Taking a risk-based approach for landslide planning: An outline of the New Zealand landslide guidelines

Wendy Saunders, GNS Science, Lower Hutt, New Zealand
Phil Glassey, GNS Science, Dunedin, New Zealand.

In December 2007, GNS Science released the publication 'Guidelines for assessing planning policy and consent requirements for landslide prone land' (Saunders & Glassey, 2007). Primarily for land use planners, the guidelines provide non-prescriptive guidance on how the landslide hazard can be incorporated into risk-based planning policy and consent requirements. Use of the guidelines is not a regulatory requirement, but is recommended as good, evidence-based practice.

The guidelines propose a risk-based approach to land use planning and consenting, based on the Australian/New Zealand Risk Management Standard AS/NZS 4360:2004. This approach considers landslide recurrence interval, and a Building Importance Category of the building proposed for a site. This approach does not guarantee that a building will not suffer damage from a landslide, but it does establish if the risk of damage is sufficiently low to be generally accepted.

This paper is based on four planning principles:
1) gather accurate landslide hazard information;
2) plan to avoid landslide hazards before development and subdivision occurs;
3) take a risk-based approach in areas already developed or subdivided; and
4) communicate the risk of landslides in built-up areas.

This paper provides an overview of this risk management process presented in the guidelines, and how it can be utilised by land use planners, based on the above four overarching planning principles.

The landslide risk management process

Where a level of landslide risk has been identified, there are a number of options available to manage that risk, including:

- **ignore the risk** - generally not considered as an appropriate option;
- **mitigate the risk –** undertake engineering works to reduce the likelihood of failure, and/or the consequences of failure;
- **accept the risk –** if the risk is accepted, emergency plans should be made to manage the consequences of an event and/or any residual risk;
- **avoid the risk –** avoid putting life and property at risk by not placing either in the risk situation; and
- **transfer the risk –** insure against any risk, however the intrinsic value of life and treasures can not be compensated by insuring against the risk. This is not generally an option where a landslide could result in loss of life.

Natural processes, as well as human activities, affect the stability of slopes and formation of landslides. Both natural processes and the effects of development on slope instability must be understood when assessing landslide risk. It is critical for a planner to appreciate these issues early in the planning process to enable them to decide whether the risk posed by the natural hazard is acceptable, treatable, or unacceptable, and therefore whether a development should proceed as planned. Mitigation strategies can often be designed to reduce risk from landslides but in some cases this might not be possible. The risk-based planning approach, adapted from the AS/NZS Risk Management Standard 4360:2004 (summarised in Figure 1), involves risk analysis, risk assessment and risk treatment, and is discussed in the following sections.

Past planning and development decisions have not always taken this risk-based approach. The risk-based approach recognises that a different planning approach is needed for an area that has not been developed (i.e. a greenfield site) and for an area that has been developed or subdivided, or where there exists an expectation to build. Each local authority will need to determine the definition of a greenfield site for their own city/district. It may be an area where there is currently no expectation to build (e.g. no zoning for intensive development), or it may be an undeveloped area of certain defined size (e.g. < 20 acres).

Figure 1. Risk-based planning approach (modified after AS/NZS Risk Management Standard 4360:2004).

RISK ANALYSIS

Step One: Identify landslides in your district or region

Where are the landslides in the district or region?

Step Two: Identify the nature of the landslide hazard

What is the likelihood of a landslide in the district? *(landslide AEP)*

What is the nature of the landslide? *(type, size, mechanism, complexity)*

Step Three: Identify the consequences of the landslide hazard

What are the elements at risk at the proposed development site? *(people/assets)*

What is the construction type? *(building importance category)*

Step Four: Estimate the risk to a subdivision or development

Likelihood of a Hazard x Consequences?

RISK EVALUATION

Step Five: Assess and evaluate the level of the risk to a subdivision or development

How does the risk compare with other hazards?

Is the risk acceptable?

Are there alternatives or options?

RISK TREATMENT

Step Six: Treat the risk

What action should be taken to avoid or mitigate the risk within the landslide hazard areas?

Regulatory planning methods

Non-regulatory methods

Limiting the risk posed by the building

Step Seven: Monitor and review

Are our outcomes being achieved?

Is new information available?

Does the district plan need to be updated?

Risk analysis

Risk analysis involves acquiring information on landslide hazards, as well as considering any consequences if people and property are affected by landslides. Firstly, a thorough assessment of the types, characteristics and frequency of landslides in the area of interest should be carried out as part of the hazard identification. Secondly, a consequence analysis establishes the elements at risk (people/property/assets).

Elements at risk

Different levels of landslide risk can be acceptable, depending on the consequences of a landslide occurring at a particular site. For example, the overtopping of a dam by a wave caused by a landslide may have significantly greater consequences than a minor landslide affecting a single dwelling. However, in any one year, a small landslide is far more likely to occur than a large landslide into a lake.

Table 1. Building Importance Categories: a modified version of New Zealand Loading Standard classifications (AS/NZS 1170.0.2002).

Building Importance Category (BIC)	Description	Examples
1	Low consequence for loss of human life, or small or moderate economic, social, or environmental consequence.	Structures with a total floor area of less than 30m^2 Farm buildings, isolated structures, towers in rural situations Fences, masts, walls, in-ground swimming pools
2a	Medium consequence for loss of human life, or considerable economic, social, or environmental consequences	Timber framed single-storey dwellings
2b	(As above)	Timber framed houses of plan area more than 300m^2 Houses outside the scope of NZS3604 "Timber Framed Buildings" Multi-occupancy residential, commercial (including shops), industrial, office and retailing buildings designed to accommodate less than 5,000 people and also those less than 10,000m^2 gross area. Public assembly buildings, theatres and cinemas of less than 1000m^2 Car parking buildings
3	High consequence for loss of human life, or very great economic, social, or environmental consequences (affecting crowds)	Emergency medical and other emergency facilities not designated as post disaster facilities Buildings 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 capacity greater than 500 for colleges or adult education facilities Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities Airport terminals, principal railway stations, with a capacity of more than 250 people Any occupancy with an occupancy load greater than 5,000 Power generating facilities, water treatment and waste water treatment facilities and other public utilities not included in Building Importance Category (BIC) 4 Buildings and facilities not included in BIC 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries
4	High consequence for loss of human life, or very great economic, social, or environmental consequences (post disaster functions)	Buildings and facilities designated as essential facilities Buildings and facilities with special post-disaster function Medical emergency or surgical facilities Emergency service facilities such as fire, police stations and emergency vehicle garages Utilities required as backup for buildings and facilities of importance level 4 Designated emergency shelters Designated emergency centres and ancillary facilities Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries
5	Circumstances where reliability must be set on a case by case basis	Large dams, extreme hazard facilities

To classify building elements at risk, a Building Importance Category (BIC) can be used, although it is recognised that there are other approaches to classifying elements at risk. An example of the use of BICs are the Australia/New Zealand Standard for Structural Design Actions, Part 0 General Principles (AS/NZS 1170.0:2002). The BIC indicates the relative importance of a building, or proposed building, where an identified landslide hazard exists. Different risk levels for building damage (collapse, burial, etc.) would need to be determined according to the building type, use and occupancy, and the size and type of landslide that could affect the site.

This classification does not cover roads, bridges and other developments that do not necessarily involve buildings, but such elements could be included, based on importance of the road or land being developed. The BIC does not directly classify people within the elements at risk, but does recognise that certain types of buildings have different numbers of people or vulnerability (e.g. many children in schools, and many infirm people in hospitals and care facilities).

Measures of consequence

The consequences of a landslide are commonly described in terms of the cost of damage, and the numbers of deaths and injuries (casualties). The Australian Geomechanics Society (AGS) landslide risk method defines measures of consequence to property (depending on the damage to a building) using terms such as: insignificant, minor, medium, major and catastrophic. The AS/NZS Loadings Standards 1170:2002 defines building damage in terms of serviceability (serviceability limit state) and life safety (ultimate limit state).

Irrespective of the measure of consequence used, the design life of the building, infrastructure or development must be taken into account when assessing the risk. AS/NZS 1170.0:2002 considers the expected lifetimes of various classes of buildings. Most common buildings of BIC 2 and 3 (see Table 1) have an expected lifetime of 50 years. The probability of landslides causing irreparable damage to a building, or threat to life, should be within acceptable limits. Riddolls and Grocott (1999) provide guidance on risk to life from landslide, but acceptability of risk is subjective and varies from person to person, and from organisation to organisation.

Risk estimation

A landslide hazard may be assessed as "extreme", but if there are no vulnerable elements then there are no consequences, and therefore no or minimal risk. Landslide risk analysis is an iterative process, whereby initially a broad appreciation of the hazard and the resulting consequences is developed (i.e. risk = hazard x consequence (or vulnerability)). This will assist in determining which aspects need more in-depth investigation.

In determining the landslide hazard, the magnitude (size) and frequency of past events, along with the probability of possible triggering events should be considered. The probability of triggering events, such as rainfall and earthquake shaking, are assessed separately. The likely soil moisture conditions also need to be considered.

Annual Exceedance Probabilities (AEPs) are suggested for design landslide hazard events for various building classes, as per AS/NZS 1170.0:2002, to assess the risk. This defines design events in terms of the Ultimate Limit State (the design event where the structure will fail),

Table 2. Annual probability of exceedance for Building Importance Categories for a 50 year design life based on AS/NZS 1170.0:2002.

Building Importance class	Annual probability of exceedance for ultimate limit state	Annual probability of exceedance for serviceability limit state
1	1/100	-
2	1/500	1/25
3	1/1000	1/25
4	1/2500	1/500
5	Determined on a case-by-case basis	

Note: AEP = 1/average return period (years) and the Serviceability Limit State, where the structure can continue to be used following the event. For a design working life of 50 years the following AEP would apply for BIC 1 to 4 as per Table 2.

The assumptions and uncertainties associated with the probability should be clearly stated. Probabilities are usually based on long-term averages of known landslide events and potentially triggering events, but can also consider changes in preparatory factors. For any landslide hazard assessment the following should be defined to qualify the limitations of the assessment:

- the extent of the site and its features;
- geological and historical evidence of landsliding at the site and within the general area;
- geographic limits of the processes that may affect the site;
- the type of analysis carried out;
- the basis for the hazard assessment; and
- the numerical uncertainty in the probability assessment (if this can be determined with any confidence).

Risk assessment

Risk assessment involves evaluating risks, making judgements on the acceptability of the risks and evaluating remedial options and mitigation measures. Such assessments depend on the hazard and consequences of the landslide event being considered, the societal acceptance of certain risk levels and the uncertainty of the hazard assessment. This is where policy decision-makers overlap with geological and geotechnical professionals in making decisions about acceptable risk and appropriate development options.

In assessing the landslide hazard and risk, a local authority should also take account of:

- community values and expectations (what the community wants and what it does not want);
- which areas of the district are, or are likely to be, under pressure for development;
- what infrastructure already exists near a landslide hazard (buildings, network utilities etc.) and the value of that infrastructure;
- what level of risk the community is prepared to accept or not accept (in practice, it is easier to define what the community will not accept using community reactions to past events as a guide); and
- consideration of the feasibility (effectiveness versus cost) of possible engineering solutions or other risk reducing mitigation works.

Landslide risk assessment requires an understanding of the likely consequences of different types of landslide events, such as injury or loss of life and damage to property and investment. It also requires consideration of the cost of clean-up, or repair or replacement of damaged property and services after the event. Riddolls and Grocott (1999), describe a methodology for quantitative risk assessment for determining slope stability risk in the building industry aimed at New Zealand geotechnical practitioners. However, there is also a need to consider the geotechnical risks in the current framework of New Zealand legislation and accepted codes of engineering practice. For example, it is ineffective to design a building to withstand earthquake ground shaking of 1/500 AEP if the land on which it is to be built is in the likely path of a large, possibly rainfall-induced landslide with a higher AEP.

Planners should take opportunities to plan to avoid landslide hazards before development and subdivisions are approved. However, in areas already developed or subdivided, approval for development at a location deemed to have a landslide hazard involves evaluating the risk of landslide, alongside the level of risk the community is prepared to accept.

Taking a risk-based approach to resource consents

Determining consent categories

The Resource Management Act 1991 (RMA) is the principal environmental legislation in New Zealand, and provides for the classification of land use activities as permitted, controlled, restricted discretionary, discretionary, and non-complying. The status of a resource consent determines those matters the local authority can consider when deciding on an application and the conditions that may be imposed. Different types of buildings can be placed into different resource consent activity categories, based upon the level of landslide risk.

Table 3 provides an example of one way that different consent status could be applied to activities in areas where landslide hazard has been identified. The BIC has been used as the key activity category, and the AEP as the trigger for a resource consent status. This table is presented as a guide only, and may require refinement as it is applied and tested. The table can only be a guide if sufficient information to define the AEP is available.

Table 3. Recommended resource-consent activity status for proposed land-use based on the probability of land slippage, falling debris or subsidence[1] causing severe building damage or life-safety risk at a specific site, based on proposed uses for buildings of different importance categories as outlined in Table 4.1.

Range of annual exceedence probability[2] (AEP)	<1/24	1/25—1/99	1/100—1/499	1/500—1/999	1/1000—1/2499	>1/2500
Qualitative acceptability of risk	Never acceptable	Seldom acceptable	Sometimes acceptable	Generally acceptable	Seldom unacceptable	Always acceptable
Building importance category (BIC)	Recommended activity consent status[3] based on proposed use and probability of severe damage or life-safety risk from the hazards of landslip, falling debris or subsidence as defined in the RMA					
BIC 1 Low consequences (temporary or uninhabited buildings)	Non-compliant	Discretionary	Permitted	Permitted	Permitted	Permitted
BIC 2 Medium consequences (normal occupancy)	Non-compliant	Non-compliant	Discretionary	Permitted	Permitted	Permitted
BIC 3 High consequences (crowds affected)	Non-compliant	Non-compliant	Non-compliant	Discretionary	Discretionary	Permitted
BIC 4 High consequences (post-disaster functions)	Non-compliant	Non-compliant	Non-compliant	Non-compliant	Discretionary	Permitted
BIC 5[3] Structures of special importance	Non-compliant	Non-compliant	Non-compliant	Discretionary (special studies)	Discretionary (special studies)	Discretionary (special studies)

1. Annual exceedence probability is 1/(return period in years).
2. Well engineered mitigation works may be used to reduce the probability of damage or life-safety risk to acceptable levels on some otherwise "non-compliant" or "discretionary" sites. This should be taken into consideration when preparing the application for consent, with an assessment of residual risk.
3. BIC 5 buildings are those where the consequences of loss or damage can be expected to have regional or national impact. As such they should be subjected to special consideration and are expected to be subjected to special studies and specific planning restraints. The term 'Special Studies' is used in the New Zealand Loading Standard classifications (AS/NZS 1170.0.2002), and requires justifying any departure from the Standard, or for determining information not covered by the Standard.

The consent categories have been determined using the annual exceedance probability for ultimate limit state as shown in Table 2. The stated AEP for ultimate limit state is deemed to be the point at which the local authority should exercise some control over the activity. At this point the activity requires resource consent to allow the local authority to assess the risk and potential effects of the activity on the hazard. For higher AEPs (i.e. more likely) the local authority should exercise greater control. This allows the local authority to decline an application where either the risk or the potential effects of the hazard are significant. This approach recognises that up until the AEP for the ultimate limit state is reached (lower risk), it is appropriate that the activity is permitted.

The BIC categories in Table 3 are directly applicable to the construction or alteration of structures, but the table can also be applied to the subdivision and earthworks associated with such developments. Where subdivision or earthworks are required for residential structures, then the BIC 2 consent categories can be applied; where earthworks are proposed for a dam, then the BIC 5 consent categories are relevant; and so forth. Similarly, the categories could be applied during the rezoning of land for particular purposes.

While it takes time and resources to undertake a plan change to incorporate these planning principles into an existing operative plan, principles from the guidelines can be integrated into existing internal council planning processes. For example, as a result of the guidelines, the Hutt City Council based in Lower Hutt has stated:

'Council now has a geotechnical engineer which we refer applications to where planners have concerns about slope stability. This engineer peer reviews the application and advises as to whether further information is required, whether the proposed stability measures are acceptable and provides suggested conditions of consent. This has turned out to be very successful with several applications having fundamental changes to their design as a result of his comments. Other changes which have been implemented include the development of checklists to help new planners as well as ongoing education from our geotechnical engineer who gives seminars on relevant stability matters (i.e. what is a geotechnical engineer and when should we request a geotechnical report etc …)'. (Beban, pers com, 28 November 2008).

Second generation planning offers the best time to incorporate the principles of the guidelines into planning policy. In New Zealand, second generation planning processes are underway in many districts, and provides an opportunity for these principles to be included, or to strengthen existing policies which may be in place.

Conclusion

This paper is based on the guidelines by Saunders & Glassey (2007), and has provided an overview of the risk management process used in the guidelines. The guidelines are based on four overarching planning principles: 1) gather accurate hazard information; 2) plan to avoid hazards before development and subdivision occurs; 3) take a risk-based approach in areas likely to be developed or subdivided; and 4) communicate the risk of hazards.

Risk analysis involves assessing the hazard as well as considering the consequences if people and property are affected by these hazards. To classify building elements at risk, a Building Importance Category (BIC) is used. Risk assessment involves evaluating risks, making judgements on the acceptability of the risks and evaluating remedial options and mitigation measures. Such assessments depend on the hazards and the risk posed by them and societal acceptance of certain risk levels. Risk assessment can then be linked to land use development applications and used in determining the resource consent categories and conditions.

References

Australian/New Zealand Loadings Standards AS/NZS 1170.0:2002.

Australian/New Zealand Risk Management Standard AS/NZS 4360:2004.

Beban, James, Senior Resource Consent Planner, Hutt City Council. Letter dated 28 November 2008, 'Slip Data'.

Riddolls & Grocott Ltd, 1999: *Quantitative Risk Assessment Methods for Determining Slope Stability Risk in the building Industry.* Building Research Association of New Zealand, Study Report, SR 83, Judgeford.

Saunders, W. & P. Glassey (Compilers) 2007: *Guidelines for assessing planning policy and consent requirements for landslide-prone land.* GNS Science Miscellaneous Series 7.

Acknowledgments

This project was funded through the Foundation of Research, Science and Technology Geological Hazards & Society programme of research, New Zealand. Thanks to Julia Becker who reviewed this paper.

About the authors

Wendy Saunders is a full member of the New Zealand Planning Institute. Wendy recently won the Zonta/Building Research Award for PhD study, where she is researching innovative land use planning for natural hazard risk reduction.

Phil Glassey is an engineering geologist with GNS Science, a member of the Geotechnical Society and Geological Societies of New Zealand and the IAEG. Phil currently manages the Mapping section at GNS Science, with an interest in utilising GIS for hazard analysis.