ACTIVE FAULT AND LANDSLIDE GUIDELINES FOR PLANNERS

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ABSTRACT: GNS Science has produced two guidelines for policy and consent planners on managing development on and around active faults and landslides. Both guidelines primarily aim to assist land use planners (and other interested parties) in determining whether planning documents and development applications at regional and district government levels incorporate appropriate information on fault rupture, landslide and slope instability hazards. They provide suggestions that could be used to assess hazards related to risk at the consent stage, and examples of issues, objectives, policies, rules, and assessment criteria. Basic underpinning scientific and engineering concepts related to active fault and landslides are outlined in the guidelines to assist planners in understanding hazard processes, triggers, and hazard and risk assessment.

The active fault and landslide guidelines are both based on four overarching planning principles: 1) gather accurate hazard information; 2) take a risk-based approach in areas likely to be developed or subdivided; 3) if the risk is unacceptable, plan to avoid or mitigate hazards before development and subdivision occurs; and 4) communicate the risk of hazards in built-up areas. A risk-based planning approach incorporating risk analysis, evaluation and management is presented, followed by resource consent tables which can assist planners in categorising consent activity status.

Due to the variable nature of the geology and associated risk across New Zealand, the guidelines do not provide prescriptive planning requirements. Rather, they provide the planner with guidance on what should be considered when considering development or planning for fault rupture or landslide hazard. The guidelines will also be of interest to emergency management planners, engineering geologists, engineers, and others who deal with active fault and landslide issues.

Keywords: active fault, landslide, planning, risk-based, guidelines

1. Introduction

Located on the Australian and Pacific plate boundary, New Zealand is at risk from a broad range of natural hazards, including geological and weather related. Fault rupture, ground shaking, land deformation, tsunami, landslides (including debris flows), flooding, high winds, volcanic eruptions and cyclones are all hazards that are a reality in New Zealand. In response to increasing pressure to develop near or on active faults and on steeper marginal slopes, two guidelines have been produced to assist planners in locating development around these two hazards. In 2003, the Ministry for the Environment (in association with GNS Science) published 'Planning for development of land on or close to active faults: a guideline to assist resource management planners in New Zealand' (Kerr et al, 2003). This was followed up in 2007 with the release of 'Guidelines for assessing planning policy and consent requirements for landslide prone land' (Saunders and Glassey, 2008). This paper is based on these two guidelines.

Both these guidelines are based on four common overarching planning principles: 1) gather accurate hazard information; 2) take a risk-based approach in areas likely to be developed or subdivided; 3) it the risk is unacceptable, plan to avoid or mitigate hazards before development and subdivision occurs; and 4) communicate the risk of hazards in built-up areas. Each of these principles will be discussed in this paper, followed by an outline of the risk-based planning approach used, which incorporates risk analysis, evaluation and management. Development consent tables for both active faults and landslides are presented and described.

2. Principles for planning approaches

The two guidelines are based on four common planning principles, outlined below:

Principle 1: Gather accurate hazard information

Identifying active fault or landslide-prone areas and plotting them on maps is essential for communicating the risk they may present and mitigating such hazards. Collection of relevant hazard information often requires specialised technical knowledge and surveys. Maps that locate active faults and landslide hazards must be developed at an appropriate scale for planning purposes. Because the existence of an active fault or landslide may have an effect on a decision to purchase or build on a property, all information on hazards should be as accurate as knowledge, technical standards and resources permit.

Principle 3: Take a risk-based approach in areas already developed or subdivided

If land has been subdivided and sites have been purchased, there is an expectation that building on these sites will be allowed. Land use planning in active fault or landslide-prone areas can mitigate the increased risks from these hazards from land-use intensification (such as urban infill) and inappropriate building.

Principle 2: If the risk is unacceptable, plan to avoid or mitigate hazards before development and subdivision

Active fault and landslide hazards can be avoided by preventing building and development on known fault rupture and landslide hazard areas. For example, the developer of a new subdivision may be required to avoid building on or near an active fault. Avoidance is the safest and most satisfactory long-term solution for current and future landowners and for the local authority, although it is recognised that this may result in a loss of opportunity to the developer). Where these hazards cannot be avoided, mitigation measures may be implemented so that the risk is reduced to an acceptable level.

Principle 4: Communicate risk of hazards in built-up areas

One of the most difficult problems concerning active fault and landslide hazards is dealing with existing urban areas where buildings are constructed on or close to an area of potential fault rupture or landsliding. The ideal approach in this situation is to avoid further development in high-risk areas, limit existing-use rights to rebuild, and limit the use of buildings. The most realistic approach, however, is to accept the status quo whilst ensuring that:

- any further development and use of buildings (building type) is consistent with the level of risk posed
- district plan maps clearly show landslide hazard zones.

Non-regulatory approaches, such as hazard education programmes and incentives to retire at-risk land, would also ensure that landowners and building occupiers are made aware of the probability of active faults and landslides, and the hazards they present. Hazard education initiatives must reflect the complex socio-economic nature of communities, therefore programmes need to target a range of at-risk groups, and may require a mix of approaches.

3. A risk-based planning approach

Both guidelines are based on a common risk-based planning approach to the active fault and landslide hazard. This approach is presented as a framework in Figure 1. The approach involves risk analysis, risk evaluation, and risk management.

Risk analysis

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

To classify building elements at risk, a Building Importance Category (BIC) is promoted (see Table 1). Based on 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 within, or proposed to be built within, an identified landslide hazard area. Different levels of acceptable risk 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, or many infirm people in hospitals and care facilities).

Risk evaluation and 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 nature of the active fault or landslide hazard events being considered, the likely impact resulting from such an event, and societal acceptance of certain risk levels. This is where policy and decision-making overlaps with geological and geotechnical professionals in making decisions about acceptable risk and appropriate development options.

In assessing the active fault or 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)
- consideration of the feasibility (effectiveness versus cost) of possible engineering solutions or other risk reducing mitigation works.

Risk management

Where a level of earthquake or 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 option.
- Mitigate the risk – in the case of landslides and to some extent fault rupture, engineering works to reduce the risk or likelihood of failure occurring, and the consequence of an event.
- 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 them in the risk situation.
- Transfer the risk – insure against any risk, however the intrinsic value of life and treasures can not be compensated by insuring against the risk.

Natural hazard risk management is predominantly the domain of the policy- and decision-makers, and in New Zealand terms, relates to the responsibilities that regional and territorial governments have in controlling and consenting development in landslide-prone areas.

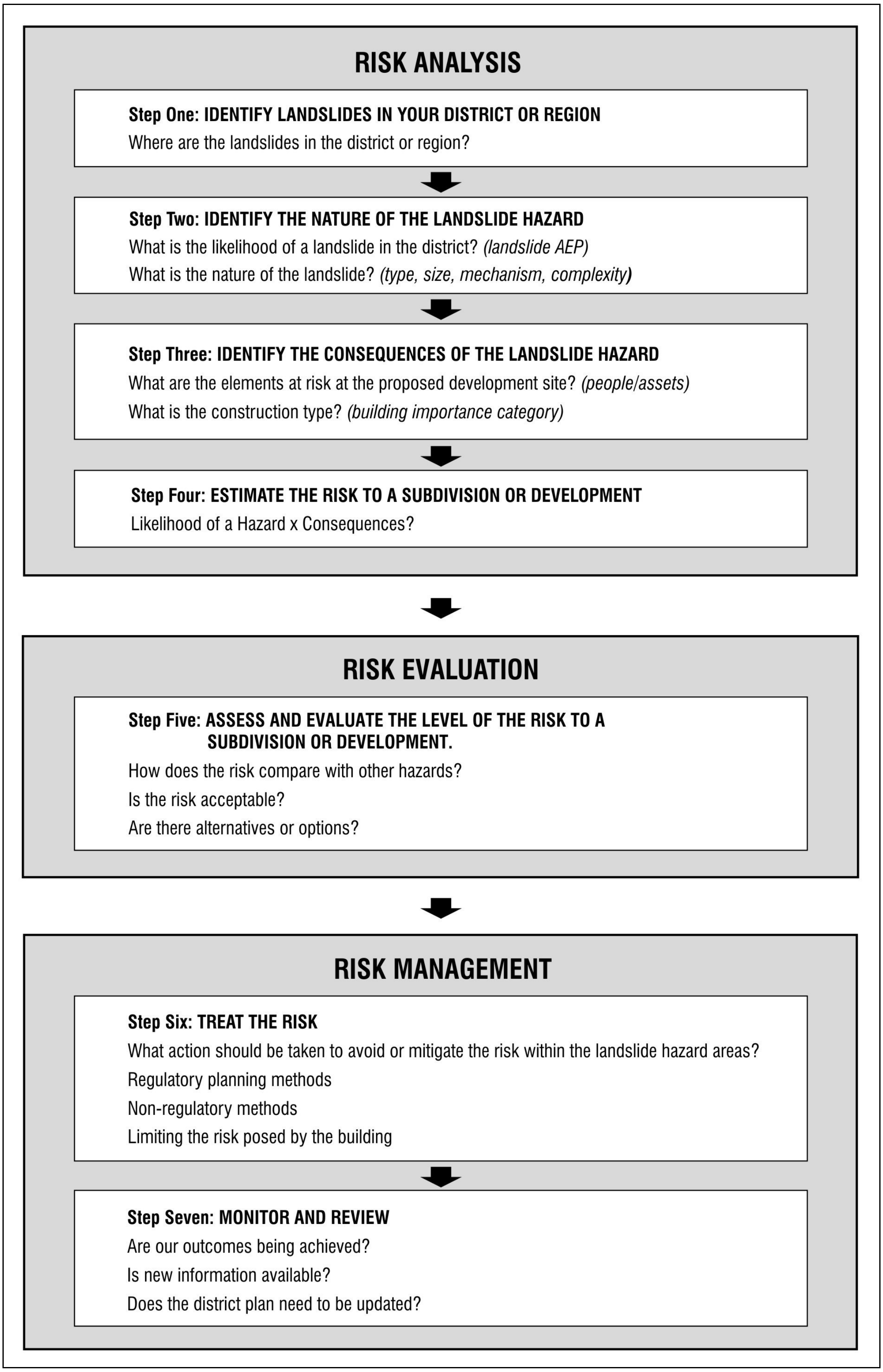

Figure 1 Risk-based planning approach for landslides (In Saunders & Glassey 2007, modified after AS/NZS Risk Management Standard 4360:2004)

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 consequences.	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

4. Taking a risk-based approach to resource consents

The primary piece of environmental legislation in New Zealand is the Resource Management Act 1991 (RMA). The RMA 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 risk, as shown in Figure 2.

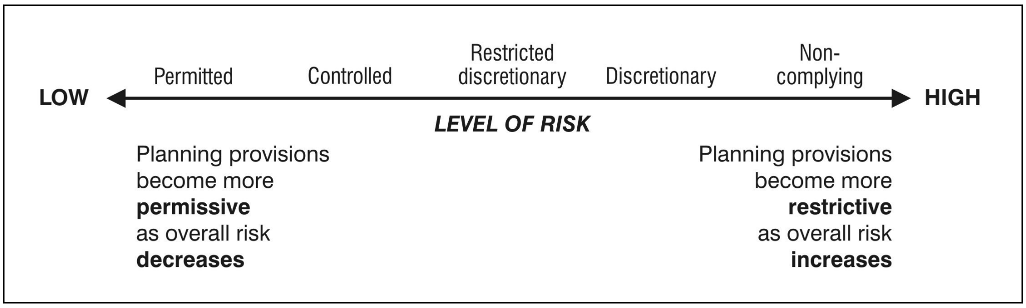

Figure 2 Scale of risk and relationship to planning provisions (Saunders & Glassey, 2007)

As the risk of fault rupture or landslide increases, the consent category becomes more restrictive, and the range of matters the local authority needs to consider will increase. The local authority can set requirements for the bulk, location and foundations of any structure, and has wide powers to impose consent conditions that will avoid or mitigate the adverse effects of any fault rupture or landslide-prone areas considered to be hazardous.

If the risk of fault rupture or landslide is low, the provisions contained in plans may be more permissive and make use of the permitted or controlled activity consent categories. If the risk is high, then provisions in plans become more restrictive, and greater use is made of discretionary and non-complying activity consent categories.

A rule may require that a resource consent be obtained for a new building. On landslide-prone land, this may require a geotechnical report (which will likely contain development recommendations) be included with the application as part of the assessment criteria.

Before granting a resource consent the local authority needs to be satisfied that:

- the risk to the community represented by the local authority is acceptable
- appropriate mitigation measures have been taken, or
- consent is not contrary to the district plan.

Each local authority will want to apply the resource consent activity status categories that suit its own circumstances (i.e. to account for varying geological environments). The key is to ensure a local authority has the ability to address the landslide hazard risk properly when assessing a resource consent application. The matters over which a local authority can reserve control or restrict its discretion could include, but are not limited to:

- the proposed use of the building
- site layout, including building setback and separation distance
- building height and design
- construction type
- financial contributions (for example, reserves contributions).

To assist planners in determining resource consent categories, consent tables are presented in both guidelines. While following similar rationale, these tables do differ between each guideline to reflect the differences between active faults and landslides. Each table and explanation is presented below.

Active fault consent tables

Before being able to classify consent categories, the fault recurrence and fault complexity must be established. The fault recurrence interval is the average time between surface ruptures on a fault, and is considered the best measure to use when evaluating the hazard of an active fault. Fault recurrence interval classes and their relationship to the BIC are shown in Table 2.

Table 2 Fault recurrence intervals and BIC category

Recurrence interval class	Fault recurrence interval	Building importance category (BIC) limitations* (allowable buildings)	
		Previously subdivided or developed sites	"Greenfield" sites
I	≤2000 years	BIC 1	BIC 1
II	>2000 years to ≤3500 years	BIC 1 and 2a	
III	>3500 years to ≤5000 years	BIC 1, 2a and 2b	BIC 1 and 2a
IV	>5000 years to ≤10,000 years	BIC 1, 2a, 2b and 3	BIC 1, 2a, and 2b
V	>10,000 years to ≤20,000 years		BIC 1, 2a, 2b and 3
VI	>20,000 years to ≤125,000 years	BI Category 1, 2a, 2b, 3 and 4	

Note: Faults with average recurrence intervals >125,000 years are not considered active.

The fault complexity refers to the width and distribution of the deformed land around the fault trace, as shown in Figure 3.

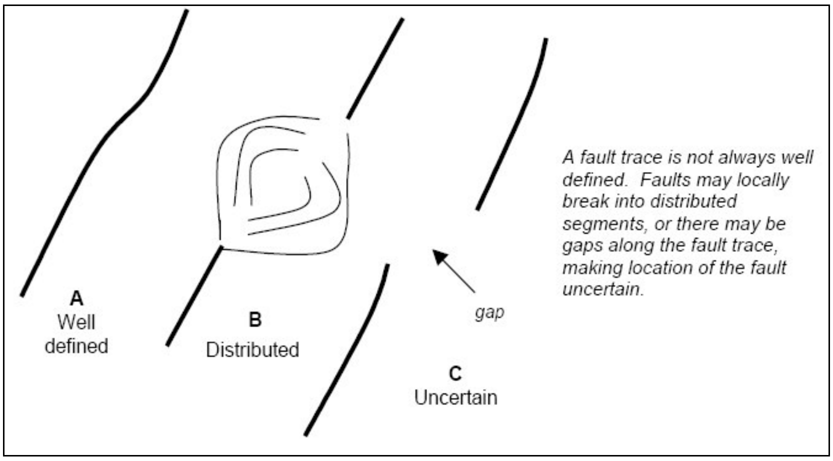

Figure 3: Types of fault complexity (Kerr et al, 2003)

A well defined (A) fault trace has limited geographic width, typically metres to tens of metres wide. A distributed fault (B) is deformed and distributed over a relatively broad geographic width, and can be tens to hundreds of metres wide. Distributed fault types usually comprise of multiple fault traces or folds. Finally, the location of fault traces may also be uncertain (C) due to not being mapped in detail or not being able to be identified. This may be due to a gap in the fault trace caused by erosion or coverage of the trace.

Two consent tables are provided in the active fault guidelines, and use is dependant on if a site is undeveloped or developed. Table 2 shows an example of the consent table for an undeveloped site, using the BIC, fault complexity, and recurrence interval.

Table 3 Resource consent activity status for an undeveloped site (Kerr et al, 2003)

Building importance category	1	2a	2b	3	4
Fault complexity	**Activity status**				
Fault recurrence interval class I less than or equal to 2000 years					
A – Well defined	Permitted	*Non-complying*	*Non-complying*	*Non-complying*	Prohibited
B – Distributed	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
C – Uncertain †	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
Fault recurrence interval class II greater than 2000 but less than or equal to 3500 years					
A – Well defined	Permitted	*Non-complying*	*Non-complying*	*Non-complying*	Prohibited
B – Distributed	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
C – Uncertain †	Permitted	*Discretionary*	*Non-complying*	*Non-complying*	Non-complying
Fault recurrence interval class III greater than 3500 to but less than or equal to 5000 years					
A – Well defined	Permitted	Permitted*	*Non-complying*	*Non-complying*	Non-complying
B – Distributed	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-complying
C – Uncertain †	Permitted	Permitted	*Discretionary*	*Discretionary*	Non-complying
Fault recurrence interval class IV greater than 5000 but less than or equal to 10,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	*Non-complying*	Non-complying
B – Distributed	Permitted	Permitted	Permitted	*Discretionary*	Non-complying
C – Uncertain †	Permitted	Permitted	Permitted	*Discretionary*	Non-complying
Fault recurrence interval class V greater than 10,000 but less than or equal to 20,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	Permitted*	Non-complying
B – Distributed	Permitted	Permitted	Permitted	Permitted	Non-complying
C – Uncertain †	Permitted	Permitted	Permitted	Permitted	Non-complying
Fault recurrence interval class VI greater than 20,000 but less than or equal to 125,000 years					
A – Well defined	Permitted	Permitted*	Permitted*	Permitted*	Permitted*
B – Distributed	Permitted	Permitted	Permitted	Permitted	Permitted**
C – Uncertain †	Permitted	Permitted	Permitted	Permitted	Permitted**

Note: Faults with a recurrence interval of greater than125,000 years are not considered active.

* The activity status is permitted, but could be controlled or discretionary because the fault location is well defined.

** Although the activity status is permitted, care should be taken in locating BIC 4 structures on or near known active faults. Controlled or discretionary activity status may be more suitable.

† Where the fault trace is uncertain, specific fault studies may provide more certainty on the location of the fault. Moving the fault into the distributed or well defined category would allow a reclassification of the activity status and fewer assessment criteria.

Italics show that the activity status is more flexible. For example, where *discretionary* is indicated, controlled activity status may be considered more suitable.

Landslide guideline consent table

The consent table for landslides uses similar principles to that used for the active fault consent tables, in that the BIC has been used as the key activity category, and the Annual Exceedance Probability (AEP) has been used as the trigger for a resource consent. The consent categories have been determined using the annual exceedance probability for the ultimate limit state, as shown in Table 4.

Table 4 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)

The consent status for landslide risk is shown in Table 5. A limitation of the table is that it can only be used if sufficient information on the AEP is available.

Table 5 Resource consent activity status based on the probability of landslide occurrence (Saunders & Glassey, 2007)

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[4] Structures of special importance	**Non-compliant**	**Non-compliant**	**Non-compliant**	**Discretionary (special studies)**	**Discretionary (special studies)**	**Discretionary (special studies)**

Notes:

1. Land slippage, falling debris and subsidence are the specified natural hazards in the RMA that are also commonly described by the terms "landslide", "slope instability" and "slope-stability hazard".
2. Annual exceedence probability is 1/(return period in years), See Information box 4 for further explanation of AEP's.
3. 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.
4. 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,

Example of application of guidelines – Applying the Active Fault Guidelines in Wellington Region, New Zealand

In 2005, two years after the release of the Active Fault Guidelines, Becker et al., conducted a survey to assess uptake and usage of the guidelines at local government level in New Zealand. Five local authorities reported that they had made use of the guidance, and as a result had undertaken some form of planning for fault rupture, either formally or informally.

Wellington City Council and Kapiti Coast District Council are two local authorities that have used the Active Fault Guidelines to assist in planning for fault rupture. Wellington City has incorporated elements of the guidelines (i.e. better defining a fault avoidance zone; changing rules relating to development near the Wellington Fault; requiring geotechnical assessment) to make a district plan change for activities near to the Wellington Fault (Kerr et al., 2003).

Kapiti Coast District Council (KCDC) has also made use of the guidelines. In 2003, KCDC commissioned GNS Science to undertake a study to define the fault avoidance zones around the faults in the district. Subsequent to that study, a process of consultation with the community took place, followed by drafting of new content for the district plan. In 2007 proposed changes to the district plan included:

- "Updating the District Plan maps with up-to-date information on the location of fault traces;
- Adding an objective and policies which reflect Council's goal and approach to development on or near fault traces;
- Altering rules and standards in relation to:

  Subdivision by:

    - Encouraging all new allotments created by subdivision to have building sites clear of the identified fault trace; and;
    - Setting out the matters that will be considered by Council in assessing an application if a building site cannot be provided clear of the fault trace, e.g. the provision of geotechnical information.

  New buildings by:

    - Allowing non-habitable buildings e.g. sheds and garages to be located over the fault trace; but
    - Encouraging all other buildings to be located away from the fault trace. Where this is not possible setting out the matters that Council will consider in assessing such an application" (Kapiti Coast District Council, 2007).

While the Kapiti Coast district plan has not been changed yet, the proposed plan changes were notified in late 2007 and in June 2008 the Council had asked for further submissions on the changes.

It is encouraging to see that changes regarding planning for fault rupture have been made by some local authorities. However due to the plan change process taking some time, it could be several years before planning for fault rupture becomes more widely integrated into local authority processes and planning. One window of opportunity, however, is that currently all New Zealand district plans are up for renewal. Local authorities could take advantage of this opportunity and incorporate planning for fault rupture as part of the plan renewal process, rather than doing a special plan change.

Future research (e.g. surveys and interviews) will enable the continued evaluation of uptake of the guidelines, and the identification of improvements to the document itself.

Conclusion

Two guidelines provide information for planners to understand hazard processes, triggers and hazard and risk assessment for active fault rupture and landslides. These guidelines provide examples of policy and rules that help planners to manage development on and around such hazards. They are based on four overarching planning principles: 1) gather accurate hazard information; 2) take a risk-based approach in areas likely to be developed or subdivided; 3) if the risk is unacceptable, plan to avoid or mitigate hazards before development and subdivision occurs; 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 promoted. 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 (Saunders & Glassey, submitted).

The Active Fault guidelines have been used by several district councils, with at least two of these, acquiring the information they need to identify the hazard and risk, and incorporating, or intending to incorporate, these hazards into district plans with accompanying rules and policy for development. The landslide guidelines were released in December 2007, and their uptake will be reviewed in approximately two years time.

Acknowledgments

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