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.

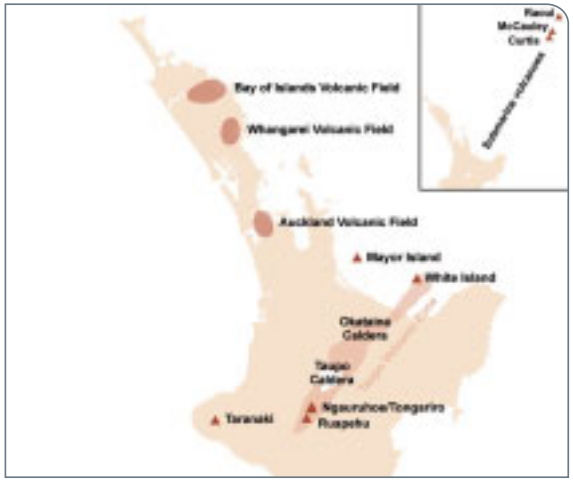
Eruptions started in the Auckland area around 140 000 years ago and the last 20 eruptions have occurred in the past 20 000 years. Eighteen of these occurred between 10 000 and 20 000 years ago. The largest and most recent eruption was Rangitoto, in Waitemata Harbour, 600–700 years ago. None of Auckland's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

THE NEXT AUCKLAND VOLCANO

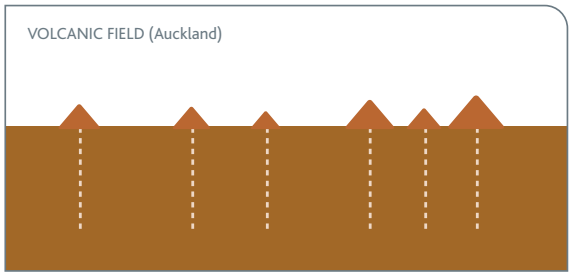
There are 530 000 people living on the Auckland Volcanic Field and a further 750 000 live in the wider Auckland region. Even a small, localised eruption would cause major damage near the vent and widespread disruption.

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.

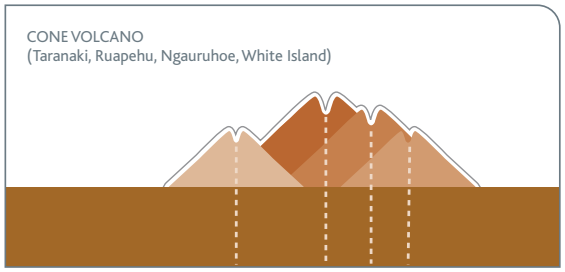
BAY OF ISLANDS AND WHANGAREI VOLCANIC FIELDS

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.

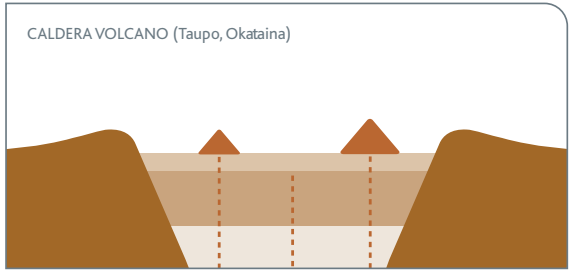
Raoul Island has experienced many historic eruptions. The most recent, in March 2006, killed a Department of Conservation worker who was taking crater lake samples at the time. This was New Zealand's first volcanic casualty in more than 50 years. Other volcanoes in the Kermadecs emit steam and gases,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

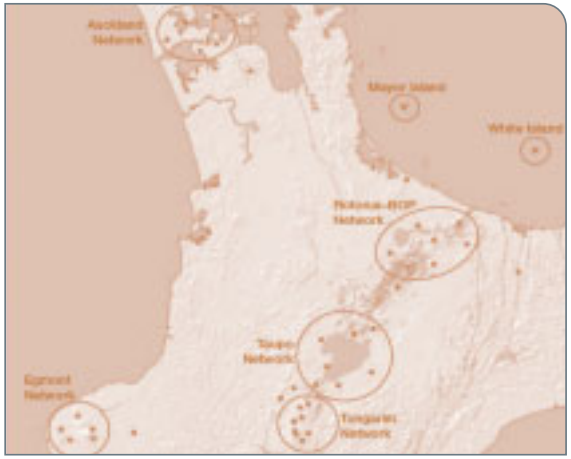
Volcanic hazards are not addressed in the New Zealand Building Code. However, the Department of Building and Housing has identified volcanic eruption impact threats, such as ash loading and corrosion, as a concern that needs addressing in the current Building Code review.

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.

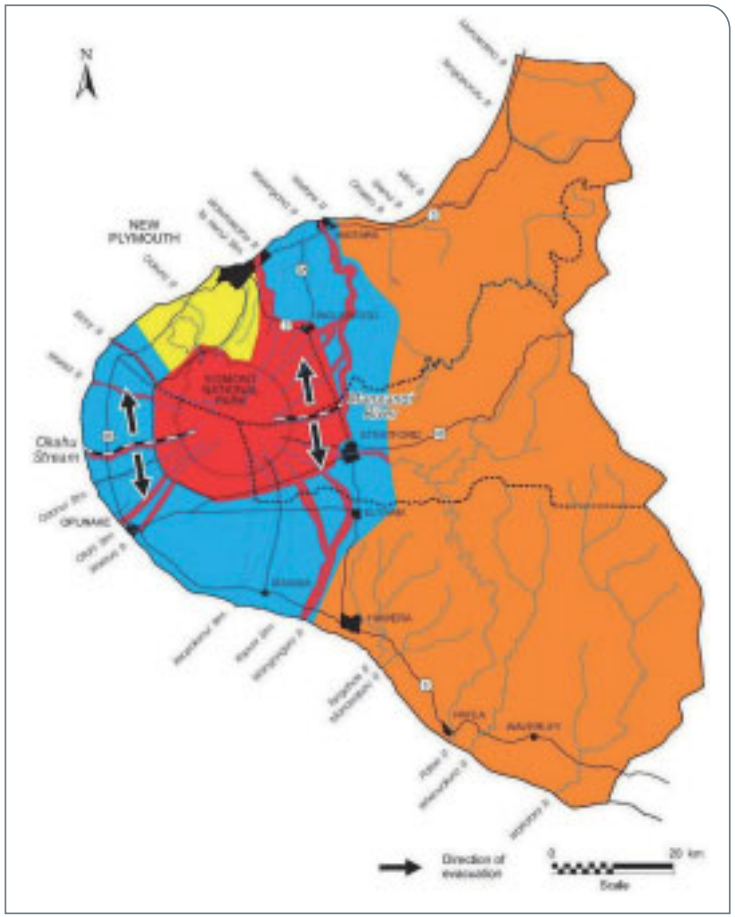
GeoNet has been operating since 2001 and is funded by the Earthquake Commission and the Foundation for Research, Science and Technology. GNS Science manages the project and the collected information is freely available to researchers and the public.

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