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A review of natural hazards information for Northland region

Science Report

By R. D. Beetham, M. McSaveney, G.Dellow,
M. Rosenberg, D. Johnston & W. Smith

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ABSTRACT

The levels of Natural Hazards that Northland Region is exposed to, excluding floods and climatic events, are relatively low. Of the landslide, volcanic, seismic, tsunami, and mine subsidence hazards considered, the landslide hazard is assessed to be the most significant. Slope instability is common in the region and there are large areas of creeping slope failures in some rock types. However, these areas can be readily and clearly identified and action taken if required. A brief summary is shown below.

Hazard	Occurrence	Notes
Landslide	Common in some rock types	Affected and potentially unstable areas can be readily identified.
Volcanic	Two potential sources are identified 1. local centres 2. ash fall from distant eruptions in NZ	Are the local centres still active? There is ash fall from distant sources in NZ, such as Taupo Region (TVZ) and Taranaki. Further study is need for both. Partially funded student theses may be a practical option for getting studies done.
Seismic	MM6 shaking occurs every ~1,000 years. MM7 shaking every ~7,000.	Low hazard and small earthquakes <M5. No active faults known. Small earthquakes will give short duration shaking that may not have enough cycles to cause liquefaction. Microzoning studies probably not required as hazard is low.
Tsunami	Local and tele-tsunami sources. Local tsunami may be large but is a probable long recurrence interval (~4,000 year) event. Tele-tsunami have been small.	Most hazardous areas could be readily identified. Low hazard.
Mine Subsidence	Localised hazard above underground coal mines.	Areas of hazard are known and clearly identified for Kamo and Hikurangi. Other mines at Kiripaka, Whareora and Whauwhau may need evaluation. Mine shafts and adits are shown at Hikurangi but may need consideration at the other mines.

KEYWORDS

Natural hazards, Northland Region, landslide, volcanic, seismic, tsunami, mine subsidence.

1.0 INTRODUCTION

The Northland Region is subject to a range of natural hazards. The aim of this report is to assemble and present a review of existing information on natural hazards and their effects in the region for earthquake, tsunami, volcanic hazards, mine subsidence and landslides, and to identify "gaps" that may require additional work. The work has been undertaken by staff from GNS, Northland Region and Whangarei District Councils.

2.0 SEISMIC HAZARD

Earthquake risk in Northland is low. No active faults are mapped within the Northland Region, and the whole Northland peninsula has been generally regarded as tectonically stable (Eiby 1955). There was some damage in December 1963 from two earthquakes of magnitudes 4.8 and 4.9 near Mangonui and Peria (100 km to the northwest), preceded by one of magnitude 3.5 in November of that year (Eiby 1964, Figure 2.1). Earthquakes were also reported near Russell (50 km north of Whangarei) in November 1919 (Richter magnitude probably less than 4). More recent events have been:

- April 1964, magnitude 3.9 just west of Kerikeri (75 km northwest of Whangarei)
- February 1975, magnitude 4.4 near the Hen & Chickens Islands (45 km southeast)
- May 1978, magnitude 3.9 near Maungaturoto (40 km south)
- May 1995, magnitude 4.3 near the Poor Knights Islands (60 km northeast).

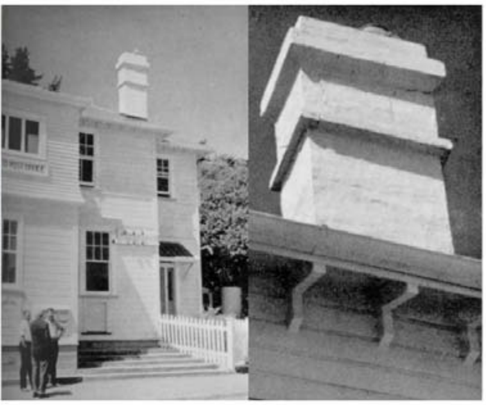
There is thus a proven risk of small earthquakes that have caused slight damage in Northland. However, the earthquake risk is lower than for much of New Zealand (Figure 2.2).

The felt effects of earthquakes are described using the Modified Mercalli (MM) scale of intensities (from I-XII), for which a New Zealand version has been prepared by Dowrick (1992) – see Figure 2.3 for a brief summary version. Studies at GNS have used the seismicity model of Stirling et al (2000) and the attenuation model of Dowrick & Rhoades (1999) to estimate a mean return period of 1000 years for MM VI and 7000 years for a MM VII in Whangarei, compared with 9 and 42 years respectively for Wellington. Intensities of VI or greater are those which may start to cause damage to some buildings (Figure 2.3). The felt effects vary according to the underlying geology and topography, so the above estimates indicate the expected average response throughout the area. However, earthquake waves can be amplified on areas of thick unconsolidated material, including alluvium and man-made fill. This includes the thick lacustrine, swamp and alluvial deposits at Springs Flat and the thick alluvium and fill as are found for example between the central Whangarei city and the port. The felt intensities and the likelihood of damage from an earthquake may be greater in these areas, where liquefaction and surface settlement might occur within poorly consolidated sediments, although the small M5 or less earthquakes seen in the historical record are unlikely to have enough energy or cycles of strong shaking to cause liquefaction. The long recurrence interval for MMVII, the intensity of shaking when liquefaction begins to occur, indicates the risk is low.

2.1 Identified gaps

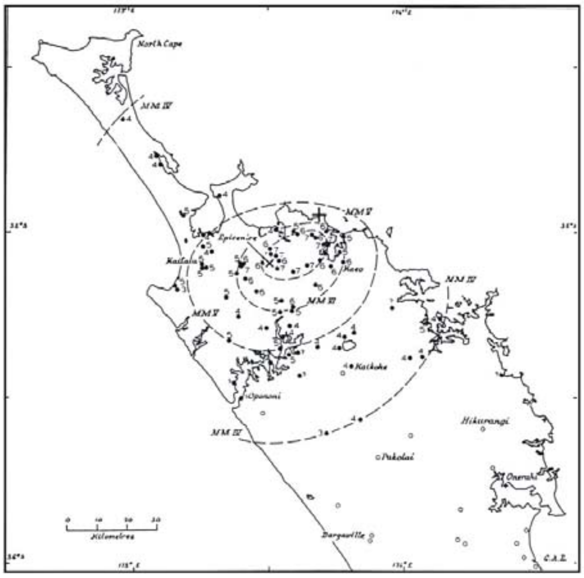
Seismic microzoning surveys have not been carried out in Northland to assess the degree of shaking amplification that may occur in areas of thick unconsolidated sediment and fill. Microzoning studies, such as those carried out by GNS in south Auckland, Wellington and Whakatane, would characterise the probable shaking response of materials like those found in the Whangarei area. Such studies would allow areas susceptible to seismic shaking amplification and possible liquefaction to be identified and mapped. However, the low level of seismicity and the long recurrence intervals (1,000 years for MMVI and 7,000 years for MMVII) means that seismic amplification and liquefaction are low probability hazards, since significant liquefaction is not expected until MMVII intensity shaking is reached. In this case seismic microzoning is a low priority task.

Material dislodged from an existing roadside slip at Kaingapipiwai, on the Pupuke Road.



Kaeo post office, with enlargement showing cracks in the upper part of the chimney.

Peria Earthquake
22nd December 1963
Magnitude 4.5_L and 4.9_L



Isoseismals of the Peria earthquake. Open circles indicate a “not felt” report. Map and photos from Eiby 1964

Otangaroa School. General view, and details of damage to concrete path. The rule lying on the grass in the lowest view is 1m long.

Figure 2.1 Examples of damage caused by the 1963 Peria earthquakes.

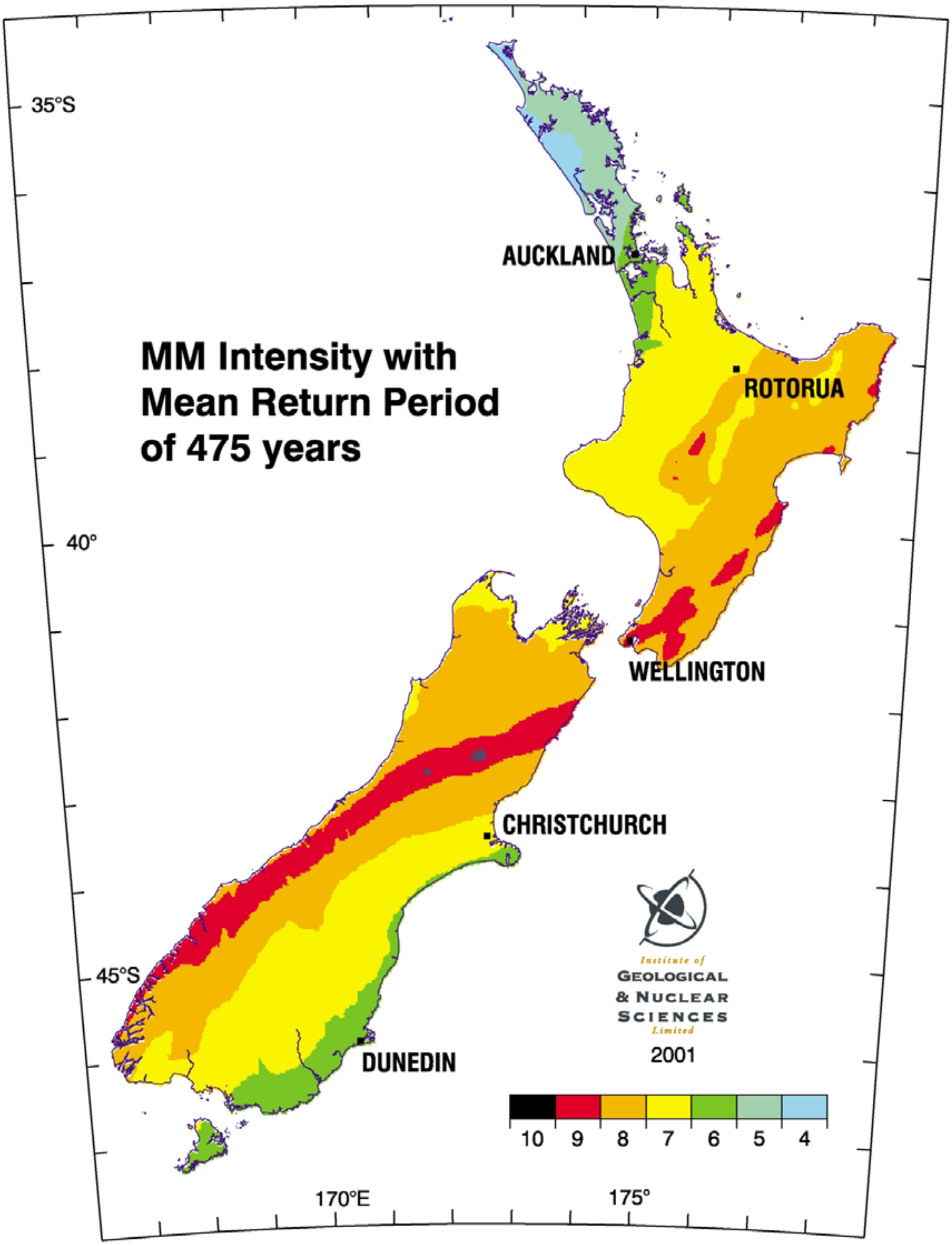


Figure 2.2 A Modified Mercalli (MM) Intensity recurrence map for New Zealand.

HOW AN EARTHQUAKE FEELS

The Modified Mercalli Intensity (MM) scale is a means of categorising the effects of shaking on people, structures and the environment.

MM 5
Generally felt outside.
Small unstable objects displaced.
Some windows and pipes crack.

MM 6
Felt by everybody.
Difficulty experienced in walking.
Objects from shelves tend to fall.
Slight damage to poorly constructed buildings.

MM 7
Difficulty standing.
Noticed by drivers of cars.
Furniture movement.
Tiles, water tanks, walls and some buildings damaged.

MM 8
Steering of cars affected.
Buildings damaged, including some damage to earthquake resistant buildings.
Cracks in ground.

MM 9
Heavy damage to buildings, bridges and roads.
Larger cracks in ground.
Landslides on steep slopes.
Liquefaction effects intensify.

MM 10
More intense damage, including serious damage to earthquake resistant buildings and bridges.
Most unreinforced masonry structures destroyed.

Figure 2.3 A brief summary of Modified Mercalli Intensity descriptions.

3.0 LANDSLIDING

3.1 Introduction

Landslides are an ongoing geological hazard in the area administered by the Northland Regional Council. Landslides can be a threat to life and property in the region, with one fatality at Dargaville in 1998 and significant damage to property occurring on an annual basis. Historically in New Zealand, most landslides are initiated either by earthquakes or by meteorological events (intense or prolonged rainfall). In Northland the dominant trigger is intense or prolonged rainfall which initiates many landslides annually. The seismic hazard in Northland is very low (previous section & Stirling *et al*, 2002) and historically only the 1963 Peria earthquakes have been of sufficient strength to initiate landslides. The landslide damage caused by these earthquakes was very minor and less than the annual landslide damage due to meteorological events. Earthquake-induced landslides thus represent less than 1% of the total landslide damage occurring in Northland.

In the Whangarei area more detailed information is available. Here landslides have been mapped from aerial photographs, with limited field verification, at a scale of 1:25,000 by White & Perrin (2003). In addition the region has been similarly mapped as part of the large landslides data base held by GNS. It should be noted that this mapping does not detect many of the smaller landslides which may be of local significance. Most natural slopes developed on soft rocks in the Whangarei area exhibit an undulating hummocky surface that is characteristic of soil creep and surficial slumping.

3.2 Current knowledge

GNS current knowledge of landslides in Northland comes mainly from the New Zealand Landslide Database. GNS uses two methods to systematically collect landslide data for the New Zealand Landslide Database. The two methods are referred to for convenience, as the ‘landslide inventory’ and the ‘landslide catalogue’. The ‘landslide inventory’ data records the event location accurately but has little information on when the landslide occurred. For the ‘landslide catalogue’ the location of the event is less well defined but there is good data on timing – when the landslide occurred.

The ‘landslide inventory’ data has been collected by using air photos to identify historic and prehistoric landslides in the landscape. Landslides are then plotted on 1:50,000 scale topographic base maps so that the location and outline features can be digitised. Locations are accurate to ±100 metres. The mapping is complete for landslides with a volume greater than 1×10^6 m^3 at 1:50,000 scale. The New Zealand ‘landslide inventory’ of the North Island currently contains digital records for over 5773 landslides. Figure 3.1 is an example of a large landslide in Northland from the ‘landslide inventory’ data base.

The ‘landslide catalogue’ consists of a data set of contemporary landslides. Systematic daily monitoring of news media and other sources is used to record landslide occurrence. Landslide locations are reported as point data with an uncertainty that can range from 100 metres to 25 kilometres. This data set is based on the concept of earthquake catalogues, that record the magnitude, time and location of an earthquake, and has been designed to systematically record landslides when they occur. Systematic recording for the ‘landslide catalogue’ started in August 1996 and since then has recorded over 500 landslides that have caused damage worth millions of dollars and killed 6 people. ‘Landslide catalogue’ data is also available for a 150 year record of earthquake induced landslides.

The GNS landslide catalogue has recorded a number of landslides in the Northland Regional Council area since 1996. These include:

Northland, December 1996: Cyclone Fergus ($200,000 ground damage);
Tutukaka, January 1997: landslide;
One Tree Point, Whangarei, 1997: coastal erosion;
Dargaville, September 1997: landslide;
Dargaville, May 1998: landslide (1 death)
Hukerenui, June 1998: landslide;
Mangonui, July 1998: landslides;
Mackenzie Bay, July 1998: landslide (houses evacuated);
Langs Beach/Waipu, July 1998: landslide (houses evacuated);
Brynderwyns, July 1998: landslide;
Pawarenga, January 1999: debris flows;
Matapouri, December 2000: several slips on roads;
Tutukaka, January 2001: landslide;
Oruaiti, September, 2001: landslide;
Whangarei, June 2002: landslide;
Taipa and Mangonui, March 2003: landslides (>$550,000) and
Brynderwyns Hill, August 2003: landslide.

This list is not a complete record of landslides in the Northland region. The list has been compiled from reports in the news media of landslides and represents those landslides considered newsworthy.

3.3 Future development

The key to improving knowledge of the landslide hazard in the Northland region is the collection and storage of landslide and meteorological data. Better data will enable more accurate identification of the landslide hazard and consequent risk. By linking landslide and meteorological data with slope and geology data, characteristic landslide profiles for different geological units can be developed.

The collection of detailed data on landslides and the adding value to it through comparison with other data sets (e.g. rainfall, slope and geology) will enable landslide hazards to be better identified. For example, 200 mm of rain in 30 hours (27-28 March 2003) on Tangihua Complex rocks of the Northland Allochthon (Isaac, 1996) near Taipa and Mangonui caused landslides from road cuts and these were large enough to block the carriageway.

GNS is developing a methodology and procedures to improve the reporting of landslides. The data to be collected includes: location, size (affected area, volume of debris, volume of source), type of landslide, causes, trigger, activity, duration, slope angle (the default is the NZMS260 map series 20 m contour data although this can result in local areas of steeper slopes not being correctly identified), geotechnical information (rock or soil mass strength, weathering) and damage. Improving the quality and quantity of landslide data will enable the development of characteristic landslide profiles for individual geological units. Such landslide profiles have the capacity to be a significant resource in the reduction, readiness, response and recovery from landslide hazards.

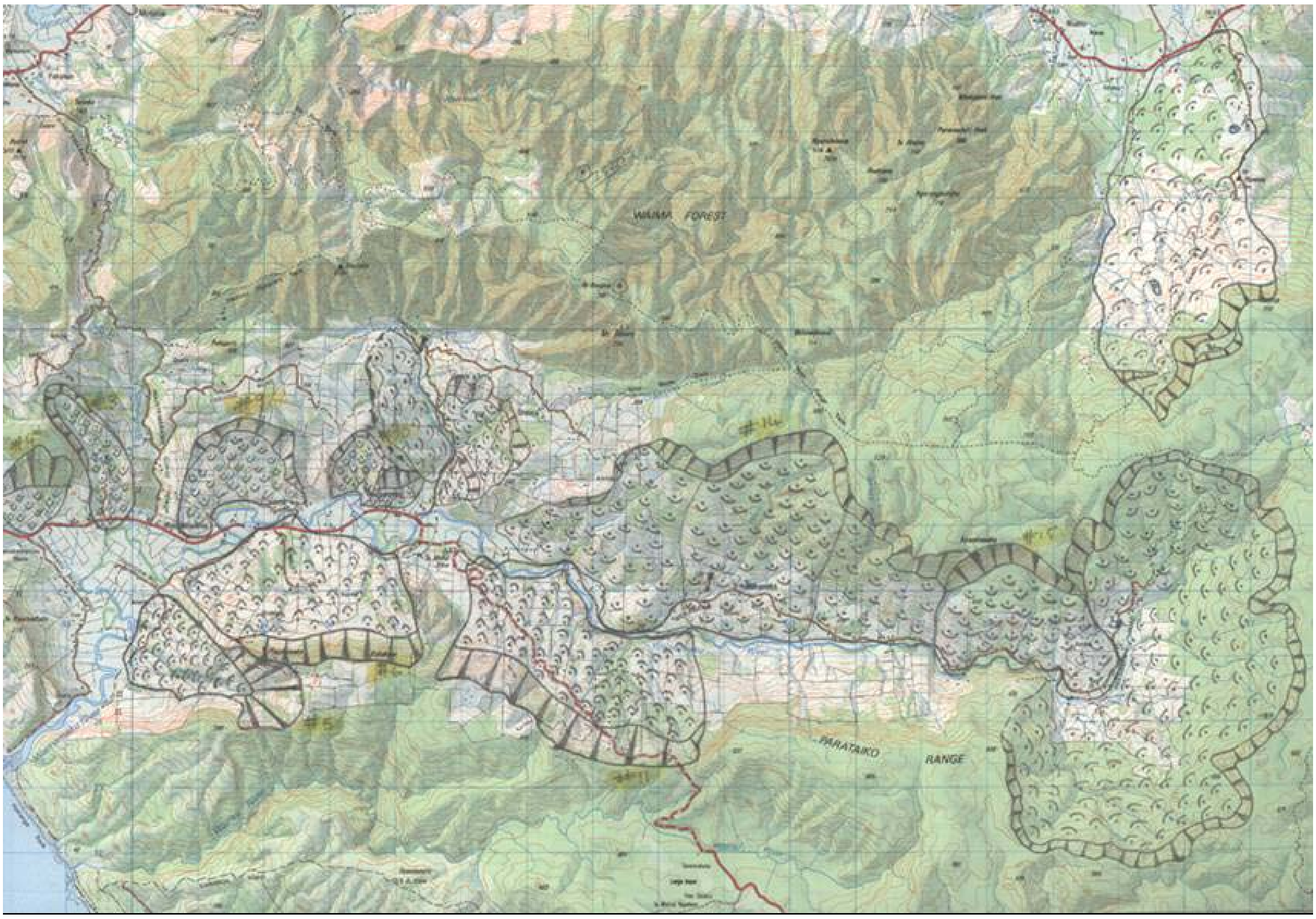


Figure 3.1 Large landslides mapped from aerial photos in the Waimamaku Valley SE of Hokianga inlet where weak silt and mudstones are overlain by strong basalt rock.

4.0 TSUNAMI

The tsunami sources for New Zealand range from local, to very distant (more than 10,000 km away) because tsunami travel very long distances with little loss of energy. Tsunami can occur anywhere around the New Zealand coastline. The highest historical rate of occurrence of tsunami in New Zealand has been along the eastern coast (Figure 4.1), because these areas face regions with frequent strong earthquake activity on the sea floor, both nearby and along the coast of South America.

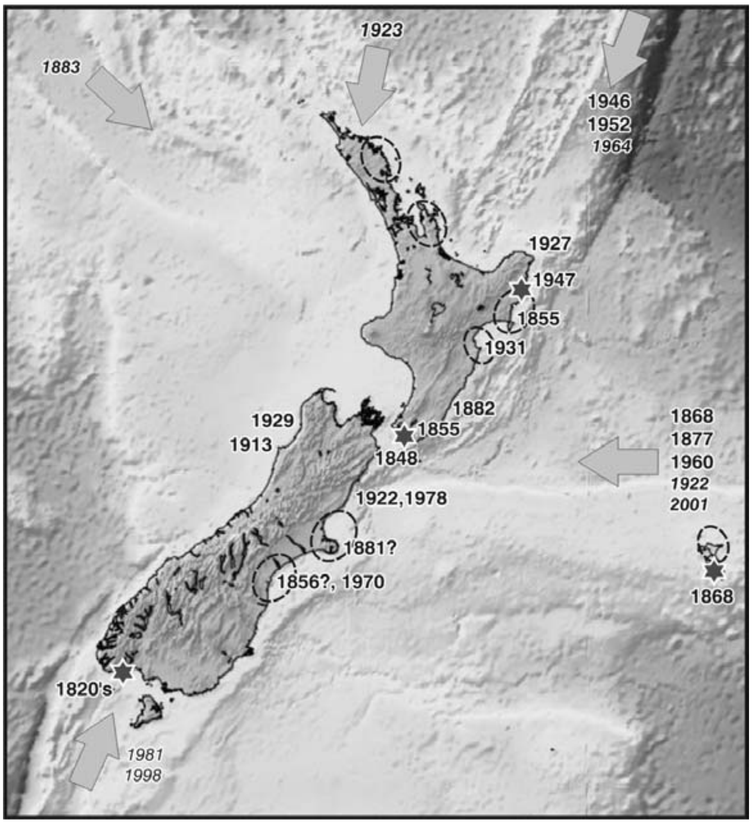


Figure 4.1 Occurrence of tsunami in New Zealand since 1820. Dates along the coastline indicate locally generated tsunami, and large arrows, tele-tsunami travelling from across the oceans. The largest local tsunami were those of 1855 and 1947 and probably that of the 1820's in Southland. All of these exceeded 10 metres in runup height (stars). The only tele-tsunami to have exceeded 10 metres runup height on land was the 1868 tsunami originating from South America. It destroyed a village on the Chatham Islands. Tele-tsunami that had negligible effect are italicised. Dashed ellipses indicate areas where tsunami amplification may occur.

Locally generated tsunami tend to have local areas of impact. The hazard from locally generated tsunami in New Zealand varies mostly according to shallow coastal and offshore seismicity. Around Northland, local seismicity is at a minimum for New Zealand. With few active near-shore geological structures (faults and folds) in the vicinity of Northland that could cause tsunami, there have been no locally generated tsunami there in the last 160 years. There are, however, "nearby" potentially tsunamigenic volcanic sources. The locally most damaging tsunami for the Northland region are likely to be generated by volcanic eruptions along the Tonga-Kermadec Trench – at for example the recently discovered Healy Caldera, only 275 km from Northland. There have been no large eruptions in this area in the last 160 years.

In addition to "local" tsunami sources, Northland also is exposed to tsunami generated at very distant sources around the Pacific and Southern Oceans. These are called tele-tsunami. Historical tele-tsunami that have been detected around the New Zealand coast since 1840 are shown in Figure 4.1. Each tele-tsunami reaches to all parts of our coast, but some locations are affected more than others. This depends in part on the tsunami source, and in part on local coastal bathymetry. Tele-tsunami appear to be amplified along some sections of the New Zealand coast relative to others, and parts of Northland are among them (Figure 4.1). Although tsunami from South America have been historically more frequent in Northland, we expect that some of the more northern earthquake sources around the Pacific Ocean (the Washington-Oregon coast of North America) may be more hazardous for the Northland region. These areas have not had large earthquakes during New Zealand's brief recorded history.

In the Tsunami Risks Project of the UK Tsunami initiative, UK tsunami specialists have estimated tsunami height-frequency relationships for many regions of the world, including New Zealand (Figure 4.2). In estimating the relationship at larger return periods (200 to 1000 years) they used a world-wide tsunami catalogue, and adjusted a generic relationship to match the New Zealand historical data. Because the relationship is based on measured tsunami run-up on land, its measure of tsunami height is the run-up height and not peak height above normal sea level. Run-up height can be larger than the peak-to-trough height because of the momentum of the water mass.

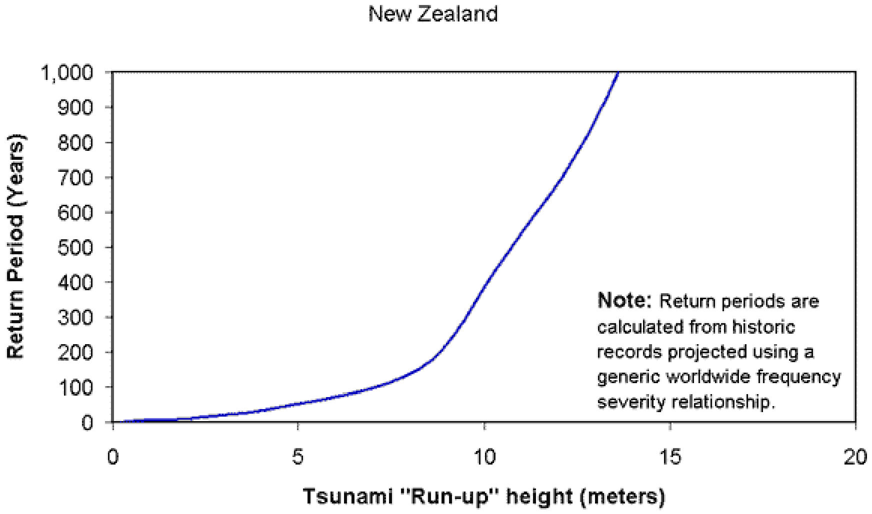


Figure 4.2 Estimated tsunami-height probability-density distribution for New Zealand from the Tsunami Risks Project of the UK Tsunami initiative.

Despite its sheltered location at the head of Whangarei Harbour, Northland's major city Whangarei may be exposed to a small tsunami hazard. Port Whangarei has experienced historic tsunami. A series of waves one metre high were reported there following a Great Earthquake in Chile in May 1960. This is close to the average height reported for this tsunami around New Zealand (it reached to a little over 3 m at a few sites noted for their amplification of waves). Such fluctuations in sea level within the harbour are small but may have generated strong currents, and some scouring and redeposition of sediment within the harbour channel system.

Dr Nichol (2003, and in work in preparation) and his team reason that the largest tsunami in Northland, possibly reaching 30 m in height, was generated by an eruption of Healy Caldera about 600 years ago, and there has been one such event in the last 4000 years or so. Although there must be potential for further similar eruptions, the eruption histories of this and the other largely underwater volcanoes along the Tonga-Kermadec Trench are unknown.

4.1 Identified gaps

GNS has developed a GIS-based method for modelling tsunami inundation using detailed digital topography and the "footprint" of significant built features, such as buildings in urban areas. If this data were available, inundation models for the coast of vulnerable parts of Northland Region could be produced for a range of possible tsunami landfall heights.

5.0 VOLCANIC HAZARDS

5.1 Background

There are two areas of past local volcanic activity in Northland, at Puhipuhi-Whangarei and at Kaikohe-Bay of Islands (Figure 5.1).

5.1.1 The Puhipuhi-Whangarei volcanic field

Volcanic activity in the Puhipuhi-Whangarei Volcanic Field is represented mainly by basaltic rocks although rhyolitic and dacitic rocks do occur. Early Miocene-age centres such as Parahaki, Whangarei Heads, and Hen Island and Chicken Islands (rhyolite and andesite, ~15 Ma [million years] to 20 Ma), are genetically related to an ancient subduction zone to the north of New Zealand and are not related to the younger basalts (Smith *et al.* 1993). Parahaki (20 Ma), Parakiore (dacite, 0.45 Ma) and Hikurangi (dacite, 1.2 Ma) share a common alignment on the ancient Harbour Fault, but differ in age by almost 20 million years (Hayward *et al.* 2001) and are otherwise unrelated to each other.

The Whangarei landscape is dominated by numerous, small volume, youngish basalt volcanoes which occur as plateau forming sequences of lava flows, thick valley-filling flows, small shield volcanoes (e.g. Whatitiri) and prominent scoria cones that commonly are breached by lava. The cones are single entities, or nested in a common edifice. Extrusion of rhyolite and dacite lava (e.g. Hikurangi, Parakiore, Parahaki) formed steep dome-like hills without flows.

The distribution of the younger basalts appears to have been strongly controlled by local fault structures (Brothers 1965a,b, Smith *et al.* 1993) and their ages span the range 10 Ma to 0.3 Ma (Smith *et al.* 1993, Hayward *et al.* 2002); the most recent volcanism near Whangarei probably occurred between 1 Ma and 0.3 Ma (Smith *et al.* 1993). The young basalt volcanoes are essentially all monogenetic i.e., one batch of magma, one new vent, one eruption sequence. It is possible that some centres e.g. Whatitiri shield volcano and Matarau, were constructed by multiple cycles of weakly explosive eruption of scoria, followed by (or generating) lava flows. The styles of activity are thought to have been within the range of styles historically observed at basalt volcanoes worldwide. In broad terms these are an initial vent-opening explosion, followed by weakly energetic eruption of ash, scoria, and bombs, then effusion of fluid lava. Associated phenomena are likely to have included expulsion of volcanic gases, generation of acid rain, lightning strikes and volcanic seismicity.

In summary, eruption centres of the Puhipuhi-Whangarei Volcanic Field are geographically spread across the Whangarei District. Some periodicity in activity can be inferred from the age data available and it can be implied that the most recent re-activation of the field occurred around 1 million years ago, focussed in the southern part of the field (Whangarei-Kamo). The youngest eruptions occurred more than 250 thousand years ago and there is some doubt as to whether the field should be considered active or not.

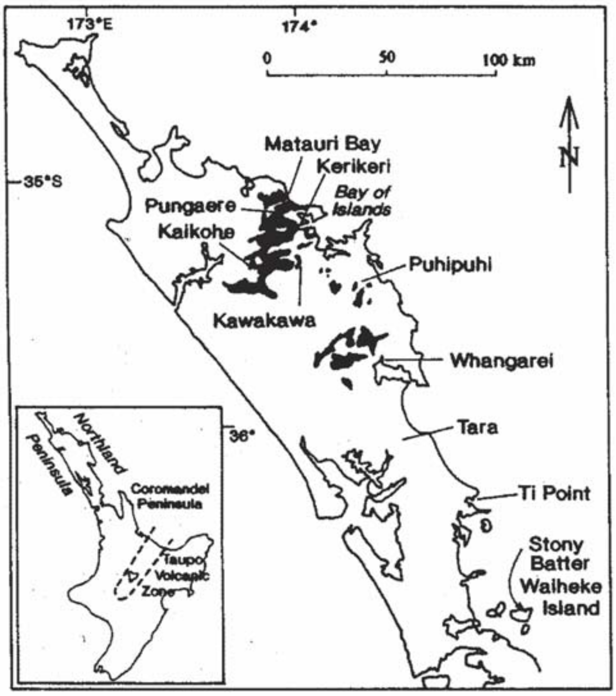


Figure 5.1 Location of late Cenozoic basalts and associated volcanics in Northland (after Smith *et al.* 1993).

5.1.2 The nature of volcanoes in the Kaikohe- Bay of Islands field

Since ~10 million years ago (Ma), eruptions of mainly basaltic magma have occurred from at least 26 centres in the Kaikohe-Bay of Islands Volcanic Field. It is possible to separate the volcanoes by age and spatial association into Tertiary age (~9 Ma to 2 Ma) and Quaternary age (~1.4 Ma to 0.06 Ma) groups. Therefore it is possible that the field may have been re-activated in late Quaternary times and could be considered as still active. The heat source driving the Ngawha Geothermal Field is considered to be magma related and of unknown, but probably Quaternary age (Browne *et al.* 1981).

The cone-building, flow generating style of activity of basalt volcanoes was the same as for the Puhipuhi-Whangarei field, with the important exception of eruptions at Kawiti, Tauanui and possibly at a vent near the Puketona-Te Puke centres, where sustained, explosive interaction of basalt magma and groundwater occurred. The undated Kawiti phreatomagmatic eruption created a maar crater (May 2000) similar to those common in the Auckland and South Auckland Volcanic Fields (cf. e.g., Allen *et al.* 1996, Rafferty & Heming 1979). A second distinction of the Kaikohe-Bay of Islands field from the Puhipuhi-Whangarei field is its much larger spatial extent. However, according to Bogalo (2000) the volcanoes in the Whangarei area have a larger average volume.

A number of young cones and associated flows in the Kaikohe-Kawakawa area and at Waitangi are thought to have erupted in the last 50 000 years but surprisingly little (including true age) is known about them. Following earlier interpretations (Kear 1961, Waterhouse 1961, Wellman 1962) of degree of landform preservation, paleo sea-level and in one case by carbon dating, (Kear & Thompson 1964) suggested that 10 centres of the Kaikohe- Bay of Islands field were of Holocene age i.e. Less than 20 thousand years old (<20 ka), including Kawiti (<5 ka) and Te Puke (~1.5 ka). Stipp and Thompson (1971) obtained an age (by K-Ar dating) of 17 ± 6 ka for basalt from Te Puke. In similarity to the Puhipuhi-Whangarei field where age-related spatial patterns are generally defined, the vent locations of these youngest eruptions appear to be confined to a graben (elongate downfaulted trough) bounded by the northeast-southwest-trending Waipapa and Kawakawa Faults (Smith *et al.* 1993, May 2000).

Except for Bogalo (2000), no research emphasis has focussed on the potential hazards and physical and social impacts of renewed activity anywhere in the Kaikohe- Bay of Islands Field.

5.2 The nature of volcanic hazard

In consideration of the hazard presented to the Northland Region by volcanic activity, there are two scenarios to consider:

(a) the effects of an eruption from local volcanic fields i.e., the Puhipuhi-Whangarei Volcanic Field and the Kaikohe-Bay of Islands Volcanic Field, and
(b) effects of ash fall from a distant volcano or volcanic field/centre.

In scenario (b), the principal hazard is presented by tephra (ash) fall from renewed activity within the Taupo Volcanic Zone (TVZ) and/or Taranaki volcano. Based on the nature and volume of prehistoric Auckland Volcanic Field eruption deposits, prevailing wind directions, and the likely small magnitude of future eruptions, ash fall from this source is unlikely to affect Whangarei District. In scenario (a), a strombolian/hawaiian/phreatomagmatic style eruption of basalt from the Kaikohe-Bay of Islands field may produce thin ash fall over part of Whangarei District, although scenarios created by Bogalo (2000) suggest that this would not be significant. Basaltic eruption within the Whangarei-Puhipuhi field would produce lava flows, which may travel 10 km or more down valleys, a scoria cone and a local ash fall hazard within the district. There is no way of predicting when or where in the field a future eruption might occur.

5.3 Previous risk and hazards assessment

By far the majority of research conducted on Northland's Tertiary and Quaternary volcanic history has focussed on the chemistry and age of the rocks and implications for the tectonic history of the region. Except for the first published assessment by Kear and Thompson (1964), the hazard presented by the young volcanism has only been mentioned in passing (e.g., May 2000). Bogalo (2000) re-assessed potential hazards by describing volcanic centres in Kaikohe-Bay of Islands field and Puhipuhi-Whangarei field, examining lifeline and infrastructure vulnerability and discussing mitigation measures. Bogalo (2000) also presented possible scenarios for future eruptions near Whangarei City and near Puketona.

To date, volcanic hazard assessments for the Northland Region have only considered the effects of a re-activated volcanic field within Northland. Kear and Thompson (1964) paid particular attention to the nature and age of scoria cones and flows in the Puhipuhi-Whangarei and Kaikohe-Bay of Islands fields. They stated that the most likely type of eruption would be the same as in the past, i.e. ejection of basalt scoria and flow of lava, but from a new vent in the south or east of either field. Based on somewhat subjective indications of age, they suggested an eruption recurrence interval of 1000 to 2000 years for either field and estimated the land area affected by a new eruption to be roughly 10 square miles (26 km^2). Bogalo (2000) did not use available age data or her deposit volume estimates to assess eruption frequency or magnitude, but estimated a maximum extent of ash/scoria ash fall (20 km^2), and average lava flow reach (5 km) within a maximum potential direct-impact area of 78 km^2.

Significantly, no investigation of the potential impact of distal (e.g. TVZ source) eruptions has been made, despite evidence that ash from central North Island and Taranaki volcanoes has frequently fallen on Auckland and Northland regions (Sandiford *et al.* 2001, Shane & Hoverd 2002).

5.4 Suggestions for future work to improve volcanic hazard assessment

(1) ***Examine the frequency of distal (TVZ; Taranaki) ash fall and assess potential impacts on Northland.***

Ash from central North Island and Taranaki volcanoes has frequently fallen on the Auckland and Northland regions. Sandiford *et al.* (2001) and Shane and Hoverd (2002) have demonstrated that at least 80 layers of ash fell on the Auckland region between ~50 ka and 9.5 ka ago, with more than 70 of the tephra beds sourced at distal volcanic centres (Taupo, Okataina, Tongariro, and Taranaki). Most of the layers are 1-2 mm thick but a few are 1 cm or more, and one (Rotoehu ash) exceeds 60 cm at one locality. Many of these tephras also reached Northland, as evidenced by the 14 ash layers found in sediment cored from Lake Omapere (Lowe *et al.* 2002). The Omapere core includes tephra deposited more than 70 thousand years ago and importantly, includes the Kaharoa tephra that erupted ~700 years ago from Okataina Volcanic Centre.

The potential for future ash fall on Northland Region needs to be studied and formally recognised because even one millimetre of ash across part of the region would present a risk of respiratory problems, visibility hazard (contributing to airport closure), disposal problems and some water supply contamination (Table 3). A risk of abrasion-induced mechanical wear and electrical system interference or failure is also presented by thin ash fall.

(2) ***Assess the extent of explosive volcanism in the Kaikohe-Bay of Islands field.***

Basaltic volcanism in Northland has until recently, been regarded as almost entirely effusive in style because lava flows and scoria cones are the dominant surface expressions. Few, if any tuff rings or maars (low cones and craters formed by explosive interaction of magma and water) were recognised in the past because of extensive erosion or their naturally subdued form. An initial stage of phreatomagmatic activity often occurs in small basaltic eruptions, but persistent magma-water interaction or a final phase is rare in Northland. Recent investigations (e.g., Elliot *et al.* 1997, May 2000) have revealed deposits from this explosive style of activity, and recognised their very young age. Phreatomagmatic eruptions can produce dense, high velocity, directed surges (Fisher & Schminke 1984) and consequently, recognition of phreatomagmatic deposits is very important in the assessment of the style of future volcanism.

(3) ***Improve the age/dating of Northland volcanic fields***

There is uncertainty in ascertaining the true age of the most recent eruptions in the Puhipuhi-Whangarei field and particularly the Kaikohe-Bay of Islands field. Radiometric carbon (14C) and potassium/argon (K/Ar) dating techniques have been applied to wood fragments and fresh lava (respectively) but there is a recognised problem with excess non-radiogenic Argon in rock samples. Some K/Ar dates presented by Smith *et al.* (1993) have very large errors, making them only broadly indicative; for example the reported age for sample 44032 (basalt flow; Tauanui, Kaikohe-Bay of Islands) is 60 ka ± 50 ka. There is a natural scarcity of material suitable for 14C dating.

Heming (1980) compared geomorphically young Puhipuhi-Whangarei centres with cones and flows of known age in the Auckland Volcanic Field and suggested some were probably less than 50 thousand years old. Cox (1973) reported a 14C age of 35.5 ka to 36 ka for carbonised wood found beneath lava in the Puhipuhi-Whangarei field, but the more reliable K/Ar dates of Smith *et al.* (1993) provide an age range of ~1 Ma to 0.3 Ma for the Whangarei area and a much older (~10 Ma to 2 Ma) association in the Puhipuhi area.

The age of the Kaikohe-Bay of Islands field is contentious and is based on insufficient age data. Recently published literature includes suggestions that explosive eruptions occurred in the Kaikohe district 4000 to 5000 years ago. At Te Puke volcano near Kerikeri, activity may even have occurred in historic times (as recently as 1800-1300 years ago). Better chronological control must be established in order to test these assertions and to provide the framework for a substantially improved volcanic hazard assessment for Northland. This could be achieved by obtaining new ages for young deposits by carbon-dating of wood, charcoal or peat/organic soil recovered from sites where eruptions appear to have occurred in Holocene times.

5.5 Identified gaps

There is a need to assess the potential hazard to Whangarei District from ash fall from distant volcanic activity i.e. Taupo Volcanic Zone and Taranaki. Work to establish the recent history of ash fall in the district should be a priority. The investigation of suitable lake bed cores would be a useful research initiative.

Improved dating of late Cenozoic volcanism in the district will be important for gaining a better understanding of recent volcanic activity and the probable eruption interval.

Table 3 Impacts of ash falls

Less than 1 mm ash thickness

- Will act as an irritant to lungs and eyes.
- Airports will close due to the potential damage to aircraft.
- Possible minor damage to vehicles, houses and equipment caused by fine abrasive ash.
- Possible contamination of water supplies, particularly roof-fed tank supplies.
- Dust (or mud) affects road visibility and traction for an extended period.

1-5 mm ash thickness

Effects that occur with < 1 mm of ash will be amplified, plus:

- Possible crop damage.
- Some livestock may be affected but most will not be unduly stressed but may suffer from lack of feed, wear on teeth, and possible contamination of water supplies.
- Minor damage to houses will occur if fine ash enters buildings, soiling interiors, blocking air-conditioning filters etc.
- Electricity may be cut; ash shorting occurs at substations if the ash is wet and therefore conductive. Low voltage systems more vulnerable than high.
- Water supplies may be cut or limited due to failure of electricity to pumps.
- Contamination of water supplies by turbidity levels and chemical leachates may occur.
- High water-usage will result from ash clean-up operations.
- Roads may need to be clear to reduce the dust nuisance and prevent storm-water systems may become blocked.
- Sewage systems may be blocked by ash, or disrupted by loss of electrical supplies.
- Damage to electrical equipment and machinery may occur.

5-100 mm ash thickness

Effects that occur with < 5 mm of ash will be amplified, plus:

- Burial of pasture and low plants. Foliage may be stripped off some trees but most trees will survive.
- Most pastures will be killed by over 50 mm of ash.
- Major ash removal operations in urban areas.
- Most buildings will support the ash load but weaker roof structures may collapse at 100 mm ash thickness, particularly if the ash is wet.
- Road transport may be halted due to the build up of ash on roads. Cars still working may soon stop due to clogging of air-filters.
- Rail transport may be forced to stop due to signal failure bought on by short circuiting if ash becomes wet.

100-300 mm ash thickness

Effects that occur with < 100 mm of ash will be amplified, plus:

- Buildings that are not cleared of ash will run the risk of roof collapse, especially large flat roofed structures and if ash becomes wet.
- Severe damage to trees, stripping of foliage and breaking of branches.
- Loss of electrical reticulation due to falling tree branches and shorting of power lines.

> 300 mm ash thickness

Effects that occur with < 300 mm will be amplified, plus:

- Heavy kill of vegetation.
- Complete burial of soil horizon.
- Livestock and other animals killed or heavily distressed.
- Kill of aquatic life in lakes and rivers.
- Major collapse of roofs due to ash loading.
- Loading and possible breakage of power and telephone lines.
- Roads unusable until cleared.

6.0 MINE SUBSIDENCE

6.1 Background

Sub-bituminous coal has been mined at several places in Northland Region, namely at Kamo, Kiripaka, Hikurangi, Kawakawa and Avoca coalfields (Figure 6.1).

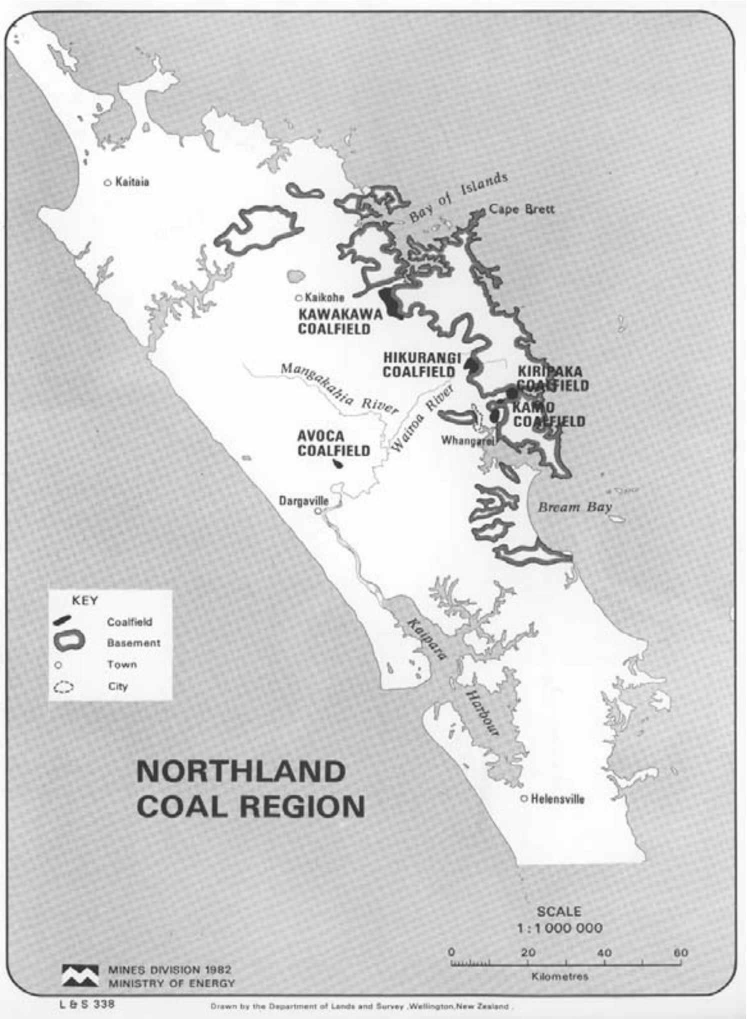


Figure 6.1 Coalfields in the Northland region

At Kamo, some 6 km north of central Whangarei coal was mined almost continuously from 1876 until 1955. The first serious coal production was from the Ruatangata Mine, and together with the Harrisons and Kamo mines, quite large quantities of coal were produced. However production at Kamo ceased in 1955 when the New Kamo No. 3 Mine was flooded by almost unlimited flows of groundwater from the overlying sand and limestone strata. In total some 1.6 million tonnes of coal was produced from the underground mines at Kamo (Kear 1959, Isaac 1985).

6.2 Subsidence occurrence

The risk of surface subsidence due to the underground mining of coal seams is recognised and well studied at Kamo and Hikurangi. However, it appears that the other coal mines have not been investigated for their subsidence potential.

6.3 Subsidence hazard assessment

Kelsey (1980), St George (1981), Tonkin & Taylor (1983, 1984, 1999) and several others in the 1980's have assessed the subsidence hazard from the old coal mine at Kamo. The latest review by Tonkin & Taylor (1999) concludes that the past subsidence studies have been exhaustive and without any new information the current three hazard zones shown on the planning maps should remain unchanged.

It is understood that a similar level of work and review has been undertaken for the Hikurangi coal field, which also underlies part of the Hikurangi township.

Section 38.6 of the Proposed Whangarei District Plan (2003) recognises Mining Subsidence as a natural hazard in mined areas and specifies a well thought out and logical set of requirements that must be met before a new building can be approved for construction. Figure 6.1 subdivides the mine subsidence hazard area into three zones:

Zone 1 (maximum hazard of subsidence). Crown hole subsidence has occurred. Cover is less than 10t - where t is the coal seam thickness. In Zone 1 approximately 20 crown hole subsidences have occurred affecting an area of ~0.2 ha out of a total area of 13ha include in the zone.

Zone 2 (medium subsidence hazard). Subsidence is less likely. 10t is less than the cover which is less than 100m, or 10t is less than the cover which is greater than 100 m for two seam mining (pillaring). In Zone 2 there has been one case of trough subsidence covering and area of 3 ha out of a total area of 105 ha included in the zone

Zone 3 (low subsidence hazard). No subsidence has occurred and cover over the coal is greater than 100 m. Minor trough subsidence may be possible but is considered unlikely to result in significant damage to structures. Zone 3 covers an area of 139 ha.

Shafts and Drives Collapse of shafts and drives (adits) pose specific localised risks to nearby structures and these need to be identified and managed on a case by case basis. If shafts and drives have a potential to collapse and cause subsidence it is our recommendation that they should be included in Zone 1, and their locations clearly shown on the hazard maps.

The three hazard zones are clearly defined over the extent of the old mine workings at Kamo. At Hikurangi, two subsidence hazard zones are shown with explanations that are based on similar logic to that described above for Kamo (Proposed Hikurangi Section 1993 of the

Whangarei District Plan).

Risk. Mine subsidence is included as a natural hazard although it is clear that it is caused by the activities of man. The ground surface subsidence arising from crown hole or trough development would not normally pose a threat of personal injury or loss of life. Overseas experience with such subsidence is that personal injury resulting from it is of negligible significance (Tonkin & Taylor 1999). Initially the greatest threat to personal safety may be when a crown hole develops in a road.

The sudden collapse of an old mine shaft could pose a significant threat to personal safety, and the location and current status (filled, unfilled, capped, type of capping) of shafts should be carefully considered and evaluated.

The risks of mine subsidence need to be considered in the context of other risks associated with natural hazards, in the District.

The relative risk of all the hazards considered are discussed later in the report.

6.4 Conclusions

It is apparent that significant, useful and definitive work has already been carried out to determine the subsidence hazard above the old mine workings at Kamo and Hikurangi, but not at the other old mines. Old mine maps in the possession of GNS confirm the extent of the old mine workings at Kamo and Hikurangi. We have obtained copies of the Kelsey (1980), St George (1981), (and Tonkin & Taylor) reports on which this hazard zonation appears to be based, and we have been able to review the methodology used to assess the subsidence hazard zoning at Kamo. We are satisfied that a useful, practical and workable system is in place to allow for the potential for mine subsidence at Kamo and Hikurangi.

We recommend that the current status of all shafts and drives are carefully evaluated and their locations clearly marked on the planning maps. In addition a check should be carried out on all the other areas of coal mining in Northland Region to ascertain whether mine related subsidence could cause difficulties at these places.

7.0 RECOMMENDATIONS

7.1 Seismic hazard

Seismic microzoning surveys have not been carried out in the Northland Region to assess the degree of shaking amplification that may occur in areas of thick unconsolidated sediment and fill. Microzoning studies, such as those carried out by GNS in south Auckland, Wellington and Whakatane, would characterise the probable shaking response of materials found in the

Northland Region and map out areas susceptible to seismic shaking amplification and possible liquefaction. However, the low level of seismicity and the long recurrence intervals (1,000 years for MMVI and 7,000 years for MMVII) means that seismic amplification and liquefaction are low probability hazards, since significant liquefaction is not expected until MMVII intensity shaking is reached. In this case seismic microzoning is a low priority task

7.2 Landslide hazard

The key to improving knowledge of the landslide hazard in Northland region is the collection and storage of landslide and meteorological data. Better data will enable more accurate identification of the landslide hazard and consequent risk. By linking landslide and meteorological data with slope and geology data, characteristic landslide profiles for different geological units can be developed.

The collection of detailed data on landslides and the adding value to it through comparison with other data sets (e.g. rainfall, slope and geology) will enable landslide hazards to be better identified. GNS is developing a methodology and procedures to improve the reporting of landslides. The data to be collected includes: location, size (affected area, volume of debris, volume of source), type of landslide, causes, trigger, activity, duration, slope angle, geotechnical information and damage. Improving the quality and quantity of landslide data will enable the development of characteristic landslide profiles for individual geological units. Such landslide profiles have the capacity to be a significant resource in the reduction, readiness, response and recovery from landslide hazards.

7.3 Tsunami hazard

GNS has developed a GIS-based method for modelling tsunami inundation using detailed digital topography and the “footprint” of significant built features, such as buildings in urban areas. If this data were available, inundation models for the coast of Northland Region could be produced for a range of possible tsunami landfall heights.

7.4 Volcanic hazard

There is a need to assess the potential hazard to Northland Region from ash fall from distant volcanic activity i.e. Taupo Volcanic Zone and Taranaki. Work to establish the recent history of ash fall in the district should be a priority. The investigation of suitable lake bed cores would be a useful research initiative.

Improved dating of late Cenozoic volcanism in the district will be important for gaining a better understanding of recent volcanic activity and the probable eruption interval.

Separate, partially funded student studies (theses) may be an effective way of achieving these assessments.

7.5 Mine subsidence hazard

It is apparent that significant, useful and definitive work has already been carried out to determine the subsidence hazard above the old mine workings at Kamo and Hikurangi but not at the other mines in the region. GNS has been able to thoroughly review the methodology used to assess the subsidence hazard zoning at Kamo and Hikurangi and is satisfied that a useful, practical and workable system is in place to allow for the potential for mine subsidence that could readily be applied to the other mines.

As well the sudden collapse of a mine shaft could pose a significant threat to personal safety. The location and current status (i.e. filled, unfilled, capped, type of capping) of shafts and near surface drives should be carefully considered and evaluated for all the mines in the region, although this appears to have been done at Hikurangi. We recommend that the locations of these shafts are clearly marked on planning maps for all areas of coal mining in Northland Region.

8.0 ACKNOWLEDGMENTS

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