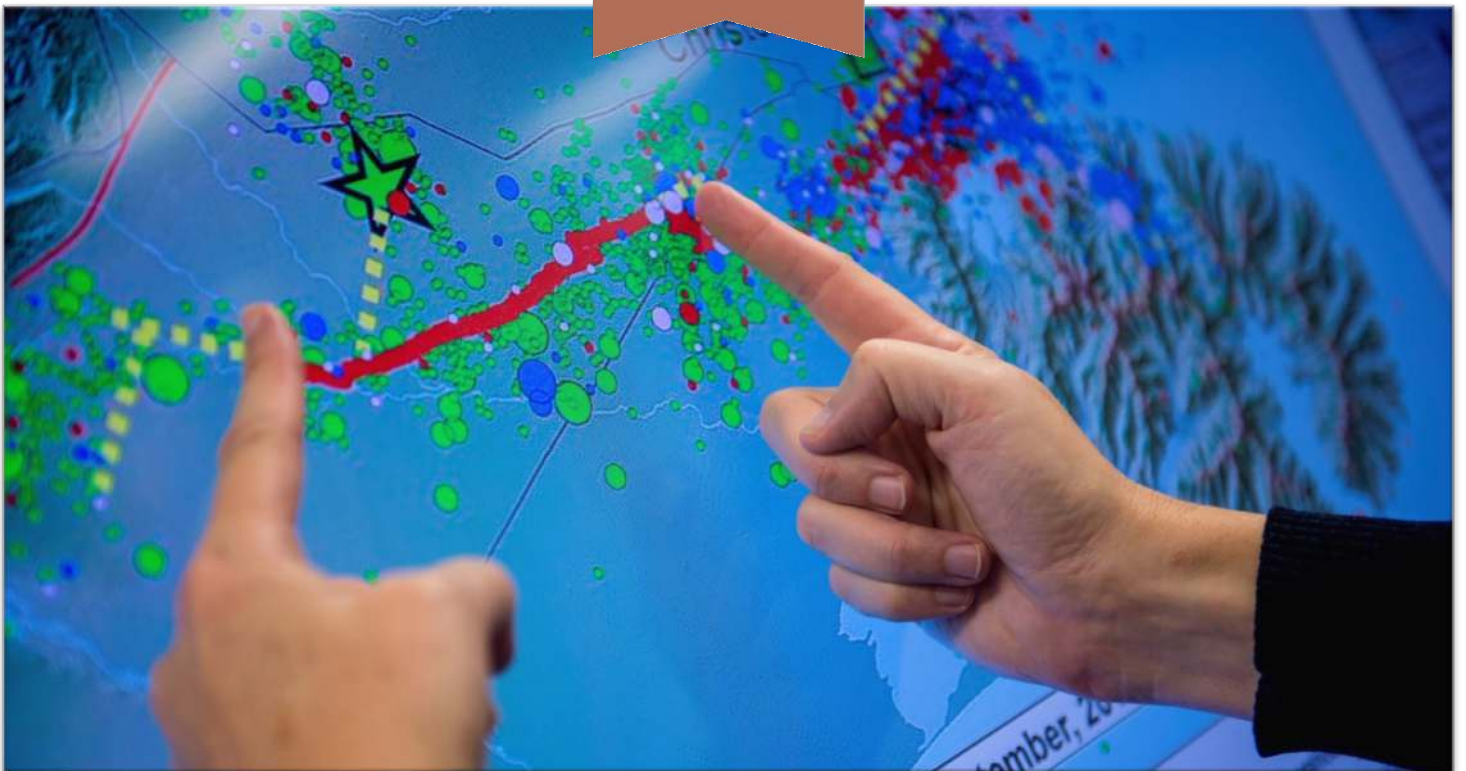


National  
**SCIENCE**  
Challenges

RESILIENCE  
TO NATURE'S  
CHALLENGES

Kia manawaroa –  
Ngā Ākina o  
Te Ao Tūroa



**Resilience to Nature's Challenges**  
**Kia Manawaroa – Ngā Ākina o Te Ao Tūroa**

## **Future Strategy**

10 July 2018

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# Executive summary

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Our wide range of natural hazards is unavoidable. However, we can avert natural hazard disasters if we understand and govern our risks well.

The National Disaster Resilience Strategy (NDRS; to be launched in April 2019) guides the Resilience Challenge's second phase of research. The NDRS is a government-wide initiative encapsulating New Zealand's response to the UN Sendai Framework for Disaster Risk Reduction. Our research structure will underpin, inform and monitor this national strategy. We will re-organise our work around two central models that address the NDRS and harness the combined New Zealand research strengths of the Natural Hazard Research Platform and the phase 1 Resilience Challenge.

The *Multihazard Risk Model* will facilitate previously unattainable resilience planning in New Zealand by merging time-varying hazard, risk and socio-economic impact modelling tools. By integrating all major natural hazard risk approaches under a single framework, the Resilience Challenge will objectively align natural estimates of varying hazard types and scales. This will provide a new degree of rigor to support decisions toward New Zealand's resilience. *Multihazard Risk* will harness research from four specialist themes on: Coastal, Volcanism, Earthquake/Tsunami and Weather hazard.

The *Resilience in Practice Model* will harness the valuable end-user partnerships we have built during the co-creation process of phase 1 to ensure that new resilience knowledge becomes part of daily decision making in New Zealand. Social-science research will seek out and target blind-spots in our current policy and community action on resilience. We will empower the co-design of risk governance and best practice resilience planning across four diverse areas encompassing our Urban, Rural, Māori, and Built environments. These will produce tailored resilience interventions that fit communities, leadership, infrastructure and industries across our country.

We will ensure that research is of the highest standard and relevance through strong advisory groups and international review. Our research team includes New Zealand's most internationally renowned resilience researchers. These thought-leaders will drive teams of energetic early and emerging researchers (and PhD students) across the diverse disciplines of resilience. A mix of flexible and contestable funding will enable team growth and agility for the Resilience Challenge to re-focus and respond to scientific needs in case of future major natural hazard events.

Knowledge and understanding of New Zealand's natural hazards alone is not enough to ensure resilience. Research outputs must be targeted and functional for end-users to translate into tangible resilience practice. We can achieve this through deeply co-created research that emphasizes the needs of end-users and their unique challenges. Our holistic approach brings an exciting and cohesive body of research that will best support New Zealand's resilience transformation.

# Long-term goal

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## Our vision of New Zealand beyond 2024

New Zealand has mainstreamed natural hazard risk management and resilience underpinned by new knowledge and supported by significant societal attitude change. We have embraced the productivity benefits of building and working in smarter, more proactive ways alongside natural hazard. We have a clear national resilience strategy that guides community design and land-use planning, along with emergency response and recovery. We integrate natural hazard resilience into daily business.

1. Our productive economy and industry are responsive and adaptive to natural hazard risk, applying approaches such as:
  - a. Economic-risk and benefit modelling to harness the most effective resilience opportunities for future investment by government, industry and iwi/Māori.
  - b. Incentivisation of diversified and alternative futures for business, agriculture, tourism and other major industries for New Zealand's future.
2. Artificial barriers to the unified governance and ownership of natural hazard risk are replaced by collective risk ownership by all sectors of society. This requires:
  - a. Negotiated revision of unclear policy, legislation and practices around risk ownership, such as the debate between central government, local government, iwi and private land-owners over risk responsibility.
  - b. Joint private and public investment into risk reduction, response and recovery.
  - c. Prioritising rapid recovery initiatives through collective action.
  - d. Using trusted economic and risk modelling tools to consider the long-term societal benefits of alternative resilience recovery options in business cases, including identification of unsustainable communities and fast-tracking resilient alternatives.
  - e. Opportunities for Māori to participate in decisions and apply Mātauranga Māori.
3. Our buildings and infrastructure include new design and retrofit engineering to better resist multiple-hazard impacts and be more rapidly serviceable after events. This requires:
  - a. Discovery and implementation of new engineering solutions for cost-effective resilience-based design.
  - b. Incentivising resilience and valuing resilience in cost structures – especially in strategic construction, retrofit, resilient service, and system redundancy.
  - c. Evolving attitudes of government, iwi/Māori, industry and public consumers to demand and implement higher standards of design and build.
4. Our understanding of natural hazard and risk is enhanced, consistent and more clearly quantifiable, including uncertainties on future risk scenarios; this depends on:
  - a. New unified models of multi-hazard risk, integrating timescales and impacts of different hazard types in different parts of New Zealand.
  - b. Economic and risk modelling tools that examine impacts of extreme events under climate change and evolving knowledge of tectonic and geological hazard.
  - c. Underpinning hazard science that is strong and trusted, with a responsive science sector assisting government and communities before and during emergency events.
  - d. Improved education around natural hazard across the board in New Zealand.
  - e. Access and appropriate use of Mātauranga Māori.

# Five-year strategy

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## Overview

*The Resilience Challenge Objective is to “enhance New Zealand’s resilience to natural disasters”*

A wide range of natural hazards regularly strike New Zealand. In the past two years, earthquakes, wildfires and tropical cyclones caused loss of life and lasting damage to infrastructure, business and welfare. Such events continue to raise the stakes in natural hazard risk management for us all. We need research to develop new methods to better understand natural perils and new practices to help New Zealand communities live through and recover from hazard events.

This strategy builds on the success of the phase 1 Resilience Challenge and the recently completed Natural Hazards Research Platform. From these, we advance research to increase our understanding of the risks, impacts and resilience to natural hazards in a Multihazard Risk Model (MRM), coupled to research into resilience initiatives and practice in partnership with end users in a Resilience in Practice Model (RPM). Examples of this approach are our current research contribution to the complex interactions of hazard and lifeline networks during the South Island-wide Alpine Fault “AF8” scenario, and integrated resilience planning for 100 years of coastal change in the Hawkes Bay. Our research scope includes geologic, extreme weather and gradual shifting of the hazard “baseline” through sea level rise and climate change. Further, we research new economic, social science and engineering solutions for our hazard issues tailoring them to fit end-users through co-creative partnerships in the diverse Urban, Rural, Māori and Built environment settings of New Zealand.

We re-cast our Resilience Challenge mission to guide our future strategy:

*With multiple end-users we will generate co-created research solutions to accelerate New Zealand’s journey toward natural hazards resilience. We will unify underpinning research of geophysical, weather and fire hazard into a multi-hazard risk model. In parallel, we will design economic, social and engineering solutions to build inter-generational resilience.*

Following eight end-user workshops held over the last 12 months, formal advisory group meetings and input from end-users working within the Resilience Challenge, the most important national need for New Zealand was identified as: new natural hazard risk reduction and resilience practices to be useful and used by government, industry, Māori/iwi and communities. In phase 2, we will refine our co-creation and co-design methods to focus on developing solutions for multi-hazard risks that are fit-for-purpose. Our co-creation process will also help unlock the science and innovation potential of Māori resources, people and knowledge. Co-creation is the most potent mechanism we can use to develop new research with the best chance to influence policy and give effect to Vision Mātauranga.

We have learnt that it takes more than just knowing and understanding hazard in New Zealand to build resilience. We must move beyond ignorance of low-probability events, the pervasive attitude that natural hazard is someone-else’s problem, or the optimistic view that natural hazard is avoidable. Instead we must emphasise the productivity and societal benefits for New Zealand of proactively addressing natural hazard resilience in business and governance. This requires underpinning research that helps our end-users to understand complex natural hazard threat and devise effective resilience countermeasures.



**Figure 1.** The draft National Disaster Resilience Strategy (NDRS), an all-of-Government strategy developed by the Department of the Prime Minister and Cabinet to be launched in April 2019.

We move into the next phase of our work for the first time under the umbrella of the **National Disaster Resilience Strategy (NDRS)** (Fig. 1). This all-of-Government initiative will launch in April 2019. The NDRS represents New Zealand’s response to the United Nations sponsored Sendai Framework for Disaster Risk Reduction 2015-2030. Our research and researchers have already contributed to the international and New Zealand strategy documents and during our next five years of research, we will underpin, inform and monitor this strategy with new research knowledge.

The phase 1 Resilience Challenge took a co-creation approach to resilience research in New Zealand. This meant partnering with end-users to focus on resilience in practice, extending from other hazard and risk investments in the sector (e.g., the Natural Hazards Research Platform and QuakeCoRE). The phase 1 Co-creation Laboratories tackled four areas that characterize the different needs of our spatially and culturally diverse country, including coastal settings (Edge Laboratory), primary sector and rural environments (Rural Laboratory), Māori resilience and Mātauranga contexts (Māori Laboratory), and urban areas (Urban Laboratory). In addition, supporting toolbox research in six areas provided specialist research inputs to the laboratories.

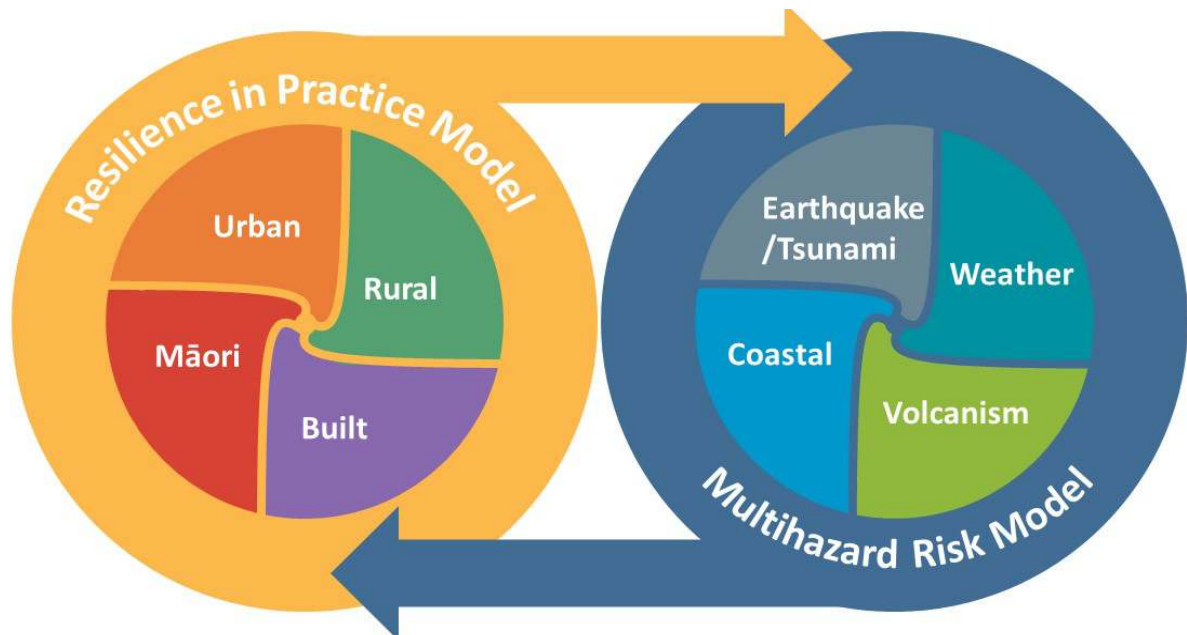
In the future research strategy for the Resilience Challenge we simplify the overall phase 1 structure into two central components that address the NDRS (Table 1, Fig. 2). The **Multihazard Risk Model (MRM)** brings the first coherent approach to understanding and integrating knowledge of our diverse natural hazard and risk in New Zealand. This is complemented by the **Resilience in Practice Model (RPM)** that strives to create a resilience culture, through co-created solutions targeted to the diverse environments in New Zealand.

**Table 1.** Relationship of the Resilience Challenge (past and future) to the National Disaster Resilience Strategy.

Resilience Challenge 2014-2019	National Disaster Resilience Strategy	Resilience Challenge 2019-2024	
Culture Toolbox	<b>P1. Building a Culture of Resilience</b>	Resilience in Practice Model	
	P1. F2. Recognizing the importance of culture to resilience		
	P1. F3. Increase outreach and education in risk and resilience		
Governance Toolbox	P1. F1. A whole of society approach to the governance of risk and resilience		
Co-creation Laboratories	P1. F4. Ensure we are “future ready”		
Economics Toolbox	<b>P2. Improve our understanding of risk to enable better risk-informed decision making</b>	Multihazard Risk Model	
Hazard Toolbox			
Trajectories Toolbox			P2. F5. Collect and centralise risk and resilience data.
Hazard Toolbox			P2. F6. Improve ability to assess risk.
Co-creation Laboratories			P2. F7. Better understand the social aspects of risk and vulnerability
			P2. F8. Improve risk communication and literacy
Economics Toolbox			P2. F9. Develop decision support tools
	<b>P3. Reduce risk</b>	Resilience in Practice Model	
Infrastructure Toolbox	P3. F10. Infrastructure protection and upgrading		
Edge Laboratory	P3. F11. Retreat and relocation		
	P3. F12. Incorporate climate change in Risk Management		
Co-creation Laboratories	P3. F13. Encourage resilient development		
Economic Toolbox	P3. F14. Improve ability to quantify losses, risk and fund resilience	Multihazard Risk Model	
Co-creation Laboratories	<b>P4. Strengthen resilience</b>	Resilience in Practice Model	
	P4. F15. Resilient homes and households		
	P4. F16. Resilient businesses and organisations		
	P4. F17. Resilient communities		
	P4. F18. Resilient cities and districts		
	P4. F19. Seamless response system		
	P4. F20. Promote recovery		

Our end-users strongly support the laboratory elements of our phase 1 Resilience Challenge and they will extend under revised formats and refreshed teams. The future of the Resilience Challenge also involves integration of core successful components of the completed Natural Hazards Research Platform. The Platform’s past work, divided into five themes, will be tracked into the future Resilience Challenge as follows:

- Geohazard Theme – will form the Earthquake/Tsunami and Volcanism themes of the MRM.
- Weather Hazard Theme – will form the core of the Weather Theme of MRM.
- Engineering Theme – will form part of the Built Environment Theme of RPM.
- Risk Theme – will form part of MRM, continuing to link tools such as RiskScape and MERIT.
- Societal Theme – will feed into several parts of RPM.



**Figure 2.** The structure of the phase 2 Resilience Challenge. Our strategy is organized around two models that collectively address the NDRS: (1) a Multihazard Risk Model (MRM) – addressing Priority 2 of the NDRS; and (2) a Resilience in Practice Model (RPM) – coordinating co-creation approaches to building resilience solutions with end-users (addressing Priorities 1, 3 and 4).

The foundation of our research is underpinning science for the cultural (includes Mātauranga Māori and kaitiakitanga), social (includes iwi/hapū and whanau), physical (includes tikanga) and engineering mitigation and management of natural hazard in New Zealand’s future. Our research strategy encompasses a very broad range of topics organized to provide targeted underpinning science for more effective social, physical and engineering mitigation of natural hazard risk. End-users include all New Zealand communities, businesses, iwi/Māori and all levels of government, especially in the infrastructure, emergency management and natural resources sectors.

This collective research is more than the sum of its parts; themes will be interconnected – leveraging the maximum strength of a multidisciplinary approach. Collaboration across discipline and specialist boundaries will also be enhanced by:

- Building joint case studies, bringing multiple teams to bear on the same end-user issue – e.g., AF8, coastal retreat strategies for New Zealand, urban resilience, tourism and rural resilience, resilient buildings, transport and electricity network resilience.
- Collective delivery and targets (e.g., integrated models between diverse hazard into the MRM).
- Monthly meetings of science leaders – to tease out new opportunities for collaboration as they arise and foster active links across the programme.
- Collaborative public engagement initiatives within issue-focused fora (e.g., Lifelines or Emergency Management conferences) and annual research meetings.
- Co-creation activities – driven through the mechanism of the RPM themes.
- Event response and strategic planning for leveraging additional funds (e.g., via QuakeCoRE, Endeavour Fund, industry and government aligned and co-funding).



## *The Multihazard Risk Model (MRM)*

New to phase 2 of the Resilience Challenge, the MRM will be the first attempt to create an integrated framework for evaluation of natural multihazard risk for New Zealand. This addresses Priority 2 of the National Disaster Resilience Strategy and includes underpinning hazard-specific research organised in the following hazard themes:

- Earthquake/Tsunami
- Volcanism (airborne ash and gas, ashfall, explosive processes, lahars, landslide)
- Weather (cyclones, floods, droughts, rural fire, winter storms)
- Coastal (land changes, storm surge, erosion, coastal flooding, implications of sea-level rise).

We will construct new “hazard-to-impact” evaluations that incorporate changes expected in tectonic state, climate, demography and culture, technology and our natural environment. By harnessing Mātauranga Māori knowledge and kaupapa Māori approaches we will further seek to integrate a longer history and deeper cultural understanding of hazard and its impact throughout New Zealand.

Research in these themes will be centrally coordinated by the MRM team to ensure consistency in approach, spatial and temporal outputs and treatment of uncertainties. In this way we will build the first holistic and quantitative national view of multi-hazard facing New Zealand. The evaluation and comparison of complex multiple hazards of different types (and cascading hazard) has been a constant request during all end-user engagement by the Resilience Challenge since 2014, particularly by civil defence and emergency management groups, local authorities and iwi throughout the country

To **improve our understanding of risk**, we will integrate research into the societal (including Mātauranga Māori) and economic attributes of vulnerability and resilience via new mathematical, statistical and economics research. The Multihazard Risk Model will also collate and adapt the latest simulation and risk evaluation tools under one umbrella. We will build toward a central knowledge database to discover, plan and evaluate the most urgent and effective risk reduction and resilience interventions across New Zealand. Economic planning tools, such as MERIT will be extended to inform the most effective new resilience business cases. Aligning with the government priorities on intergenerational wellbeing, our resilience business case tools will test and highlight the enduring, long-term payoff of resilience interventions, e.g., to issues such as transport infrastructure, city planning and managed retreat.

A further component of the MRM is the evaluation of resilience performance (P2. F5; Table 1). Extending from the Trajectories Toolbox of phase 1, the Multihazard Risk Model will refine quantitative methods for indexing or measuring resilience via public data and embed these into the monitoring strategy for the NDRS. This will also enable us to report against the UN Sendai Framework for Disaster Risk Reduction.

## *The Resilience in Practice Model (RPM)*

Paired with our new understanding of multihazard risk, we continue our hugely successful co-creation approach to partner with end-users across diverse areas of New Zealand for joint development of new resilience practice. The Resilience in Practice Model aims to produce new resilience practices that are well targeted, and well used by decision-makers. Guided by knowledge of the cultural, legal, social and governance context of New Zealand, we will co-design initiatives tailored to a range of contexts and scales. Real examples of such resilience initiatives from phase 1 include:

- A comprehensive 100-year coastal management strategy for the Hawkes Bay region, endorsed by all local-government agencies and community partners.
- New network resilience evaluation tools applied to single and multiple inter-connected electricity distribution and communications networks in the Canterbury-West Coast region.
- New resilience modules for NZTA planning for transport disruption and repairs/replacements during major outages anywhere in New Zealand.
- New emergency management plans and practices developed and tested by all South Island local authorities under an Alpine Fault (AF8) earthquake scenario.

Four RPM themes address the main geographic and cultural areas of New Zealand. These require uniquely different and specialised resilience approaches, although they will be anchored in the same guiding philosophy and driven by the same integrated risk information. The Co-creation Laboratories of phase 1 are well-embedded with end-users, and the end-user pull for these to continue has been emphasised by many letters of support. For example, the mayors of South Island territorial local authorities have requested the continuation of the Rural theme, seven cities have supported the Urban theme, with similar levels of support for the Māori and Engineering/Infrastructure themes from end-users.

We highlight here a new Built Environment Theme. This “co-creation laboratory” combines highly successful elements of the Infrastructure Toolbox of phase 1 and the Engineering theme of the Natural Hazards Research Platform. The New Zealand Lifelines Council urged expansion of the Infrastructure Toolbox, while recent reviews of the Engineering theme of the Natural Hazards Research Platform have shown how strongly this supports innovation in the building sector for resilience. Further aligned to this theme, is the research power of QuakeCoRE. Successful partnership of QuakeCoRE and Resilience Challenge research during phase 1 has amplified research outcomes, far beyond the possibilities of either entity alone. Examples of this are the research following the Kaikōura earthquake into building resilience in Wellington, as well as infrastructure impact research of the AF8 and extended-AF8 earthquake sequences.

To give effect to the Vision Mātauranga policy, a theme will investigate Māori awareness and decision-making in resilience and generate fundamental Mātauranga Māori and applied Māori hazard, risk and resilience knowledge. We have identified Māori end-users to work alongside, as well as Māori academics, researchers, and practitioners to develop new and innovative acceptable tools, whilst seeking outcomes that are mutually beneficial. A key outcome will be the promotion of a Mātauranga Māori Academy of Natural Hazards and Environmental Systems Research through the advancement of Māori ontologies and the sharing of information, resources and opportunities.

## *Future strategy development*

Over the last 12 months, a series of 8 workshops were held in Wellington and Christchurch to integrate the Resilience Challenge with the Natural Hazards Research Platform and build our phase 2 strategy. Workshops involved between 40-80 participants and were open to researchers from all science organisations in New Zealand, our end-user and Māori advisory groups, and our local government, central government, private sector and NGO end-users from across the country. The workshops also helped us define the most important resilience questions in New Zealand and explore structures to best create a broad collaborative programme that is more than just a collection of diverse projects.

To assist the Challenge Director with research strategy development, a writing group of senior researchers was recruited. These writing leads assembled teams of researchers and key end-users in their areas to develop research ideas that addressed the priorities identified in workshops: Weather, Earthquake/Tsunami, Volcano, Coastal, Multihazard Risk, Mātauranga Māori, Recovery and Delivering Resilience. In writing this strategy we have accessed all relevant documents associated with resilience in New Zealand, including, but not limited to, the following:

- New Zealand National Disaster Resilience Strategy (MCDEM)
- Ministry for Environment Research Roadmap
- Ministry for Primary Industries Research Roadmap
- Land Information New Zealand Resilience Strategy
- Local Government New Zealand Hazards Think-piece (2014)
- Ministry for Business, Innovation and Employment, Built building safety and energy strategies
- The United Nations Sendai Framework for Disaster Risk Reduction
- Treasury National Infrastructure Unit guidance and Living Standards Framework
- New Zealand Transport Association Resilience plans
- Ministry for Foreign Affairs and Trade Strategic plan
- New Zealand Fire and Emergency Strategy and associated documents
- Earthquake Commission of New Zealand Statement of Intent
- Other relevant plans and strategies of Ministry of Māori Affairs, Treasury, Ministry of Economic Development, along with Local Government plans.
- GNS Science Strategic Initiative Funding plans (as communicated by Dr Gill Jolly)
- NIWA Strategic Initiative Funding (as communicated by Dr Sam Dean)
- Ministry of Business, Innovation and Employment - Endeavour research funded proposals in hazard (ECLIPSE-Caldera Volcanoes, Kaikōura Earthquake-induced Landslides, Hikurangi Margin Megathrust Earthquake, Extreme Wildfire, NZ Sea Level Rise.
- QuakeCoRE research strategy.

The first proposal was revised by a group of New Zealand experts before the International Science Advisory Group (ISAG) interviewed writing team leaders on 1-2 March 2018. Their detailed report informed revision of the strategy. Follow-up workshops for each writing group led to revised theme-proposals on 30 March 2018, which were integrated into a central framework.

In order to deepen consultation around the specific earthquake/tsunami and earthquake engineering areas, the Chair of our End-user Advisory Group (Roger Fairclough) ran two facilitated workshops. These helped to resolve the physical science, engineering and social science balance of work and how tsunami research is best incorporated.

All writing teams engaged with end-users to develop detailed workplans and some (e.g., Edge/Coastal) ran national workshop tours. Based on end-user feedback, a revised strategy was prepared on 17 April 2018. This was formally reviewed by: the science leaders of the Resilience Challenge and Natural Hazards Research Platform; the Challenge Parties Group; and our three advisory groups.

Since May, two feedback meetings have been conducted with the full Challenge Parties Group, the End-User Advisory Group and the science leaders. In this period also two sets of written feedback have been received from the International Science Advisory Group and the Mātauranga Māori Advisory Group. These commentaries and the Governance Group comments have all fed into the final strategy.

### ***Best team approach***

Throughout the Resilience Challenge, in every model and theme, we involve internationally recognised researchers at the highest levels of New Zealand science in their fields. These thought-leaders help to maintain the ultimate quality and international relevance and benchmarking of our science. In addition, the powerhouse of our research activity rests on the next tier of researchers, typically at early to mid-career stages. Emerging researchers are our future and those rising through our phase 1 work have developed a broader than ever awareness of the transdisciplinary needs of resilience. Alongside excellent science communicators and end-user interlocutors, we also need specialists in areas as diverse as social theory, engineering design and mathematics. Excellent examples of the new generation of scientists emerging from the Resilience Challenge are Dr Caroline Orchiston (University of Otago) and Dr Sarah Bevan (University of Canterbury), who have taken major roles in ensuring that Project AF8 was a success (garnering co-funding from the Ministry of Civil Defence and Emergency Management). A.Prof. Liam Wotherspoon (University of Auckland) proved his leadership credentials through prodigious research and publication output, very strong end-user support and international science endorsement, and collaboration with QuakeCoRE. In our future research strategy, we aim to foster many more such new leaders.

Throughout phase 1 we have supported over 20 PhD research projects, including three Māori student projects. These drive high levels of science output, facilitate excellent co-creation with our partners and build our collective talent pool. In phase 2, we aim to train at least a further 20 PhD students in core resilience topics and create opportunities for some of our most talented PhD graduates to make their way into post-doctoral positions. By developing postgraduate research projects in close cooperation with end-user agencies, we also aim to produce a wider skilled workforce imbued with resilience knowledge and practice. By working with iwi, we aim to recruit several more Māori students.

Our phase 2 contestable funding is also designed to build new researchers and encourage young researchers to gain early leadership opportunities. In phase 1 contestable funding, we have supported several new researchers into their first major independent research projects, for example Morag Ayers (Market Economics), Dr Loïc Le Dé (AUT), and Dr Emily Grace (GNS Science). We will also encourage indigenous innovation and opportunities for growth in our Mātauranga Māori and kaupapa Māori research team. In phase 1 we supported the young Māori researcher Ms Lucy Carter (Massey University) to take on her first ever research project leadership opportunity in kaupapa Māori approaches to tsunami hazard education.

# Specific research objectives

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## **Multihazard Risk Model (MRM)**

*To merge time-varying hazard, risk and socio-economic impact modelling tools for multiple hazard types on a consistent basis with a universal treatment of uncertainties.*

The MRM is a centrepiece of the Resilience Challenge (Fig. 2). This programme will advance resilience in New Zealand by providing the first tools to collectively quantify the highly variable and diverse natural hazards and risks we face. The work will also produce a framework to objectively measure the efficacy of risk reduction solutions and forecast long-term benefits of resilience investment. The focus will include 'normal' hazards and more extreme and complex event sequences. The dramatic effect of cascading hazards was exemplified during phase 1 when the 2016 Kaikōura earthquake caused a cumulative disruption over the first two years costing \$513 million. The cascading hazards, such as landslides following earthquakes, highly magnified impacts far in excess of a simple adding of individual event impacts.

A new coordinated approach, achievable for the first time with the scale of phase 2 Resilience Challenge, allows us to develop the first ever central data "rules" to compare and integrate a range of natural hazard types and scales. The MRM results will provide a new degree of rigor to support decisions on resilience adaptation, mitigation, retreat and retrofit that enhance New Zealand's local, regional, and national resilience to natural hazards. The primary delivery mechanism for the MRM outputs is via the Resilience in Practice Model which will feed and integrate research into four environments characteristic of New Zealand (Fig. 2).

Key researchers: The research team will be sourced across challenge parties and beyond, including thought leaders Prof Mark Bebbington and Dr Garry McDonald, hazard researchers, RiskScape researchers, economists, engineers, Māori researchers and social scientists.

### Specific Research Objectives:

- A. Integrate multiple diverse hazard types, scales, frequencies and impacts into consistent formats, and models, including uncertainties, coordinating inputs from hazard themes.
- B. Examine risk and impact from a dynamic perspective, including multiple and cascading events, and post-event adaptation within our socio-economic system.
- C. Extend, link and adapt existing risk tools developed in New Zealand by the Natural Hazards Research Platform and the Resilience Challenge, such as RiskScape and the "Measuring the Economically Resilient Infrastructure Tool" (MERIT).
- D. Build additional compatible tool suites that enable wider aspects of impact evaluation (infrastructure, economy, environment and society/wellbeing) and risk-reduction planning.

### Outcomes anticipated:

- A. Discovery of the statistical and mathematical approaches most effective for integrating multiple hazard evaluations.

- B. Methods for examining dynamic cascading and coincident hazard scenarios in likelihood and impact terms.
- C. Integrated hazard, risk and impact models applied to assess policy and decision-making scenarios.
- D. Models to assess hazard and impact continually in relation to changing hazard baselines, ongoing hazard events, and changing social, infrastructure and economic situations.
- E. Uncertainty integrated into multi-hazard and impact tools and integrated into decision-making frameworks to improve resilience in New Zealand.

Mātauranga Māori: in collaboration with the “*Whakaoranga Tūrangawaewae*” and “*Whakaoranga Iwi Whānui*” projects of the Mātauranga Māori Theme, the MRM team will establish a framework for multihazard and impact modelling to support Māori decision-making. Māori researchers will be funded to collaborate with the MRM in order to co-develop an interdisciplinary approach to integrate Mātauranga Māori within iwi natural resource management frameworks. Success will be meeting the needs of iwi nationwide and contribute towards national guidance for all New Zealanders.

### ***MRM Weather Theme***

*To enhance resilience to extreme weather events through new fine-scaled physical impact scenarios.*

An integrated understanding of extreme weather impacts on communities, infrastructure and economic activity will be used to help end-users design a range of practical, cost effective and socially acceptable mitigation options, leading to improved national resilience. Weather-related hazards are forecast to cost >\$18b over the next 50 years even without extreme events that are forecast to rise under all climate change scenarios. We will build resilience by developing much better knowledge of how weather extremes will impact us. New generation “convective scale” numerical weather models already show radically different scenarios for extreme weather events compared to the simple physical-statistical methods used in policy guidance today. With these data additional insights to wider climate systems from the Deep South Challenge and guided by co-creation partnerships within the Resilience in Practice Model, we will work with decision-makers to design the most effective resilience measures for extreme weather hazards throughout New Zealand.

Key Researchers: Thought leaders Dr Richard Turner and Dr Sally Potter have drawn together a team of researchers with expertise in weather, infrastructure engineering, and social science from across the challenge parties.

#### Specific Research Objectives:

- A. To create hazard models of extreme weather events over time and space scales not previously available in New Zealand.
- B. To use three extreme scenarios (ex-tropical cyclone, post-drought wildfires/flash floods, extreme winter storm) to quantify the multi-component affects (wind, flood, snow, drought, rural fire, etc.) on infrastructure, buildings and communities.
- C. Develop more effective weather hazard mitigation, including communication strategies, via in-depth case-study research on risk perception and warning behaviours.

### Outcomes anticipated:

- A. Improved and quantifiable estimates for the range of impacts experienced now and under climate change scenarios from high-impact weather events.
- B. An enhanced ability for regional councils, infrastructure providers, and rural agribusiness to identify the optimum resilience options to minimise loss and damages.
- C. More effective communication of weather warnings to key agencies and the public.
- D. Through close collaboration with the Deep South National Science Challenge, increased understanding of how climate change will impact the frequency and magnitude of weather events and its impact on design standards.
- E. Improvements to district, city, Civil Defence Emergency Management and/or infrastructure plans based on better characterization of the risks, preparedness measures, and strategies for mitigation and recovery through the Resilience in Practice Model.

Mātauranga Māori: Research will support tailored Māori community resilience knowledge for decision-making. This will extend from strategic and tactical Māori adaptation to weather extremes from our phase 1 research and collaboration with the Deep South National Science Challenge.

### ***MRM Earthquake and Tsunami Theme***

*To improve the understanding of magnitude, frequency and geographic distribution in New Zealand of fault movement and ground shaking, consequent tsunami and landslide generation.*

The risk posed to New Zealand's prosperity from earthquakes and their consequent impacts is well known. Recent events have radically changed our perspectives of earthquake hazard (e.g., blind faults; long-frequency ground motion; and complex long-duration destructive ground motion due to multiple fault rupture). These surprises show that we do not know enough about our earthquake hazard to develop appropriate resilience countermeasures. We will improve earthquake resilience by building a better understanding of earthquake phenomena and their subsequent co-seismic and cascading hazards, with a deeper view into New Zealand's earthquake history and applying a range of virtual/mathematical and ground-truth studies. This project will provide crucial information for understanding temporal clustering of large earthquakes in New Zealand, especially increasing understanding of seismic hazard in low-strain rate areas such as Auckland and Hamilton, alongside high-strain rate areas like Wellington, Napier, and Gisborne.

Key Researchers: The multidisciplinary team includes the thought leaders Prof Andy Nicol and Dr Bill Fry (earthquake) and Dr William Power (tsunami), and a broad cohort of earthquake, tsunami, landslide and seismic researchers from across the challenge parties.

### Specific Research Objectives:

- A. Develop physics-based modelling of earthquakes to assess and forecast fault rupture, ground shaking, landslides and tsunami.
- B. Building earthquake source models and simulations using existing data for >M6 magnitude earthquakes across New Zealand and calibrating simulated earthquakes against existing geological and geophysical datasets.

- C. Developing probabilistic estimates of the likelihood of future larger >M7 earthquakes over the next century.
- D. Developing a probabilistic tsunami hazard model for local and regional earthquakes.
- E. Testing the physical limitations of earthquake early warning and tsunami early warning algorithms in New Zealand.
- F. Improving probabilistic landslide hazard models by assessing the triggering potential of simulated earthquake catalogues.

Outcomes anticipated:

- A. Greater understanding of the underlying physical processes that drive earthquake rupture in New Zealand to improve accuracy and precision of hazard forecasting.
- B. A more robust basis for earthquake risk modelling, including uncertainty based on new modelling of extreme ranges of earthquake behaviour using a variety of international best-practice methods.
- C. Stronger models linking earthquake rupture to cascading hazard, including specific new models coupling New Zealand earthquake sources to tsunami and landslide hazards.
- D. A new framework for quantifying how local and regional-sourced tsunami will affect the New Zealand coastal assets with improved inundation and physical impact models (including currents/dynamic forces).

Mātauranga Māori: we contribute to the “*Whakaoranga Iwi Whānui*” project in collaboration with the Mātauranga Māori Theme, by supporting dynamic assessment and decision-making. Māori researchers will work alongside iwi to design new pathways to incorporate our outcomes into iwi decision-making processes.

### ***MRM Volcanism Theme***

*To produce short-term forecasts and long-term probabilistic hazard estimates for New Zealand volcanoes.*

Volcanoes threaten New Zealand’s resilience through multiple and complex cascading hazards with large footprints and permanent landscape changes. The most urgent threats are to the downwind and downslope communities as well as the transport (e.g., air transport), electricity, tourism and agricultural sectors. We will generate the fundamental and applied risk science to support resilience in response to New Zealand’s active volcanoes. This includes developing reliable forecasts of volcanic eruptions, their multiple dynamic hazards and their complex impacts on our businesses, infrastructure and society. Sector-based case studies will test our models, identify impacts and evaluate the effectiveness of resilience adaptation/mitigation strategies. This research programme will support resilient and sustainable development in threatened areas by integrating improved knowledge of the multiple and dynamic threats of volcanism into long-term planning and emergency management processes.

Key Researchers: Thought leaders A.Prof. Tom Wilson and A.Prof. Jonathan Procter have built a diverse group of volcanologists, seismologists and hazard impact specialists across all challenge parties and close end-user organisations (e.g., Department of Conservation, Iwi).



### Specific Research Objectives:

- A. To advance national capability in forecasting volcanic hazard by developing probabilistic models that integrate long- and short-term patterns of behaviour at New Zealand's most frequently active volcanoes and integrating these with monitoring data to forecast volcanic hazard sequences.
- B. To build simulations for the multiple phases of eruptions, identifying the complex and variable hazards and measuring their impacts on specific sectors, including transport (e.g. aviation), electricity, agriculture and tourism.
- C. Use volcanic impact knowledge and multihazard impact models to design the most effective volcanic resilience and mitigation solutions.

### Outcomes anticipated:

- A. Quantitative volcanic hazard assessment capabilities and dynamic forecasting techniques incorporated in platforms such as GeoNet, to inform land-use planning, economic development, lifeline operation, emergency and evacuation planning.
- B. Numerical/computational models are ready and tested for specific hazard/impact advice before and during eruptions.
- C. Volcanic impact knowledge and monitoring systems are improved via physical testing and numerical modelling benchmarked with our international networks.
- D. Volcano science knowledge is better focused to overcome gaps in understanding and handling uncertainty to support resilience decision-making.

Mātauranga Māori: We will explore Taiao and iwi environmental management practices around solutions to large-scale volcanic landscape change, as well as ongoing emergency management for co-governed volcanic regions. We will also build capacity by explicitly supporting new and emerging Māori researchers and iwi-researchers at Taranaki, Bay of Plenty and the Central Plateau.

## **MRM Coastal Theme**

*To resolve the physical coastal hazard futures faced by communities around New Zealand*

Incremental sea-level rise and changing wave patterns will fundamentally re-shape our coastlines and re-define New Zealand's future coastal hazard and risk. We will improve the knowledge of coastal risk to the combined effect of sea level rise, flooding, erosion and sedimentation around New Zealand to underpin a national resilience coastal strategy. Working closely with end-users, we will identify hotspots of coastal risk (current and future) and provide integrated scientific datasets to underpin robust decision-making. From this, we will develop a new suite of technical guidelines to assist management agencies to cope with coastal adaptation. Through timely assessment of New Zealand's coastal erosion and flooding/inundation risk, along with evaluation of the most useful mitigation options, this theme will support better targeting of adaptation plans, reducing the financial costs of hazard exposure.

Key Researchers: With thought leaders A.Prof. Mark Dickson, and Dr Rob Bell, this team includes geomorphologists, wave modellers, coastal engineers and climate change adaptation experts from across the challenge parties.

### Specific Research Objectives:

- A. Develop and implement a new approach to define and understand national-scale coastal hazards and risk (encompassing land and sea processes at the coastal margin) to resolve (1) physical changes in New Zealand's coastline and (2) current and future changes in coastal inundation and flooding risk.
- B. Develop a consistent national approach for the assessment of coastal hazards and risk.
- C. Develop a new suite of coastal hazard adaptation strategies and solutions that are locally suited, practicably implemented and cost-effective.

### Outcomes anticipated:

- A. A national scale analysis of current erosion hotspots and coastal flooding, including an enhanced ability to project future erosion and flooding of diverse coastal types (sand, rock or estuaries) in response to sea-level change and changing wave regimes.
- B. Improved understanding of future erosion rates, land loss and flood risk along New Zealand's coast at high spatial resolution (<1 km).
- C. Integration of results to the Multihazard Risk Model to support evaluation of infrastructure loss and wider social and economic impact of coastal hazards.
- D. Improved regional understanding of the fundamental drivers of coastal erosion and flood hazards (sea level, geological and sedimentological processes).
- E. New consistent risk and vulnerability assessment methods codified for application nationally, along with adaptation solutions tailored for different scales and governance settings, supporting efforts of the Resilience in Practice Model.
- F. Raised public awareness and acceptance of coastal resilience measures via working with the Resilience in Practice Model.

Mātauranga Māori: we will work closely with the Mātauranga Māori Theme and collaborative researchers in the Deep South National Science Challenge to identify Marae and wāhi tapu sites at risk from coastal hazards and sea-level rise. Furthermore, tikanga Māori will be incorporated into our new suite of technical guidelines and practices to future proof coastal adaptation solutions.

## **Resilience in Practice Model (RPM)**

*To co-create best practice in resilience via four New Zealand co-creation themes involving deep end-user partnerships.*

This is the second centrepiece of the future research strategy and it harnesses the strength and innovation of our co-creation process. RPM will be the vehicle to integrate multihazard risk quantification into the activities of decision makers at all levels throughout New Zealand. Via co-design and deep collaboration, risk reduction and resilience strategies will be built and tested. We will deliver science for reducing loss and damages, inform decision-making, enhance communication across a range of hazards, provide targeted support for livelihoods resilience and wellbeing, and inform pre-event recovery planning and post-event recovery at national and local levels.

The Resilience in Practice Model is the "front door" of the Resilience Challenge, where we welcome end-users into our internal research engine. RPM will provide underpinning and applied social science

support to deliver resilient outcomes for New Zealand. Through insights with our collective end-users, we will produce a clear scientific view on the current state of knowledge uptake in disaster risk, the potential socio-economic impacts of natural hazards, and methods to reduce significant human and economic losses. Outcomes from this research will inform current and future decision making, by identifying “blind spots” in policy and planning. New resilience assessment processes will facilitate the inclusion of social, cultural and cross-cultural perspectives. They will also produce robust analysis of the economic, operational, and strategic benefits of resilience practices. Further, by understanding future recovery scenarios, we will help ensure recovery resources and frameworks are best fit.

Key Researchers: This model gathers a diverse range of social scientists from across the challenge parties marshalled by thought leaders such as Dr Nick Cradock-Henry and Dr Julia Becker.

Specific Research Objectives:

- A. To identify institutional, behavioural, and financial barriers to applying resilience in different settings, and to improve practice to overcome these.
- B. To provide coordination to bridge interactions between MRM research and cultural, ecological and built environments, promoting resilience before and after hazard impacts.
- C. To determine the most effective strategies and practices for risk communication across weather, earthquake, volcanic, and coastal hazard areas.
- D. To assess the effectiveness of tools, processes and practices in evaluating resilience outcomes at local, regional and national scales to support decision-making.
- E. To create a set of recovery outputs (models, visualisation, frameworks), that demonstrate future recovery options.

Outcomes anticipated:

- A. Guidance for policy makers and practitioners on integrating resilience within complex and contested decision-making processes.
- B. An improved New Zealand culture of resilience.
- C. More effective communications strategies to enhance hazard mitigation, adaptation and resilience practices.
- D. Robust monitoring and evaluation frameworks for resilience practice and decisions.
- E. Modelled plans for effective recovery (e.g., adaptive/transformational/build back better strategies for recovery), including an understanding of governance structures.
- F. Monitoring tools for the effectiveness of recovery.

Mātauranga Māori: We will partner with Māori communities and the Mātauranga Māori Theme to co-produce research that benefits resilience and recovery within a Māori context, and meets Māori needs within the context of Te Ao Māori.

## ***RPM Mātauranga Māori Theme***

*To generate the fundamental Mātauranga Māori and applied Māori hazard, risk and resilience knowledge to improve the resilience of New Zealand communities.*

Through regional case studies, we will develop new culturally acceptable research methods and models applied to investigating the complex impacts of multiple natural hazards on Māori assets and New Zealand society. This research will help New Zealand in transforming approaches to Mātauranga Māori and its contribution to natural hazard resilience research, extending global knowledge for resilient indigenous cultures. Mātauranga Māori is a knowledge system that could inform existing frameworks and processes of resilience. Within the Resilience Challenge research to date, Māori have found innovative ways to add value to diverse disciplines. We have also developed a growing Academy of Māori language, culture and practice in natural hazards resilience. Our new research will help Māori researchers and partners to place Mātauranga Māori alongside plural and integrated strategies for adaptation and mitigation of natural hazard in New Zealand.

Key researchers: with Dr Charlotte Severne acting as thought leader, this team includes a range of Mātauranga Māori scholars from across the Challenge parties.

### Specific Research Objectives:

- A. Whakaoranga Te Whenua: Increasing iwi, hapū and whanau awareness to natural hazards.
- B. Whakaoranga Tūrangawaewae: Improving Māori decision-making around built infrastructure, technologies lifelines, warnings, all-hazard risk modelling, designs, codes, communication, and environmental management plans.
- C. Whakaoranga Iwi Whānui: Growing Māori resilience with respect to urban/rural, social, health, economics, communities, businesses, iwi, hapū and whanau.

### Outcomes anticipated:

- A. A reframing of scientific approaches to natural hazard research by promoting the value and benefits of differences in plural knowledge and learning.
- B. A Mātauranga Māori Academy of natural hazards resilience through the advancement of Māori ontologies and the sharing of information, resources and opportunities.
- C. A toolkit of meaningful ways to communicate resilient solutions to Māori and New Zealand.
- D. Extension of natural hazard resilience Mātauranga Māori into other fields of Māori learning.

## ***RPM Built Environment Theme***

*To improve the hazard response of the built environment and infrastructure that supports New Zealand.*

Direct and indirect socio-economic impacts of infrastructure and building damage following major natural disasters are of great threat to sustainability. We will develop new tools and approaches that support the improved resistance and reparability of our horizontal and vertical infrastructure and improve resilience in New Zealand. Our co-creation will centre around a future earthquake (and multiple co-seismic events) scenario event. We will apply our state-of-the-art impact modelling, with the Multihazard Risk Model, to estimate direct and indirect engineering and socio-economic consequences for a major urban scenario. We will also examine future resilience trajectories based on

a range of standard or radical (new design) decision-making options. The work will include developing resilient engineering solutions to seismic hazard, tsunami, ground motion site amplifications and liquefaction and physical damage to infrastructure. As in the former Natural Hazards Research Platform's Engineering Theme, we will closely partner with industry end-users and regulatory bodies to apply new resilience knowledge to design and building codes and promote the resilience benefits for construction practices that go beyond code-compliance.

Key researchers: Thought leaders Prof. Brendon Bradley and A.Prof. Liam Wotherspoon have gathered a wide team of engineers and engineering hazard and resilience specialists from across the Challenge parties as well as a range of end-user agencies.

Specific Research Objectives:

- A. Advancing methods of natural hazard design and assessment in order to meet the rapidly evolving role of built infrastructure in society.
- B. Understanding natural hazard-induced demands on vertical and horizontal infrastructure, including the geotechnical susceptibility of residential and commercial structures.
- C. Designing analytical methods for quantifying performance of new and retrofit buildings.
- D. Developing novel seismic design methodologies and technologies, particularly 'low-damage design' infrastructure.
- E. Quantification of infrastructure component and structural fragility and vulnerability from case history observations and modelling
- F. Developing methods to quantify system-level performance of infrastructure networks and interdependencies.
- G. Examining future resilience trajectories and decision-making options under major cascading-hazard case studies with high-fidelity modelling.

Outcomes anticipated:

- A. New approaches and tools for engineers to quantify the seismic performance of infrastructure for decision-making on life cycle costs (including uncertainty).
- B. Identifying technological advances that can be implemented economically at scale to address the societal needs of earthquake resilience in the built environment.
- C. Quantifying the anticipated impacts of future major earthquake hazard cascading scenarios on New Zealand urban centres and evaluating the outcomes of alternative resilience adaptation/mitigation.

Mātauranga Māori: We will contribute to "*Whakaoranga Iwi Whānui*" with the Mātauranga Māori theme, by supporting dynamic assessment and decision-making with Māori researchers around their built assets.

## ***RPM Rural Theme***

*To design resilience initiatives and practices for the rural communities and economy of New Zealand.*

Following the success of phase 1, the Rural theme will work with agricultural-production and tourism-based industries and communities that support our rural communities and economies. A resilient New Zealand will require our rural sector to thrive. Solutions for rural resilience will be developed around rural industry (dairy, high-value horticulture, forestry) to ensure value-chain resilience and robust rural economic policy. In the case of rural communities, with high hazard pressures and low economic reserves, our research will focus on rural-specific resilience solutions – extending from experiences gained in phase 1 in areas such as Kaikōura and the West Coast to create widely applicable tools for other rural communities in need around New Zealand.

Key researchers: With thought leaders including Dr Nick Cradock-Henry and Dr Caroline Orchiston, a group of multidisciplinary hazard researchers having a rural social science, rural fire and agribusiness focus have been gathered from across Challenge Parties.

### Specific Research Objectives:

- A. To identify the rural-specific resilience initiatives required for the most isolated parts of New Zealand.
- B. To determine how to build resilient syn- and post-disaster outcomes for rural businesses, including supply chains, labour supply, and health and safety of permanent residents and transient workers.
- C. To establish the most-appropriate resilience solutions for the tourism sector under present and future growth strategies.

### Outcomes anticipated:

- A. An integrated national framework for valuing, promoting, incentivising and assessing resilience across rural value chains, from households to regions and small to global-scale agribusinesses.
- B. Tools for resilience interventions and defining opportunities, co-produced through comprehensive scenario activities with rural sectors, communities and regions.
- C. A resilience science communication strategy for policy and practice leadership.

Mātauranga Māori: This research will be conducted in close partnership with iwi landowners and businesses, as well as Māori communities tied to traditional land with unique resilience challenges.

## ***RPM Urban Theme***

*To develop a New Zealand urban resilience best practice that is applied throughout the country.*

Our urban areas are growing rapidly, with increasingly diverse populations and greater loads on our infrastructure. The urgency for future urban resilience solutions has grown throughout phase 1. In this theme, we will extend from Auckland-centred urban resilience work to build an “all of New Zealand” urban resilience framework. We will concentrate on the development of a strong cohort of urban resilience professionals within our cities for knowledge exchange and benchmarking, including the 100

Resilient Cities approach and work of the Better Homes, Towns and Cities Challenge. With this group, we will seek research solutions to address emerging challenges and opportunities for resilience from population changes, technological disruption and densification of our built environment. By collaborating with the MRM themes in urban case studies, we will co-design multi-hazard resilience solutions (such as retrofitted Water Sensitive Urban Design) that can be as rapidly adaptable as our communities are.

Key researchers; thought leaders Prof Suzanne Wilkinson, A.Prof Jan Lindsay and Dr Vivienne Ivory have gathered a national team of multidisciplinary urban hazard researchers from across the Challenge parties.

Specific Research Objectives:

- A. Developing a framework for best practice in urban resilience for the New Zealand context, an inter-city expertise network and cross-city collaboration on development of new urban resilience initiatives.
- B. Working with the case study of the seven largest New Zealand cities, lever resilient solutions that support businesses and multiple diverse sub-communities of different cultures and vulnerabilities.
- C. Investigate city-wide opportunities for the use of new technologies, multi-media and communication networks to enhance resilience.
- D. Develop within-city and city-to-city solutions for managing increasing interdependencies of utilities that can mitigate vulnerabilities and build resilience.

Outcomes anticipated:

- A. A consensus of solutions (resilience tools, measures and indicators) that will support all New Zealand cities to build resilience to natural hazards.
- B. Integration of resilience design into future planning and re-development in our growing urban areas, including implementing and evaluating resilience initiatives for spatial planning and asset management.
- C. The development of resilient diverse communities within our urban centres, with a focus on Māori, Pacific Island and Asian communities, along with vulnerable migrant and refugee groups.
- D. Adoption of resilience indicators for infrastructure networks and lifelines.

Mātauranga Māori: This research will partner with the Mātauranga Māori Theme to discover new resilience solutions for urban Māori, including supporting resilience during the development of major new iwi-owned housing and other urban initiatives, the role of marae for affiliated Māori, and investigation of other cultural support mechanisms for non-iwi affiliated urban Māori.

# End-user involvement in research design and implementation

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To develop this research strategy, each of the teams has worked with a range of end-users. Many individuals from our end-user agencies will work alongside our research teams, either embedded within the research or taking advisory group roles for individual projects. These agencies include (but are not limited to) the following:

- Treasury (National Infrastructure Unit & Higher Living Standards),
- Ministry of Transport, NZ Transport Agency, KiwiRail, Auckland Transport
- Local Government NZ, most Regional Councils and many Territorial Land Authorities
- Dairy NZ, Beef & Lamb NZ, Zespri, Meat and Wool, Merino NZ, NZ Forest Owners Association
- National Lifelines NZ, and regional lifelines groups
- Emergency Management Offices and Civil Defence Emergency Management Groups of NZ
- NZ Geotechnical Engineering Society, NZ Society for Earthquake Engineering, Engineering NZ, Structural Engineers Society,
- Iwi, hapū entities (Ngāti Rangī, Taranaki, Ngāti Mutunga ki Parihaka, Ngāti Tūwharetoa, Ngāti Kahungunu ki Wairarapa, Te Taiwhenua o Heretaunga, Ngāti Porou, Ngāti Awa, Ngāi Tūhoe, Te Piringa o Te Awakairangi, Ngāti Apa, Ngāti Kuia, Rangitane o Wairau, Ngāti Koata, Ngāti Rarua, Ngāti Toa, Ngāti Kuri, Te Hapua Iwi). The Auckland Māori Statutory Board
- Ministry for Primary Industry,
- Ministry for Business, Innovation and Employment (Department of Building and Housing),
- Ministry for Civil Defence and Emergency Management,
- Ministry for the Environment, Department of Conservation,
- Ministry for Housing and Urban Development
- Fire and Emergency NZ,
- Heritage NZ, Ministry of Culture and Heritage,
- New Zealand Federated Farmers Association,
- Transpower, First Gas, Electricity Networks Association
- Building Research Association of NZ,
- Earthquake Commission,
- MetService, GeoNet
- Department of the Prime Minister and Cabinet,
- Ministry of Health, National Welfare Working Group
- Tourism Strategy Group (MBIE), Tourism NZ and Tourism Industry Aotearoa,
- NGOs involved in response and recovery (e.g. Red Cross),
- QuakeCoRE and other National Science Challenges (Deep South, Our Land and Water, Better Homes and Buildings), Ngā Pae o te Māramatanga



# Ensuring Research Quality

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The scope of research within the Resilience Challenge spans the fundamental (physical models of earthquake, weather, coastal and volcano processes) through to the applied (decision support tools for land-use planning). Achieving the optimal balance in this scope and investing appropriately across the areas against the relative differences in costs of research will be managed through several mechanisms. Firstly, we will appoint a **Chief Scientist** who will be a senior natural hazard resilience scientist (Professor or equivalent) with an international reputation and excellent research track record. This person will be responsible for updating and promoting the science aspects of the Resilience Challenge strategy, monitoring output standards and reporting on research and impact. Currently this role is wrapped into the tasks of the 0.5 FTE Challenge Director, and our future strategy will ensure a greater specialist research oversight alongside a full-time **Director**. The Chief Scientist will coordinate regular reviews of the science by the **International Science Advisory Group**.

The International Science Advisory Groups will contribute regular robust scientific peer-review to the ongoing research and strategy of the Resilience Challenge on an annual basis. The ISAG members will also provide an important conduit through which the Challenge activities and research outputs can be applied and integrated internationally. The ISAG members are:

- Prof Mary Comerio (Chair), University California Berkeley, USA (seismic design/architecture)
- Dr Linda Anderson-Berry, Meteorological Association of Australia (social science)
- Prof John McAneney, Risk Frontiers, Australia (risk evaluation and risk management)
- Dr George Pankiewicz, Met Office, United Kingdom (weather hazard and risk management)
- Dr Richard Thornton, Director Bushfire and Natural Hazards CRC, Australia.
- Prof Bruce Houghton, University of Hawaii at Manoa, USA (volcanic risk management)
- Prof William Ellsworth, Stanford University, USA (earthquake hazard and risk management)
- Prof Bruce Thom, University of Sydney, Australia (coastal hazard and risk management).

The Director and Chief Scientist will be assisted in science quality matters by a **Science Leadership Team** nominated and elected from key researchers representing each of the programme themes. The Science Leadership Team will have the specific task to drive coordination across the two major models of our strategy. The Team will meet monthly to update research progress, report problems and issues and maintain records of science outputs and outcome KPIs.

New research directions and new research talent will be brought into the Resilience Challenge through a proactive contestable research approach. Two calls for contestable funding will be made during phase 2, with an emphasis on new ideas, deepening (not widening) the approach to resilience in New Zealand, and the addition of new skills, datasets and areas of co-funding.

In addition, specific contestable pools will be targeted to the development of new research and researchers. An annual call for funding for PhD students and Postdoctoral Fellows will be made, including independent research funds, stipend top-ups, collaborative activities etc. Further, an annual call for research funds will be made to support the development of female researchers in resilience, addressing the gender imbalance in senior resilience researchers as noted by our International Science and End-user Advisory Groups.

# Delivering impact

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The Resilience Challenge will deliver impactful research through the following mechanisms.

*A focus on end-user needs through a co-creation structure.*

The first phase of the Resilience Challenge focused on the needs of end-users in its design philosophy, particularly the development of Co-creation Laboratory programmes that focused attention and resilience research results into the main “geographies” of New Zealand. End-user support and testimonials are very strong for the continuation and/or expansion of these.

Adding the Building and Infrastructure Theme is an extremely important and overdue step change. The Infrastructure Toolbox of the current Resilience Challenge had already developed a strong Advisory Group of industry/lifelines users and the New Zealand Lifelines Council have strongly urged for its continuance in letters of support. Similarly, the Engineering theme of the Natural Hazards Research Platform has built up a very strong and engaged industry support network, with full integration of the researchers and research into building code committees and other industry fora. Combining these two elements into a full outward facing co-creation theme will complement other areas of the Resilience in Practice Model and signal how strongly we will work with end-user needs.

In addition to the co-creation partnerships, all programmes will develop and maintain end-user steering groups to guide the research. An example of this is the phase 1 Infrastructure steering group that meets every two months to receive reports on research advances and advises on future direction as well as co-funding opportunities.

*Engagement Advisor and End-User Advisory Groups*

The future Resilience Challenge will benefit from the services of an engagement specialist who will put into effect a formal engagement strategy with our current and new end-users. Further, our research strategy, outputs and outcomes will be subject to formal annual review by our End User and Mātauranga Māori Advisory Groups. Furthermore, these groups have expressed interest in regular updates and interactions as well as “patronage” type relationships to support various parts of the programme. The group members will also be called upon to assist with the evaluation of proposals for contestable funding and our annual research plans.

## End-user Advisory Group

*Role:* To contribute a broad end user and research implementation perspective to maximise the relevance, visibility and impact of the science plans of the Resilience Challenge.

## *Current Members*

- Mr Roger Fairclough (Chair), NZ Lifelines Council, Wellington
- Ms Elizabeth McNaughton, McNaughton and Wills Consultants, Wellington
- Mr Gary Bedford, Taranaki Regional Council, New Plymouth
- Mr Graham Spargo, Beca Ltd, Wellington

- Dr Richard Smith, Earthquake Commission, Wellington
- Mr Bryce Davies, IAG Insurance, Auckland
- Ms Jo Horrocks, Ministry of Civil Defence and Emergency Management, Wellington
- Mr Tim Mitchell, National Fire Authority

#### Māori Advisory Group

*Role:* To provide critical advice and feedback on the implementation of Vision Mātauranga and Māori science for all work of the Resilience Challenge.

- Dr Daniel Hikuroa, University of Auckland, Auckland
- Ms Hollei Gabrielson, Department of Conservation, Taupo
- A.Prof. Nick Roskrige, Institute of Agriculture, Massey University, Palmerston North
- Mr James Whetu, Whetu Group Ltd.

#### *Longitudinal review and evaluation of the co-creation process*

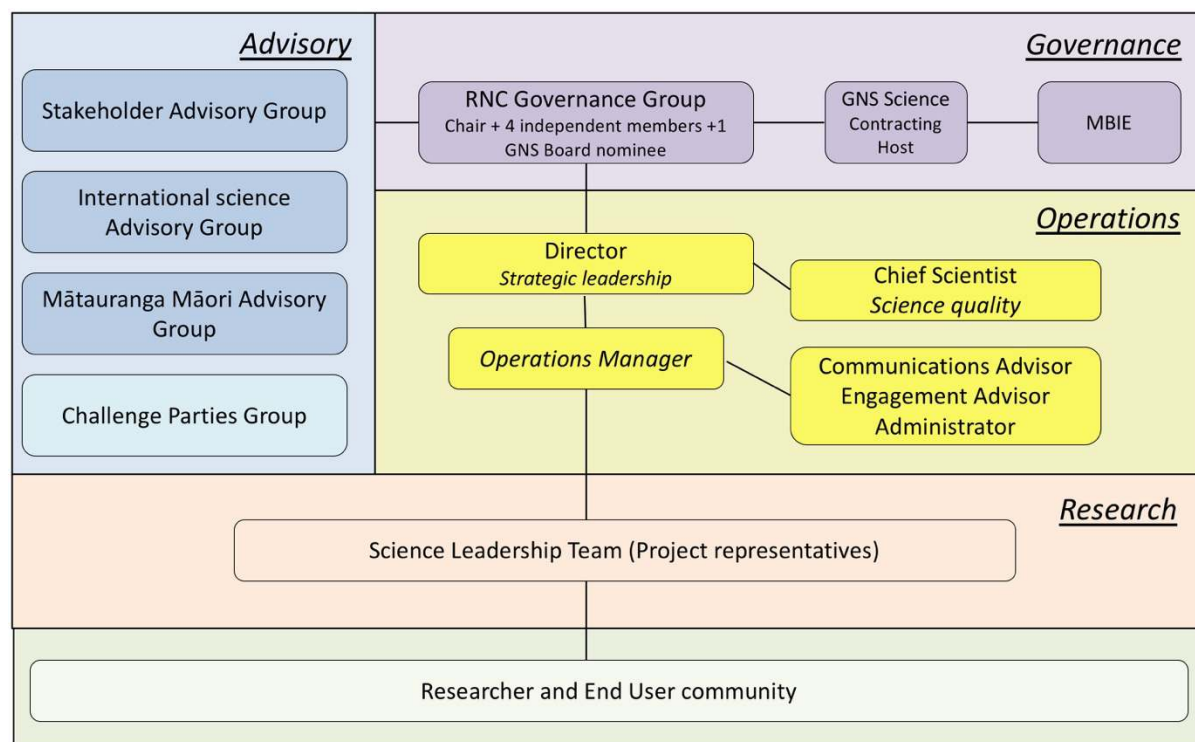
The co-creation and co-design research process is an important advance in the field of transdisciplinary research, particularly in the case of contested environmental problems. It does not come without risk, however, particularly in gaining trust and building true shared agendas. In 2015 we began a longitudinal monitoring and research programme into the co-creation process itself (examining the partnerships and expectations of end-users and researchers in Co-creation Laboratories). This led to one paper published in 2017 within the high-quality journal *Environmental Science and Policy* “Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions”, by Dr Mary Anne Thompson, and co-authors. The full reference and the abstract is provided in the additional materials section. This work highlighted the tensions at the outset of the co-creation process, as agendas are co-developed and the limits of cooperation tested. Completed research in the last year has re-evaluated the positions of these groups and is showing a strong improvement in the attitudes of the researchers and end-users about the joined-up approach and this is also evident in the many end-user support letters for continuing with our Co-creation Laboratories. The interim work is being written up now, but as part of the future research strategy of the Resilience Challenge we will include ongoing scholarly review and investigation of the practice of co-creation and document its efficacy in improving the impact of research.

#### *Adaptive research and major event response*

It is inevitable during the course of the Resilience Challenge that science response will be required for a major natural hazard emergency or disaster, such as the 2016 Kaikōura earthquakes. We will ensure that appropriate members of our Science Leadership Team and/or nominee experts from the Resilience Challenge are available to participate in science advice and response in the case of major events. If deemed necessary by our Governance Group, contestable funding resources will be positioned to allow for extra science response and research. We will also coordinate funding requests for emergency or follow-up research via mechanisms of affected government and regional agencies. Further, for very large-scale or important events we will allow flexibility in contracting for research teams to negotiate revision of their original research milestones in order to learn important new resilience insights for New Zealand during and following hazard events that would not have been possible otherwise.

# Decision-making and accountability

The governance structure of the Resilience Challenge for the next phase of activity (Fig. 3) will reflect the successful arrangements established during phase 1. Changes proposed in the future strategy are to the management and science leadership team to aid integration of new research associated with the completed National Hazards Research Platform, which has doubled the size of the Challenge.



**Figure 3.** Resilience Challenge governance, management, and operational structure 2019 to 2024

**Governance** continues under the existing Terms of Reference, with members having terms of 3 years. An additional Governance Group member (David Middleton; the current Chair of the End-User Advisory Group for the Natural Hazards Research Platform) was added to the Governance Group in 2018, increasing the total number to six. Our Governance Group members are:

- Mr Ian Fraser (Chair)
- Ms Parekawhia McLean
- Mr Greg Orchard
- Prof. Steve Weaver
- Mr Bruce Wills
- Mr David Middleton

The **Challenge Parties Group** currently has 11 members, as signatories to the Challenge Parties Agreement. While not formally an advisory group, they contribute to the strategic direction of the Resilience Challenge by providing advice and feedback on research proposals and strategic plans. Furthermore, they assist by aligning staff, infrastructure and other resources to research plans. This group meets twice a year to receive updates and provide advice to Challenge Governance and Management, with special meetings to comment on and endorse strategy when required.

*Current Resilience Challenge Parties include:* University of Otago, Canterbury University, Lincoln University, Scion, Victoria University of Wellington, NIWA, GNS Science, BRANZ, Opus, Massey University, University of Auckland. The Group agreed in principle to invite additional parties based on the changing membership of researchers during the course of the Challenge (specifically Manaaki Whenua Landcare Research and the University of Waikato).

The three formal **Advisory Groups** meet to provide review and advice on research strategy, contestable research funding and will continue to convene to provide reviews of Challenge research progress on at least a bi-annual basis. The end-user advisory group has advised it wishes to meet at least three times per year and participate in developing additional research opportunities for the Challenge.

The **Challenge Management Team** will expand for the second phase of research (Table 2), reflecting the incorporation of the Natural Hazards Research Platform and doubling of size and overall complexity of the Resilience Challenge from phase 1. Further, experience from phase 1 has shown the strong benefits of strong coordination of end-user and public engagement in our science, which is best facilitated by dedicated staff.

**Table 2.** Composition of the future Resilience Challenge Management Team.

2015-2019	2019-2024	Role
0.5 FTE Director	1.0 FTE Director	Responsible for the corporate operation of the Resilience Challenge, high-level stakeholder relationships, performance management of the Management Team, reporting to the Governance Group, Parties Group and MBIE. Representing the challenge at MBIE fora.
(Director)	0.4 FTE Chief Scientist	Responsible for maintaining the national and international standing and quality of the research and provide strategic science leadership to the Resilience Challenge. Reports to the Director.
1.0 FTE Challenge Manager	1.0 FTE Challenge Manager	Responsible for operational and research management for the Resilience Challenge. This will include implementing the business processes for the Resilience Challenge, interface with GNS Science administrative systems, leading the contracting and reporting processes, monitoring of financial and output data for reporting to the Governance Group, MBIE and Challenge Parties Group. Manages the Challenge Office positions and reports to the Director.
1.0 FTE Communications Officer	1.0 FTE Communications Advisor	Responsible for the science communication objectives and implementing the external communications plan of the Resilience Challenge.
(Challenge Manager)	0.6 FTE End User Engagement Advisor	Responsible for facilitating engagement and co-funding by building and managing strong bridging links with government and industry end-users associated with the Resilience Challenge

## Five-year indicative budget

Budget item	Annual Budget Years 1-5	Total
Governance and Advisory Groups	\$200,000	<u>\$1,000,000</u>
Management and Science Leadership	\$800,000	<u>\$4,000,000</u>
Multihazard Risk Model		
Earthquake/Tsunami Theme		
Volcanism Theme		
Weather Theme		
Coastal Theme		
<b>Multihazard Risk Total</b>	<b>\$3,600,000</b>	<b><u>\$18,000,000</u></b>
Resilience in Practice Model		
Built Environment Theme		
Rural Theme		
Urban Theme		
Mātauranga Māori Theme		
<b>Resilience in Practice Total</b>	<b>\$2,800,000</b>	<b><u>\$14,000,000</u></b>
Contestable Funding Call		
Women in Resilience Fund		
New Researcher/PhD student Fund		
<b>Contestable Total</b>		<b><u>\$3,000,000</u></b>
<b>Resilience Challenge Total</b>		<b><u>\$40,000,000</u></b>

The budget for the future strategy is based on estimates of programme costings supplied by the writing teams. Specific budgets between teams will be negotiated over the contracting period and keyed to the needs for the timing and type of milestones. Some research areas require fieldwork or modelling costs (mainly within MRM and the Built Environment Theme) which generally make them significantly more expensive than other areas dependent only on researcher time.

# Scenario planning – next priority area

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Locally sourced tsunami hazard is within our core research priorities of phase 2 (Earthquake/Tsunami Theme). However, broader tele-tsunami research cannot be added without losing any other core component of our research strategy. With our original writing group funding requests totalling \$65 million, strong prioritisation decisions were already made to reduce areas of scope to fit within a \$40 million allocation. The next-highest priority identified that did not make the final cut is outlined below.

## **Nationally consistent tsunami inundation and impact modelling:**

*To apply tsunami modelling consistently at the national scale to improve resilience solutions.*

New Zealand's plate boundary setting places it at risk from tsunami on a similar scale as the 2011 Tohoku tsunami in Japan, as well as from tsunami originating from around the Pacific. Paleo-tsunami and paleo-earthquakes evidence, supported by Māori oral history, point to far larger tsunami in the past than those recorded since European colonization, and experiences in Japan and Indonesia confirm that we cannot rely on the recent historical record to understand our tsunami risks. Mitigation of the risks posed by tsunami is critical for improved resilience.

Key researchers: Thought leaders Dr William Power and Dr Emily Lane have assembled a team of all tsunami hazard researchers from across New Zealand. This is supported by end-users including Ministry of Civil Defence and Emergency Management.

Specific Research Objectives:

- Develop methods for producing probabilistic tsunami inundation hazard maps considering distant, regional and local sources, and apply these with national consistency.
- Design models for the transport of debris (logs, shipping containers, floating oil), and the erosion of coastal dune systems during tsunami.
- Adapt tsunami models to calculate the parameters required for engineered resistance.
- Develop methods to reconstruct the size and sequence of waves in tsunami from deposits.
- Understand the flow of currents around harbours during a tsunami.
- Model the flow of people during tsunami evacuations of cities to recommend new practice.

Outcomes anticipated:

- NZ has a clear understanding of the hazard/risk of tsunami.
- Land-use planning for improved tsunami resilience.
- More effective tsunami evacuation.
- Less disruption to port and harbour activities.
- Recommendations for coastal dune management.
- Planning for response and recovery from tsunami events is enhanced.

Mātauranga Māori: This project will promote plural learning opportunities about tsunami hazard (and history) between Mātauranga Māori and the natural hazards and earth systems sciences. This will be achieved through cross-disciplinary (and cross-cultural) research approaches that draw upon Māori oral histories, geological archives and modelling to produce 'new' scientific and Māori narratives (i.e. plural knowledge production) about tsunami risk.

**Budget indication:** \$4M over 5 years.

# Supplementary Information

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Supplementary information to be provided for panel members includes:

- A. Sample evidence of our science quality processes: Review comments of the International Science Advisory Group on the current Resilience Challenge (following review of content, presentation and interview of all science leaders).
- B. Sample evidence of our science management processes: Paper to the Governance Group on science management actions in response the International Science Advisory Group Report.
- C. Sample evidence describing monitoring of our co-creation process: Paper on the co-creation of research in the Resilience Challenge.
- D. List of publications from the Resilience Challenge
- E. List of PhD projects supported by the Resilience Challenge
- F. Sample science output describing co-created AF8 Research (Orchiston et al., 2018)
- G. Sample science output describing co-created Coastal research (Kench et al., 2018).
- H. Resilience Challenge “glossy” booklet.