NATIONAL Hazardscape REPORT




FOREWORD

As Chair of the Officials' Committee for Domestic and External Security Coordination (ODESC), I am pleased to introduce to you the National Hazardscape Report. ODESC has broad oversight roles in the area of emergency readiness and response. It is charged with providing strategic and policy advice to the Government for events of national importance, and it coordinates the activities of central government agencies in preparing for and responding to emergencies, natural disasters, and security crises.

The primary audience for the National Hazardscape Report is national and local decision-makers and emergency management stakeholders. I hope that the Report will also be a useful resource for a wider range of readers such as the education sector, international emergency management organisations, and the general public.

Hazard managers and decision-makers need to understand the range and nature of New Zealand's hazards, what their impacts could be in any given locality and how they can best be managed. The National Hazardscape Report takes the first steps towards meeting these needs.

The National Hazardscape Report provides a contemporary summary of New Zealand's hazardscape. Seventeen of our most significant hazards are discussed, along with their impacts, distribution, frequency, and how they are currently managed. New Zealand has a large and varied number of natural, technological, and man-made hazards, and we must understand them and the risks they pose.

I encourage you to read the National Hazardscape Report and consider the ways we can all reduce risks and make our communities safer.

Maarten Wevers.

Maarten Wevers
Chair
Officials' Committee for Domestic and External Security Coordination

National Hazardscape Report
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EXECUTIVE SUMMARY

New Zealanders are, and will continue to be, at risk from a broad range of hazards. Many communities, and much industry and infrastructure, are located in areas that are likely to be affected by hazards.

Flooding is the most common natural hazard in New Zealand, and earthquakes and tsunamis are potentially the most damaging and disruptive. Probably the most underrated natural hazard is volcanic eruption.

Accidental release of a hazardous substance, introduced organisms, and diseases may also affect New Zealand's environment, health and economy, and terrorism could become a threat to public safety and national security. Technological hazards and increasing reliance on key infrastructure, urbanisation, more intense land use generally, and climate change all compound New Zealand's exposure and vulnerability to damage, death and injury, and social and economic disruption.

Significant legislation and policy changes since 1994 include the increasing importance of hazard management in local authority plans and policy statements under the Resource Management Act 1991, the Civil Defence Emergency Management Act 2002, the Local Government Act 2002 and the Building Act 2004. Emergency management arrangements have been strengthened by that legislation. Arrangements and responsibilities across local communities, local authorities, central government, the emergency services, and lifeline utility operators are now clearer.

Alongside these Acts, many other statutes set out further functions, roles and responsibilities of individuals and agencies for managing hazards and risks.

The *National Hazardscape Report* (NHR) does not set out to provide a comprehensive guide to all these arrangements. However, to inform discussion of a hazard or risk, references are made to some specific agencies and legislation.

The NHR is a non-statutory document aimed at informing policy makers, hazard managers and their advisors in carrying out hazard and risk management at the national and local level. It provides a contemporary summary of the physical nature, impacts, distribution, and frequency of occurrence of the 17 key hazards affecting New Zealand. The NHR also provides general information on the current management of hazards, through a focus on reduction and readiness initiatives. The hazards described in the NHR include geological, meteorological, biological, technological, and social hazards.

Additionally, four key factors that influence New Zealand's current hazardscape are discussed in the NHR: climate change, demographic and future development trends, reliance on technology, and human modification of the natural environment. These four factors, separately and collectively, will play a continuing role in determining the nature of hazards and risks that New Zealand faces, and their management.

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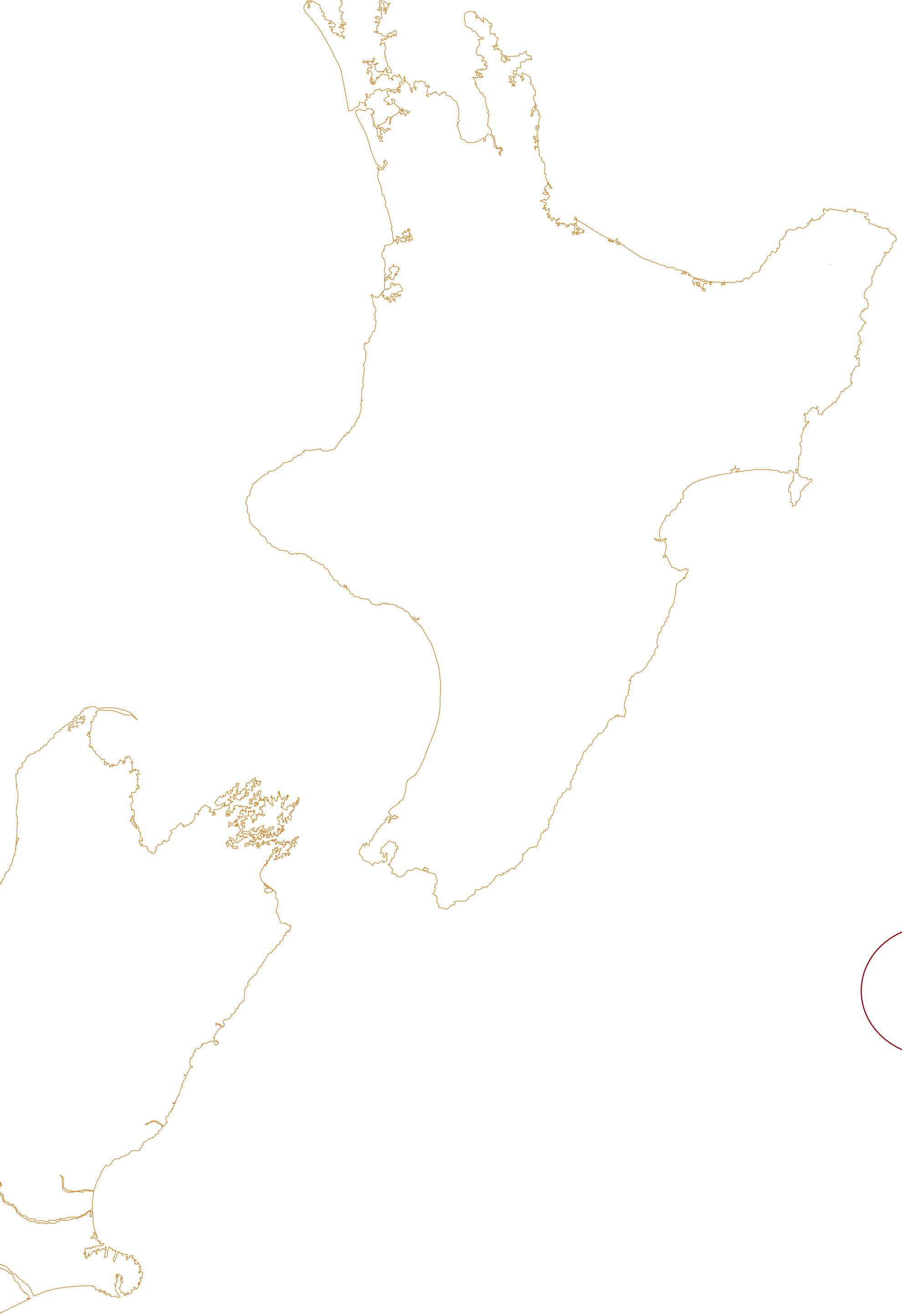


INTRODUCTION

Purpose and audience

New Zealand's citizens, businesses, hazard managers, and decision makers need to understand our hazards, the risks they pose, and how they are currently managed, if we are to improve our hazard and risk reduction, emergency readiness, and response and recovery arrangements. The Officials' Committee for Domestic and External Security Coordination (ODESC) is issuing the *National Hazardscape Report* (NHR) to help meet this need.

The central decision-making body of executive government that addresses emergency management is the Cabinet Committee for Domestic and External Security Coordination (DES). The DES committee is chaired by the Prime Minister, and includes those ministers responsible for departments that play essential roles in such situations. To support that process, the ODESC is the committee of government chief executives charged with providing strategic policy advice to the Prime Minister on such matters. ODESC provides oversight in the areas of emergency readiness, intelligence and security, terrorism, and maritime security. The chief executive of the Department of the Prime Minister and Cabinet chairs the committee, and members are the chief executives from relevant government agencies.

ODESC is issuing the NHR to assist ministers and those agencies at the national and local level with a direct role in hazard and emergency management. As everyone in the country is a stakeholder in emergency management, the NHR also contains useful information for the wider community.

The NHR does not place additional requirements on any individual or organisation beyond their existing responsibilities, roles and functions within any legislation and subordinate policy. However, the NHR will help identify priorities and effective courses of action to meet their obligations.

Scope

The NHR summarises New Zealand's hazardscape and, to a lesser level, its risk exposure. Hazards are described by their physical nature, impacts, spatial distribution, frequency of occurrence, and current management arrangements.

Emergency management plans for local and central government were reviewed to help assess aspects of current hazard management and the national significance of hazards. While acknowledging the 4Rs approach – reduction, readiness, response, and recovery – the NHR focuses primarily on reduction and readiness. This focus recognises that reduction and readiness policy and programmes generally need to be specific to each hazard. In comparison, response and recovery policy and programmes are organised on 'generic' sets of consequences regardless of the hazard source.

Furthermore, core emergency readiness, response, and recovery operational arrangements are set out in emergency management strategies and plans at the national and local levels, including:

- CDEM Group plans
- the National Civil Defence Emergency Management Plan Order 2005 (National CDEM Plan) and the Guide to the National Civil Defence Emergency Management Plan 2006 (the Guide to the National CDEM Plan)
- the New Zealand Influenza Pandemic Action Plan
- the National Marine Oil Spill Contingency Plan.

New Zealand’s emergency management context

Central to emergency management in New Zealand is an all-hazards, all-risks, multi-agency, integrated, and community-focused approach. Risk management is based around various strategies that have evolved over the years. One generic template involves the 4Rs of reduction, readiness, response, and recovery.

The 4Rs are:

- **reduction** – identifying and analysing long-term risks to human life and property from hazards, and taking steps to eliminate these risks if practicable, or if not, to reduce their likelihood and the magnitude of their impact
- **readiness** – developing operational systems and capabilities before an emergency happens, including self-help and response programmes for the public as well as specific programmes for emergency services, lifeline utilities (infrastructure providers) and other agencies
- **response** – taking action immediately before, during or directly after an emergency to save lives and property, and to help communities recover
- **recovery** – using coordinated efforts and processes to bring about the immediate, medium-term, and long-term regeneration of a community following an emergency.

This report takes a broad interpretation of the term ‘hazard’. Historically, natural hazards, and in particular flooding and earthquakes, were the main focus of emergency management. Technological development in New Zealand has created significant new hazards and risks, and increasing reliance on infrastructure has led to potentially greater community vulnerability. Hazardous substances, introduced organisms and diseases, and terrorism are included here as they may threaten public safety or adversely affect New Zealand’s environment, health, and economy.

Individual agencies at the national and local level have a direct role in hazard and risk management, and operate under existing legislation and polices.

At a regional level, 16 regionally based CDEM Groups and their constituent local authorities and emergency services are responsible for implementing local risk management and civil defence emergency management. Legislation setting out these responsibilities includes the Resource Management Act, the Local Government Act, the Building Act, the Health Act, and the Civil Defence Emergency Management Act.

Key terminology and definitions

Several key terms used in the report may need to be explained.

An event, for the purposes of the NHR, is an extreme occurrence of a natural process or a large-scale man-made incident.

Natural events may be:

- meteorological (for example, strong winds, snow or heavy rain)
- geological (for example, earthquakes, tsunamis, landslides, and volcanic eruptions)
- biological (for example, animal and crop diseases, and human disease epidemics).

Man-made events can be classified into two main groups:

- technological (for example, major transport accidents and major infrastructure failures)
- social (for example, terrorism).

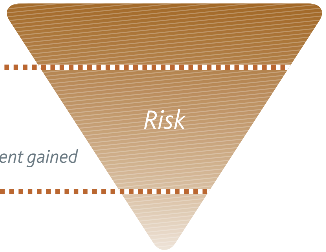
Some biological threats may also be considered to be man-made.

RISK

Unacceptable
Risk cannot be justified except in extraordinary circumstances

Tolerable
Justified only if reducing the risk is not practical or affordable
Justified only if the cost of reducing the risk is more than the improvement gained

Acceptable
Necessary to maintain assurance that risk remains at this level



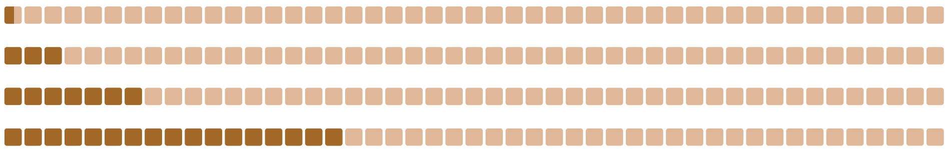
A hazard is the potential for an event to interact with individuals and communities, and the social, economic, cultural and environmental resources supporting them.

Risk, by contrast, is the combination of the likelihood and the consequences of a hazard. It can also be expressed as a combination of exposure to a hazard and a community's vulnerability to it. A hazard may pose many risks such as death, injury, property damage, and social, economic and environmental consequences.

When an event actually affects people, their activities, or the built or natural environment, the consequences range from being a nuisance through to a disaster. A disaster generally means an event where the consequences include many deaths or injuries, or extensive damage to property, infrastructure, or the environment.

With time the probability of experiencing a natural event changes.
For example, the chance of a "1-in-200 year" flood occurring…

in any 1 year is 1-in-200
in a 10 year period is 1-in-20
in a 30 year period is 1-in-7
in a 70 year period is 1-in-3



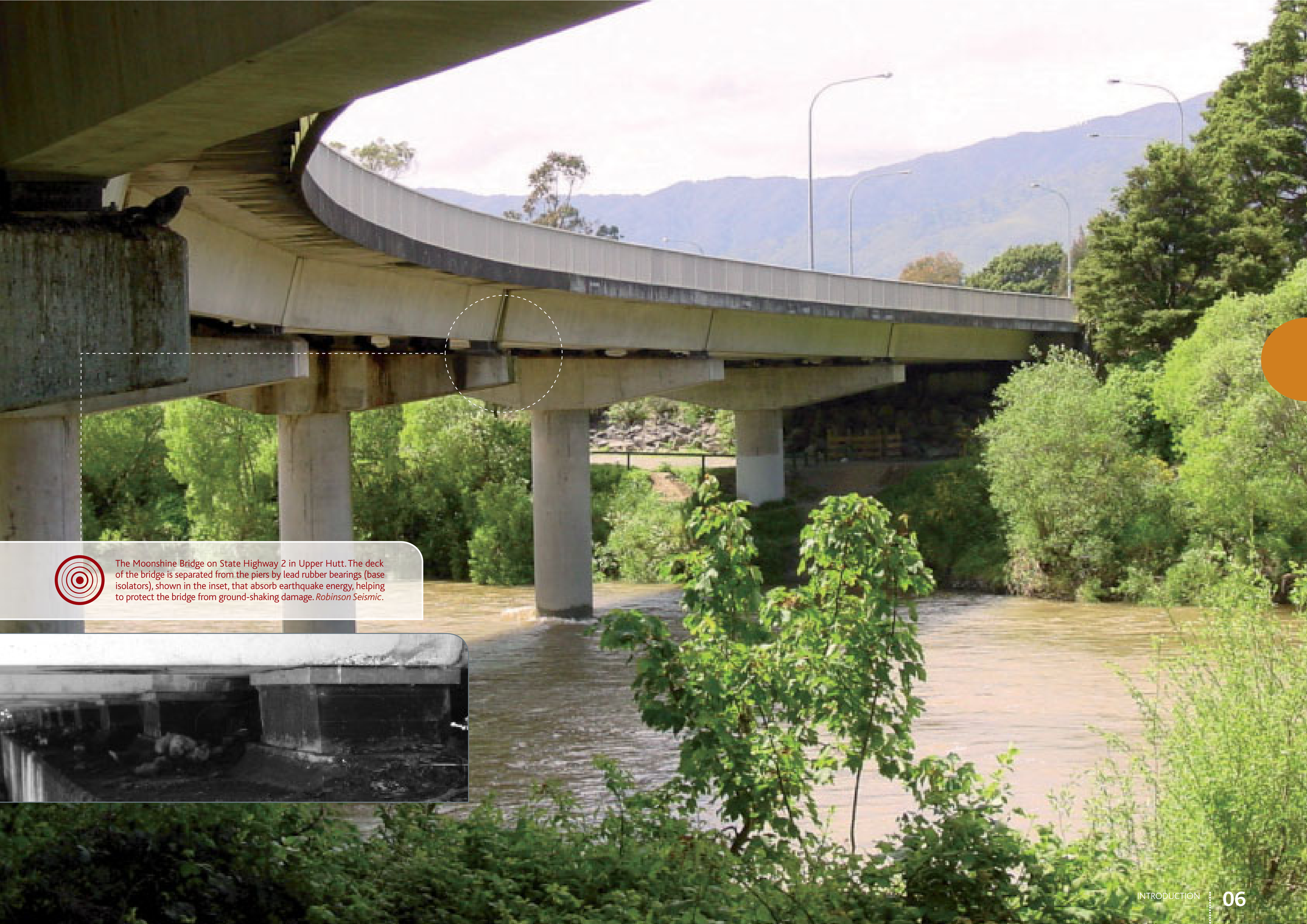
Understanding risk is important for two reasons. First, knowing how risk comes about helps identify ways of reducing it. Second, being able to calculate a value for risk helps with setting priorities for reducing risk.

Reducing risk requires either reducing the likelihood of the event or reducing its potential consequences, or both. Risk management has financial costs, and may require environmental, economic, or social trade-offs. These costs and trade-offs must be weighed against the benefits gained from reducing the risk. 'Acceptable', 'tolerable', and 'unacceptable' levels of risk will differ between communities, and may vary over time.

To assess risk, the probability of an event occurring and its consequences need to be known. Risk management in New Zealand is based on best practice as provided for by the Australian and New Zealand Standard (AS/NZS 4360:2004).

For some hazards, the probability, or chance, of an event occurring is calculated by averaging the number of times an event of a particular size has occurred over a defined period of time. For example, the chance of a magnitude 7 earthquake can be estimated by counting how many magnitude 7 earthquakes have occurred over a given period of time. If there have been 11 magnitude 7 earthquakes in the last 150 years, then an earthquake of that size has occurred every 13.6 years on average. The chance of another earthquake this size in any one year is 1 in 13.6, or about 1 in 15.

A river flood with a flow of 2000 m^3/s may be a '1-in-200-year flood'. This means a flood of this size or larger is likely to occur about once every 200 years. This does not mean that if a 1-in-200-year flood occurs, it will not happen again for another 200 years. Rather, it means that there is a 1-in-200, or 0.5 per cent, chance that there will be a flood of this size or greater in any year.



The Moonshine Bridge on State Highway 2 in Upper Hutt. The deck of the bridge is separated from the piers by lead rubber bearings (base isolators), shown in the inset, that absorb earthquake energy, helping to protect the bridge from ground-shaking damage. *Robinson Seismic*.

Hazard and risk management

The focus of hazard and risk management in the NHR is reduction and readiness. Recovery can also include, for example, taking the opportunity to relocate people and property away from hazard-prone areas after an event.

There are three main ways to reduce risk from hazards – modifying the event, modifying the proneness to damage, and minimising the consequences through rapid intervention.

Reducing risk by modifying the nature of an event or by modifying a community's proneness to damage works by cancelling or reducing at least one of the two factors – an extreme event and human use of an area – that interact to create a hazard. Removing one of those factors removes the hazard itself.

For natural hazards, modifying an event includes measures such as building retaining walls for unstable slopes, stopbanks for flood control, and sea walls to control coastal erosion and inundation. Stopbanks prevent flooding up to a certain design level. Their appeal lies in the direct and specific protection they offer. However, stopbanks cannot be built high enough to protect against all floods, and the consequences of their overtopping or failure during a flood may be severe.

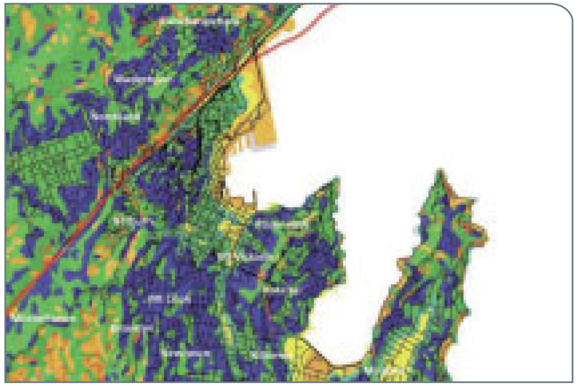
Avoiding places where an event is likely to occur and strengthening buildings are examples of modifying proneness to damage. Hazard maps can help planners make decisions on where development should take place and can be used for a wide range of land-use matters. An example of modifying a man-made risk is restricting the transporting of hazardous substances through urban areas.

Minimising the consequences of an event requires a wide range of planning. Response plans, part of readiness activities, are an example of a measure that provides a decision-making and coordination framework to help organisations respond efficiently and effectively to an event, and support the recovery of the community or affected facility. Exercises are valuable to test these frameworks and to highlight areas where they need to be amended or refined.

Readiness, response and recovery arrangements recognise that events may still happen that affect people, property and infrastructure, despite risk reduction measures that may have been taken. For example, there is always a risk that stopbanks and other flood mitigation structures may not contain a flood. Stopbanks can be breached or overtopped by floods larger than they were designed to cope with. In these cases, land-use controls and higher floor levels are effective ways to further reduce risk.

Minimising the consequences deals with the emergency that follows when a hazard becomes a reality. Response and recovery operations will address the consequences of the flood, and try to prevent an escalation of them. Damage and losses that are unavoidable (and uninsurable) are the residual risk associated with that event that individuals and the community must live with.

Stopbanks along the Hutt River protecting the Lower Hutt central business district during flooding in 1998. *Greater Wellington Regional Council*.



Part of the combined earthquake hazard map for Wellington City. Hazard maps help with planning decisions. *Greater Wellington Regional Council*.

Legislative framework for hazard and risk management

The Resource Management Act 1991 (RMA), the Civil Defence Emergency Management Act 2002 (CDEM Act), and the Building Act 2004 are three key pieces of legislation influencing and promoting integrated environmental management and recognition of hazards and risks. None of these Acts has priority over the others. They sit alongside each other and other legislation.

Other Acts address other specific aspects of hazard and risk management, such as the Biosecurity Act 1993, the Soil Conservation and Rivers Control Act 1941, the Environment Act 1986, the Hazardous Substances and New Organisms Act 1996, the Local Government Act 2002, the Health and Safety in Employment Act 1992, the Maritime Transport Act 1994, the Health Act 1956, and the Forest and Rural Fires Act 1977.

Resource Management Act 1991

The purpose of the Resource Management Act (RMA) is to promote the sustainable management of natural and physical resources. Under the RMA, both regional councils and territorial authorities have responsibilities to avoid or mitigate natural hazards.

Natural hazards must be considered in the preparation of regional policy statements, regional plans, and district plans. These documents are subject to preparation of a regulatory impact statement, and must allow the reasonable use of land. Regional councils identify significant environmental issues, and provide policy and certain regulatory controls. Territorial authorities are the principal consent authorities (through district plans) for subdivision and land-use approvals. Consideration of natural hazards by regional councils and territorial authorities is also achieved by monitoring the state of the environment and as part of a wide suite of considerations relevant to sustainable management and community well-being.

Civil Defence Emergency Management Act 2002

The CDEM Act was enacted in 2002 to repeal and replace the Civil Defence Act 1983. The Act promotes the sustainable management of hazards and encourages communities to achieve acceptable levels of risk. It specifies the role and function of civil defence emergency management organisations, and also the responsibilities of government departments, lifeline utilities, and emergency services for the 4Rs (reduction, readiness, response, and recovery).

The CDEM Act required the formation of regional CDEM Groups by 1 June 2003 and the preparation of a CDEM Group plan by 1 June 2005. There are 16 CDEM Groups in New Zealand and each comprises a regional consortium of local authorities, emergency services, health organisations, and lifeline utilities.

A focus of the CDEM Groups is identifying hazards and mitigation activities (reduction), and identifying gaps in hazard knowledge and inefficiencies in mitigation. The implementation of actions and initiatives to address the gaps and inefficiencies is core work for CDEM Groups. Hazard and risk reduction requirements identified as part of this process will be implemented mostly through RMA and Local Government Act planning.

Building Act 2004

The Building Act 2004 provides the means for ensuring the safety and integrity of structures. The Act is administered by the Department of Building and Housing and covers the performance requirements for the construction of buildings. The Act establishes a certification process to ensure compliance. The Building Code sets out specific criteria to which buildings and structures must conform.

The Act requires consideration of the nature of the land on which a building is to be built, as this may influence its structural requirements. Land that is, or is likely to be, subject to erosion, avulsion, alluvion, falling debris, inundation, or slippage may be the subject of a notice to ensure that all interested parties are informed.

THE NEW ZEALAND SETTING

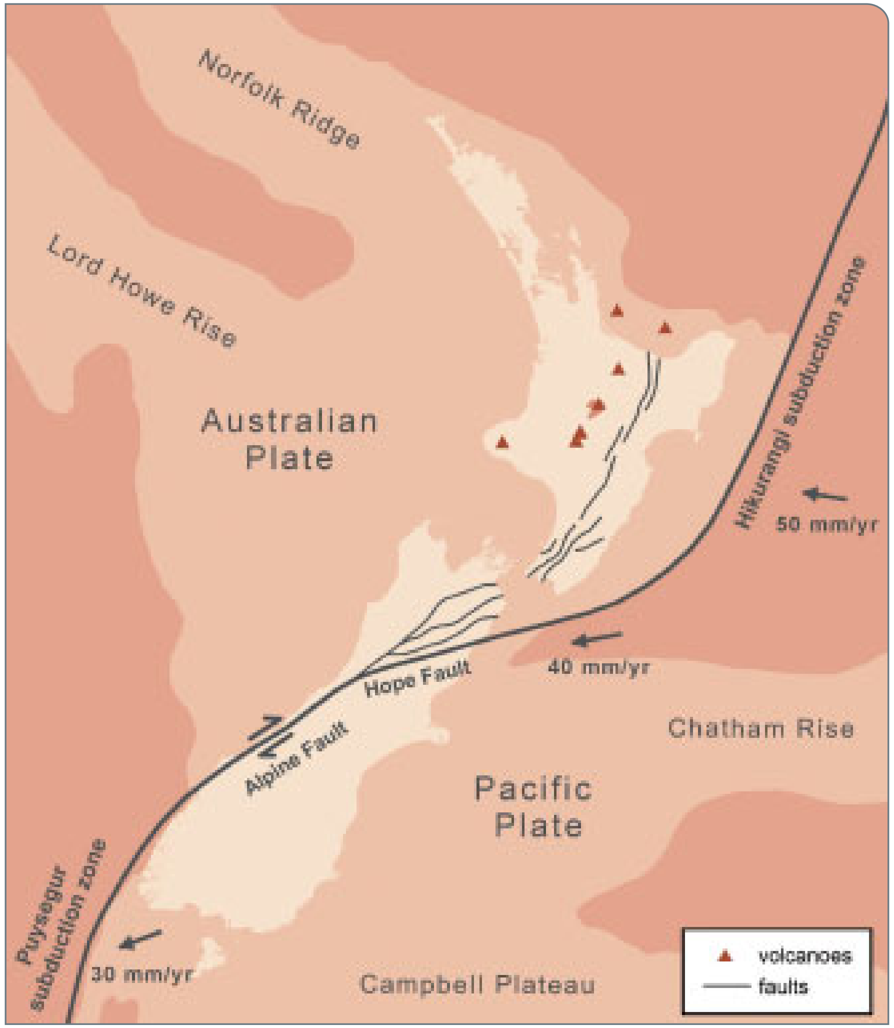
New Zealand is an island nation in the southwest Pacific. Its landscape has been shaped over millions of years by earthquakes, volcanoes, storms, and glaciers. Unique ecosystems evolved over this time in isolation from other land masses.

People arrived in New Zealand several hundred years ago and soon realised the destructive potential of these natural processes. By modifying the landscape and introducing many new species, people have altered some of these natural processes and New Zealand's ecosystems.

Geography

New Zealand lies midway between the equator and Antarctica, about 2600km east of Australia. Its three main islands, the North Island (113 729km^2), the South Island (150 437km^2), and the much smaller Stewart Island, stretch 1500km across latitudes 34° to 47° south and are the visible parts of an extensive, mostly submarine continent.

New Zealand lies across the boundary of the Australian and Pacific tectonic plates. To the east of the North Island, the Pacific Plate is being subducted under (pushed under) the Australian Plate. To the southwest of the South Island the opposite is happening – the Australian Plate is being subducted under the Pacific Plate. These two subduction zones are connected by the Alpine Fault and several smaller faults that run through the South Island.



The tectonic setting of New Zealand showing the generalised plate boundary between the Australian and Pacific tectonic plates. The Pacific Plate is moving towards the Australian Plate at around the same rate that fingernails grow. *University of Canterbury.*

Volcanoes, fed by melting of the subducted Pacific Plate, rise in the centre, north, and west of the North Island. Lake Taupo, New Zealand's largest lake, fills the depressions left by several extremely large eruptions of the Taupo volcano, and is overlooked by Mt Ruapehu, the North Island's highest point at 2797m. The remainder of the North Island is mainly rolling hill country, much of which is farmed. A series of narrow ranges – Tararua, Ruahine, Kaimanawa, and Raukumara – runs along the eastern side of the island.

Farmland near Raglan, in the western Waikato region. This rolling hill country is typical of much of the North Island. *GNS Science.*

The geography of the South Island is dominated by the Southern Alps, rising to more than 3000m, created by uplift along the plate boundary over several million years. To the west and north, short, steep rivers flow through rainforest to the Tasman Sea. To the east, the Canterbury Plains are dissected by large braided rivers that flow to the Pacific Ocean. To the south are long glacial lakes that drain through inland basins and rich farmland.

The Rakaia River and the Southern Alps. The Rakaia is one of many large braided rivers that run from the mountains across the Canterbury Plains farmland to the east coast of the South Island. *GNS Science.*

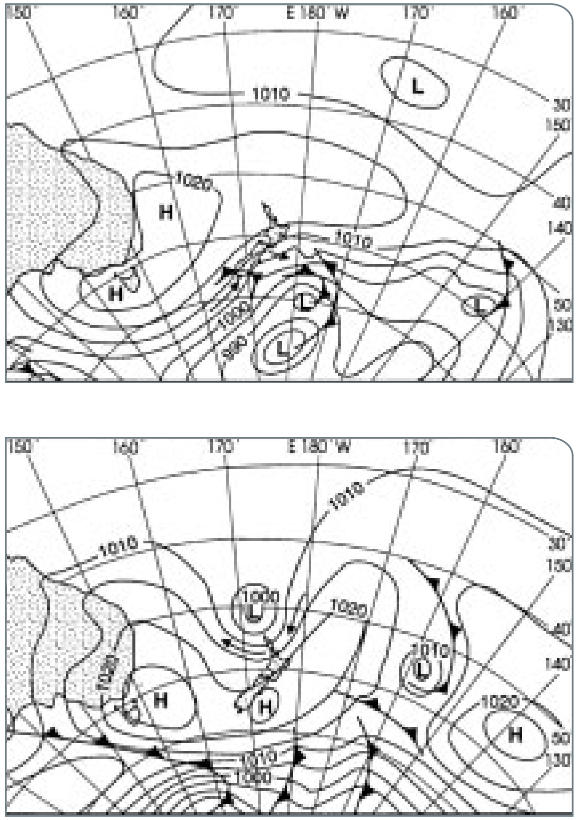
New Zealand has around 18 000km of coastline. Of that, 11 000km are exposed to the open ocean and the remainder are sheltered in harbours and estuaries. The western and southern coasts are exposed to persistent swells, while the northern and eastern coasts are more sheltered. Warm, salty, subtropical currents exist in the north and west of New Zealand, with cold, less saline, subantarctic currents in the south. Summer water temperatures range from about 21°C in the north to 14°C in the south.

Climate

New Zealand lies in the mid-latitude zone of westerly winds, known as the 'roaring forties', which flow around the Southern Hemisphere. The weather is typically dictated by an irregular succession of anticyclones and troughs of low pressure on a 6- to 7-day cycle. Anticyclones (high-pressure systems) generally track eastwards across the North Island and bring settled weather with little or no rain. The intervening troughs of low pressure, often containing cold fronts, extend northwards over the country from low-pressure systems that track eastwards to the south of the South Island. The cold fronts bring rain, followed by showers.

The prevailing wind direction is westerly. This wind pattern is modified by the blocking effect of the Southern Alps and North Island ranges. Wind strength decreases on the western side of the ranges, but increases through any gaps in the ranges such as Foveaux Strait, Cook Strait and the Manawatu Gorge. Air is also forced upwards over the ranges (orographic lift), which creates a warm, dry (föhn) wind in the lee areas to the east of both islands.

New Zealand's climate is influenced by the El NiñoSouthern Oscillation, a Pacific-wide oscillation that affects air pressure, wind, sea-surface temperature, and rainfall. New Zealand generally experiences stronger than normal southwesterly airflows in El Niño phases, which results in drier conditions in northern and eastern areas, and stronger than normal northeasterly airflows in La Niña phases.



Typical synoptic maps for the New Zealand area during La Niña (top) and El Niño (bottom) phases of the El Niño Southern Oscillation. *Mosley and Pearson, 1997.*

The mountain ranges also control the distribution of rainfall, which varies greatly over short distances. The highest rainfall occurs in the west of both islands where mountains are exposed to westerly winds. More than 8000mm of rain is recorded each year in the Southern Alps. The areas of lowest rainfall are in the lee of the main ranges, such as Central Otago where average annual rainfall is as low as 300mm. However, average annual rainfall in most of the country is between 600 and 2000mm.

Average temperatures decrease from about 15°C in the Far North to about 10°C in the south of the South Island. January and February are the warmest months of the year and July is the coldest. The highest temperatures are recorded east of the main ranges; 42°C has been recorded in the Awatere Valley (Marlborough), Christchurch, and Rangiora (Canterbury). The lowest recorded temperature is -22°C at Ophir (Central Otago).

The North Island has a small permanent snowfield above 2500m on the central plateau, but the snowline rarely descends below 600m. In the South Island, the snowline varies from 2000m in summer to around 1000m in winter. Snow commonly falls to around 300m, and occasionally to sea level in the south and east of the South Island in the winter, but the snowline rarely remains below 1000m for extended periods.

New Zealand society

New Zealand has a population of about 4.23 million. Its population density, of around 15 people per km^2, is relatively low by world standards. About 75 per cent of the population live in the North Island and almost 86 per cent of New Zealanders live in urban areas. New Zealand's population is projected to reach about 5 million by 2050.

New Zealand's population is ageing. This is the result of a surge in the birth rate after the Second World War (the 'baby boomer' generation) and the influx of immigrants who arrived at that time and started families. In 1971 children aged below 15 made up 32 per cent of the population; by 2001 this figure had dropped to 23 per cent. Life expectancy at birth in 2000 was 81 years for females and 76 for males.

New Zealanders of Māori origin account for around 16 per cent of the population, 90 per cent of whom live in the North Island. Just over two-thirds of New Zealand's population is European in origin, largely because between the early 1800s and the mid-1970s immigrants came mainly from Europe. More recent immigrants have come mainly from the Pacific Islands and Asia, and now each of those groups makes up around 7 per cent of the population.

The most notable contrasts in population are between Auckland, where one-third of the population lives, and the rest of the New Zealand. Auckland has a higher percentage of Asian and Pacific Island people than the rest of the country.

New Zealand has a very mobile population – about half the resident population aged five or over moves house at least once every 5 years. The fastest growing regions are currently Auckland, Bay of Plenty, Nelson/Tasman, Northland, and Waikato. However, much of this growth is the result of immigration, and higher Māori and Pacific Island birth rates in the northern North Island, rather than internal migration.

New Zealand's economy

New Zealand's economy is based on market forces. The Government provides a framework of commercial law in which transactions occur. In some sectors, most notably education and health, the Government is the most important funder and provider. Although the market mechanism has been dominant ever since European settlement, the balance between government involvement and voluntary market transactions has varied.

The tertiary (service) sector dominates production and employment, and the share of secondary (manufacturing) and primary (resource) industries is decreasing. Most industries are technologically sophisticated by world standards, relying on a skilled workforce.

Primary sector

The primary sector includes agriculture, fishing, forestry, energy, and mining and quarrying. The most important forms of farming are dairy, sheep, beef, deer, goats, pigs, poultry, bees, crops, fruit and vegetables, and vineyards. The primary sector has historically been a strong contributor to the New Zealand economy. It continues to be influential, directly contributing 8 per cent of gross domestic product (GDP) and indirectly 17 per cent of GDP through flow-on effect into manufacturing, processing, education, technology, communications, and transport businesses.

Most of New Zealand's agriculture remains internationally competitive, partly because animals are largely grass-fed, but also because New Zealand farming is technologically innovative and sensitive to market opportunities and changes.

Being a resource-based industry, much of the primary sector is strongly influenced by meteorological conditions.

Because New Zealand is highly dependent on its land-based industries, inadequate hazard management, along with climate change and human modification of the natural environment, poses a real threat to New Zealand's economic sustainability. Hazards to property –

farms, forestry plantations, vineyards, orchards, farm animals, and on-farm infrastructure – pose a significant risk to the economic viability of individuals, communities, and industries.

Secondary sector

In 2001 the manufacturing sector contributed about 16 per cent to GDP, down from the 25 per cent that was typical of much of the 1900s. In part this decrease reflected the trend occurring in other developed countries, but it was also a result of the elimination of all import licensing and of most tariffs from the mid-1980s.

The largest sub-sectors are food, beverages, and tobacco, followed by machinery and equipment. Auckland was the largest centre for manufacturing in 2001, with 53 per cent of the 235 000 manufacturing labour force.

Tertiary sector

Transport, communications, commercial services, and tourism are New Zealand's main tertiary sectors. Transport plays an important role because of New Zealand's long and rugged terrain, its thinly spread population, and its distance from other countries.

New Zealanders have had choice and technological sophistication in communications since the late 1980s. New Zealanders have also quickly accepted telecommunications developments, especially cell-phones and the internet. The information and communications technology (ICT) sector is thriving, and New Zealand exports hardware, software, and services.

Other significant commercial services include wholesale and retail trade, banking, and insurance. More and more New Zealand companies provide services offshore using broadband internet. New Zealand is also developing a significant role in the world biotechnology industry.

Tourism is New Zealand's largest industry. During the 1990s, overseas tourist numbers doubled and tourism became the country's leading earner of foreign exchange.

Exports

New Zealand has had a high level of trade since becoming part of the world economy in the 1800s.

Before 1960 more than 90 per cent of New Zealand's exports were farm products, mostly wool, meat, butter, and cheese, two-thirds of which went to Britain. Farm exports today are much more sophisticated and involve more processing beyond the farm. Dairy products account for 21 per cent of New Zealand's exports by value but most dairy products are exported as milk powder rather than as butter or cheese. Meat exports have dropped from 30 per cent in the mid-1960s to 10 per cent today. Exports now also include timber, cut flowers, kiwifruit, apples, vegetables, and wine. Primary products continue to be New Zealand's biggest and most consistent revenue earner.

The manufacturing sector is a major exporter, either by processing and adding value to the primary sector exports, or by general and specialist products in their own right. Among the range of goods sold overseas are whiteware (fridges and dishwashers), electric fences, newsprint, and furniture.

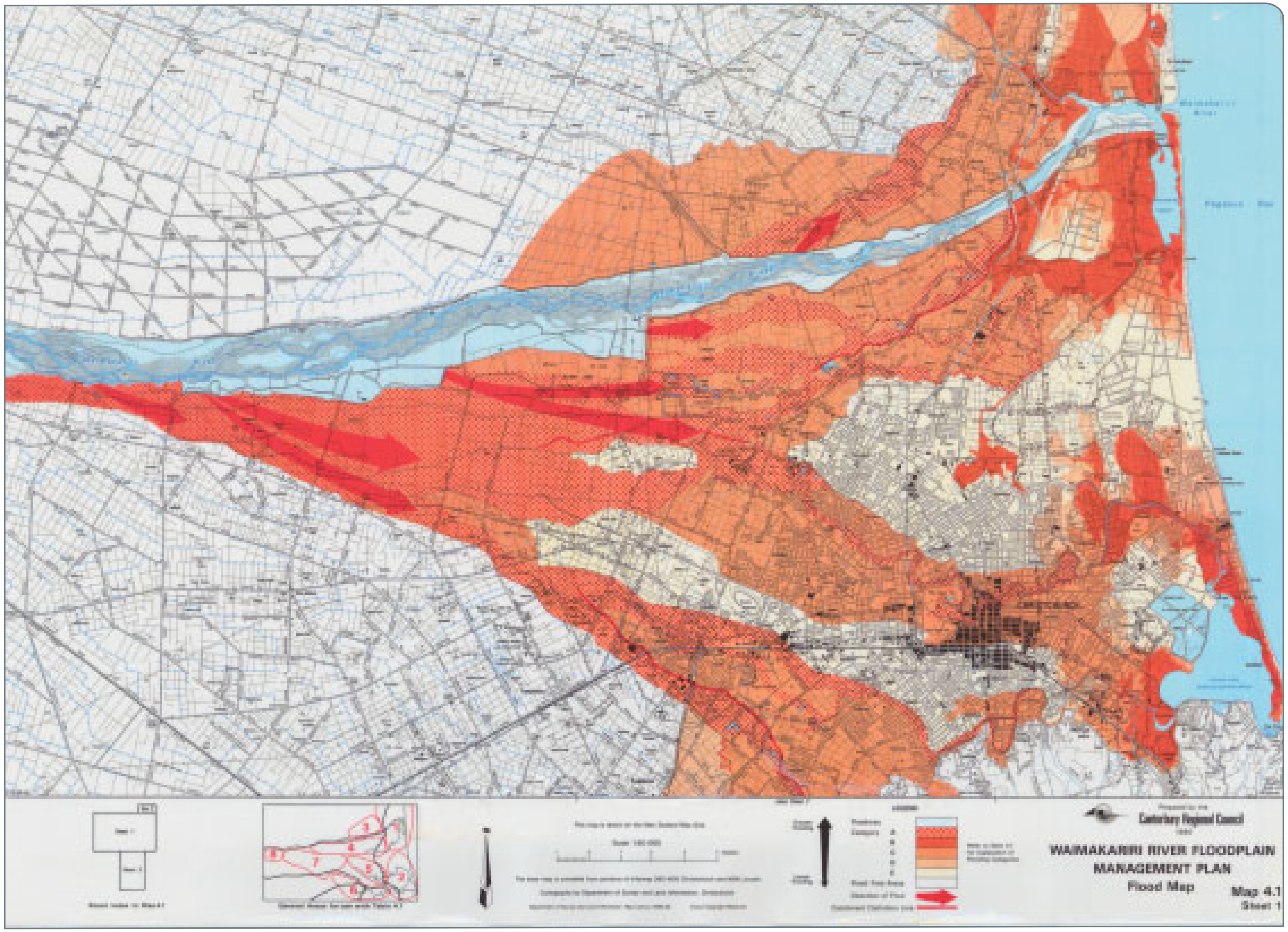
The biggest change in exporting has been providing services, which by 2001 were contributing about a quarter of the country's exports. This was largely a result of the rise of international tourism to New Zealand, although other service activities, most noticeably the film industry, also made a considerable contribution.

Export destinations have changed dramatically. Australia is now New Zealand's single largest export market with more than 22 per cent of exports in 2006, followed by Japan, the United States of America, China, and Korea. Asia takes about a third of all New Zealand exports.

FURTHER INFORMATION

GENERAL INFORMATION

MOSLEY, M P AND PEARSON, C P (EDS), 1997, FLOODS AND DROUGHTS. New Zealand Hydrological Society, Christchurch.



Flood hazard to Christchurch from the Waimakariri River, 1990. Flood protection works costing about $30 million are proposed. The existing flood protection works and proposed improvements are expected to contain flood flows of 6500 m^3/s – a one in 10 000 year event. Environment Canterbury estimates a major flood could inundate residential and industrial areas, causing up to $2 billion worth of damage and affecting up to 300 000 people. *Environment Canterbury.*

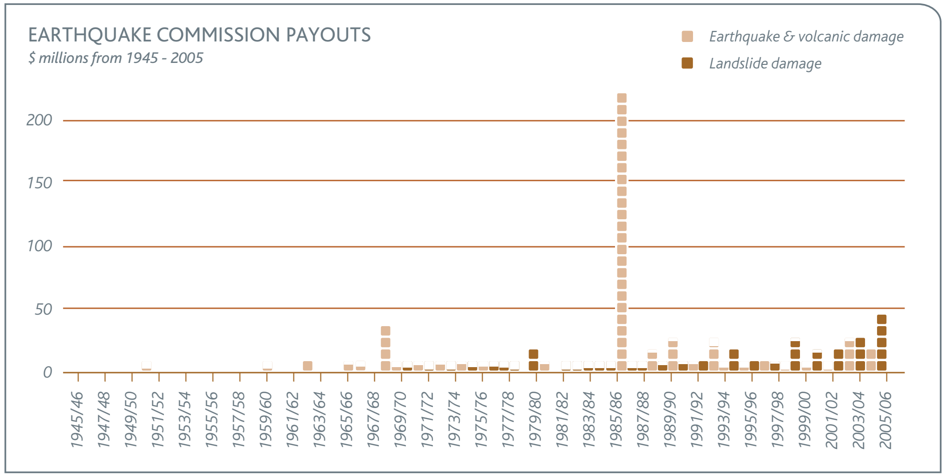
HAZARD EVENTS IN NEW ZEALAND

New Zealanders have been, and continue to be, at risk from a broad range of hazards. However, the types of emergencies that have occurred in New Zealand have changed over time. In the 1800s and early 1900s many people died in shipping accidents, fires and epidemics – the 1854 measles epidemic and 1918 influenza epidemic collectively accounted for more than 12 600 deaths. The Mt Tarawera eruption in 1886 and Hawke's Bay earthquake in 1931 were the most significant natural events of this period, with 153 and 256 deaths respectively.

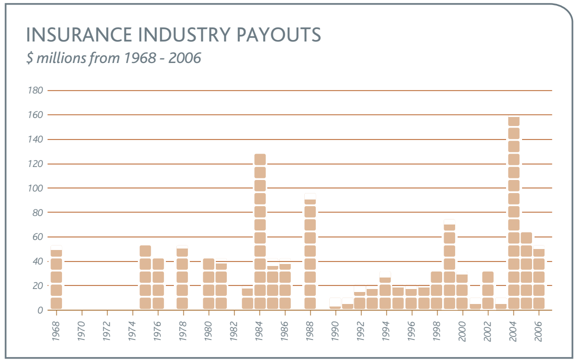
Since the mid-1900s relatively few people have died from natural hazards, with most hazard deaths attributed to transport accidents. The three main transport accidents were the Tangiwai train derailment in 1953, the sinking of the *Wahine* in 1968, and the Air New Zealand flight TE901 Mt Erebus crash in Antarctica in 1979. The crash of flight TE901 remains New Zealand's deadliest disaster with 257 deaths.

The scene of the 1953 Tangiwai train derailment. The Wellington to Auckland express train plunged into the Whangaehu River on Christmas Eve, killing 151 people, after a lahar from Mt Ruapehu washed away part of the rail bridge. *Alexander Turnbull Library.*

Since 1970 there have been many floods causing significant evacuations of people and damage to property, but few deaths. The most notable natural hazard event in the last 20 years was the 1987 Edgecumbe earthquake.



Earthquake Commission payouts for earthquake and volcanic damage (light brown) and landslide damage (dark brown) 1945/46-2004/05 in 2006 dollars. The 1987 Edgecumbe earthquake was by far the most expensive event during this period, resulting in $209 million in Earthquake Commission payouts, followed by the 1968 Inangahua earthquake, and landslide events during 2005. *Earthquake Commission.*



Insurance industry payouts for weather-related events 1968-2006 in 2006 dollars. The 1984 Southland flood, Cyclone Bola in 1988, and the February 2004 storm have been New Zealand's most expensive weather-related events during this period. *Insurance Council of New Zealand.*

Some significant New Zealand hazard events (1846 to 2007)

Some significant New Zealand hazard events are listed in the following table. Many of the geological and meteorological events, and in particular earthquakes, floods and snowstorms, have had significant economic impacts.

Date	Event
May 1846	Landslide at Te Rapa, Lake Taupo – at least 60 dead
October 1848	Marlborough earthquake – 3 dead
1854	Measles epidemic – 4000 dead
January 1855	Wairarapa earthquake – 7 dead
January 1858	Flooding in the Hutt Valley – 9 dead
February 1863	HMS Orpheus wrecked on the Manukau Bar – 185 dead
July 1863	Snowstorm and floods in Otago – about 100 dead
April 1865	The ship Fiery Star burned near the Chatham Islands – 78 dead
September 1878	Severe floods in the Clutha Valley with widespread damage
February 1879	Kaitangata mine explosion – 34 dead
April 1881	The steamer Tararua wrecked at Waipapa Point – 131 dead
June 1886	Eruption of Mt Tarawera – 153 dead
February 1909	The steamer Penguin wrecked in Cook Strait – 75 dead
September 1914	Explosion and fire at Ralph's mine, Huntly – 43 dead
1918	Influenza epidemic – 8600 dead
July 1923	Train crash at Ongarue – 17 dead
June 1929	Murchison earthquake – 17 dead
February 1931	Hawke's Bay earthquake – 256 dead
February 1938	Flash flood at Kopuawhara – 21 dead
June 1943	Express train derailed at Hyde, Otago – 21 dead
November 1947	Ballantyne's department store fire, Christchurch – 41 dead
October 1948	National Airways Electra crash on Mt Ruapehu – 13 dead
March 1949	National Airways Lodestar crash in the Tararua foothills – 15 dead
December 1953	Express train derailed at Tangiwai – 151 dead
July 1963	National Airways Dakota crash in the Kaimai Range – 23 dead
January 1967	Explosion at the Strongman mine, Greymouth – 19 dead
April 1968	TEV Wahine wrecked in Wellington Harbour – 51 dead
May 1968	Inangahua earthquake – 3 dead, 300 evacuated
February 1973	Parnell chemical leak – 4000 families evacuated
October 1978	Otago and Southland floods – about 3000 evacuated
August 1979	Abbotsford landslide – 69 houses destroyed or badly damaged
November 1979	Air New Zealand DC10 crash at Mt Erebus – 257 dead
June 1980	Taieri flood – 1400 evacuated
September 1980	Marton LPG leak – 1500 evacuated
April 1981	Thames Valley flood – 2250 evacuated
July 1983	Golden Bay and Marlborough flood – 200 evacuated
January 1984	Southland floods – damage to more than 1200 homes
February 1985	Thames Valley flood – 4 dead, 170 evacuated
July 1985	Poverty Bay flood – about 100 evacuated
January 1986	Nelson Bays flood – 150 evacuated
March 1986	Aorangi flood – 1 death, 1360 evacuated
March 1987	Edgecumbe earthquake – 5000 evacuated
March 1987	Southland flood – 700 evacuated
March 1987	Thames scrub fire – 130 evacuated
March 1987-88	Canterbury drought
March 1988	Cyclone Bola – 5 dead, 5000 evacuated
May 1988	Greymouth flood – 402 evacuated
July 1988	Palmerston North flood – 1200 evacuated
September 1988	Greymouth flood – 1 death, 356 evacuated
January 1989	Great Barrier Island flood – 154 evacuated
March 1990	Cyclone Hilda (Taranaki and Wanganui) – 147 homes evacuated
February 1991	Catlins flood – 128 evacuated
August 1992	Canterbury snowstorm
January 1994	Southland and Otago floods – more than 3000 tourists displaced
March 1994	South Canterbury flood – 240 evacuated
August 1994	Timaru grain store bulge – 300 evacuated
November 1994	Wanganui flood – 157 evacuated
April 1995	Cave Creek viewing platform collapse – 14 dead
1995	Mt Ruapehu eruption
July 1995	Thames Valley flood – 30 evacuated
December 1995	Waitaki and Waimate flood – 100 evacuated
1996	Mt Ruapehu eruption
December 1996	Thames-Coromandel storm – 1 dead, 2000 evacuated
January 1997	Thames-Coromandel storm – 3 dead, 140 evacuated
February 1997	Opuha dam failure, Timaru district – 200 evacuated
June 1997	Wairoa flood – 166 evacuated
October 1998	Buller flood – 66 evacuated
October 1998	Buller flood – 220 evacuated
October 1998	Kapiti Coast and Wanganui flood – 1 death
January 1999	Far North flood – 270 evacuated
February 1999	Central Otago rural fire – 1 dead, more than 200 evacuated
November 1999	Otago floods – 140 evacuated
June 2002	Thames and South Waikato flood – 1 dead, 500 evacuated
October 2003	Kapiti Coast flood and landslides – 5 evacuated
February 2004	Manawatu-Wanganui, Taranaki, Hawkes Bay, Waikato, Wellington and Marlborough floods – more than 1800 evacuated
July 2004	Opotiki and Whakatane flood and landslides – 1 dead, more than 1300 evacuated
May 2005	Bay of Plenty flood and landslides – more than 410 evacuated
April 2006	Dunedin flood – about 120 evacuations
June 2006	Canterbury snowstorm – widespread power and telecommunication outages, and many roads closed
March 2007	Mt Ruapehu lahar
March 2007	Far North flood – evacuations and damage to roading and other infrastructure
July 2007	Taranaki tornadoes – 73 properties damaged
July 2007	Upper North Island flood and severe wind – settlements isolated, roads closed, power and telecommunication outages
July 2007	Hawke's Bay flood – 1 evacuated
July 2007	South Otago flood – 40 evacuated

Hill country erosion after Cyclone Bola in 1988. Up to 750 mm of rain fell over an area from Hawke's Bay to East Cape in four days. *GNS Science*.

Milk silos at the Edgecumbe dairy factory after the 1987 Edgecumbe earthquake. This earthquake remains New Zealand's costliest to date. *Whakatane Beacon*.

Prestonville industrial area and part of suburban Waikiwi, Invercargill, January 1984. *Otago Daily Times*.

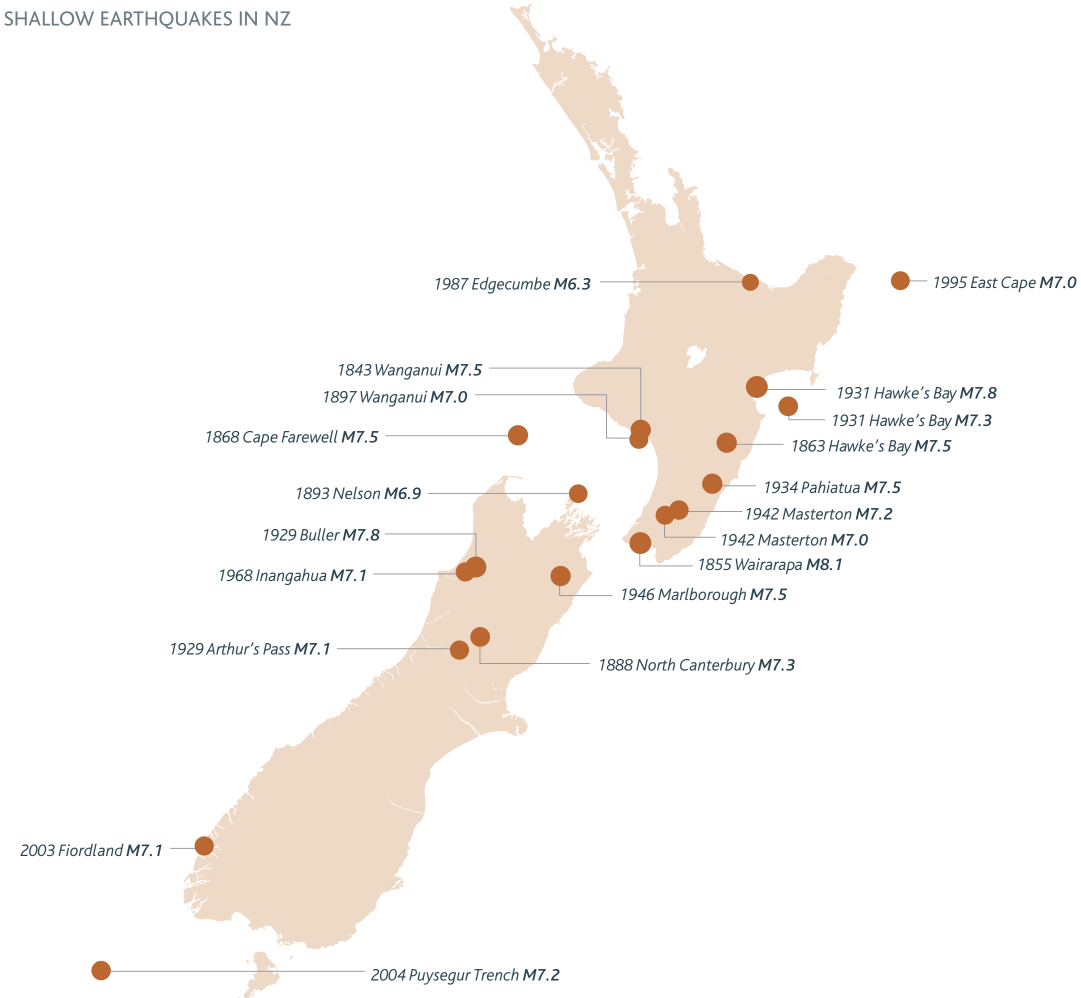
Waimakariri River flood, 1868. Flooding near the Canterbury Provincial Council Buildings in Christchurch. The Waimakariri River overflowed near Halkett and entered old channels flowing through Avonhead and Fendalton to the Avon River. *D. L. Mundy, Canterbury Museum collection.*

EARTHQUAKES

New Zealand experiences many earthquakes because it is located across the boundary of two tectonic plates. Ten to fifteen thousand earthquakes are recorded each year in and around New Zealand, but only about 150 of these are felt.

Based on its seismic history, New Zealand should experience 10 to 20 magnitude 5 earthquakes and one magnitude 6 earthquake each year, and a magnitude 7 earthquake each decade. However, earthquakes are not evenly spread over time and they often occur in clusters. The last 60 years have been relatively quiet with only two onshore earthquakes greater than magnitude 7. But a damaging earthquake could happen at any time. At least a million New Zealanders (around 25 per cent of the population) are expected to experience shaking great enough to damage household contents and buildings in the next 50 years.

NOTABLE SHALLOW EARTHQUAKES IN NZ
1840–2005



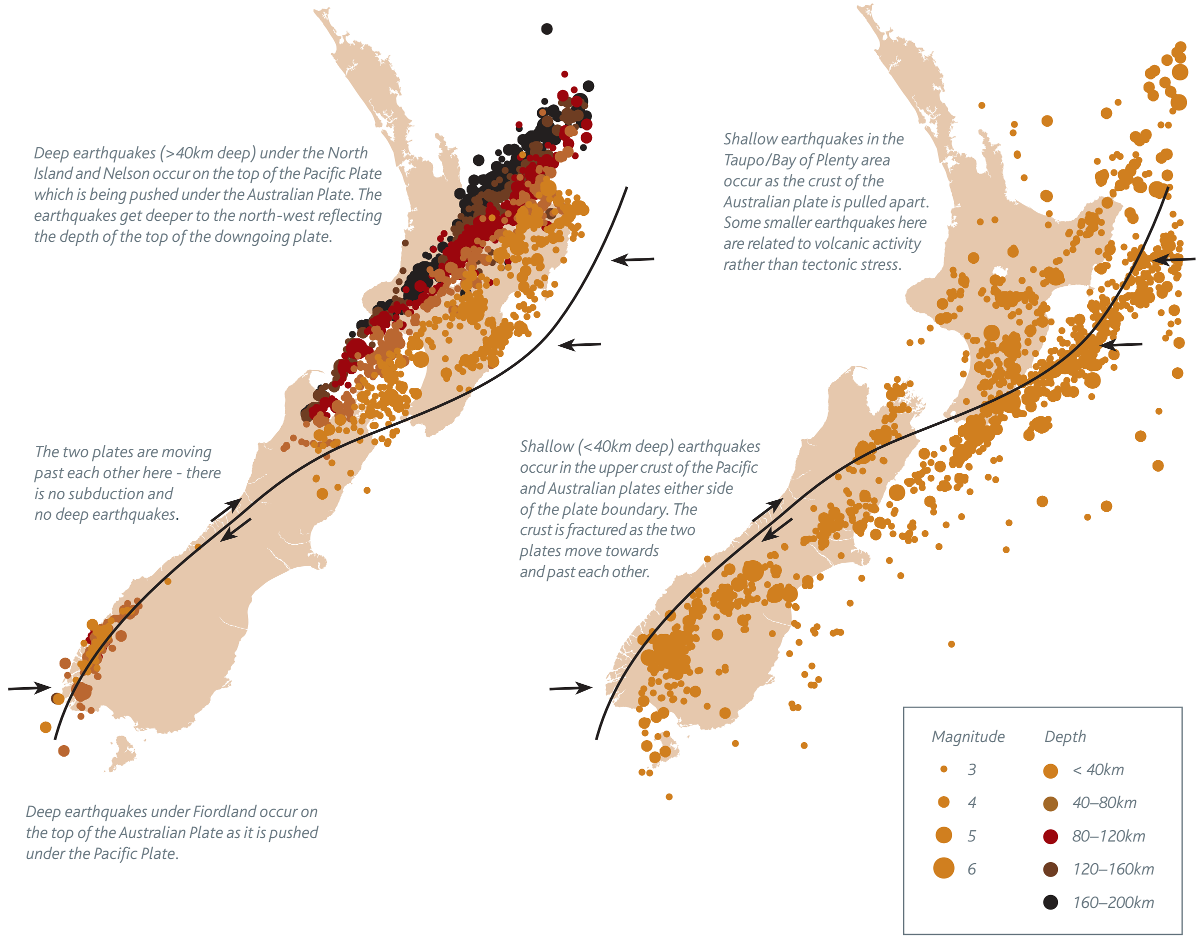
Major historic earthquakes in New Zealand since 1840. Many damaging earthquakes occurred in the early years of European settlement but there have been few over the last 60 years. *GNS Science.*

New Zealand's earthquakes

An earthquake is the sudden release of slowly built-up strain along a fault (fracture) in the earth's crust. In New Zealand that strain accumulates as the Pacific and Australian tectonic plates move past each other. Most of New Zealand's seismic activity, including its major historic earthquakes, occur within a broad zone of deformation about 100km wide that runs along the plate boundary from offshore East Cape to Fiordland.

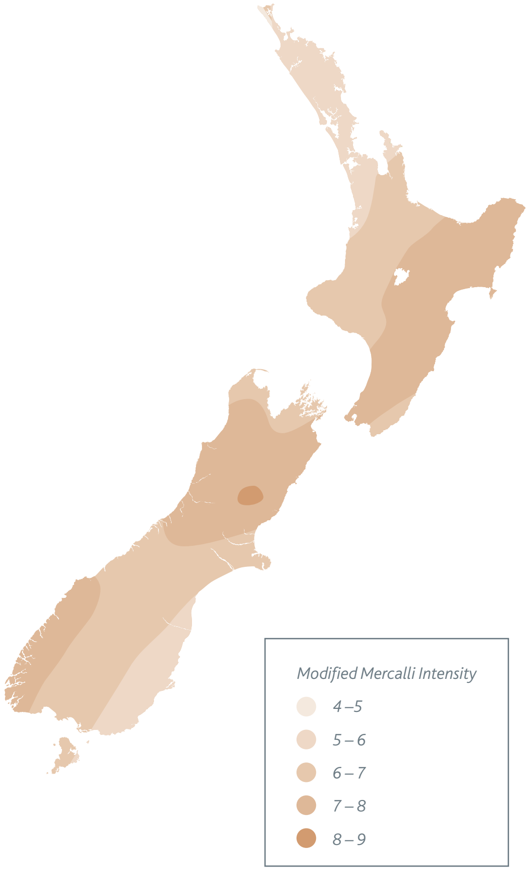
High-hazard areas along this zone include Gisborne, Hawke's Bay, Wairarapa, Wellington, Marlborough, North Canterbury, Buller, the Southern Alps, and Fiordland. The earthquake hazard in these areas is comparable to that in California. Northland and southeastern Otago, farthest from the plate boundary, have the lowest earthquake hazard. Moderate but damaging earthquakes have however occurred in both these locations.

SHALLOW AND DEEP EARTHQUAKES



Earthquakes of magnitude 2 or greater recorded in New Zealand in 2005. The distribution and depth of earthquakes is related to the behaviour of the two tectonic plates. *GNS Science*.

INTENSITY OF GROUND SHAKING



The earthquake hazard in New Zealand represented as the intensity of ground-shaking expected in a 50-year period, based on historical seismicity and the location of active faults in New Zealand and how frequently they move. *GNS Science*.

EARTHQUAKE MAGNITUDE AND INTENSITY

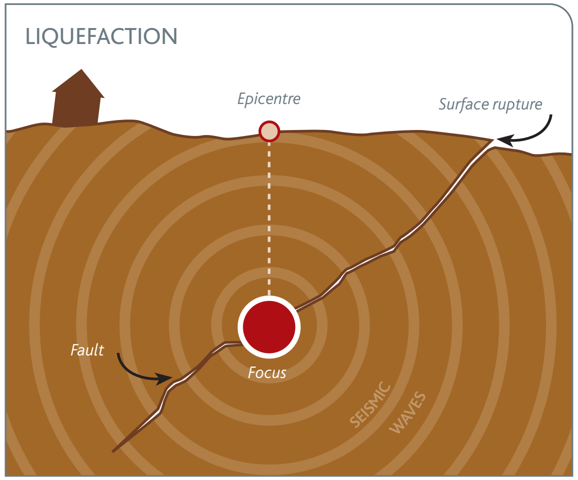
Earthquakes are described by both their magnitude and their intensity. Earthquake magnitude is a measure of the energy released during an earthquake, or its 'size'. Charles Richter first devised a magnitude scale in 1935 using data recorded on seismographs.

Earthquake intensity describes how much ground shaking occurred, or how 'strong' the earthquake was, at a particular location. Earthquake intensity depends not only on the magnitude of the earthquake but also on how far away it was, how deep it was, and the local geology, for example whether the ground is sand or rock. An earthquake generally feels less intense further away from the epicentre. In New Zealand intensity is measured using the Modified Mercalli (MM) intensity scale which is a descriptive scale from 1 to 12 based on how people feel an earthquake, and the damage to contents and buildings.

Shaking below MM intensity 4 is generally not felt or only felt inside. With MM intensity 7 shaking, it is difficult to stand, furniture breaks and loose bricks and tiles fall. Intensity 8 shaking damages ordinary masonry and topples chimneys and towers. Intensity 9 shaking causes panic and damages or destroys masonry and foundations. Damage is almost total with shaking at MM intensity 12.

Earthquake hazards

The energy released in an earthquake, and the permanent ground deformation produced, creates earthquake hazards with a range of both local and widespread impacts.



Earthquakes generated on faults in the earth's crust can cause fault rupture, ground shaking and liquefaction at the ground surface.

Ground-shaking

The energy released during an earthquake radiates away from the earthquake source as a variety of wave types. The intensity of ground-shaking at a particular point depends not only on the magnitude of the earthquake but also on the distance from the earthquake and the local geology. Soft ground, such as sandy or silty sediments, tends to amplify ground-shaking. Aftershocks will also occur after a large earthquake as the land adjusts to the displacement that has occurred.

1931 HAWKE'S BAY EARTHQUAKE

New Zealand's most destructive earthquake happened on the morning of 3 February 1931. A magnitude 7.8 earthquake centred 25km northeast of Napier was felt from Auckland to Canterbury.

Many of Napier's and Hastings' masonry buildings collapsed, including the new nurses' home, killing staff and sleeping nurses. The technical college also collapsed but, as it was morning tea time, most students were outside. In total 256 people died in Napier, Hastings, and Wairoa, and thousands were injured. About 3500 hectares of land, formerly the Ahuriri Lagoon north of Napier, was uplifted almost 2m. A lack of water and sewerage hampered recovery, as did aftershocks including a magnitude 7.3 earthquake 10 days after the main shock. The earthquake highlighted the need for stronger buildings and prompted the development of New Zealand's building standards.

Much of Napier's central business district was destroyed in the 1931 earthquake - many buildings collapsed and were subsequently gutted by the fire that burnt for two days. *Hawke's Bay Museum and Art Gallery.*

These smaller earthquakes can continue for weeks, months, or even years after a large earthquake.

Ground-shaking during an earthquake is inevitable and can be regionally extensive, but buildings and other structures can be sited and constructed in ways that reduce the likelihood of damage and injury.

Fault rupture

If an earthquake is large and shallow (generally greater than magnitude 6.5 and less than 40km deep) the displacement on the fault may reach the ground surface, offsetting the ground both horizontally and vertically. New Zealand has many active faults within the plate boundary deformation zone that have ruptured the ground surface in this way. The largest historic fault displacement was recorded on the Wairarapa Fault, which moved 18m horizontally in the 1855 Wairarapa earthquake. Some faults move more often than others – there are more than 50 faults in New Zealand that, on average, move every 2000 years or less. The most active faults, the Alpine Fault and the Hope Fault in the South Island, move on average every few hundred years, creating large earthquakes and metres of permanent displacement along the fault.

Fault rupture will sever underground services, such as water pipes, that cross the fault, and can damage or destroy structures built on the fault. Fault-rupture hazard is confined to a relatively narrow corridor along the fault, and because fault rupture tends to generally occur repeatedly in the same place, the location of future ground rupture can be predicted with some degree of confidence.

Surface rupture of the Edgecumbe Fault in the 1987 Edgecumbe earthquake, New Zealand's most damaging earthquake in the last 35 years. The ground surface was vertically displaced across several fault strands by a total of 2.5 metres. *GNS Science.*

Liquefaction

Liquefaction occurs when saturated fine-grained sediments, such as sand and silt, behave more like a liquid than a solid during an earthquake. During intense ground shaking (greater than MM intensity 7) these sediments can lose their strength, and buildings may sink or tilt. Buried services such as pipes can become buoyant and rise to the surface, and unsupported or poorly-supported land such as riverbanks and wharves can spread sideways.

A road after the 1931 Hawke's Bay earthquake. Liquefaction of soil under the road caused it to subside. *Hawke's Bay Museum and Art Gallery.*

Areas that may be susceptible to liquefaction can often be identified by their geology. Important facilities can be sited away from these areas, or the soil can be treated by compaction or other engineering techniques to reduce the potential for liquefaction.

Landslides and tsunamis

Landslides are second only to building collapses as causes of death in New Zealand earthquakes, claiming 16 lives in the 1929 Murchison earthquake and three in the 1968 Inangahua earthquake. Large earthquakes can cause widespread landsliding, particularly in the steep and fractured Southern Alps.

Tsunamis can be generated when earthquakes occur off the New Zealand coast, either by rupture of the sea floor or through underwater landslides. Tsunamis triggered by local earthquakes may reach the shore within minutes.

Coastal areas may be inundated due to uplift or subsidence of land during an earthquake. For example, parts of Lambton Quay in Wellington were temporarily flooded immediately after the 1855 Wairarapa earthquake. This was because land west of the Wairarapa Fault was raised, causing water to 'slosh' back and forth across the harbour.

Landslides and tsunamis are also caused by other mechanisms. The consequences of landslides and tsunamis, whatever the cause, can be catastrophic and they are discussed in further sections of this report.

Managing earthquake hazards

Earthquakes happen with little or no warning. Hazard and emergency management for earthquakes relies on risk reduction and planning for response and recovery at an individual and organisational level.

Research by the Institute of Geological and Nuclear Sciences (GNS Science), National Institute of Water and Atmospheric Research (NIWA), universities, and many private consultancies contribute to earthquake hazard management in New Zealand. Research ranges from paleoseismology – determining when prehistoric earthquakes have happened – through to geodesy – measuring how much New Zealand is being deformed on either side of the plate boundary.

Risk reduction

BUILDING DESIGN AND CONSTRUCTION

Building collapses account for the majority of earthquake deaths worldwide. New Zealand, however, is a world leader in earthquake engineering and has a resilient housing stock and high building standards. Most residential buildings in New Zealand are one- or two-storey houses with light timber frames and timber cladding. European settlers realised after the 1848 Marlborough and 1855 Wairarapa earthquakes that wooden buildings withstood earthquake shaking much better than unreinforced brick or stone buildings.

The first earthquake loading standard for buildings, intended to improve lateral strength, was introduced in 1935 in response to damage from the 1931 Hawke's Bay earthquake. The standard was updated in 1965, 1976, 1984, 1992, and 2004. Today's building code aims to avoid structural damage in a moderate earthquake, and to prevent collapse and protect life in a major earthquake. Previous building codes only applied to new buildings but recent changes in the Building Act 2004 apply standards retrospectively to older buildings, which must now be strengthened.

A significant number of vulnerable early concrete and steel buildings, and unreinforced masonry buildings, still exist. Many road and rail bridges were also constructed before modern earthquake codes, and with limited hydrological information.

Lead rubber bearings (base isolators), invented in New Zealand, have been fitted in many buildings both in New Zealand and overseas. These steel-covered blocks of rubber with a lead core isolate the building from its foundations and absorb earthquake energy, helping to protect the building and its contents from ground-shaking damage.

LAND-USE PLANNING

While widespread ground-shaking during a large earthquake is inevitable, some earthquake hazards can be avoided. However, land use planning has, until recently, placed little or no emphasis on earthquake hazards with regard to either the location or the intensity of development.

Areas of soft sediments, which may amplify ground shaking or liquefy in an earthquake and zones where fault rupture may occur are being mapped. This information is used to inform land-use planning at local and regional level. Land-use planning policies are generally not designed to prohibit development in identified high earthquake-hazard areas, but rather to control the type of development. For example, some district plans restrict or place conditions on developing high-rise or important community buildings, such as hospitals, in areas of liquefaction potential, while still allowing lower-risk residential housing.

This approach is advocated in Ministry for the Environment guidelines produced in 2004 for development on or close to active faults, which have been adopted by several territorial authorities in New Zealand. These guidelines promote a risk-based approach to controlling development on or near active faults, based on the fault's activity and complexity and the type of building proposed.

Fault-avoidance zones delineated around the active Ohariu Fault in Kapiti Coast District. The width of the zones depend on how well the location of the fault can be determined. Fault-avoidance zones have been incorporated into several district plans around New Zealand so that development on or near active faults can be managed. *Greater Wellington Regional Council*.

THE NEXT ALPINE FAULT EARTHQUAKE

The South Island's Alpine Fault marks the boundary between the Australian and Pacific tectonic plates through the South Island and forms the western margin of the Southern Alps. The Alpine Fault has not moved since European settlement of New Zealand, but geologists believe it is capable of producing magnitude 8 earthquakes involving many metres of fault movement at the ground surface. Evidence suggests that the last earthquake on the fault, involving surface rupture along almost 400km of the fault, occurred in 1717 AD. Previous earthquakes have been dated at approximately 1630, 1460 and 1220 AD.

Probability estimates for the next Alpine Fault earthquake vary, but are as high as or higher than for any other fault in New Zealand. Most scientists agree that given the current rate of stress accumulating along the Alpine Fault, a large earthquake is very likely within the next 100 years.

The next Alpine Fault earthquake will cause major damage across the South Island. Transport routes will be impassable with bridges damaged and landslides blocking roads and railway lines. Electricity supply will be disrupted in large parts of the South Island. If the earthquake occurs in summer, many tourists will be isolated on the West Coast. International assistance is likely to be required and many aftershocks will affect response and recovery.

Earthquake-induced landslides in the Southern Alps will also feed large amounts of sediment into rivers, which will slowly work its way down valleys and onto the coastal plains. This is likely to produce erratic river behaviour including major changes of course and flooding, particularly on the West Coast lowlands, for years after the earthquake.

The South Island looking north along the Alpine Fault, one of the most significant onshore faults on earth. The fault has displaced rocks in Nelson and Fiordland that were once adjacent by 480km and has created the Southern Alps. *Image Science and Analysis Laboratory, NASA Johnson Space Center, image ISS006-E-39504.*

WELLINGTON EARTHQUAKES

The Wellington region was the scene of New Zealand's largest historic earthquake – the magnitude 8+ 1855 Wairarapa earthquake. Occurring on the evening of 23 January, the earthquake was accompanied by surface rupture along 140km of the Wairarapa Fault on the eastern margin of the Tararua Range. The earthquake also caused up to 6m of uplift to the west of the Wairarapa Fault, triggered landslides across 20 000km^2 of land, and generated a tsunami that measured 9m in Palliser Bay and 2–3m in Wellington Harbour.

The population of Wellington at the time was only around 6000, and the mostly timber framed buildings sustained little damage. It had become apparent after the 1848 Marlborough earthquake seven years earlier that timber buildings were the best construction for earthquake resistance. However, almost all the chimneys in Wellington fell down – one killing a hotelier – and there was severe damage to brick buildings. Up to six more people were killed in the Wairarapa when a whare collapsed.

The Wairarapa Fault is one of several active faults under the Wellington region. The residents of Wellington in 1855, who had recently moved there from the flood-prone Hutt Valley, didn't realise that they had settled over the active Wellington Fault. One hundred and fifty years later, Wellington is the nation's capital and the Wellington metropolitan area is home to 375 000 people. An earthquake on this fault today would cause around 3000–4000 casualties, including between 200 and 600 deaths (depending on the time of day), and cause more than $10 billion worth of direct damage. The Wellington Fault is thought to rupture, producing a major earthquake, every 500–800 years; it last ruptured about 400 years ago.

The active Wellington Fault, capable of generating a magnitude 7.6 earthquake, runs from the Wellington south coast, through Karori Reservoir and Thorndon and north along the western side of Wellington Harbour and the Hutt Valley. *GNS Science.*

Readiness

The ability to monitor earthquake location and size is improving but scientists still cannot predict when and where a damaging earthquake will occur. Some major earthquakes, such as the 1929 Murchison, 1888 North Canterbury and 1987 Edgecumbe earthquakes, were preceded by many small tremors, but most of New Zealand's damaging earthquakes have occurred with no warning. However, high quality, near real-time earthquake information, provided by the EQC funded national geological hazard monitoring system 'GeoNet', enables emergency management organisations to quickly establish the location and size of a major earthquake and the appropriate response.

New Zealanders will need to be self-reliant for days, if not weeks, after a large earthquake because infrastructure may be damaged over a wide area, with lengthy repair times. The lack of recent damaging earthquakes may have created some complacency, and some people may not be adequately prepared.

Response and recovery

Pre-event recovery planning – identifying in advance the land-use planning decisions that will need to be made during the recovery phase of a large hazard event – is particularly important for earthquakes but has received little attention in the past. One of the challenges in this is weighing the need for communities to regain daily functioning versus the opportunity for more considered planning resulting in increased long-term resilience. This issue warrants more discussion, particularly at territorial authority level in high earthquake-hazard regions.

The Earthquake Commission provides insurance against earthquake damage, up to a certain limit, for residential buildings and contents that are covered for fire damage.

Emergency services and local authorities will be involved in responses to damaging earthquakes. CDEM response to damaging earthquakes follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

THE EARTHQUAKE COMMISSION

New Zealand is unique in having the Earthquake Commission (EQC), a government-owned organisation that insures the holders of residential fire insurance against natural hazard damage.

Originally established in 1945 to protect against earthquake and war damage, it now covers earthquake, landslide, volcanic eruption, hydrothermal activity, tsunami, storm/flood (land only), and fire caused by any of these events (war damage was removed in 1994). Residential houses are insured for up to $100,000 worth of damage, and contents for $20,000. EQC's Natural Disaster Fund currently totals $5.4 billion which is reinsured offshore and also backed by a Government Guarantee.

As well as providing insurance, EQC also encourages preparedness through public education, funds natural hazard research and research capabilities including university teaching, engineering standards development, and the national geological hazard monitoring system 'GeoNet'.

FURTHER INFORMATION

GENERAL EARTHQUAKE INFORMATION

GNS SCIENCE
www.gns.cri.nz/what/earthact/earthquakes/index.html
TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/en

GEONET

GEONET
www.geonet.org.nz

EARTHQUAKE COMMISSION

EARTHQUAKE COMMISSION
www.eqc.govt.nz

EARTHQUAKE ENGINEERING

CANTERBURY UNIVERSITY
www.civil.canterbury.ac.nz/research/research.shtml

BUILDING CODE

DEPARTMENT OF BUILDING AND HOUSING
www.dbh.govt.nz/blc-building-code-and-review

LEAD RUBBER BEARINGS

ROBINSON SEISMIC
www.robinsonseismic.com/products/lrb.html

ACTIVE FAULT GUIDELINES

MINISTRY FOR THE ENVIRONMENT
www.mfe.govt.nz/publications/rma/planning-development-active-faults-dec04/index.html

Bay of Plenty earthquake 1987. Damage to rail infrastructure.
David Plews, Whakatane.

VOLCANOES

Volcanic activity occurs when magma (hot molten rock) rises to the surface from deep within the earth. Most of New Zealand's volcanic activity is associated with its location on a plate boundary and the subduction of the Pacific Plate under the Australian Plate.

Volcanic eruptions since human settlement have been uncommon and most have been relatively small. Even so, these eruptions have had significant impacts: volcanic activity has caused at least 338 deaths over the last 150 years, more than any other natural hazard in New Zealand, and infrastructure, agriculture, and tourism have all been affected. Any level of eruption can have potentially catastrophic impacts on the primary sector.

On a geological time scale, however, New Zealand's volcanoes have erupted very frequently over the last several hundred thousand years, and have erupted large quantities of magma, compared to other volcanic regions in the world. Eruptions have ranged from small, localised eruptions of ash and lava to catastrophic landscape-altering events.

A large volcanic eruption in New Zealand, while very unlikely in any given year, will certainly occur again in the future. Volcanic activity has been called New Zealand's most underrated hazard.

Volcanic hazards

Volcanoes create a range of hazards varying greatly in geographic extent and potential impact.

Ash fall

Ash can be carried and deposited over an area up to hundreds or even thousands of kilometres, making it the most likely volcanic hazard to affect the most people. In large concentrations ash can even influence climate. Ash fall is dictated by wind strength and direction. Westerly winds prevail in New Zealand, but any part of the North Island and possibly parts of the northern South Island could be affected by ash fall during an eruption.

Even a small amount of ash – as little as a few millimetres – can have significant effects such as:

- skin, eye and throat irritation
- damage to electrical and electronic systems
- interference with radio communications
- damage to machinery and engines, particularly aircraft engines with consequent disruption to air travel
- contamination of waterways and open water supplies
- blockage of stormwater and sewerage pipes and damage to pumping systems
- crop and stock losses, through fluorine poisoning or lack of feed (although soils generally benefit from a small amount of ash).

Heavier deposits (more than 50mm thick) can damage buildings, close road and rail links, disrupt electricity supplies, bury crops, damage trees, kill or distress stock, and poison aquatic life in streams and lakes.

Lava flows

Lava flows in New Zealand are usually confined within a 10km radius of the volcano vent. The distance they travel depends on the lava's viscosity, the volume and rate of lava erupted, and local topography. Lava flows rarely threaten life because they move so slowly, but they will destroy any built infrastructure in their path.

Pyroclastic flows

Pyroclastic flows are rapid, ground-hugging surges of gases, ash and rock. At temperatures of up to several hundred degrees Celsius, and travelling at several hundred kilometres an hour, they are the most destructive volcanic hazard. Pyroclastic flows obliterate everything in their path and have shaped large areas of New Zealand's landscape. They are extremely rare.

Lahars

Lahars are fast-flowing, slurry-like mixtures of water, ash, and rock. Lahars can occur during volcanic eruptions, especially if the eruption has melted a lot of snow, or they can occur months or years after an eruption, when ash and debris are mobilised during heavy rain or a crater lake overflow. Lahars are generally confined to existing drainage channels but can be highly destructive.

A lahar in the Whangaehu River during the 1995/96 Ruapehu eruptions. Lahars have the consistency of wet concrete and are highly erosive. *Vince Neall.*

Sector collapses and debris avalanches

Volcanic cones are often steep-sided and can be unstable. Occasionally the side, also called a sector, of a cone volcano collapses catastrophically, creating a debris avalanche that can travel many kilometres. These collapses can be triggered by rising magma bulging the flanks of a cone, by earthquakes, or by heavy rainfall. Debris flows travel extremely fast and will destroy everything in their path. There is evidence that New Zealand's cone volcanoes have had sector collapses but, like pyroclastic flows, they are rare.

Tsunamis

Offshore volcanic activity can cause tsunamis that could reach New Zealand's coastline, particularly in the northeast. It is unlikely, however, that such tsunamis would be large enough to cause significant damage. Tsunamis can be triggered by submarine eruptions or by landslides or debris avalanches flowing into the sea from an island volcano. Volcanic material entering a lake can cause seiching ('sloshing'), causing the lake water to inundate adjacent low-lying areas.

New Zealand's volcanoes

Volcanic fields

Volcanic fields produce many small volcanoes (0.1–1.0km^3), which each erupt only once, at intervals of hundreds to thousands of years. It is difficult to determine where the next eruption is likely to occur in a volcanic field until it is imminent.

Eruptions within New Zealand's volcanic fields generally involve lava flows and lava fountains forming small scoria cones. Explosions of rock and steam are also likely where hot magma meets cold groundwater or seawater, creating craters in the ground.

Mt Eden and Auckland city. One of 50 volcanoes in the Auckland Volcanic Field, Mt Eden was created 20 000–30 000 years ago. *GNS Science.*

AUCKLAND VOLCANIC FIELD

The Auckland Volcanic Field contains 50 known volcanic vents within a 360km^2 area. The field is fed by a 'hot spot' about 100km below the earth's surface, from which 'bubbles' of magma occasionally rise to create a new vent. Eruptions in this field have generally been of two types. The first type is when magma meets cold groundwater or seawater, causing short explosive eruptions which blast out steam, gas, and rock fragments. These eruptions create circular craters up to 1km across, such as Orakei and Panmure basins. The second type is when lava fountaining over a longer period of time produces small scoria cones like One Tree Hill.

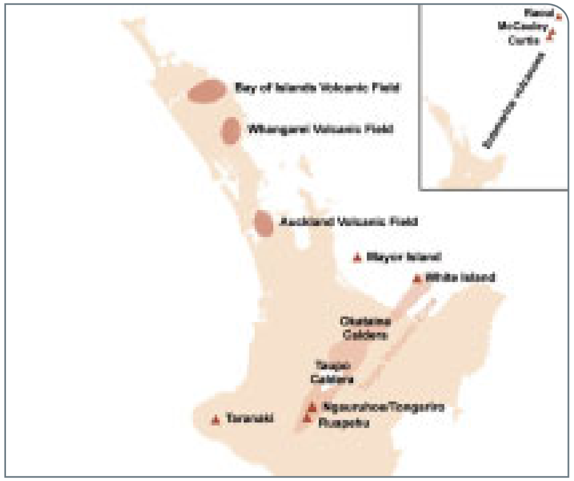
Eruptions started in the Auckland area around 140 000 years ago and the last 20 eruptions have occurred in the past 20 000 years. Eighteen of these occurred between 10 000 and 20 000 years ago. The largest and most recent eruption was Rangitoto, in Waitemata Harbour, 600–700 years ago. None of Auckland's existing volcanoes is likely to erupt again, but the Auckland Volcanic Field is still geologically young and potentially active.

THE NEXT AUCKLAND VOLCANO

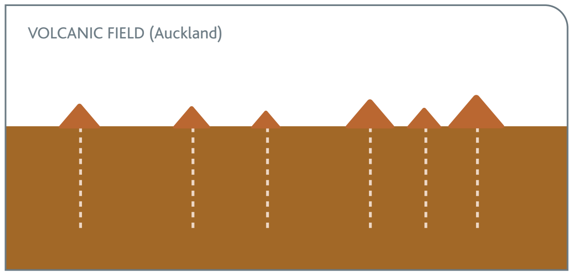
There are 530 000 people living on the Auckland Volcanic Field and a further 750 000 live in the wider Auckland region. Even a small, localised eruption would cause major damage near the vent and widespread disruption.

Planning for an Auckland Volcanic Field eruption assumes that buildings and infrastructure within 3km of the new vent would be destroyed by an initial surge of hot gas, steam and rocks. Ash would fall over most of the greater Auckland area, up to 10cm thick near the vent. Ash and acid rain would pollute water supplies and most likely damage stormwater and sewerage infrastructure. Auckland International Airport would be closed for weeks. Insured losses could be in the order of $1–2 billion, and indirect costs could be much more.

Managing an Auckland Volcanic Field eruption presents significant challenges. Mass evacuation, for an unknown length of time, would be essential. Even though the field is monitored to detect magma movement within the earth's crust, the location of the next vent, and hence the area to be evacuated, may not be known until eruption is imminent.



New Zealand's volcanic areas. Most of New Zealand's volcanoes are located in the Taupo Volcanic Zone, New Zealand's most active volcanic area, which extends from Ruapehu to White Island. *GNS Science*.



Volcanic fields produce many small volcanoes.

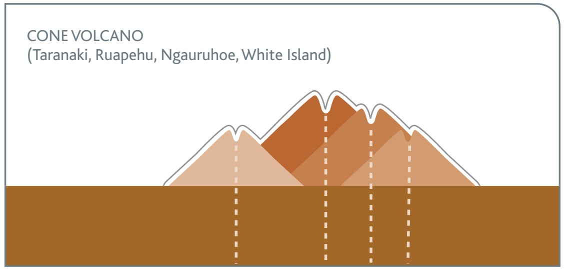
BAY OF ISLANDS AND WHANGAREI VOLCANIC FIELDS

The Bay of Islands Volcanic Field contains 30 vents, mostly comprising scoria cones and lava flows and domes. Little is known about the field or its activity but it is likely to have erupted 10 times in the last 20 000 years. The last eruptions, which produced explosions and small lava flows, occurred 1300–1800 years ago. The area is not heavily populated but the Bay of Islands is a popular tourist destination.

The smaller Whangarei Volcanic Field last erupted around 250 000 years ago with small eruptions of ash, scoria, and lava.

Cone volcanoes

Cone volcanoes are the product of many eruptions at approximately the same location, which build up layers of lava and ash to form a cone. Lahars and sector collapses can originate from cone volcanoes. New Zealand has three onshore cone volcanoes – Taranaki, Ruapehu and Tongariro/Ngauruhoe – and many offshore cone volcanoes.



Cone volcanoes form through many eruptions from one volcanic vent.

TARANAKI

The Taranaki volcano has been erupting for the last 1.7 million years forming a series of cones, including the now eroded Pouakai and Kaitake ranges to the north of the current vent of Mt Taranaki. The volcano has been erupting at its current site for around the last 130 000 years, but most of the cone that can be seen today is less than 10 000 years old because the mountain has gone through successive phases of cone formation and collapse.

Taranaki has produced mostly lava domes and flows, which make up most of the cone itself, as well as small amounts of pumice, scoria and ash. Sector collapses occurred before human settlement, spreading debris up to 80km from the volcano. Taranaki has erupted at least nine times in the last 1000 years – the last eruption was around 1755.

More than 85 000 people live within 30km of Mt Taranaki. Of these, 40 000 live in high-priority evacuation areas, if an eruption occurs. Lahars are likely to travel down many of the watercourses draining the mountain. Pyroclastic flows and sector collapses could affect areas up to 15–20km from the vent. Ash fall is almost certain, but the area affected will depend on the amount erupted and the wind at the time. Lava flows are likely to be confined within Egmont National Park which comprises the area within a 10km radius of the vent.

The Taranaki region has a large dairy industry, partly due to its fertile volcanic soils, which would be significantly affected by an eruption. It is also the source of all New Zealand's natural gas, and an eruption would disrupt petrochemical industries within the region as well as reticulated supply throughout the North Island.

Mt Taranaki dominates the region's landscape. Prehistoric collapses of the cone have spread debris across the Taranaki lowlands creating the hummocky landscape between Opunake and New Plymouth. *GNS Science.*

RUAPEHU

Ruapehu is New Zealand's largest cone volcano and is unusual in that it has a crater lake which modifies eruptions and creates a high lahar hazard. Ruapehu has probably been erupting for at least 800 000 years, but the oldest known lava is only around 230 000 years old because the volcano has gone through several cycles of building and destruction.

Ruapehu has produced mostly lava and ash in its frequent eruptions. Eighteen eruptions have been recorded since 1861, the most recent and smallest of these in 1995/96. Lahars have also occurred, the most destructive on Christmas Eve 1953. The main trunk railway line was washed away at Tangiwai causing a passenger train to derail into the Whangaehu River, killing 151 people.

The area around Ruapehu is sparsely populated but the region is heavily dependent on tourism, particularly skiing. The effects of an eruption on these industries is significant. Ash from Ruapehu eruptions can spread over large areas, especially towards the east from the prevailing westerly winds.

Ruapehu erupting in 1996. Ash covered the upper slopes of Mt Ruapehu and fell up to 250km away during the 1995/96 eruptions. *GNS Science.*

RUAPEHU 1995/96

The 1995/96 Ruapehu eruptions were the largest volcanic events in New Zealand for 50 years. The first eruption began in September 1995 and eruptions continued episodically until August 1996. Ash was deposited up to 250km from the volcano, affecting Hawke's Bay, Gisborne, and the Bay of Plenty. A wide flight-exclusion zone disrupted air travel, and central North Island airports were closed and flights were cancelled. State Highway 1 was closed three times. Many lahars were triggered both during and after the eruptions, which mainly affected the Whangaehu and Tongariro rivers.

The eruptions were a similar size to the previous 1945 eruption but they had a much greater effect due mainly to the increase in population and development, and expansion of the tourism and aviation industries between the two eruptions. There were no deaths, but total economic losses were calculated at around $130 million.

Two ski seasons were shortened which was the main contributor to the estimated $100 million loss to the tourism industry. Electricity generation losses were estimated at $22 million. About half of that was the cost of repairing the Rangipo power station damaged by ash-laden water moving through its turbines.

Cancelled flights accounted for at least $2.4 million. Agriculture sustained relatively light losses of around $400,000 – 2000 sheep were poisoned when they ate ash-covered grass, and ash destroyed Gisborne's cauliflower crop.

TONGARIRO/NGAURUHOE

At 2500 years old, Ngauruhoe is the youngest cone in the large Tongariro complex. It has been built up and partially destroyed (mostly by glacial erosion) over the last 340 000 years. Ngauruhoe's last eruption was in 1975, producing lava flows and ash. It is currently experiencing the longest period of inactivity in its recorded history.

WHITE ISLAND

Uninhabited White Island lies 55km off the Bay of Plenty coast and is the visible tip of a mostly submerged volcano 750m high and 17km wide. It is currently New Zealand's most active volcano, with three eruptive cycles recorded since 1976. White Island produces lava flows and minor ash falls, and its crater has collapsed several times in the past. One collapse in 1914 killed 11 sulphur miners living on the island. There is no evidence of material erupted from White Island reaching the mainland, but geological research suggests that the volcano is capable of producing large eruptions.

White Island with its characteristic steam plume. The privately owned island was mined for sulphur intermittently between the 1880s and 1930s. *GNS Science*.

SUBMARINE VOLCANOES AND THE KERMADEC ISLANDS

A string of large, mostly submarine volcanoes extends from White Island northeast to Tonga. The largest of these – Raoul, Macauley, and Curtis – form the Kermadec Islands, 1000km to the northeast of New Zealand. They are all similar in size to Ruapehu. Little is known about the eruptive history of these volcanoes, especially those that are wholly submarine, but their range of eruption sizes is larger than would normally be expected for cone volcanoes.

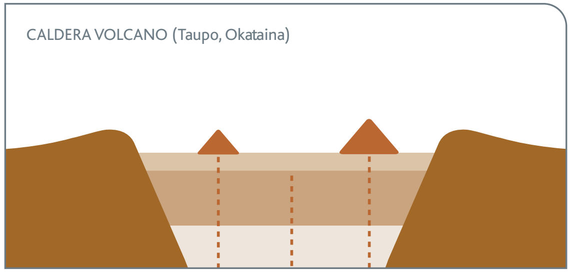
Raoul Island has experienced many historic eruptions. The most recent, in March 2006, killed a Department of Conservation worker who was taking crater lake samples at the time. This was New Zealand's first volcanic casualty in more than 50 years. Other volcanoes in the Kermadecs emit steam and gases, indicating magma is present at shallow depths.

Caldera volcanoes

A caldera is a large depression created by the collapse of a volcano after the rapid eruption of magma from a vent. A caldera may contain several different vents and eruptions can vary greatly in size and frequency. Caldera eruptions in New Zealand are often highly explosive, characterised by pyroclastic flows, lava flows, and ash fall.

Caldera volcanoes frequently exhibit periods of unrest marked by earthquake activity, ground deformation, and changes in gas and steam discharge. These signs of unrest are not necessarily indicative of an impending eruption, but can be hazards in themselves.

There are three caldera volcanoes in New Zealand – Taupo, Okataina, and Mayor Island.



Caldera volcanoes collapse in on themselves creating large craters, often containing smaller lava domes.

TAUPO

Taupo has not erupted since human settlement of New Zealand, but it has been one of the most active caldera volcanoes on earth over the last 300 000 years. Lake Taupo partially fills depressions left by the explosive eruptions and subsequent collapses of the Taupo volcano during that time. The largest known eruption, 26 500 years ago, expelled more than 500km^3 of lava, ash, rocks and gas. Taupo is thought to have erupted at least 28 times since then – the last major eruption, around 180 AD, was the most violent eruption in the world in the last 5000 years. The effects of the ash from this eruption are recorded in Chinese writings of the time.

The size and the time between past eruptions has varied greatly. Taupo has been intensively studied but scientists do not know when or how big the next eruption will be. The impact of a relatively small eruption from Taupo could be devastating for the central North Island, and the effects would be felt across the entire country. Apart from direct damage, the tourism, agriculture, forestry and North Island hydroelectric generation industries would suffer severe losses.

OKATAINA

Okataina is the second most productive caldera volcano in the world after Taupo, and has a similar history of eruptions. The last major collapse of the volcano was 64 000 years ago and since then smaller eruptions have largely filled in the collapsed area with lava domes like Mt Haroharo and Mt Tarawera.

Okataina's last activity was the eruption of Mt Tarawera on 10 June 1886. The eruption occurred with almost no warning, burying nearby buildings in ash and hot mud, killing at least 153 people, and destroying the world-famous Pink and White Terraces. It was the largest and most destructive volcanic eruption in New Zealand's written history, but one of the smallest in the Okataina caldera over the last 21 000 years.

MAYOR ISLAND

Mayor Island is the summit of a volcano 15km wide and 750m high, rising from the sea floor 25km off the Bay of Plenty coast.

The volcano has erupted at least every 3000 years for the last 130 000 years, including at least three caldera collapses. Most eruptions have been relatively small and have not greatly affected the mainland, but the most recent and largest eruption, involving a caldera collapse, produced a pyroclastic flow into the sea and deposited ash on parts of the North Island.

Only renewed activity equivalent to the largest known prehistoric eruption on the uninhabited island would pose a direct threat to people on the mainland. However, ash could fall over parts of the Bay of Plenty, Coromandel, the Waikato, and South Auckland from even a small eruption. Mayor Island magma is rich in toxic chlorine and fluorine which would poison stock and pollute water, even with small amounts of ash.

McRae's Hotel in Te Wairoa after the 1886 eruption of Mt Tarawera. Many people were sheltering in the hotel when it collapsed under the weight of ash and mud. The eruption is the largest volcanic event to have occurred in New Zealand over the last 1000 years. *Charles Spencer/Museum of New Zealand Te Papa Tongarewa*.

GEOTHERMAL HAZARDS

There are extensive geothermal areas in the Taupo Volcanic Zone, where geysers, mud pools, and hot springs exist. Minor hydrothermal eruptions are common in these areas as steam expands under the ground. Occasionally these areas experience large violent hydrothermal eruptions that can throw steam, mud, and rocks tens of metres into the air and scatter debris over a wide area. Volcanic activity or earthquakes may trigger these eruptions.

Smaller hydrothermal eruptions have affected residential areas around Rotorua in the past, and houses have had to be moved away from new steaming vents and mud pools. Other buildings have been declared uninhabitable because of toxic levels of hydrogen sulphide gas seeping up from the ground. Eleven deaths have been attributed to hydrogen sulphide poisoning in Rotorua in the last 50 years.

Managing volcanic hazards

The focus of managing volcanic hazards is on readiness, particularly monitoring, and response and recovery once an event has happened, rather than on risk reduction. There are two reasons for this. Some volcanic hazards can cover a large area and the exact size of that area can be difficult to predict in advance. Also, there is often some warning period before a volcanic eruption during which precautions such as evacuations and covering water tanks can be taken.

Research into the nature of New Zealand's volcanoes and associated hazards is undertaken at GNS Science and the universities of Canterbury, Otago, Waikato, Auckland, and Massey University.

Risk reduction

Volcanic hazards, except ash fall, have been mapped for all New Zealand's most active volcanoes. The main purpose of these maps is to aid evacuation planning before an eruption.

Land-use planning is only viable for volcanic hazards where the area of potential impact is relatively localised and can be defined reasonably accurately, such as lahars. There are currently no land-use planning provisions in New Zealand specific to volcanic hazard. However, National Parks surrounding two of the most active volcanic areas (Taranaki and Ruapehu/Ngauruhoe/Tongariro) can be considered de facto land-use planning tools where restrictions on development exist.

Volcanic hazards are not addressed in the New Zealand Building Code. However, the Department of Building and Housing has identified volcanic eruption impact threats, such as ash loading and corrosion, as a concern that needs addressing in the current Building Code review.

Readiness

GeoNet continually monitors New Zealand's active volcanoes, particularly the most active ones – White Island, Ruapehu and Ngauruhoe. Monitoring techniques include visual observations through field visits and remote photography, and seismic monitoring to detect volcanic tremors indicating movement of gas and magma within the earth's crust. GeoNet also analyses gas, hot-spring, and crater-lake chemistry, and monitors deformation of the land surface. Seismic monitoring of Mt Taranaki and the Auckland Volcanic Field is undertaken in partnership with Taranaki and Auckland regional councils.

The Department of Conservation also operates an eruption detection system (EDS) on Mt Ruapehu to warn of a possible eruption and lahar from the crater lake through Whakapapa ski field. If activity is detected the chairlifts are stopped and skiers and boarders must move from valleys to higher ground

GNS Science has developed scientific alert levels, based on observed activity, ranging from 0 (dormant or quiescent state) to 5 (large hazardous volcanic eruption in progress). Scientific alert bulletins are issued to emergency management agencies and the news media when there is a significant change in volcanic activity, whether the scientific alert level changes or not.

GeoNet's volcano-seismic network monitors volcanic earthquakes that indicate magma movement within the earth's crust. Volcanic earthquakes are distinguished from normal tectonic earthquakes by their slower vibration frequency. *GNS Science.*

GEONET

The GeoNet project monitors earthquake, volcanic, landslide, and tsunami activity within and around New Zealand. It provides real-time data collection and dissemination to enable rapid response to geological events. GeoNet includes strong and weak earthquake motion recording, volcanic surveillance, landslide response, and earth deformation monitoring, supported by data communication and management systems.

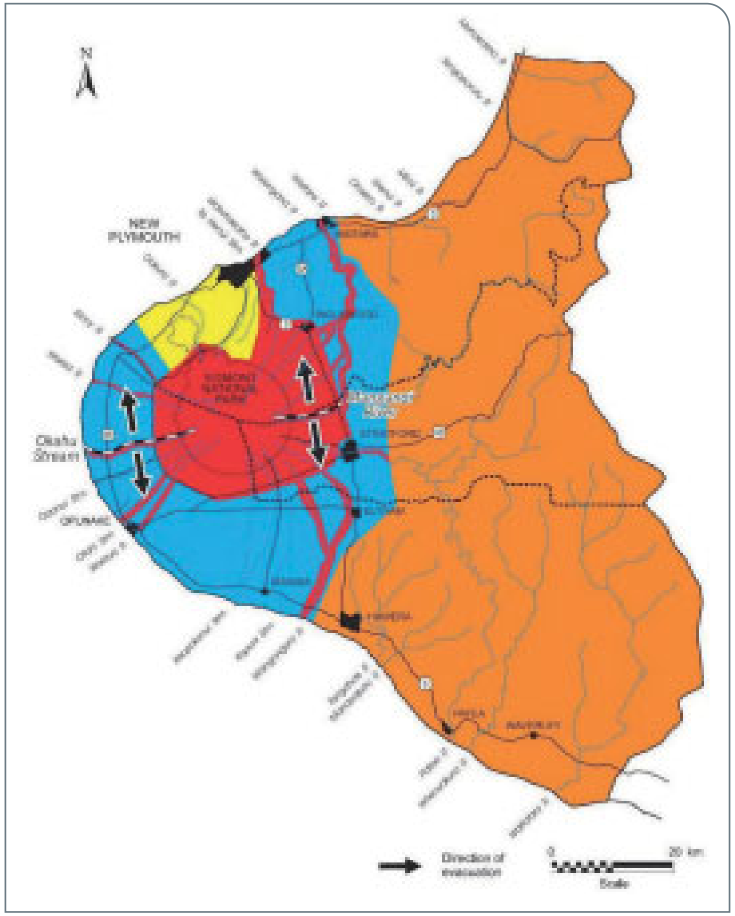
GeoNet has been operating since 2001 and is funded by the Earthquake Commission and the Foundation for Research, Science and Technology. GNS Science manages the project and the collected information is freely available to researchers and the public.

Response and recovery

While volcanic eruptions can often be predicted, the precise timing of the eruption and how long it will last are generally unknown. Ash fall alone, unless very heavy, is unlikely to warrant evacuations and people can stay in their homes as long as precautions, such as protecting water supplies, are taken.

Eruptions involving lava flows, pyroclastic flows, or lahars could significantly change the landscape, and evacuations for an unknown amount of time may be necessary. This creates challenges for managing response and recovery efforts for volcanic emergencies.

Caldera unrest is one of the most difficult volcanic hazards to manage because the unrest may or may not indicate impending volcanic activity. There is potential for adverse social and economic effects to escalate unnecessarily through media speculation and unwarranted emergency management action.



The Taranaki CDEM Group Volcanic Strategy includes procedures for evacuating people from pre-mapped hazard zones around Mt Taranaki. The red and blue zones will be priority areas for evacuation. *Taranaki CDEM Group*.

During an eruption the MetService works with GNS Science to issue volcanic-ash advisories to the aviation industry outlining the areas and heights where ash could be a hazard. GNS Science also models ash fall based on wind data supplied by the MetService, and information on the volume of ash erupted, and the ash column height.

The Earthquake Commission provides insurance, up to a certain limit, for residential buildings and contents that are covered for fire damage if they are affected by volcanic and hydrothermal eruptions.

The National CDEM Plan has superseded the former National Contingency Plan for Volcanic Eruption. The provisions within the National CDEM Plan are intended to be generic and to enable a coordinated response and recovery to all hazards, including volcanic eruption.

The Auckland, Bay of Plenty, and Taranaki CDEM Groups have volcanic strategies or contingency plans in place. These plans outline the coordinated CDEM response to a volcanic eruption and set out roles, responsibilities, and actions for organisations involved. Emergency management actions are related to scientific alert levels.

FURTHER INFORMATION

GENERAL VOLCANO INFORMATION

GNS SCIENCE
www.gns.cri.nz
TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/en
GEONET
www.geonet.org.nz
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2004-Index?OpenDocument

RUAPEHU CRATER LAKE AND THE ERLAWS ALARM SYSTEM

DEPARTMENT OF CONSERVATION
www.doc.govt.nz/Regional-Info/007~Tongariro-Taupo/004~Conservation/Crater-Lake/index.asp

TARANAKI CDEM GROUP VOLCANIC STRATEGY

TARANAKI CDEM GROUP
www.trc.govt.nz/PDFS/EM/volcanic_strategy.pdf

AUCKLAND VOLCANIC PLAN AND AUCKLAND VOLCANIC FIELD

AUCKLAND REGIONAL COUNCIL
www.arc.govt.nz/arc/environment/hazards/volcanoes-of auckland/volcanoes-of-auckland_home.cfm
www.arc.govt.nz/arc/environment/hazards/vcp.cfm

VOLCANIC ASH ADVISORY CENTRE (FOR AVIATION)

METSERVICE
vaac.metservice.com

BUILDING CODE REVIEW

DEPARTMENT OF BUILDING AND HOUSING
www.dbh.govt.nz/blc-building-code-and-review

AGRICULTURAL IMPACTS

MINISTRY OF AGRICULTURE AND FORESTRY
www.maf.govt.nz/mafnet/rural-nz/emergency-management/volcano-eruption-impact/httoc.htm

LANDSLIDES

Landslides are frequent in New Zealand, because of the country's steep slopes, active tectonics, and high rainfall in some areas. But while New Zealand has a relatively high landslide hazard compared to other countries, there are relatively few landslide deaths because of the country's low population density, especially in steep mountainous areas. Landslides most commonly affect New Zealand's property and infrastructure – they are the natural hazard most frequently responsible for road closures.

Most landslides in New Zealand are triggered by earthquakes or intense or prolonged rainfall, although there may be other contributing factors. Some landslides, like the 1991 Mt Cook rock avalanche, have no apparent trigger. New Zealand has had some massive prehistoric landslides. The 12 000–13 000-year-old Green Lakes landslide in Fiordland is one of the world's largest landslides, involving the collapse of a 27km^3 portion of mountainside covering a 45km^2 area in debris.

Landscape modification has significantly increased the incidence of landslides in New Zealand. Vegetation clearance, excavations for buildings and roads, altered natural drainage, and poorly-controlled stormwater have all increased the frequency of landslides in urban and rural areas, particularly those triggered by rainfall.

The 1979 Abbotsford landslide. Undercutting of the landslide toe and a leaking water pipe contributed to the movement along the boundary of two different rock types. This landslide prompted changes to legislation enabling territorial authorities to refuse building permits on hazard-prone land. *Otago Daily Times*.

Landslide types

A landslide is the downward movement of rock, soil, or vegetation, but the type of movement, the amount of material moved, and the speeds at which they move vary. A landslide may be a few falling rocks or it may be the rapid failure of many cubic kilometres of debris.

Slides, slumps, flows, and falls

Landslides are classified by the material and the movement mechanism involved.

Shallow soil slides, sometimes referred to as regolith slides, involve the movement of the upper soil layer including vegetation or rock debris. These regularly occur over large areas of grass-covered slopes of the North Island hill country during intense rain, but can also happen on steep, bush-clad slopes in the Southern Alps during heavy snowfalls or earthquakes.

Larger, deep-seated slides involve translational sliding or rotational slumping within weak rock and soil and can happen slowly or accelerate into a fast-moving landslide. Deep-seated slides can also form along the boundary of two different rock types. One of New Zealand's most damaging landslides happened in this way, destroying 69 houses at Abbotsford in Dunedin. The landslide had moved very slowly for almost 10 years before sliding 50m in 15 minutes in August 1979.

Deep-seated creeping earthflows occasionally happen in saturated clay-rich sediments, particularly in the North Island hill country. Earthflows can happen even on very shallow slopes and are generally slow moving, travelling a few metres each year.

On very steep slopes, such as cliffs or terraces, rock and soil may simply fall and accumulate at the bottom of the slope as debris. Rock falls often comprise large boulders and can be particularly damaging.

Debris flow

A debris flow is a mixture of water, sediment, rock, and vegetation. Debris flows are typically generated in small, steep and easily erodible catchments during intense rainfall, and deposit material onto steep debris fans downstream, which can be identified by their uneven surface.

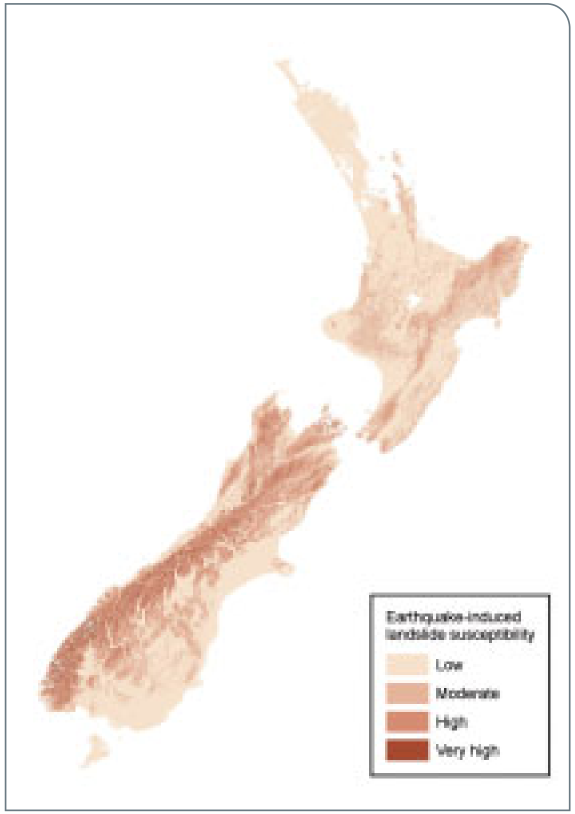
Debris flows have the consistency of wet concrete and are more dangerous than floods because they generally travel faster and can carry large boulders and other material such as tree trunks. They present considerable risk to life, property, and infrastructure but it is often difficult to predict their size and occurrence. Recent debris flows at Paekakariki in 2003 and Matata in 2005 have highlighted the damage that these flows can cause.

2005 MATATA DEBRIS FLOWS

Two debris flows engulfed parts of the small community of Matata in the eastern Bay of Plenty on the night of 18 May 2005. The debris flows were caused by a band of very intense rain – as much as 95mm fell in one hour in the small steep catchments behind Matata. This initiated many small landslides in the already-saturated catchments. These small slides, mixed with water, boulders, and vegetation, created two debris flows, the larger of which is estimated at 100 000m^3. The debris flows destroyed 36 houses and damaged another 25. The most surprising aspect of the Matata debris flows is that no lives were lost.

The rainfall that triggered the 2005 debris flows was estimated to have a 200 to 500-year return period. The land on which Matata is built shows evidence of debris flows over the last 7000 years that were as large or much larger than the 2005 flow, and there have been smaller debris flows over the last 150 years. Debris detention dams and building exclusion zones have been recommended to reduce the risk from future debris flows at Matata.

Matata debris flow. The catastrophic flow from Awatarariki Stream on 18 May 2005 destroyed 36 houses in the eastern Bay of Plenty village. *Whakatane Beacon*.



Probability of earthquake-induced landslide in New Zealand over a 475-year time frame, and the main areas affected by landslides during large earthquakes during the last 150 years. The areas of highest hazard are the steep slopes of the Southern Alps along the plate boundary. *GNS Science.*

Earthquake-induced landslides

Earthquake-induced landslides are the second-largest cause of death in New Zealand earthquakes (after building collapses) and they have caused significant damage to roads and other infrastructure.

Earthquake-induced landslides in New Zealand are strongly controlled by the amount of ground shaking and the angle of the slope. Landslides occur on susceptible slopes with ground shaking of MM intensity 7 and become progressively more widespread and damaging at MM intensity 8 and 9. Ground shaking of MM intensity 7 or higher can be expected near the epicentre of even a moderate magnitude 6 shallow earthquake.

The largest earthquake-induced landslides in New Zealand (those greater than one million m^3) have been rock avalanches and rock slides or falls from slopes steeper than 30°. Most earthquake-induced landslides, however, are smaller (less than 10 000 m^3) rock and debris falls and slides on gravel banks, terrace edges, road cuts and natural slopes steeper than 50°.

ROCK AND DEBRIS AVALANCHES

Rock and debris avalanches are extremely large (greater than one million m^3), turbulent, fast-moving landslides of fractured rock. They have very long run-out zones that can extend several kilometres. Rock avalanches generally only occur in the highly fractured rocks of sparsely populated mountainous areas in New Zealand and are rare – estimated at one a century for every 10 000km^2 in the Southern Alps. However, they can affect a large area, and will obliterate anything in their path, and so present a serious risk to alpine communities and infrastructure.

Rock avalanches can be triggered by earthquakes, such as the Falling Mountain rock avalanche generated by the 1929 Arthur's Pass earthquake, or they can occur without any obvious trigger, like the 1991 Mt Cook rock avalanche that narrowly missed a group of climbers in an alpine hut. Debris avalanches include those generated from very rare collapses of sections of volcanic cones. These have occurred prehistorically at Taranaki, Ruapehu, Ngauruhoe, and Tongariro. Some have travelled up to up to 80km from their source and devastated the landscape.

The Falling Mountain rock avalanche in the Southern Alps, triggered by the 1929 magnitude 7.1 Arthur's Pass earthquake. Fifty-five million m^3 of rock fell and flowed 4km down the Otehake River. This avalanche occurred in a remote area and did not directly affect people or property. *GNS Science.*

1929 MURCHISON EARTHQUAKE

The magnitude 7.8 Murchison earthquake in June 1929 caused widespread landsliding over approximately 7000km^2 of Buller and northwest Nelson. Sixteen of the 17 deaths caused by the earthquake were from landslides. The earthquake caused more than 50 landslides of more than one million m^3, including two giant slides of 120 and 210 million m^{3}on the northwest Nelson coast 40km from the earthquake epicentre.

Many landslides dammed rivers. Landslide dams in larger valleys lasted only a few days but many in small, narrow valleys remain today. Landslide damage to roads was widespread and parts of the earthquake–affected area were isolated for weeks.

The Matakitaki landslide near Murchison, triggered by the 1929 Murchison earthquake. Debris from this very large (18 million m^3) rock slide travelled one kilometre across the valley floor, killing four people in two houses in its path. The inset shows the top story of one house rafted on the slide debris. The landslide dammed the Matakitaki River, forming a lake extending 5km upstream. The dam breached 10 years later but caused little damage downstream. *GNS Science.*

LANDSLIDE DAMS

Landslides, particularly in steep valleys, can form dams which block rivers and create lakes. These dams are dangerous because they can breach suddenly, releasing a flood of water down the river.

Most landslide dams fail within a few days, usually during a 'fresh' or flood in the river, but some dams remain for years before overtopping and breaching.

Landslide dams blocked the Matakitaki River after the 1929 Murchison earthquake and the Buller River after the 1968 Inangahua earthquake. Residents downstream of the Buller landslide dam were evacuated before it breached the next day.

A rock avalanche from Mt Adams with no apparent trigger blocked the Poerua River in South Westland in 1999. The dam breached after six days sending a torrent of water down the river, flooding farmland.

The danger of a landslide dam breach in the Callery River near Franz Josef was recently recognised and a camping ground was moved as a result. Motel units in the area are also considered at risk from flooding, but these continue to operate, and warning signs have been erected. Engineering works, such as stopbanks, were considered but not adopted because of the high cost and questionable effectiveness.

Areas affected by significant rainfall-induced landslide episodes since 1970. Most large rainfall-induced landslide events have been in the North Island, the most extensive being caused by Cyclone Bola in 1988, and the February 2004 storm. *GNS Science*.

Rainfall-induced landslides

Rainfall-induced landslides, like earthquake-induced landslides, are dependent on the slope angle but are also strongly influenced by other factors such as vegetation cover, soil depth, drainage patterns, and the frequency of intense rainstorms (more than 100mm of rain in 24 hours).

Some slopes that typically fail under strong earthquake-shaking, like narrow ridges, very steep rock slopes, cliffs, and escarpments, are generally less affected by heavy rainfall.

Most rainfall-induced landslides are small (less than 1000m^3) shallow soil slides and flows on moderate to steep (more than 20^o) grass-covered hill slopes. Few are large or deep-seated bedrock landslides. Individually these small landslides do little damage and rarely threaten life but cumulatively, over a widespread area, they can cause a large amount of damage to road, rail and farm infrastructure, and are the most common form of hill country soil erosion.

Significant rainfall-induced landslide events occur more frequently in New Zealand than earthquake-induced events. There have been at least 15 rainstorms in the last 35 years that have caused extensive landsliding over large areas, especially in areas of erodible mudstone hill country in the North Island from Manawatu–Wanganui to Gisborne. The effects of these events are far-reaching. Pasture loss decreases productivity, and silt washed into streams and rivers degrades water quality and increases flood risk. The annual cost of soil erosion is estimated at $100–150 million.

Very few rainfall-induced landslides occur in areas covered in native bush, scrub, or exotic forest. The forest canopy intercepts rainfall, reducing the rate of run-off on the ground, and tree roots help to bind the soil. Deforestation is estimated to have increased landsliding in the North Island hill country by around seven times its natural rate.

Rainfall-induced landslides also damage buildings and infrastructure on steep urban slopes, particularly those modified by cutting into the slope to create building platforms, roads, and sports grounds. All but two of the 1149 landslides identified in Wellington in 1974 occurred on cut slopes, as did 70 per cent of the landslides in the December 1976 Wellington storm.

Climate change is likely to increase the frequency and intensity of rainstorms in some areas of New Zealand, which may mean an increase in rainfall-induced landslides.

FEBRUARY 2004 STORM

Shallow soil slides and deep-seated landslides in the Mangawhero Valley after the February 2004 storm. The storm caused widespread landsliding in the lower North Island hill country. The Whangaehu, Turakina and Pohangina valleys were also severely affected. *Graham Hancox*.

The heavy and prolonged rainfall of the February 2004 storm caused widespread landsliding over approximately 16 000km^2 of the southern North Island. Many thousands of small to medium (less than 1000m^3), shallow (1–2m deep) soil and debris slides and flows occurred, along with some larger (1000–200 000m^3), deep-seated landslides. Landslide damage during this storm was more extensive than in Cyclone Bola in 1988, and affected a more diverse area.

Damage to farmland was extensive across the region, and many roads were severely damaged and closed by landslides. State Highway 3 through the Manawatu Gorge was closed for three months. Landslides came close to houses and other buildings but few were significantly affected – only one house, at Karaka Bay in Wellington, was destroyed. Another large landslide (200 000–300 000m^3) dammed the Hutt River near Upper Hutt and diverted the river through the golf course, causing extensive erosion.

Most landslides occurred on steep (20–35º) grass-covered hill slopes and gullies. Debris from landslides in gullies and riverbanks put considerable sediment and vegetation into flooded rivers, contributing to bridge failures and covering downstream farmland with silt and debris.

Land use and vegetation clearly influenced landslide distribution. Hill slopes covered with native bush or exotic forest were much less affected by landslides than grass slopes.

Managing landslides

Risk reduction is central to managing landslides. There is greater opportunity for human intervention in landslide processes compared to other geological hazards. Readiness, response, and recovery from landslides are generally small scale, or part of a larger response to an earthquake or rainfall event.

Risk reduction

LANDSLIDE HAZARD MAPPING

Landslides tend to occur at or near the sites of previous landslides, and are more likely to occur on steeper slopes or areas of weak or fractured rock. Landslide hazard zones can be defined using aerial photo interpretation and GIS mapping.

Landslide-hazard zones include not only the area of the landslide itself but the area at the bottom of the slope where material is deposited (the run-out zone). This is particularly important for debris flows which have large run-out zones. Landslide-hazard zone information can be used for land-use and infrastructure planning.

LAND-USE PLANNING

Avoidance is the best landslide-risk reduction option, especially for rapid landslides such as debris avalanches and debris flows, where engineering solutions are often ineffective or uneconomic. It is generally unrealistic, however, to completely avoid development on slopes or debris fans, and a risk-based approach should be adopted using site-specific information.

Few district plans outline specific landslide-hazard zones for which a resource consent is required before development. Most planners rely on provisions in the RMA and Building Act 2004 to make decisions on land-use planning with respect to landslide hazards. However, district plans generally do contain rules to control the scale of excavations and vegetation removal on erosion-prone land.

GNS Science has completed a landslide hazard guideline for local government planners. The guideline allows planners to evaluate the effectiveness of their current plans and better assess consent applications based on risk evaluation. The public-good funded guideline was developed with input from MCDEM, the Ministry for the Environment, the Earthquake Commission, the New Zealand Geotechnical Society and local government planners.

ENGINEERING SOLUTIONS

The likelihood of a landslide occurring can be reduced by removing or strengthening susceptible material, or by modifying the slope. Engineering works are often expensive, and the decision to undertake this work depends on the value of the assets to be protected and environmental considerations.

An example of major landslide stabilisation work that was justified on the basis of asset value and the reduction of risk to local communities is the Lake Dunstan landslide stabilisation programme. More than $900 million (2006 value) was spent stabilising 16 landslides along the lake above the Clyde Dam, to prevent a sudden slide into the lake and consequent overtopping of the dam. Some of the slopes have required recontouring and buttressing.

Rapidly-moving landslides – debris flows and rock avalanches – are more difficult to prevent or modify. Debris-flow barriers can be constructed but they are very expensive to build and maintain. This is a cost that communities cannot usually afford. They are usually only economic where high value assets that cannot be relocated are at risk. As with flood stopbanks, the owner and consenting authority must also consider and accept the consequences of events that

WAIHI LANDSLIDES

Several large landslides, which have formed very large debris flows, have occurred at the Hipaua Steaming Cliffs on the Waihi Fault scarp at the southern end of Lake Taupo over the last 230 years.

The first of these landslides is thought to have occurred around 1780, burying a nearby pa and killing around 150 people. A better-documented event occurred at night in May 1846, killing at least 60 people in Te Rapa (Little Waihi) village. The most recent landslide happened on 20 March 1910 but people were alerted to the debris torrent and all but one person escaped. The village of Te Rapa was subsequently abandoned.

The landslides appear to be related to ongoing geothermal activity in the area, and future landslides could be triggered by geothermal eruptions, earthquakes, or prolonged heavy rainfall. The probability of another debris flow at Waihi in the next 50 years is estimated at 65 per cent. Such a debris flow has the potential to damage State Highway 41, as well as a fishing lodge and houses in Waihi village.

The 1910 landslide at Waihi on the southern shores of Lake Taupo and the same area in 2002. The landslide debris covered an area 800m wide and extended two kilometres from its source to the lake shore, with an estimated volume of 3 million m^3. *GNS Science*.

exceed the design capacity of the structure.

Developers of residential subdivisions on hill slopes are now tending to move away from cut-and-fill engineering to create building platforms, towards extensive recontouring of the land, removing ridges and partially filling gullies. This often removes the shallow landslide hazard.

PUBLIC AWARENESS AND LAND OWNER ACTION

Land owners can take measures to reduce the risk of landslides on their own and neighbouring properties. Poorly-maintained retaining walls, inadequate stormwater drainage, vegetation removal, and excavation can all contribute to landslides. Some territorial authorities, such as Hutt City Council, have produced guidelines for land owners outlining these issues and how landslide risk can be reduced.

CATCHMENT MANAGEMENT

Sustainable land management in the headwaters of river catchments is an integral part of shallow landslide and soil erosion control. This requires long-term, multi-faceted approaches to encourage sensible land use, including education, advice, farm planning, possible land purchase by local and central government, regulations, monitoring, and financial assistance to help farmers with the capital cost of changing land use. Regional councils play a significant role in soil and catchment management along with LandCare Research in raising public awareness.

Readiness

Many landslides occur rapidly with little or no warning, giving little opportunity for people or assets to move or be moved. Signs that often indicate the onset of landsliding are cracks in the ground or buildings, subsidence or bulging of the land, and tilting trees or seepage.

Some currently slow-moving landslides in New Zealand are monitored by asset owners and councils where there is potential for movement to accelerate and affect assets. Monitoring may range from yearly measurements of a few survey points across a landslide to complex networks, such as that along Lake Dunstan, which involves 3500 monitoring instruments and measuring points.

Response and recovery

Emergency services, local authorities and asset owners will be involved in responses to small damaging landslides. Any CDEM response to major damaging landslides follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan. Because widespread landsliding is almost always triggered by heavy or intense rainfall or earthquake shaking, the response is usually part of a wider response to a flood or an earthquake.

The Earthquake Commission (EQC) insures residential buildings and contents against landslide damage for those home owners who hold fire insurance.

Landslides onto roads, particularly during an earthquake, create a large amount of debris which must be removed to reopen roads. MfE and MCDEM have recently developed a guide for the use of the emergency works provisions of the RMA for use in such situations.

GeoNet maintains a rapid-response capability for large or significant landslides. The primary aims of these responses are to provide advice for managing public safety and to collect information that will contribute to a better understanding of the causes and mechanisms of landslides.

FURTHER INFORMATION

GENERAL LANDSLIDE INFORMATION

GEONET
www.geonet.org.nz
TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/Landslides/en
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2002-Index?OpenDocument

LANDSLIDE HAZARD PLANNING GUIDELINE

GNS SCIENCE MISCELLANEOUS SERIES 7
www.qualityplanning.org.nz/pubs/Draft-Landslide-Guideline-Feb-2007.pdf

TSUNAMIS

Tsunamis are waves generated by a rapid displacement of a large volume of water. Tsunamis are most commonly produced by large, offshore earthquakes that cause uplift or subsidence of the sea floor, but they can also be caused by coastal or submarine landslides, volcanic eruptions, and meteor impacts.

Tsunami waves differ from normal sea waves because they move through the entire column of water from the surface of the sea to the seabed and therefore have significant momentum. They travel extremely quickly, up to 900km/h in the open ocean where their wave heights are generally less than a metre. As water becomes shallower near the shore, the tsunami's wave speed reduces and the wave height increases. The time between successive tsunami waves can vary between several minutes and a few hours, and the first wave may not be the largest. A tsunami may approach the land as a large breaking wave, or like an extremely high tide moving rapidly onto the shore.

New Zealand's tsunami risk is comparable to or larger than its earthquake risk. Large tsunamis have occurred in New Zealand within written history, but have resulted in few deaths and only modest damage. However, Maori tradition records several large tsunamis killing many people within the last 1000 years. Archaeological evidence indicates that several coastal settlements around New Zealand were abandoned for higher ground in the mid-1400s. There is also geological evidence of tsunamis with up to 60m run-ups affecting the New Zealand coast within the last 6000 years.

With intensification of coastal development over the last few decades, a large tsunami today is likely to be highly damaging.

TSUNAMI HEIGHT AND RUN-UP

Tsunamis are described by both their wave height and their run-up. Tsunami height is a measure of the vertical trough-to-crest height of a tsunami wave. Tsunami height is not constant – height increases substantially as the waves approach shore and depends on the near shore bathymetry.

Tsunami run-up is the maximum vertical height that the tsunami reaches on land above normal sea level at the time. Run-up is dependent on the type and size of the tsunami as well as coastal topography and land use. Tsunami run-up is a more useful measure than tsunami height as it relates more closely to the onshore effects of a tsunami.

Tsunami sources

Distant sources

Distant-source tsunamis are those that are generated more than three hours' travel time from New Zealand. Distant-source tsunamis that are large enough to cause damage in New Zealand originate from subduction zones around the rim of the Pacific Ocean, particularly those along the coast of South America.

The subduction zone at the boundary of the Pacific and South American tectonic plates off the South American coast produces very large earthquakes and is one of the most frequent sources of tsunamis in the Pacific Ocean. Tsunamis generated along this coast can be directed towards New Zealand both by the orientation of the plate boundary and the shape of the sea floor between South America and New Zealand. The three largest distant-source tsunamis to hit New Zealand within written history – in 1868, 1877 and 1960 – have all originated from this area. Tsunami-generating earthquakes of magnitude 8.5 or greater off the South American coast have an average return period of 50 years.

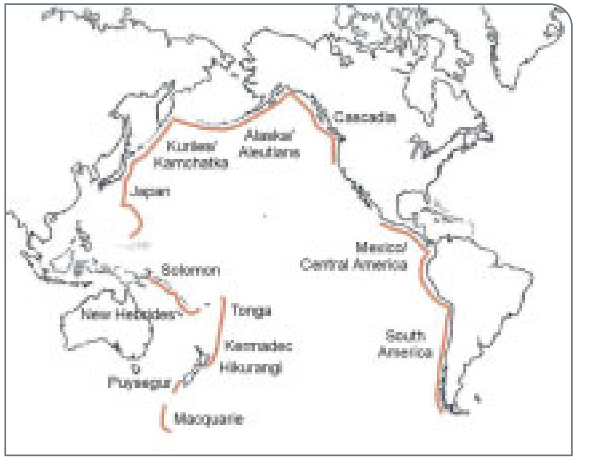


Plate boundary areas around the margins of the Pacific Ocean. The most likely distant tsunami source for New Zealand is the South American coast, particularly adjacent to Peru, followed by Alaska/Aleutian Islands and Cascadia. *GNS Science*.

The 1868 tsunami was generated by a magnitude 9.1 earthquake off the Peru/Chile coast, an area oriented in a manner which directs tsunami waves toward New Zealand. The tsunami destroyed a village and killed one person in the Chatham Islands, and caused damage in Lyttelton Harbour and other bays around Banks Peninsula.

1960 TSUNAMI

The most recent damaging distant-source tsunami to affect New Zealand was generated by a magnitude 9.5 earthquake off the coast of Chile in 1960. The tsunami arrived in New Zealand 14 hours later during the night of 24 May. It caused fluctuations of up to 4.5m above normal sea level along the New Zealand coast, damaging many boats and harbour facilities.

There were no deaths in New Zealand, but the tsunami washed people from their tents and damaged cabins at Te Awanga, north of Hastings. It damaged boats and electrical equipment at the port in Lyttelton, and further inside the harbour it inundated a hotel and several houses, and drowned 200 sheep.

The 1960 tsunami arriving in Lyttelton harbour and flooding the dry dock. There were no deaths in New Zealand but the tsunami killed several thousand people in Chile, 61 in Hawaii and 199 in Japan. *Christchurch Star*.

Tsunamis generated by large earthquakes near Alaska and the Aleutian Islands have historically only caused wave run-ups of up to 2m in northern and eastern New Zealand, although they have been devastating in parts of the northern Pacific. It is possible that future earthquakes in this region, and along the Cascadia margin between California and Vancouver Island, may produce damaging tsunamis in New Zealand, but the earthquake sources are not well oriented for directing tsunamis towards the southwest Pacific.

Other areas around the margin of the Pacific Ocean, such as Mexico and Central America, Japan the Solomon Islands and Papua New Guinea, are unlikely to produce tsunamis with damaging impacts in New Zealand, either because they do not produce very large earthquakes, or because their orientation does not direct tsunamis towards New Zealand.

Distant landslides and volcanic cone collapses or eruptions are unlikely to cause damaging tsunamis in New Zealand. The possibility of a tsunami generated by an asteroid impact does exist, but the probability is very low.

Regional sources

Regional-source tsunamis are those that are generated one to three hours' travel time from New Zealand. The most significant regional tsunami sources for New Zealand are earthquakes in tectonically active areas to the north of New Zealand. Regional-source tsunamis from the south, east, or west are unlikely.

The southern Kermadec trench is the most significant regional tsunami source with wave run-ups of up to 13m possible along parts of the Auckland coast. Modelling of a large (magnitude 8.6) earthquake along the southern New Hebrides subduction zone indicates the possibility of a tsunami in northern New Zealand, but run-up heights are unlikely to exceed 2m.

Other regional earthquake sources, mainly Tonga and the northern Kermadec trench to the north and the Macquarie Ridge to the south, are not thought to produce earthquakes over magnitude 8.5, and their orientation makes them an unlikely tsunami source.

Volcanic activity between White Island and the Kermadec Islands, northeast of New Zealand, is not a likely source of damaging tsunamis for New Zealand, and any regional landslide sources are unknown.

Local sources

Local-source tsunamis are those generated less than one hour's travel time from the nearest New Zealand coast.

Around one third of New Zealand's earthquakes occur on offshore faults. Large offshore earthquakes are capable of producing large (7–10m or greater) tsunamis along tens to hundreds of kilometres of coastline. Thirteen local-source tsunamis have been recorded since 1840 in New Zealand, all generated by earthquakes and some accompanied by coastal landslides. The 1855 Wairarapa earthquake produced a tsunami measuring 9m in Palliser Bay, 4–5m along parts of Wellington's south coast, 2–5m in the inner harbour, over 4m in Marlborough, and 2–3m along the Kapiti coast. Two local tsunamis, one up to 10m high, occurred along the coast north of Gisborne in 1947. Geological research indicates that even larger local-source tsunamis have occurred before human settlement of New Zealand.

The most significant potential local tsunami source from earthquakes is the Hikurangi subduction zone along the east coast of the North Island. This subduction zone has not ruptured historically, but it is capable of producing a magnitude 7.5–8.5 earthquake, large enough to generate a tsunami which would affect many kilometres of coastline along the east coast of the North Island and upper South Island, and the Chatham Islands. There are also many faults along the continental shelf off New Zealand's east coast which are capable of generating tsunamis.

There are many other offshore faults around New Zealand that could be capable of generating localised damaging tsunamis along tens of kilometres of coast, particularly off the eastern North Island, Manawatu, Fiordland, and Kaikoura coasts, and in Cook Strait.

Submarine and coastal landslides are possible local tsunami sources. Many large submarine landslides have been identified off the New Zealand coast with volumes ranging from $0.25km^3$ to $3000km^3$ from the 170 000-year-old Ruatoria debris avalanche. The tsunami generated by the Ruatoria debris avalanche is estimated to have been 125–700m high but such a tsunami is extremely rare. Smaller but still significant landslides in the Kaikoura Canyon or along the northern Hikurangi margin and the Kermadec Trench are more likely. Tsunami waves generated by landslides tend to rapidly reduce in height away from the source because the source is a point rather than a line, which is more typical of fault rupture-generated tsunamis. They can also be highly directional, sending a concentrated 'beam' of waves in the direction of the landslide movement. So while the waves generated can be large, their impact is often very localised.

Coastal earthquake-triggered landslides have caused localised tsunamis in the past at Westport during the 1929 Murchison earthquake, north of Napier in the 1931 Hawke's Bay earthquake and in Charles Sound in the 2003 Fiordland earthquake.

Mayor and White Islands are the only near-shore active volcanoes in New Zealand. Neither volcano is expected to experience large enough eruptions or sector collapses to generate damaging tsunamis along the Bay of Plenty or Coromandel coasts.

1947 GISBORNE TSUNAMI

On 26 March 1947 a tsunami up to 10m high struck the Gisborne coast between Mahia Peninsula and Waipiro Bay, half an hour after an apparently small earthquake. It inundated the Tatapouri Hotel, just north of Gisborne, up to its windowsills and swept nearby small outbuildings out to sea. It almost entirely demolished a cottage at Turihaua, leaving only the kitchen, with three people inside. The tsunami swept the Pouawa River bridge 800m inland and shifted a house off its foundations at Te Mahanga Beach. There were no deaths, but there could have been many casualties had the tsunami struck during the busy summer holidays.

Less than two months later another tsunami up to 6m high, also generated by an offshore earthquake of magnitude 7.1, hit the coast between Gisborne and Tolaga Bay.

All that remained of a four-bedroom cottage at Turihaua after the 1947 Gisborne tsunami. Seaweed was left hanging off the power lines behind the cottage. *Tairawhiti Museum*.

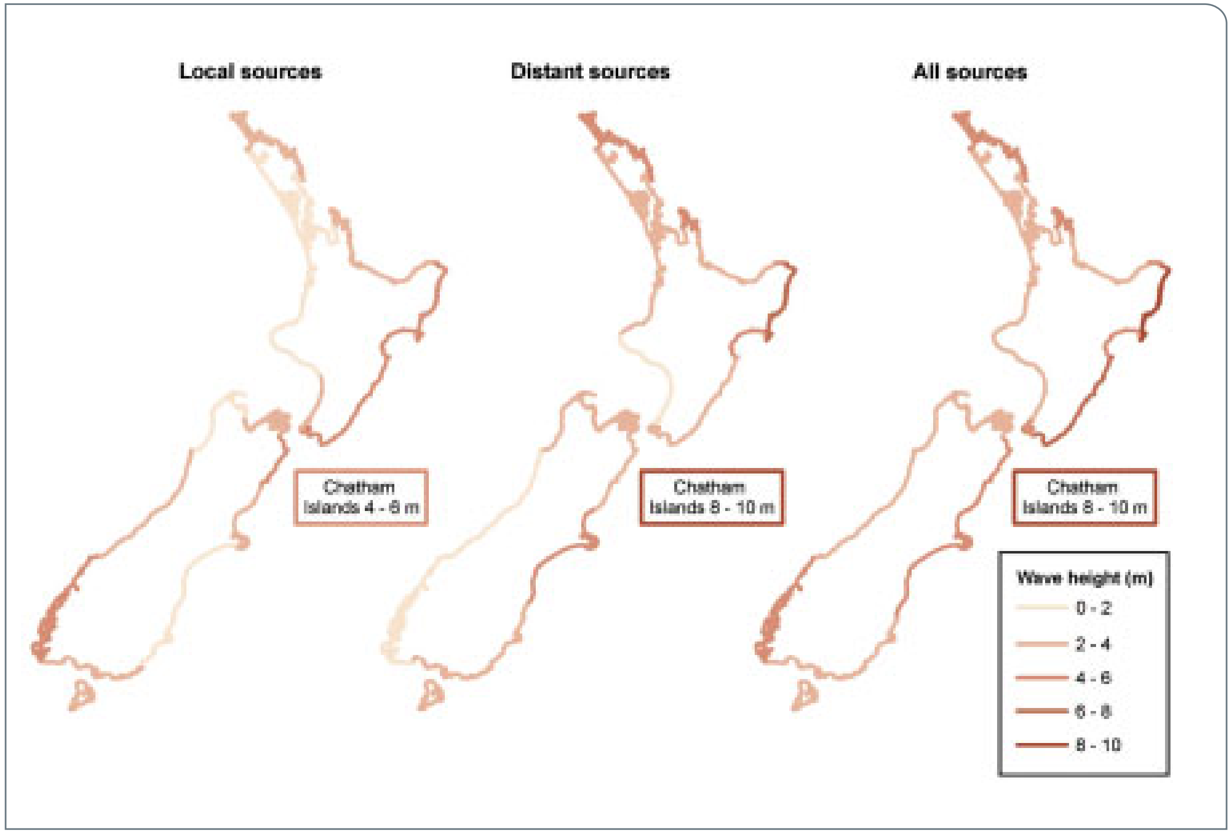
New Zealand's tsunami hazard

While no part of the New Zealand coastline is completely free from tsunami hazard, there is a large variation in the tsunami hazard around New Zealand from local, regional, and distant sources.

The tsunami hazard from local sources is greatest along the east and south coasts of the North Island, and the Marlborough and Fiordland coasts in the South Island. The tsunami hazard from distant sources is greatest along the Northland, Bay of Plenty, Coromandel, Gisborne, Hawke's Bay, and Canterbury coasts. The Chatham Rise, in particular, tends to enhance distant-source tsunami wave heights around Banks Peninsula.

The area of greatest hazard from any tsunami source, combining local and distant-source hazard information, is the east coast of the North Island. The tsunami hazard in the Chatham Islands is most likely even greater.

The largest contributors to New Zealand's tsunami hazard are earthquakes off the South American coast or along the southern Kermadec and Hikurangi subduction zones to the east of the country. Other offshore local faults also contribute but to a lesser degree.



Generalised tsunami hazard in New Zealand expressed as the 500-year return period wave height above sea level. Significantly higher or lower water levels may occur at a particular location depending on local bathymetry and coastal topography. *GNS Science.*

A tsunami hazard and risk study undertaken by GNS Science for MCDEM in 2005 estimates damages of $12–21 billion nationally from a 500-year return period tsunami. Deaths and injuries are highly dependent on the time of year and time of day, and on whether a warning can be issued before the tsunami reaches the coast. All major distant tsunami sources are more than 10 hours' travel time from New Zealand giving, in theory, adequate time for warning and evacuations, although wave heights may be difficult to predict.

Regional and local tsunami sources, however, may be only minutes to a few hours travel time from the nearest New Zealand coast. This creates serious challenges for emergency management and there may not be enough time to confirm a tsunami and issue a warning before it reaches New Zealand.

The impacts of a tsunami depend on tsunami height and run-up. Several factors contribute to tsunami damage and casualties. Fast-flowing water hits structures, vessels and people, and can erode coastal land. The 'outrush' of water when a tsunami wave recedes is often the main cause of drowning as people are swept out to sea. A large amount of debris is picked up in tsunami waves, which damages structures and injures people on both the incoming and outgoing waves. Fire and contamination are often caused by tsunamis when fuel installations are damaged and hazardous substances and sewage are released into the water. Ponding of saltwater over large areas causes damage to buildings, electronics, and fittings, and destroys pasture and crops.

Managing tsunamis

Risk reduction

The emphasis for managing tsunami hazards is on readiness and response. However, there is growing recognition of the potential effectiveness of risk reduction, particularly land-use planning and urban design. There has been little progress in implementing such measures in New Zealand because of the infrequency of damaging tsunamis in the recent past in New Zealand and the low population density. Few territorial and regional authorities in New Zealand have plan provisions that specifically address tsunami hazards, but many have provisions to reduce the risk from coastal erosion and other coastal hazards which help reduce the risk from tsunamis.

In some locations the tsunami risk could be considered high enough to warrant restrictions on the location and type of coastal development, particularly where the risk is from local source tsunamis.

Non-regulatory mitigation methods could be considered in planning and development proposals, many of which can be incorporated into new developments with minimal or no extra cost. Methods include dune restoration (dunes act as a buffer to some of the tsunami impact and are also useful in protecting against coastal erosion), increasing surface roughness by planting vegetation behind dune systems, locating reserves between the coast and development, and meandering or angled beach access ways.

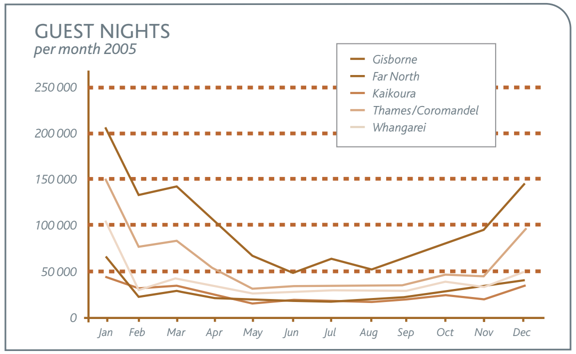
Other methods, including locating key infrastructure and community facilities away from the coast, designing roading patterns that increase access perpendicular to the coast, and designing higher or stronger buildings, could also be considered.

Structural protection works that are used in other countries such as Japan to protect against tsunami waves are unlikely to be economically viable or environmentally acceptable in New Zealand.

Readiness

The Pacific Tsunami Warning Center (PTWC), based in Hawaii, monitors the Pacific Ocean for large earthquakes and tsunamis. MCDEM (as well as the MetService and Airways Corporation) receives warnings for distant and some regional-source tsunamis from the PTWC and passes them on to CDEM Groups. CDEM Groups then coordinate evacuations in their regions if necessary, following procedures set out in their CDEM Group plan.

PTWC warnings do not contain forecasted wave heights. It is the responsibility of each nation's response system to evaluate likely



Guest nights per month for selected territorial authorities with coastal resort towns. Coastal populations show significant seasonal variation peaking between December and March. A tsunami occurring during these months would have a much larger impact than one occurring during winter. Guest nights make up only around a third of the total population increase over the summer months, the remainder staying in private accommodation. *Ministry of Tourism*.

TSUNAMI RISK AND READINESS IN NEW ZEALAND

The disastrous consequences of the 26 December 2004 Indian Ocean tsunami prompted the Government to review New Zealand's risk from tsunamis and its preparedness for them. GNS Science was commissioned by MCDEM to prepare a science report assessing New Zealand's tsunami hazard and risk, and a preparedness report reviewing the adequacy of current tsunami warnings in New Zealand. The reports incorporated work by many New Zealand tsunami researchers and were completed in September and December 2005 respectively.

The tsunami preparedness report gave several recommendations for improving national and regional management of tsunami risk. Recommendations centred around improving GeoNet's capability for generating alerts and predicting effects, developing national level resources and guidelines, investment at a national level in tsunami research, and CDEM Group level improvements in risk reduction and readiness.

Following consultation with stakeholders on the report findings and recommendations, MCDEM prepared a report for the Minister of Civil Defence outlining priority areas for further work. In September 2006, the Minister endorsed the report and outlined a number of steps to be undertaken. In the shorter term the Minister has directed that a Tsunami Working Group involving a broad range of stakeholders be formed for improving the national warning system and developing public warning systems. In the longer term a commitment has been made to improve tsunami risk management, including support for developing local tsunami evacuation plans, tsunami contingency planning, and scenario modelling.

Tsunami warning signs, like this one at Castlepoint Beach, have been installed at some coastal locations around New Zealand. There is reluctance in some at-risk areas, however, to erect signs amid concerns they will alarm people and deter tourists. *Masterton District Council*.

impacts in their area and to implement response plans. There is currently a high level of uncertainty in determining wave heights and areas of inundation. Modelling tsunami inundation is currently being undertaken to define evacuation zones in some areas of New Zealand, for example Northland.

Regional source tsunamis have travel times of between one and three hours. Work is currently being carried out by GeoNet to improve detection and alert notification capabilities for these threats to New Zealand.

Local-source tsunamis may hit the New Zealand coast within minutes of an earthquake or landslide, before GeoNet can locate an earthquake, confirm a tsunami has been generated, and issue a warning. In these instances the public will need to evacuate themselves without an official warning if they have felt a strong earthquake or notice unusual changes in sea level. Public education is therefore extremely important in coastal areas of New Zealand and is the most effective readiness measure for local-source tsunamis.

Local-source tsunami warning systems that deliver warnings within three to five minutes exist in Japan but given their very high cost they are unlikely to be justifiable in New Zealand with its low population density.

Asteroids are tracked by NASA and substantial advance warning can be given before a likely asteroid impact that may cause a tsunami.

PACIFIC TSUNAMI WARNING CENTER

The Pacific Tsunami Warning Center (PTWC) in Hawaii was established in 1949 as an international programme to provide Pacific nations, including New Zealand, with tsunami warnings. The PTWC continuously monitors earthquake activity and sea levels in the Pacific region using data from participating nations.

The PWTC issues a tsunami information bulletin when an earthquake between magnitude 6.5 and 7.5 is detected within or near the Pacific Ocean basin. A tsunami warning/watch bulletin is issued for earthquakes greater than magnitude 7.5. This alerts civil defence emergency management agencies of the possibility that a tsunami may have been generated.

If an earthquake appears to be large enough to cause a tsunami and is located in an area where tsunami generation is possible, the PTWC will check water-level data from automatic tide stations near the earthquake for evidence of a tsunami. If the water-level data indicates a tsunami that poses a threat to countries around the Pacific Ocean has been generated, a Pacific-wide tsunami warning bulletin is issued. If tide stations indicate a negligible or no tsunami the tsunami warning/watch bulletin is cancelled.

Because of the time taken to analyse data and confirm or dispel the existence of a tsunami, warnings issued by the PWTC cannot be relied upon to warn against local-source tsunamis in New Zealand.

Response and recovery

Response to a tsunami begins when it is known that a tsunami has been generated (in the case of a local-source tsunami this could be when the tsunami reaches the shore), and if there is time may include organised evacuations for several hours or even days, and the provision of scientific advice to Government following generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan. In addition, MCDEM is currently preparing a tsunami contingency plan.

The Earthquake Commission insures residential buildings and contents against tsunami damage, up to a certain limit, for those home owners who hold fire insurance.

FURTHER INFORMATION

GENERAL TSUNAMI INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/Tsunamis/en
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/MEMWebsite.nsf/Files/tephra99/$file/tephra99.pdf
NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH
www.niwascience.co.nz/rc/prog/chaz/news/tsunami

GNS SCIENCE TSUNAMI HAZARD AND RISK REPORT

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tsunami-Risk-and-Preparedness-in-New-Zealand-Reports?OpenDocument

GNS SCIENCE TSUNAMI PREPAREDNESS REPORT

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tsunami-Risk-and-Preparedness-in-New-Zealand-Reports?OpenDocument

PACIFIC TSUNAMI WARNING CENTER

PACIFIC TSUNAMI WARNING CENTER
www.prh.noaa.gov/ptwc

GEONET

GEONET
www.geonet.org.nz

Brighton Spit, Christchurch, is at risk from tsunami inundation, storm surge events and sea-level rise.

COASTAL HAZARDS

New Zealand's 18 000km of coastline is constantly changing, shaped by frequent high swells and occasional storm surges, that erode and occasionally inundate coastal land. Less frequent but potentially very damaging tsunamis also hit New Zealand's shores.

Managing the residential, recreational, and economic use of New Zealand's dynamic coastal environment is a challenge. Coastal development, particularly for residential use, has increased in recent years, placing more people, property, infrastructure and recreational facilities at risk from coastal hazards.

Swells

Wind creates waves on the surface of the ocean. Swells are series of these waves with a long distance between wave crests, which lose very little energy as they travel across large distances of up to thousands of kilometres of open ocean.

The prevailing westerly winds in the Southern Ocean create persistent southwest swells along the west coast of both islands, where the swell is rarely below 2m high. The exception is the Kapiti-Horowhenua coast, which is sheltered from this direction by the South Island. This low-lying coast can sustain serious damage, however, when subject to occasional large swells from more westerly and northerly directions.

The northeast of the North Island, on the less energetic Pacific coast, is sheltered from the southwesterly swell. However, this coastline is occasionally exposed to northeast swells of more than 4m created by tropical cyclones, which are often accompanied by storm surges.

Swells along the east coast from East Cape to Bluff are more variable in direction and height. They average 0.5m to 2m, but can occasionally rise to between 4m and 6m.

Waves crashing over a sea wall near Wellington airport on Wellington's south coast in 1998. This coast is often subject to southerly swells which can damage sea walls and boats, and deposit material over coastal roads. *The Evening Post*.

Very large swells affect various parts of the New Zealand coast several times a year, most commonly in autumn and winter. Heavy swells can damage moored boats and coastal infrastructure, and cause or contribute to coastal inundation and erosion.

WAITANGI DAY 2002 SWELL

An unusually large summer swell hit eastern New Zealand from Canterbury to Gisborne on 6 February 2002, created by a deep low to the east of the South Island. The low generated gale force southerly winds and high seas in Canterbury, which sank five boats in Lyttelton Marina. It also generated a very large swell which travelled up the east coast, striking Wellington on what was an otherwise calm and sunny morning. Thirteen metre waves were recorded on the Baring Head wave buoy at the entrance to Wellington Harbour. The southerly gale hit Wellington around noon, just as high tide approached, creating extremely high seas. Debris covered coastal roads, and waves entered the back yards of several coastal properties and damaged sea walls. Damage amounted to several hundred thousand dollars.

Further north, the log carrier Jody F Millenium attempted to leave Port Gisborne to avoid being battered against the wharf but ran aground on a sand bar outside the harbour. It took two and a half weeks and $1.5 million to refloat the ship. This work was hampered by further big swells.

Storm surge

A storm surge is a temporary elevation in sea level during storm conditions created by two factors – low barometric pressure and wind. Low-pressure systems responsible for storms create a vacuum effect over the sea, causing the water level to rise by one centimetre for every one-hectopascal fall in air pressure below average air pressure. This 'inverted barometer' effect can cause sea level to rise by up to 0.5m above tide level.

On top of the inverted barometer effect, strong winds can pile water up against a coast creating what is known as wave set-up. This can increase sea level another 0.5m. The combination of the inverted barometer effect and wave set-up can create storm surges of up to 1m above the tide level around New Zealand. Storm surges are often caused by ex-tropical cyclones to the northeast of New Zealand. Large areas of low-lying coast, such as around the Firth of Thames (particularly the Hauraki Plains) and Tasman Bay, are most vulnerable to storm surge.

A large storm surge can cause damage at any time, but the degree of damage is highly dependent on the tide at the time. A storm surge that occurs around a very high tide is likely to be much more damaging than one arriving at low tide. Coastal inundation can be extreme if storm surge and high swells combine with an unusually high tide. This happened in March 1936 when a low-pressure system creating a storm surge on top of the highest spring tide of last century flooded much of the Hauraki Plains.

Coastal inundation and erosion during storm surges or swells is unlikely to result in deaths because adequate warnings can usually be issued. Coastal infrastructure such as ports, roads, and rail, along with buildings in coastal communities, can be damaged. Coastal land may be eroded and large areas of coastal farmland may be contaminated by salt water inundation. Storm surge may also worsen river flooding by reducing river flow into the sea.

The probability of damage from storm surges is likely to increase with sea level rise induced by climate change.

Coastal erosion

Coastal erosion is the retreat of the shoreline caused by water currents, waves, and wind. It is part of a natural process of shoreline movement that can be influenced by human activities.

New Zealand has a range of coast types dictated by geology and wave exposure. Much of New Zealand's coast is steep cliffs. Cliffs composed of young, soft, sedimentary rocks, such as those along the east coast of the North Island, erode easily. In other areas, such as Fiordland, very old, hard rocks are more resistant to erosion. Around a third of New Zealand's coastline is beach, either long stretches of open beach, like those on the west coast of both islands, or small disconnected beaches separated by rocky headlands, like those in northeastern New Zealand. Beaches go through cycles over various time scales of building up (accreting) and eroding.

Most coastal erosion occurs in large increments during storms when heavy swells, sometimes accompanied by storm surges, buffet the coast. Eroded beaches are sometimes gradually rebuilt during intervening calm periods. Several underlying factors, however, contribute to the location and severity of coastal erosion. These include the local geology, the supply of sediment to and along the coast, and the presence of artificial structures such as breakwaters and sea walls.

Human activities can disrupt sediment supply and increase erosion. Extracting sand near the shore can reduce the supply of sediment to nearby beaches. Damming and extracting water from rivers changes the flow conditions and the supply of sediment to the coast. Building port breakwaters alters sediment transport along

Rates of coastal erosion in New Zealand. About one quarter of New Zealand's coast is eroding. *Adapted from Gibb, 1984.*

the coast. Stormwater discharge across beaches can also contribute to localised erosion.

Large-scale coastal erosion is generally a gradual process occurring over many storm events, and areas susceptible to coastal erosion can generally be identified in advance. Ideally, coastal erosion can be planned for and the effects mitigated. However, there are periods when coastal erosion is more rapid and severe than normal, and significant damage can occur. Deaths are not anticipated, but land and the assets on it, such as houses, roads, and recreational areas, can be damaged or destroyed.

Sea level in New Zealand has risen steadily by about 16cm over the last 100 years. This rate is likely to increase with climate change.

Rising sea level contributes to coastal erosion as each successive storm is able to encroach further inland. Climate change is also likely to cause other changes in coastal erosion drivers such as wave patterns, storminess, and other factors affecting coastal sediment supply, such as sediment input from rivers.

COASTAL EROSION IN HAWKE'S BAY

Coastal erosion and inundation are significant issues for several small settlements along the Hawke's Bay coast, particularly since the 1970s when several large storms caused erosion and inundation damage. Seawater flooded 300 hectares of coastal horticultural and urban land in East Clive in 1974. A sea-exclusion bank was built in 1976/77 to prevent further inundation but continued erosion, made worse by construction of the Hastings sewage outfall in 1979, resulted in the bank being moved further inland.

More recently, 20 Haumoana residents evacuated their seafront homes on 3 April 2002 as high seas threatened a dozen properties. The waves destroyed fences, cracked doors, and smashed windows. Further south, campers at Kairakau Beach abandoned caravans and tents as waves encroached onto the camping ground, filling some caravans with sand and pushing them 2 or 3m back with their force. The sea eroded land and inundated homes again in March 2005 and July 2006.

The shoreline is retreating at Haumoana by 0.3–0.7m each year. Increased storminess over the next few decades, associated with a positive phase of the Interdecadal Pacific Oscillation and sea level rise, are likely to increase erosion and inundation. Many residents have built their own sea walls in the past, but this piecemeal approach to protection has generally been ineffective and has disrupted natural processes. It is highly likely that more homes will be damaged or destroyed in future, and retreat away from the shoreline may be the only viable option.

Heavy seas hit Haumoana on the Hawke's Bay coast in July 2006. Erosion has been causing damage to property along the Hawke's Bay coast since the 1850s. *Hawke's Bay Regional Council.*

Sea wall at St Clair beach in Dunedin. The 500m-long sea wall was built in 2004 at a cost of $5.7 million and replaced an existing 80-year-old sea wall. *Otago Daily Times*.

Managing coastal hazards

The demand for coastal living, often in inundation or erosion-prone areas, is high, and managing coastal hazards is a complex issue. Many different approaches to coastal hazard management, usually involving a combination of measures (some more effective than others) are used around New Zealand. Direct engagement with communities affected by coastal hazards is a widely used approach to develop solutions. However, this is often a long and difficult process involving disparate points of view.

Risk reduction

STRUCTURAL PROTECTION

Structural protection measures are used in New Zealand in an attempt to prevent or lessen erosion in specific locations. Central government has not provided subsidies for structural protection since 1971 and local authorities only provide protection for public assets. Therefore structural protection for private property must now be funded by property owners. This approach has led to many ad hoc structures being placed along New Zealand's coastline, many of which are unattractive and in a state of disrepair. Private structures now require consents from the local territorial authority or regional council under the RMA.

Structural protection often creates or worsens erosion further along the coast, shifting the problem rather than solving it. It is often ineffective and can be expensive to build and maintain, particularly if it sustains frequent damage. It is often uneconomic in the long-term and is becoming a less desirable option for coastal erosion management.

BEACH STABILISATION AND RENOURISHMENT

About 1100km of New Zealand's coastline is dunes. There is growing recognition of the role dunes play in buffering coastal land from coastal inundation and erosion. Recent years have seen a large increase in community-based projects to restore and stabilise dunes around New Zealand. Dune restoration includes planting with sand-binding native grasses such as pingao and spinifex, and restricting access across the dunes to defined walkways.

Beach nourishment involves bringing in sand to replenish beaches. Many beaches in New Zealand, for example Mission Bay in Auckland and Oriental Bay in Wellington, have been replenished. This is only a temporary solution, however, and ongoing nourishment is expensive.

LAND-USE PLANNING AND RELOCATION

Set-backs from the coast are now generally accepted as the best way to reduce risk from coastal inundation and erosion in undeveloped areas. This represents a shift away from managing beaches to managing human activities.

Knowledge of long-term coastal erosion and sedimentation trends is crucial for making land use planning decisions in coastal areas. Some coastal settlements were developed when the adjacent coast appeared to be stable or advancing, but have subsequently suffered from coastal erosion when the coastline retreated in an erosional phase. Significant research now goes into determining reasonable set-back lines for land use planning in some areas.

However, it can be difficult for territorial authorities to gain acceptance of land-use planning controls to reduce coastal erosion and inundation risk. Coastal properties now have high values and development proposals are often only resolved in the Environment Court.

Some territorial authorities require beach front houses to be relocatable so that they can be removed if they are threatened by coastal erosion. The 'do nothing' approach is also sometimes used, where houses are left to fall into the sea. This approach is often unacceptable to the individuals and communities involved.

Under the RMA, regional councils are required to prepare a regional coastal plan for their coastal marine areas. These plans address coastal issues, control the effects of activities and discharges, and identify conservation values.

New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS) is the only mandatory national policy statement under the RMA. It includes policies for, among other things, avoiding and mitigating the effects of natural hazards in the coastal environment, to which local authorities must give effect. There are six policies specifically related to coastal hazard management, which focus on avoiding coastal hazards, avoiding the need for structural protection works, and promoting 'soft' options such as dune restoration above structural protection works for existing development.

The NZCPS also promotes a precautionary approach to proposed activities within the coastal marine area, particularly where there is a lack of understanding of coastal processes or of the effects of the proposed activities.

The NZCPS became operative in 1994 and a review of its ability to address coastal issues was released in 2004. The review included a report assessing the NZCPS's effectiveness in promoting sustainable coastal hazard management. The report drew attention to the many barriers to sustainable coastal hazard management and recommended more specific coastal hazard policies. The Department of Conservation is currently undertaking a full review of the NZCPS, and is aiming to have a draft revised NZCPS to Cabinet by October 2007.

Readiness

Tides are calculated well in advance and the timing of particularly high spring tides (just after the full and new moon) and perigean tides (when the moon is closest to earth), when the probability of coastal inundation is greatest, can be forecast. NIWA predicts and distributes 'red alert' and 'carefree' dates for each year. Even small storm surges could cause coastal inundation on 'red alert' days, but coastal inundation is unlikely on 'carefree' days, although it could occur in an extreme storm surge.

The state-owned MetService gathers, analyses, and provides weather information to New Zealanders. The MetService provides marine forecasts and swell warnings, and also issues advisories for abnormally high water within enclosed bays along the northeastern coast. Different areas of the New Zealand coast have different swell-warning thresholds, depending on their topography and vulnerability. For example, southeast swells of more than 3m can be destructive along the Canterbury coast, whereas swells of more than 5m pose a threat to State Highway 1 along the Marlborough coast. East coast areas from South Canterbury to Gisborne, Cook Strait, and the Kapiti Coast, are carefully monitored for swells.

Storms that are likely to cause greater than 3m swells are closely monitored and advisories may be issued several days in advance. A swell warning is issued 24 hours before the warning criteria is expected to be reached along a particular stretch of coast.

Forecasts use moored wave-rider buoys, which supply continuous information on swell height, direction, and period, and ships at sea send in six-hourly wind, sea, and swell reports. Data from the open sea was previously sparse, but satellites now use scatterometers, which measure sea surface roughness.

Response and recovery

Storm surge and coastal erosion hazards are generally localised events, and any emergency response to storm surges is likely to be managed at a local level by emergency services and local authorities. Any broader CDEM response required for storm surges or coastal inundation or erosion would follow generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

FURTHER INFORMATION

COASTAL FLOODING, TIDES, AND STORM SURGE

NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH
www.niwascience.co.nz/rc/prog/chaz/news/coastal

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2003-Index?OpenDocument

COASTAL EROSION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/OceanStudyAndConservation/CoastalErosion/1/en
www.teara.govt.nz/EarthSeaAndSky/MarineEnvironments/CoastalShoreline/1/en

NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH
www.niwascience.co.nz/rc/prog/chaz/news/erosion

GIBB, J, 1984, 'COASTAL EROSION'. In Crozier, M and Speden, I (comp), 1984, Natural Hazards in New Zealand. New Zealand National Commission for UNESCO, Wellington.

FLOODS

A flood occurs when the amount of water in a river exceeds the capacity of the river channel and inundates adjacent land. Floods are an integral part of a river's natural cycle – they transfer sediment through the river system to floodplains and offshore.

New Zealand's early settlers lived close to rivers to take advantage of fertile soils, fresh water, and the transport links that rivers provided. The settlers, with limited knowledge of New Zealand's landscape and climate, didn't realise the high flood hazard.

Floods continue to be New Zealand's most frequent and costly natural hazard. Today, with structural protection works and monitoring and warning systems, floods claim few lives, but they still regularly cause millions of dollars' worth of damage to structures, infrastructure, and agriculture.

Factors that control flooding

The size of a flood in a river depends on the intensity, duration and total amount of rainfall, and the characteristics of the catchment and floodplain.

Widespread heavy rain

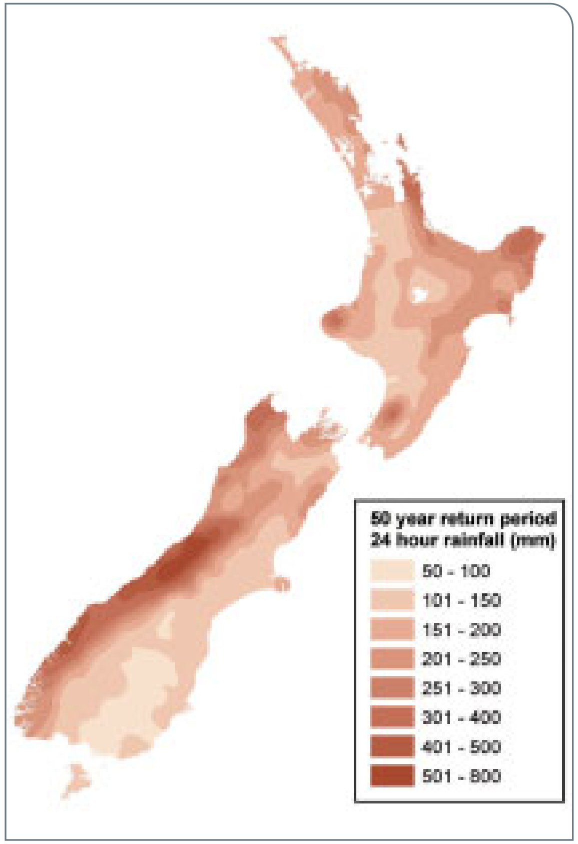
New Zealand is surrounded by ocean and lies in the zone of strong westerly winds which flow around the southern hemisphere where warm, moist air of tropical or subtropical origin meets cold, dry air from high latitudes. Topography and the angle at which the airstream hits New Zealand's ranges, along with the temperature and humidity of the air, dictate the distribution of rainfall over the country. Consequently, heavy rainfall can occur at any time of the year in any part of the country.

Widespread heavy rain occurs when air is forced upwards either within a frontal system, as moist warm air is driven up over a mass of colder air (frontal rain), or within moist air that is forced to rise over mountains (orographic rain), or as a combination of the two processes.

Heavy rainfall in the west and south of the South Island is common and is produced by a combination of fronts within west or northwest airflows and one of the highest rates of orographic uplift of air in the world. Moisture-laden air arriving from the west is forced up over the Southern Alps, rising 2500 to 3500m within 10–20km of the coast. Annual precipitation (both rain and snow) is up to 15m in the Southern Alps and rainfall of more than 600mm in one day has been recorded on the West Coast.

Heavy rainfall in the North Island and the northeast of the South Island is often associated with mid-latitude cyclones or ex-tropical cyclones that move over or past New Zealand from the north. Very strong winds often accompany ex-tropical cyclones.

Heavy rain in the southeast of the South Island may be produced by slow moving mid-latitude cyclones to the east of the island or north-south oriented fronts between a mid-latitude cyclone in the Tasman Sea and a high pressure system in the Pacific Ocean.



The 50-year return period rainfall for a 24-hour period. The west coast of the South Island, Mt Taranaki, the Tararua Range and the northeastern North Island have the highest 24-hour rainfalls. *National Institute of Water and Atmospheric Research.*

FEBRUARY 2004 STORM

The February 2004 storm was New Zealand's most widespread and damaging flood since Cyclone Bola in 1988.

Unusually wet conditions were created during late January and early February by a series of westerly airflows across central New Zealand. On 11 and 12 February a front brought northwesterly rain and winds to the lower North Island, with almost 400mm of rain recorded over 24 hours in the Tararua Range, bringing the Otaki, Hutt, and Wairarapa rivers into flood.

On 14 February a depression deepened rapidly east of the North Island, bringing further falls of heavy rain to the already saturated lower North Island and upper South Island during 15 and 16 February. Many districts in the southern half of the North Island received more than 100mm of rain, and up to 250mm fell in the Tararua and Ruahine ranges.

Rivers and streams in the Hutt Valley, Kapiti, Wairarapa, Manawatu, and southern Taranaki all flooded. The Oroua, Whangaehu and Turakina rivers in the Manawatu experienced at least 100-year return period flows. Four stopbanks burst in the Manawatu, inundating farmland, settlements, and roads. Many bridges were damaged, and water and gas lines across them cut. The Manawatu Gorge was closed for almost 3 months. No lives were lost but more than 1800 people were evacuated from their homes in the Manawatu.

The storm was the largest rainfall event in the lower North Island since major vegetation clearances of the early 1900s. Shallow landslides affected more than 16 000km^2 of hill country and more than 200 million tonnes of soil is estimated to have been lost from the Manawatu-Wanganui region. The soil was deposited over farmland downstream, and significantly raised riverbeds reducing flood carrying capacity.

The storm caused losses estimated at $380 million (2006 value). This included $195 million in agricultural losses from stock, crop, and pasture loss; milking interruption; and fence and farm building damage. Roads suffered more than $75 million worth of damage, and flood protection schemes and rivers more than $25 million. Insured losses totalled $121 million.

Ngaputahi Station in the Manawatu after the February 2004 storm. Millions of tonnes of soil was washed into flooded rivers and deposited on farm land downstream. *Westmount School*.

Localised rain

Localised intense rain is generally associated with thunderstorms – unstable air masses formed by convective conditions as air rises and cools rapidly through solar heating, or frontal or orographic uplift. Thunderstorms can generate very intense rain, damaging winds, hail and lightning. They often develop rapidly, making them difficult to forecast accurately, but they are generally short-lived and often only affect a small area, usually less than 100km^2.

Thunderstorms most commonly occur in New Zealand as small, brief storms lasting for less than half an hour. Larger and longer-lived thunderstorms known as multicell line storms may last for several hours but are generally mobile and only affect individual areas for a short time. Multicell line storms, also known as squall lines, can produce intense rain, hail, strong wind gusts, and occasionally small tornadoes. Supercell thunderstorms, which bring intense rain, severe wind gusts including damaging tornadoes, and large hail (golfball-sized or larger), are also occasionally observed in New Zealand but are uncommon.

The intense rain produced in thunderstorms is the main cause of flash flooding in New Zealand. Twenty-one people were killed in 1938 at Kopuawhara Stream near Wairoa when around 130mm of rain fell in one hour, creating a flash flood that washed away 47 workers' huts. The May 2005 Matata flash flood and resulting debris flow was the result of a thunderstorm that delivered 95mm of rain in one hour in the catchments behind the village. Intense rain can produce shallow landslides, soil erosion, and debris flows, particularly in rural catchments, and surface flooding is common in urban catchments where stormwater systems may not cope.

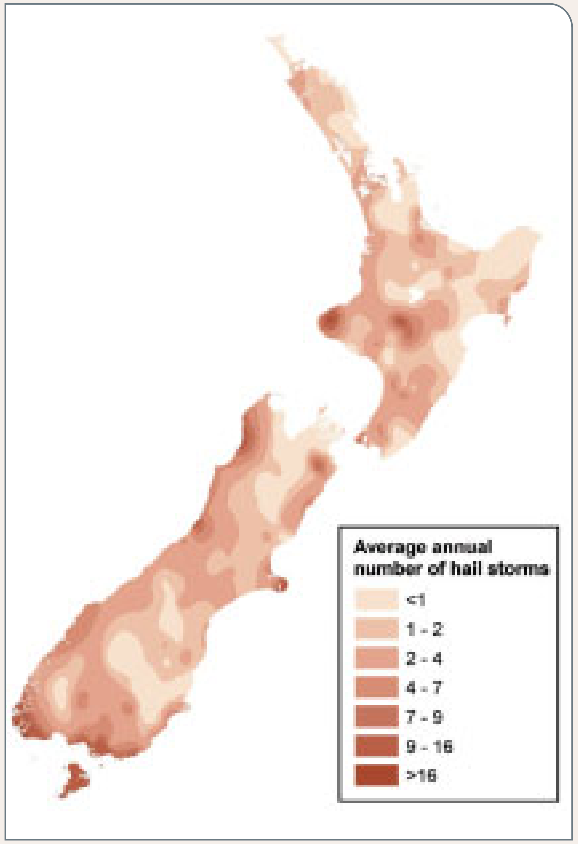
HAIL AND LIGHTNING

Along with flooding, the hail and lightning produced by thunderstorms can affect property, infrastructure and crops.

Hailstones larger than 5mm in diameter can damage fruit and vegetable crops; for example, hailstorms in 1997 caused more than $50 million worth of damage to apple crops in Hawke's Bay. Hail can block stormwater drains and increase surface flooding in urban areas.

More than 100 000 lightning strikes hit New Zealand each year. Lightning strikes are most frequent in or to the west of the main mountain ranges, particularly in spring and summer, as air is pushed up over the mountains. The less frequent lightning strikes in eastern areas occur mostly during summer afternoons and evenings when surface temperatures are high. Lightning kills someone every 5–10 years in New Zealand, regularly disrupts electricity and telecommunications, and can also start fires.

Susceptibility to hail and lightning can be mapped at a regional scale, based on historical data. This helps with making decisions about locating crops and infrastructure. Because hail and lightning are localised events, they are unlikely to be of national significance unless they affect important infrastructure or a densely populated urban area.



Average annual number of hailstorms in New Zealand. Hailstorms most frequently occur in western areas in winter and spring, but the most damaging hailstorms occur in eastern areas during spring and summer. *National Institute of Water and Atmospheric Research.*

Catchment conditions

The size and effects of a flood are influenced by conditions within the river catchment that control the relationship of rainfall to runoff. The more permeable the ground surface, the more rainfall it can absorb before it becomes saturated and the water runs off into streams and rivers. Previous weather conditions have a large influence on the severity of a flood caused by a particular rainfall event. For example, rainfall on an already saturated catchment will lead to a more extreme flood than in a dry catchment where there is capacity for rain to infiltrate the soil.

The type of bedrock, soil, and vegetation in a catchment also influence runoff rates during rainfall. Vegetation clearance in a river catchment increases the rate of runoff causing rapid and high flood peaks. Shallow landslides and soil erosion are also much more likely on cleared hill country, causing more sediment to be fed into flooded rivers. The sediment is deposited on floodplains and raises river bed levels, reducing the flood-carrying capacity of the river.

Wetlands act as storage areas and slow the flow of water into waterways. In contrast, impermeable surfaces in urban areas increase runoff rates because rainfall is unable to infiltrate the soil.

Flooding in New Zealand

New Zealand's river catchments are relatively short and steep, compared to other countries. This makes for a short interval (from hours to a few days) between when the rain falls and when the flood peaks. Warning times are therefore short and water speeds can be high, but the flood itself is over relatively quickly.

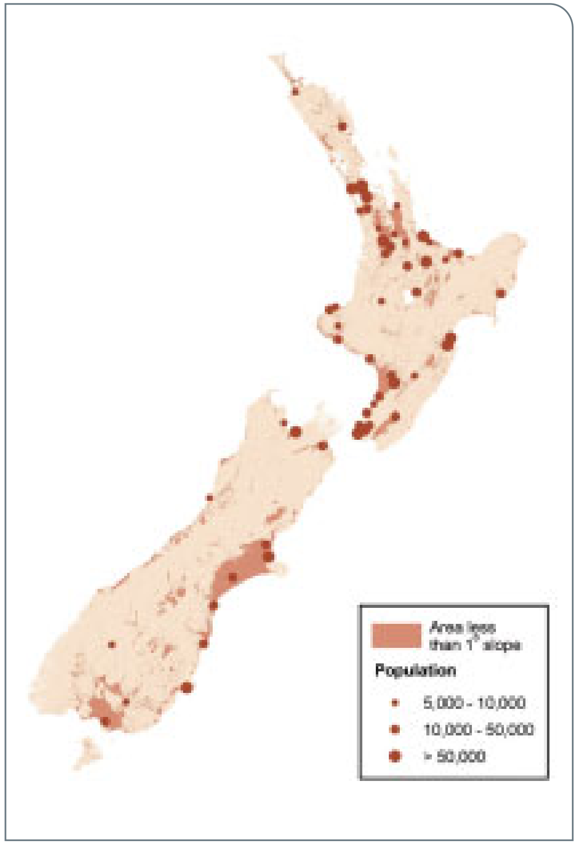
There is no standard measure of flood hazard or risk across New Zealand. Flood-hazard maps are developed by individual regional councils and do not necessarily depict the hazard from floods of the same frequency. Flood-hazard assessments are often only carried out for major rivers and in areas where significant flooding has occurred in the past. Flood hazards also depend on the existence or otherwise of protection works, which vary in design and standard across New Zealand.

The effects of a flood depend on the depth and speed of water in the flooded area. These in turn depend on the 'size' of the flood, which is measured by the amount of water involved or, more commonly, by its estimated return period.

New Zealand has a low population density and many of the country's fertile floodplains are intensely farmed. A large proportion of flood losses in New Zealand are therefore related to damage to farm infrastructure, livestock and pasture loss, and indirect economic impacts.

Floods are one of the more significant hazards for agriculture. The on-farm effects from flood events are often long-lasting with economic and social impacts continuing for several years after the event. Floods often result in livestock welfare issues.

Roading and rail infrastructure is also often damaged, particularly by rainfall-induced landslides that often accompany flooding. Scour of bridge piers is a major contributor to flood damage, and lives have been lost as a direct consequence. Flooding in urban areas leads to evacuations, damage to houses, and environmental and public health issues as water and sewerage systems are overcome and hazardous substances released. Risk to life from flooding in New Zealand is relatively low compared to other countries, but social disruption can be considerable when people are evacuated for long periods of time.



Areas of New Zealand with gentle slopes of less than 1°, giving a general indication of flood-prone land. The actual flood hazard in these areas depends on regional catchment and floodplain management, including physical flood-protection measures. These areas contain some of the country's richest agricultural land, and several towns and cities have a high flood risk, either because of the high flood hazard or the number of people and amount of assets that are exposed. *National Institute of Water and Atmospheric Research.*

Managing floods

Where and when rain falls cannot be controlled but what happens to the water once it reaches the ground can be influenced to reduce the flood hazard. Decreasing the rate of runoff into streams and containing the flood within the river channel are two measures that can be taken. However, these measures cannot eliminate flooding, and land will still occasionally be inundated. The consequences depend on how communities choose to use flood-prone land.

Risk reduction

Reducing flood risk involves managing entire river systems from the catchment to the sea.

Traditionally, flood risk reduction in New Zealand has focused on building structures to keep water away from people. Less regard was given to non-structural measures such as land-use planning to keep people and property away from flood-prone areas, and adopting building standards to keep people and property above flood levels. Effective flood-risk reduction involves a combination of structural and non-structural measures on floodplains and managing land use in river catchments.

Regional councils and territorial authorities are both involved in managing flood risk using a variety of approaches and design standards. There is a growing interest in a more consistent approach to flood-risk reduction across New Zealand, which has generated three recent projects. The Ministry for the Environment funded the Floodplain Management Planning Guidelines, released in 2001, to guide regional councils on floodplain-management planning practice and methodology.

THE FLOOD RISK MANAGEMENT REVIEW AND THE FLOOD RISK MANAGEMENT PROTOCOL

The Ministry for the Environment began the *Flood Risk Management Review* in July 2005 in response to the large floods of 2004. The review, expected to be completed in 2007, focuses on three key areas:

- current flood-risk management practices and whether they are appropriate
- central and local government's role in ensuring good flood-risk management practices are adopted
- who benefits, who pays, and who can afford flood-risk mitigation.

The draft *Flood Risk Management Protocol*, an initiative sponsored by regional councils and supported by central government, gives councils a set of principles for managing flood risk. The protocol was also developed after the 2004 floods to help address increasing development pressures in flood-prone areas, the increasing cost of flood mitigation measures, increasing public expectation for protection and the limitations of some present mitigation measures.

The protocol outlines key elements and implementation principles for sustainable, integrated and holistic flood-risk management, promoting engineering, building design, land-use planning, and emergency management. The draft protocol is currently being developed into a New Zealand standard.

The 2004 lower North Island and Bay of Plenty floods prompted two further flood-risk management initiatives – the Flood Risk Management Review led by central government, and the Flood Risk Management Protocol sponsored by local government. In March 2007, the government decided that a national policy statement on flood risk management was desirable. The formal process under the Resource Management Act 1991 to develop a national policy statement is currently underway.

STRUCTURAL MEASURES

Flood protection structures – most commonly stopbanks but also including groynes and floodgates – modify river behaviour and protect people and property from floods up to a specified standard.

Design standards for stopbanks vary greatly throughout New Zealand, from protection from a flood with a 5-year return period for some rural stopbanks, to floods with 400–500-year return periods for major rivers like the Hutt and Waimakariri rivers.

Early flood protection structures were piecemeal, often deflecting flood water onto neighbouring properties. Catchment boards, established in 1941, adopted an integrated catchment and river management approach including soil conservation, with a focus on engineering works. About 3000km of central government-subsidised stopbank were built in the 1950s and 1960s to protect agricultural land and some urban areas.

Stopbanks offered a sense of security, and high-density development has occurred behind them, in areas such as in Christchurch, the Hutt Valley and the Heretaunga Plains in Hawke's Bay. Stopbanks have failed in the past in New Zealand, through poor construction, a lack of maintenance, or through floods exceeding the design capacity of the protection work. A significant residual flood risk still exists despite many flood protection schemes.

Stopbanks are costly to build and maintain. Central government subsidies for stopbank construction and maintenance ended in the

The Fitzherbert stopbank at Palmerston North during the February 2004 storm. The stopbank had recently been upgraded and held the Manawatu River during the flood. Had the stopbank been breached or overtopped, however, the city would have suffered major flood damage. *Horizons Regional Council*.

late 1980s. Since then local government has been solely responsible for their funding. In some areas, this cost is becoming increasingly difficult for some ratepayers to bear.

Structural measures also include maintaining the capacity of river channels through realignment or gravel extraction, and using flood detention dams, although detention dams are not often used for flood reduction alone for a variety of reasons, including costs.

All structural measures have effects on the environment. They affect sediment transport and deposition, and ecological habitats. Poorly designed structures can also increase the downstream flood hazard. Structural measures are an important component of floodplain management but the costs and benefits must be appropriately managed across social, economic, and environmental values.

NON-STRUCTURAL MEASURES

Floodplain management aims to reduce vulnerability to floods through a variety of measures, rather than by attempting to control flooding through structural measures alone.

The simplest way to reduce flooding exposure is to not develop in flood hazard areas. This is relatively easy to do at undeveloped sites where flood-prone land can be used for parks, sports fields, or car parks, rather than housing and infrastructure. However, as floodplains are often intensively farmed due to the productive soils, their potential for damage is often significant within the agricultural community. Awareness in these communities is likely the best option for risk reduction.

Discouraging further development in existing flood-prone communities is more difficult. It involves complex political, social, and economic issues. Relocation may be an option in some situations.

Flood-hazard zones are often incorporated into district plans, where rules may apply to building construction or alteration and earthworks. Accurate information on flood inundation levels and their frequency is important in mapping hazard zones. Some of this information is available, to different degrees of accuracy, for some parts of New Zealand. NIWA is currently revising flood frequency estimates for New Zealand rivers, building on work completed in 1989, to determine both river flow and floodplain inundation levels using hydraulic modelling.

Building standards, including minimum floor levels, are often used to reduce the effects of flooding. The Building Code specifies that floor levels must be above the 50-year return period flood level. Some district plans, however, set out provisions that require floor levels in flood-hazard zones to be above that specified in the Building Code.

CATCHMENT MANAGEMENT

Catchment management involves managing land use in upper river catchments to reduce the amount of sediment that goes into rivers, and therefore reduce the flood hazard. Catchment management requires long-term, multi-pronged approaches including education, advice, farm planning, possible land purchase by local and central government, regulations, monitoring, and financial assistance to help farmers with the capital cost of changing land use.

Risk-reduction initiatives by farmers and others include planting forest and other vegetation to help stabilise ground and absorb water.

Restoring wetlands in river catchments can also help reduce the flood hazard. Wetlands store water and reduce the rate at which it enters rivers.

Readiness

The MetService issues a severe-weather warning when more than 50mm of rain is expected in a widespread area within the following 6 hours, or when more than 100mm is expected in a widespread area within the following 24 hours. A severe-weather watch is generated if more than 50mm of rain in 6 hours or more than 100mm of rain in 24 hours is expected 24 to 72 hours ahead. Severe weather outlooks are issued for severe weather which could occur 3–6 days ahead. These messages are sent to local authorities and CDEM Groups.

The MetService is currently developing a warning service for small-scale intense thunderstorms and is proposing to install additional weather radars to support this.

Regional councils have primary responsibility for flood forecasting and public warnings, using MetService information and data from NIWA's and their own rainfall and river level recorders. Warning times are relatively short because New Zealand's catchments are short and steep. NIWA is increasing its flood-forecasting capacity to complement regional council functions, using rainfall-runoff models incorporating rainfall data and river catchment conditions. It is also developing routine rainfall forecasts up to 48 hours ahead and integrating these into a rainfall-runoff model to give a longer warning time for impending floods.

Response and recovery

The Earthquake Commission (EQC) insures residential land (but not houses or contents) against storm or flood damage for those home owners who hold fire insurance. EQC will contribute to the cost of removing flood debris from under and around homes, and will cover damage to retaining walls, bridges, or culverts within 60m of a house.

Like earthquakes, more consideration could be given to pre-event recovery planning for floods – identifying in advance the land-use planning decisions that will need to be made during the recovery phase. Unlike damaging earthquakes, damaging floods often occur at the same location on a frequent basis. Recovery from recent floods, such as the February 2004 storm, has concentrated on communities regaining daily functioning rather than taking the opportunity to improve long-term resilience.

Floods are New Zealand's most common and costly natural hazard, but generally they do not affect more than one region at the same time. Particularly large floods, such as those of central New Zealand in February 2004 and those in the South Island of the mid-1980s, are of national interest and have required central government support with response and recovery.

Any coordinated local or national CDEM response to floods follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

MAF's On-Farm Readiness and Recovery Plan for Adverse Climatic Events and Natural Disasters sets out individual and community responsibility to adverse events that affect farm businesses and outlines available recovery measures for different scale events.

FURTHER INFORMATION

GENERAL FLOOD AND WEATHER INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND

www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/Floods/en

www.teara.govt.nz/EarthSeaAndSky/ClimateAndAtmosphere/Weather/en

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT

www.civildefence.govt.nz/MEMWebsite.nsf/Files/tephra97/$file/tephra97.pdf

www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2001-Index?OpenDocument

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FLOODPLAIN MANAGEMENT PLANNING GUIDELINES

MINISTRY FOR THE ENVIRONMENT

www.mfe.govt.nz/withyou/funding/smf/results/9035_floodplain
_management_planning_guidelines.pdf

FLOOD RISK MANAGEMENT REVIEW

MINISTRY FOR THE ENVIRONMENT

www.mfe.govt.nz/issues/land/natural-hazard-mgmt/flood-risk-review.html

FLOOD RISK MANAGEMENT PROTOCOL

CENTRE FOR ADVANCED ENGINEERING

www.caenz.com/info/MFR/MFR.html

METSERVICE WARNINGS

METSERVICE

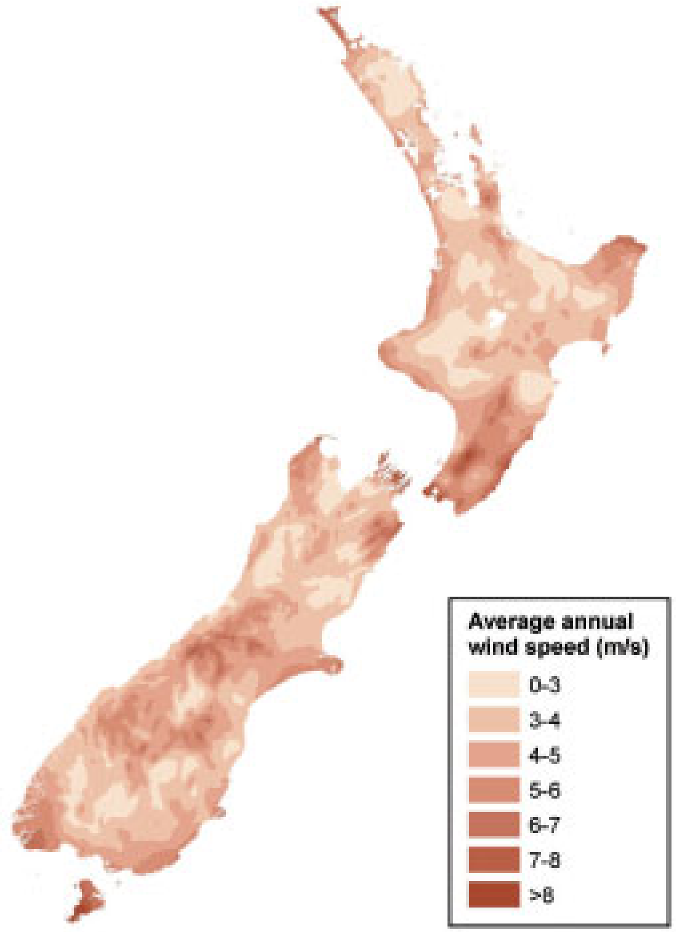
www.metservice.co.nz/default/index.php?alias=weatherwarningcriteria

SEVERE WINDS

New Zealand lies in the path of the strong mid-latitude westerly winds, known as the 'roaring forties', and frequently experiences strong winds that can be extremely damaging.

New Zealand's predominant winds are from the west quarter – between northwest and southwest. When stable westerly airstreams hit the mountains they are forced up, over, and down into the lee of the ranges, creating strong eddies and downstream winds in areas such as Canterbury, Wairarapa, and southern Hawke's Bay. Winds are also funnelled through gaps in the ranges, such as the Manawatu Gorge, Cook Strait, Waitaki Valley and Foveaux Strait, making the surrounding areas particularly windy. Westerly winds are strongest in spring when the temperature difference between the equator and the South Pole is greatest.

The north and east of the North Island can also be affected by strong winds from the remnants of tropical cyclones moving down from the tropics during the summer. Localised wind gusts and tornadoes are often experienced with thunderstorms, most commonly in the west and north of the country.



Average annual wind speed in New Zealand. The values are for 10m above the ground surface and do not take into account small-scale topographic effects. *National Institute of Water and Atmospheric Research.*

Downslope wind storms

Wave motions are generated in the atmosphere in the lee of mountain ranges, which can cause strong downslope winds. The nature of these wave disturbances depends on the strength of the airflow over the mountains, how stable the atmosphere is, and topography.

Downslope wind storms occur in Canterbury in the lee of the Southern Alps, and in Wairarapa in the lee of the Tararua Range in strong northwesterlies. They have also occurred in Te Aroha in the lee of the Kaimai Range during strong easterlies.

Downslope wind storms can be relatively localised and do not generally bring rain, because most of the rain falls on the windward side of the mountains. Strong winds blew down power lines in Canterbury in October 1988, even though no high wind speeds were recorded at any monitoring stations. The behaviour of wind in the lee of mountains – the strength, duration and location of wave activity – remains difficult to forecast, although developments have been made recently in refining wind models.

1975 CANTERBURY WIND STORM

The Canterbury wind storm of 1 August 1975 was generated by a front moving over New Zealand between 31 July and 1 August with a strong northwesterly flow ahead of it. The situation was worsened by a stationary high-pressure system to the north of the country.

The storm affected areas from Southland to Wairarapa but was most intense in Canterbury. Lee waves formed to the east of the Southern Alps, producing bands of strong gusty winds along the Canterbury Plains. The period of highest winds only lasted one to two hours but caused severe damage. Northwesterly winds in Timaru reached 130km/h (70 knots) gusting to 165km/h. At the peak of the storm winds in Christchurch reached 130km/h (70 knots) gusting to 190km/h.

The strongest gust of 195km/h was recorded in Kaikoura. Roofs were blown off many buildings, aircraft were damaged, and garages and sheds were destroyed. Many electrical fires were ignited by falling power lines. Many trees were blown down or uprooted – Temuka lost 300 trees, some 80–100 years old, from its domain.

Eleven thousand hectares of plantation forest were damaged. Most of the pine plantations beside State Highway 1 north of Rakaia were flattened and there was widespread damage in the Eyrewell, Ashley, Balmoral, and Hanmer forests in North Canterbury.

Glasshouses damaged in the 1975 Canterbury wind storm. The return period of the storm was estimated at more than 100 years and insured damage was around $55 million (2006 value). *The Christchurch Press*.

Tornadoes

In certain circumstances, rotation inside a thunderstorm produces a tornado – a narrow, tightly spinning funnel of air which extends below the cloud. Wind speeds within a tornado can be up to 300km/h, but tornadoes in New Zealand are mostly small and short-lived, unlike the very destructive tornadoes of the United States.

Around 20–30 tornadoes are observed in New Zealand each year, most lasting less than 15 minutes. They are most frequent in the west and north of the country, particularly the Waikato, Bay of Plenty, and Westland. Damage paths are 10–20m wide and usually less than 5km long.

New Zealand's worst tornado killed three people in Hamilton in 1948. More recently, two Taranaki people were killed in August 2004 when their house was destroyed by a tornado, and a tornado swept through Greymouth in March 2005 causing $9.6 million worth of damage (2006 value).

The passage of squall lines associated with thunderstorms can also produce the sudden onset of very strong wind gusts followed by a gradual decrease in intensity over several minutes. Squall lines have been responsible for some of the highest wind gusts recorded – up to 145km/h – in northern New Zealand. Squalls can also be experienced within tropical cyclones and more commonly with southerly changes along the east coast of the country. Downbursts (plummeting downdraughts of cold, heavy air out of thunderstorms) pose a major risk to aviation.

1948 FRANKTON TORNADO

New Zealand's worst tornado struck Frankton and other parts of Hamilton on 25 August 1948. The tornado, which was accompanied by heavy rain, originated in the northwest of Frankton and swept through the village before travelling through Hamilton West and over the Waikato River into Hamilton East.

The tornado demolished most commercial buildings along the main street of Frankton and damaged 163 houses. It uprooted trees and threw corrugated iron, timber, and other debris into the air. It killed three people and badly injured seven. Damage was estimated at $60 million (2006 value).

Damage to houses from the 1948 Frankton tornado. The tornado was New Zealand's deadliest, killing three people. *Hamilton City Library.*

Ex-tropical cyclones

Ex-tropical cyclones and depressions of subtropical origin are the most common source of widespread high wind in the northern half of the North Island, especially Northland, Auckland and the Bay of Plenty, and they are often accompanied by heavy rain causing flooding. New Zealand's most memorable storms have been ex-tropical cyclones – the 1936 storm, the Wahine Storm in 1968, Cyclone Bernie in 1982, Cyclone Bola in 1988 and Cyclones Drena and Fergus in the summer of 1996/97.

Between November and April tropical cyclones, containing belts of sustained strong winds rotating around an area of low pressure, form in the tropics to the north of New Zealand, at around 10 to 20 south. The heaviest rain and highest winds of a tropical cyclone, sometimes more than 200km/h, are mostly confined to a belt 10–20km wide around the centre or 'eye' of the storm.

Tropical cyclones are fuelled by warm water and either weaken or change their structure as they travel over increasingly cool seas away from the tropics. Sometimes, as ex-tropical cyclones head south toward New Zealand, they can evolve into large, damaging mid-latitude storms with the infusion of colder air. However, they retain the circulation pattern and the large amounts of moist air of the former tropical cyclone. Of the 10 or so tropical cyclones that form on average each year in the tropical southwest Pacific, only one or two are likely to affect New Zealand as ex-tropical cyclones.

The frequency of tropical cyclones is unlikely to increase with climate change. However, the rise in average sea surface and air temperatures will provide tropical cyclones with more energy, so ex-tropical cyclones affecting New Zealand are likely to be more intense in future.

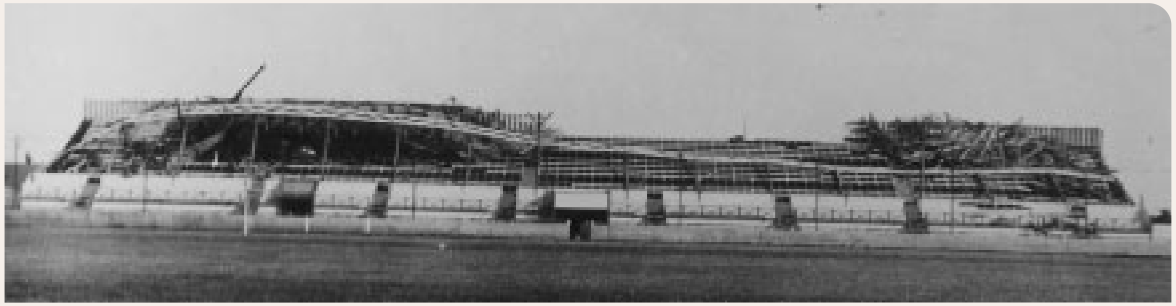
1936 STORM

The 1936 storm has been described as the North Island's worst storm of the twentieth century. It caused widespread wind and rain damage from Northland to Marlborough. The storm initially formed in late January as a tropical cyclone near the Solomon Islands. As it moved south it joined a cold front over the north Tasman Sea and redeveloped into an intense mid-latitude storm.

The storm crossed the North Island on 2 February causing most rivers to flood resulting in widespread damage. Winds generated by the storm destroyed buildings from the Bay of Plenty to Taranaki and Manawatu, blew fruit off trees, and flattened crops.

The Manawatu was particularly hard-hit. Many houses lost roofs and the grandstands of the A&P Association, the Awapuni Racecourse, and the sports ground were demolished. A man was killed when he was blown off his roof while repairing it. The Longburn Anglican church was scattered over the adjacent road and railway line. The Feilding Aero Club hangar and two planes were destroyed. Trees were uprooted from ridges in the Tararua Range and thrown into valleys.

More than 40 boats were blown from their moorings in the Waitemata and Manukau Harbours in Auckland, and the ferry *Rangatira* hit rocks at the mouth of Wellington Harbour with 800 people on board. In today's dollars, this storm is estimated to have cost New Zealand $800 million.



The A&P showground grandstand in Palmerston North, demolished in the 1936 storm. The storm was possibly New Zealand's worst storm of the twentieth century. *Palmerston North City Library.*

Severe wind impacts

Widespread strong winds can be produced by different large-scale weather systems over New Zealand. However, wind speed experienced at a particular site on the ground is highly dependent on local topography. Wind accelerates over ridges, hilltops and coastal escarpments – the steeper and nearer the top of the slope, the greater the wind speed. Factors such as whether the site is surrounded by substantial buildings or trees, and whether the site is urban or rural, also influence wind speed but to a lesser degree.

The most common effects of high winds are damage to buildings, particularly roofs, and infrastructure such as power lines. Driving can be difficult and Cook Strait ferry crossings are sometimes cancelled due to high winds and associated swells in the strait.

Exotic plantation forests are particularly susceptible to wind damage during downstream wind storms and tropical cyclones, especially where trees are of an even age. Windthrow is one of the most significant risks to forestry investments, and there is evidence that wind can affect wood quality. Also, dead wood debris left after wind damage to forests increases the wildfire risk.

Managing severe winds

Risk reduction

The design and construction of buildings and infrastructure has a large influence on their resilience to severe winds. New Zealand's Building Code has provisions that ensure wind loading is taken into account during design and construction. Wind zones, which consider local topography, site exposure, ground roughness, and wind region, dictate a structure's bracing requirements.

While severe wind is generally not addressed in district plans, several urban territorial authorities have provisions that aim to avoid or mitigate local effects such as wind tunnelling in high-rise streets.

Probabilistic wind analyses have been undertaken as part of local or regional engineering lifeline projects. This information enables lifeline utilities to design and site infrastructure to minimise the risk of severe wind damage.

The risk of wind damage to forestry can be reduced by selecting low-wind condition sites for planting and employing particular planting, pruning and felling regimes.

Readiness

The MetService issues a severe weather warning when widespread (over a 1000km^2 area) gales with a minimum wind speed of 90km/h, or frequent gusts exceeding 110km/h, are expected within 24 hours. A severe-weather watch is generated if these conditions are expected to occur 24–72 hours ahead.

Response and recovery

A widespread severe-wind event can cause significant damage in several regions. However, most wind events are able to be managed at a local level, or are often part of a larger flood event response. Tornadoes are localised events and, unless they impact on a critical area, infrastructure, or building, are unlikely to require a regional or national response.

MAF's On-Farm Readiness and Recovery Plan for Adverse Climatic Events and Natural Disasters sets out individual and community responsibility to adverse events that affect farm businesses and outlines available recovery measures for different scale events.

Any CDEM response to severe winds follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

FURTHER INFORMATION

GENERAL WIND INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/ClimateAndAtmosphere/Weather/en
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
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www.civildefence.govt.nz/memwebsite.NSF/Files/TephraVol20%20complete/$file/TephraVol20%
METSERVICE LEARNING CENTRE
www.metservice.co.nz/default/index.php?alias=learningcentre

METSERVICE WARNINGS

METSERVICE
www.metservice.co.nz/default/index.php?alias=weatherwarningcriteria

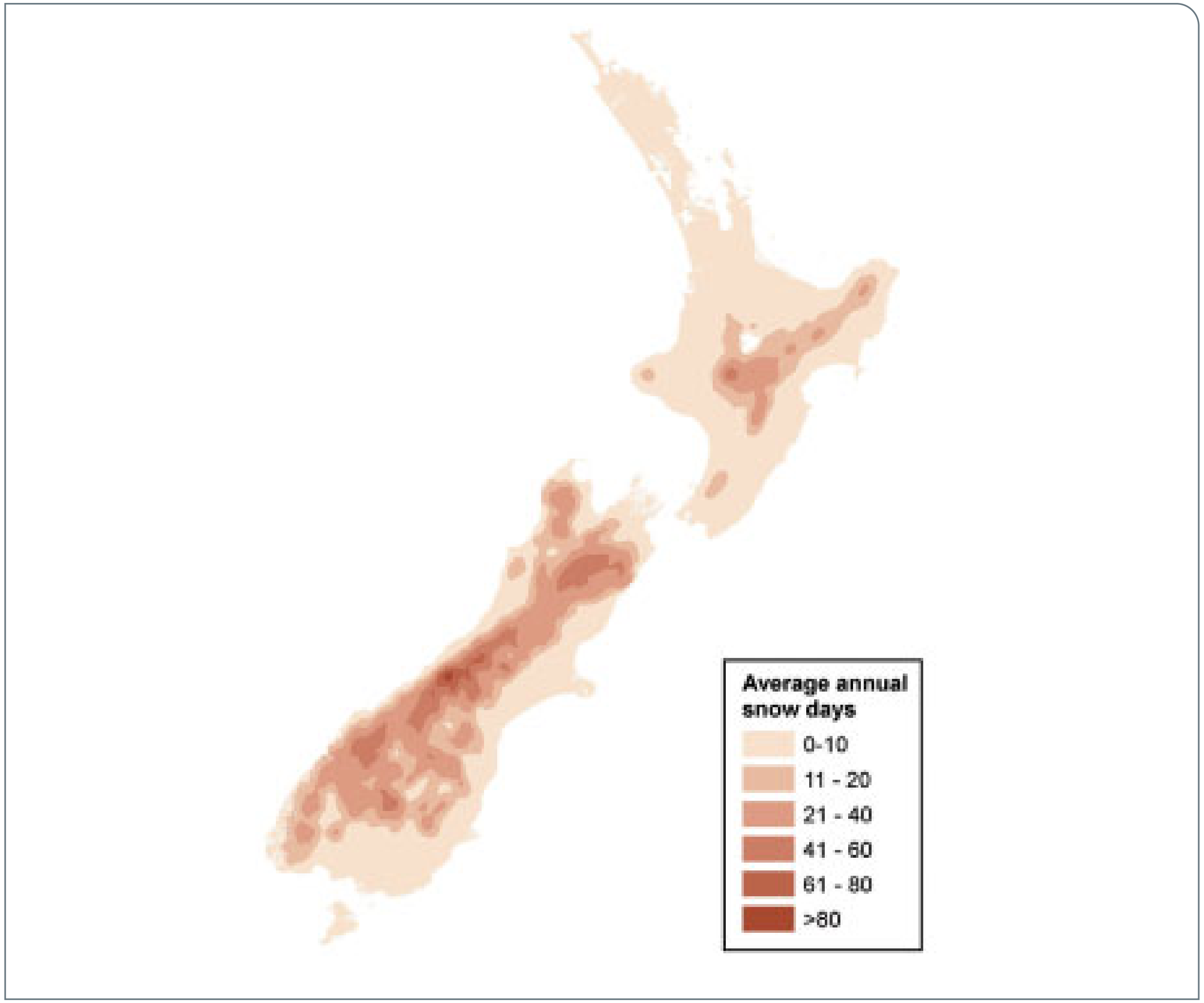
WIND DAMAGE TO FORESTRY

MCFARLANE, P, PEARCE, G, AND MOORE, J, 2001,
FORESTRY AND RISK MANAGEMENT – NEW ZEALAND IN A GLOBAL CONTEXT. Risk Management and Sustainable Forestry, 8 September 2001, Bordeaux, France.

SNOW

Winter snowfall is common above 1000m in the Southern Alps and the North Island ranges. Heavy snowfalls below 1000m altitude are less common and mostly affect rural areas of Canterbury, Otago and Southland and high-altitude roads in both the North and South Islands. Snow occurs only occasionally at sea level in the south and east of the South Island and in the hill country of the Wairarapa and Hawke's Bay. It rarely falls to sea level in the west and north of the South Island or the North Island.

Snowstorms in New Zealand may bring snow to low levels but they are not accompanied by sustained periods of intense cold as in some Northern Hemisphere countries. They can, however, cause significant disruption simply because they are unusual and not normally planned or designed for. Damaging snowfalls are usually confined to parts of one or two regions at a time. They can vary significantly over relatively short distances – snowstorms can severely affect one part of a region and produce little or no effect in other parts.



Average annual number of days on which snow falls.
National Institute of Water and Atmospheric Research.

JUNE 2006 CANTERBURY SNOWSTORM

The 12 June 2006 snowstorm was generated by a depression that deepened as it moved southeast over the South Island from the Tasman Sea. The precipitation associated with the depression fell as heavy, 'wet' snow as the warm air mass was undercut by a very cold southwesterly airstream.

Up to 30cm of snow fell at sea level between Temuka and Rakaia, increasing to 80cm in the foothills. North of the Rakaia River 20–30cm fell at Lincoln, 10–15cm in Amberley and around 5cm at sea level in Christchurch. Inland South Canterbury, around Fairlie, had snow depths greater than 70cm, and 40–50cm fell in the Mackenzie Basin. Snow depths were the highest in 60 years over large parts of the Canterbury Plains and foothills. Ashburton experienced its greatest snow depth on record – 38cm.

Many kilometres of power lines collapsed under the weight of snow, snapping or bending power poles. This caused widespread loss of electricity in South Canterbury for up to 4 weeks in isolated areas and loss of telecommunications for up to 11 days. Trees and fences collapsed, as did some buildings including a piggery near Methven and three large buildings in Timaru and Temuka.

Farmers were forced to use winter stock feed much earlier than usual, which had a medium-term economic impact on farmers. The Ministry of Agriculture and Forestry appointed rural coordinators to facilitate ongoing support to rural communities.

Pleasant Point near Timaru after the June 2006 snowstorm. Roads took many days to clear in some areas. *Jeff Tollan.*

Snowstorms

Cold southerlies

Snow is usually produced by slow-moving, deep depressions within cold southerly airstreams travelling north from the Antarctic. These systems often deposit snow on the mountains of the South Island and southern central North Island. They occasionally bring snow to sea level in the south and east of the South Island and the hill country of the southeastern North Island. Snow generated by southerly airstreams often covers a large area but is relatively light, 'dry' snow. Cold air does not hold much moisture and so large accumulations are unlikely.

In an extreme event, a series of cold southerly outbreaks between June and August 1939 covered much of the country, even as far as Northland, in snow. Estimates place it as a 100-year return period event at that time, but with climate change such snowfall would now be considered even rarer.

Warm advection snow

The most damaging snowstorms in New Zealand are formed when warm, moist airstreams travelling down from the north are pushed up over colder, denser airstreams from the south. This process is known as warm advection. As the moist air is forced up, the water vapour it contains cools directly into ice crystals which fall as snow.

Snow generated through warm advection usually falls over a relatively small area because the warm airstreams involved are often only tens of kilometres wide. They are more damaging though, because warm air can hold three times as much moisture as cold air, and the snow produced in this manner is wetter, heavier, and thicker than snow from cold southerly airstreams.

Warm advection has been responsible for heavy snowfalls in the South Island in 1945, 1996, and 2006.

Snow on the hills at Clevedon near Auckland in 1939. Snow fell the length of the country during this snowstorm, and caused serious disruption in the southern South Island. *New Zealand Herald*.

Snowstorm impacts

Heavy snowstorms commonly disrupt electricity and telecommunications as lines collapse under the weight of snow. The combination of electricity outages and cold temperatures can create welfare issues for vulnerable members of communities such as the sick and elderly. Road, rail, and air transport may be disrupted, but snow is usually cleared from main roads within a few days. Occasionally, buildings are damaged or collapse from the weight of snow. The density of snow in New Zealand can be as high as 500kg/m^3, with the potential to cause significant damage to forestry plantations and in particular radiata pine.

Snowstorms, particularly in early spring during lambing, can result in stock losses through cold, lack of access to water supplies, and lack of feed in the short and long term. During the 1992 Canterbury snowstorm stock losses were particularly high, with estimates of a million lambs lost and a half-million ewe deaths. Estimates of financial cost to the Canterbury region have been as high as $100m.

THE MILFORD ROAD

The Milford Road in Fiordland, linking Te Anau with Milford Sound, is a unique avalanche hazard area in New Zealand. The road is one of the highest alpine roads in the country. It is surrounded by very steep terrain and high snow basins, and a 29km stretch of it can be affected by avalanches from June to November.

The road was constructed in the 1930s and 1940s, and during this time avalanches killed several construction workers and damaged the road, bridges and the east Homer Tunnel portal. When it was completed in 1952 the road was only open during summer to avoid the avalanche hazard. It opened all year round in the 1970s following increased pressure from the tourism industry. The death of a road maintenance supervisor in a large avalanche in the early 1980s, however, prompted the formation of an avalanche monitoring and control programme.

The Milford Road avalanche monitoring programme aims to minimise road closures and maximise avalanche safety. An avalanche control team, funded by Transit New Zealand, monitors the avalanche hazard using data on snow pack and local weather conditions, and site specific forecasts from the MetService. The avalanche risk is managed passively, by not allowing traffic to stop within avalanche areas or by closing the road completely, or actively, by using explosives to trigger avalanches when the road is closed.

A controlled avalanche on the Milford Road, triggered by explosives while the road is closed. There have been no avalanche deaths on the Milford Road since the avalanche monitoring and control programme was instigated in the early 1980s. *Wayne Carran, Works Infrastructure.*

Snow avalanches

Snow avalanches are triggered by increased loading on a weak layer or sliding surface within the snow. The increased loading can be caused by gravity, new snow or rain, or human activity such as backcountry skiing, snowboarding or active control with explosives.

New Zealand has a large amount of avalanche-prone terrain. The winter snowline ranges from 1000m in Fiordland to 2000m in the North Island. Snow covers steep slopes on approximately 35 per cent of the South Island and five per cent of the North Island during the winter.

New Zealand's alpine areas are sparsely populated, and many are within national parks or reserves, so the risk to infrastructure, residential buildings, and people is relatively low compared to more densely populated alpine areas overseas. However, many people are exposed to avalanche risk each year in New Zealand through recreational activities, especially skiing, snowboarding, and mountaineering. These risks are managed by education programmes and by the owners of ski field facilities.

There were 140 reported avalanche deaths between 1863 and 2005, including 40 gold miners who died in a Central Otago avalanche in 1863. Deaths in the late 1800s and early 1900s were rare and mostly work-related. However, recreational deaths have increased since 1940, as alpine recreation has become more popular. Ninety-five percent of avalanche deaths have occurred in the South Island, a reflection of the terrain and snow cover.

Over the last decade at least 250 people have been caught in avalanches and 16 have died as a result. Most of these people were mountaineering, skiing, snowboarding, or on avalanche training courses at the time. Most avalanche deaths occur in July, August, and September, when avalanches are most common, and in December and January, when many mountaineering trips are undertaken.

Managing snow hazards

Managing snow hazards focuses on readiness in the form of weather forecasting and warnings, and on response and recovery.

Risk reduction

The Building Code requires snow loadings to be considered in building design and construction. Design snow loadings depend on the region and altitude of the site, and are currently under review by the Department of Building and Housing.

Some snowfall analyses, such the as number of snow days per year and 50-year return period snow depths, have been undertaken at a local or regional level for some engineering lifeline projects. This information is used by some lifeline utilities in planning future infrastructure development and upgrades.

The Department of Conservation recently undertook a hazard-mapping exercise for their backcountry huts, which included avalanche hazard. Several huts were relocated, closed completely, or temporarily closed in winter as a result of this analysis. Many tracks now also have signs warning of the avalanche hazard.

The need for more individual risk-reduction measures in rural areas, such as alternative electricity supply and livestock feed budgeting, has become more evident in recent years.

Readiness

The MetService issues a severe weather warning when widespread (over a 1000km^2 area) snowfall of 10cm is expected within 6 hours or 25cm is expected within 24 hours below 1000m in the North Island or below 500m in the South Island. The MetService will issue a severe weather watch if these conditions are expected to occur 24–72 hours ahead.

The MetService provides snowfall warnings for South Canterbury and Otago when more than 20cm of snow is expected within 24 hours below 1500m. These warnings are primarily for high-country farmers in these areas.

The MetService also issues road snowfall warnings if snow is likely to settle within 24 hours on the Desert Road and the Rimutaka Road in the North Island, and the Lewis Pass, Porters Pass, Arthur's Pass, Lindis Pass or Milford roads in the South Island.

The MetService will issue a special weather advisory if the snowfall is not expected to reach the warning level but is likely to cause significant disruptions to normal business.

Response and recovery

MAF's On-Farm Readiness and Recovery Plan for Adverse Climatic Events and Natural Disasters sets out individual and community responsibility to adverse events that affect farm businesses and outlines available recovery measures for different scale events.

Any CDEM response to snowstorms or avalanches follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

FURTHER INFORMATION

GENERAL SNOW INFORMATION

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
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MINISTRY OF AGRICULTURE AND FORESTRY READINESS AND RECOVERY PLAN FOR NATURAL AND CLIMATIC DISASTERS IN RURAL AREAS

MINISTRY OF AGRICULTURE AND FORESTRY
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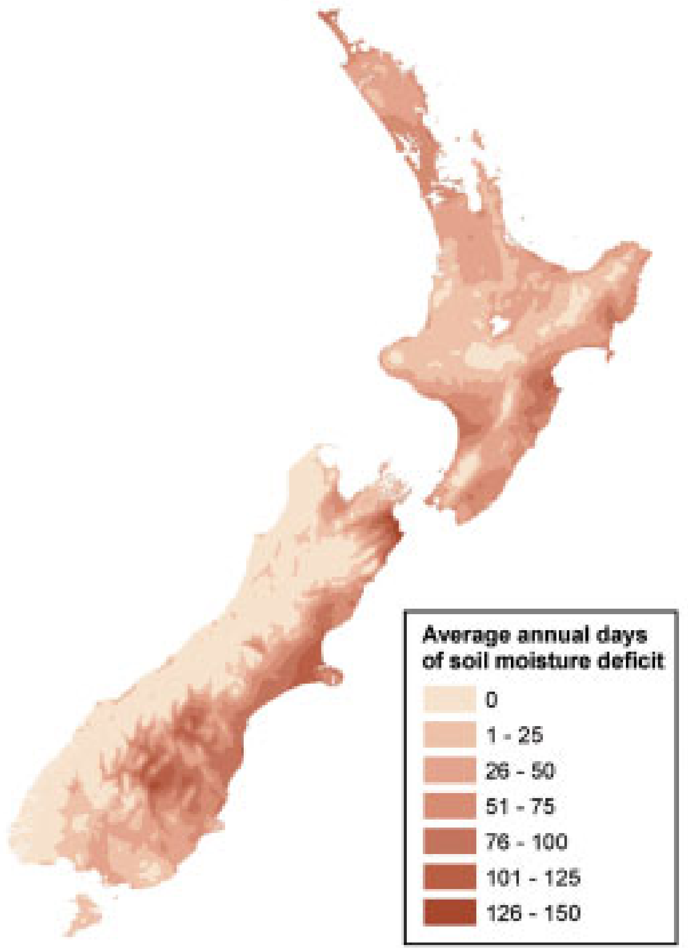
Christchurch during the August 1992 Canterbury snowstorm.

DROUGHTS

Drought, from a hazard management perspective, is a prolonged period when rainfall is lower than normal for a specific locality. As a result soil moisture levels are much lower for longer than communities normally experience, sometimes being insufficient for plant growth, and restrictions are often placed on water supply for domestic use, stock, and irrigation.

Drought is a natural phenomenon. It becomes a hazard when the effects of a continuing dry period become greater than people who live and work in the area are used to managing. For example, the management of high stock numbers is adjusted in response to expected dry periods, but at some stage when the dry period becomes a drought, the farmer starts to incur high losses from lower-yielding crops or from having to sell stock early or pay more for feed.

Droughts are one of New Zealand's most common and costly hazards, because they can affect a very large area and the effects linger for several years afterwards.



Average annual number of days of soil moisture deficit. Days of soil moisture deficit measures the number of days that plant growth is restricted by insufficient moisture in the soil. *National Institute of Water and Atmospheric Research.*

Drought conditions

Dry periods in New Zealand usually last for 3–4 months and are most common from December to March. As a dry period continues it becomes a drought at some point that is not easily defined, and may run over more than one summer or one year. Droughts therefore develop over time.

Although the start of a drought is not easy to identify, its end may be clear, if it is broken by heavy rain or a period of sustained rainfall. Even once broken by rain, the effects on production, and therefore on communities, continues for several years as farmers need to restock and recover financially.

The occurrence of drought in New Zealand, like that of heavy rain, is related to topography. Although any part of the country can be affected by drought, the most susceptible areas are those in the lee of the main ranges subject to dry winds – Hawke's Bay, Wairarapa, Marlborough, Canterbury and Central Otago. Particularly drought-prone areas are also likely to have soils with low moisture-storage potential and to have little or no irrigation available. Severe droughts have occurred in these areas at least once every decade. There is a point, however, where a series of droughts becomes 'normal' for a location and therefore ceases to be described as unusual. Again, this point is not easily defined.

The severity of a drought is often described using potential evapotranspiration deficit (PED), a measure of the gap between the water demand of plants and what water is actually available. PED is measured in millimetres and can be thought of as the amount of water that would need to be added, by rainfall or irrigation, to keep pasture growing at an optimum rate. Typical New Zealand pasture requires around 5–6mm of water per day in summer so, for example, a PED of around 35mm represents one week's reduced growth.

Marlborough recorded a PED of 835mm during the severe 1997/98 drought, representing more than 6 months of low or no plant growth.

The occurrence of droughts is influenced by El Niño cycles and the Interdecadal Pacific Oscillation. Droughts in eastern areas are more common during El Niño periods when northwesterly winds followed by southwesterly winds predominate. Climate change is likely to accentuate existing rainfall patterns. East coast regions from Hawke's Bay to Otago are likely to become drier with an increasing frequency of droughts.

1997/98 EL NIÑO DROUGHT

The 1997/98 drought, associated with a strong El Niño event, severely affected eastern regions from Hawke's Bay to Central Otago. The drought was predicted soon after the rapid development of the El Niño event between March and July 1997.

The El Niño resulted in more frequent or stronger southwesterlies and westerlies in the following spring and summer. In general, western areas were wetter than usual and eastern areas were drier. In some areas, however, there were significant departures from typical El Niño patterns. The very high summer temperatures recorded in many regions were unusual for an El Niño and may have contributed to drought conditions in places.

Marlborough was the worst-hit region. The potential evapotranspiration deficit measured there during the drought was 835mm, representing more than 6 months of low or no growth and estimated to have a 60-year return period. The Wairau, Awatere, and several smaller rivers experienced low flows, and groundwater levels were so low that water had to be trucked in from elsewhere.

North Canterbury, parts of the Wairarapa and Hawke's Bay also experienced reduced pasture growth. High rainfall in the Southern Alps, however, kept flows in Canterbury's alpine-fed rivers high.

Economic losses were estimated at $750 million (2006 value), or 0.9 per cent of GDP, and stress and hardship took a large toll on New Zealand's farming community. However, changes in farming practices over the previous decade, resulting in generally lower stocking rates, had reduced the farming community's vulnerability to drought and feed shortages. Also, the fact that the drought was anticipated some months in advance led to early action by many farmers, such as selling stock and moving animals to other regions, which reduced farmers' exposure.

The 1997/98 El Niño also contributed to droughts and wildfires in Australia and South-East Asia, and shifted tropical cyclones in the South Pacific eastwards towards the Cook Islands and French Polynesia.

A dry stock pond near Gisborne during the 1997/98 El Niño drought.
PhotoNewZealand.

Drought impacts

Droughts often affect the rural sector, through crop failure and lack of stock feed, with predominantly regional economic impacts. Farmers may need to sell stock or temporarily move them to other non-affected regions. The economic impact generally has a lag effect whereby it is not felt in the year of the drought, when farmers may be cash-rich from stock sales, but rather the following years as farmers restock at higher prices due to shortages in a sellers' market. Animals that have been carried through a drought may be out of condition and have a lower reproductive performance in the following year. National economic impacts tend to be lower than the local impacts because stock are often moved to other locations within New Zealand or are processed earlier than they would have been under normal conditions.

Droughts can have significant psychological and social impacts on farming communities. Difficult farm management decisions are made in pressured situations as droughts develop and the financial effects continue well beyond the end of the drought.

Droughts also cause water shortages or restrictions, and irrigation supplies can be affected, although this is not always the case. In most of Canterbury, for example, northwesterly winds that dry out the plains also provide more water for the alpine-fed rivers. Private domestic water supplies along with large urban water supplies can run low. Hydroelectric generation capacity, accounting for around two-thirds of New Zealand's electricity generation, can be affected.

Wildfire risk increases during dry periods and droughts. This is particularly so when a sudden dry period follows a period of good rainfall, as the vegetation that has grown well dries and becomes easily combustible. Dry periods in eastern areas of the country are often accompanied by warm, and potentially strong, northwesterly winds that can help fires spread quickly. The wildfire hazard can eventually decrease during prolonged droughts as the amount of vegetation available to fuel fires declines, but then there is often less water readily available to fight a fire if one does occur.

1991/92 HYDROELECTRIC DROUGHT AND THE 1993/94 AUCKLAND WATER SUPPLY DROUGHT

The 1991/92 hydroelectric drought led to electricity shortages through the winter of 1992. Persistent, cool southwesterly weather brought low rainfall to the central Southern Alps and low flows into the hydroelectric storage lakes from November 1991 to May 1992. The situation was likely worsened by cooler temperatures, caused by ash in the atmosphere from the Pinatubo eruption in the Philippines, which lowered the snow level in the Southern Alps during the 1992 winter, locking up water. The then Electricity Corporation of New Zealand had to rely heavily on thermal and geothermal generation, and households and businesses conserved energy where possible. Estimates place the direct impact on the economy at more than $600 million. Indirect impacts included a loss of overseas investor confidence.

Following the hydroelectric drought, low rainfall in Auckland during 1993 and 1994 led to low water levels in the region's 10 storage reservoirs in the Waitakere and Hunua ranges. Water use was restricted in the last few months of the drought before it broke in July 1994. A drought plan was prepared during the drought and an emergency proposal to pipe water from the Waikato River to Auckland was put to Parliament. A pipeline supplying water from the Waikato River was eventually completed in 2002 and now provides additional capacity should the region experience another water supply drought.

These two droughts highlighted New Zealand's dependence on regular rainfall and led to the first in-depth studies of the relationship between the El Niño Southern Oscillation and low rainfall and river flows in New Zealand. The 1991/92 hydroelectric drought helped prompt the formation of the Electricity Commission, whose functions include ensuring security of electricity supply during dry years.

Upper Huia Dam in the Waitakere Range during the 1993/94 Auckland water supply drought. *Watercare Services*.

Managing droughts

Risk reduction and readiness

Farming in drought-prone areas carries with it more risk of variable returns and higher costs from having to maintain feed buffers, use irrigation, or plan for variable crop yields. Due to the nature of drought (having a slow onset), considerable time is available to manage this hazard and communities are expected to mitigate its effects where possible. Reducing risks from drought focuses on good farm management and irrigation where it is available. Strategies for coping with drought where irrigation is not available include using drought-resistant pasture species, preventing over-grazing, having more flexible stocking strategies, early lambing, building small farm dams and buying in feed where necessary.

Droughts are not easily predicted. NIWA produces monthly climate outlooks for the following 3 months based on rainfall, river flow and soil moisture data, and likely climate patterns (such as the El Niño Southern Oscillation). These outlooks assist farmers and water users to make early decisions and prepare for the possibility of a drought. Some regional councils, for example the Greater Wellington Regional Council, have developed regional drought-prediction models based on the El Niño Southern Oscillation that may assist in drought management planning.

Local authorities monitor water levels, which assists in identifying at-risk water resources and allocation limits for sustainable water management.

Response and recovery

Effective response to droughts is different from many other hazards because droughts develop over a longer time, and response and recovery issues can be addressed as the situation evolves. Rural communities have time to make business decisions to ensure, for example, animal welfare needs are met. Severe droughts may eventually involve coordinated efforts by many organisations and the affected communities.

The Ministry of Agriculture and Forestry (MAF) may assist drought-affected rural communities with livestock disposal, rural recovery coordination, labour, and deployment of Defence Force personnel to assist in water supply or supplementary feeding. MAF's On-Farm Readiness and Recovery Plan for Adverse Climatic Events and Natural Disasters sets out who is responsible for responding to adverse events in rural areas and outlines available assistance. Early farm management decisions are required during droughts, particularly around the timing of stock sales.

Emergency water can be brought into drought-affected areas but this is costly, especially if the drought is across a wide area. Water is more likely to be rationed by local authorities.

Any CDEM response to droughts follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

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EL NIÑO AND ITS INFLUENCE ON NEW ZEALAND'S CLIMATE

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1997/98 DROUGHT

MINISTRY OF RESEARCH, SCIENCE AND TECHNOLOGY
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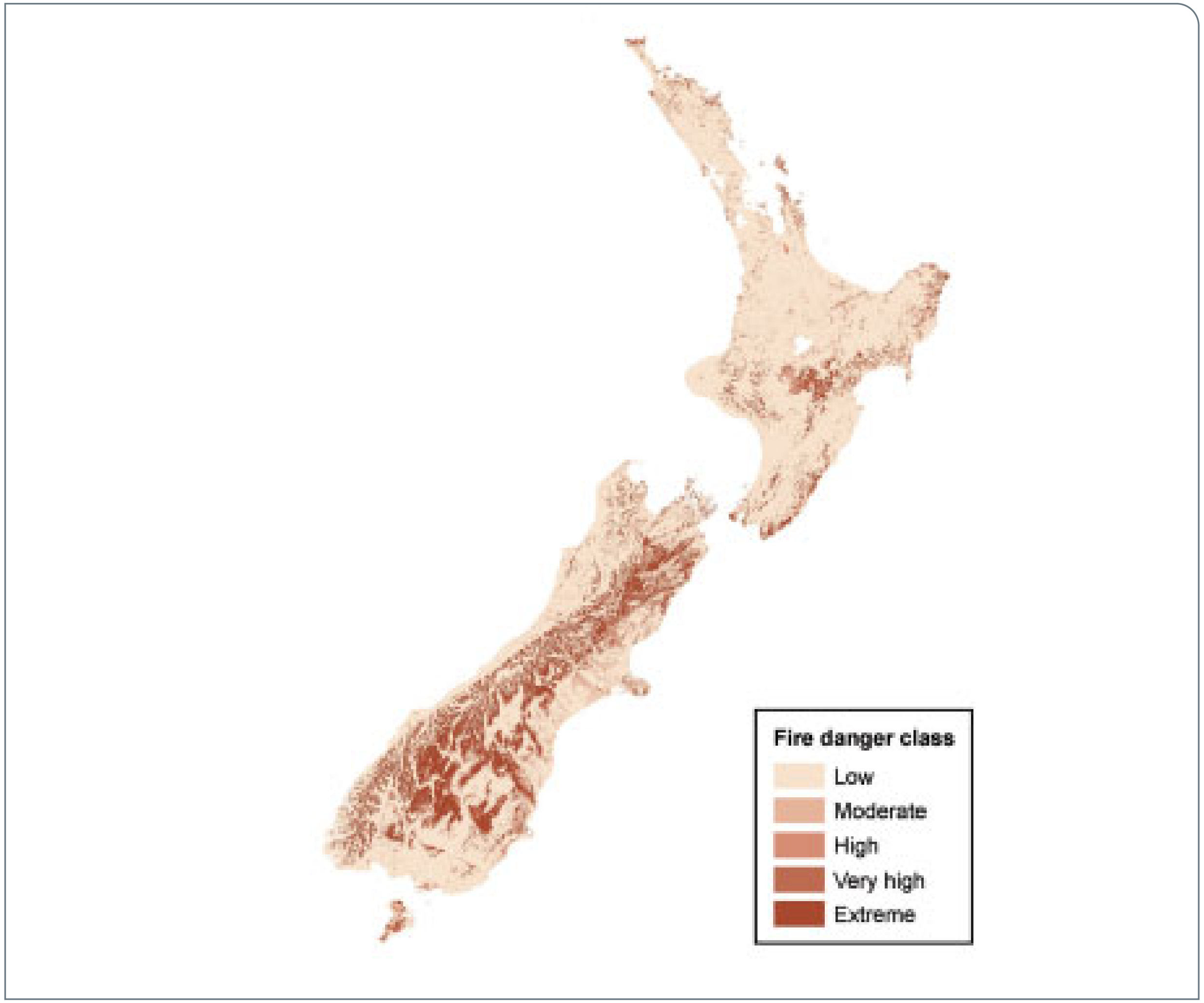
http://www.morst.govt.nz/pubs/elnino/index.htm#21

Canterbury drought, 1987/88. There is, on average, one significant drought every six years in Canterbury. The consequences of severe drought are generally widespread with significant economic impacts beyond the directly affected areas.
The Christchurch Press.

WILDFIRES

A wildfire is any unexpected fire in an open space, such as a gorse-covered hillside, grassland, or forest. A wildfire hazard is created when wildfire threatens lives, properties, commercial plantations, or areas of natural or cultural significance. Fire is not a natural part of New Zealand's ecosystems as it is in North America and Australia, and so native species have not developed adaptive traits to cope with fires.

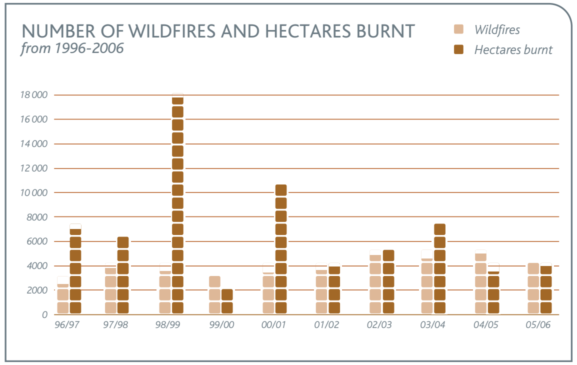
New Zealand's wildfire risk is much smaller than that of other countries, such as Australia and the United States. New Zealand has a generally wetter climate and many sources of water for fighting fires, unlike Australia where water for firefighting is often brought in from a distance. However, wildfire is still a significant risk to New Zealand's forestry industry, which produces more than 10 per cent of New Zealand's total exports. The risk to populated areas in New Zealand is lower, except for places like Wellington, Canterbury, Marlborough and Nelson, where there is increasing development on the rural fringe or in steep areas surrounded by bush.



Average summer fire danger class, 1961–2005. The fire danger class is related to the potential heat output of a fire, which depends on a combination of weather conditions, available fuel, and topography. *National Rural Fire Authority.*

Wildfire occurrence

People start most wildfires, either deliberately or unintentionally; for example, when a land-clearing burn gets out of control. Only one to two per cent of wildfires in New Zealand are ignited naturally. However, the conditions conducive to wildfire ignition and spread depend on the amount of fuel available, temperature, humidity and wind speed. Topography also has a large influence on fire spread – the steeper the slope, the faster the fire will advance. There is a large variation in these factors and, therefore, in the wildfire hazard across New Zealand.



The number of wildfires (light brown) and hectares burnt (dark brown) from 1996/97 to 2005/06. Large fires in Central Otago in the 1998/99 summer, and the Marlborough Boxing Day 2000 fire contributed to those years' high number of hectares burnt. *National Rural Fire Authority.*

The areas most susceptible to wildfire coincide with those most prone to drought: Gisborne, Hawke's Bay, Marlborough, Canterbury, and Central Otago. These areas experience the most severe fire climate with hot, dry summers with frequent warm, gusty northwesterly winds. Taranaki, Southland, and the West Coast have the least severe fire climate.

There are, on average, between 3000 and 4000 wildfires each year in New Zealand, most of which occur between November and March. New Zealand has experienced a large wildfire with significant property or forestry loss about every 10 years. The wildfire hazard is likely to increase with climate change, particularly in eastern areas as they become drier.

Wildfire impacts

Wildfire can have devastating impacts on forests, particularly exotic plantations, which are more flammable than native forests. There are 8 million hectares of forest in New Zealand, covering 30 per cent of the country's land area, 1.8 million hectares of which is exotic forest. An average of 0.05 per cent of New Zealand's exotic forest area is burned each year, although this is less than the average annual wind loss. The 1946 Tahorakuri Fire near Taupo, which burned 30 700 hectares of land including 11 000 hectares of plantation forestry, remains Australasia's largest single pine plantation fire.

Wildfires also cause damage to rural development and lifestyle blocks including farm buildings, fences and stock. Rural communities are at increased risk from wildfire because of their isolation and difficulty with evacuation. Wildfires damage or disrupt infrastructure, for example State Highway 1 was closed for several days during the 2000 Marlborough fire.

The risk to human life from wildfire is low in New Zealand because most fires occur in sparsely populated areas and there is usually time for evacuation if fires threaten an urban area. Fire fighters, forestry and bush workers, and trampers are most at risk.

Wildfires also have impacts on biodiversity, conservation and tourism.

BOXING DAY 2000 MARLBOROUGH FIRE

The Marlborough fire of 2000 started on Boxing Day and swept through 7000 hectares of land on the Wither Hills behind Blenheim before being brought under control 4 days later. Fanned by a strong northwesterly wind, the fire spread easily through grassland and bush made dry by drought conditions.

The National Rural Fire Management Team and Marlborough District Council Civil Defence were required to help in the response, which was coordinated from the Marlborough District Council Emergency Operations Centre. Many firefighters were needed; bulldozers cut fire breaks and 14 helicopters and planes dumped water on the fire. The response involved many organisations; for example the local 4WD club and Air Force drivers supplied food to firefighters in remote locations.

No lives were lost but there were some injuries. The fire spread faster than a person could run and there were close escapes for people walking in the Wither Hills Farm Park. Several houses were evacuated, but none was lost. Many farm buildings and fences, sheep and cattle, pine plantations, olive groves, vineyards, and a Queen Elizabeth II covenanted block of native bush were lost. State Highway 1 was closed for over 12 hours, disrupting the busy holiday traffic.

The cause of the fire was never determined.

The Boxing Day 2000 Marlborough fire burning in the Wither Hills behind Blenheim. The fire was the largest in the region in 20 years.
Marlborough District Council.

Managing wildfires

All territorial authorities in New Zealand, along with the Department of Conservation and the New Zealand Defence Force, are rural fire authorities and are responsible for wildfire control within their areas of jurisdiction. The National Rural Fire Authority (NRFA), which is part of the New Zealand Fire Service, provides policy, support and some funding for rural fire management in New Zealand.

Risk reduction

Rural fire authorities are responsible for declaring whether a fire season is open, restricted, or prohibited, and for issuing fire permits during restricted fire seasons. Rural fire authorities also maintain fire breaks.

Public education is an extremely important aspect of wildfire-risk reduction, given that people cause most wildfires. People living in high wildfire-hazard areas can make their properties more resilient by keeping a vegetation-free area around their house, clearing roofs and gutters of dead vegetation, and ensuring clear access for firefighters.

Individual rural fire authorities can require land owners or occupiers to remove flammable vegetation or material from their land, if it is considered to be a fire hazard, under the Local Government Act 2002.

Readiness

Rural fire authorities are responsible for training and exercising a rural fire force and for public education.

The NRFA gathers data from 150 remote automatic weather stations, monitored in partnership with rural fire authorities, the MetService and NIWA. The weather data collected is used in conjunction with a Fire Weather Index System to calculate vegetation moisture and expected fire behaviour across the country. This information is supplied daily to rural fire authorities (and to the public by the internet) and is used to manage resources and responses to fires.

A fire-danger sign in North Canterbury. Rural fire authorities maintain fire-danger signs throughout New Zealand that inform the public of the daily fire danger during summer. *Ministry of Civil Defence & Emergency Management*.

Response and recovery

The Rural Fire Authority is the first responder to most wildfires. If a fire occurs close to an urban centre, the New Zealand Fire Service (NZFS) will also attend. In some rural fire districts the NZFS is contracted to provide rural fire response and will be the only attendees to a wildfire.

Managing large wildfires can be beyond the capacity of the local NZFS and Rural Fire Authority, in which case the NRFA may become involved to manage the fire response and coordinate resources from other rural fire authorities.

CDEM involvement may be required during a large wildfire to provide support in an Emergency Operations Centre, and to help in coordinating resources and welfare support to any evacuees. The CDEM response to wildfires follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

People responsible for lighting a wildfire, if apprehended, can be prosecuted and made to pay for the cost of fighting the fire. The Rural Fire Fighting Fund, administered by the NRFA, also provides funding for firefighting costs.

A rural firefighter fighting a wildfire at Makara Beach near Wellington.
Wellington Emergency Management Office.

Recovery after a wildfire involves removing any remaining and potentially dangerous vegetation, for example, trees that have been damaged and that may present a windfall hazard; reseeding the burnt area; and repairing damaged assets and infrastructure. These are the responsibility of private land and asset owners.

FURTHER INFORMATION

GENERAL WILDFIRE INFORMATION

NATIONAL RURAL FIRE AUTHORITY
nrfa.fire.org.nz
MCFARLANE, P, PEARCE, G, AND MOORE, J, 2001, FORESTRY AND RISK MANAGEMENT – NEW ZEALAND IN A GLOBAL CONTEXT. Risk Management and Sustainable Forestry, 8 September 2001, Bordeaux, France.
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www.fire.org.nz

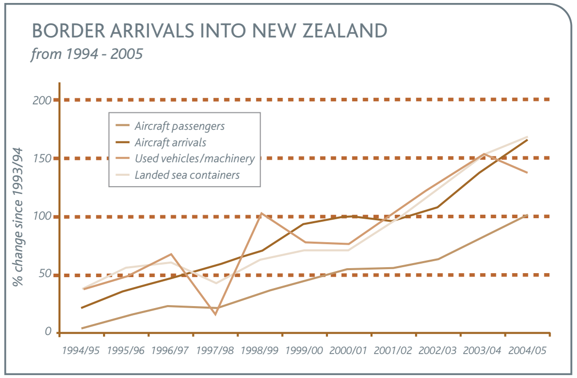
BOXING DAY 2000 MARLBOROUGH FIRE

BROOKS, C, 2001 ONE EYED AND BLINKERED – FORTY YEARS OF CIVIL DEFENCE IN MARLBOROUGH. Darcy Christopher Foundation Civil Defence Trust.

ANIMAL AND PLANT PESTS AND DISEASES

New Zealand's geographical isolation from the rest of the world has meant that its indigenous flora and fauna have been protected from many predators, pests, and diseases. This lack of pests and diseases has benefited New Zealand's agricultural, forestry and marine sectors, by reducing costs of pest control and therefore keeping the cost of production down.

New Zealand's reliance on trade and tourism means that there are now many pathways by which serious pests and diseases may arrive and become established in the country. Pests and diseases can arrive as hitchhikers associated with goods or conveyances, as the result of inadvertent contamination (including genetically modified organisms), or sometimes by deliberate or illegal introductions. A pest or disease that is benign in its country of origin may have significant consequences if it arrives in New Zealand, as its behaviour – distribution, host species, and population growth – cannot always be predicted.



The growth in border arrivals into New Zealand since 1993/94. The large increase provides more opportunities for pests and diseases to be introduced. *Ministry of Agriculture and Forestry.*

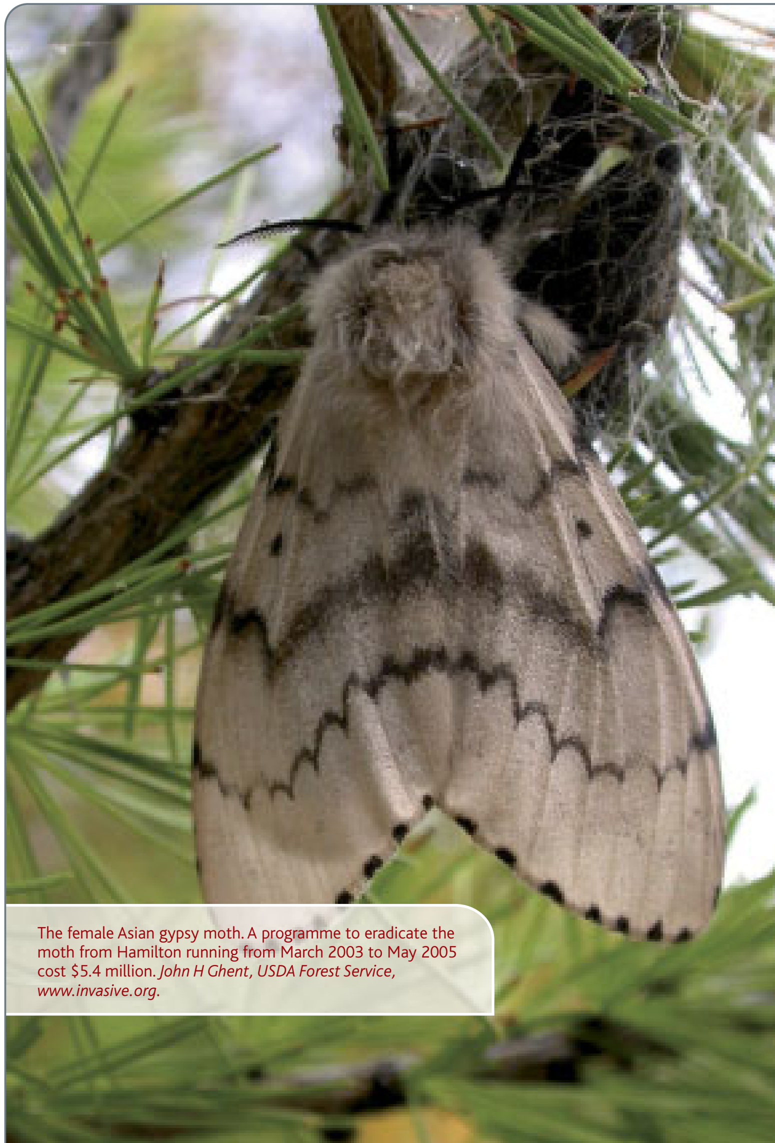
Outwards trade may be affected if some pests and diseases are detected within New Zealand. Many countries New Zealand exports to that do not have particular pests and diseases, and their consumers, will not accept the risks of potential infection.

Some diseases, such as anthrax and avian influenza, can also affect human health. Mosquitoes and other pests can transmit diseases, such as Ross River virus.

Animal pests and diseases

Animal diseases pose a number of threats to New Zealand. They can reduce livestock productivity, or increase pest control costs. They may create risks for handling animals or their products when they can infect humans. Some diseases and their treatments mean the animal cannot enter the food chain or be exported. Some diseases, such as foot-and-mouth disease and avian influenza, are highly contagious and may spread rapidly. Other diseases, such as bovine spongiform encephalopathy (BSE or 'mad cow disease') may not become apparent until long after infection has occurred.

There is a high cost in managing animal pests and diseases. For example, since the bovine tuberculosis strategy was implemented in the mid-1990s, over $600 million has been spent to eradicate the disease. Over $1 billion will be spent by the time the level of infection is reduced to 'official freedom' levels.



The female Asian gypsy moth. A programme to eradicate the moth from Hamilton running from March 2003 to May 2005 cost $5.4 million. *John H Ghent, USDA Forest Service, www.invasive.org.*

2003 ASIAN GYPSY MOTH ERADICATION, HAMILTON

Asian gypsy moth feeds on a wide range of plants, including forestry and amenity species and causes millions of dollars' worth of damage in the Northern Hemisphere. Egg masses containing 50–800 eggs are laid on a range of surfaces, including ships, cars and containers, and can survive through the tropics. Hatching larvae can be dispersed by wind.

The Ministry of Agriculture and Forestry inspects sea containers and imported vehicles for Asian gypsy moth and other species. Pheromone traps are also placed around ports of entry and other risk sites for early detection.

A live male moth was caught in an early warning trap in Hamilton in March 2003. An aerial spray programme using *Bacillus thuringiensis var kurstaki*, a naturally occurring biopesticide, was carried out over 8 weeks. The overall eradication programme lasted for 2 years and included a public communication campaign and spray avoidance protocols for members of the public, and post-operative monitoring. No more moths have been caught, and eradication was declared in May 2005.

The Asian gypsy moth eradication programme cost $5.4m. The social impact of the pest eradication was significant with the people of Hamilton having to endure considerable inconvenience and discomfort during the aerial spray and plant movement controls components of the eradication effort.

FOOT-AND-MOUTH DISEASE

Foot-and-mouth disease (FMD) is a highly contagious disease of cloven-hoofed animals, including sheep, goats, cattle, and deer. It has no known cure. Symptoms include lesions or blisters on the tongue, muzzle, udders and feet, lameness, and salivation. The disease can be carried on infected animals, by air, and on contaminated equipment and vehicles. The preferred approach to a FMD outbreak is to eradicate the disease by destroying and then burying or burning infected and suspect animals.

A FMD outbreak in New Zealand would close trade to key markets, including the EU, North America, Australia and Japan. The potential cost to GDP is estimated at $6 billion in the first year, rising to $10 billion over two years. Fifteen to twenty thousand jobs would be lost.

The 2001 FMD outbreak in Britain saw nearly 5 million sheep, 764 000 cattle and 428 000 pigs killed and burned. Agriculture and tourism were severely affected and about 60 deaths in the farming community were attributed to extreme stress following the outbreak.

In 1971 a piggery near Temuka in South Canterbury reported suspect blisters in 28 pigs. It turned out that this was not the result of an animal disease, but 800 pigs and some sheep were slaughtered and burned as a precaution. In May 2005 the New Zealand Prime Minister received a letter claiming a release of FMD on Waiheke Island. This proved to be a hoax, but a full response was initiated, which directly involved around 100 people.

Plant and forestry pests and diseases

There are many plant pests and diseases that affect plants and forests. Effects may be minor, or severe enough to make cultivating the host species uneconomic. Clover root weevil, for example, discovered in the Waikato in 1996, significantly reduces pasture quality over time because nitrogen-fixing nodules in clover are depleted and alternative nitrogen sources are needed. This weevil costs New Zealand's pastoral industry around $1 billion a year. After ten years of research into biological control, a parasitic wasp has been released in some key locations around New Zealand to mitigate the effects of this introduced pest.

Aquatic pests and diseases

Aquatic pests and diseases are extremely difficult to treat or eradicate because they are often widespread when they are first detected. Ballast water and boat hulls are common means of spread. Risks can be reduced by preventing the discharge of ballast water in New Zealand waters, and by using anti-fouling paints.

When pests and diseases are established, efforts are directed at localised controls or preventing the spread into pristine areas of high ecological value. A public awareness programme, based on 'check–clean–dry', is used to reduce the speed of spread of didymo. However it is unlikely that the spread of a microscopic organism of this nature can be prevented.

Pest and disease impacts

The effects of pests and diseases vary, depending on a number of factors. The key factors are how quickly the population can grow, what parts of New Zealand it can spread to, and the presence or absence of potential predators that may limit spread. The pest or disease may have a narrow or wide range of hosts, and its impact will depend on how important those hosts are to the economy, as well as environmental and biodiversity values. The host species could be destroyed or the increase in costs associated with the pest or disease could make growing the host species no longer economic.

The effect of a pest or disease on New Zealand's trade depends on the closure of export markets, the amount of additional screening required to demonstrate freedom from the pest or disease, and consumer behaviour, which may be based on a perception of risk rather than the actual risk. If New Zealand is identified as having a significant plant or animal disease, importing countries under bilateral and other trade agreements have rights to refuse to accept imports of potentially affected product until New Zealand can again demonstrate freedom from the disease.

Even where freedom can be demonstrated, this will not prevent importers refusing New Zealand products, and this can be wider than the specific hazard identified. For example, when fruit fly was detected near Auckland airport in 1996, a number of countries put in place different responses. China banned all imports of fresh produce from the North Island for a period of over 12 months, and Indonesia for approximately 5 years.

Some pests and diseases may also have the capacity to be transferred to humans, with associated effects on human health and wellbeing.

Effects will also depend on the technical feasibility of response options; the availability of effective chemical, biological or other controls; and the public acceptability of these options.

Some pests and diseases may be of minor or localised significance, or may be managed alongside existing management options, such as treatment for intestinal parasites.

Managing animal and plant pests and diseases

Animal and plant pests and diseases are managed by the Ministry of Agriculture and Forestry (MAF) and MAF (Biosecurity NZ). Their role extends across reduction, readiness, response and recovery.

Wide-scale responses to new pest or disease incursions require rapid access to resources, and can quickly exceed the capability of communities to respond. Central government plays a large role in these responses, while regional government and industry sectors have a greater role in long-term pest and disease management. While central government does not have a legal responsibility for responding to animal and plant pests and diseases, the Biosecurity Act 1993 sets out the provisions for reducing the risks by the implementation of border controls, and through a range of powers that can be used to manage responses to pests and unwanted organisms.

Managing biosecurity hazards can have considerable economic impact. For example, 1080 is a pesticide that can negatively affect our forestry certification. This effect is a trade-off against our ability to control pests and disease.

Biosecurity risks can increase from efforts to reduce losses from natural hazards events. For example, responding to animal welfare issues following an adverse event can have longer term implications for biosecurity risk. In a drought, for instance, stock feed may be brought in from other areas that pose an unacceptable biosecurity risk. In 1996 in Australia, a drought led to stock being fed cotton trash. The trash was contaminated with pesticide residues which subsequently contaminated the meat and led to a loss of confidence in Australian residue-tracing.

Risk reduction

The primary means of risk reduction is preventing pests and diseases from entering New Zealand. Strategies include pre-border screening and inspection of risk goods and conveyances at ports of entry. Public awareness and reporting complements surveillance programmes, where early detection of a problem means a wider range of possible options for response, including eradication.

Readiness

Readiness focuses on the capability and systems to detect and respond to pest and disease incursions. MAF's capability is complemented by arrangements with biosecurity and research organisations and by inter-country cooperation. Contingency plans for specific organisms or groups of organisms are prepared, and site-specific readiness plans within industry sectors are encouraged. The involvement of other stakeholders depends on those affected, but always includes the public.

Response and recovery

Biosecurity responses may involve rapid emergency response measures or more considered long-term approaches. Generic responses consider the costs and benefits of the values being protected, the impact of the organism being managed and the impact of the response actions. Incursions may be managed for long periods of time, including pest management strategies of greater than 10 years. Options include eradication, containment, or exclusion from designated areas.

Many pests and diseases affect a specific sector – for example, the seasquirt *Styela* affects the aquaculture and recreational marine sectors – or they may have a flow-on effect to the wider economy, as with foot-and-mouth disease. The scale of the impact will determine whether MAF handles the response, leads a whole-of-government response, or helps regional councils and industry groups manage responses. The Governor-General can declare an emergency on the advice of Ministers under Part VII of the Biosecurity Act 1993.

For livestock diseases, a national livestock standstill may be needed to prevent further spread of the disease, while government agencies attempt to find the source of the outbreak or identify clusters of infection. Processing plants may stop production to reduce the risks to shareholders. Recovery, which mostly involves rebuilding herds and restoring markets, may take several years, but the damage to buildings and equipment is likely to be minimal.

In a large enough response, MAF's stand-alone capability may be quickly exceeded, or be unable to be sustained. Field-based responses will require local support, operations centres and other logistical supply services that cannot be obtained through national industry organisations where MAF's main stakeholder relationships lie. Support can come from government agencies and the CDEM sector, particularly through their knowledge of existing community infrastructure, and local coordination of resources.

FURTHER INFORMATION

GENERAL BIOSECURITY INFORMATION
BIOSECURITY NEW ZEALAND
www.biosecurity.govt.nz

ANIMAL PESTS AND DISEASES AFFECTING GLOBAL TRADE
WORLD ORGANISATION FOR ANIMAL HEALTH
www.oie.int/eng/maladies/en_classification.htm

PLANT PESTS AND DISEASES AFFECTING GLOBAL TRADE
INTERNATIONAL PLANT PROTECTION CONVENTION
www.ippc.int

ECONOMIC IMPACTS OF A FOOT-AND-MOUTH DISEASE OUTBREAK
THE TREASURY
www.treasury.govt.nz/footmouth/

INFECTIOUS HUMAN DISEASE PANDEMICS

Infectious disease pandemics are characterised by the global spread of a new type of virus that can cause unusually high rates of illness and mortality for an extended period of time. Most people are not immune to a new virus and are therefore susceptible to infection. A pandemic can overwhelm the resources of a society due to the exceptional number of people affected. A new strain of the influenza virus is the most likely cause of the next infectious disease pandemic.

Influenza

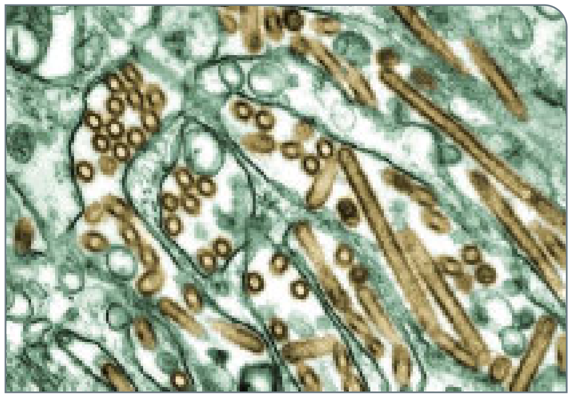
The influenza virus

The influenza virus infects the respiratory tract, causing fever, aches and fatigue for around 7–10 days, and sometimes secondary infections such as pneumonia. The virus is easily spread from person to person through droplets and hand to mouth transmission, and can be fatal. The incubation period is generally 1–3 days but can be up to 7 days. Minor influenza outbreaks (epidemics) typically occur during winter and influenza is directly responsible for around 100 deaths each year in New Zealand.

There are three types of influenza virus – A, B and C. Influenza C viruses only cause mild symptoms and are not thought to generate epidemics, whereas influenza A and B viruses can cause epidemics. Influenza B viruses are only found in humans, but influenza A viruses, responsible for pandemics, are found in humans and many different animals including birds, pigs, whales, horses, and seals.

Influenza A viruses are divided into subtypes based on the hemagglutinin (H) and neuraminidase (N) proteins on the surface of the virus. There are 15 different H subtypes and nine different N subtypes, all of which have been found among influenza A viruses in wild birds.

Influenza A and B viruses continually change over time through antigenic drift, which occurs when small changes in the virus create new strains. People may have some degree of immunity to these new strains as they are similar to previous ones. Influenza A viruses can also undergo antigenic shift. This is an infrequently occurring abrupt major change in the virus resulting in new H or N proteins and the formation of a new influenza A subtype. This process can occur within humans or other animals, such as pigs, if they are infected with two different types of virus at the same time. Most people have little or no immunity against the new virus, and developing a vaccine for a new virus can take 6–9 months.



A colourised transmission electron micrograph of the H5N1 Avian influenza virus. *Center for Disease Control*.

Influenza pandemics

An influenza pandemic is generated when a new type of influenza virus evolves which causes illness in humans and is efficiently transmitted between people, spreading rapidly around the globe. Pandemic influenza is different from seasonal influenza – it can occur at any time of year and can affect any age group, not just the young or elderly.

The emergence of several new influenza A virus subtypes caused three pandemics last century, all of which spread around the world within a year of being clinically recognised.

The 1918/19 'Spanish flu', A(H1N1), was the most severe pandemic causing between 50 and 100 million deaths worldwide with a large impact in New Zealand. The 1957/58 'Asian flu', A(H2N2), and the 1968/69 'Hong Kong flu', A(H3N2), each killed one to four million people worldwide. The 1957/58 pandemic infected 70–80 per cent of New Zealanders but the mortality rate was very low, and the 1968/69 pandemic had little effect in New Zealand.

Both the 1957/58 and 1968/69 pandemics were caused by viruses containing a combination of genes from a human influenza virus and an avian influenza virus. The 1918/19 pandemic virus appears to have been completely avian in origin.

1918 INFLUENZA PANDEMIC

The 1918 pandemic arrived in New Zealand in early October 1918 and had a profound effect on the country, which took years to recover. Many people died within the first few days after infection and others died of secondary infections like pneumonia. Little was known about the cause of the disease or how it spread, and a variety of ineffective treatments such as public throat-spray facilities, while well-meaning, may have created additional sources of cross-infection. Quarantining and travel restrictions around the country were not introduced until the pandemic was well under way. Public health knowledge was limited and in each community doctors were totally overwhelmed; there was ultimately little they could do to halt the course of the influenza in those who contracted it. Communities formed groups and committees to look after those most in need with food or home help, and it seems that without this basic care even more could have died.

Within 4 months, 30–50 per cent of the population had contracted the virus and 8600 had died, nearly half of whom were young, healthy adults. Because it occurred at the end of World War I the trauma suffered was masked, but in many ways it was more damaging than the effects of the war itself.

The 1918 pandemic had a severe impact on Māori, whose death rate of 4.2 per cent (a total of 2160) was around six times higher than non-Māori. Possible explanations for this difference have included inequalities in socio-economic status, lack of access to health care, and a higher incidence of other illnesses at the same time. Some of these factors still exist today, potentially making the Māori population more vulnerable in the event of a pandemic.

An influenza medicine depot in Cathedral Square, Christchurch, during the 1918 influenza pandemic. The pandemic was the worst disease outbreak to hit New Zealand and prompted reforms to the health system, including the 1920 Health Act. *Alexander Turnbull Library.*

New Zealand's pandemic hazard

Another pandemic will occur in the future but there is no certainty about when or how large it will be, or where it will originate. New Zealand has some advantages in being a geographically isolated country with a limited number of well-controlled entry points. Depending on the nature of a pandemic it may, therefore, be possible to delay the impact in New Zealand, but the effects would still be significant.

Current influenza viruses

There are currently five different types of new influenza A virus that have caused human infections. One virus, H5N1, is an avian influenza virus that, since 2003 in particular, has been infecting birds in an increasing number of countries. It has also caused severe human disease although so far it has been reported as only affecting a relatively small number of people. Should a virus such as H5N1 mutate to become easily and readily transmissible between humans it would represent a credible and potentially serious pandemic threat.

The World Health Organisation uses six phases of pandemic alert level to convey the seriousness of the pandemic threat and the need to launch progressively more intense preparedness activities. Phases range from 1 (interpandemic phase: low risk of human cases) to 6 (pandemic: efficient and sustained human-to-human transmission). The current status is phase 3 (pandemic alert: no or very limited human-to-human transmission) as at September 2006, in response to the H5N1 avian influenza situation.

New Zealand pandemic planning model

It is not possible to predict what will happen in New Zealand if a pandemic occurs, because that will depend on the nature of the new virus, which cannot be known until it exists. However, New Zealand has adopted a pandemic planning model, based on World Health Organisation guidelines and the impacts of the 1918 epidemic, to assist in pandemic planning.

The model assumes a pandemic wave in which 40 per cent of New Zealand's population, around 1.6 million people, become ill over an 8-week period. The peak incidence is over weeks 3 to 5 when about 1.3 million people, or a third of the population, would be ill, convalescent or just recovered.

The model assumes a fatality rate of two per cent of those infected, which would see about 33 000 deaths over the eight-week period, peaking at about 10 000 in week 4, compared to around 550 deaths per week normally.

Pandemic impacts

In contrast to many other hazards, the impacts of a pandemic manifest as a loss of human capability. They affect the ability of society and the economy to function normally, and can indirectly lead to a subsequent deterioration of infrastructure services. These impacts would occur on a national and international level. Consequently a greater degree of community resilience is required, compared to the response for other hazards, because assistance is unlikely to be available from outside affected areas.

A pandemic is likely to cause high absentee rates in the workforce as people fall ill or stay at home to care for the sick. The planning assumption used in New Zealand is for up to 50 per cent absenteeism at the peak of an epidemic. This would significantly affect all services including health and other essential services such as police, fire, transportation, communications and CDEM organisations.

Other services and supplies – including food, water, gas, electricity supplies, educational facilities, postal services and sanitation – are also likely to be affected. Food shortages are possible if food distribution and shopping is affected. A heavy load is likely on information and communication technology infrastructure as people work and interact from home.

National and international business activities, regardless of their nature, are likely to suffer during a pandemic. A serious pandemic is likely to have severe adverse short-term effects on the economy. Uncertainty about how serious any pandemic may turn out to be, how long it may last, and when communities may regain daily functioning, would have a major effect on business and consumer confidence. Such confidence effects are likely to play a major role in how severe the economic impact is, and in how quickly the economy can recover afterwards. Based on the pandemic planning model Treasury has estimated a reduction in GDP of 5–10 per cent in the year of the pandemic and cumulative losses over 4 years of 10–15 per cent of one year's GDP.

Managing pandemics

The Ministry of Health is the lead agency for managing pandemics. The Ministry of Health has led the development of the New Zealand Influenza Pandemic Action Plan that provides a consistent framework for pandemic management in New Zealand. The plan is built around a five-stage strategy to:

- plan for it – reduce the health, social and economic impact
- keep it out – prevent, or delay to the greatest extent possible, its arrival
- stamp it out – control or eliminate any clusters that are found
- manage it – reduce the impact on the population
- recover from it – speed the recovery of health, communities and society.

Managing the pandemic hazard involves a whole-of-government approach, and early, decisive leadership is critical in the event of a pandemic.

Risk reduction and readiness

MONITORING

An ongoing effective national surveillance system is an essential component of preparedness. There are currently two national surveillance systems in New Zealand.

The general-practice sentinel disease and virological surveillance system, involving more than 90 practices throughout New Zealand, operates annually during winter (May to September), recording the daily number of consultations that fit the case definition of an influenza-like illness.

In addition, specimens are collected from hospitalised patients with an influenza-like illness throughout the year for analysis at designated virology diagnostic laboratories. Data collected from these laboratories is reported nationally in the Virology Weekly Report. Authorities in New Zealand maintain contact with the World Health Organization Collaborating Centre for Reference and Research on Influenza in Melbourne.

Internationally, the Global Outbreak Alert and Response Network is a technical collaboration of institutions and networks who pool human and technical resources for the rapid identification, confirmation

People receiving a dose of zinc sulphate in an inhalation chamber in Christchurch during the 1918 influenza pandemic. Such treatments probably did more harm than good by bringing people together. Social distancing would be encouraged in any future pandemic. *Alexander Turnbull Library.*

and response to outbreaks of international importance. The Network provides an operational framework to link expertise and skill, keeping the international community constantly alert to the threat of outbreaks and ready to respond.

COMMUNICATION AND PUBLIC EDUCATION

An important element of reducing the impact of a pandemic and maintaining readiness for one is to raise people's awareness of the threat and prepare them for it by suggesting actions that can be taken to mitigate the threat. This includes informing people about community self-support, and advising them of good infection prevention and control practices to promote good hygiene and prevent cross-infection. Important messages include covering coughs and sneezes and keeping a distance of at least one metre from other people where at all possible.

People are encouraged to have a well-stocked emergency supplies kit, including food for a period of at least 10 days, along with a plan that includes how they will manage if they live on their own and are unwell, identification of pre-arranged contacts, and having a way to call for help and to offer help to neighbours.

BUSINESS CONTINUITY PLANNING

Organisations will need robust arrangements for continuing their business in the event of a pandemic. A pandemic represents a particular challenge for business continuity planning, which will need to include staff welfare, solutions for working in an environment of 'social distancing', managing large-scale absenteeism, maintaining continuity of senior management roles and management systems, realigning business activities to focus on critical functions and services, and identifying any additional roles in responding to the pandemic.

Response

A range of control measures may prevent, eliminate, or slow down transmission of an influenza virus, in the hope that it would allow time for the development and arrival of a pandemic vaccine. These traditional public health measures include border management, intensified surveillance, early detection and isolation of cases and quarantine of contacts, use of antivirals, restriction of public gatherings, and closure of educational institutions.

The particular pandemic control interventions that will be adopted depend on the nature and stage of the pandemic, the severity of disease (a more virulent strain will justify more socially demanding measures), and the extent of transmission within the country and community. In general, as a pandemic develops, the strategy changes from individual interventions, such as finding and identifying cases, tracing contacts, prevention and quarantine, to more population-wide actions, and managing their impacts.

In a severe pandemic, alternatives to providing a regular health service may be required as primary and secondary health services struggle to cope with the increased demand for services. Community-based assessment centres may be established as a means of concentrating the initial assessment of people who may have the pandemic influenza virus away from individual general practices and hospital emergency departments. They may also distribute antivirals or antibiotics to those who meet agreed clinical criteria, support home-based self-care and advice, and refer patients to the hospital if clinical interventions are required.

It is expected, however, that even in a substantial pandemic most people will suffer uncomplicated influenza, which will resolve itself. Self-management at home can be safe and effective if good information is available to the public on how to look after themselves and others, how to identify complications, and how to seek advice if complications occur.

Planning and coordination by the CDEM sector, as noted in the New Zealand Influenza Pandemic Action Plan, can help support the health sector and local government in community leadership and in managing community services and assets. It also supports the 'fast moving consumer goods' sector to maintain essential food and grocery supplies.

Recovery

The recovery from a pandemic will be a very long process involving complex global issues. In particular, New Zealand's economy is strongly linked to international economies which will also be affected, prolonging economic recovery. On a national level a pandemic will affect the physical, financial and emotional wellbeing of large numbers of people who may suffer bereavement, severe illness or separation from families and support. People may also experience losses of employment and income along with social and community isolation. Recovery strategies therefore need to be based primarily around social and economic initiatives.

FURTHER INFORMATION

GENERAL PANDEMIC INFORMATION
MINISTRY OF HEALTH
www.moh.govt.nz/pandemicinfluenza

NEW ZEALAND INFLUENZA PANDEMIC ACTION PLAN 2006
MINISTRY OF HEALTH
www.moh.govt.nz/moh.nsf/indexmh/nz-influenza-pandemic-action-plan-2006

LOCAL GOVERNMENT AND CDEM GROUP PANDEMIC PLANNING GUIDE
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Readiness-and-Response-Pandemic-Influenza

BUSINESS CONTINUITY PLANNING AND WORKPLACE ISSUES
DEPARTMENT OF LABOUR
www.dol.govt.nz/initiatives/workplace/pandemic/index.asp
MINISTRY OF ECONOMIC DEVELOPMENT
www.med.govt.nz/templates/ContentTopicSummary____14451.aspx

IMPACTS OF AN INFLUENZA PANDEMIC ON NEW ZEALAND'S MACROECONOMY
THE TREASURY
www.treasury.govt.nz/workingpapers/2006/tpp06-03.pdf

VIROLOGICAL SURVEILLANCE
ENVIRONMENTAL SCIENCE AND RESEARCH
www.surv.esr.cri.nz/virology/virology.php

1918 INFLUENZA EPIDEMIC IN NEW ZEALAND
NEW ZEALAND'S HISTORY ONLINE
www.nzhistory.net.nz/culture/influenza-pandemic
RICE, G, 2005, BLACK NOVEMBER: THE 1918 INFLUENZA EPIDEMIC IN NEW ZEALAND.
Canterbury University Press, Christchurch.

WORLD HEALTH ORGANISATION PANDEMIC ALERT PHASES
WORLD HEALTH ORGANISATION
www.who.int/csr/disease/avian_influenza/phase/en/index.html

INFRASTRUCTURE FAILURES

New Zealand, like all developed nations, is highly reliant on its infrastructure: energy (electricity, gas, petroleum), information and communications technology (ICT), transport, and water. New Zealand's linear shape, rugged topography, and low population density result in long and often isolated infrastructure networks that are vulnerable to natural hazards. Infrastructure networks may also be disrupted by other external factors such as terrorism, or internal causes such as a lack of maintenance or planning.

Local infrastructure failure is not uncommon and can generally be dealt with by lifeline utilities (infrastructure providers). However, because of interdependencies, a failures of one can cascade across others. The resulting widespread and potentially long-term failure can affect the economy and may require coordinated regional involvement for welfare and logistical issues. While a single utility failure can be a significant event, the disruption from multiple utility failure is potentially very severe.

The physical nature, along with ownership, operational and regulatory frameworks of infrastructure sectors vary, as do levels of resilience and operational response capability. While there are pressures in some sectors, for example energy supply and road congestion, a 2004 infrastructure audit prepared by PricewaterhouseCoopers (PwC) as part of a government infrastructure stocktake concluded that at a national level New Zealand's infrastructure is in reasonable condition. The audit did, however, draw attention to some previously identified local and sector-level issues that may have a significant local and national impact.

Energy

Electricity

New Zealand currently uses almost 40 000 gigawatt hours (GWh) of electricity each year and this is projected to grow significantly over the next 20 years.

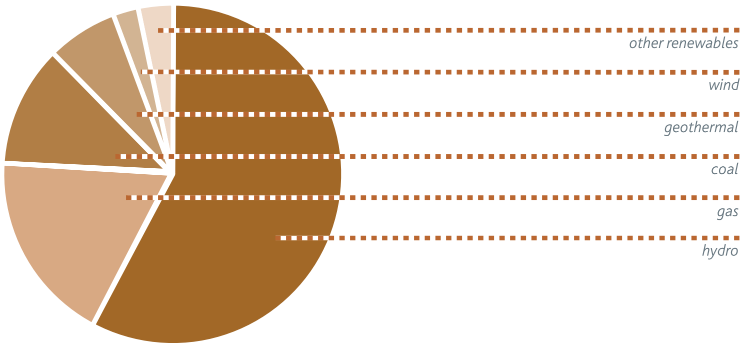
Before 1987 the Government controlled and operated almost all electricity generation and transmission in New Zealand through the New Zealand Electricity Department. Reforms over the last 20 years have seen the Department and other electricity market entities corporatised to a combination of state-owned enterprises and trust-owned or private companies.

Five major power companies now generate 93 per cent of New Zealand's electricity and dominate the electricity retail market. Transpower, a state-owned enterprise, operates the national transmission grid connecting power stations to local distribution lines and major industries. The grid comprises more than 12 300km of high voltage transmission lines including the Cook Strait submarine cable between the North and South Islands.

As at March 2005, 28 network distribution businesses in New Zealand supplied electricity from the national grid to customers. Network ownership ranged from community-owned trusts, shareholder cooperatives, and local authorities, to publicly listed companies.

The 2004 PwC infrastructure audit identified long-term security of electricity supply as a concern. The national transmission grid is

ELECRICITY PRODUCTION
2005



In the year ending March 2005, hydro-generation provided 64 per cent of New Zealand's electricity (65 per cent of this in the South Island). Ten per cent was generated by other renewable resources and the remaining 26 per cent from fossil fuels. Figures vary from year to year because of hydro-generation's dependence on rainfall. Industry was the largest user of electricity during the same period. *Ministry of Economic Development*.

coming under increasing pressure as electricity demand grows, but new regulatory arrangements need to be established, and land access issues resolved, before new investment can take place. Capacity into and north of Auckland, and between the Waitaki Valley and Christchurch, are key areas requiring upgrading.

Transpower has plans to upgrade the national grid's capacity. Vulnerabilities do exist; for example, just one substation supplies most of Auckland city. This vulnerability was highlighted in the power cut of 12 June 2006, which blacked out central Auckland for 5 hours.

While New Zealand's existing electricity generation plant is generally reliable, there is uncertainty around fuel availability for future generation and supply during dry periods. Uncertainty about regulation – for example, the Government's response to climate change – may also affect new generation investment. In December 2006, the Government released a Draft Energy Strategy and associated documents aimed at establishing clear policies for electricity generation and other energy sources.

Along with internal risk factors, electricity infrastructure is vulnerable to natural hazards. Earthquakes, volcanic eruptions, lahars, tsunamis, wind, lightning strikes, and snow could all cause widespread damage to electricity infrastructure, particularly transmission and distribution lines. An influenza pandemic could also affect electricity supply if illness causes staff shortages.

Power poles brought down by the weight of snow during the June 2006 Canterbury snowstorm. The snowstorm left thousands of people in South Canterbury without power for up to 4 weeks. *Electricity Ashburton*.

The consequences of a widespread or long-term electricity outage include:

- welfare issues, particularly heating, sanitation, and medical facilities for vulnerable groups such as the elderly and sick
- water and wastewater pump system failures and subsequent sewage releases
- disruption to communications, air-traffic control and fuel supply (as many fuel pumps rely on electricity)
- economic losses from businesses unable to operate without ATM and EFTPOS transactions
- loss of refrigerated food
- farm animal welfare issues
- reduced security and lighting
- school closures.

These consequences can be reduced where local emergency generation is available.

Auckland, early morning, during the 1998 power crisis. The crisis left the city without power for five weeks. *PhotoNewZealand*.

1998 AUCKLAND POWER CRISIS

New Zealand's worst recent infrastructure failure occurred in January and February 1998, when electricity supply to the Auckland central business district (CBD) was disrupted for almost 2 months.

Four cables supplied almost all of the Auckland CBD's electricity. One cable failed on 20 January, followed by another on 9 February. The two remaining overloaded cables failed on 19 and 20 February, leaving most of the CBD without power.

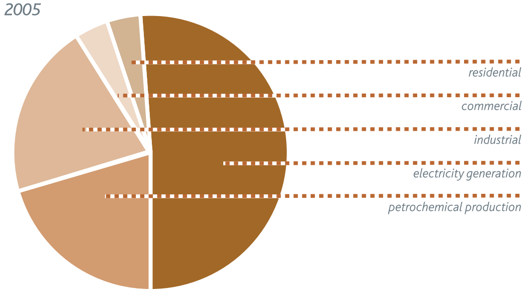
Generators were brought in to the CBD to power essential services, such as Auckland Hospital, but most shops and businesses could not operate. Around 6000 inner-city apartment residents had to find alternative accommodation. Sixty thousand of the 74 000 people who usually worked in the CBD had to work from home or in relocated offices elsewhere in Auckland or further away.

It was 5 weeks before an emergency cable was completed and electricity restored to the CBD. The long-term economic impact was estimated at 0.1–0.3 per cent of GDP, and many small businesses never recovered from the event.

Gas

New Zealand's natural gas comes primarily from seven gas fields in the Taranaki region, with 74 per cent coming from the two largest fields, Maui and Kapuni.

GAS USAGE
2005



Electricity generation uses most of New Zealand's extracted gas. The remainder is used to produce petrochemicals or is reticulated for industrial, commercial and residential use. *Ministry of Economic Development*.

Gas is supplied throughout the North Island by two transmission companies through 3400km of high-pressure transmission pipelines, and five distribution companies through 2800km of distribution networks. There are two small South Island LPG reticulation networks in Christchurch and Queenstown. The gas industry is currently moving from a situation of a few large companies managing a few large gas fields to a larger number of companies managing a larger number of fields of varying sizes.

Most of the gas transmission network in New Zealand was constructed in the late 1960s, and both transmission and distribution networks are currently able to meet demand. However, natural gas is a non-renewable resource. Supply will be determined by the rate of use and by the discovery and exploitation of new gas fields.

Gas supply is vulnerable to hazards, in particular earthquakes, floods, landslides, and tsunamis. Gas supply may also be affected by staff shortages during an influenza pandemic. A volcanic eruption affecting Taranaki, the source of all New Zealand's gas, could disrupt gas supply throughout the country.

Possible effects of gas infrastructure failure include:

- reduced capacity for industry and businesses (for example, food processors) to operate
- disruption to heating, cooking, and hot water for homes and essential facilities such as hospitals
- reduced gas-fuelled electricity generation.

Petroleum

New Zealand, like other developed countries, is highly dependent on oil products, particularly petroleum.

New Zealand's only oil refinery is operated by the New Zealand Refining Company at Marsden Point near Whangarei. Built in the mid-1960s, Marsden Point refines fuel for the country's four major fuel distribution companies and supplies around 80 per cent of New Zealand's jet fuel, 72 per cent of its diesel, and 63 per cent of its petrol. The remainder is imported directly, mostly into Lyttelton, Wellington, and Tauranga. About half Marsden Point's produce is transported by pipeline to the Wiri storage facility in South Auckland, and the remainder is either shipped to other New Zealand ports for road distribution or trucked directly from the refinery around Northland and North Auckland.

A natural hazard or hazardous-substance event at Marsden Point refinery could result in a loss of production capacity which would be felt nationwide. Damage to a number of New Zealand's ports or a large area of the road network, most likely from an earthquake, flood, or tsunami, could disrupt fuel supplies. Oil is a non-renewable resource and petroleum prices in New Zealand will continue to be dependent on global oil availability and international events.

Disruption to petroleum supplies would reduce the ability of many businesses and households to function normally, reduce emergency services' capability, and disrupt supply lines of other goods and services.

Information and communication technology

New Zealand has a high uptake of information and communication technology (ICT). ICT networks in New Zealand are generally privately owned by a few large companies.

ICT infrastructure tends to be more flexible than other infrastructure sectors and investment can generally occur in small increments. The ability to re-route traffic, along with the diverse capacity of main trunk lines, helps reduce the impact of failure or congestion along a particular route. The PricewaterhouseCoopers infrastructure audit did not identify any immediate ICT concerns with respect to security of supply.

ICT failures can occur through electricity outages, software problems (including viruses and hackers), or electromagnetic pulses. Hardware failure is often responsible for ICT failure. This includes the accidental severing of cables and damage from natural hazard events such as earthquakes, volcanic eruptions, floods, landslides, tsunamis, wind, or snow.

Service outages due to hardware failure, including those caused by natural hazard events, are often much shorter than failures in other sectors. For example, most ICT links were restored within 2 days after the 2006 Canterbury snowstorm, compared to up to 4 weeks for the restoration of electricity supply to some users. The New Zealand rural community is highly dependent on ICT, particularly landlines. Restoration of ICT services is a major priority for rural communities following adverse events.

Where ICT is most vulnerable is in the potential for overloading during and after an emergency. An influenza pandemic could also place stress on the ICT sector through both staff absences and an increase in ICT traffic as people work and interact from home using the internet.

While the undergrounding of the ICT infrastructure has lowered its risk to physical damage, modern ICT systems, particularly the extension of broadband, means ICT is increasingly reliant on mains power supply and is therefore more vulnerable to extended mains power failure. Facilitating access to Asymmetric Digital Subscriber Line (ADSL) broadband has increased the dependence of networks on continuous power supplies as electronic equipment is moved progressively closer to end-users. Radio ICT links are also reliant on mains power and are widely used in remote regions where difficult terrain makes cable ICT links uneconomic. Cabinets and radio sites both rely on mains power to operate and contain batteries that provide short term (up to 24 hours) back-up power.

The consequences of a large-scale ICT failure include:

- security issues
- economic losses to business
- disruption to banking and implications for international trade
- disruption to air and sea transport
- risk to public safety from disruption to the medical sector, emergency services, water and electricity supply, and traffic.

ICT failure is unlikely to be of national significance unless it seriously disrupts large areas of a major city such as Auckland, Wellington, or Christchurch.

Transport

Roads

There are 11 000km of state highway in New Zealand, managed by Transit New Zealand, and 82 000km of local road managed by territorial authorities. Overall, the state highway network is of a good, consistent standard, but the standard of the local road network is variable.

The road network is particularly vulnerable to earthquake shaking and liquefaction, landslides, lahars, and tsunamis. Floods and earthquakes often damage bridges and the services attached to them. Work has been carried out in recent years to strengthen major links such as the Thorndon overbridge in Wellington and the Newmarket viaduct in Auckland.

Disruption to the road network could isolate communities and cause economic losses from disrupted freight services.

Rail

New Zealand's rail network carries more than 14 million tonnes of freight a year, mainly coal, forestry and dairy products, and containers, and this amount is increasing. There are now only four remaining passenger services, linking Christchurch with Picton and Greymouth, Palmerston North with Wellington, Wellington with Auckland, and two metropolitan commuter systems in Auckland and Wellington.

Although there has been a general lack of investment in rail infrastructure over recent years, the main risks to failure of the rail network are from earthquake, landslide, tsunami, lahars, and flood damage. The primary impact of rail infrastructure disruption would be on freight distribution. However, a major event in Wellington or Auckland metropolitan areas would have a significant impact on commuters.

Ports

New Zealand has 13 commercial ports throughout the country. Sea ports carry 80 per cent by value and 99 per cent by weight of New Zealand's exports. Twenty-six billion dollars worth of cargo was exported from New Zealand sea ports, and almost $28 billion worth of cargo was imported into them in the year to June 2005.

Ports are particularly vulnerable to earthquakes and tsunamis. If the event is very large and affects a number of ports, or affects one of the larger ports – Auckland, Wellington, Tauranga, Lyttelton or Port Chalmers – it is likely to have a significant national economic effect.

Airports

Major international airports are located at Auckland and Christchurch with five minor international airports at Dunedin, Hamilton, Queenstown, Palmerston North, and Wellington. There are 20 local airports. Airports are critical for New Zealand's economy in terms of both trade and tourism, particularly Auckland International Airport. In the year ending June 2005, 70 per cent of international visitors, 80 per cent of air exports and 92 per cent of air imports by value went through Auckland International Airport.

Airports are vulnerable to earthquake damage and to disruption during volcanic eruptions and extreme weather. It is unlikely that an event would seriously affect more than one major airport and there is generally enough airport capacity within New Zealand to cope

The Saddle Road bridge over the Pohangina Bridge in the Manawatu after the February 2004 storm. The bridge carried the main gas transmission line between the Manawatu and Hawke's Bay and its loss affected food processing industries in Hawke's Bay. *Westmoreland School*.

with this. An exception would be a volcanic eruption in Auckland which would likely close Auckland International Airport for weeks to months, or ash from a large central North Island eruption affecting several airports.

Given the importance of Auckland International Airport for international visitors and trade, closure for a length of time would have significant impacts on tourism and export industries. An influenza pandemic would also have major impacts on airports, particularly international airports, as international visitor numbers reduce, and from staff absences.

Air travel in New Zealand can be significantly affected by poor localised weather conditions at any one of the five main airports (Auckland, Wellington, Christchurch, Dunedin and Nelson), causing widespread disruption of flights across the country. It is unusual for poor weather conditions to continue for longer than 24 hours.

Water

Territorial authorities manage most of New Zealand's water supply, stormwater, and wastewater infrastructure as geographically self-contained networks. Most of the country's medium to large urban areas have reliable and high-quality water supplies, although supplies for communities of less than 5000 people tend to vary in quality.

Most New Zealanders (83 per cent) receive water from around 700 public water-supply systems run by local government. These water networks are generally integrated – most territorial authorities, except those in the Auckland and Wellington metropolitan areas, collect, treat and distribute water, and collect, treat, and dispose of wastewater. Four per cent of the population are connected to around 1500 small privately owned or cooperative supplies. The remaining 13 per cent of the population have their own water supply, mostly from rainwater collection or bores, and dispose of wastewater through septic tank systems.

The water infrastructure sector is governed by several pieces of legislation and standards and is accountable to several different organisations. There has been substantial investment in water and wastewater treatment plants over the last 10 years. However, the 2004 PwC infrastructure audit noted concern over the security of water supply in drought-prone areas, such as Nelson, Tasman, Kapiti, and Tauranga; and over water supply and wastewater treatment capacity in small communities with large tourist-driven seasonal population fluctuations, such as Kaikoura.

Water infrastructure is critical for communities and is highly vulnerable to earthquakes, volcanic eruptions (particularly ash, in the case of surface water supplies), floods, tsunamis, droughts, and electricity failure. An influenza pandemic may disrupt water supplies due to staff shortages and disruption to supplies of treatment chemicals, electricity and telecommunications. Hazardous substance releases, pollution incidents, and terrorism can result in contaminated water supplies.

The potential consequences of damage to water and wastewater networks include:

- environmental damage and public health risk from sanitation issues or untreated sewage releases
- reduced fire fighting capability
- economic losses for industries reliant on reticulated water supplies
- school closures.

Dam failure

There are currently around 400 large dams in New Zealand – that is, those that are more than three metres high and with a capacity greater than 20 000m^3. These dams are predominantly used for irrigation, stock water, flood control, hydroelectric generation and water supply. Of these 400 dams, 96 are classed as having a medium potential impact if they fail, and 58 as having a high potential impact, under the New Zealand Society of Large Dams Dam Safety Guidelines.

Most dam failures worldwide have occurred within a few years of construction as a result of inadequate foundation or construction materials, or because of internal erosion. Dams have also failed when they have been overtopped because of inadequate spillway capacity. Dams may also fail by overtopping in natural events such as earthquakes, which cause the dam to settle, or landslides into reservoirs, which generate waves.

The potential consequences of dam failure include:

- downstream flooding of land and communities with associated casualties, damage, and economic losses
- erosion and deposition of sediment
- reduced capacity of the dam's function, for example electricity generation or water supply.

The failure of a high potential impact dam may require a coordinated response through regional or national CDEM involvement, particularly if it affects a large community, or the water supply for a large urban area or hydroelectric generation.

Managing infrastructure vulnerability

Many different organisations are responsible for managing New Zealand's infrastructure.

Electricity assets are owned mostly by government agencies; gas, petrol and ICT are largely privately owned; transport infrastructure is in private, central and local government ownership; and water is controlled by local government. All infrastructure sectors are governed by a range of regulatory and funding organisations. They have well-developed arrangements for asset maintenance and new investment.

The need for continued investment across all infrastructure sectors is recognised but there is uncertainty over required margins for security of supply. However, resilience depends not only on security of supply but also on managing demand. The more reliant New Zealand is on infrastructure, the more vulnerable it is to infrastructure failure.

Managing demand means promoting efficient use of existing assets, but there are differences between sectors in the scope for and adoption of demand-management approaches.

Risk reduction

ENGINEERING AND PLANNING

Engineering lifeline groups play a significant role in raising the awareness of infrastructure vulnerability, and promoting and advocating engineering, planning and other initiatives to reduce risk.

REGULATION AND MONITORING

The policy frameworks within which infrastructure sectors operate are set out in sector-specific legislation including the Electricity Act 1992, the Gas Act 1992, the Telecommunications Act 2001, the Local Government Act 2002, and the Land Transport Management Act 2003. These Acts contain provisions relating to establishing markets, regulation of monopolies, new investment and safety. In addition, the RMA sets out a framework to consider community and environmental impacts of infrastructure development, and the Commerce Act 1986 contains provisions that promote competition and control prices where necessary.

Policy advice on infrastructure is provided to the Government by a range of Ministries. These include the Ministry of Economic Development (for energy and ICT) and the Ministry of Transport (for transport). Policy advice on water issues is provided by Ministry for the Environment, the Ministry of Health, the Ministry of Agriculture and Forestry, and the Department of Internal Affairs. The Treasury also has a role in infrastructure policy advice, especially where central government provides funding.

Many of the sector-specific Acts set up governance institutions or other arrangements to ensure that policy objectives are met.

1997 OPUHA DAM COLLAPSE

The partially completed Opuha Dam in the Opihi catchment in South Canterbury collapsed on 6 February 1997, releasing 13 million m^3 of water down the Opuha River.

Intermittent heavy rain over the preceding few days had exceeded the capacity of the culvert through the dam and the available storage within the reservoir. A cut was made at the dam abutment but water was able to erode a larger channel into the earth dam, and eventually the dam collapsed.

A state of emergency was declared early on 6 February, and 200 residents were evacuated from four settlements. No human lives were lost but 1000 head of stock died and farms adjacent to the river sustained hundreds of thousands of dollars' worth of damage.

Half a million dollars' worth of damage was done to flood protection works in the Opuha and Opihi river catchments, and State Highway 79 was washed away at Skipton Bridge.

This collapse, along with floods in 2004, highlighted the need for dam safety provisions and reinforced the need for emergency management plans to be developed for medium and high potential impact dams.

The Electricity Commission was set up by Government in 2003 under the Electricity Act 1992, to ensure security of supply in response to the variability of water levels in New Zealand's main hydro-generation lakes resulting from uneven year-to-year rainfall. The Gas Industry Company is the industry body under the co-regulatory governance model established for the gas sector. They are responsible for developing and implementing gas market arrangements.

Land Transport New Zealand was formed in 2004 to take responsibility for land transport funding and promote land transport safety and sustainability. New Zealand is required under the International Energy Agreement to hold 90 days' supply of petroleum for emergency use.

Infrastructure supply risks are also addressed in the CDEM Act, which requires lifeline utilities to plan so they can function during and after an emergency, even if at a reduced level, and to take part in developing CDEM plans.

DAM SAFETY

Changes in the Building Act 2004 recognise the potential for dam failure and the need for a formal system of monitoring and maintaining dams given the continuing changes to dam ownership, operation, and management.

Dam owners are required to classify their dam according to the potential impact its collapse would have (low, medium, or high) and to register that classification with their regional council. This classification is regularly reviewed, which means that changing risk factors such as new downstream development or changing hydrological conditions can be taken into account. Owners must also prepare dam safety assurance programmes, which include emergency action plans, and provide an annual compliance certificate for medium or high potential impact dams.

Regional councils process building consents for dams, administer and monitor dam safety management (including holding a dam register) and develop policy.

Readiness

The gas industry has developed its own emergency and contingency arrangements in the National Gas Outage Contingency Plan. The Gas Industry Company is currently reviewing the contingency arrangements to ensure they are appropriate to the changing nature of the gas market.

The Transport Emergency Management Coordination Group aims to coordinate responses to critical transport infrastructure failures. This will support the transport sector to make rapid damage assessments, identify critical interdependencies, and set regional transport infrastructure recovery priorities.

Most of the territorial authorities surveyed as part of the 2004 PwC infrastructure audit had water supply contingency plans but they varied in standard. These included emergency response plans, risk management, and lifeline documentation and scenario planning. MCDEM is engaging with a number of local government and other organisations to develop a water sector CDEM contingency plan. The main issues to be addressed are the supply of drinking water for vulnerable populations during an emergency, and the most rapid and effective way to restore damaged water systems.

Government agencies, regulatory bodies, and industry organisations are working with lifeline utilities to develop or review contingency plans for the supply of water, wastewater, transport, energy, and telecommunications services.

The Guide to the National CDEM Plan encourages the formation of regional and national CDEM clusters of lifeline utilities. The Guide encourages lifeline utilities to coordinate readiness activities, to develop disaster resilience summaries, hold joint exercises, and exchange emergency contact details with other lifeline utilities and CDEM agencies.

ENGINEERING LIFELINES GROUPS

Engineering lifelines groups are regionally based voluntary organisations of lifeline utilities (infrastructure providers) working together and with other agencies to identify interdependencies and vulnerabilities to emergencies.

There are currently engineering lifelines groups in most regions, which aim to reduce both the damage to infrastructure during an emergency and the time taken to restore services after a large event. This includes coordinating hazard investigations and collaborating on reduction and readiness activities.

Lifelines groups focus on hazard events which are likely to affect several infrastructure sectors at the same time. Until recently, engineering lifelines projects have dealt mainly with natural hazards, particularly earthquakes, but are now including other hazards such as influenza pandemic.

Lifelines groups do not have any statutory basis or obligations, but operate within the context that the member lifeline utilities are responsible under the CDEM Act for ensuring they can function to the fullest extent possible.

Response and recovery

Priorities for restoring infrastructure after an event are determined by individual lifeline utilities. However, the Guide to the National CDEM Plan does outline the priorities for restoring services to different groups or areas.

The Guide to the National CDEM Plan requires lifeline utility and CDEM Group coordination if:

- a lifeline utility service is disrupted in more than one territorial authority area or multiple lifeline utility services are disrupted by an event
- significant community impacts are expected because of a lifeline utility service disruption.

In other aspects, CDEM response to infrastructure failures would follow generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

FURTHER INFORMATION

GENERAL INFRASTRUCTURE INFORMATION AND REGULATION
MINISTRY OF ECONOMIC DEVELOPMENT
www.med.govt.nz/templates/StandardSummary____11.aspx
www.med.govt.nz/templates/StandardSummary____33.aspx
www.med.govt.nz/templates/StandardSummary____36.aspx
www.med.govt.nz/templates/StandardSummary____37.aspx
MINISTRY OF TRANSPORT
www.mot.govt.nz
ELECTRICITY COMMISSION
www.electrictycommission.govt.nz
COMMERCE COMMISSION
www.comcom.govt.nz
GAS INDUSTRY COMPANY
www.gasindustry.co.nz

2004 PRICEWATERHOUSECOOPERS INFRASTRUCTURE AUDIT
MINISTRY OF ECONOMIC DEVELOPMENT
www.med.govt.nz/templates/ContentTopicSummary____5541.aspx

INTERNATIONAL CARGO STATISTICS
STATISTICS NEW ZEALAND
www.stats.govt.nz/products-and-services/info-releases/oseas-cargo-info-releases.htm

BUILDING ACT 2004 (DAM SAFETY)
MINISTRY OF BUILDING AND HOUSING
www.dbh.govt.nz/bofficials-dam-safety

OPUHA DAM COLLAPSE
LEES, P AND THOMSON, D, 2003, 'EMERGENCY MANAGEMENT, OPUHA DAM COLLAPSE, WAITANGI DAY 1997'.
IPENZ Proceedings of Technical Groups 30/2.
www.ipenz.org.nz/nzsold/2003Symposium/LargeDams2003pages84-104.pdf#search=%22opuha%20dam%20collapse%22

LIFELINE UTILITIES AND CDEM, AND ENGINEERING LIFELINES GROUPS
MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT
www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Lifelines-Index?OpenDocument&menuexpand=forthecdemsector

HAZARDOUS SUBSTANCE INCIDENTS

New Zealand imports, uses, stores, and transports hazardous substances to a similar extent to most other developed countries. There is less primary manufacturing of hazardous substances in New Zealand compared to other countries, but New Zealand does have a significant petrochemicals industry, based on oil and gas resources in the Taranaki region, and a large-scale oil refinery at Marsden Point. Storage and usage quantities are generally smaller than other countries because of the low population.

Hazardous substances in New Zealand

Many different hazardous substances are used, stored, transported and, to some extent, manufactured in New Zealand.

Petrochemicals, including petrol, diesel, aviation fuel, and natural gas-based products and solvents are manufactured, transported, used, and stored. Pesticides are widely stored and used, although not generally manufactured in New Zealand. Pesticide use is highest in timber treatment, antifouling treatments for boats, agriculture, and horticulture.

Explosives are both imported and manufactured in New Zealand and are extensively stored and used in mining, quarrying, tunnelling, demolition and military operations.

Industrial chemicals are widely used, typically in urban industry and within specific zones. For example, resins are used in manufacturing plastics and other polymers, inks are used in printing, and specialty chemicals are used in research and diagnostic laboratories. Paints are used in the industrial, motor vehicle, and domestic sectors. Domestic products, such as cleaners and detergents, that incorporate hazardous substances are widely used.

The use of hazardous substances has many benefits, but New Zealand experiences day-to-day adverse effects of hazardous-substance use on people, property, and the natural environment. There is no readily available data that gives the precise extent of these impacts, but there is sufficient information to show that death and illness from acute and chronic exposure to hazardous substances affect many thousands of people each year.

Most adverse health effects arise from exposure to hazardous substances in the workplace. Other common incidents result from LPG use, and children swallowing household products. There are about 8000 chemically contaminated sites in New Zealand, and about 800 of these are timber industry sites.

Hazardous substance incidents

A hazardous substance incident is an unplanned or uncontrolled release of hazardous substances such as fuels, flammable substances, explosives, toxic chemicals, pesticides, radioactive material, or micro-organisms, including contaminated waste products. The New Zealand Fire Service attended more than 1750 hazardous substances incidents in 2003/04.

Hazardous substance incidents can be caused by a natural hazard affecting a production and storage site, transport vehicle or end-user site, a transportation accident, lack of care during use, criminal activity, or inadequate storage or disposal. Hazardous substance releases can cause large explosions or toxic gas plumes and can, therefore, affect large areas. The consequences of hazardous substance incidents can include death, illness (potentially long-term), evacuations, environmental contamination and economic losses for businesses involved from damage and site clean-up. The effects of a hazardous substance release can be worsened if two hazardous substances stored near each other trigger a chemical reaction.

However, large-scale hazardous substance incidents that would require mass evacuations and coordinated CDEM involvement are uncommon. The most likely cause of an incident would be the release of a hazardous substance during transit, either at a port or from a road transport accident in an urban area, or a large fire ignited by, or near, chemicals.

1973 PARNELL DEFOLIANT LEAK

One of New Zealand's largest hazardous substance incidents occurred in February 1973 when drums which were leaking cotton defoliant were unloaded from the ship *Good Navigator* in Auckland.

The boat had encountered a storm en route from San Francisco to Auckland, which had damaged some of the drums and washed off the toxic warning labels. Twenty-five drums were unloaded from the boat when it berthed on 26 February and taken to two storage facilities in Parnell. By the following morning fumes were affecting people in the vicinity, and the leaking drums were discovered. A state of emergency was declared, which lasted 6 days. Parts of Parnell were evacuated and several hundred people required medical attention.

A commission of inquiry found that several factors had contributed to the incident, in particular the actions of the ship's captain and the removal of drums from the port contrary to New Zealand Customs Service and Ministry of Health instructions. However, the response to the incident was effective. This hazardous substance incident led to the establishment of emergency services coordinating committees to assist in the coordinated response to emergencies.

The New Zealand fire service removing drums after the 1973 Parnell defoliant leak. 4000 families were evacuated from the area during a six-day Civil Defence emergency. *New Zealand Herald*.

Managing hazardous substances

The response to hazardous substance incidents is managed by the New Zealand Fire Service. Hazardous substance technical liaison committees provide expertise in managing hazardous substance emergencies. The Environmental Risk Management Agency (ERMA) is the principle agency implementing the Hazardous Substances and New Organisms Act 1996 (HSNO Act).

Risk reduction and readiness

Most hazardous substances are regulated under the HSNO Act. The purpose of the Act is, among other things, to protect the environment and people by preventing or managing the adverse effects of hazardous substances. All hazardous substances in New Zealand must be approved and used in accordance with risk management controls set by ERMA.

Other agencies manage specific substances, many of which are also regulated under the HSNO Act. The Ministry of Health approves medicines and regulates radioactive substances (under the Radiation Protection Act 1965), and the New Zealand Food Safety Authority registers agricultural compounds and veterinary medicines. The Department of Labour enforces provisions of the HSNO Act in the workplace.

Regional councils are responsible under the RMA for controlling the discharge of hazardous substances and territorial authorities are responsible for managing land use to prevent or mitigate the adverse effects of storing, using, transporting and disposing of hazardous substances.

Response and recovery

The New Zealand Fire Service is responsible for managing the response to a hazardous substance incident. Other agencies such as the Police and health organisations may also need to assist with response and recovery, particularly if many people are affected or evacuated, or if a large cleanup is necessary.

Any CDEM response to hazardous substance incidents follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

HAZARDOUS SUBSTANCES TECHNICAL LIAISON COMMITTEES

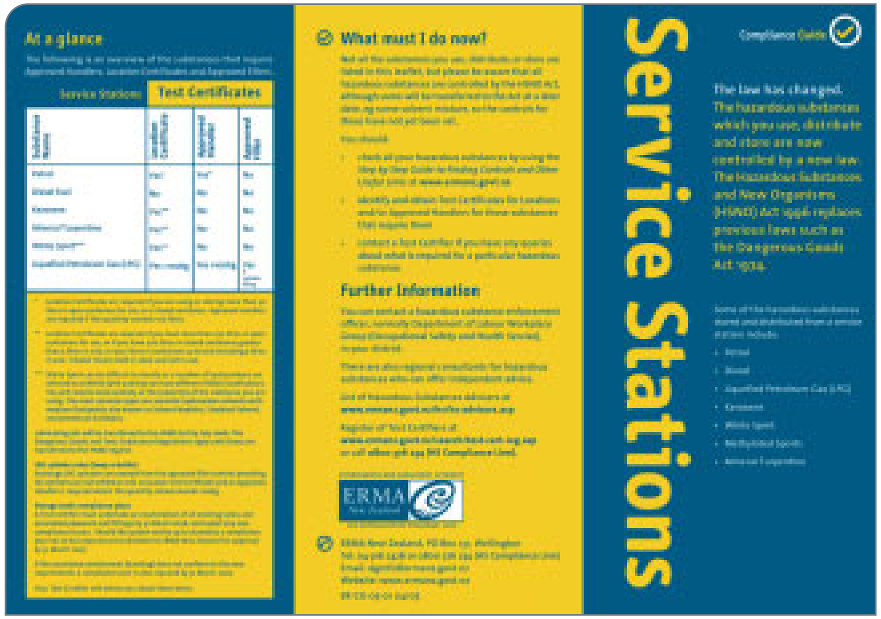
Hazardous substances technical liaison committees (HSTLCs) have been established in many parts of New Zealand. These voluntary groups are chaired by local New Zealand Fire Service representatives and include people from other emergency services, health organisations and CDEM Groups. HSTLCs provide technical information on a 24-hour basis for co ntrolling, neutralising and disposing of hazardous substances and decontaminating affected sites. HSTLCs also catalogue hazardous substance information and provide advice for hazardous substance emergency planning.

Unknown hazardous substances leaking from unlabelled, unsealed drums into a drain, Christchurch. *Environment Canterbury.*

FURTHER INFORMATION

GENERAL HAZARDOUS SUBSTANCES INFORMATION

ENVIRONMENTAL RISK MANAGEMENT AUTHORITY
www.ermanz.govt.nz/hs/index.html



Part of a Compliance Guide for Service Stations. Service stations are an essential element of the New Zealand economy and contribute significantly to the transport sector. In order to achieve this they store and handle significant quantities of flammable substances. Careful management of these is important to protect people and the environment. ERMA New Zealand has produced a series of compliance guides for a wide range of industry groups. *ERMA New Zealand.*

MAJOR TRANSPORT ACCIDENTS

Many of New Zealand's disasters during the 1800s and early 1900s were transport accidents. Many people drowned when ships, which were a common mode of transport at the time, sank in bad weather or because of navigation errors in poorly charted waters. Over the last 60 years, New Zealand's most serious disasters, in terms of deaths, have been transport accidents – the 1953 Tangiwai train derailment, the 1968 *Wahine* sinking, and the 1979 flight TE901 crash at Mt Erebus in Antarctica. Together these three accidents killed 459 people.

Major transport accidents often have high death and injury rates and are generally localised occurrences. Transport accidents killed 573 people in New Zealand in 2000.

Damage to property and infrastructure from transport accidents is usually confined to a much smaller area than damage from natural hazards. However, the economic impact of a major transport accident could have short-term consequences for tourism, and the loss of a large aircraft or ship has significant financial implications.

Transport accidents are a common cause of hazardous substance releases or spills, which are hazards themselves.

Land transport

New Zealand has 93 000km of road and about 3.1 million registered motor vehicles, of which 416 000 are heavy vehicles. The number of vehicles on the road and the amount of freight carried by road both continue to increase. Road crashes are frequent and kill about 400 people each year. Major crashes involving several vehicles, however, are uncommon and rarely affect many people. A bus colliding with a petrol tanker is considered a potentially possible event.

Few long-distance passenger rail services remain in New Zealand and rail accidents are uncommon. The probability of a major rail accident causing many deaths is low. An accident involving a full commuter train carrying up to 750 people in either Wellington or Auckland would requires significant emergency service and local authority response, and most likely require broader CDEM involvement.

Marine transport

New Zealand's often rocky coastline, and its windy and changeable weather, make marine navigation a challenge. There have been more than 2300 shipwrecks around New Zealand since 1790, killing hundreds of people. The worst single shipwreck was that of the *Orpheus* at the entrance to Manukau Harbour in 1863, when 189 naval officers and crew died.

Several factors contributed to these shipwrecks, including a poorly charted coastline, a lack of navigational aids, the difficulty of manoeuvring sailing ships, the wooden construction of many ships, a lack of lifeboats, and in some cases poorly trained captains.

Today's navigation aids, better boat construction, and safety regulations mean that marine transport accidents are much less common. However, New Zealand's weather and the possibility of human error may cause a large marine accident, such as the 1968 *Wahine* sinking in Wellington Harbour and the 1986 sinking of the *Mikhail Lermontov* in the Marlborough Sounds.

Passenger ferries and cruise ships can carry hundreds or even thousands of people, so the consequences of an accident involving such a ship could be large and likely require coordinated emergency service and CDEM involvement. The risk of a large container ship grounding and releasing fuel or hazardous cargo is significant on much of New Zealand's coastline, and this would also likely require coordinated emergency service and CDEM involvement.

1968 WAHINE SINKING

Although there have been worse shipping disasters in New Zealand, the sinking of the *Wahine* in 1968 is the most recent and well known.

The ferry *Wahine* set out for Wellington from Lyttelton Harbour on the evening of 9 April. The weather was calm, and although a storm was causing problems in the north of the North Island, it was considered too far away to be a problem for the sailing. However, during the night of 9 April the storm, which was expected to move southeast towards the Chatham Islands, changed course and headed south towards Wellington. The storm collided with a deep depression that had been moving north up the South Island directly over Wellington on the morning of 10 April, creating winds of up to 230km/h just as the *Wahine* was approaching the harbour entrance.

The ship struggled in the large swell; the radar was not operating and visibility was poor. It hit Barrett Reef at the entrance to the harbour, losing its starboard propeller and sustaining damage to the hull and the port engine. The ship started taking on water, and with no propulsion it drifted into the harbour, listing to starboard. Anchors were dropped and finally held just off Seatoun beach on the western side of the harbour entrance. Rescue efforts with tugs failed in the rough seas, and at 1.15 pm the order was given to abandon the ship.

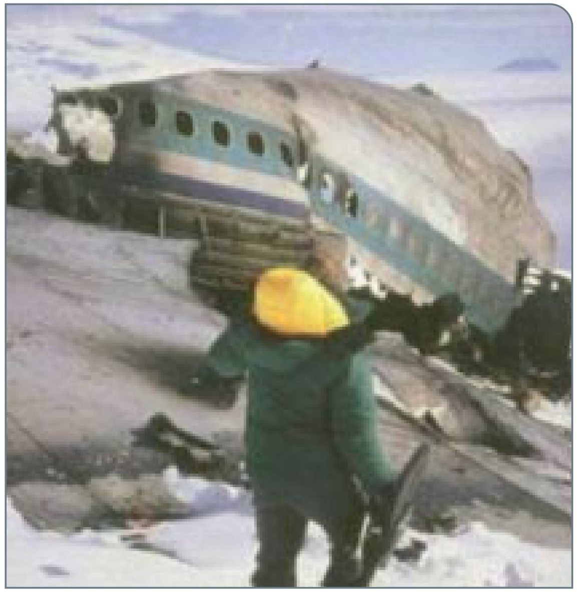
The first lifeboat launched capsized in the heavy seas, killing many people. Other lifeboats capsized as they approached the shore and people died from exposure or because they were driven against rocks. Some passengers had no choice but to jump into the water and were blown to the eastern side of the harbour entrance. The *Wahine* finally capsized at 2.30 pm. Fifty-one of the 734 passengers and crew died.

The weather was the main cause of the *Wahine* sinking, but a subsequent Court of Inquiry found that a number of errors and omissions were made both on shore and on the ferry.

The *Wahine* after capsizing in 12m of water at the entrance to Wellington Harbour.
The ship took 5 years to demolish and remove from the site.
New Zealand Maritime Museum.

Air transport

New Zealand has a high number of aircraft, particularly small privately owned planes, for its low population. This is the main reason for the high rate of small-aircraft crashes compared to other developed countries. However, aside from the 1979 Air New Zealand DC10 crash at Mt Erebus, Antarctica, which killed 257 people, there have been few major aircraft accidents in New Zealand.



The wreckage of Air New Zealand flight TE901 on Mt Erebus near McMurdo Sound in Antarctica. The sightseeing flight crashed into the active volcano in November 1979 in whiteout conditions. *Antarctica New Zealand.*

Thirteen people were killed when a National Airways Electra flew into Mt Ruapehu in 1948 and 15 people died the following year when a National Airways Lodestar crashed in the Tararua Range. These accidents were caused by a number of factors, but deficiencies in aircraft and ground navigation systems were major contributors. The crashes highlighted the need for better safety measures and industry regulation. The worst aircraft crash in New Zealand was the National Airways DC3 crash in the Kaimai Range in 1963, which killed 23 people.

There have been no large commercial aircraft crashes within New Zealand. However, aircraft crashes involving many deaths are not uncommon worldwide and an aircraft accident involving a large passenger plane is possible in New Zealand.

Most aircraft crashes result from a combination of factors. Human error, either during manufacture, maintenance, or flying, is often the underlying cause. However, weather conditions can also contribute, especially with New Zealand's mountainous terrain and often strong winds and turbulence.

A jet aircraft crash in an urban area is likely to cause several hundred deaths and injuries, structural and fire damage to buildings and infrastructure, local economic impacts, and require evacuations.

Managing transport systems

Many organisations are involved in managing transportation in New Zealand. Regulators include the Civil Aviation Authority, Maritime New Zealand, and Land Transport New Zealand. Airport and port authorities also play a role, as do Transit New Zealand (for state highways) and territorial authorities (for local roads).

Emergency services provide the initial response to all major accidents.

Risk reduction and readiness

Air, sea and rail transport systems adopt a complete approach to risk reduction which requires operators to use safety or quality management systems that cover the machines (boat, plane or train), the guidance systems (radar, lighthouses, signals, radio beacons) and the human input (pilots, drivers, controllers).

The road transport system does not have the benefit of such well-controlled management systems, and risk management is less rigid. Registrations and warrants of fitness set minimum operational standards for vehicles, and driver testing and licensing sets minimum operator standards. Standards relating to the safety of the roading infrastructure include warning and regulatory signs, road markings, and controls.

Most agencies with transport safety functions have developed risk assessment plans that identify vulnerable areas of operation and have developed response plans for various scenarios.

Response and recovery

The effects of major transport accidents place extreme demands on emergency services in the initial response stage of dealing with victims, and controlling secondary hazards such as fire or pollution. The requirements for preserving evidence at the scene for accident investigators can mean that roads and rail could be out of use for many days, causing disruption. The Transport Accident Investigation Commission (TAIC) is responsible for the independent investigation of significant aviation, rail and marine accidents and incidents. Police also carry out accident investigations in order to support criminal prosecutions.

Most transport accidents are localised events and can be managed at a local level. Broader CDEM involvement may be required during a major transport accident to provide support in an Emergency Operations Centre, and to assist in coordinating resources and welfare support to any other people affected.

FURTHER INFORMATION

GENERAL TRANSPORT INFORMATION

MINISTRY OF TRANSPORT
www.mot.govt.nz

GENERAL LAND TRANSPORT AND ACCIDENT INFORMATION

LAND TRANSPORT NEW ZEALAND
www.ltsa.govt.nz

GENERAL MARINE TRANSPORT AND ACCIDENT INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/SeaAndAirTransport/Shipwrecks/en
Maritime New Zealand
www.msa.govt.nz

WAHINE DISASTER

WELLINGTON CITY LIBRARIES
www.wcl.govt.nz/wellington/wahine.html
New Zealand Maritime Museum
www.nzmaritime.co.nz/wahine.htm

GENERAL AIR TRANSPORT AND ACCIDENT INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/SeaAndAirTransport/AirCrashes/en
CIVIL AVIATION AUTHORITY
www.caa.govt.nz

TERRORISM

A terrorist act is defined as 'an act that has the purpose of advancing an ideological, political or religious cause, with the intention of inducing terror in a civilian population or of compelling or forcing a government or international organisation to do or abstain from doing any act.'

The consequences of terrorism can include:

- death or serious injury
- damage or destruction of property of great value or importance
- interference or disruption to infrastructure with the intention of causing large-scale impacts on the functioning of society
- devastation of the national economy through the introduction or release of a disease-bearing organism or significant contamination of the environment.

There has been an increased worldwide focus on terrorism and preventing terrorist incidents since the attacks on the United States in September 2001.

The *Rainbow Warrior* in Auckland Harbour in 1985. The sinking of the ship was the first and only act of international state-sponsored terrorism to be committed in New Zealand. *Greenpeace*.

Terrorism in New Zealand

The most significant act of terrorism to occur in New Zealand in recent times was the bombing of the *Rainbow Warrior*, the flagship of international environmental organisation Greenpeace, ordered by the French Secret Service. The ship was visiting Auckland before leading a fleet of vessels to Mururoa Atoll in French Polynesia to protest against French nuclear testing in the South Pacific. Just before midnight on 10 July 1985, two explosions rocked the harbour, sinking the *Rainbow Warrior*. One of the twelve crew members on board at the time was killed.

The letter to the Prime Minister in 2005, claiming release of foot-and-mouth disease on Waiheke Island, while later proved a hoax, and the deliberate introduction of rabbit calicivirus by farmers to control rabbits, are examples of the risks of bioterrorism to primary industries. Illegal introductions of unwanted organisms may have far-reaching consequences. For example, the introduction of varroa mite, affecting both the honey industry and industries relying on pollination, may have been through a smuggled, infected honey bee.

Managing terrorism

Managing the risks associated with terrorism involves dealing with a problem of low probability but potentially high consequences, and as such involves difficult judgments about possible threats.

The government framework for managing terrorism is well established and uses the Domestic and External Security Coordination (DESC) system. Within this system, the Cabinet Committee for Domestic and External Security Coordination (DESC) is the central decision-making body on terrorism.

The Cabinet DESC Committee is chaired by the Prime Minister, and includes those Ministers responsible for departments that play an essential role in managing terrorist risks and in responding to a particular terrorist event. Cabinet involvement is necessary to ensure that responses meet New Zealand's national interests, quickly restore community functioning, and minimise adverse outcomes: death and injury, damage to property and the environment, and social and economic disruption.

The Officials' Committee for Domestic and External Security Coordination (ODESC) advises the Cabinet DES Committee on matters relating to terrorism. Its members are the chief executives of departments and agencies that have a role to play in counter-terrorism and it is chaired by the Chief Executive of the Department of Prime Minister and Cabinet. ODESC is primarily concerned with the strategic aspects of counter-terrorism including incidents requiring whole-of-government management.

Legislation is an important part of countering terrorism, providing the necessary powers to enable intelligence, security, law enforcement, border control, public health, fire, and defence agencies to prevent, suppress, and respond to terrorism. It establishes serious offences and penalties for planning, organising, facilitating, financing, and carrying out terrorist acts. The legislation acts as a deterrent and enables prosecution of those who are involved in such activities. Legislation also implements New Zealand's obligations under international conventions and agreements.

Risk reduction

Reducing the threat of terrorism involves taking whatever steps are possible to reduce the likelihood of terrorists selecting a target in New Zealand or attacking New Zealanders or their interests overseas.

The Interagency Combined Threat Assessment Group assesses terrorist threats to New Zealand. Risk reduction measures include collecting, analysing, and disseminating intelligence on terrorist intentions and capabilities; having robust pre-boarding and border security management that prevents known or suspected terrorists from travelling to or entering New Zealand; and identifying and protecting critical infrastructure and assets.

Readiness

Readiness for a terrorist attack includes whole-of-government planning to reduce vulnerability of potential victims and targets, training, and providing contingency resources for critical infrastructure.

Response

Response includes providing the skills, capabilities and logistics needed to act quickly to prevent further damage or cascading effects, and dealing with the immediate consequences.

These resources include early warning and alert systems, Coordinated Incident Management Systems, prompt messages to the public and other response agencies, and in the case of events overseas, having international arrangements to ensure the security of New Zealanders and New Zealand interests.

The national crisis management arrangements for a terrorist event are collectively known as the Terrorist Emergency Group (TEG). The TEG comprises:

- the Cabinet DESC Committee
- ODESC
- an interdepartmental watch group responsible for analysing the terrorist situation and advising on response and recovery strategies
- an interdepartmental media coordination centre responsible for advising on the media and public information aspects of a terrorist event
- a joint intelligence group responsible for providing operational situation reports, intelligence and assessments
- support groups from departments and agencies.

Recovery

Recovery after a terrorist attack aims to return communities to everyday functioning quickly and efficiently. This involves having robust financial, legal and social systems in place, and having support systems for those affected by overseas attacks where New Zealand interests or citizens are involved. This may include assisting survivors and their families, rebuilding destroyed or damaged property, rebuilding or replacing critical infrastructure, re-establishing New Zealand's reputation, and rapidly regenerating economic and social functions.

FURTHER INFORMATION

GENERAL TERRORISM INFORMATION

NEW ZEALAND POLICE
www.police.govt.nz/service/counterterrorism
MINISTRY OF FOREIGN AFFAIRS AND TRADE
www.mfat.govt.nz/foreign/spd/terrorism/campaignterrorism.html

FOOD SAFETY

The food and beverage sector is by far the largest contributor to the New Zealand economy. It is growing at approximately the same rate as the overall economy, averaging a nominal growth of 5.3 per cent a year over the past decade. The sector:

- generates NZ$25.3 billion net of exports (Coriolis Report, 2005)
- employs one in five New Zealanders across the entire population, and 40 per cent of the total workforce
- generates half of New Zealand's merchandise export earnings.

As the most significant contributor to the New Zealand economy, the food and beverage sector is critical to our country's economic performance. Any significant change in its performance will materially and directly affect the national economy.

New Zealand's food hazardscape

Potential food hazards may arise naturally, accidentally, or deliberately. They may be chemical, biological, physical, or radiological in nature.

Common natural or accidental food chemical hazards include, for example, cadmium, lead, and mercury. Chemical hazards include compounds such as residues of pesticides, veterinary medicines, a range of environmental contaminants such as dioxins and polycyclic aromatic hydrocarbons, or toxic breakdown products such as histamine in scombroid species of fish.

An increasing number of New Zealanders identify themselves as allergic to specific food groups. The Australia New Zealand Food Standards Code[1] has identified the eight most common food allergens, which are responsible for up to 90 per cent of all allergic reactions. These are the proteins in cows' milk, eggs, peanuts, wheat, soy, fish, shellfish, and tree nuts. Allergic reactions vary, ranging from a mild skin rash to life-threatening anaphylactic shock.

Biological food hazards are an equally diverse group and include many infectious pathogens. In 2006 enteric pathogens formed the overwhelming majority of all human disease notifications in New Zealand. Of the 15 873 cases of enteric illness, campylobacteriosis contributed almost 70 per cent of notifications that identified food as a possible significant source.

E coli (Escherichia coli) is a bacteria and one of the leading causes of food poisoning. However, not all strains are harmful – without a type of E coli found in intestines, humans wouldn't be able to absorb vitamins.

Other food-borne biological hazards include *Salmonella*, *Shigella*, *Yersiniosis*, *Escherichia coli (E coli)*, *Listeria monocytogenes*, *Clostridium perfringens*, *Staphylococci*, rotavirus, norovirus, and *Bacillus cereus*, which in 2006 collectively caused over 1000 notified infections.

Mycotoxins are naturally occurring metabolites produced by certain species of moulds. Moulds may occur on a crop when growing or during storage or processing.

Parasites can also be found in this group although they are rare. Examples are, *Cysticercus bovis* in beef meat (producing the tapeworm *Taenia saginata* in humans), *Anisarkis simplex* in some species of fish and *Trichinella spiralis* in pork.

Marine biotoxins may be present in molluscan shellfish after they have fed on toxic algal blooms. The most serious biotoxins found in New Zealand are those that cause paralytic shellfish poisoning in humans.

Physical food hazards include, foreign body contamination such as glass, metal, wood or plastic which results in a significant number of food product recalls. Physical hazards inherent in the food such as bone, may also cause problems.

Avoiding eating food that has been exposed to nuclear irradiation is a key means of limiting human exposure following a nuclear event. Although New Zealand has no nuclear installations, a nuclear accident anywhere is a nuclear accident everywhere. Radiation as a result of the Chernobyl disaster which occurred over 20 years ago is still excluding a range of foods across Europe from the food chain.

In addition to these naturally occurring and accidental hazards, food has been identified as a vehicle for terrorist acts. Deliberate contamination of food by chemical, biological, physical, or radiological agents can occur at any vulnerable point along the food chain, from farm to table, depending on the food and the agent.

Although few incidents or threats of deliberate contamination of the food supply on a massive scale have been documented, food is regarded as a vulnerable target.

Factors that increase the vulnerability of food to be used effectively as a terrorist vehicle include:

- large batch size
- short shelf life
- production systems that facilitate the uniform mixing of a contaminant into food
- ease of accessibility to product at a critical point.

[1]The Food Standards Code is a set of food labelling and composition standards for both New Zealand and Australia. The Code was adopted in New Zealand in February 2001 and took full effect on 20 December 2002.

Impacts

New Zealand exports over 80 per cent of the food it produces. It also imports an increasing variety of foods from a widening range of countries. Unmanaged food safety hazards in this country therefore pose risks not only to New Zealanders but to customers throughout the world. And in the same way, unmanaged hazards arising offshore may have an impact on New Zealand.

A recent example of a relatively small impact arising from an imported hazard was the Eden Park gastroenteritis outbreak. In June 2006, 387 rugby supporters succumbed to norovirus infection after eating uncooked Korean oysters, likely to have been grown in sewage-contaminated waters[2].

Contamination of food products can have significant health, economic, trade, and political consequences. In 1985, for example, the unintentional contamination of milk in the United States resulted in 17 deaths and 16 000 confirmed cases in six states. Health experts estimated that 200 000 individuals were sickened in this event as a result of bacterial contamination of milk from a single, small, dairy plant in midwest United States[3].

The current campylobacteriosis epidemic is costing New Zealand about $78 million a year. This estimate includes only direct costs and so is conservative. It does not include wider indirect economic costs and possible harm to the export and tourism industries[4].

New Zealand is a significant participant in global trade in a limited number of food items that it is exceptionally good at producing. Total production is small in world terms for most food items (sheep meat being the exception). However, a high percentage of New Zealand's product is exported, due to volume of production and the small domestic market.

Relatively small food incidents in New Zealand, or identified by any country as relating to New Zealand food, are quickly picked up by overseas governments and consumers, and may quickly escalate into costly sanctions.

[2]An outbreak of norovirus gastroenteritis associated with the consumption of imported Korean oysters. June 2006. Outbreak report AK 2006124

[3]Agenda item: VI.F.2 2006/sOM1?CTTF/012 APEC Counter-terrorism task force meeting, Hanoi 27 Feb 2005

[4]Proceedings of the Food Safety, Animal Welfare and Biosecurity Branch of NZVA, 2007. 'The Compelling case for urgent action to control New Zealand's Foodborne Campylobacterioisis epidemic.' M Baker, N Watson

Generally, natural or accidental food contamination incidents result in few deaths but many cases of illness. Intentional contamination events have the potential to result in many deaths.

Managing food safety

Risk reduction and readiness

The New Zealand Food Safety Authority (NZFSA) takes a risk-based approach to food safety that allows it to identify, evaluate, and manage risks in food.

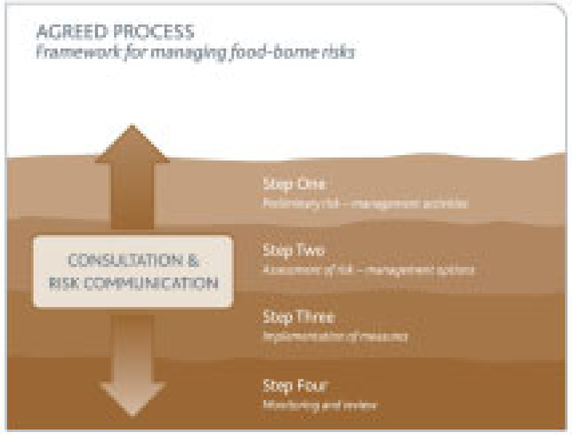
NZFSAs risk-management framework ensures a regulatory response that is appropriate to the level of risk and provides a consistent and transparent way of ensuring safety and suitability of food sold domestically and exported.

It sets out a process that takes the results of risk assessments and identifies appropriate options to manage these risks. This framework is underpinned by a four-step procedure, which involves:

- identifying a specific food safety problem and evaluating the risks presented
- assessing the risk and the management options available and deciding on the appropriate level of consumer protection to be provided
- implementing the risk-management decision
- monitoring and reviewing – analysing the data at appropriate points from farm to fork.

An integral part of this process is communicating with stakeholders.

NZFSA risk managers rely on risk assessments to make decisions on food controls. Having identified which hazards are risks, an assessment allows NZFSA to prioritise its work in this area so that it can tackle those risks of most concern first.



NZFSA is currently upgrading the systems relating to managing risks in domestic and imported foods, and associated legislation, to synchronise with this approach.

The food regulatory system

The Domestic Food Review initiated in 2003 is aimed at better managing the food regulatory system to ensure it can address problems and gaps, and deal adequately with the significant growth expected over the next 20 years.

A key aim is to make food operators responsible for providing safe and suitable food. There are interfaces with the production sector, tourism, environment, imports and exports. People and organisations at every step in the food chain have a part to play to ensure the safety of food. But in a country like New Zealand, where the food sector is so important, it is crucial that consumers have confidence in the food they buy at the time of purchase.

As a result of the review the current Food Act 1981 and Food Hygiene Regulations 1974 are being redrafted with a view to introducing a new Food Bill.

Other legislation managing risks to food include the Animal Products Act 1999, the Wine Act 2003 and the Agricultural Chemicals and Veterinary Medicines Act 1997.

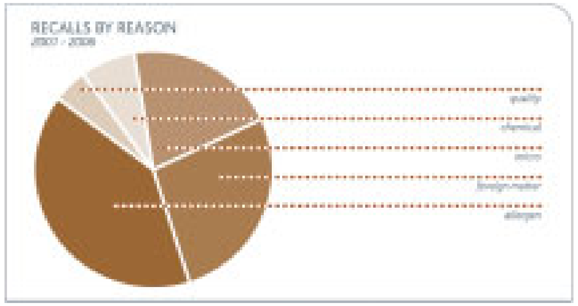
A range of surveillance programmes support reduction and readiness activities. The Ministry of Health carries out surveillance activities and reports on notifiable and other diseases. NZFSA completes a number of surveys targeting a range of foods in the National Chemical Contaminant Programme and the National Chemical Residue Programme. NZFSA also collates microbiological information on foods in a national microbiological database.

In addition to these programmes, New Zealand shares information on food safety incidents with Australia under the National Food Incident Response Protocol, and with the World Health Organisation as part of the INFOSAN network. It completes daily environmental scanning, usually via food-focused web-based list serves such as FSNet.

Response

Day-to-day frontline investigations and management of domestic food-safety issues or breaches are carried out by public health unit staff contracted by NZFSA. Overview of food safety incidents relating to exported food is the responsibility of NZFSA, sometimes working alongside independent third-party verifiers.

All incidents must be notified to NZFSA, and many procedures outline possible emergency risk-mitigation activities. The most common of these is a voluntary recall of the affected product by the manufacturer or distributor.



NZFSA has a dedicated Event and Emergency Response Coordination Unit to support incident management, which is carried out under a risk-based framework. As incidents scale up in size and complexity, the operational team evolves to work in a modified Coordinated Incident Management System type structure, and strategic command rises to the level of appropriate delegation. Likely joint agencies in food incidents are the Ministry of Foreign Affairs and Trade, the Ministry of Health, and the Ministry of Agriculture and Forestry.

Recovery

During management of food incidents, the incident action plan will identify risk-mitigation measures. Once the issue at hand is brought under control, the risk is fed into the business as usual workstream so that standards that will describe how the risk should be managed can be developed or amended.

FURTHER INFORMATION

GENERAL FOOD SAFETY INFORMATION

CORIOLIS REPORT TO THE FOOD AND BEVERAGE TASKFORCE, SEPTEMBER 2005: MAPPING THE STRUCTURE OF THE NEW ZEALAND FOOD INDUSTRY.

FOOD HAZARDS

www.nzfsa.govt.nz

NOTIFIABLE AND OTHER DISEASES IN NEW ZEALAND ANNUAL REPORTS – prepared as part of a Ministry of Health contract for scientific services by Population and Environmental Health Group Institute of Environmental Science and Research Limited.

FACTORS THAT INFLUENCE THE HAZARDSCAPE

CLIMATE VARIABILITY AND CLIMATE CHANGE

New Zealand's climate varies from year to year but is strongly influenced by natural climate cycles operating on scales of years to decades.

Climate change is a phenomenon that is driven by the increasing concentration of greenhouse gases in the atmosphere and how the global climate system responds to these changing concentrations. The evidence for climate change comes from measured increases in the concentration of carbon dioxide and other greenhouse gases in the atmosphere, measured sea-level rise, and measured increases in global-average temperatures. This is driving changes in atmospheric circulation and rainfall patterns. Regional climate change impacts are now also evident in increasing stresses on water supply and agriculture, changed natural ecosystems, reduced seasonal snow cover and ongoing glacier shrinkage. Natural climate variations may offset or enhance some of the predicted impacts of climate change for New Zealand in the short-term.

Climate variability

Some of the shortest-term climate variability arises simply because of the natural variability in the weather and its random fluctuations. However, other changes are associated with large-scale climate patterns over the Southern Hemisphere or the Pacific Ocean. There are a number of natural processes that operate over time scales of seasons to decades, particularly the El Niño Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO).

The ENSO is a tropical, Pacific-wide oscillation that affects air pressure, wind, sea-surface temperature, and rainfall. In the El Niño phase, New Zealand usually experiences stronger than normal southwesterly airflows. This generally results in lower seasonal temperatures nationally with drier conditions in northern and eastern areas. Stronger than normal northeasterly flows are experienced during the opposite La Niña phase.

The IPO is a recently identified cause of natural variability in climate with cycles that last over several decades. Three phases of the IPO during the twentieth century have been identified. In a positive phase (for example, 1978–1998) sea-surface temperatures around New Zealand tend to be lower and westerly or southwesterly winds stronger. Temperatures throughout New Zealand are lower. In the negative phase (for example, 1947–1977), airflows from the east and north-east increase, as do temperatures in all regions. More rainfall occurs in the north of the North Island and it is drier in the south-east of the South Island. A new negative phase of the IPO started in 1998.

Climate change effects

Global average temperatures are projected to increase by between 1.1 and 6.4°C by 2100 if greenhouse gas emissions are not reduced. The increase is expected to be less in New Zealand than the global average because of the delayed warming of the oceans surrounding New Zealand.

Temperature projections for New Zealand are for an increase of 0.2-1.3°C by the 2030s, and 0.5-3.5°C by the 2080s. There are likely to be slightly greater increases in winter temperatures, meaning that the difference between winter and summer temperatures is likely to decrease. The difference in temperature between the north and south is expected to increase.

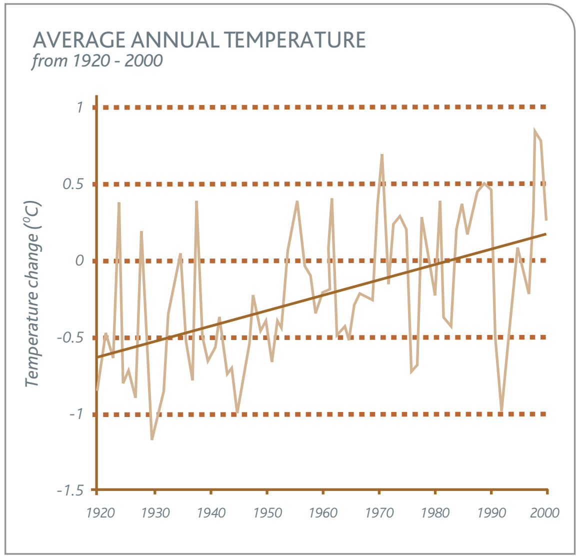
Rainfall projections for New Zealand for the same periods are from less than 19 per cent of what it is now to more than 15 per cent (-19 to +15 per cent) by the 2030s, and from less than 32 per cent of what it is now to more than 40 per cent (-32 to + 40 per cent) by the 2080s. Generally, a trend to drier conditions in northern and eastern regions and wetter conditions in the west and south is expected, meaning that the difference in rainfall between western and eastern regions is likely to increase.

These and other climate patterns (for example, the Interdecadal Pacific Oscillation (IPO) and the El Niño-Southern Oscillation (ENSO) cycles) are likely to lead to more floods and more droughts in some parts of New Zealand, with significant consequences for land-based industries.

Climate change projections for New Zealand also include fewer frosts, increased frequency of heavy rain, and an increase in average sea level.

Climate change is not expected to create new hazards, but it may change the frequency and intensity of existing hazards, as well as introducing long-term shifts in climate patterns.

In any year the annual New Zealand-wide temperature can deviate from the long-term average by up to +/-1°C. Despite these fluctuations, there has been a long-term increase of about 0.6 °C between 1920 and 2000. Annual rainfall, too, can deviate from its long-term average, by about +/-20 per cent. Sea levels have risen by an average of 16cm between 1900 and 2000, with similar +/-20 per cent year-to-year variations.



Average annual temperatures are shown by the light brown line and the long-term trend by the dark brown line (represented as the change in °C from the 1961 to 1990 average). *National Institute of Water and Atmospheric Research.*

Climate change and hazards

Temperature, rainfall and wind are the key influences on climate related hazards. The general indications are that New Zealand could experience more climatic extremes in the future. This could include:

- more intense rainfall, and associated flooding, in most parts of New Zealand
- more frequent and more intense droughts in eastern areas
- more damaging windstorms
- more heat waves
- increased wildfire risk in drier eastern areas.

Rainfall is the key climatic influence on river flow. River flows are likely to increase, on average, in western areas and decrease in eastern areas of New Zealand. More intense rainfall could increase flooding. It is estimated that by the 2080s there could be up to four times as many heavy-rainfall events. Less water for irrigation in northern and eastern areas, and increasing demand, is likely to lead to extended periods of drought. Increased rainfall in western areas and more intense rainfall throughout New Zealand, could lead to higher rates of soil erosion and slope instability.

Sea-level rise, storm frequency and intensity, wave patterns, and sediment supply are key climate influences for coastal areas. Effects of sea-level rise and other changes will vary regionally. Coastal erosion is likely to accelerate where it is already occurring, and erosion may become a problem over time in coastal areas that are presently either stable or advancing.

Temperature and rainfall are key climate influences for biosecurity. Even small increases in temperature could significantly increase the incidence of pest outbreaks in New Zealand, particularly in the North Island and the north of the South Island. Existing and new plant and animal pests could become established more widely.

The main features of New Zealand climate projections are qualitatively summarised in the following table using the best current scientific estimate of the direction and magnitude of change – the level of confidence in the projections is indicated in brackets (VH = very high, H = high, M = medium, L = low).

NEW ZEALAND CLIMATE CHANGE PROJECTIONS FOR 2030s AND 2080s - IPCC 3rd Assessment Report

CLIMATE VARIABLE	DIRECTION OF CHANGE	SIZE OF CHANGE
Average temperature	Increase (VH)	0.5–0.7°C by 2030s, 1.5–2.0°C by 2080s (M) (mid-range projection)
Daily temperature extremes (frosts, hot days)	Fewer cold temperatures and frosts (VH), more high temperature episodes (VH)	
Average rainfall	Varies around New Zealand. By 2080s Taranaki, Manawatu–Wanganui, West Coast, Otago and Southland show increases, and Hawke's Bay, Gisborne, eastern Canterbury, and eastern Marlborough show decreases (M)	Substantial variation around New Zealand
Extreme rainfall	Heavier or more frequent extreme rainfalls, especially where average rainfall increase predicted (M)	Ranges from no change through to halving of heavy rainfall return period by 2030s, and no change through to fourfold reduction in return period by 2080s (L)
Snow	Snow cover decrease, snowline rise, shortened duration of seasonal snow lying (all M)	
Wind (average)	Increase in the average westerly wind flow across New Zealand (M)	Ranges from slight increase up to doubling of average annual westerly flow by 2080s (L)
Strong winds	Increase in severe wind risk possible (L)	Ranges from little change up to double the frequency of winds above 30m/s by 2080s (L)
Storms	More storminess possible, but little information available for New Zealand (L)	
Sea level	Increase (VH) It is important to note that many parts of the New Zealand coast will experience tectonic uplift at a rate equivalent to, or even faster than, sea level rise	30–50cm rise (New Zealand average) between 1990 and 2100 (H), accelerating the historic trend (mid-range projection) Strong regional variability can be expected because of variable rates of tectonic uplift
Waves	Increased frequency of heavy swells in regions exposed to prevailing westerlies (M)	

Adapting to climate change

There is a general acceptance in New Zealand and internationally that climate change is happening, that the changes are due to human activity, and that many areas of life will be affected. New Zealand's response to climate change is in its early stages, but is gaining momentum particularly at central government level. The two main approaches to the management of climate change impacts are mitigation of climate change impacts by reducing greenhouse gas emissions (for example, through afforestation and decreasing transport emissions), and adaptation by preparing for the effects of climate change.

Avoiding or minimising risks from climate hazards in New Zealand is the responsibility of local government under the RMA. Planning to reduce the adverse effects of natural hazards is particularly important at local government level because the hazards usually have localised effects and may require locally distinct management and adaptation methods.

Ongoing research will lead to a greater understanding of the possible impact of climate change but there are still large uncertainties. These uncertainties have made it difficult to react to climate change at a national level. However, policy makers at both national and local level, and decision makers within industry groups, now recognise the importance of adaptation. This recognition is becoming increasingly reflected in policy and strategic planning documents where issues such as dune restoration, including climate change effects in storm water system design, developing crops for biofuels, and the role of irrigation are being addressed.

The United Nations Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report says that without further adaptation, the impacts of climate change for New Zealand are likely to be substantial. Based on the vulnerabilities for New Zealand identified by the IPCC, the Ministry for the Environment has identified four critical decision areas on which stakeholder efforts should focus. The four areas have considerable adaptive capacity and a significant emergency management context. They are:

- water and coastal emergency and hazard management, for example, Civil Defence Emergency Management Group plans and Regional Council plans, flood and storm surge preparedness, and coastal management
- infrastructure investment and maintenance, for example, asset management, design and resilience
- primary industry, for example, sustainable agriculture, drought, flood and snow preparedness, and land use changes
- biodiversity and biosecurity.

A sound risk-assessment process is fundamental to ensuring that climate change is appropriately planned for. The purpose of risk assessment for climate change is to identify where climate change may have a material effect and to evaluate the significance of the impact. This also allows climate change risks and responses to be compared equally with other risks and their associated costs and required resources.

FURTHER INFORMATION

GENERAL CLIMATE CHANGE INFORMATION

MINISTRY FOR THE ENVIRONMENT
www.climatechange.govt.nz
www.climatechange.govt.nz/resources/local-govt/guidance.html
www.ipcc.ch/

CLIMATE CHANGE AND DROUGHT

NIWA, 2005, CHANGES IN DROUGHT RISK WITH CLIMATE CHANGE.

CLIMATE CHANGE AND AGRICULTURE

NIWA, 2005, CLIMATE CHANGE – LIKELY IMPACTS ON NEW ZEALAND AGRICULTURE.

HUMAN MODIFICATION OF THE NATURAL ENVIRONMENT

Human modification of the natural environment can both worsen and mitigate natural processes that create hazards. Much of the natural landscape has been modified since people first settled in New Zealand several hundred years ago. This has generally led to an increase in hazards, particularly floods, landslides, and coastal hazards. Restoration of catchments, wetlands, dunes, and other natural systems is now recognised as an integral part of hazard management.

Vegetation

Native forest covered around 85 per cent of New Zealand's land area before people arrived. Much of this forest was cleared by Māori for hunting, and later by Europeans for farming. Today native forest covers around 23 per cent of New Zealand, with exotic forest making up another 6.5 per cent. Pasture is now the dominant land cover, making up 52 per cent of the North Island and 29 per cent of the South Island.

Vegetation helps to stabilise slopes by intercepting rainfall and binding the soil. Removal of much of New Zealand's native vegetation has left many areas, particularly in the North Island hill country, exposed to landslides and soil erosion. Soil erosion decreases the productivity of land. Pasture takes about 20 years to recover to within 70–80 per cent of its pre-erosion level, and growth is generally less productive because the soil is thinner and holds fewer nutrients. Soil erosion also contributes large amounts of sediment to rivers and floodplains, which reduces the flood-carrying capacity of rivers.

The contrasting effects of different land uses on erosion-prone hill country in the Mangawhero Valley, Manawatu. Many shallow landslides occurred on grass-covered slopes during the February 2004 storm, but there were few landslides in areas of mature pine forest. *Graham Hancox*.

Awareness of soil erosion on New Zealand's hill country increased after storms in the 1930s and 1940s caused widespread soil erosion on recently developed pastoral hill country. Concerns over the increased flood risk led to the Soil Conservation and Rivers Control Act 1941. The Act brought together soil conservation, river control, and land drainage matters under unified control at both national and local levels. Soil conservation initiatives included planting trees, erosion control and retiring land from pasture.

The removal of farm subsidies has led to land reverting back to scrub and native bush in some areas. In other areas, such as the hill country around Gisborne, exotic forest has been planted to reduce soil erosion and runoff into rivers. Progress has been made, but the February 2004 storm again illustrated how vulnerable pastoral hill country is to heavy rain.

Wetlands

Wetlands are areas that are permanently or temporarily wet and include streams, lakes, lagoons, estuaries, swamps, bogs, and tarns. Wetlands contain unique plants and animals that have adapted to wet conditions.

Wetlands store large amounts of water during heavy rain and release it gradually, reducing downstream flooding. Coastal wetlands help stabilise shorelines and protect against coastal hazards. Wetlands also retain sediment and nutrients, improve water quality, mitigate climate change by storing greenhouse gasses, and have important biodiversity and cultural values.

Scientists estimate that the area of wetlands in New Zealand was reduced from 672 000 hectares in the early 1800s to around 100 000 hectares in the mid-1970s, an 85 per cent decrease. Farmers were encouraged, through government subsidies, to drain wetlands up until the mid-1980s. The draining or filling of mostly lowland wetlands has reduced the water-storage capacity within river catchments, creating quicker and higher flood peaks after heavy rain.

Many wetlands in New Zealand are under Department of Conservation or Fish and Game New Zealand control. Many others, however, are privately owned and are threatened by excess runoff and sedimentation, stock grazing, and draining or infilling for pasture or urban development. Wetland restoration often requires a collaborative effort between local authorities and landowners and involves removing drains, fencing to prevent grazing, reducing nutrient inputs, controlling weeds, and planting.

Dunes

Coastal dunes occur along approximately 1100km of New Zealand's coastline and provide natural protection from coastal hazards. Dunes act as buffers that absorb the impacts of coastal erosion and storm surge, protecting areas further inland, and contain sand reserves that help maintain beaches. Dunes may also reduce the impact of tsunamis, as they did in some places during the tsunami of 26 December 2004. The role they play will become increasingly important with climate change and sea-level rise.

Most of New Zealand's coastal dune systems have been removed or modified by people. This has led to major changes in dune shape and vegetation, and has affected other natural coastal processes, leaving coastal buildings and assets more vulnerable to coastal hazards.

The benefits that dunes contribute to hazard risk reduction, as well as to biodiversity and amenity values, are now recognised. Many dune systems are being restored around New Zealand through community-based dune management groups (often called coast care or beach care groups) that involve local authorities working in partnership with community groups. Natural dune repair and restoration is dependent on plants that trap sand on the seaward face of the dune. Native sand-binding plants, such as pingao (or pikao) and spinifex are more effective at this than the exotic marram grass, ice plant and kikuyu grass. Planting pingao and spinifex allows dunes to recover between storms, reducing further erosion, and these plants also reduce wind erosion.

Dune restoration also involves restricting people and vehicles to specific accessways across dunes, to protect the sensitive dune vegetation.

The Coastal Dune Vegetation Network, established in 1997, provides both technical support for coast care programmes in New Zealand and a forum for information exchange.

Papamoa Domain in 1995 (left), 2000 (bottom left) and 2004 (bottom right). Lack of native dune plants meant sand was regularly blown into the car park which blocked beach access. Coast Care Bay of Plenty members fenced off parts of the dunes and planted spinifex and pingao which have now trapped sand, restoring the dunes. *Environment Bay of Plenty.*

Urbanisation

Urban areas make up less than one per cent of New Zealand's land cover. However, almost 86 per cent of New Zealanders live in these urban areas, so the impacts of urbanisation on the natural environment affect many New Zealanders and their assets.

Urban areas have a high proportion of impermeable surfaces, such as roofs, roads, driveways, and car parks. Rainfall is unable to soak into the ground in such areas, and runoff is rapidly fed into waterways and stormwater drains, which may overflow. Subdivision design now often incorporates designated water retention areas or swales where water can pond and infiltrate the ground, decreasing the rate of stormwater runoff.

Urbanisation on slopes also often involves modifying the natural slope for building platforms and roads. Poorly constructed or retained cuts in slopes have created or worsened landslide hazards in many hillside suburbs in New Zealand. Developing high-density residential subdivisions on hills often involves extensive earthworks. The earthworks now commonly completely recontour the natural slopes, removing the need for oversteepened and unsupported cut slopes, and reducing the likelihood of shallow landslides.

Modification of slopes is not only an urban issue. Many slopes around New Zealand have been modified for road and railway line construction. Landslides triggered by high intensity or long duration rainfall often close roads in New Zealand.

FURTHER INFORMATION

URBAN DESIGN PROTOCOL

MINISTRY FOR THE ENVIRONMENT
www.mfe.govt.nz/issues/urban/design-protocol/index.html

WETLANDS

NATIONAL WETLAND TRUST OF NEW ZEALAND
www.wetlandtrust.org.nz/index.html
DEPARTMENT OF CONSERVATION
www.doc.govt.nz/Conservation/Wetlands/index.asp

DUNES

COMMUNITY-BASED DUNE MANAGEMENT FOR THE MITIGATION OF COASTAL HAZARDS AND CLIMATE CHANGE EFFECTS
www.lgnz.co.nz/projects/ClimateChange/index.html
COASTAL DUNE VEGETATION NETWORK
www.ensisjv.com/WorkingwithEnsis/Collaborations
/CoastalDuneVegetationNetworkCDVN/tabid/286/Default.aspx

VEGETATION AND SOIL CONSERVATION

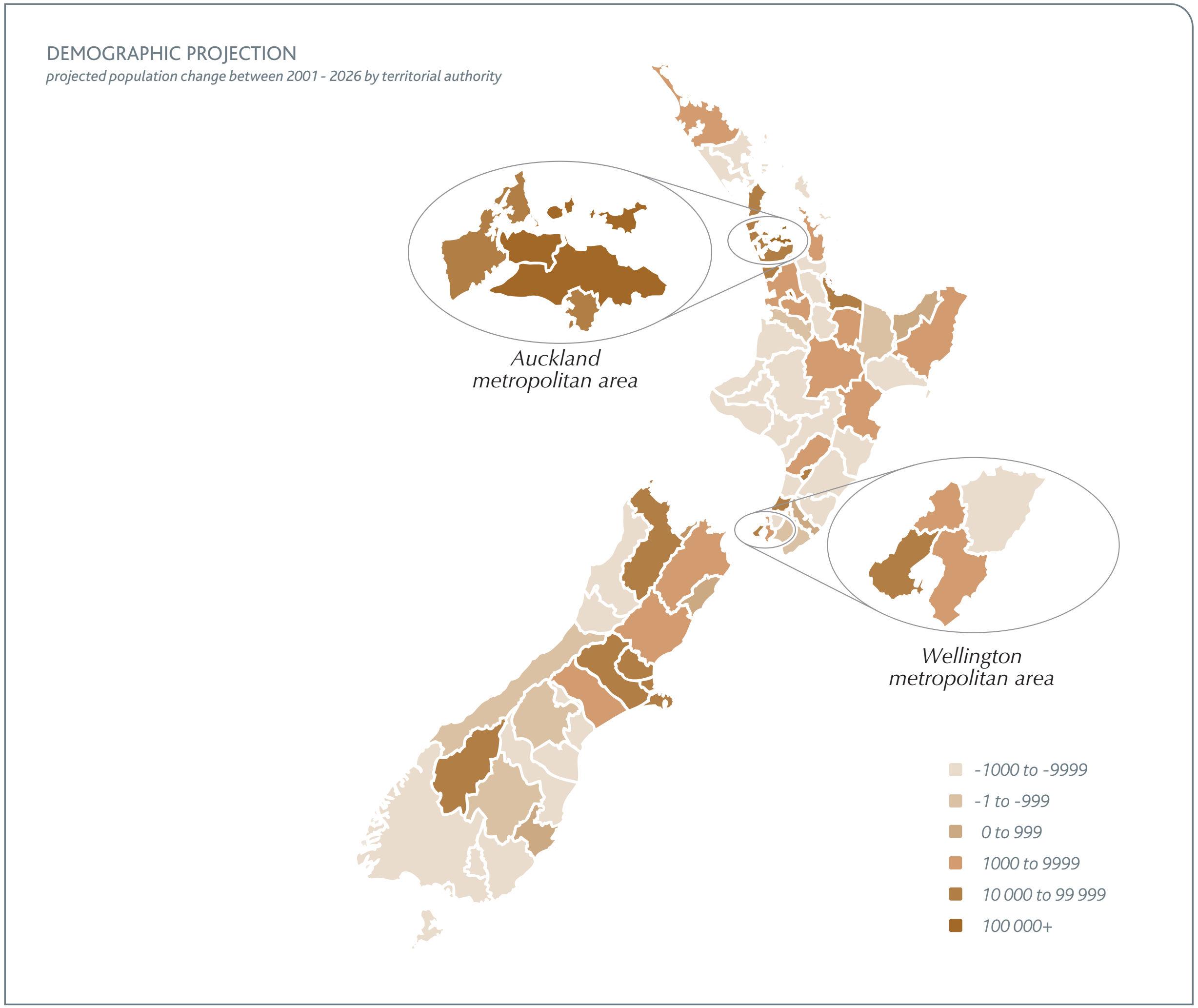
MONITORING PROGRESS TOWARDS A SUSTAINABLE NEW ZEALAND
www.stats.govt.nz/analytical-reports/monitoring-progress/default.htm
MINISTRY OF AGRICULTURE AND FORESTRY
www.maf.govt.nz/forestry/forestmanagement/ecfp/index.htm
MINISTRY FOR THE ENVIRONMENT
www.mfe.govt.nz/issues/land/soil/

DEMOGRAPHIC TRENDS

Demographic projections

New Zealand's population is increasing, but the rate of increase is slowing. New Zealand's population is projected to reach 5 million by 2051, an increase of 20 per cent from the current population of around 4.15 million. The age structure of the population will undergo significant changes in the future. There will be fewer children and more older people. Half of New Zealand's population will be aged 46 or older by 2051, compared to age 35 in 2004. By 2051, 25 per cent of the population will be aged 65 and over, compared with 12 per cent of the population in 2004. The most significant projected future changes in ethnic diversity will be the growth of the Asian population, from seven per cent of the total population in 2001 to 15 per cent in 2021.

The average size of households is likely to continue declining, from 2.6 people in 2001 to 2.4 people in 2021. There are likely to be more couples without children, overtaking two-parent families, and a continuing increase of one-person households.



Projected population changes between 2001 and 2026 by territorial authority. Most growth is expected to occur in urban areas. Almost half of New Zealand's 74 territorial authorities, mostly rural, will have fewer residents in 2026 than they did in 2001. *Statistics New Zealand.*

New Zealand's labour force numbered 1.97 million in 2001. This is projected to peak at 2.39 million in the mid-2020s before declining to 2.38 million in 2051. The average age of people in the workforce will also increase.

Population growth is fastest in New Zealand's cities and on the urban fringe because of the increase in 'lifestyle' properties. This growth is expanding urbanisation and creating higher urban property values, particularly in at-risk areas such as coastlines and steep slopes.

In contrast, the population of New Zealand's rural areas, which make up most of the country's land area, is decreasing. Intensification of farming has led to fewer but bigger properties, more commercial enterprises with fewer family-owned properties, the dissolution of rural schools, and generally lower rural populations.

Two-thirds of New Zealand's population growth between 2001 and 2026 is projected to be in the Auckland region with an increase of 560 000 people (46 per cent) from 1.22 million to 1.77 million. After Auckland, the highest growth regions will be Canterbury, Bay of Plenty, Waikato, and Wellington.

Implications for emergency management

Knowing where people live and work or study is important for response planning, especially for providing information and warnings. Health, mobility, wealth, and cultural values, which influence a community's vulnerability and ability to recover from emergencies, vary across the community. There is an increasing range of ethnic groups. Knowing a community's perspectives, expectations and needs, and how these are likely to change over time, is crucial to hazard management across reduction, readiness, response and recovery.

Changing demographics have a large bearing on risk. As the population grows, along with assets and infrastructure, so too do the potential consequences of hazards. As population density increases in urban areas, more people are potentially vulnerable to a hazard event in those areas. People also tend to be more reliant on infrastructure, the built environment, and commercial food supply chains, leaving them vulnerable if those resources fail. Of particular current interest is the demand for coastal property for residential development, and the rising value of coastal property, which is a worldwide trend. However, many of these properties, and others behind them, are in areas subject to coastal hazards.

One of the implications of the intensification of farming is that it creates greater geographical distance between rural neighbours and more isolated rural communities. This highlights the need for appropriate emergency management planning in rural areas.

The increase in the percentage of the population who have English as a second language presents challenges for communicating hazard and readiness information. The growth of the elderly population, which may be less mobile, has implications for evacuation and welfare planning. Neighbourhood support networks are becoming more important as the number of people living alone grows.

FURTHER INFORMATION

GENERAL DEMOGRAPHIC INFORMATION

STATISTICS NEW ZEALAND
www.stats.govt.nz/analytical-reports/dem-trends-05/default.htm
POPULATION AND SUSTAINABLE DEVELOPMENT
www.population.govt.nz/tools-resources/new-trends-in-topical-population-issues.htm

RELIANCE ON TECHNOLOGY

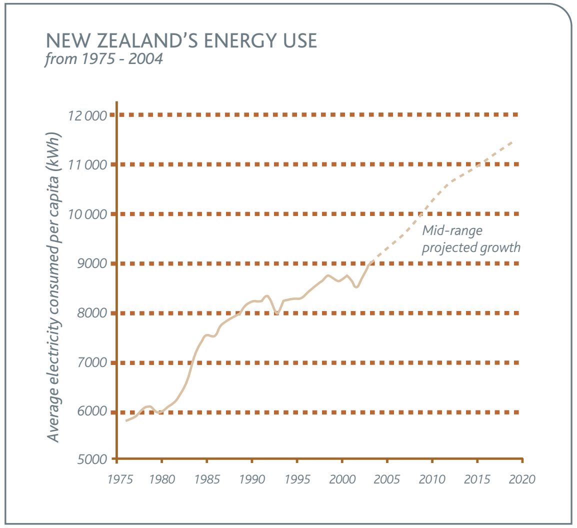
New Zealand society relies heavily on technology and interconnected infrastructure. This reliance continues to grow, and with it New Zealand's vulnerability to failure of these systems due to external or internal causes.

Trade, education, and entertainment are international. New Zealanders can travel to most places in the world within 2 or 3 days, buy products from many countries, and talk to people any time, anywhere.

New Zealand's commercial environment and social conditions are based on these opportunities. Tourism is a significant economic sector in New Zealand (4.8 per cent of GDP), and relies on well-functioning transport and information and communication systems. Imports total 27 per cent of GDP, and New Zealand has a diverse range of trading partners. Computer-based payments systems (EFTPOS and inter-bank settlements) work efficiently to support internal and overseas trade. It is possible to send and receive large amounts of data over the internet at low cost.

Competition within New Zealand has led to increased business efficiency, with small inventories and increased out-sourcing. Most of New Zealand's businesses are small to medium enterprises, and many contribute small parts to long production chains. Stock-turnover in supermarkets is rapid and highly organised. Industrial monitoring and control systems enable lifeline utilities to manage daily infrastructure operation from remote locations. Courier systems enable rapid deliveries, and New Zealand's economy is based on a 'just-in-time' model.

New Zealanders today are much more reliant on technology than past generations, with high expectations of immediate access to goods and services. For example, many households buy their food daily from supermarkets, restaurants, or fast-food outlets. Restaurants and takeaways now account for 25 per cent of New Zealanders' food consumption.



New Zealand's average annual energy use per capita has grown from around 6000 kilowatt hours a person in 1976 to around 9000 in 2004. This trend is likely to continue. *Electricity Commission*.

An effective supply chain enables New Zealanders to enjoy high living standards, but also leaves communities vulnerable when something goes wrong. The June 2006 Canterbury snowstorm led to electricity and communication outages that created difficulties for rural communities, and the failure of a single wire shackle at the Otahuhu substation in the same month resulted in a disruptive electricity blackout in Auckland.

Lifeline utilities are highly dependent on each other. For example, banks rely on the internet, computers need electricity, water supply depends on electricity-driven pumps, and monitoring and control systems within many infrastructure sectors rely on electricity and communications. A breakdown in even one part of this matrix can easily cause breakdowns in other parts.

The keys to infrastructure resilience are awareness and adaptability. These are functions not of the infrastructure itself but of the organisations that own, fund and regulate it. Organisations working together, through initiatives such as engineering lifelines groups, help minimise the risk of failure. Good business continuity and household planning helps minimise direct economic and social impacts. Business continuity planning can also reduce the loss of business confidence and promote recovery.

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