MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

VOLCANIC RISK SOLUTIONS

RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Towards a science and research informed resilient Aotearoa

1. Resilience Research
2. Hazards and Risk Background
3. Forecasting – a volcanology case study
4. Mātauranga Māori

Professor Jonathan Procter – Massey University - Volcanic Risk Solutions

Resilience Challenge: The numbers

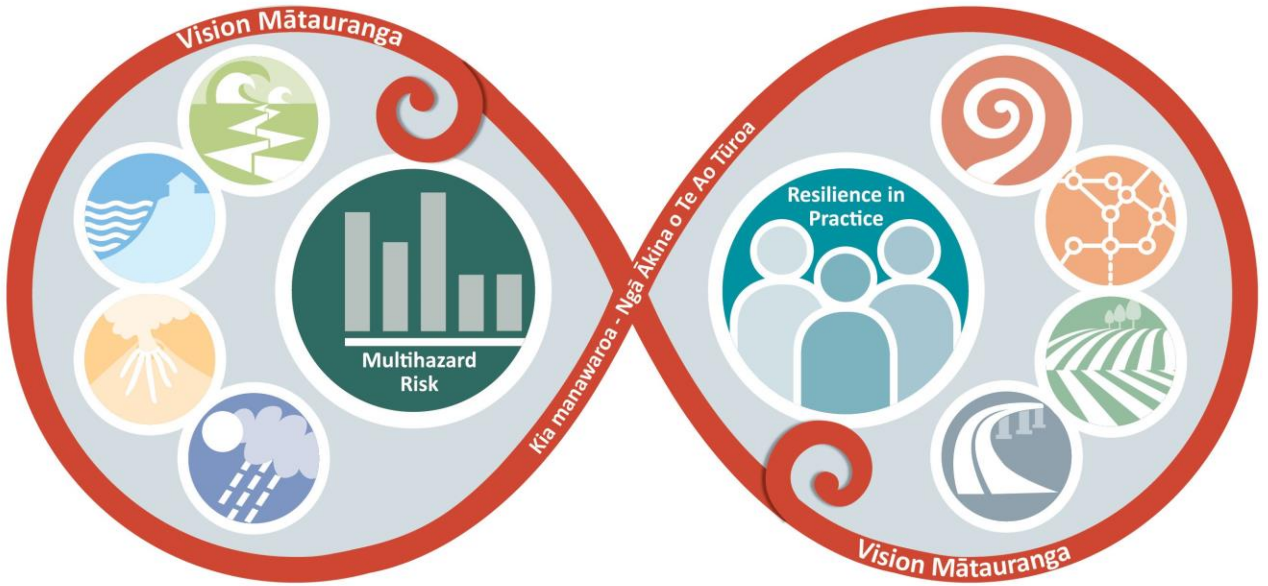
$40M Funding until mid-2024

330+ researchers

135 Students

9 Post-docs

10 programmes; **37** projects



Ten Research Programmes

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Integrated multi-hazard science

Stronger partnerships with Māori

Elevated Mātauranga Māori

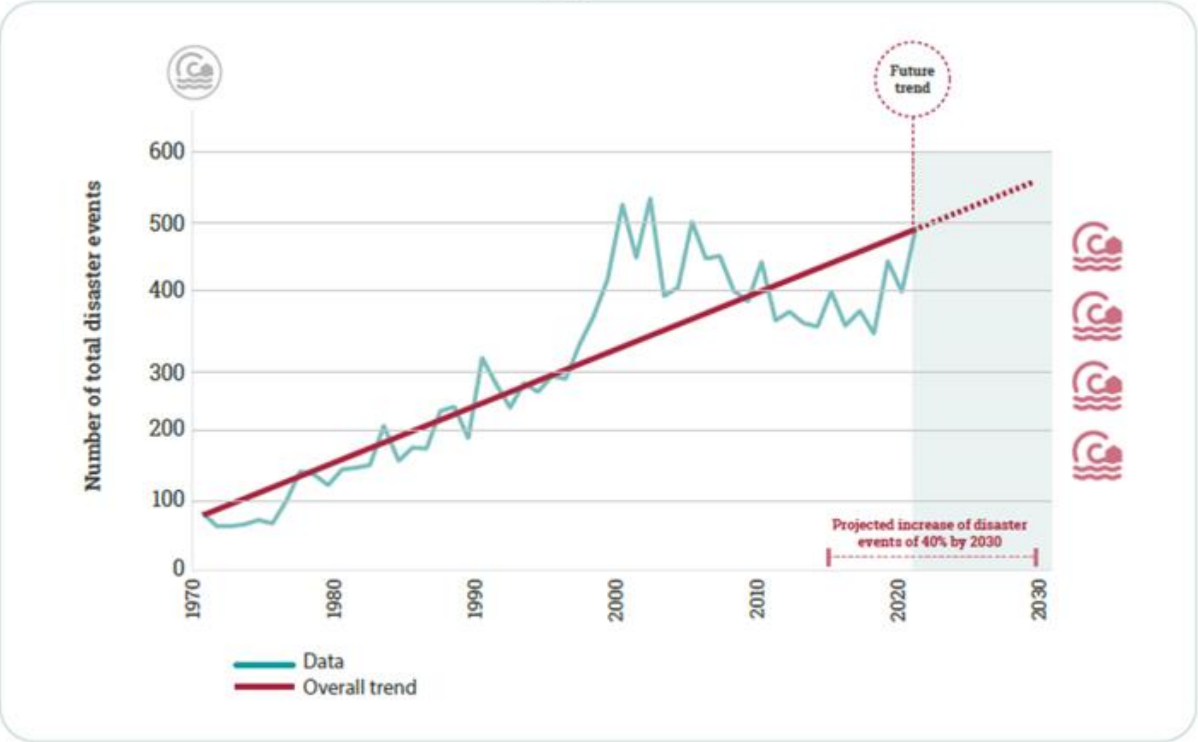
Maximising impact

Telling our story well

The world is not on track to reducing risk

If current trends continue, the number of disasters per year globally may increase from around 400 in 2015 to 560 per year by 2030 – a projected increase of 40% during the lifetime of the Sendai Framework

Figure S.1. Number of disaster events 1970–2020 and projected increase 2021–2030

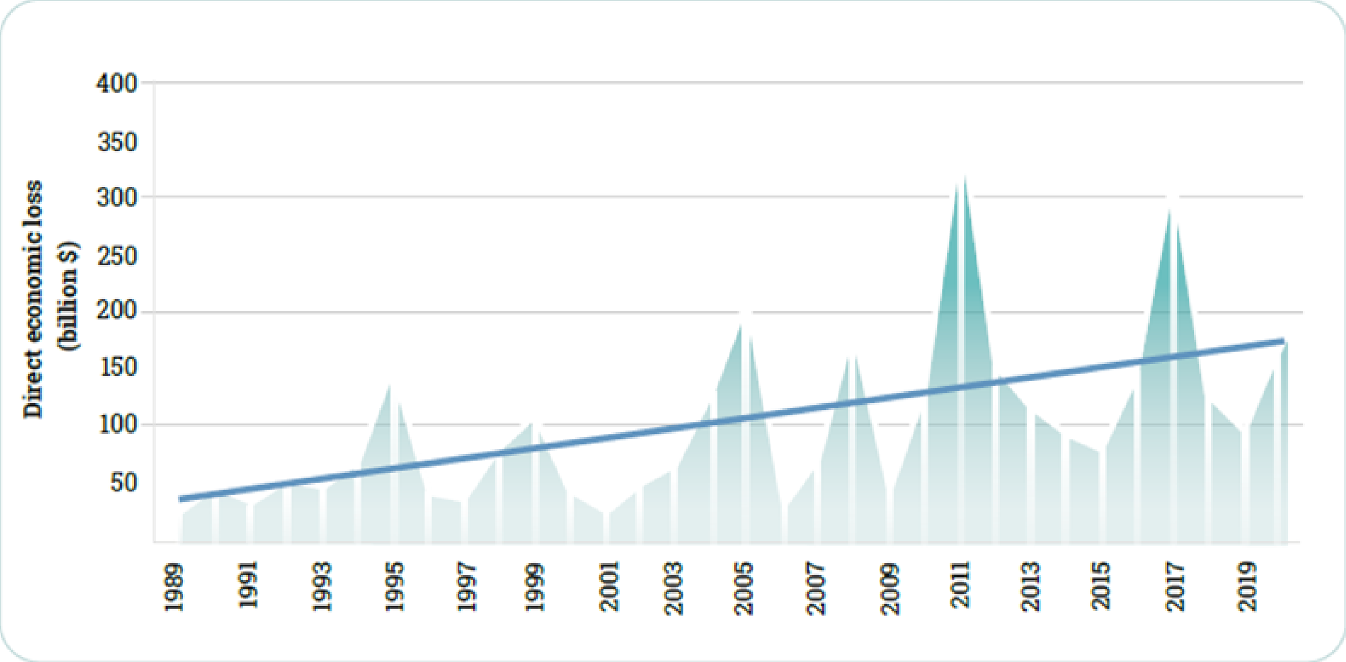


Source: United Nations Office for Disaster Risk Reduction (UNDRR) analysis based on the International Disaster Database (EM-DAT; CRED, 2021)

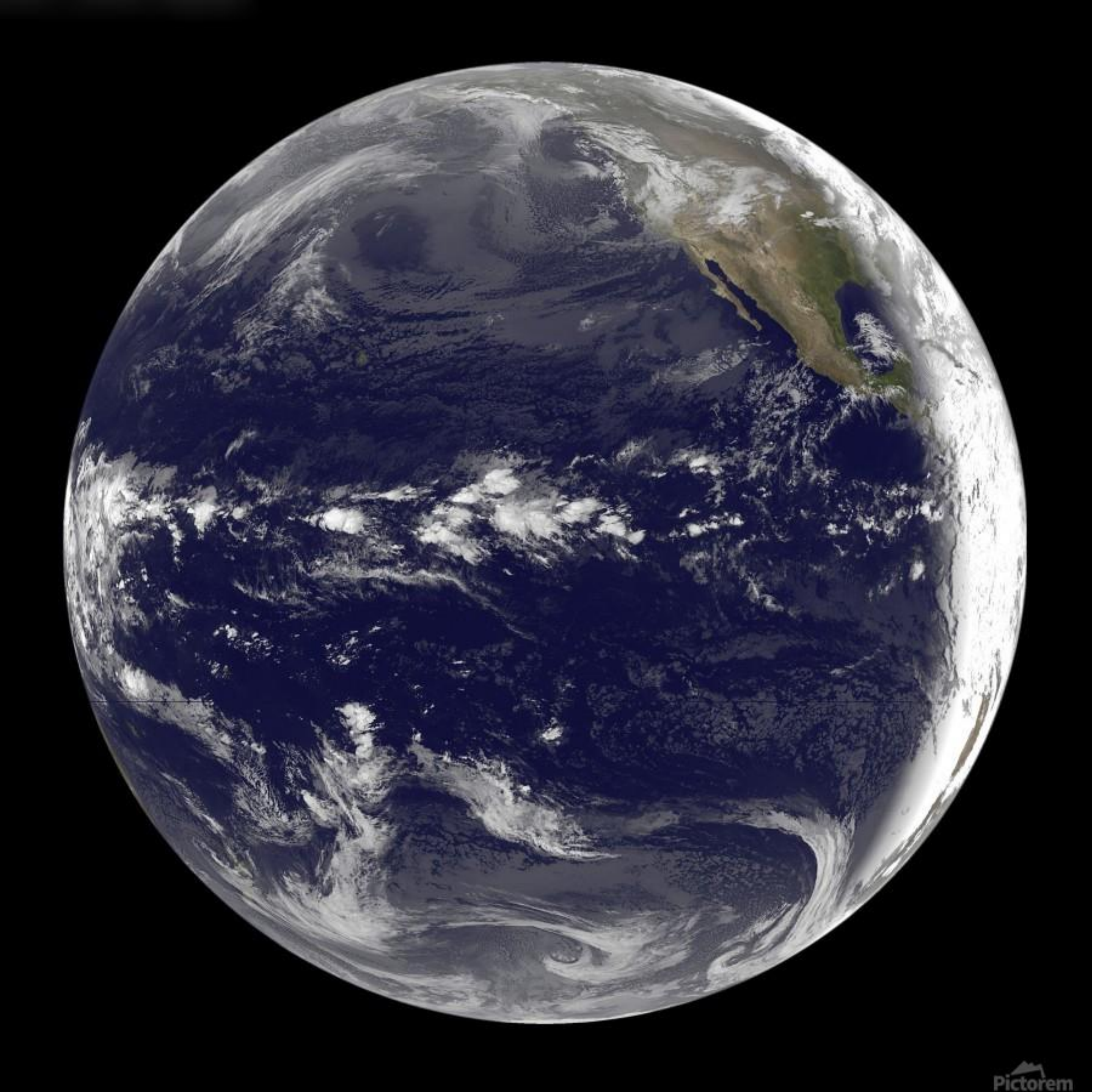
Human choices are driving vulnerability and exposure and increasing losses

The average annual direct economic loss from disasters has more than doubled over the past three decades, showing an increase of approximately 145% from an average of around $70 billion in the 1990s to just over $170 billion in the 2010s. However, the impacts of disasters stretch further than economic losses; they also fundamentally undermine social and ecological systems.

Figure S.4. Direct economic loss from disasters (billion $), 1989–2020



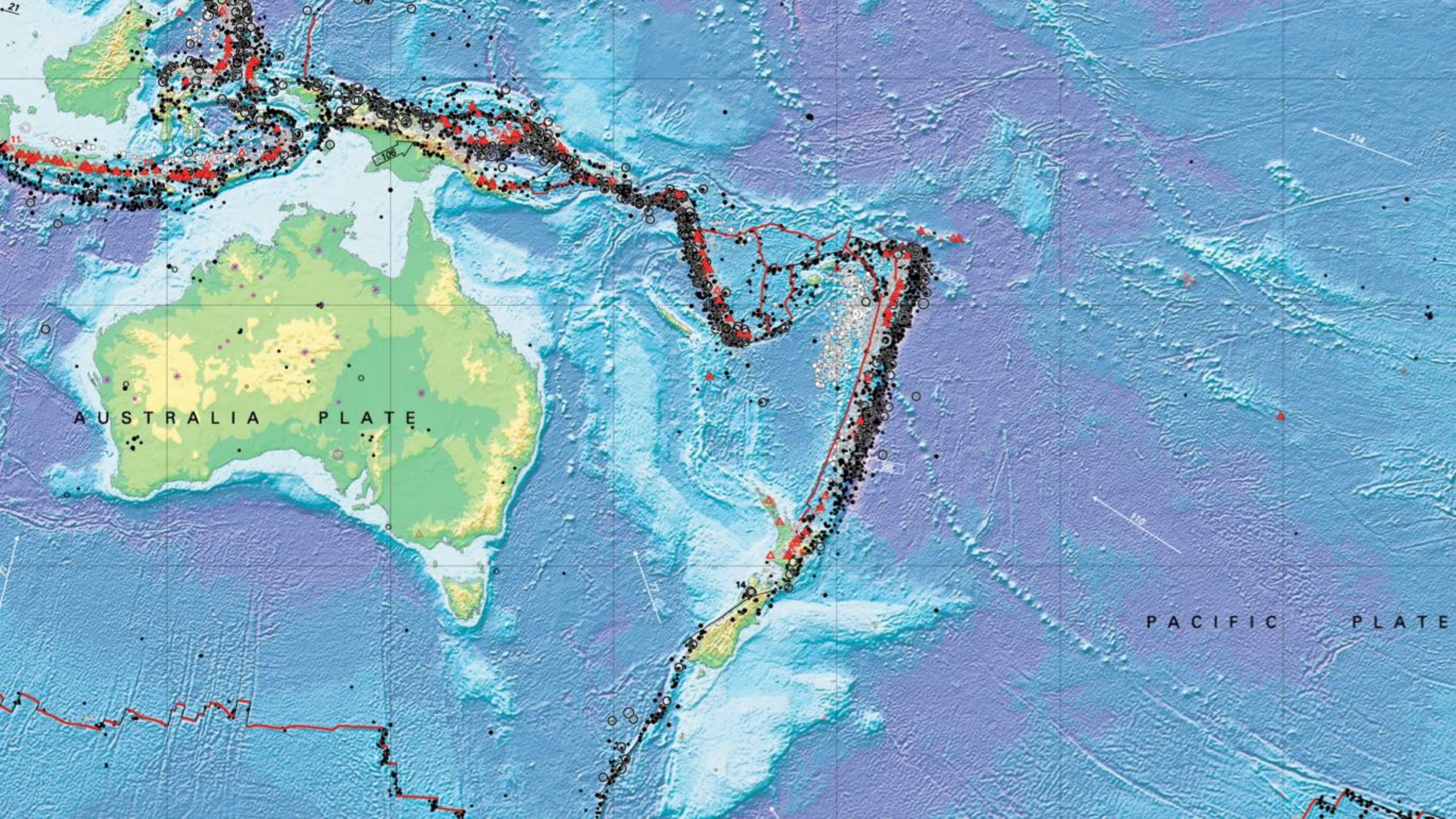
Source: UNDRR analysis based on EM-DAT (CRED, 2021)

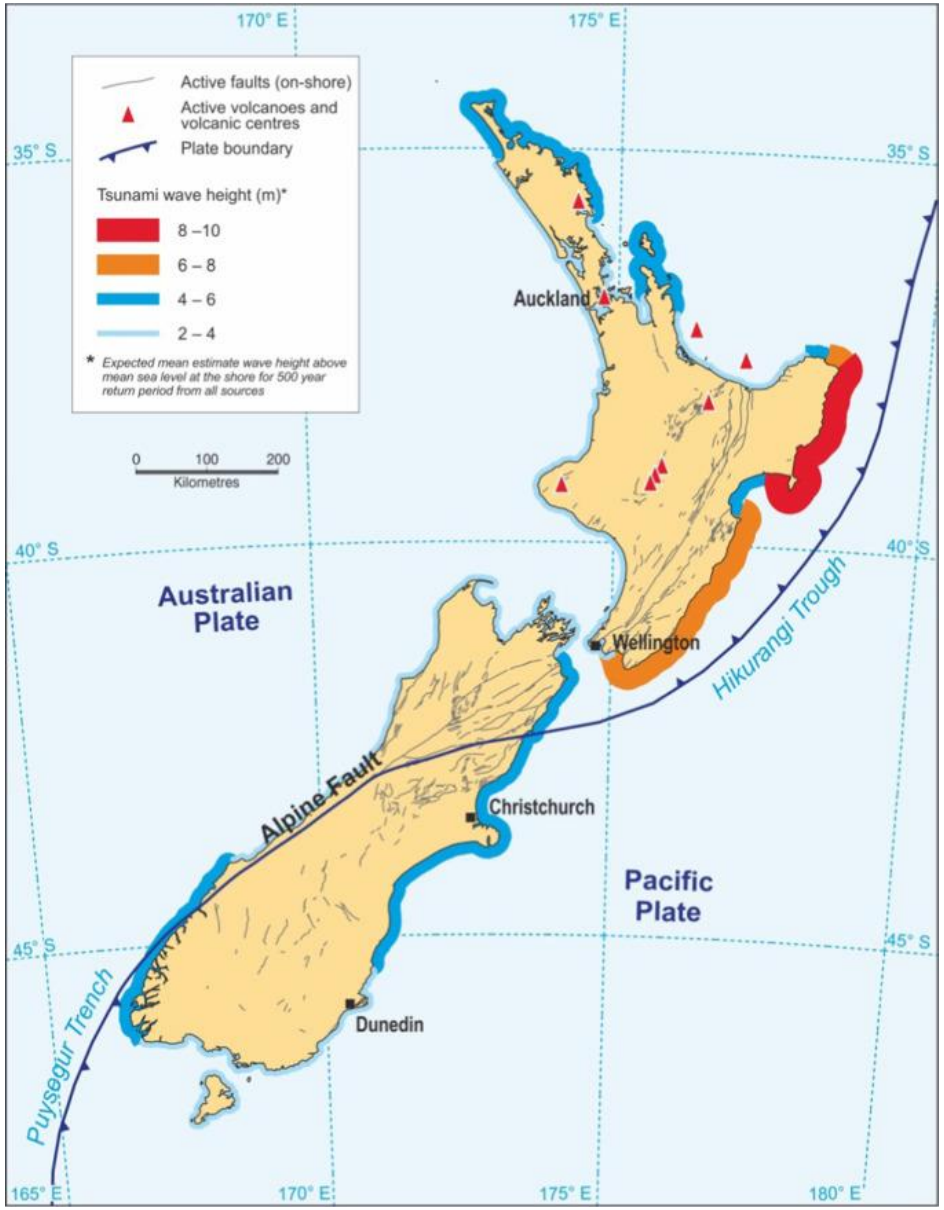


New Zealand is the perfect natural hazards laboratory!

“It does us a power of good to remind ourselves that we live on two volcanic rocks where two tectonic plates meet, in a somewhat lonely stretch of windswept ocean just above the Roaring Forties. If you want drama - you've come to the right place“

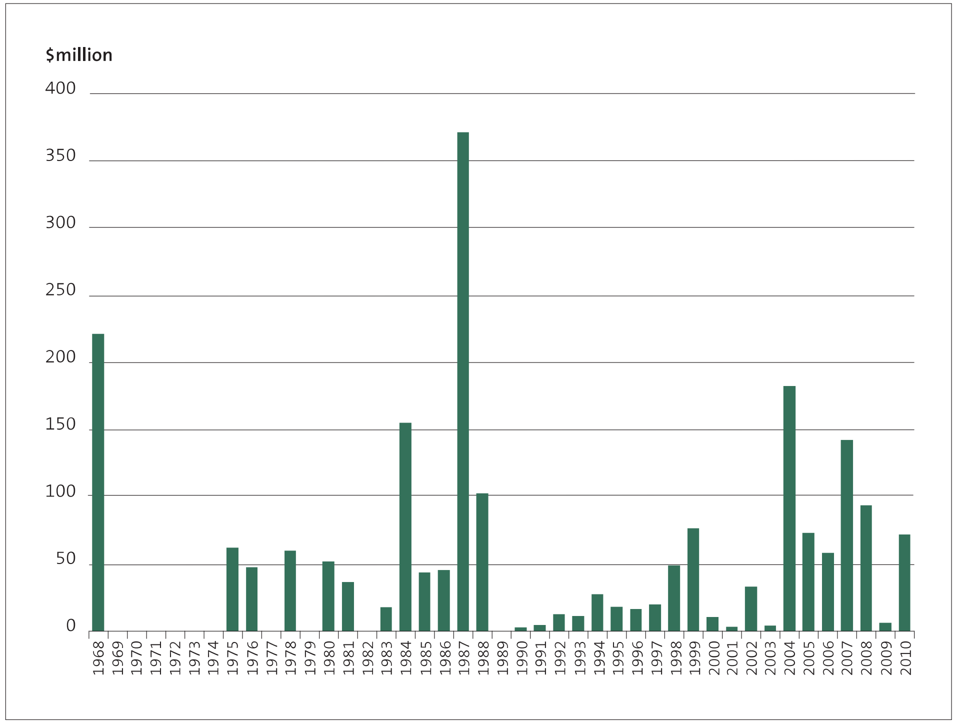
Sir Geoffrey Palmer


AUSTRALIA PLATE
PACIFIC PLATE

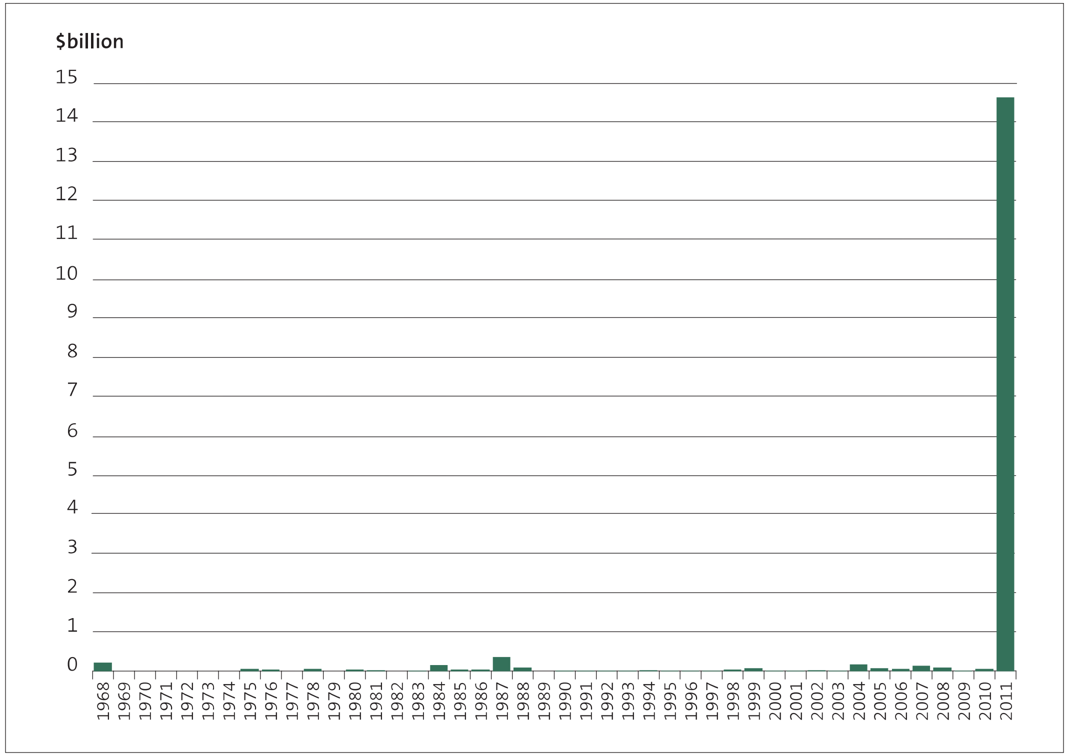


170° E
175° E
35° S
40° S
45° S
165° E
180° E
Active faults (on-shore)
Active volcanoes and volcanic centres
Plate boundary
Tsunami wave height (m)*
8 –10
6 – 8
4 – 6
2 – 4
* Expected mean estimate wave height above mean sea level at the shore for 500 year return period from all sources
0
100
200
Kilometres
Auckland
Wellington
Christchurch
Dunedin
Australian Plate
Pacific Plate
Alpine Fault
Hikurangi Trough
Puysegur Trench

Insurance claims from natural disasters in New Zealand, 1968-2010, excluding claims relating to the Canterbury earthquakes



Insurance claims from natural disasters in New Zealand, 1968-2011



MASSEY UNIVERSITY TE KUNENGA KI PŪREHUROA UNIVERSITY OF NEW ZEALAND

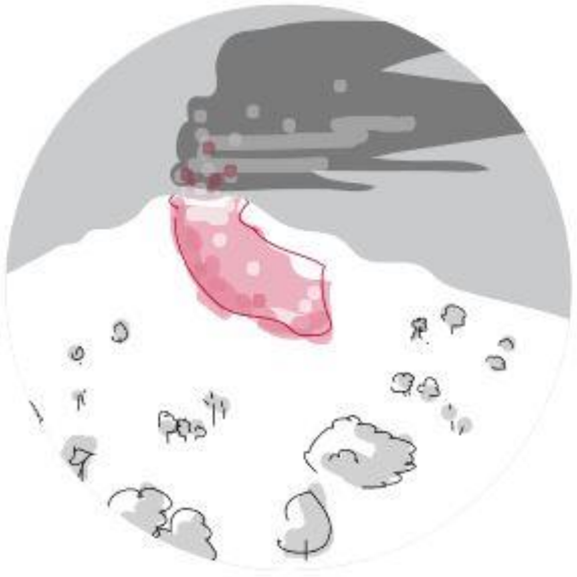
VOLCANIC RISK SOLUTIONS

HAZARD VS DISASTER

a phenomenon, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihood and services, social and economic disruption, or environmental damage.

disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources

Risk = Hazard x Exposure x Vulnerability



There is no such thing as a **natural disaster**, only **natural hazards**

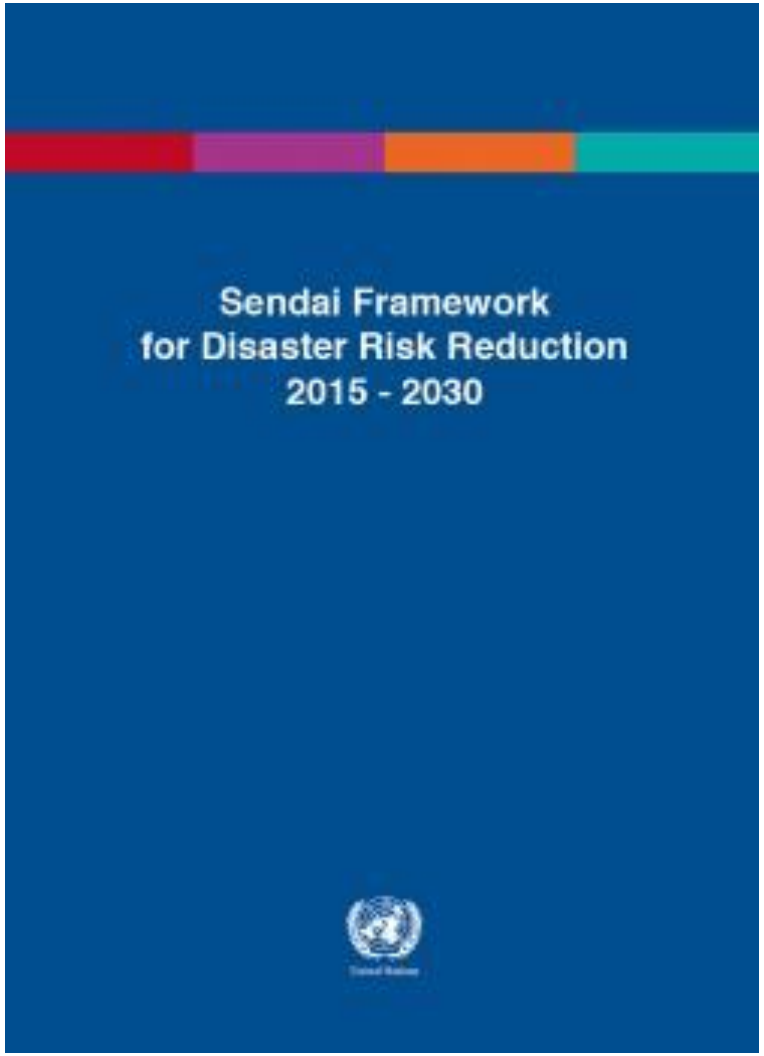
We make **choices** as to where we inhabit, how we build and what research we do

Risk is the combination of **hazard**, **exposure** and **vulnerability**

Death, **loss** and **damage** is the function of the context of hazard, exposure and vulnerability

(Source: UNDRR 2019)

The Sendai Framework



Sendai Framework was adopted March 2015 to reduce the number and consequences of disasters.

15-year, voluntary, non-binding agreement, with seven targets and four priorities for action.

Emphasis on disaster risk management instead of disaster management

Reduction of disaster risk as an expected outcome, preventing new risk, reducing existing risk and strengthening resilience
• Improved understanding of disaster risk
• Strengthening of disaster risk governance
• Recognition of stakeholders and their roles
• Building resilience: ie infrastructure, health, cultural heritage
• Strengthening of international cooperation and global partnership
• Preparedness, emergency response “Build Back Better

GAR - Recommendations

The world is not on track to reducing risk

If current trends continue, the number of disasters per year globally may increase from around 400 in 2015 to 560 per year by 2030 – a projected increase of 40% during the lifetime of the Sendai Framework

Measure what we value

Human biases and decision-making impact risk reduction outcomes

Current systems undervalue key assets, opportunities for learning including from indigenous knowledge

Design systems to factor in how human minds make decisions about risk

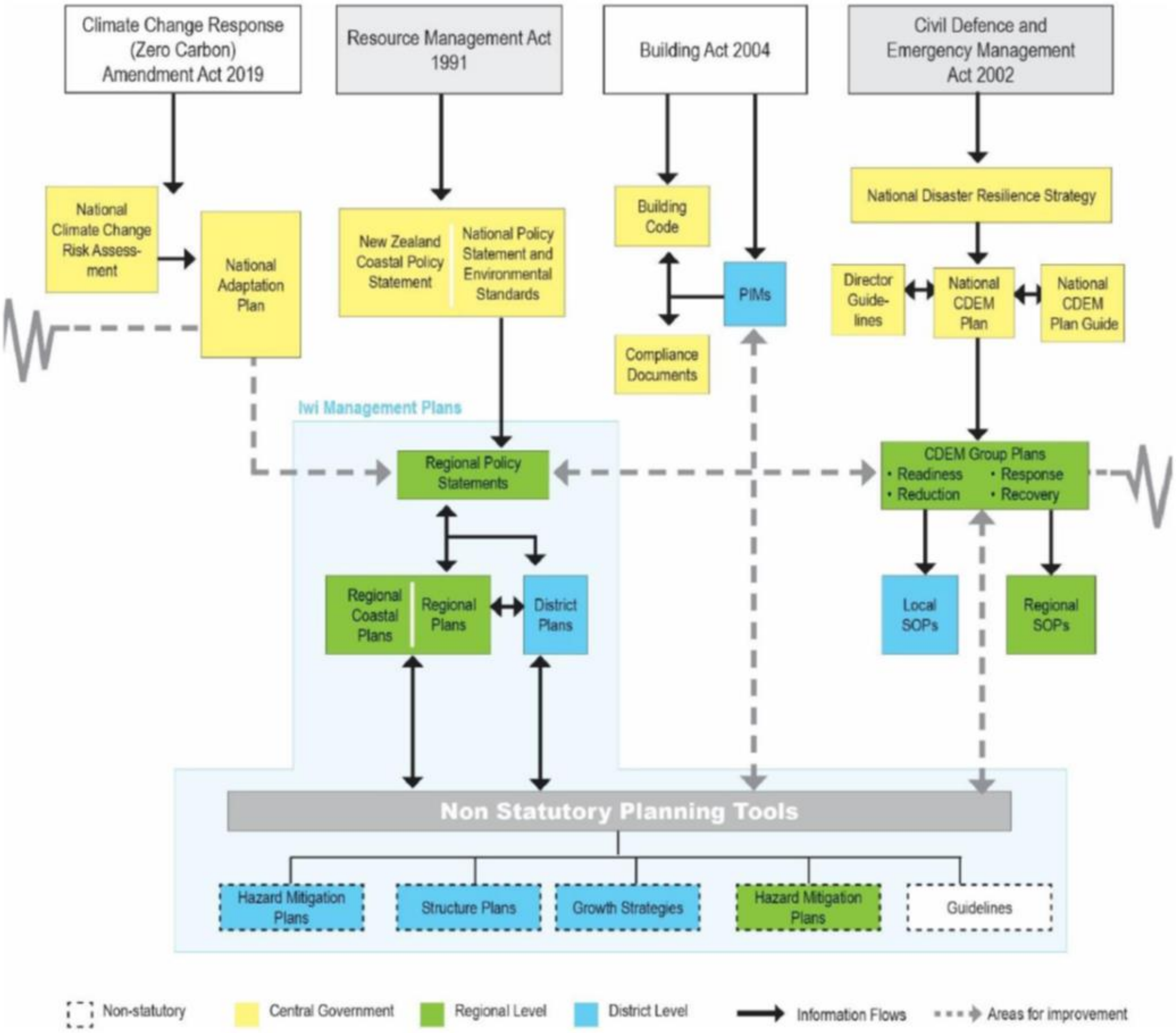
Towards a more resilient future

Design systems to factor in how human minds make decisions about risk

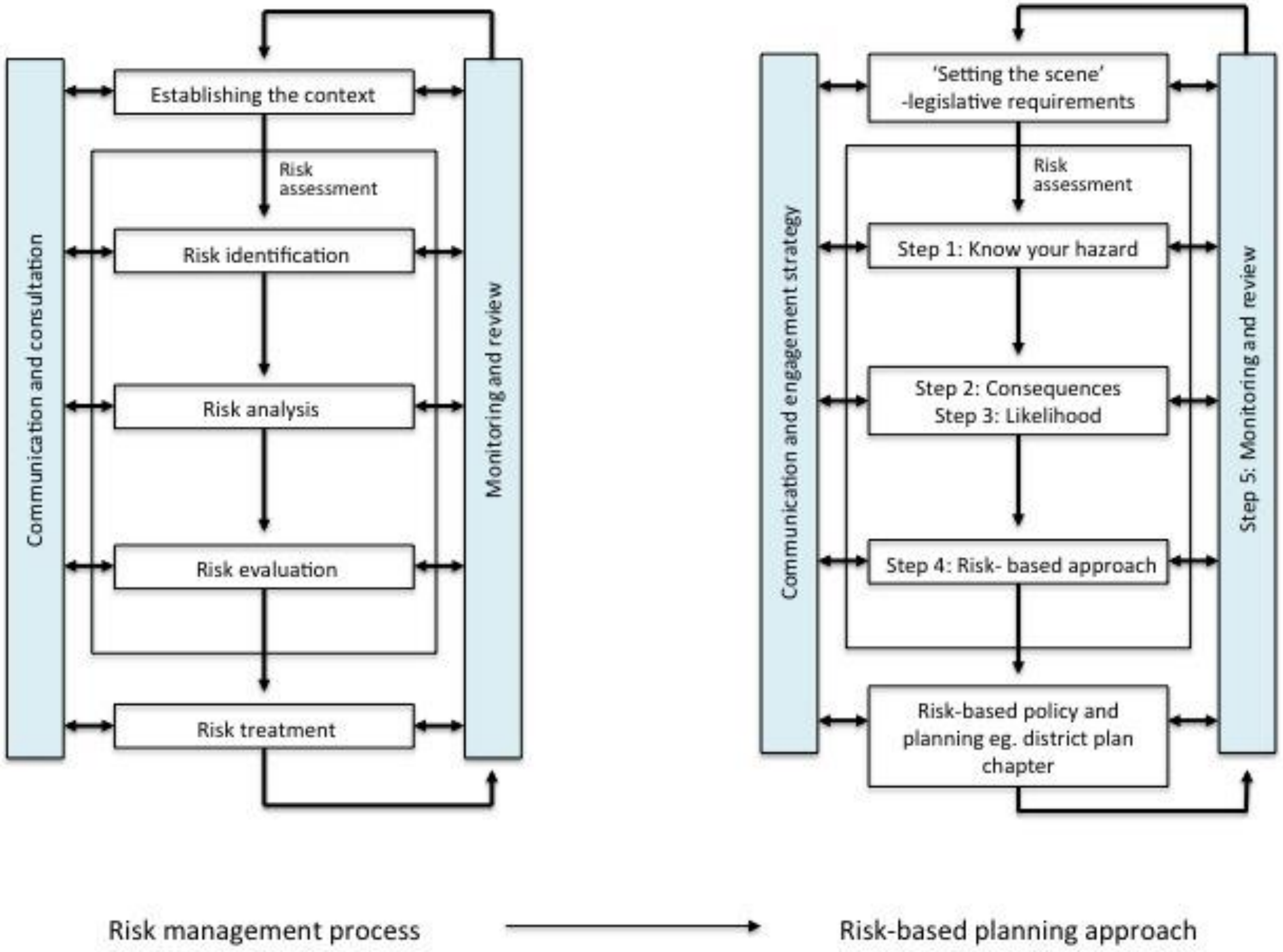
Reconfigure governance and financial systems to work across silos and design in consultation with affected people

Plan with, not against, how people take decisions about risk

- A key concept of the CDEM Act is applying the '4 Rs' (**R**eduction, **R**eadiness, **R**esponse, **R**ecovery)
- The key instruments established by the CDEM Act include:
  - establishment of a CDEM framework, including:
    - CDEM regulations
    - National CDEM Strategy
    - National CDEM Plan
    - CDEM group plans
  - appointment of a Director of CDEM
  - establishment of Civil Defence Emergency Management Groups
  - requirement for the preparation of Civil Defence Emergency Management Plans
  - setting out emergency declarations and powers including states of emergency.



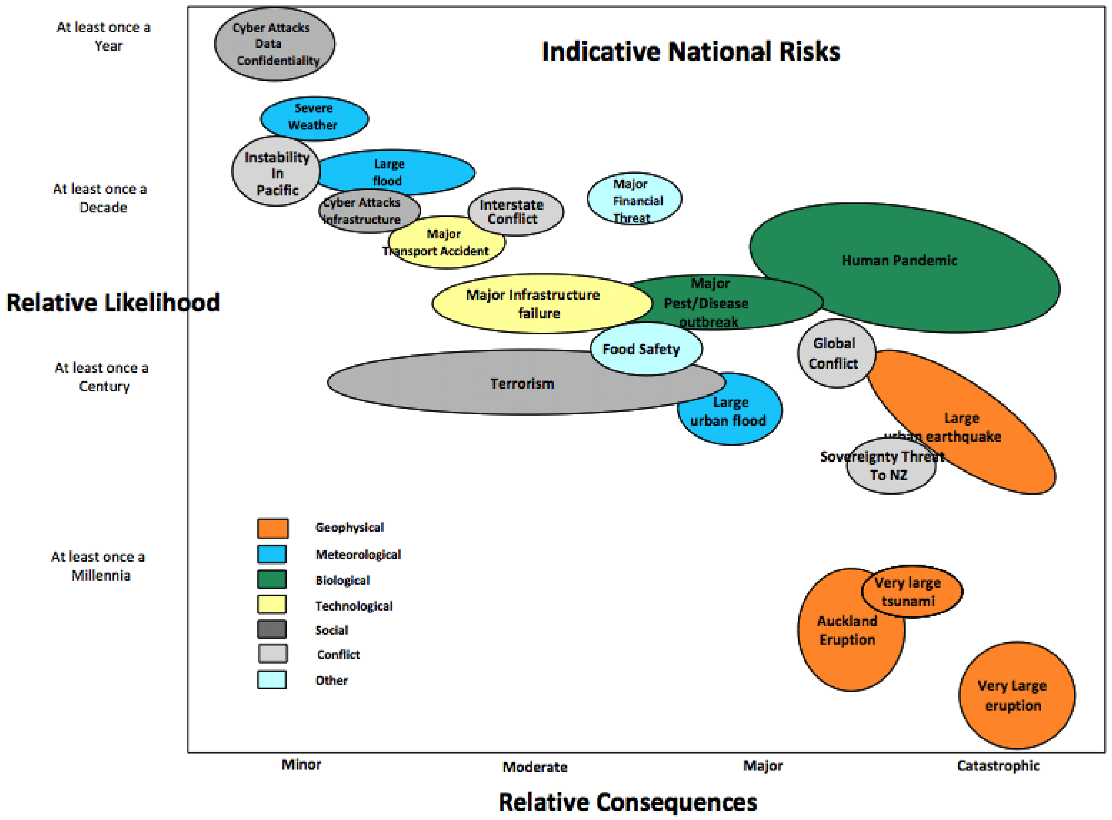
Climate Change Response (Zero Carbon) Amendment Act 2019
Resource Management Act 1991
Building Act 2004
Civil Defence and Emergency Management Act 2002
National Climate Change Risk Assess-ment
National Adaptation Plan
New Zealand Coastal Policy Statement
National Policy Statement and Environmental Standards
Building Code
PIMs
Compliance Documents
National Disaster Resilience Strategy
Director Guide-lines
National CDEM Plan
National CDEM Plan Guide
Iwi Management Plans
Regional Policy Statements
CDEM Group Plans
• Readiness • Response
• Reduction • Recovery
Regional Coastal Plans
Regional Plans
District Plans
Local SOPs
Regional SOPs
Non Statutory Planning Tools
Hazard Mitigation Plans
Structure Plans
Growth Strategies
Hazard Mitigation Plans
Guidelines
Non-statutory
Central Government
Regional Level
District Level
Information Flows
Areas for improvement



1. Know your hazard
2. Determine severity of consequences
3. Evaluate likelihood of event
4. Risk-based approach to policy and resource consents
5. Monitoring & Evaluation

- Engagement strategy for each step
- Examples

National Risk Register



Regional Risk Register

	Earthquake	Volcano	Tsunami	Severe Storm / Flood	Infrastructure Failure[5]	Drought/Extreme Temp	Animal Pandemic	Human Pandemic	Rural Fire	Transport Accident	Other
Northland			H	VH	H			H			
Auckland	H	H	H	VH	H			VH	H	H	Coastal erosion, hazardous spill, land instability, urban fire.
Waikato	H	VH	VH	H	H	VH	VH	VH			Marine Spill Land Instability
Bay of Plenty	H	H Local	H	H/M	M	H	H	H		H	Dam Failure, Storm surge
Gisborne					H	H	H	VH	H	H	Criminal
Hawkes Bay	‘top 10’	‘top 10’	‘top 10’	‘top 10’	‘top 10’		‘top 10’	‘top 10’	‘top 10’		Multiple urban fire Hazardous Substance
Taranaki	3	1	8	10	15	13	5	2	29	20	
Manawatu-Wanganui	VH	H	VH	VH	H	VH	VH	VH	H	H	Landslide, HAZMAT
Wellington	VH	H	VH	VH	VH			E			Landslide, Urban Fire
Marlborough	E		H	E	H	E	VH	VH	VH	VHV H	Pests and diseases, Malicious act Urban Fire, Hazardous Substance, Dam break, Landslide, Liquefaction, Coastal erosion
Nelson-Tasman	VH		H	H				H	H		
West Coast	1st		4th	3rd Flood 5th Storm	9th		7th	2nd	10th	8th	*Risk rating not listed – SMG results used to prioritise* *6th - Tornado*
Canterbury	VH		VH	H				VH			
Otago	Different process used which provides risk ‘perception’ this process groups all natural hazards in one line item https://www.otagocdem.govt.nz/media/1200/2017-risk-register-version-4-under-review.pdf										
Southland	E		E	VH	VH	VH	VH				Snow, frost

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

VOLCANIC RISK SOLUTIONS

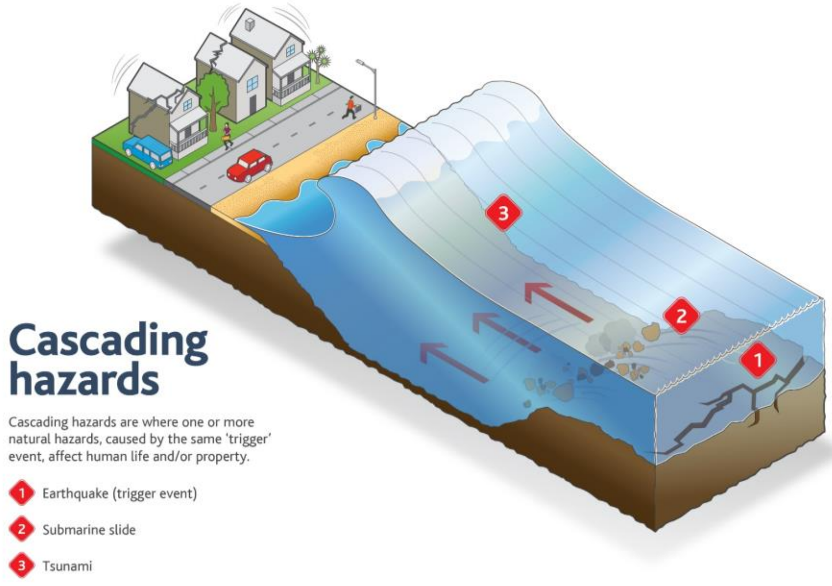
Hazards in reality

- **CASCADING HAZARDS**

(a primary hazard triggering one or more secondary hazards such as an earthquake triggering landslides which may block river channels with dammed lakes and ensued floods)

- **CUMULATIVE/MULTI HAZARDS**

(two or more primary hazards coinciding to trigger or exacerbate secondary hazards such as an earthquake and a rainfall event simultaneously creating landslides),



Secondary impacts


Vehicle air filters


Repeated clean-up

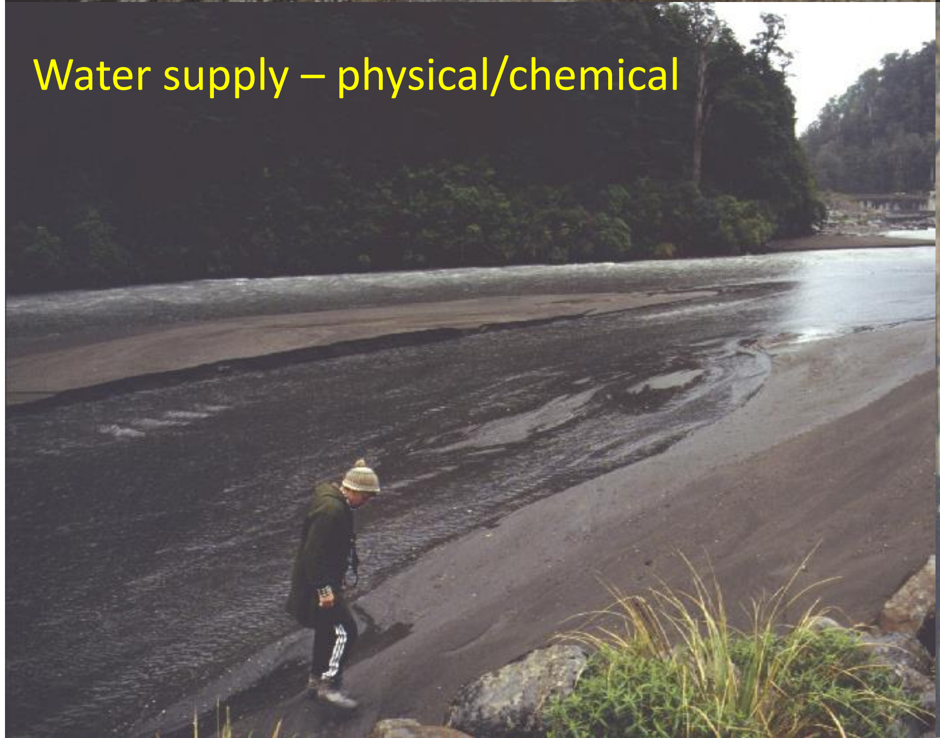

Lahars vs. Bridges


Dangerous driving conditions


Toxic
Acidic
13 1 2005
Acidic
Unpalatable
Contaminating

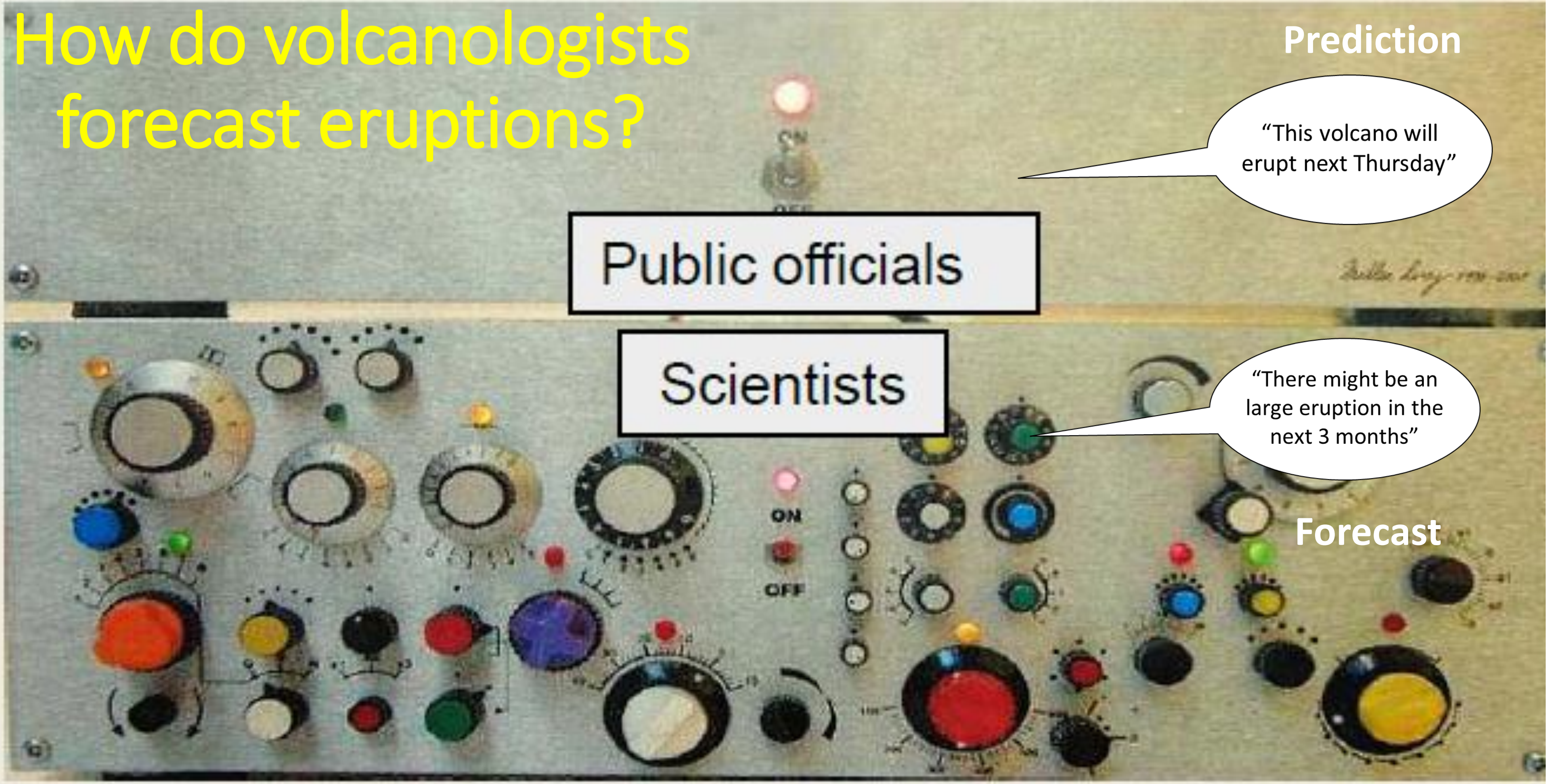

Corrosion


Water
Wastewater


Water supply – physical/chemical


Power/gas

How do volcanologists forecast eruptions?



National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

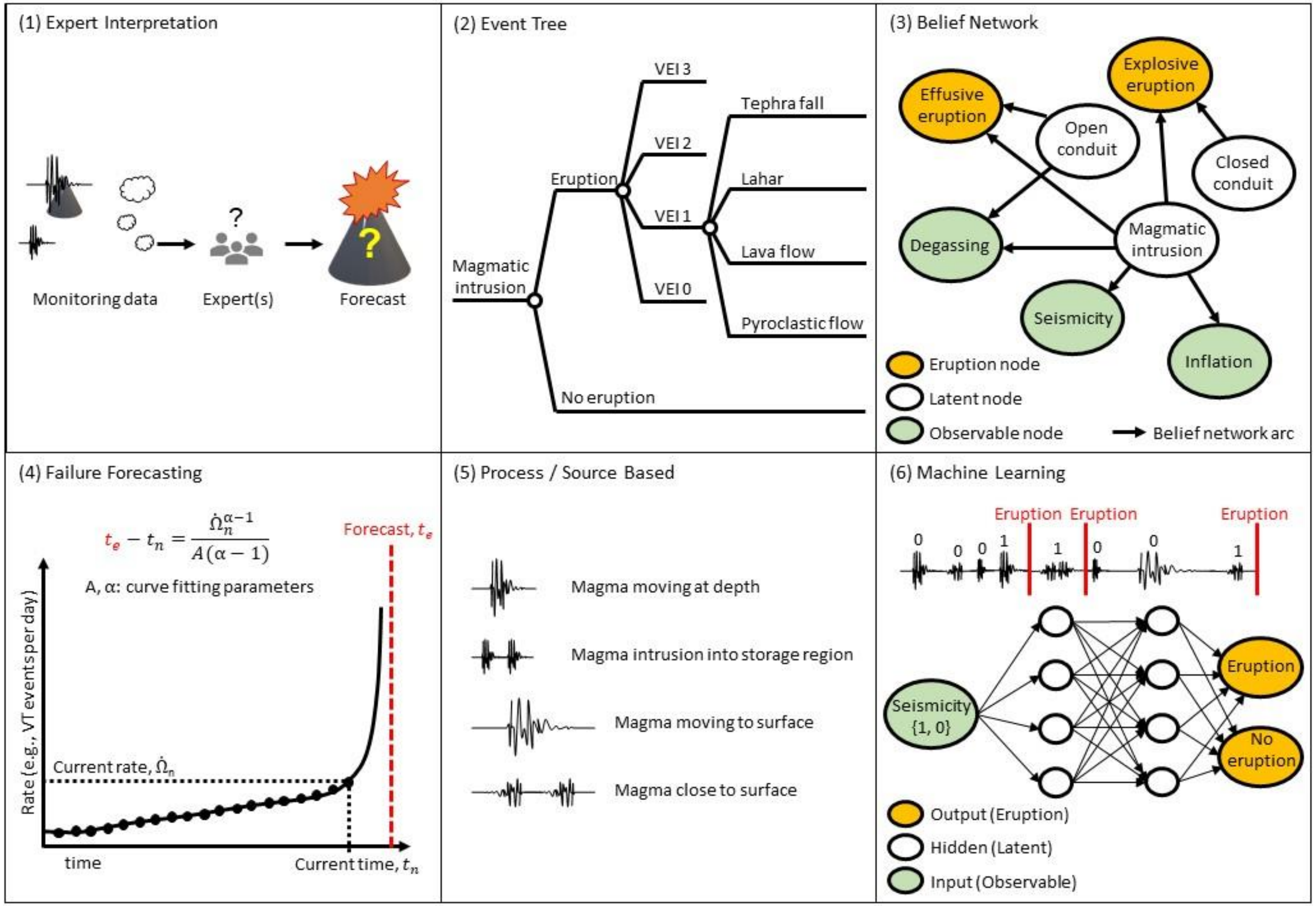
Can ~~How do~~ volcanologists accurately forecast eruptions?

"This inherent complexity [of volcanoes] and the large uncertainty in the knowledge of these processes lead to the practical impossibility of predicting deterministically, or even with a small uncertainty, the onset time, location, and size of the impending eruption." (p1777)

"Uncertainties cannot be completely eliminated….but they can be reduced significantly through the development of more reliable and skilled forecasting models." (p1800)

Marzocchi W & Bebbington MS (2012) Probabilistic eruption forecasting at short and long time scales. *Bulletin of volcanology*, *74*(8), 1777-1805.

How do volcanologists forecast eruptions?

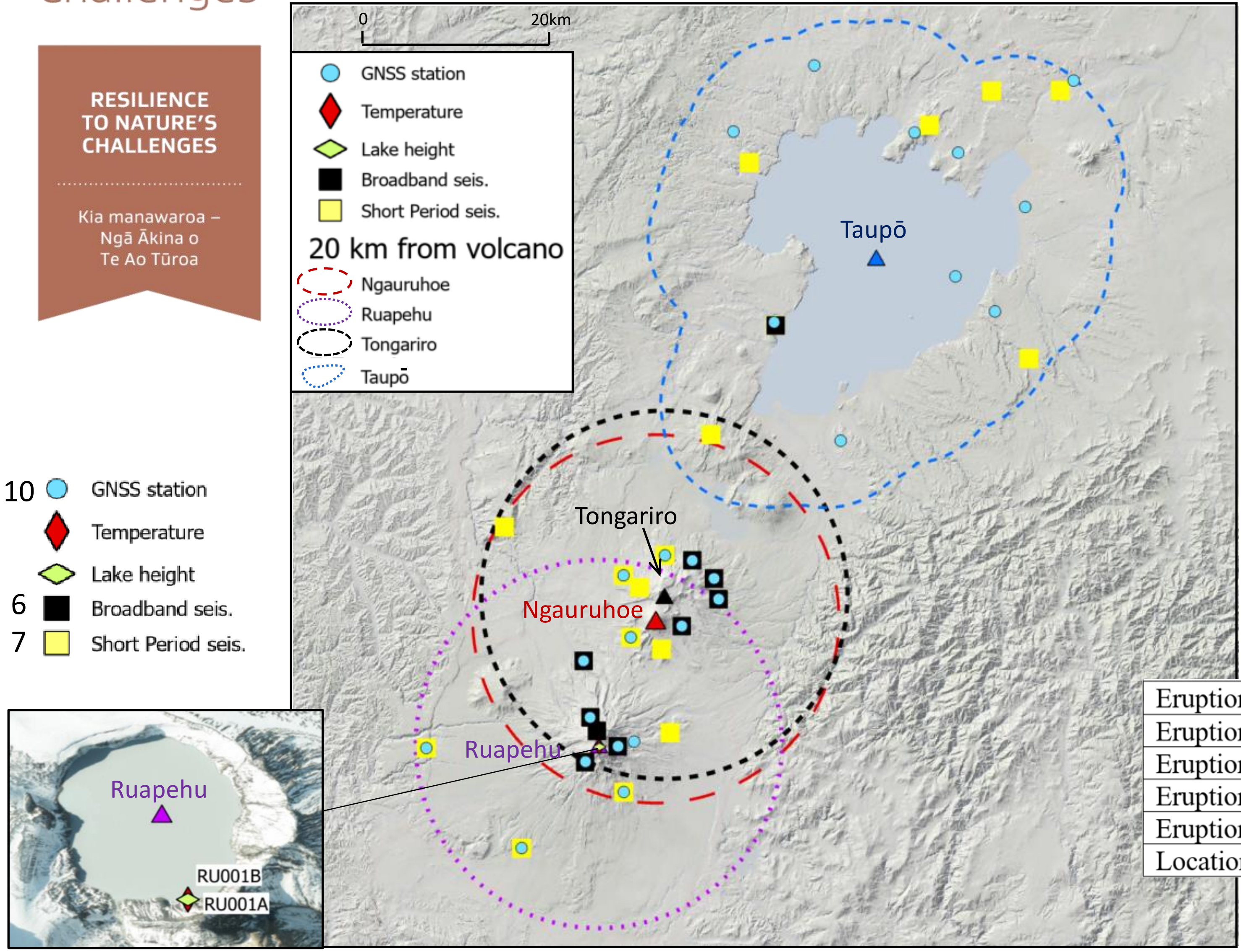


National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Ruapehu



Area used: < 20 km from crater lake

Sufficient seismic stations (> 6 broadband) suggests relative ease of application of FFM.

Several eruption-monitoring pairs available for belief network training. Data to train machine learning algorithms are available but must first be vectorised from paper seismograms.

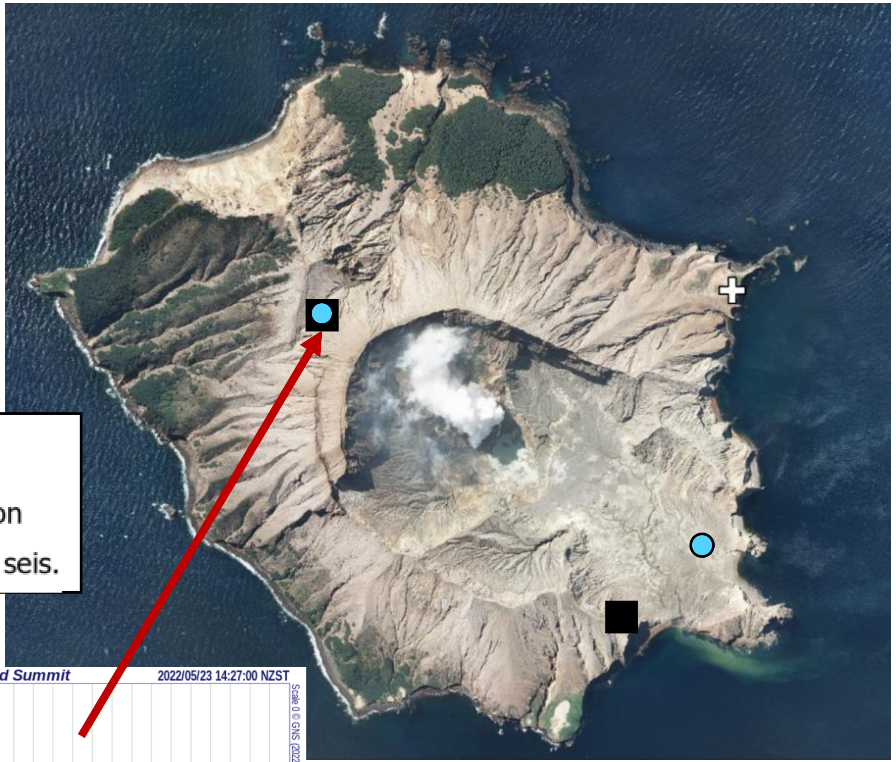
	Expert Interpretation	Event Trees	Belief Networks	Belief Networks with training	Failure Forecasting	Process/Source based	Machine Learning
Eruption onset time							
Eruption size							
Eruption style/type							
Eruption duration							
Eruption specific hazards							
Location specific parameters							

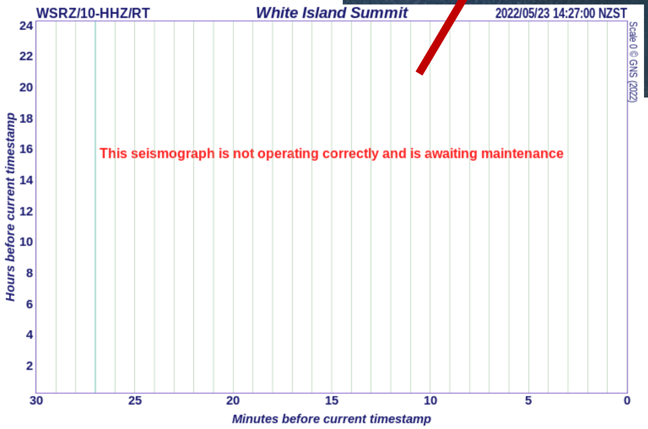
Negligible effort/time
Some effort/time
Medium effort/time
Significant effort/time
Not currently feasible

Mel Whitehead

Volcano

Whakaari





Seismogram, May 2022: https://www.geonet.org.nz/volcano/monitoring/whiteisland

Area used: On island

Data to train machine learning algorithms are available but must first be vectorised from paper seismograms

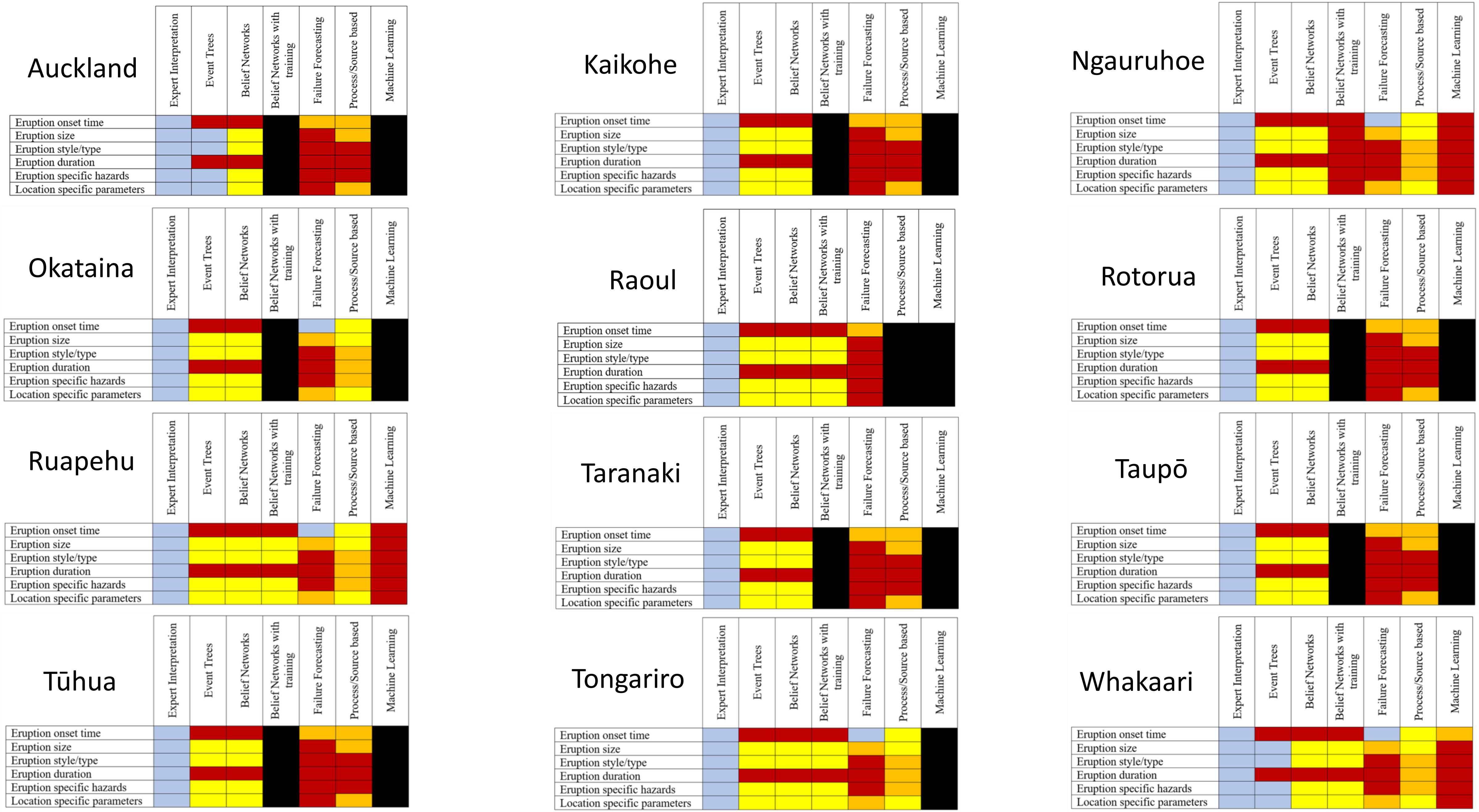
Several eruption-monitoring pairs available for belief network training

Expert elicitation exists for belief networks (Christophersen et al. 2018) and potentially allowing easier application of event trees

Machine-learning algorithm already constructed for eruption onset & currently being tested (Dempsey et al. 2020)

	Expert Interpretation	Event Trees	Belief Networks	Belief Networks with training	Failure Forecasting	Process/Source based	Machine Learning
Eruption onset time							
Eruption size							
Eruption style/type							
Eruption duration							
Eruption specific hazards							
Location specific parameters							

Negligible effort/time
Some effort/time

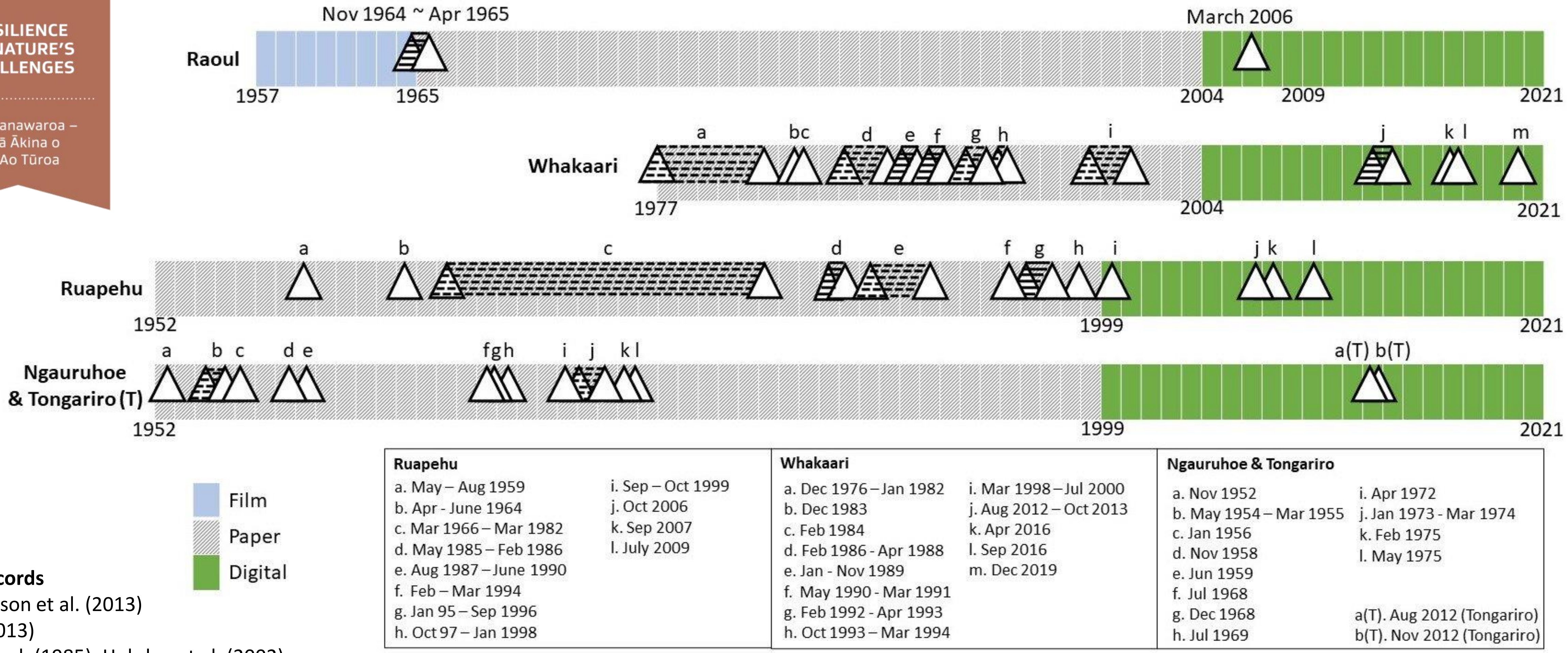

Auckland
Kaikohe
Ngauruhoe
Okataina
Raoul
Rotorua
Ruapehu
Taranaki
Taupō
Tūhua
Tongariro
Whakaari
Expert Interpretation
Event Trees
Belief Networks
Belief Networks with training
Failure Forecasting
Process/Source based
Machine Learning
Eruption onset time
Eruption size
Eruption style/type
Eruption duration
Eruption specific hazards
Location specific parameters

National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Seismic data yet to be exploited

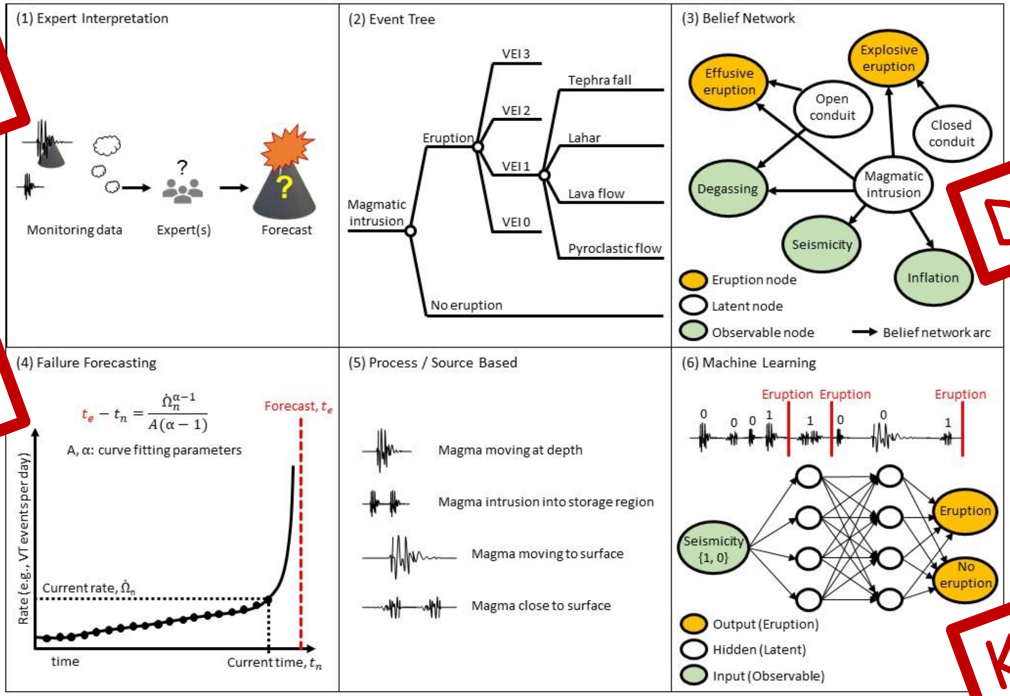


Eruption records
Ra: Christenson et al. (2013)
Ru: Scott (2013)
Ng: Latter et al. (1985), Hobden et al. (2002)
To: Scott and Potter (2014)
Wh: Kilgour et al. (2021)

How do volcanologists forecast eruptions?

Assumptions

Data requirements

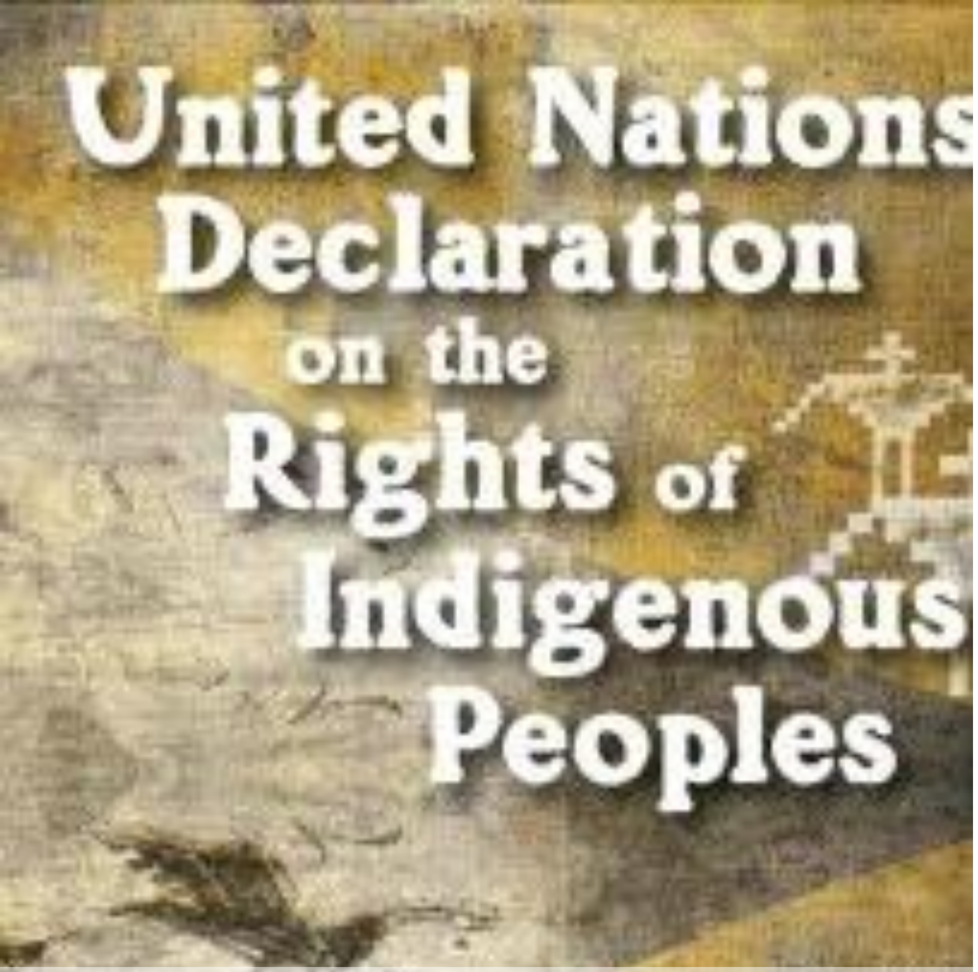


Forecast parameters

Knowledge requirements

Responsibly develop as many methods as possible for each volcano to better characterize epistemic uncertainty and to cover all required eruption parameters

Disclaimer: *The results here are based on practical implementation requirements with no implied assumption that those methods that are easiest to apply will provide the most accurate estimates. This work has addressed the matter of method feasibility; however, questions remain about which methods are most accurate and which are more likely to be trusted.*



- How can the traditional knowledge of indigenous peoples benefit everyone?
- How can it help us achieve the Sustainable Development Goals, Climate Adaptation, Resilience etc?
- Local Adaptive Solution that are cost effective and work?
- How has indigenous knowledge been transferred and been so effective?

Mātauranga Māori
Durie et al (2012)

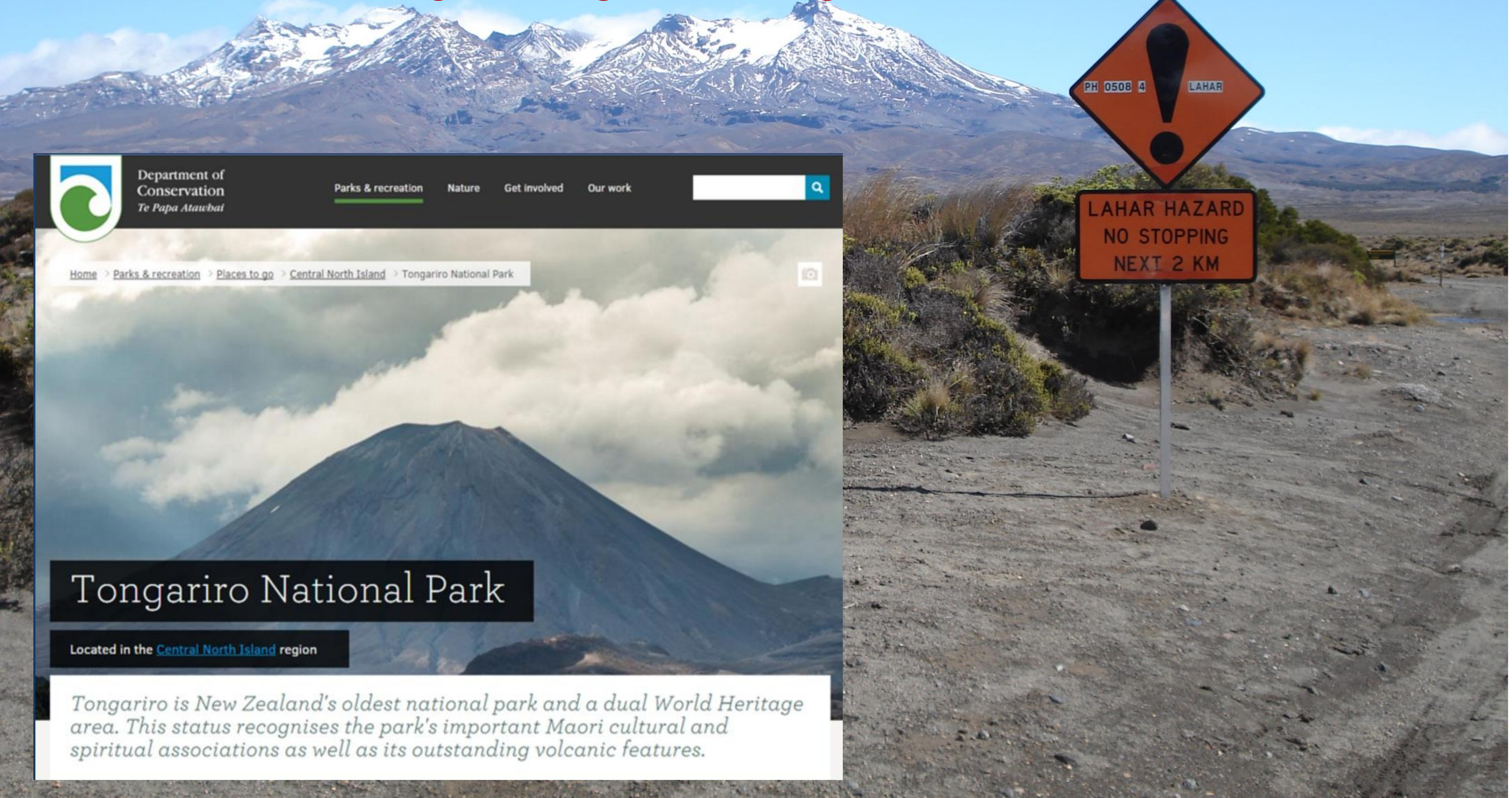
Mātauranga Māori is about an evolving knowledge. What students of Mātauranga Māori should come away with is a sense that knowledge is always changing, and that there are different approaches to it. The values might be derived from long ago, but knowledge changes. There is a difference between discovering, developing, and being excited by new knowledge, and simply being told the old knowledge… But when you look back on ancient times, Mātauranga Māori was an evolving form of knowledge. You didn't survive otherwise. You had to adapt to new situations all the time.

- Long term
- Powerful at predictions - locally
- Holistic
- Focused on people's wellbeing
- Nonhierarchical
- Nonlinear

He Ha Taku Maunga, Ko Taku Manawa
The Breath of my Mountain is my heart

Volcanic *(Hazards) from the perspectives of indigenous peoples; A case study from the Tongariro National Park (World Heritage Area)*

Ngati Rangi – Paerangi I Te Whare Toka



Ngati Rangi Trust
Te Kahui o Paerangi

Hannah Rainforth
Hollei Gabrielson
Jake Robinson

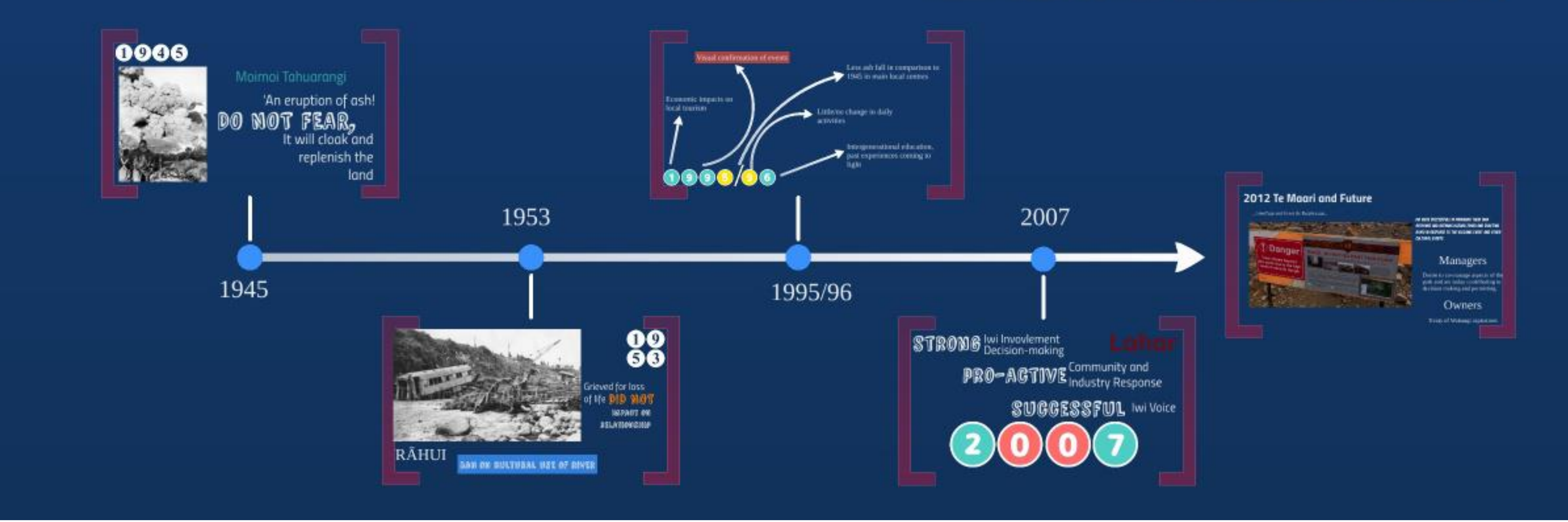
Massey University

Jonathan Procter
Tai Black

Landcare Research
Manaaki Whenua

G. Harmsworth

VOLCANIC RISK SOLUTIONS



Ngāti Rangi
Paerangi – i – Te Whare Toka

Te Matua o Te Mana

Our ancestor is not a volcanic ~~HAZARD~~

A living memory of responding and recovering to events

AHI-KĀ-ROA

Ngāti Rangi based

PARK MANAGEMENT

Marae are utilised

Spiritual relationship and connection with environment recognised

Inter-generational education/learning occurring in tandem

Oral narratives and traditional knowledge systems are central to assessing solutions

Tangata Tiaki
Self-sufficiency and capacity building within and by iwi

Community, iwi and hapū connections
Family-based networks enhanced

Hunter/gatherer lifestyle of traditional and contemporary resources maintained

'A lahar is Koro sharing some of his mana with us.'
Che Wilson

6. TE POU TUAONO: *RŪAUMOKO*

"E kore e ngaro te riringa o Ruapehu
Ka tuku te puehu, te auahi ee
Ko te riri koromaki, ka ngārue te whenua
Ka puha, ka ngunguru me he tai tuki ee"

Rūaumoko is the atua of our maunga Ruapehu; through Koro Ruapehu he is able to share his raw power with us. Rūaumoko is responsible for the many natural occurrences that we as Ngāti Rangi experience: earthquakes, lahars, volcanic eruptions and the associated thunder and lightning events. Ngāti Rangi have lived under the mantle of Matua te Mana for many generations and with that comes an acceptance and celebration of the natural events that take place here. We live alongside both Koro Ruapehu and Rūaumoko and have placed our pā and kāinga some distance from the pathways of volcanic events.

Our main issues around this area lie with the approach taken to address and mitigate Rūaumoko's events, termed by managers as "natural disasters" or "hazards". Other issues not included in here are:

- Volcanic monitoring and research
- Disaster response

NGĀ TAKE – ISSUES
6.1 MANAGEMENT OF NATURAL EVENTS

It is Ngāti Rangi's view that Rūaumoko's processes are natural, and should be allow to occur. Rūaumoko was, after all, in existence before humans. We consider that 'natural hazard management' should not so much be a matter of constraining natural processes in order to protect humans, but of removing ourselves and our buildings from areas of risk in order to let these processes occur as intended. In some ways, the designation of tapu areas is a recognition that those areas are not necessarily safe and should probably be avoided.

NGĀ WHĀINGA – OBJECTIVES

- The natural processes of Ruapehu as a volcano are not restricted by human intervention.

Artwork by Rangihikitia O'Neil

KAUPAPA TOHU – POLICIES
MANAGEMENT OF NATURAL EVENTS

6.1.1 Ruapehu Maunga will not be altered or tampered with in any way as part of any management strategy as a means to divert or withhold the flow of a lahar.

6.1.2 No new buildings will be erected in known lahar paths.

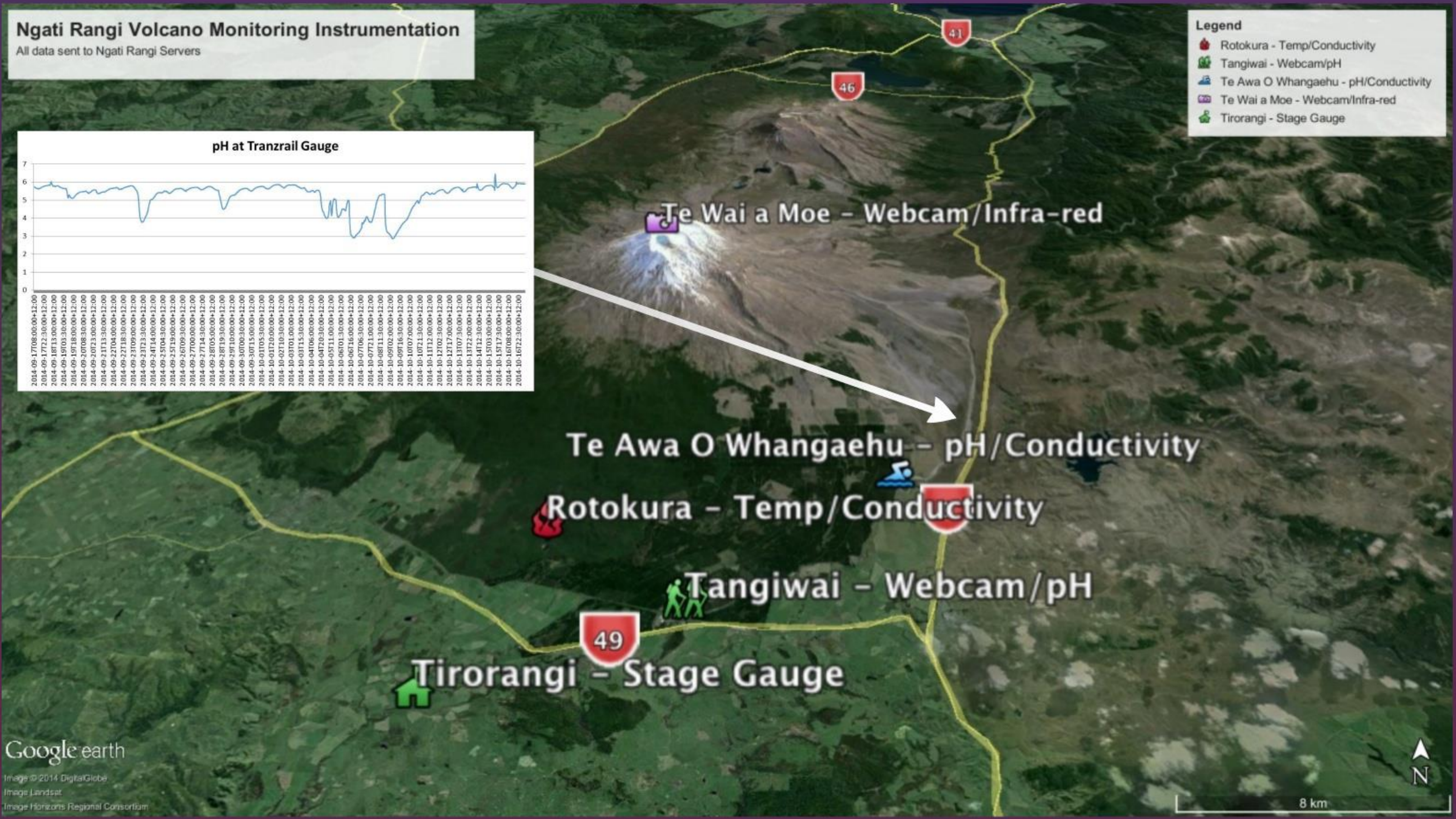
6.1.3 Monitoring and management of natural events in connection with Rūaumoko will involve Ngāti Rangi.

NGĀ TURE – RULES
RŪAUMOKO

Management of Natural Events
6.1.1.1 Ruapehu maunga will not undergo any physical works, or have any structure installed as part of any emergency management strategies, to divert or withhold the flow of a lahar.

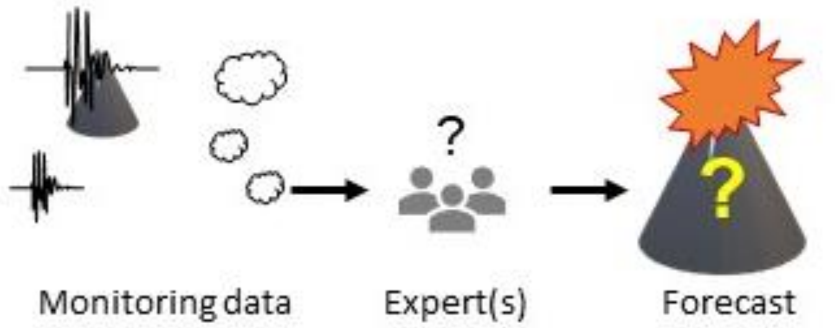
6.1.2.1 New consents will not be granted for buildings within known lahar paths.

The 2007 lahar in the Whangaehu River, Karioi.
Photo: Keith Wood.


Ngati Rangi Volcano Monitoring Instrumentation
All data sent to Ngati Rangi Servers
Legend
Rotokura - Temp/Conductivity
Tangiwai - Webcam/pH
Te Awa O Whangaehu - pH/Conductivity
Te Wai a Moe - Webcam/Infra-red
Tirorangi - Stage Gauge
pH at Tranzrail Gauge
Te Wai a Moe - Webcam/Infra-red
Te Awa O Whangaehu - pH/Conductivity
Rotokura - Temp/Conductivity
Tangiwai - Webcam/pH
Tirorangi - Stage Gauge
41
46
49
Google earth
8 km
N

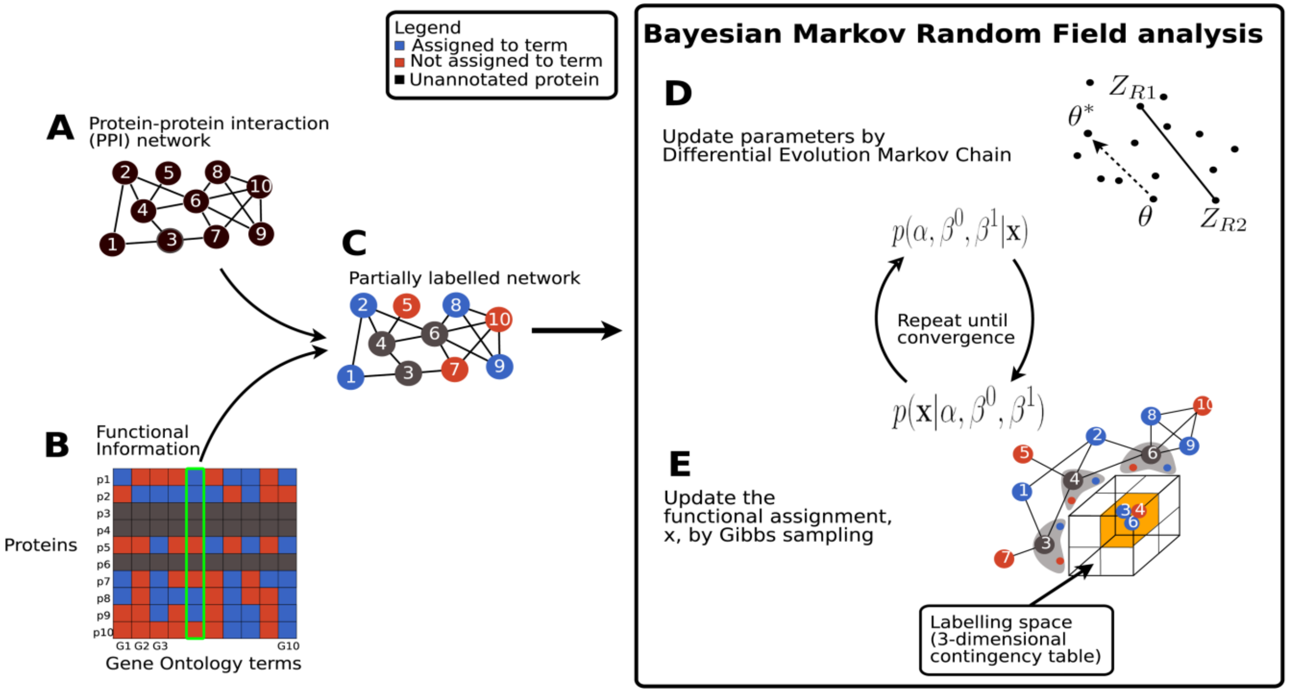
Future work - Incorporating traditional indicators alongside Western Science statistical forecasts

Expert Interpretation



Observation of tohu

Bayesian belief network



Statistical forecast model built on tohu observations

Māori Disaster Risk Reduction and Resilience Research in Aotearoa, New Zealand

- Research is about building the foundations to make fundamental change in society
- Māori researchers create new knowledge alongside creating new mātauranga Māori
- We can explore local knowledge, local solutions and mātauranga-a-iwi and hapū to examine how robust it is to transfer to new solutions
- Māori DRR research takes a long view and focuses on creating new knowledge and tools that will - Initiate changes that enable tangta whenua and wider Aotearoa New Zealand to be more resilient to future events, over multiple generations

"Innovation curve" – from destructive to regenerative approaches

(Source: UNDRR 2019)