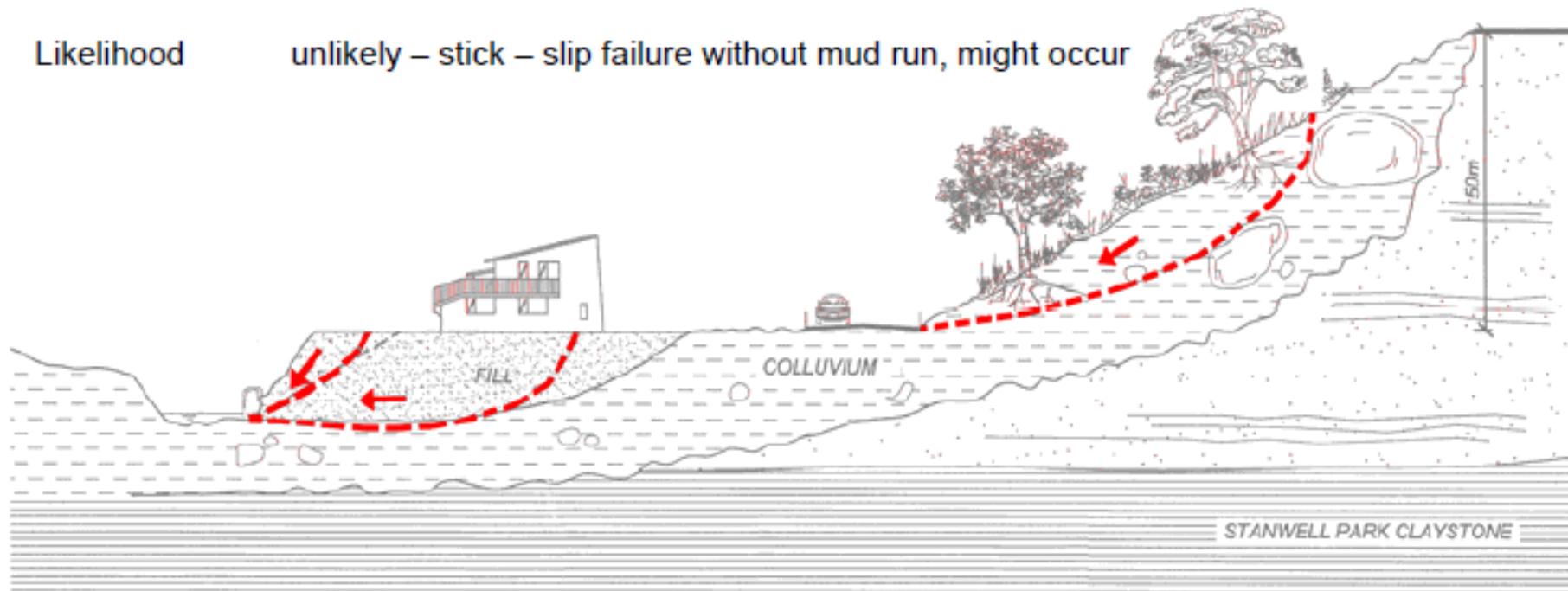
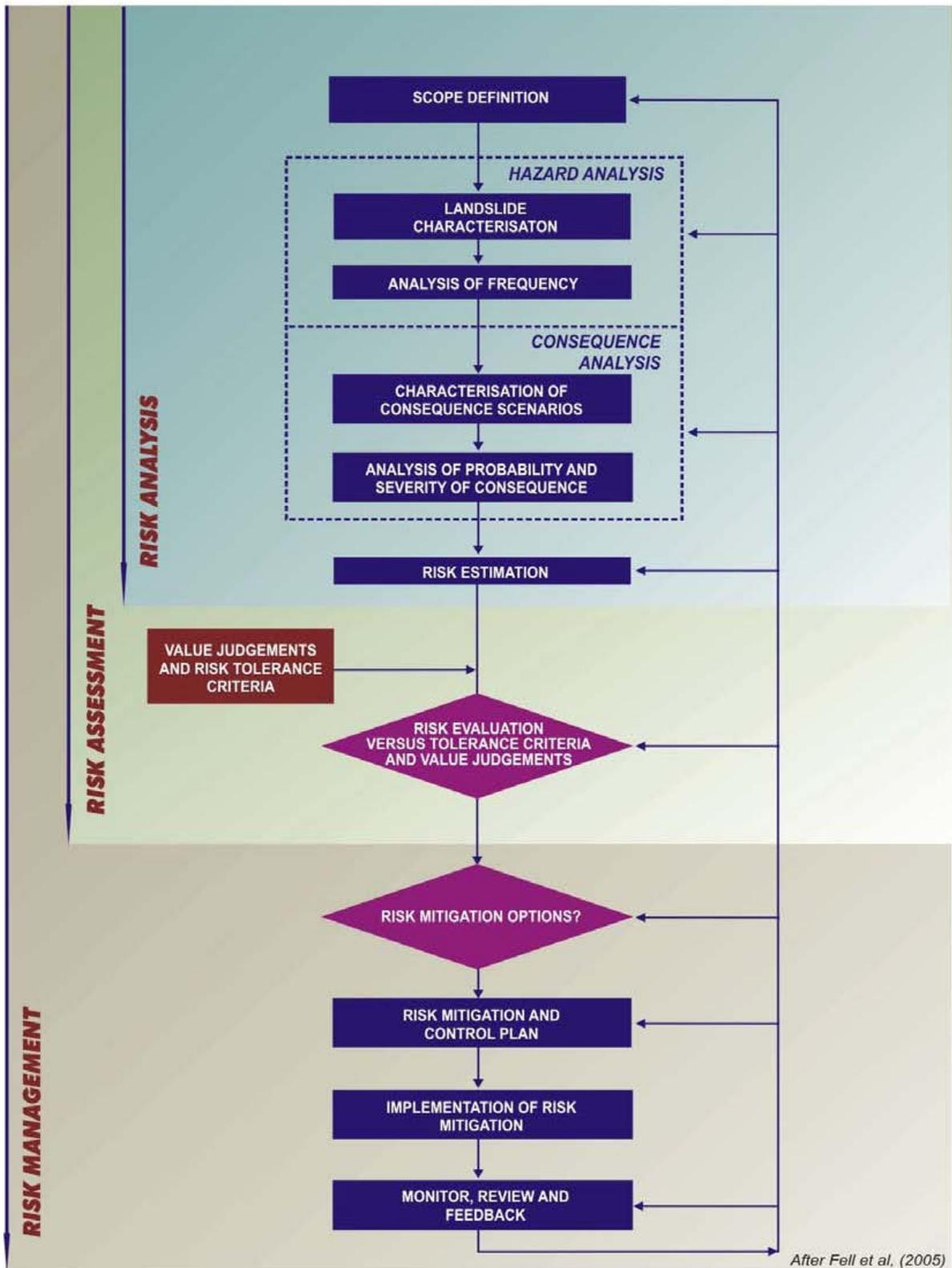


Figure A.3 is a flow chart demonstrating the process involved in landslide risk assessment process (AGS 2007c).

Figure A.3 –Landslide risk assessment & management (Source: AGS 2007c)



Identification of Potential Hazards

This includes hazards that might impact upon the development or equally that might be impacted by the development. This means that potential hazards can exist uphill of the site of the proposed development, upon or beneath the site, laterally beside the site or downhill of the site. Examples of identification of such hazards are provided within Figure A.4 and Figure A.5.

Figure A.4 – Examples of good hillside practice (AGS 2007c)

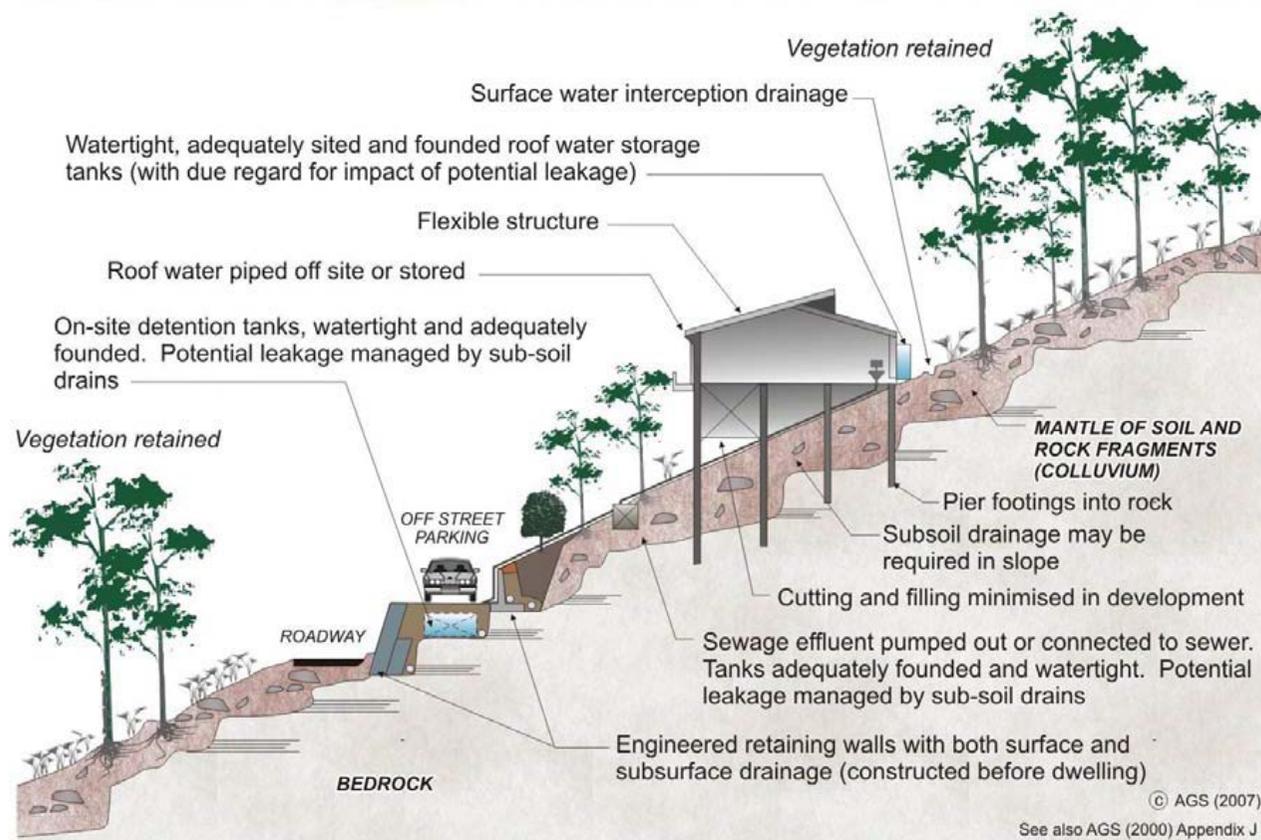
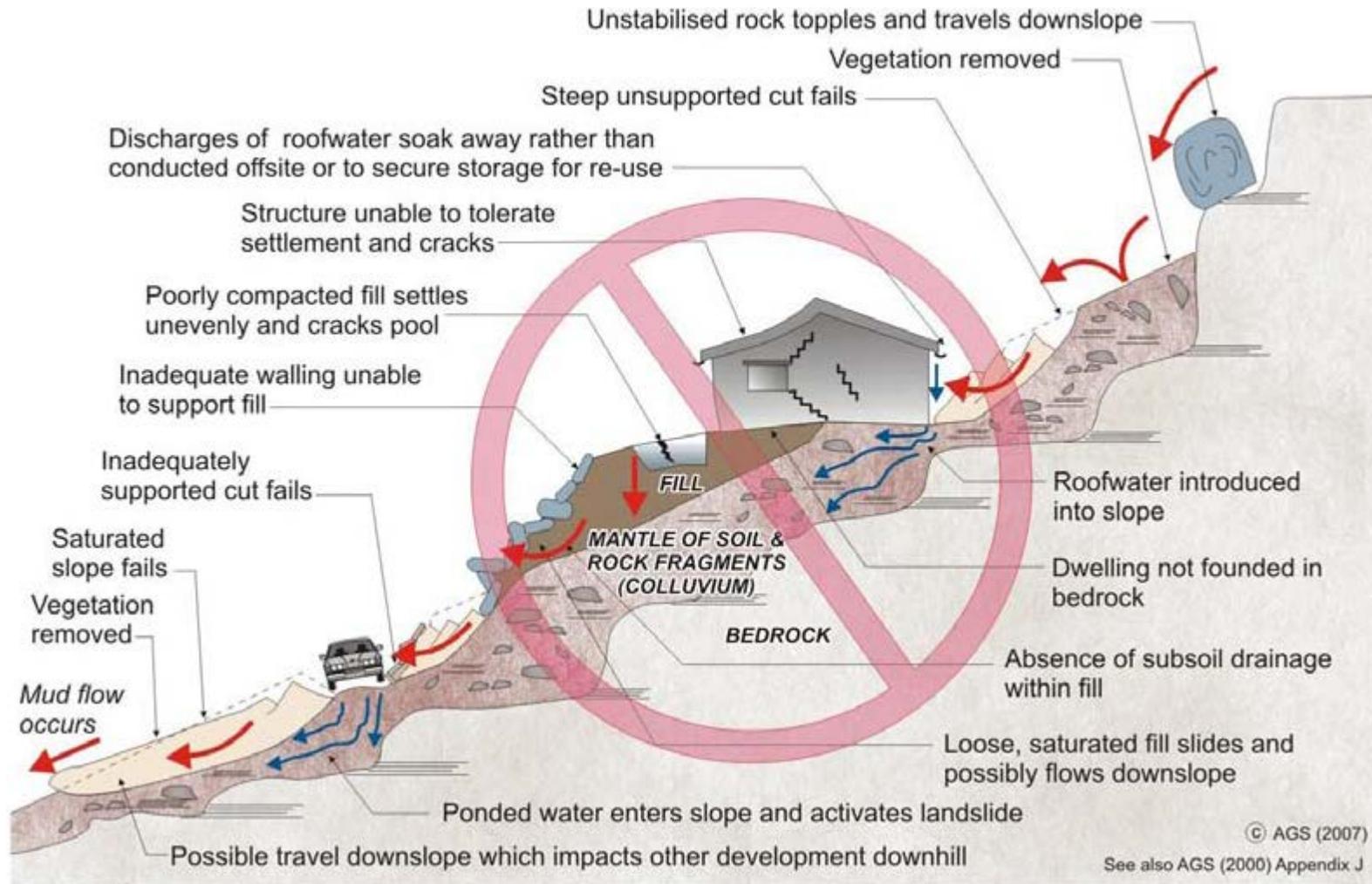


Figure A.5 – Examples of poor hillside practice (AGS 2007c)



Reporting by the Geotechnical Practitioner

The reporting of the landslide risk assessment should be clear and precise. It should be made understandable to other stakeholders, who may not be familiar the landslide risk assessment and management process.

Documentation to accompany a development application should at least contain the following:

- comprehensive site mapping of geomorphic features observed at the site and its environs;
- advising whether sub-surface investigation was required, and if so, providing the results of that investigation – for example, test hole logs, material test results, piezometric pressures, etc.;
- presentation of an inferred "type-section" representative of the expected sub-surface conditions at the site; at a scale which clearly presents the information;
- presentation on the type-section of the geotechnical hazards and their mechanism;
- reporting the results of the frequency and consequence analyses;
- reporting the risk estimation or calculation;
- reporting the risk evaluation for property and life, and advise the basis of the evaluation;
- advising whether the assessed risks meet acceptable risk criteria; and
- recommending the geotechnical works that are to be incorporated into the civil and structural design and into the site management plan to remove/reduce risk to acceptable levels where reasonable and practical.

References

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Appendix B

Summary of State and Territory Advice

Introduction

This appendix presents a review of current state and territory advice for handling construction on sloping sites.

Regulatory control is directed toward preventing exposure to landslides. Local governments require more thorough site investigations on questionable sites. Planning regulations prohibit building or subdividing on known landslide areas. Builders should check with relevant authorities for any records of the area's history of landslides or instability.

In steep areas, tell-tale signs of ground movement such as tilting trees, water seepage or ground breakage should be investigated.

AUSTRALIAN CAPITAL TERRITORY

In the ACT building sites are classified in accordance with AS 2870. This classification is undertaken by the developer and is part of the lease condition prior to the sale of the land. The site report will be undertaken by a geo-technical consultant and part of that report may address issues such as ground water and associated site problems. The original estate civil design works will also address issues such as land slippage in preparing a design on hillside blocks for residential development.

NEW SOUTH WALES

The NSW Department of Planning and Environment provides the following advice to all Councils in NSW on issues to be considered when assessing development applications involving hillside land.

Section 79C of the *Environment Planning and Assessment Act 1979* (EP&A Act) requires a consent authority to take into consideration matters of relevance including:

- the suitability of the site for development; and
- the public interest.

The consent authority is required to assess the suitability of the site and the impact of the conditions of the site on the proposed development and vice versa. This would include hazards from landslide and subsidence.

For alpine areas, any relevant State Environmental Planning Policy should be complied with, including any referenced geotechnical policies. Referenced documents and information on development in alpine areas is available from the Department of Planning and Environment's website.

At the time of handbook publication, the *State Environmental Planning Policy (Kosciuszko National Park – Alpine Resorts) 2007* required the consent authority to take into consideration the Geotechnical Policy—Kosciuszko Alpine Resorts (2003, Department of Infrastructure, Planning and Natural Resources) for all Development Applications on lands to which this SEPP applies.

The National Parks and Wildlife Service (NPWS) is a determining authority for activities under Part 5 of the EP&A Act and responsible for leasing matters within the NSW ski resorts. Consideration of geotechnical risk forms part of the Part 5 activity assessment and new lease assessment. The Kosciuszko National Park Geotechnical Policy 2011 sets out requirements for a geotechnical report and structural documents

NORTHERN TERRITORY

Requirements

No clear statutory requirement, although general practice is where abnormal slope is encountered (usually cut or fill) the landowner is requested to make the land stable by providing either a certification signed by a soils engineer stating that the slope is considered.

QUEENSLAND

In terms of planning requirements, the State Planning Policy outlines requirements for local planning instruments to consider natural hazards, including landslide, based on a fit for purpose natural hazard study. It requires local governments to identify natural hazard areas and address the hazard by:

- including provisions that seek to achieve an acceptable or tolerable level of risk, based on a fit for purpose risk assessment consistent with AS/NZS ISO 31000:2009 Risk Management, and
- including provisions that require development to:
 - avoid natural hazard areas or mitigate the risks of the natural hazard to an acceptable or tolerable level, and
 - support, and not unduly burden, disaster management response or recovery capacity and capabilities, and

- directly, indirectly and cumulatively avoid an increase in the severity of the natural hazard and the potential for damage on the site or to other properties, and
- maintain or enhance natural processes and the protective function of landforms and vegetation that can mitigate risks associated with the natural hazard, and
- facilitating the location and design of community infrastructure to maintain the required level of functionality during and immediately after a natural hazard event.

The *State Planning Policy (SPP) - state interest guideline - Natural hazards, risk and resilience* further defines natural hazards as a specific matter of state interest in land use planning and development. Part D provides a model development assessment code applicable to the following aspects of development where a landslide hazard overlay area has been identified under a local government planning instrument:

- Material change of use and associated reconfiguration of a lot that involves:
 - Population increases (e.g. residential development, shopping centres, tourist, and facilities).
 - Institutional uses where evacuating people may be particularly difficult (e.g. hospitals, education establishments, child care, aged care).
 - The manufacture or storage of hazardous materials in bulk.
- Building or other work on potentially unstable slopes that involves earthworks exceeding 50 cubic meters (other than the placement of topsoil), vegetation clearing or redirection of existing flow of surface or groundwater.

Local governments are able to incorporate the model landslide code into their planning schemes. The *State Planning Policy – state interest technical manual – natural hazards, risk and resilience* outlines two approaches for local governments to assess natural hazards: a comprehensive approach that develops a local area map using detailed local information or a basic approach, using a 15% slope to trigger site based assessments. A separate guideline for considering natural hazards, risk and resilience when designating land for community infrastructure is also available.

A number of local governments have already incorporated specific requirements for hillside developments into their planning schemes, including Townsville City Council, City of the Gold Coast, Lockyer Valley Regional Council, Sunshine Coast Regional Council, and Cairns Regional Council. Typically these provisions address issues such as the slope of the land, soil types, surface and subsurface water control, the extent of impervious surfaces, retaining walls and vegetation control.

In terms of building requirements, the *Building Act 1975* requires that building work be constructed in accordance with the relevant building assessment provisions, including the NCC, the Queensland Development Code, and referenced Australian Standards. Building certifiers are responsible for assessing whether proposed building work complies with these provisions.

SOUTH AUSTRALIA

Council development plans under the Development Act 1993 are expected to exclude development from areas that are vulnerable to, or cannot adequately be prevented from, the risk of natural hazards, including landslide. In particular, sensitive community facilities and key infrastructure should be located to avoid areas of high natural hazards. This provision is of course dependent on the extent to which the local council can reasonably be expected to be aware of the existence of these natural hazard areas within their boundaries.

The Building Rules under the Development Act 1993 do not specifically refer to landslide areas but the assessing building surveyor will normally require a geotechnical report for the site so that the suitability of any footings or retaining structures for a proposed development can be assessed. The report, by a geotechnical engineer or geologist, will usually identify any particular geological features of the site that are significant and may require special attention.

TASMANIA

Note: in Tasmania the term “landslip” is used instead of “landslide”.

Under current Tasmanian legislation, geological assessment for determining proclaimed landslip areas is undertaken by Mineral Resources Tasmania (Department of State Growth). Land may then be declared landslip areas A or B under the *Mineral Resources Development Act 1995*. However, only very small areas of the State that are landslip-prone have been proclaimed under this regulatory system.

Part 10 of the *Building Act 2000*, Restrictions on Buildings, has provisions for building work in A or B areas. Generally, new building work is not permitted in a landslip A area unless small in size and it then requires ministerial approval. New work in a B area is permitted subject to strict conditions. Relevant sections of the Act:

- Section 148 – references provisions of the *Mineral Resources Development Act 1995* that declares Landslip areas A or B;
- Section 150 – Effect of order in A landslip area;
- Section 151 – Effect of order in B landslip area;

- Section 152 – Activities prohibited in landslip areas;
- Section 154 – Compensation not payable for certain damage to buildings erected in known landslip areas;

Part 2, Division 1 of the *Building Regulations 2014* regulates building work in landslip B areas:

- Regulation 12 – Effect of order in B landslip area; and
- Regulation 13 – Activities prohibited in landslip area.

New landslip regulatory framework (details current at March 2015)

A new regulatory structure for building work in landslip areas is being developed for inclusion in the *Building Regulations 2014*. Main features are expected to include the following:

- Referencing new landslip hazard banding (mapping) of all susceptible landslip-prone areas of the State;
- Defining what is building work in a landslip-prone area and what work or activities in those areas are exempt from a permit;
- Classifying and reporting of landslip hazards by experts as part of a risk assessment;
- Prescribing qualifications of persons classifying and reporting on landslip hazards;
- Referencing construction manuals for design and building in landslip hazard areas;
- Restrictions on activities that may aggravate existing risks in landslip-prone areas.

The framework will incorporate the current requirements for building in declared A or B areas. It is expected that the new regulatory system will commence in late 2015.

VICTORIA

In terms of planning requirements, the State Planning Policy Framework in the Victoria Planning Provisions and all planning schemes outlines requirements relating to the consideration of erosion and landslip, with the overarching objective to protect areas prone to erosion, landslip or other land degradation process.

The state policy requires local government to:

- identify areas subject to erosion or instability in planning schemes and when considering the use and development of land
- prevent inappropriate development in unstable areas or areas prone to erosion

- promote vegetation retention, planting and rehabilitation in areas prone to erosion and land stability.

An 'Erosion Management Overlay' can be applied in local planning schemes to implement State and local government policy. The overlay triggers the requirement for a planning permit for particular types of buildings and works, including vegetation removal.

Currently, planning scheme mapping for landslide hazard is undertaken by local government, with support from relevant technical experts.

In regard to building requirements, the Building Regulations 2006 adopt the National Construction Code Series. This code requires that a building or structure must perform adequately - and avoid causing damage to other properties - from ground movement caused by landslip.

WESTERN AUSTRALIA

The Building Act 2011 and the Building Regulations 2012 provides that in general a person must not do building work unless a building permit is in place. The application for a building permit requires a registered building surveyor to sign and issue a certificate of design compliance that contains a statement of the building surveyor to the effect that if the building or incidental structure that is the subject of the application is completed in accordance with the plans and specifications that are specified in the certificate, the building or incidental structure will comply with the requirements of the NCC.

The NCC Performance Requirements require ground movement caused by landslip to be considered as an action that must be resisted by a building or structure during construction and use. It is therefore the responsibility of the registered building surveyor to ensure landslip has been considered and the relevant building or structure has been designed to resist the ground movement caused by landslip.

When determining compliance with the NCC, a building surveyor may rely upon geotechnical investigation of the site and certification of the structural system by a competent person, usually an engineer. The engineer should consider landslide/landslip when assessing the site and the building structure. Ultimately the registered building surveyor would have the responsibility of ensuring that any engineering certification for sloping sites has considered landslide/landslip and is carried out by a competent person.

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