4. VOLCANO

Note Section 4.2 has been updated to reflect the updated material on volcanic hazard presented at the June 2018 ALG/VISG seminar. Updated volcanic ash posters have been included.

At the June 27 2018 ALG meeting, any further work to be undertaken to update this report will be discussed.

4.1 Summary

The volcanic hazards in the Auckland Region arise from both an Auckland Volcanic Field (AVF) eruption or from ash fall from a distant source eruption outside the region.

- Ash fall can create significant infrastructure impacts such as ash disposal issues for road managers and facility owners, disruption to road and air travel and electricity outages resulting from flashovers with subsequent disruption to other services.
- An AVF volcanic eruption would cause extensive damage to the immediate area surrounding the eruption site as well as widespread effects across the region from ash fall. The severity of the impact will depend on the location and proximity to critical infrastructure and infrastructure 'hotspots'.

The volcanic scenario assessed in this section is the 'Ruaumoko' volcano, taken from a national exercise held in March 2008 which was based around an eruption located in the Manukau Harbour. From an infrastructure perspective this is one of the worst case scenarios (outside a CBD eruption) with significant national impacts on most infrastructure sectors for months to years. Infrastructure impacts are summarised below.

Infrastructure Impacts from the Auckland Eruption Scenario 'Ruaumoko'

Electricity

- Ongoing outages caused by flashovers, for the duration of the eruption.
- Main electricity transmission lines to north and west of region damaged, several weeks to repair causing widespread outages to north, central and west of the region and Northland.

Fuel

- Expected significant damage to Marsden-Wiri fuel line, repair taking up to six months causing national fuel supply disruption for that period of time. Marsden Refinery unable to operate until main electricity transmission lines north restored.
- Most fuel stations unable to dispense fuel in the areas of electricity outages.

Gas

- The pipeline from Onehunga to Mangere Bridge is likely to be breached, with gas supply north of that point disrupted for months, including gas supply to the Otahuhu electricity generation plant.
- Potential to impact on other gas delivery points (ash impact on air intakes to combustion units).

Telecommunications

- Potential ash damage to air conditioning systems which can cause overheating and equipment failures, resulting in disruption to telecommunication systems.
- Cellular and landline coverage intermittent across Auckland, Waikato and Northland and very significant slowdown in broadband speed, due mainly to overloading. Systems will also be disrupted by electricity outages, especially during initial period of fuel disruption where diesel for generators will be limited.

Water Supply

- More than 95% of the water supply is from large, open impoundment dams and river abstraction. Ash in these areas would cause increased turbidity, fluoride levels, acidification creating challenging treatment conditions and other water quality issues. Transmission systems may be damaged by ash.
- On top of these issues, there would be increased demand for water for cleaning ash and further impacts from electricity / fuel disruption.
- Restoration of treatment and transmission systems destroyed or damaged by ash or eruption could take months or years.

Wastewater and Stormwater

- Wastewater Treatment Plant processes disrupted and plant and equipment damaged by ash and debris.
- Restoration of Treatment and Transmission systems destroyed or damaged by ash or eruption could take months or years.
- Flooding issues where ash fall clogs wastewater and stormwater pumping and collection systems.

Air Transport

- Air space closure, likely for duration of eruption, with significant national economic impacts (Auckland Airport receives the majority of international transport into New Zealand).

Road Transport

- Ash on road hampers the movement of people for evacuation as well as access for lifelines to critical infrastructure for repairs and maintenance.
- SH 20 near Manukau Harbour closed for weeks (months if SH 20 Manukau Harbour Bridge damaged).

Solid Waste Disposal

- Major disruption to collection networks due to road disruptions.
- Will need to find emergency disposal process for ash if landfill space exceeded.

Response and Recovery Activities

Lifeline utilities would operate in accordance with their own emergency management procedures, guided by the Volcanic Ash posters, which are provided in this section.

Social and Economic Consequences

As part of the lead-up to the Ruaumoko Exercise, a study was undertaken to identify the potential economic impacts of an AVF eruption along with techniques to minimise impacts and ensure a quick recovery. To assess economic impacts, a 'worst case scenario' Rangitoto Island size eruption located at Mt Eden was used.

The scenario resulted in the displacement of 200,000+ residents and disruption to 40,000 businesses. From an infrastructure perspective, SH16 and SH1 roads were closed with widespread disruption to most infrastructure sectors.

A number of social and economic consequences were modelled which predicted that, in the year following the eruption:

- Auckland's gross domestic product (GDP) would decline 40-50%.
- Between 200,000 and 300,000 jobs would be lost in the Auckland region.
- New Zealand's GDP and employment rate would decline by around 10-15%.

4.2 Auckland's Volcanic Hazards[1]

Local Source Volcanoes

The Auckland Volcanic Field

Metropolitan Auckland is built directly on the Auckland Volcanic Field (AVF). The AVF covers an area of 360km^2 and comprises an estimated 53 small "monogenetic" basaltic centres in the form of maars, tuff rings, scoria cones and associated lava fields.

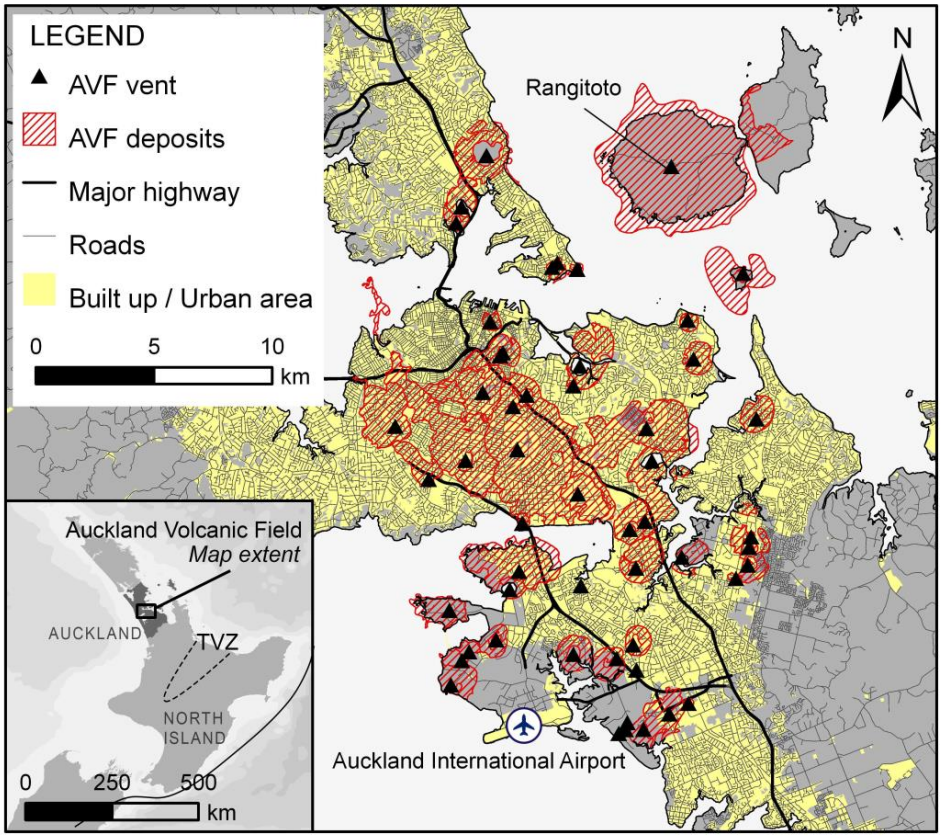


Figure 4-1: Distribution of Auckland Volcanic Centres

The field is an 'intraplate' field not related to the main Plate Boundary subduction zone and has been active from ca. 200,000 to 550 yBP (Rangitoto). Volcanic activity has been highly episodic over this time. A major flare-up of volcanic activity occurred in the period 25,000 – 35,000 years BC. In contrast, very little volcanic activity has occurred in the last 10,000 years. It is therefore very difficult to estimate when the next episode of volcanic activity will occur.

Types of Volcanoes

In the event of a future eruption, if rising magma passes through water or rocks with high moisture content (Maars or explosion craters), such as the Waitemata Group sediments, the eruption will typically begin with an explosive phreatomagmatic phase. The resulting explosions generate highly destructive base surges and convecting ash columns and form an explosion crater (e.g. Lake Pupuke, Orakei basin, Onepoto).

[1] Information for this section was sourced from presentations at the 2018 ALG/VISG Seminar by Jan Lindsay and Thomas Wilson. Presentations are available at http://www.aelg.org.nz/events/alg-and-visg-2018-seminar-papers/

If rising magma passes through relatively dry rock, or if the water source is used up, fire-fountaining and ash fall leads to the development of a scoria cone (e.g. Mt. Wellington, Mt Eden, Three Kings) and lava flows. Individual vents often display several different eruption styles (Smith and Allen, 1993; Houghton et al. 1996) as the amount of magma:water interaction changes through the course of an eruption.

Auckland's volcanoes are generally small with most <150m in height and with volumes of <0.1 km^3 ($10^6 m^3$). Tuff rings and maars are typically <1 km in diameter. The youngest centre, Rangitoto, has produced the largest volume of lava erupted in the AVF (~2 km^3). It is currently unknown whether this represents an anomaly, or the start of a period of larger eruptions in the field.

AVF Hazards

In summary, the hazards from and AVF eruption include:

- **Edifice formation** (explosion crater, scoria cone, fissure)
- **Base surges** (fast moving clouds of ash, gases and debris)
- **Tephra fall** (fine ash as well as larger particles)
- **Ballistics** (large pieces of lava thrown out of the vent)
- **Lava flows** (magma erupting effusively; ocean entry)
- **Gases** (mostly H2O, CO2 and SO2)

Likelihood of an Eruption

A simple calculation of the average number of eruptions per year in the 200,000 year history indicates an eruption rate of around 1 eruption every 3,600 years.

However, in the late 60,000 years there has been an increased eruption rate with a recurrence of between 1,500 – 2,600 years.

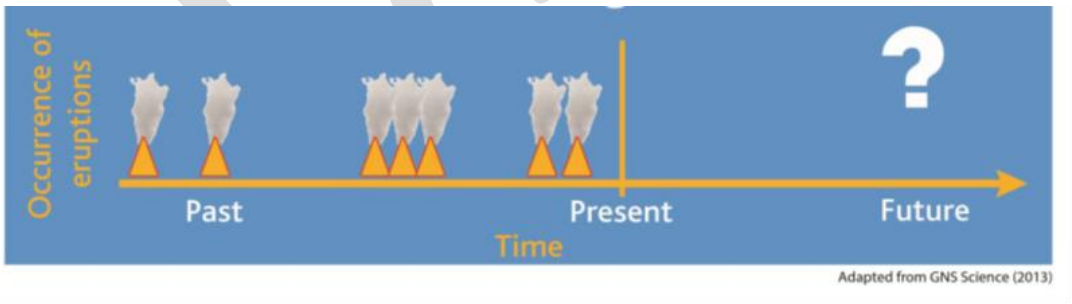


Figure 4-2: Likelihood of Local Basaltic Eruptions in Auckland

Distal Source Volcanoes

In addition to the risk posed by a local eruption in the Auckland Volcanic Field (AVF), Auckland is at risk from ash fall from eruptions at several large and frequently active andesitic and rhyolitic volcanoes in the central North Island, 140-280 km to the south and southeast, as well as from any reawakening of volcanic activity in Northland.

The central North Island volcanoes are characterised by relatively large and frequent eruptions. Eruptions from New Zealand stratovolcanoes such as Ruapehu and Egmont occur, on average, every 50 to 300 years and continue for weeks to months. Activity at caldera volcanoes is characterised by far less frequent (on average every 1000 to 2000 years) but larger eruptions capable of generating huge ash volumes that can be distributed many hundreds of kilometers downwind. Whether or not ash from any given distant eruption will reach Auckland, and the thickness of any associated ash fall deposit, will depend on a number of factors including the style, size and duration of the eruption, and importantly, the wind direction (Newnham et al. 1999).

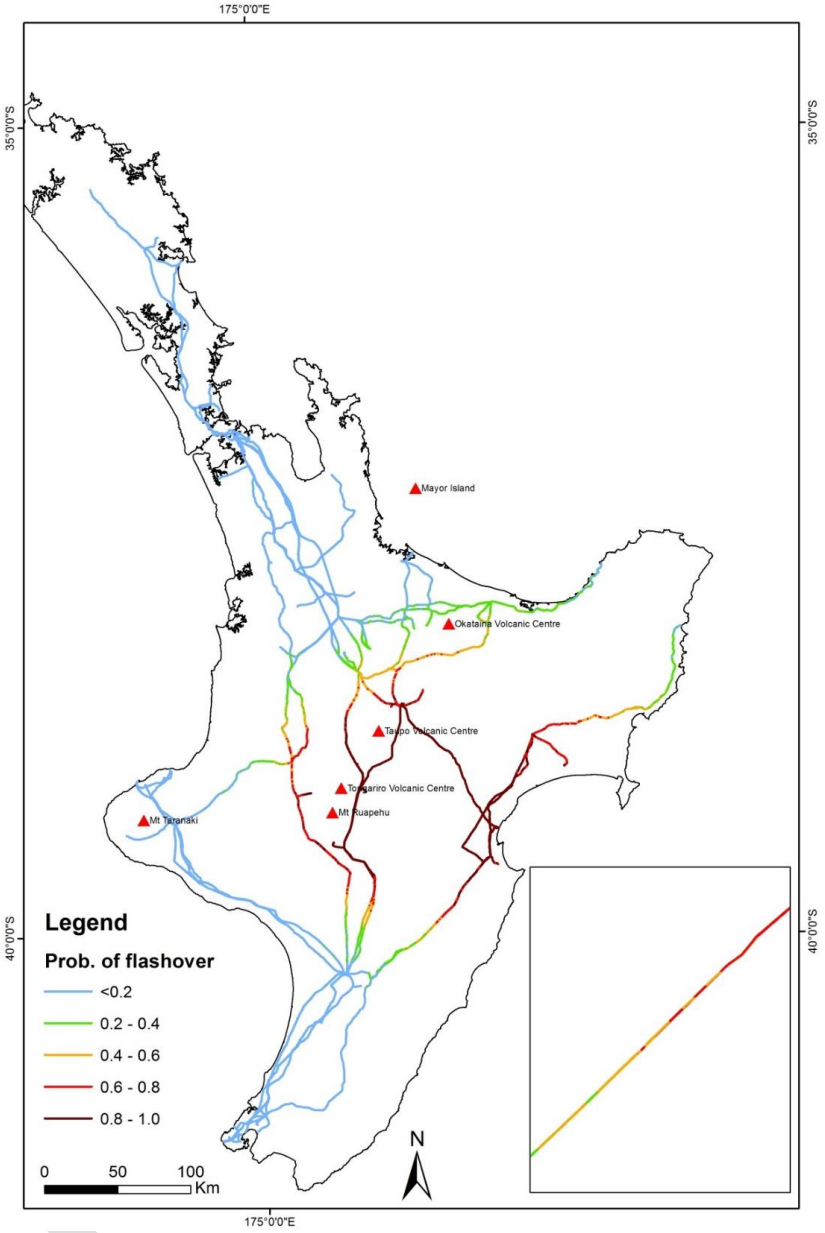


Figure 4-3: Ash hazard exposure, North Island 500 year return period

Over the last 80,000 years, eruptions from distant volcanoes have deposited at least 82 different tephra (eruption material) layers >0.5 mm thick in the Auckland area (Wright et al 2009). The majority of these are from Egmont volcano (52), with the remainder deriving from Okataina and Taupo (21), Tongariro (7) and Mayor Island (2). Over the same time period, local AVF eruptions have produced 24 tephra layers.

Volcanic Source	**Minimum frequency**
Okataina Volcanic Centre	Once every 3,000 years
Taupo Volcanic Centre	Once every 1,300 years
Mayor Island	Once every 9,000 years
Taranaki Volcanic Centre	Once every 3,000 years
Tongariro Volcanic Centre	Once every 2,200 years
Auckland Volcanic Field	Once every 3,000 years
Total – all sources combined	**Once every 400 years**

Table 4-1 Estimated minimum frequency of tephra fall from local and distal volcanoes in Auckland over the last 11,000 years

'Exercise Ruaumoko' Scenario

In 2008, a significant amount of work was undertaken to assess volcanic hazard scenarios for *Exercise Ruaumoko* (a national CDEM exercise). Exercise Ruaumoko illustrated the criticality of Auckland to the NZ economy and the vulnerability of its infrastructure. The Ruaumoko eruption commenced with steam emissions through the shallow waters of Mangere Inlet, less than 500m offshore from Kiwi Esplanade (Figure 4-3). Small explosions throwing rock fragments ~100m into the air in vertically directed dark plumes began less than an hour later.

The volcanic hazards associated with the Ruaumoko eruption scenario are summarised as follows:

- A 0.5 – 0.7km wide explosion crater surrounded by a 50m high tuff ring rampart of coarse ash and scoria.
- Base surges affect areas within 2km from the vent in all directions.
- Fire fountaining (and ash column) and the eruption lasts 35 days, creating a 150 m high scoria cone.
- Undisturbed ash deposits within 10 km are up to 10-100mm (thicker in south east downwind direction). Heavy tephra fall (>64mm thickness) occurring within 3 km of vent. Ash continues for up to 6 months.
- Lava flows fill much of the harbour in the Onehunga Wharf area blocking Mangere Inlet causes water from catchment drainage to begin ponding east of Mangare Bridge and local flooding of upstream shorelines.
- Emission of CO^2 and other volcanic gases from the vent area.
- Volcanic induced seismic tremors of up to M4.5.

Figure 4-4: Ruaumoko volcano on day 35 (ash deposits not shown).

Central Auckland Scenario

As part of the lead-up to the Ruaumoko Exercise, a study was undertaken to identify the potential economic impacts of an AVF eruption along with techniques to minimise impacts and ensure a quick recovery. To assess economic impacts, a 'worst case scenario' Rangitoto Island size eruption located at Mt Eden was used (Figure 4-4), causing a 3 km-radius devastation zone around the volcano, with a 5km-radius evacuation zone anticipated prior to the eruption.

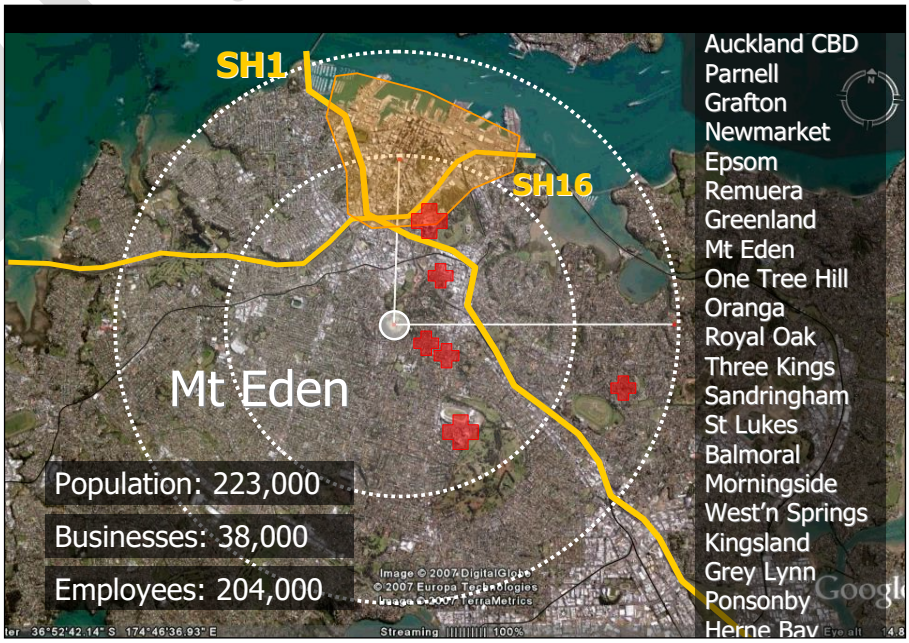


Figure 4-5: Mt Eden, Devastation and Evacuation Zones, Impacted Areas and Consequences.

4.3 Overview of Infrastructure Impacts

Localised Impact of Auckland Volcanic Field Eruption

An eruption in the AVF is likely to have severe infrastructure impacts within a few kilometres from the eruption vent due to hazards such as ground shaking, lava flows, lava bombs, base surges and the creation of a volcanic crater or cone (Table 4-3).

Beyond a few kilometers from the eruption vent, lava flows and ash will present the major hazard to infrastructure. These impacts will be similar to those posed by ash fall from distant source eruptions.

The localised impacts on Auckland's infrastructure from an AVF eruption would vary significantly depending on the location of the most explosive, damaging activity. If the eruption was centred near one of the Infrastructure Hotspots identified in Part A, Section 2, or on a 'nationally significant' piece of infrastructure, it will potentially result in months or even years of disruption to the impacted sector/s. As discussed in section 2, major disruption to any one of these sectors will also result in knock-on impacts on others.

Hazard	Area Affected*	Immediate Risk	Ongoing Risk	Anticipated Loss	Mitigation	Recovery Period following Cessation of Activity
Earthquake	3 – 5	Low	Nil	Small	Not applicable	Not applicable
Crater, Cone or Ring Formation	0.3 – 1.5	Extreme	Low	Extreme	None	Several months to years
Fire Fountaining*	0.2 – 0.5	High	Low	Extreme	Minor	1 week to several months
Lava*	3 – 5	High	Low	High	Moderate	Several weeks to several months
Base Surge	3 – 5	High	Low	Extreme	None	1 week to several months
Shock Waves	3 – 5	High	Low	High	None	1 week to several months
Lava bombs*	0.4 – 0.5	Moderate	Low	Moderate	Minor	1 week to several months
Airfall Tephra	3 – 100	Low	Moderate	Low	Moderate	1 week to several months
Gas	3 – 5	High	Moderate	Moderate	Minor to Moderate	Not applicable
Lightning	3 – 100	Low	Low	Low	None	Up to 1 – 2 days
Tsunami	1	Low	Nil	Low	Moderate	Up to 1 – 2 days
* Events which are likely to be repeated over a period of time (weeks to months) following the initial event						

**(radial distance from vent, km)*

Table 4-2: Infrastructure Impacts near to Event

Volcanic Ash Impacts

Since the completion of AELP-1, the AELG has undertaken a number of studies to improve its understanding of potential ash impacts on infrastructure. The impacts on each sector described in the following sections draws on this knowledge and summarises the expected impacts on Auckland's infrastructure from volcanic ash, either caused by an AVF eruption or from an eruption in the central North Island. More detailed reports are available at:

- *http://aelg.org.nz/document-library/volcanic-ash-impacts/*

Auckland Volcanic Scenarios

As part of Exercise Ruaumoko (a national CDEM exercise in November 2008), an analysis was carried out on a volcanic eruption in the Manukau Harbour. The infrastructure impacts are described in the following sections. A report on Exercise findings and learnings is available at:

- http://aelg.org.nz/document-library/emergency-management-reports/

As part of the Exercise planning, the infrastructure impacts of a central Auckland volcanic eruption was analysed, along with the social and economic impacts. These findings are summarised in Section 4.8.

4.4 Energy

Electricity Impacts

The primary ash impacts are ongoing outages caused by flashovers, for the duration of the eruption. In the Ruaumoko scenario, the main electricity transmission lines to north and west of region are damaged, taking an estimated several weeks to repair and causing widespread outages to north, central and west of the region and Northland. The estimated impacts are detailed in Table 4-4.

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Ash buildup on insulators causes flashover resulting in electricity outages (possible even in light ash fall). More likely if ash is fine and light rain is present. Restoration of these outages is dependent on location and number of outages as well as how widespread the ashfall is nationally which affects the number of resources available and ability to access the networks. ▪ Outdoor switchyards and overhead lines are more vulnerable to volcanic ash falls than indoor substations and underground cables. In the Central Auckland area Vector and Transpower are mostly indoor and underground, however these systems rely on overhead transmission lines lines from Penrose and Mount Roskill, which would need to be kept operational during any ashfall. Outside Central Auckland Overhead Lines and outdoor switchyards are predominately used. ▪ In heavier ash falls (> 100mm) ash loading can cause damage to lines, towers and poles (fine ash is higher risk). ▪ Control buildings and indoor switchgear buildings could collapse under weight of ash fall unless designed to withstand or ash not cleaned off. ▪ Access to outdoor switchyards could become restricted due to dangerous step/touch potentials, may delay restoration times until effects of ash fall can be mitigated and cleared. ▪ Ash penetration causes corrosion, blocks air intakes, causing breakdown of substation and control equipment, potentially causing weeks to months of disruption if major damage. ▪ Short notice outages to supplies may be required to enable cleaning or prevent flashovers.	▪ Damage to transmission lines estimated to take several weeks to repair using temporary new structures and conductors. ▪ Transpower estimated in the worst case loss of approximately 3.8km of the 220kV link from Henderson to Otahuhu (causing widespread outages in North and West Auckland and Northland) in conjunction with a similar length of the 110kV links from Penrose and Mangere. (However the completion of the NAaN cabling project in 2013 will mitigate the impact of loss of these lines in future). ▪ Ash fall was estimated to disrupt transmission from Mt Roskill to Henderson. Shut downs for distribution lines and transformers (flashovers, overheating) were needed to enable cleaning.

Table 4-3: Electricity Impacts: Volcano

Gas Impacts

Volcanic ash has the potential to impact on gas delivery points (ash impact on air intakes to combustion units). In the Ruaumoko scenario, the pipeline from Onehunga to Mangere Bridge is likely to be breached, with gas supply north of that point disrupted for months, including gas supply to the Otahuhu electricity generation plant. The estimated impacts are detailed in Table 4-5.

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Minimal physical impact on assets, most underground. ▪ Ash may affect water bath heaters by clogging air intakes to combustion units. This may cause transmission delivery points to malfunction causing possible loss of supply into connected downstream gas distribution networks. ▪ Gas supplies to domestic, commercial and industrial consumers across Auckland. Supplies to Auckland power stations at Otahuhu and Southdown also affected.	▪ Likely to breach pipeline from Onehunga to Mangere Bridge which serves the Otahuhu electricity generation plant. Gas supplied north of the breach point and to Otahuhu plant disrupted for months. ▪ Earthquakes cause concern over major pipelines in the area outside evacuation zone, leading to reduced supply (pressure reduced).

Table 4-4: Gas Impacts, Volcano

Fuel Impacts

Ash build-up may cause issues for tanks at Wiri Oil Depot. In the Ruaumoko scenario, there is expected significant damage to Marsden-Wiri fuel line, with the repair taking up to six months causing national fuel supply disruption. Marsden Refinery is unable to operate until main transmission lines north restored. Most fuel stations unable to dispense fuel in the areas of electricity outages. The estimated impacts are detailed in Table 4-6.

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Ash build up on floating roof tanks to be monitored at WOSL ▪ Possible restriction on use of floating roof tanks decreasing amount of product capable of being stored at the Wiri Terminal ▪ Supply of some products directed from other terminals ▪ Fuel stations in areas of affected electricity outages will be unable to pump fuel unless they have standby generation.	▪ Stocks reduced at Wiri Terminal (45 million litres on site, equal to 5 days supply) as eruption imminent, to reduce risks. Terminal later evacuated/closed. ▪ Pipeline from Marsden Point refinery closed (risk of 1.5 million litres released into waterways should fracture or rupture of pipeline occur) and section across Mangere Inlet was damaged - repair could take 6 months or more. ▪ Aircraft operators would need to make arrangements for refuelling other than at Auckland International Airport. Trucking of jet fuel not possible. ▪ Marsden Refinery affected by electricity supply disruption.

Table 4-5: Fuel Impacts, Volcano

Response and Recovery Plans

Response and recovery activities for the energy sector are summarised in Table 4-7. The electricity sector would also be guided by the volcanic ash poster (Figure 4-5).

Sector	Plans Activated	Specific Response Activities
Electricity	▪ Vector Emergency Response Plan (Specific event guide – Volcanic Eruption) ▪ Transpower System Operator Contingency Plans for Supply Restoration, Emergency Management Plans, including possible rolling blackouts to manage load ▪ Transpower Business Continuity Plan	▪ Systematic assessment of impacts and resources available to address them. ▪ In the event of large scale supply loss, an approved plan for restoring supplies will begin depending on equipment availability. ▪ In the event of demand exceeding capacity to supply, then an approved plan to manage load will be implemented. ▪ Should Auckland facilities put personnel and operations at risk, functions will relocate to pre-agreed fallback sites. ▪ Where an extended loss of supplies results from Transpower's network, the National Communications manager will handle all responses to the media, usually via Senior Transpower Management.
Vector-Gas	▪ Emergency Response Plan ▪ Critical Contingency Management Plan ▪ Crisis Management Plan ▪ Critical Contingency Operator Plans	▪ Isolation of any damaged sections of pipeline to make situation safe. ▪ Curtailment of demand to attempt to secure long term security of supply. ▪ Mobilisation of resources and emergency spares.
Refining NZ (Oil Pipeline)	▪ Emergency distribution controlled through C.O.L.L (Coastal Oil Logistics Ltd) ▪ Emergency repairs where possible	▪ Assess damage and activate repair plan. ▪ Activate liaison with Vector Gas Ltd and P.O.G (Pipeline Operators Group) Australia for any assistance or resources. ▪ Crisis Centre activated at Refinery for liaison with C.O.L.L. as to best means for fuel distribution with given circumstances ▪ Consider 'floating storage' at Ports of Auckland container wharf with temporary manifold and controlled by Military for loading of trucks.
WOSL	▪ Activate WOSL ERP Procedures	▪ Emergency distribution controlled through C.O.L.L (Coastal Oil Logistics Ltd). ▪ Emergency repairs where possible.

Table 4-6: Energy Sector Response and Recovery Activities

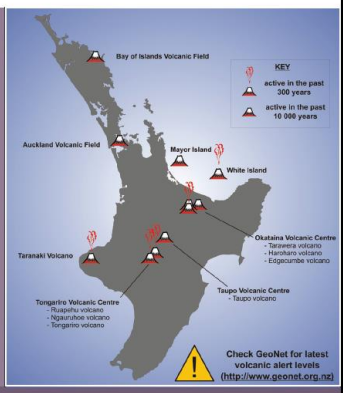
VOLCANIC ASH FALL

ADVICE FOR POWER TRANSMISSION AND DISTRIBUTION SYSTEM OPERATORS

VOLCANIC ASH IS: HARD, HIGHLY ABRASIVE, MILDLY CORROSIVE AND CONDUCTIVE WHEN WET.

IMPACTS ON TRANSMSSION AND DISTRIBUTION NETWORKS

- **Insulator Flashover :** Ash contamination of station and line insulators can lead to flashover.
  - » Flashover may occur with <3 mm of ash fall provided a significant portion of the insulator creepage distance (>50%) is covered in wet ash
  - » This is the most common and widespread impact
- **Loading Damage :** ash accumulation may overload lines, weak poles and light structures, and cause additional tree-fall onto lines. Precipitation will exacerbate the risk:
  - » Loading damage typically occurs with >100 mm ash accumulation
  - » Induced tree fall from ash load may occur with thicknesses >10 mm
- **Disruption to Control Systems :** ash ingress into heating, ventilation and air-conditioning (HVAC) systems can block intakes leading to reduced performance, and affecting dependent systems:
  - » Possible during any thickness of ash fall
- **Earth Potential Rise :** Ash may reduce the resistivity of substation ground gravel cover, reducing tolerable step and touch voltages:
  - » Not observed, but theoretically possible.



INSULATOR FLASHOVER

ASH RESISTIVITY AND ASH COVERAGE OF THE PROTECTED LEAKAGE (CREEPAGE) DISTANCE OF INSULATORS ARE THE PRIMARY CONTROLS ON FLASHOVER LIKELIHOOD

- Dry ash is highly resistive. Wet ash can be highly conductive:
  - » Light precipitation (dew, fog, drizzle or light rain) wets ash which initiates a leakage current, leading to flashover
  - » Heavy rain will wash off contaminants, and high winds will clean non-cemented dry ash from insulators
- Flashover may occur with <3 mm of ash fall provided a significant portion of the insulator creepage distance (e.g. >50%) is covered in wet ash
- Ash adherence is often variable, ranging from non-binding to cementing. Fine grained ash (<0.5mm) typically adheres and cements to insulators more readily
- Insulator profile, orientation and material will influence its ability to shed or retain ash:
  - » **Material:** Non-ceramic (e.g. polymer) insulators generally outperform ceramic designs and have smaller shed diameters which appear to shed ash more effectively
  - » **Design:** Anti-pollution insulator designs can increase performance
  - » **Orientation:** evidence suggests suspension (vertical) insulator strings are generally more vulnerable, but this depends on the direction of falling ash and weather conditions
- Overseas experience suggests over-insulation (increasing creepage distance) and clean insulators are the most effective mitigation. See **IEC TS 60815 'Selection and dimensioning of high-voltage insulators for use in polluted conditions'.**

3 mm of ash fall cover on a glass insulator string inducing a flashover. Note how the current is tracking through the volcanic ash covered insulator surface

SUBSTATIONS

- Specialist inspection and cleaning procedures may be required for substation insulators, power transformer HVAC systems and control systems
- Ash may reduce the resistivity of substation ground gravel cover, reducing tolerable step and touch voltages

RECOMMENDED ACTIONS

WHERE TO FIND WARNING INFORMATION

See **www.geonet.org.nz** for ashfall forecasts in the event of an explosive eruption.

HOW TO PREPARE

- Cleaning ash contaminated sites and components, especially insulators, is commonly required after an ash fall. Ensure availability of both live-line and de-energised cleanup plans which include:
  - » Priority schedule for inspecting/cleaning essential sites and lines
  - » Standardised ash fall clean-up procedures
  - » Ready access to cleaning supplies and equipment (air compressors, water-blasters, PPT gear, vehicle air filters, etc.)
- Cleaning Guidance: see **IEEE Std 957 'Guide for Cleaning Insulators'. Experience suggests:**
  - » Ensure all insulator surfaces are cleaned, including undersides of weathersheds
  - » Insulator cleaning method will be determined by strength of ash adherence
- Field crews should use safe operating procedures when operating in an 'ashy' environment. See **www.ivhhn.org** for guidelines for protecting people from ash hazards
- Coordinate with local, regional and national emergency planning, as appropriate

HOW TO RESPOND

- Initiate priority schedule for inspection and cleaning. Increased inspection and preventive maintenance may be prudent
- A proactive communication campaign for customers/public covering your response, expected outages/restoration times and recommended actions aids awareness and good will
  - » Advise customers not to clean electrical equipment and to be careful when using hoses near electrical equipment.

Ash is cleaned from a 220 kV strain insulator string using pressurised water following the 1995 Ruapehu eruption, New Zealand (Transpower New Zealand)

MORE INFORMATION

THE FOLLOWING RESOURCES PROVIDE FURTHER INFORMATION ON VOLCANIC HAZARDS:

http://www.geonet.org.nz
http://www.gns.cri.nz
http://volcanoes.usgs.gov/ash/index.html
http://www.ivhhn.org

DRAFTED BY TOM WILSON, CAROL STEWART AND JOHNNY WARDMAN.
28 May 2013

UC University of Canterbury — Te Whare Wānanga o Waitaha Christchurch New Zealand
Auckland Engineering Life Lines
Massey University
GNS Science Te Pū Ao

Figure 4-6: Volcanic Ash Poster, Electricity Transmission and Distribution

ADVICE FOR POWER PLANT OPERATORS

VOLCANIC ASH IS: HARD, HIGHLY ABRASIVE, MILDLY CORROSIVE AND CONDUCTIVE WHEN WET.

VOLCANIC ASHFALL

IMPACTS ON POWER GENERATION FACILITIES

GENERAL IMPACTS:

- **Flashover:** Ash contamination of station and line insulators leading to flashover is the most common impact at power plants
  - » See companion poster "Advice for Power Transmission and Distribution System Operators"
- **Step/Touch Potential:** ash may reduce the resistivity of ground gravel cover, reducing tolerable step and touch voltages
- **Disruption to Control Systems:** ash ingress into heating, ventilation and air-conditioning (HVAC) systems can block intakes leading to reduced performance, and affecting dependent systems
- **Structural damage:** Very thick ash deposits (>100 mm) may create excessive loads on structures
  - » Long span, low pitched roofs are typically the most vulnerable
  - » When ash is wet, static loads may increase by up to 100%
- **Internal gutters:** may block with ash, potentially leading to water ingress to indoor electrical equipment.

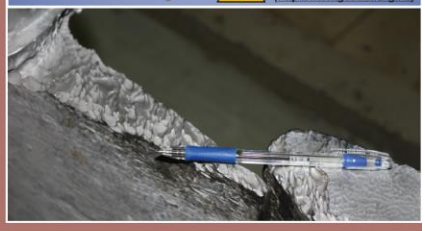
HYDROELECTRIC POWER STATIONS

- Ash suspended in intake water can cause accelerated wear of hydroelectric turbines (e.g. runner blades, labyrinth seals, cheek plates and wicket gates)
  - » Hazard depends on volume of ash deposited in catchment, reservoir size, settling rate of ash, abrasiveness of ash
- Ash may also fill rain gauges in climate stations throughout river and reservoir catchments.

THERMAL POWER STATIONS

There are few case studies to guide possible impacts or advice.

- Ash may block air intakes for gas turbines and boilers, or sub-aerial condenser systems causing blockages, abrasion and creating cleaning difficulties
  - » Ash falls have created airborne particle concentrations of up to 9 g m^{-3}, several times higher than dust- or sand-storms
- Mechanical seals may be vulnerable to abrasion and corrosion by ash
- Fine ash ingested into gas turbines may cause accelerated wear or melt on turbine surfaces (similar to an aircraft turbine)
- Ash may contaminate exposed surface water cooling reservoirs, potentially blocking heat-exchange systems.



Accelerated abrasion damage to wicket grates from Agoyan HEP, Ecuador. Normal design life of turbines at this plant is 6-7 years, but this has been reduced to 5 years due to ashfalls from nearby Tungurahua volcano contaminating reservoir water.

The October 1995 eruptions of Ruapehu volcano deposited 7.6 million m^3 of coarse ash into the Tongariro river catchment, leading to high levels of suspended ash. This catchment feeds the Rangipo power station (120 MW). While generation remained continuous throughout the eruption, two Francis turbines and all auxiliary components that had been in contact with ash-laden intake water were found to have suffered greatly accelerated abrasion damage, with 16 years' damage sustained in 6-7 months. A refurbishment program installed hardened components. Turbidity instrumentation was also installed at the intake point which is closed when thresholds are exceeded.

RECOMMENDED ACTIONS

WHERE TO FIND WARNING INFORMATION

See www.geonet.org.nz for ashfall forecasts in the event of an explosive eruption.

HOW TO PREPARE

At-risk power generation facilities should develop operational plans for ash fall events, including:

- Install turbidity monitoring instrumentation at intake and identify threshold for intake closure
- Priority schedule for inspecting/cleaning essential sites and components
- Site cleanup may be required following an ash fall. Cleanup plans should include:
  - » Standardised ash fall clean-up procedures, suitable to your local conditions and site
  - » Stock or have access to sufficient supplies and equipment for cleaning;
  - » Clean up and additional maintenance can create significant additional labour and resource demands
  - » Insulators usually require cleaning. See the companion "Transmission and Distribution " poster and IEEE Std 957 "Guide for Cleaning Insulators". Ensure that roofs and similar elevated areas where ash accumulation will need to be removed, have pre-installed fall arrest anchor points and that a safe means of access is identified
- Field crews should use safe operating procedures when operating in an 'ashy' environment. See www.IVHHN.org for guidelines for protecting people from ash hazards
- Transmission/distribution lines feeding the generation site may be disrupted and require additional planning – see "Transmission and Distribution " poster
- Hydroelectric plant (HEP) facilities may consider hardening turbines during design and refurbishment programmes.

HOW TO RESPOND

- Consider increased inspection and preventative maintenance
- Seal key facilities to limit ash ingress.
  See companion "Facilities Managers: Buildings" poster
- Clean up site to reduce remobilisation of ash and thus recontamination of energised components. Use dry methods where possible
  - » Remove ash from gutters to avoid localised flooding
  - » Internal gutters may require suction cleaning
- Be aware of increased electrocution hazard if ash covers the ground. Isolate and earth energised apparatus before entering site
- **Hydroelectric Power Plants :** Monitor the suspended solid load in water intakes. Be mindful of volcanic debris flows (lahars). Consider by-passing turbines, if necessary
- **Geothermal/thermal:** assess ash hazard and consider shut-down if necessary.

MORE INFORMATION

THE FOLLOWING RESOURCES PROVIDE FURTHER INFORMATION ON VOLCANIC HAZARDS:

http://www.geonet.org.nz
http://www.gns.cri.nz
http://volcanoes.usgs.gov/ash/index.html
http://www.ivhhn.org

DRAFTED BY TOM WILSON, JOHNNY WARDMAN AND CAROL STEWART.

20 September 2013

UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND
Auckland Engineering Life Lines
Massey University
GNS SCIENCE TE PŪ AO

Figure 4-7: Volcanic Ash Poster, Electricity Plant Operators

4.5 Telecommunications

Sector Impacts

Ash can cause damage to air conditioning systems which can cause overheating and equipment failures, resulting in disruption to telecommunication systems. In the Ruaumoko scenario, cellular and landline coverage intermittent across Auckland, Waikato and Northland and very significant slowdown in broadband speed, due mainly to overloading. Systems will also be disrupted by electricity outages, especially during initial period of fuel supply disruption where diesel for generators will be limited. Impacts are further detailed in Table 4-8.

Telecommunications exchanges are housed in buildings and will be impacted as described in Further impacts are detailed in Figure 4-8: Volcanic Ash Poster, .

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Minimal impact to over-the-air broadcasting and microwave or satellite transmission. ▪ May affect electronic equipment at exchanges or cellsites either through ingress into the equipment or by clogging air conditioning filters which can result in over-heating. Frequent replacement of such filters may be required (more likely to causes problem in summer when there is more reliance on cooling). ▪ As with any major event, network congestion may be expected in the immediate aftermath of an event (or public information release regarding expected eruption), with potential to cause blocked calls, congested data service etc. ▪ Electricity outages would cause disruption to telecommunication services.	▪ Cellular and landline coverage intermittent across Auckland, Waikato and Northland and very significant slowdown in broadband speed, due mainly to overloading. ▪ Delays occurred in delivering text messages between Telecom and Vodafone networks. ▪ Telecommunication disruption may interrupt much remote control and communication capability, EFTPOS and inter-bank transactions. ▪ Ash likely to impact on many facilities including cell-sites. ▪ If expected damage to major electricity transmission lines occur, telecommunications in north, central and west of the region likely to be significantly disrupted.

Table 4-7: Volcanic Impacts, Telecommunications Sector

Response and Recovery Plans

The sector would activate their emergency management framework. Specific response activities include:

- Review stocks of resources such as:
  - aircon filters that are likely to require replacement.
  - PPE for field contractors
- Review H&S procedures in relation to volcanic ashfall hazard and communicate requirements to contractors.
- Maintenance schedule for clean-up and PPM of access network properties (cellsites etc).
- Review need for any additional measures to prevent ingress of ash to exchanges and core nodes and implement as required.

Figure 4-8: Volcanic Ash Poster, Buildings

4.6 Transport

Sector Impacts

Air space closure is likely for duration of eruption, with significant national economic impacts (Auckland Airport receives the majority of international transport into New Zealand).

Ash will hamper movement on road networks, with particular issues for the movement of people for evacuation as well as access for lifelines to critical infrastructure for repairs and maintenance.

Further impacts are detailed in Table 4-9.

General Ash Impacts	'Exercise Ruaumoko' Impacts
Roads ▪ Build-up on roads causes driving hazard. Windy conditions can exacerbate (visibility issues) as can wet conditions (ash become slippery). ▪ Large volume of volcanic ash to be cleared and disposed of. Finer ash is likely to be harder to handle. AELG-13[2] estimated 835,000m3 to clear roads in Metropolitan areas (excludes Rodney and Franklin Districts) and an additional 480,000 m3 off roofs and paved areas. ▪ A safe close by disposal site will need to be established ▪ Thick, wet ashfall may cause overloading of bridges, however only pedestrian bridges and low load rural bridges are likely to be vulnerable. ▪ Ash can ingest into engines, block filters and abrade the engine and other mechanical parts. ▪ Ash, particularly when wet can accumulate in drainage outlets resulting in blocking and consequent flooding.	▪ Extensive damage to both SH 20 and possibly SH1 plus other arterial roads from direct impacts, seismic, lava, ash and wave activity. ▪ Extensive ash clearance required, initially for main routes and needs of emergency vehicles and other vehicles involved in response activities and/or delivery of priority goods/services. ▪ Significant disruption to traffic, and to delivery of essential supplies. ▪ On-ramps to Southern Motorway from Northern and Northwest Motorways closed. ▪ Off-ramps closed from Green Lane to Mt Wellington. ▪ All other major arterial roads within 5 km of eruption zone closed. ▪ Mangere Bridge (if not destroyed) would need detailed inspection, requiring 2 weeks from date access allowed to the site. ▪ Rebuilding of Mangere Bridge and Onehunga Bay Causeway (if required) could take a year.
Air ▪ Air transport is likely to be severely disrupted across NZ (Auckland receives majority of international traffic to NZ). Ash can damage aircraft. Hangar roofs need to be cleaned.	▪ Auckland Airport and Whenuapai Airport were closed impacting all air travel and freight (international flights diverted to Ohakea or Wellington) and jet fuel supply disrupted.
Ports ▪ Ash may cause mechanical failure of cranes, straddles and hoist stackers. Presence of ash may result in labour force being unable to work for health and safety reasons including potential respiration difficulties, low visibility or slippery pavement. Large volumes of ash may impact on the structural integrity of buildings and cranes.	▪ Vessels for Ports of Auckland redirected to Tauranga or Whangarei. ▪ Onehunga Port damaged and closed and Manukau Harbour cleared of vessels.
Rail ▪ Likely ash impacts on rail fleet ▪ Damage to tracks likely to close network for a significant period ▪ Depth of ash on tracks could close rail network	▪ Northern rail line initially open and available for evacuation but later closed due to damage.

Table 4-8: Volcanic Impacts, Transport Sector

[2] Auckland Engineering Lifelines Group: Volcanic Ash Review - Part 1: Impacts On Lifelines Services And Collection/Disposal Issues Version 1.0 – May 2001

Response and Recovery Plans

Response and recovery activities for the transport sector are summarised in Table 4-10, along with individual agency plans. The transport sector would also be guided by:

- Volcanic ash posters (Figure 4-6 and 4-7)
- AELG Critical Sites and Routes Maps
- AELG report on Volcanic Ash Health and Safety Issues
- Auckland Lifeline Utility Protocols
- Auckland Regional Council Contingency Plan for the Auckland Volcanic Field.

Sector	Plans Activated	Specific Response Activities
Auckland Transport (Roads)	▪ Auckland Transport Emergency Response Plan ▪ Contractor Emergency Response Plan	▪ Identify and clear priority routes to provide access to emergency services and other life line groups ▪ Clear other routes to provide safe access to road users. ▪ Assist police with road closures and during clean-up operation ▪ Coordinate detour routes ▪ Ensure staff are well briefed on ash removal and safety aspects ▪ Cover stormwater catchpits or put sediment control blankets around them to minimise ash getting into the catchpits ▪ Coordinate clearing to minimise double handling and contamination ▪ Frequent servicing of plant and machinery used for clean-up activities to avoid damage ▪ Monitor performance of maintenance vehicles and health of staff ▪ Dispose ash in appropriate manner to approved disposal sites. ▪ Staff and volunteers involved in cleanup activities supplied with appropriate personal protection equipment (eg: overalls, goggles, dust masks) to reduce the potential for adverse health effects.
NZTA	▪ Emergency Detour Plan ▪ NZTA Emergency Response Plan	▪ Monitor with CCTV (if possible) ▪ Notify Network Contractor and activate remote assistance protocol (seeking resource from other region) ▪ Activate active traffic management (VMS etc if the power is available) ▪ Clear all priority routes. Structural inspection of structures ▪ Liaise with emergency services and implement network closures and detours ▪ Advise media
Auckland Transport (public transport)	▪ Public Transport Emergency Response Plan (to be developed)	▪ Clear tracks Intensify monitoring and maintenance of track signals and automated electrical barriers as ash combined with rain can lead to short-circuiting of signal equipment ▪ Co-ordinate public transport needs for emergency response /evacuation between AT and other authorities ▪ Consider/Establish the number and location of passenger transport vehicles available in the Auckland Region
Auckland Airport	▪ CAA Volcanic Advisory ▪ Airport Volcanic Contingency Plan. ▪ Evacuation Essentials. ▪ Aerodrome Emergency Plan. ▪ USAR at Auckland Airport	▪ Respond to CAA ash cloud movements, effects on Airspace advice. ▪ Activate Emergency Operations Centre to determine activities and whether Airport remains open or closed ▪ Crisis Management teams activated.. ▪ Work with Airlines to establish traffic movements and disruptions. This could be both International and Domestic. ▪ Work with transport sector group and national transport group. ▪ Communicate with other utility groups for continuity of supply. ▪ Evacuation as situation requires. Staff welfare. ▪ Media statements in conjunction with other stakeholders.
Ports of Auckland	▪ Major Incident Management Plan	▪ Assessment of impacts and planning of necessary resources ▪ Ash would need to be cleared from containers, wharves and other paved areas and disposed of.

Table 4-9: Response and Recovery Activities, Transport Sector

Figure 4-9: Volcanic Ash Poster, Roads

ADVICE FOR AIRPORT OPERATORS

VOLCANIC ASH IS: HARD, HIGHLY ABRASIVE, MILDLY CORROSIVE AND CONDUCTIVE WHEN WET.

VOLCANIC ASHFALL

ASH IMPACTS TO AIRPORTS

ASH IS HAZARDOUS TO AIRCRAFT.

- It can cause engine failure and severe abrasion to exposed surfaces

ASHFALL MAY REQUIRE AIRPORTS TO CLOSE. TYPICAL IMPACTS INCLUDE:

- Difficult landing conditions due to reduced runway friction, especially when ash is wet.
- Loss of local visibility when ash on the ground is disturbed by engine exhausts during takeoff and landing.
- Ingestion of remobilised ash into jet engines during taxi-ing, takeoff and landing.
- Deposition of ash on hangars and parked aircraft, with structural loading considerably worsened if ash becomes wet.
- Contaminated ground-support systems.

ASH ACCUMULATIONS OF LESS THAN 1 MILLIMETRE MAY BE SUFFICIENT TO TEMPORARILY CLOSE SOME AIRPORTS.

Cleaning up airports after an ashfall is a time-consuming, costly and resource intensive operation. The complexity and immensity of this task should not be underestimated.

ASH IN AIRSPACE IN THE VICINITY OF AIRPORTS MAY ALSO CAUSE DISRUPTIONS TO AIRPORTS EVEN IF IT DOES NOT ACCUMULATE ON THE GROUND.

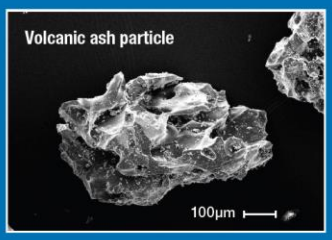
3-5 mm of ash fall at Mariscal Sucre International Airport in Quito, Ecuador, following the 3 November 2002 eruption of Reventador volcano. The airport closed for 8 days due to the ash deposition on aircraft and runways.

5-10 mm of ash fall at San Carlos de Bariloche International Airport in Bariloche, Argentina, following the June 2011 eruption of Peyuhue Cordon-Caulle volcano in Chile. The airport closed for 31 days due to the on-going ash falls, remobilisation of ash and cleanup.

WARNING INFORMATION

WHERE TO FIND WARNING INFORMATION

- ASH CLOUD FORECAST (ash suspended in atmosphere): The Wellington Volcanic Ash Advisory Centre (VAAC) will issue Volcanic Ash Advisories (VAA) and Graphics (VAG) forecasts on suspended ash in the atmosphere affecting aviation. See: http://vaac.metservice.com/
- ASHFALL FORECAST (ash falling to ground): GeoNet (GNS Science) will provide ashfall forecasts in the event of an explosive eruption (see: geonet.org.nz).
- AVIATION COLOUR & VOLCANO ALERT LEVEL (ash falling to ground): GeoNet (GNS Science) sets the Aviation Colour Codes and Volcano Alert Level for New Zealand's volcanoes (see: geonet.org.nz).



RECOMMENDED ACTIONS

HOW TO PREPARE

At-risk airports should develop comprehensive operational plans for ashfall events (including cleanup – see companion "Cleanup" poster). These plans should, where possible, be integrated with airline plans.

A more comprehensive summary of ashfall consequences to airports and detailed planning guidelines are available from:

- ICAO: www.paris.icao.int/news/pdf/9691.pdf

The ICAO resource provides guidance on:

a) standing arrangements prior to volcanic eruptions;

b) responses during an eruption

c) post-eruption cleanup and re-opening of the airport.

Field crews should use safe operating procedures when operating in an 'ashy' environment.

- Protective clothing (full-length clothing, face masks and goggles) should be worn and care must be taken on ash-covered surfaces, particularly roofs.
- See www.IVHHN.org for further advice on protecting people from ash hazards.

ROLES AND RESPONSIBILITIES

The NZ Civil Aviation Authority (CAA) has a comprehensive document outlining roles and responsibility in managing volcanic ash in New Zealand for the aviation sector.

- www.caa.govt.nz/meteorology/living_with_volcanic_ash.pdf

FURTHER INFORMATION ON DEALING WITH VOLCANIC ASH MAY BE FOUND IN THE FOLLOWING LOCATIONS:

http://www.geonet.org.nz
http://www.ivhhn.org
http://volcanoes.usgs.gov/ash/trans/index.php#airports
http://www.caa.govt.nz/

DRAFTED BY TOM WILSON AND CAROL STEWART.
7 February 2013

UC University of Canterbury · Air New Zealand · Auckland Engineering Lifelines · Auckland Airport · CAA Civil Aviation Authority of New Zealand · GNS Science Te Pū Ao

Figure 4-10: Volcanic Ash Poster, Airport

4.7 Water and Waste

Water Supply Impacts

- More than 95% of the water supply is from large, open impoundment dams and river abstraction. Ash in these areas would cause increased turbidity, fluoride levels, acidification and other water quality issues.
- On top of these issues, there would be increased demand for water for cleaning ash and further impacts from electricity / fuel disruption.
- Restoration of treatment and transmission systems destroyed or damaged by ash or the eruption could take months or years.
- Disruption to cross region conveyance transmission systems.

Further details are provided in the following tables.

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Ash can disrupt water treatment by clogging intake structures, abrading moving parts and causing corrosive damage to electrical and metallic gear. ▪ Ash contamination of raw waters and settling on open water surfaces at WTPs will create challenging treatment conditions. ▪ Contamination of water – increased turbidity (can inhibit disinfection), fluoride levels, acidification. ▪ In Auckland, >95% water supply is from large, open impoundment dams and river abstraction. Water treatment plants have large open surface clarifier & filter tanks. However treatment plant processes are capable of maintaining capacity and standards. ▪ Increased water demand for clean-up.	▪ Extensive asset and other damage estimated, including contamination of water sources (e.g. raw water impounding dams), loss of major pipeline (conveying >60% regions water from south) and Onehunga acquifer source taking months/years to repair – pipeline loss will cause major disruption to City supplies. ▪ Widespread localised flooding from broken water mains due to seismic activity and direct damage from volcanic hazards. ▪ Significant potential for health issues arising from contamination of water reticulation system, exacerbated further by electricity outages limiting ability to boil water. ▪ Severe water restrictions and outages as a result, particularly to Central, West areas and North Shore due to transmission system damage. ▪ Water restriction would be imposed to avoid high demands from clean-up activity.

Table 4-10: Volcanic Impacts, Water Supply

Wastewater Impacts

General Ash Impacts	'Exercise Ruaumoko' Impacts
▪ Blockage of sewers, catchpits, etc, resulting in overflows. Areas of Auckland have combined stormwater/ wastewater networks, increasing risk of ash entering wastewater networks. ▪ Blockages and abrasion of pumping and treatment equipment, potential to cause significant damage. Auckland wastewater treatment plants have large open surface secondary treatment tanks, increasing opportunity for ash disruption. ▪ Contamination to treatment processes.	▪ Mangere Wastewater Treatment Plant damaged by ash, restoration could take months or years. ▪ Widespread localised flooding from wastewater overflows due to seismic activity and direct damage from volcanic hazards and ash blockages.

Table 4-11: Volcanic Impacts, Wastewater

Stormwater Impacts

The stormwater sector was not part of the scope of the AELG work for Exercise Ruaumoko. However the ash impacts of the stormwater network have been assessed as follows:

Potential Volcanic Ash Impacts	Auckland Context
▪ Blockage of pipe inlets, including catchpits, and pipelines from accumulating ash. ▪ Ash washed into pipelines will result in widespread reduction in capacity of the stormwater piped system to drain stormwater. Flooding will result if heavy rain occurs prior to clean-up of ash. ▪ Wet ash is difficult to remove from pipes. Preventing ash from entering the pipe system should be a priority. ▪ Power outage disabling stormwater pumping stations for lengthy periods may lead to flooding of localised areas. ▪ Ash dumped into stormwater watercourses or manholes by private property owners during roof or yard clearing has potential to seriously impact the function of the stormwater infrastructure. If there is no heavy rainfall prior to removal of ash the impact of ash on stormwater system will be minimal.	▪ Areas relying solely on soakage into the ground for disposal of stormwater are particularly vulnerable to ash blockage of the soakage boreholes, underground caves and tunnels which may become permanently damaged and unrecoverable. Preventing ash ingress to these soakage assets is high priority. ▪ Catchpits are the primary inlets to much of the stormwater system. Key to protecting the pipes from blockage will be to prevent ingress of ash via the catchpits. ▪ Council will need to communicate clear instructions to property owners on ash disposal. ▪ Most major stormwater pipe and channel assets can be made more resilient by ensuring there are clearly defined and well maintained overland flow paths, particularly in larger catchments.

Table 4-12: Volcanic Ash Impacts, Stormwater

Day 1	Week 1	Full Recovery
▪ Protection of all catchpits in soakage areas where impacted or potentially impacted by ash fall in place. ▪ All pump station control boxes exposed to ash fall covered. ▪ Removal of ash from critical areas initiated.	▪ Continuous rounds of inspection of all critical assets located within affected areas. ▪ Continuous ash removal from streets, catchpits, pipe inlets and open drainage systems where accumulating.	▪ Ash removal operation continues until ash fall event is over and all ash blocking or likely to block stormwater systems and assets is removed.

Table 4-13: Stormwater Recovery Times

Solid Waste Impacts

The solid waste sector was also not part of the scope of the AELG work for Exercise Ruaumoko. However the ash impacts on the solid waste network have been assessed as follows:

- Ash build-up on roads will cause driving hazard for contractors picking up waste. Windy conditions will cause visibility issues. Wet conditions will make ash slippery.
- Ash from roads and properties will need to be disposed of at secure landfill (eg: Whitford). Waste volumes are likely to increase significantly in a large ashfall event.
- Ash fall may block engines and other mechanical parts causing contractor collection issues.

Response and Recovery Plans

Stormwater

- Prevention measures to be ready to put in place to keep ash out of catchpits in priority areas such as soakage catchments and other vulnerable catchments (including combined sewers) from early in the eruption. To be extended into as many other affected catchments as resources allow.
- Co-ordination with Auckland Transport is required to ensure ash is swept from streets and build-up prevented so as to reduce entry of ash into stormwater and combined sewers.
- Council (or CD) should distribute leaflet instructions as soon as possible after commencement of event as to health hazards, instructions for dealing with ash removed from roofs, driveways and yards.

Water Supply and Wastewater

- Reconfiguration of water supply system to maintain security of supply to maximum extent possible.
- Water restrictions imposed to conserve resource (largely due to transmission system disruption – loss of Hunua No 3)
- Boiled water notices as required due to cross-contamination from wastewater system damage.
- Cover filter tanks at water treatment plants
- Coverage of sewerage cess-pits in combined stormwater / sewer areas (central Auckland City) to avoid ash washing into Orakei Main Sewer.
- Shut down all equipment not strictly required, including ventilation.
- Ongoing monitoring of water quality.
- Review stocks of essential items such as spare filters and parts and treatment chemicals.
- Ensure access to back up generation.
- Maintain clean sites to reduce contamination.
- Ensure stocks of treatment chemicals are adequate due to increased consumption caused by ash contamination and also disruption to supply chain (transport systems, etc).
- Encourage the use of alternative, non-potable sources of water for clean up and fire fighting. Encourage use of brooms and shovels for clean up rather than water.
- Consider bypassing pumping stations and treatment plants as a protective measure to avoid plant damage.

Solid Waste

- Identify areas where contractors can begin clean-up operation.
- Brief staff on ash removal and safety aspects.
- Ensure Contractors service and monitor machinery .
- Staff are monitored and provided with the correct safety gear.
- Coordinate contractors.
- Ensure ash is disposed of in a secure landfill.

The sector would also be guided by relevant Volcanic ash posters (Figure 4-8 and 4-9).

Figure 4-11: Volcanic Ash Poster, Water Supply

Figure 4-12: Volcanic Ash Poster, Wastewater

4.8 Social and Economic Impacts of a Volcanic Eruption

As part of the lead-up to the Ruaumoko Exercise, a study was undertaken to identify the potential economic impacts of an AVF eruption along with techniques to minimise impacts and ensure a quick recovery. To assess economic impacts, a 'worst case scenario' Rangitoto Island size eruption located at Mt Eden was used, causing a 3 km-radius devastation zone around the volcano, with a 5km-radius evacuation zone anticipated prior to the eruption.

The following consequences were estimated:

- 200,000+ residents displaced
- 40,000 businesses disrupted – close or business continuity arrangements
- 200,000+ employees affected
- Hospitals and medical facilities shut down
- SH16 and SH1 roads closed; possible closure of other major arterials
- Widespread disruption of infrastructure: power, water, gas, telecommunication and Petroleum.

A number of social and economic consequences were modelled within the affected area to quantify the impacts on the Auckland region and New Zealand economies. The modelling exercise confirmed an eruption would severely disrupt regional and national economies. In the year after the eruption it was estimated that:

- Auckland's gross domestic product (GDP) will decline 47% (reduced to 40% with business mitigation and preparedness measures).
- 268,000 jobs would be lost in the Auckland region (reduce to 221,000 with business mitigation and preparedness measures).
- New Zealand's GDP will decline by 14% (reduced to 12% with business mitigation and preparedness measures).
- New Zealand's employment rate will fall by 14% (reduced to 11% business mitigation and preparedness measures).

To put the Mt Eden eruption scenario in perspective, the estimated economic consequences to New Zealand's GDP decline are estimated as more severe than those of the great depression in the early 1930s, when economic growth rates peaked at -7%. The assessment indicates that business continuity and risk management planning undertaken by organisations can significantly reduce the regional and national economic consequences of an AVF eruption.