

# GAPS IN THE UNDERSTANDING AND MITIGATION OF EARTHQUAKE HAZARDS

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## Abstract

New Zealanders live on the edge. The boundary between the Australian and Pacific tectonic plates passes through New Zealand producing earthquakes, volcanic eruptions, and steep terrain with associated landslides and active deformation. The geological risk in Australia by comparison may seem lower, but several damaging earthquakes have occurred there in the last 50 years. It is a challenge to plan for such unpredictable events with low probabilities of occurrence but potentially devastating consequences.

Damage from earthquake results from ground shaking, landslides, liquefaction, tsunamis, and ground rupture across active faults. The most effective mitigation measures include seismic design, good construction practices, and avoidance of hazardous sites. Within New Zealand, the first two measures are largely covered by the Building Act (1991) and associated standards, but the monitoring of earthquakes and avoidance of specific sites subject to earthquake hazards are not covered by legislation or national policy.

Communities may accept expenditure of \$100 million on flood control for a 500 year return period event, but would not consider spending 10 percent of that on earthquake monitoring or mitigation. Some of the differences in risk perception are because we see floods more frequently than we experience large earthquakes. However, because earthquakes can affect large regions simultaneously there are uncertainties about jurisdiction for monitoring and mitigating different aspects of the hazard.

Effective mitigation requires

- a deliberate process of gathering and interpreting information
- mechanisms by which new knowledge is transformed into socially desirable outcomes

Policy guidelines, regulations and education may drive required actions, but if information and knowledge are poor, the process will almost certainly be ineffective. Balancing the different priorities requires careful co-ordination of resources. The scientific and related professional societies can assist this process by improving the communication of risk information to the public, to business and to government decision-makers.

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## Introduction

New Zealanders live on the edge. Depending on their location, it might be on the edge of the Australian tectonic plate, or on the Pacific tectonic plate. The actively deforming Pacific-Australian plate boundary passes through New Zealand producing earthquakes, volcanic eruptions, steep terrain with associated landslides, and ongoing crustal deformation.

Although the Alpine Fault is an obvious indicator of the plate boundary, the zone of deformation is broad, and covers most of the New Zealand region. 95% of New Zealanders live within 200 km of the plate boundary, and are thus exposed to major geological hazards.

New Zealand has a remarkable level of earthquake hazard. Earthquake activity is almost comparable to that of California, with the added hazard of deep earthquakes between the tectonic plates (subduction zone earthquakes) that can affect large areas. Wellington, the capital city, straddles a fault line capable of generating earthquakes

greater than magnitude 7. The Wellington Fault has a recurrence interval of 500-800 years for large earthquakes, and last ruptured 600 years ago. New Zealand's largest fault, the Alpine Fault, which may rupture over a length of 450km, has recurrence intervals of 100-300 years, and last ruptured about 270 years ago. Large local and distant offshore earthquakes have the potential to generate devastating tsunamis, and several large tsunamis struck the New Zealand coastline over the last two centuries.

Nowhere in New Zealand is immune from the possibility of damaging earthquakes. A major earthquake anywhere in the country inevitably affects the whole society and economy because of New Zealand's small size, and interdependencies of infrastructure, logistics and business.

Earthquake hazard in Australia is commonly underestimated. But it is worth remembering that since 1968 there have been six damaging earthquakes large enough to rupture the ground surface. The most damaging of these, at Newcastle, NSW on December 28 1989 (M5.6), caused 13 deaths, and caused an estimated total loss of \$A1.2 billion (1991 value) (Brunsdon 1990). The high level of damage from what would be regarded in New Zealand as no more than a moderate earthquake was partly caused by the lack of earthquake-resistant design features in most Australian buildings.

### **Assessing and mitigating the effects of earthquakes**

Damage caused by earthquake results from ground shaking, landslides, liquefaction, tsunamis, and ground rupture across active faults. Of the above list, much of the damage and injuries occur when built structures and natural slopes respond poorly to shaking. Shaking is generally strongest close to the epicentre of an earthquake, and gradually decreases away from the epicentre, but local site effects can produce significant shaking at larger distances. The most effective mitigation measures for ground shaking are improvements in earthquake-resistant design combined with good construction practices. Within New Zealand these issues are covered by the Building Act (1991) and associated standards. In recent decades there has been a marked improvement in the earthquake-resistance of buildings as modern standards have gradually been enforced. Most territorial authorities have also required the strengthening or demolition of buildings that do not meet current standards.

Landslides, liquefaction, tsunamis, and ground rupture are more localised hazards, directly related to local geology, and the avoidance of these has so far been much less effective. There is often pressure to build or develop subdivisions on land that is hazardous (for example across landslides or known fault-lines). The Resource Management Act (1991) and amendments requires regional and territorial authorities to control the use of land in order to avoid natural hazards, or to mitigate their resultant impacts. These authorities have responsibility for developing controls such as policies and rules within planning documents (e.g. regional policy statements, regional plans and district plans), and monitoring resource consents to ensure adequate measures are taken to protect life, property and the environment from the effects of natural hazards. This is a complex task, requiring accurate technical information, and few authorities have the resources or expertise to do this effectively (Becker & Johnston 2001). To date the planning related to impacts of geological hazards is largely restricted to contingency controls such as civil defence and insurance schemes.

Earthquakes and various other infrequent (but high consequence) hazards, are difficult to assess and prioritise for mitigation precisely because they are perceived to be infrequent events that may not occur within a human lifetime. Communities may accept expenditure of \$100 million on flood control for a 500 year return period event, but would not consider spending 10 percent of that on earthquake monitoring or mitigation, even though the earthquake risk may in fact be comparable or greater for a given timeframe. Some of the differences in risk perception are because we see floods more frequently than we experience large earthquakes. However, because earthquakes can affect large regions simultaneously there are also uncertainties about jurisdiction for monitoring and mitigating different aspects of the hazard.

### **Interdependencies between professional groups and agencies**

Detecting, evaluating and understanding earthquake hazards involves highly skilled personnel, appropriate technology and stable infrastructure. Monitoring and understanding earthquakes and volcanoes, and detecting or responding to their effects (including landslides or tsunamis) requires national facilities and co-ordination with

regional enhancements where appropriate. Similarly, the ability to measure or predict the likely response to shaking of a slope or built structure and its contents involves specialised techniques and engineering judgement.

These steps, although crucial, are only the first in what must be a sequential transformation of information and knowledge to desirable social outcomes. The communication of basic and interpreted-information to other users and decision-makers requires outreach partnerships and co-ordination between diverse organisations, industry and local government agencies. Outreach activities are critical for the uptake of information, contributing to improved co-ordination for emergency response and incremental improvements in hazard assessment and risk mitigation.

The Civil Defence Emergency Management Bill, currently before the New Zealand Parliament (to replace the Civil Defence Act) requires that local authorities within regional boundaries form Civil Defence Emergency Management (CDEM) Groups, which will replace existing civil defence arrangements. These groups will be required to develop plans to address all hazards within a region and plan for them accordingly. In the past, civil defence focussed primarily on response to emergency events, but new CDEM arrangements require that the 4R's of reduction, readiness, response and recovery are all addressed. The reduction (mitigation) element in particular will require more collaboration between emergency managers administering the future CDEM Act, and planners administering the Resource Management Act – with both becoming more aware of common issues and imperatives. If for example, the CDEM Plan identified the earthquake hazard as 'high', a possible risk reduction measure may be to avoid or modify development in certain areas. This approach would require the development or tailoring of policy and rules within district plans.

More often than not, local authorities within a region 'share' the same hazard. This is particularly true for earthquake hazards where the fault dimensions are large. For example, the active Wellington Fault crosses areas administered by five different territorial authorities within the Wellington region. Despite this, there is little consistency noted between hazard management practices adopted by local authorities dealing with the same hazard. As CDEM Plans are to be developed on a regional basis, there will be opportunities for local authorities within a region to adopt more consistent approaches to managing the same hazards.

### **GeoNet: an upgraded monitoring network**

Monitoring of earthquakes has been undertaken in New Zealand for over 100 years, Reviews by scientists, engineers and emergency managers during the 1990s, supported by international reviews, concluded that New Zealand's existing hazard monitoring networks were inadequate, and needed upgrading. Accurate and timely information about geological hazards is vital to help us manage the response to any disaster, and reduce community vulnerability through better planning and mitigation.

In 2001 the Earthquake Commission (EQC) agreed to fund a major upgrade of the seismic network to allow continuous monitoring of crustal instability in the New Zealand region. GeoNet is a network of modern instruments and data centres to monitor earthquakes, volcanic unrest, land deformation, land stability, geothermal activity and tsunamis in New Zealand. It is designed, installed and operated by the Institute of Geological & Nuclear Sciences on behalf of the EQC. Installation of equipment will occur over the next seven years.

An immediate impact of GeoNet will be to improve earthquake emergency response by providing information on the location, size and nature of any earthquake in the New Zealand region 24 hours a day more rapidly and reliably than can be done at present. Acquiring accurate information within minutes is critical to planning an emergency response. Seismic monitoring should also provide advance warning of volcanic eruptions as well as providing early detection of tsunami-generating earthquakes.

Further information on GeoNet can found at: [www.geonet.org.nz](http://www.geonet.org.nz)

## Effective risk mitigation through long-term planning

Priorities, strategies and standards provide the foundation for co-ordination of resources and regulation in a stable society. Decision-making for general management of resources is about value judgements based on incomplete information and imperfect predictions. Inevitably there are tradeoffs between available resources to mitigate risk and the cultural perceptions and tolerance of those risks (Figure 1).

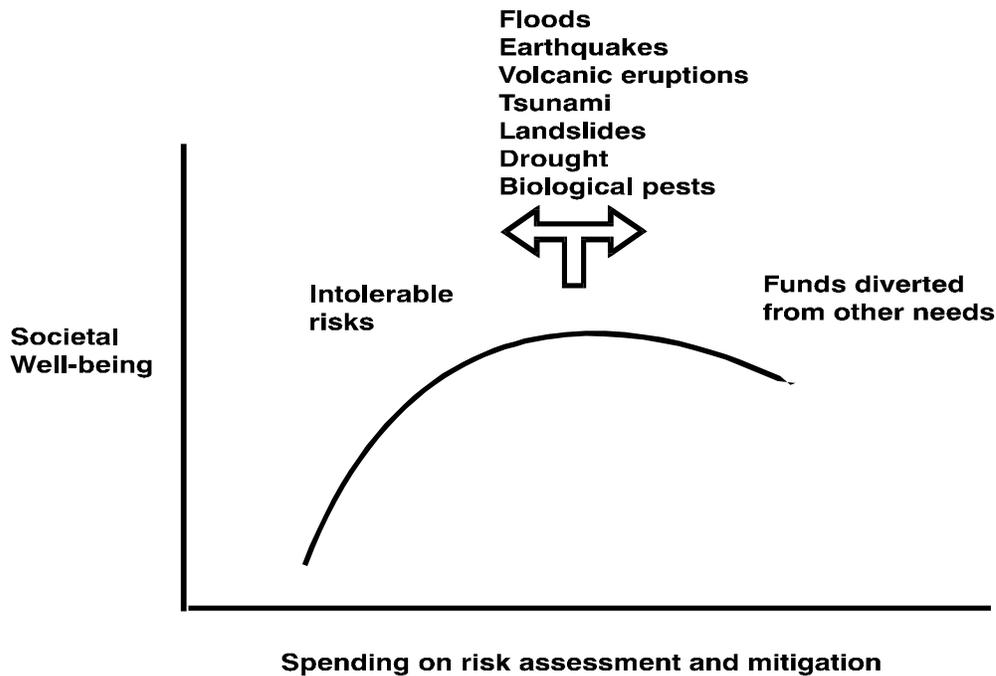


Figure 1: Expenditure on safety involves assumptions about hazard levels and societal perceptions of tolerable loss. Weighed against these concerns are competing priorities for overall societal well-being. The list of hazard agents described here is merely indicative. An appreciation of the potential consequences (economic and social losses) associated with different hazards and their probabilities should improve the quality and consistency of mitigation planning.

However, the techniques now becoming available for analysing and quantifying risk can prevent or minimize disasters, can improve safety and can markedly reduce societal disruption following disasters (Helm 1996). *Risk assessment* is the fundamental basis for the process of *risk management* and requires adequate knowledge of the phenomenon (hazard) and the ability to evaluate trends. Without such insight the risk management process has no adequate basis.

Risk management for earthquake-related hazards involves:

- (a) detecting, understanding and evaluating the different hazards;
- (b) disseminating the basic and interpreted information appropriate to the needs of different users; and
- (c) the process(es) by which different users utilise information and respond according to their role or need.

Information providers, scientists, engineers and other technical specialists are concerned primarily with the first two categories, while recognising the important linkages and feedback required between all three categories.

The Resource Management Act assigns regional and territorial authorities the responsibilities for hazard assessment and risk mitigation, but the lack of even generalised guidelines about acceptable standards means that local authorities have been given little practical assistance. This situation could be addressed through improved coordination of Planning and Civil Defence Emergency Management functions within the same organisations as well as outreach to specialists in other agencies and vice-versa. It is often perceived that emergency management deals with short-term disasters and hazards, whereas urban or regional planning deals with longer-term issues. But most disasters in fact, arise as a consequence of inappropriate planning decisions and inadequate preparedness.

A well known principle of system design is that all components and linkages need to be upgraded evenly if the entire system is to perform optimally, with an equivalent improvement of outcome (Elms 1992). The quality of information about the earthquake risk (its accuracy and timeliness) depends on the existence of monitoring and warning systems together with the knowledge of earthquake hazards derived from local and global research. The transformation of such outputs – the better data and knowledge - to desirable social outcomes (more resilient and sustainable communities) requires considerably more effort, however, and sustained commitment by many agencies and professionals.

We believe that for New Zealand the new CDEM framework offers encouraging prospects for better planning, closer relationships and improved understanding between different professional groups involved in earthquake (and other hazard) mitigation. The parallel development of a national GeoNet monitoring system is intended to deliver timely and better information about geological hazards and deeper insight into the natural hazards we live with. The value judgements required for future community development are unlikely to get any easier, but if interagency and inter-disciplinary co-ordination is better developed and sustainable the CDEM planning process should facilitate greater understanding of hazards by local authorities and more consistent planning for the same hazards within a region.

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