2020 Annual Report

Te Hiranga Rū | QuakeCoRE

Aotearoa New Zealand Centre for Earthquake Resilience

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Directors' Report 2020

Te Hiranga Rū QuakeCoRE formed in 2016 with a vision of transforming the earthquake resilience of communities throughout Aotearoa New Zealand, and after five years of funding, we are seeing important progress toward this vision through our focus on research excellence, deep national and international collaborations, and human capability development.

In our fifth Annual Report we highlight several world-class research stories, collaborations with national and international partners, and education of the next-generation of researchers.

Te Hiranga Rū QuakeCoRE researchers continue to develop and apply world-leading science to the consideration of the ground motions that result from major earthquakes. Over the past five years the methods applied to address this phenomena have transformed from simple empirical estimates based on globally-recorded earthquakes, to earthquake- and site-specific models based on representing the three-dimensional physics of earthquake rupture and seismic wave propagation. The technical expertise of its researchers, as well as the convening authority of Te Hiranga Rū QuakeCoRE have also enabled it to play a valuable role in the on-going development of the National Seismic Hazard Model, led by our Partner Organisation, Te Pū Ao GNS Science. Similarly, Te Hiranga Rū QuakeCoRE researchers have applied leading methods in large-scale experimental tests to understand the characteristics of Aotearoa New Zealand's bridges in-situ; have partnered directly with other agencies to further quantify the performance and failure mechanisms of Aotearoa New Zealand's precast concrete multi-storey building stock, and continue strong international collaborations at some of the world's largest experimental structural engineering facilities. Te Hiranga Rū QuakeCoRE has also significantly increased its activities and ambition over the past several years in the development and integration of mātauranga Māori throughout the Te Hiranga Rū QuakeCoRE research programme and its associated activities.

As a Tertiary Education Commission Centre of Research Excellence, Te Hiranga Rū QuakeCoRE has a strong emphasis on human capability and capacity development, and harnessing such development through the communities we interact with, and the places and fora that members of the Te Hiranga Rū QuakeCoRE community participate in in their professional and personal lives. This Annual Report marks the end of the first funding period, and highlights several examples of outstanding university research students who have benefited from Te Hiranga Rū QuakeCoRE collaboration and now are blazing trails in academia, the public and private sectors. As we establish our research programme and activities for the 2021-2028 funding period, we are excited to address transformative research questions in partnership with mana whenua, industry, national and international research partners. We will continue to develop the next generation of leadership capability toward our collective vision of earthquake resilience.

Chair's Report 2020

Tēnā koutou

Since inception in 2016, the research and engagement activities of Te Hiranga Rū QuakeCoRE have pushed Aotearoa New Zealand to the global forefront of earthquake disaster resilience. The successful funding rebid this year ensures that the programme can build on achievements through until 2028 and beyond, and further establish multi-institutional research programmes throughout Aotearoa New Zealand with links to international networks.

Over the last year, Te Hiranga Rū QuakeCoRE has continued to mature as Aotearoa New Zealand's Centre of Research Excellence for earthquake resilience research. Over the period covered in this Annual Report we have seen a concerted effort to deepen the understanding of how Te Ao Māori can benefit engineering thinking and planning, with research that explores the benefits that arise when non-Māori researchers have an understanding of Māori cultural values and include Māori at the conceptual stage of projects. The establishment of Te Apārangi o Hiranga Rū (Māori Advisory Board) was a significant step and I'd like to acknowledge and thank specifically the founding members: Tā Mark Solomon (Chair), Shane Graham, Diane Bradshaw and Marama Muru-Lanning.

We have also seen effort channelled to explore better linkages with industry, so that the benefits of research are accrued directly into communities and infrastructure. That's the end game after all – more resilient communities in Aotearoa New Zealand.

Some of the other highlights have included:
Advancements in ground-motion modelling, providing realistic simulations to provide practical help for researchers, planners, responders and decisions makers;
The innovative testing of the decommissioned Whirokino bridge to assess performance in different scenarios, enabling useful modelling that can be applied to other similar infrastructure; and
Key contributions to the National Seismic Hazard Model, which underpins key planning factors that are critical for building resilient cities and infrastructure.
As these examples illustrate, the greater the ebb and flow of knowledge between academia, communities and industry, the greater the benefits to Aotearoa New Zealand and other nations. Collaboration is at the heart of te mahi o Te Hiranga Rū QuakeCoRE. He waka eke noa.

COVID-19 has sorely tested Aotearoa New Zealand's economic and social wellbeing. It has also tested the resilience of Te Hiranga Rū QuakeCoRE. The response to that test has overwhelmingly been positive. Students and supervisors have seized opportunities that have arisen out of restrictions through making the most of unexpected time in Aotearoa New Zealand. This in turn has simultaneously strengthened international bonds and broadened research horizons.

Looking ahead, the next phase will provide significant advancement and application of new smart technologies to earthquake engineering, and the social and economic mitigation of future earthquake impacts. This is a privileged position, and I am grateful to Brendon Bradley (Director), to David Johnston (Deputy Director) and Ken Elwood (Research Director) for their leadership and vision in bringing us here. I would also like to acknowledge the wider team for their support and contributions. Thank you.

Thank you to the Board for their wisdom, guidance and leadership, and particularly outgoing Board members Dean Kimpton (chair, Tuhura Consulting), John Hare (Holmes Group), John Reid (Ngāi Tahu Research Centre), Jan Evans-Freeman (University of Canterbury), Bryony James (University of Auckland) and Mary Comerio (University of California, Berkeley, USA). I look forward to continuing the work with our current members, Tā Mark Solomon, David Brunsdon, Ian Wright, Wendy Saunders, Rosalind Archer and Ellen Rathjie.

On behalf of the Board, we are looking forward to an exciting next 12 months and beyond.

He toka tū moana, ara he toa rongonui [strong like a rock in the rapids].

Mike Mendonça, MBE

About Us

Te Hiranga Rū QuakeCoRE is transforming the earthquake resilience of communities and societies, through innovative world-class research, human capability development and deep national and international collaborations. As a Centre of Research Excellence funded by the New Zealand Tertiary Education Commission, QuakeCoRE is a national network of leading Aotearoa New Zealand earthquake resilience researchers. QuakeCoRE is hosted by the University of Canterbury and has seven other formal partners.

We enhance earthquake resilience across the country and internationally, by working collaboratively on integrated, multi-disciplinary programmes of world-leading research. Our research supports the development of an earthquake-resilient Aotearoa New Zealand.

Our Vision

We are creating an earthquake-resilient Aotearoa New Zealand where thriving communities have the capacity to recover rapidly after major earthquakes through mitigation and pre-disaster preparation informed by research excellence.

Our Outcomes

1. ***Improved Earthquake Resilience***
We will contribute to a step-change improvement in the earthquake resilience of the nation's infrastructure from research-informed national and local policies, implementation standards and disaster planning.

2. ***Improved Economic and Commercial Outcomes***
We will support Aotearoa New Zealand's long-term economic benefit through significantly improved seismic performance of New Zealand infrastructure, rapid business recovery after future earthquakes and the growth of engineering resilience innovation and business in the New Zealand construction sector driving international competitiveness.

3. ***Improved Societal Outcomes***
We will enable communities to recover rapidly after major earthquakes through mitigation and pre-disaster preparation, informed by research and public outreach.

4. ***Highly Skilled and Diverse Workforce***
Our graduates will be sought after for their knowledge of earthquake resilience and work-ready professional skills. They are taught in the very best national and international multi-disciplinary environment, combining research and industry elements. Through our graduates, we will seek a growth in under-represented groups (Māori and Pasifika) and gender equality in engineering disciplines.

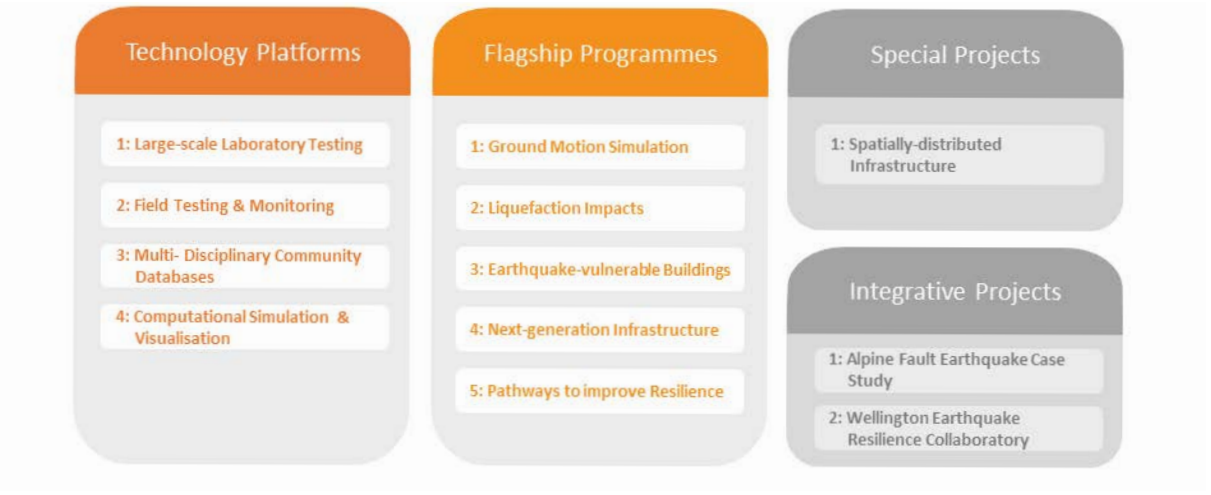
5. ***International Recognition***
We will be a focal point for international earthquake resilience, attracting the best talent and business alongside national and international research collaborations.

6. ***Growing Mātauranga Māori***
We will contribute by building close engagement with Māori leaders who have responsibility for earthquake planning and resilience and developing opportunities for Māori capability building. The distinctive contribution of Māori indigenous knowledge of earthquake resilience will enhance social, economic and environmental outcomes for Aotearoa New Zealand.

Research

Research overview

Te Hiranga Rū QuakeCoRE continues to play a leading role in supporting and linking multi-institutional, investigator-led earthquake resilience research programmes that are internationally networked and recognised. Our research programmes are advancing the science and implementation pathways of earthquake resilience through system-level science with highly integrated collaborations coordinated across the physical, engineering and social sciences and across multiple research institutions. The research is principally organised into Technology Platforms, Flagship Programmes, Integrative Projects and Special Projects.



Four technology platforms provide the underpinning experimental (lab and field), computational, and data infrastructure that are necessary to support our research programmes and realise QuakeCoRE's vision and mission. Our high-impact research is delivered via five flagship programmes, one integrative project and one special project. These programmes are advancing our research efforts to the next level through multi-institutional and multi-disciplinary research collaboration, engagement with end-users, and co-funding.

Our research programmes are supported by QuakeCoRE contestable and non-contestable funding and have strong links to end-users. Each of the flagship programmes has a named industry representative to facilitate communication at all levels between researchers and end-users.

Flagship Programmes

1 ***Ground motion simulation and validation***

Leader: Brendon Bradley | Deputy Leader: David Dempsey | Industry Representative: Didier Pettinga

This Flagship aims to provide a paradigm shift in ground motion prediction via theoretical developments in physics-based simulation methods and their utilisation in engineering design and assessment.

2 ***Liquefaction impacts on land and infrastructure***

Leader: Misko Cubrinovski | Deputy Leaders: Rolando Orense & Sjoerd van Ballegooy | Industry Representative: Sjoerd van Ballegooy

This Flagship focuses on next-generation assessment methods and mitigation strategies for soil liquefaction, one of the principal earthquake hazards affecting land and infrastructure in Aotearoa New Zealand.

3 ***Addressing earthquake-vulnerable buildings – A multi-disciplinary approach***

Leader: Ken Elwood | Deputy Leader: Ilan Noy | Industry Representative: Derek Baxter

This Flagship addresses the risk posed by collapse-vulnerable earthquake-prone buildings through a multi-disciplinary lens.

4 ***Next-generation infrastructure: Low-damage and repairable solutions***

Leader: Tim Sullivan | Deputy Leader: Rick Henry | Industry Representative: Jared Keen

This Flagship seeks a new design paradigm where reparability and damage control is explicitly considered in the design process of buildings and infrastructure.

5 ***Pathways to improved resilience***

Leader: David Johnston | Deputy Leaders: Caroline Orchiston & Wendy Saunders | Industry Representative: Dan Neely

This Flagship focuses on determining how we decide where to invest our limited resources to most effectively improve Aotearoa New Zealand's resilience to earthquakes.

Technology Platforms

1 ***Large-scale laboratory facilities***

Leader: Rick Henry | Deputy Leader: Alessandro Palermo

This Platform supports enhanced collaboration across domestic and international large-scale experimental facilities, innovative testing procedures, and instrumentation.

2 ***Field- testing and monitoring***

Leader: Liam Wotherspoon | Deputy Leaders: Quincy Ma & Geoff Rodgers

This Platform is building on Aotearoa New Zealand leadership in field testing and monitoring to focus on development of world-class testing technologies and urban system monitoring.

3 ***Multi-disciplinary community databases***

Leader: Ilan Noy | Supported By: TP3 Working Advisory Group

This Platform fosters the contribution to, and utilisation of, existing community databases, as well as enabling the development of new multi-disciplinary databases for transformative research.

4 ***Computational simulation and visualisation***

Leader: Brendon Bradley | Deputy Leader: Christopher McGann

This Platform provides computational workflows to connect the multi-disciplinary research activities within Te Hiranga Rū QuakeCoRE and to provide a pipeline by which research results can be understood in terms of their wider impacts on earthquake resilience.

Other Projects

Integrative Projects

Earthquake Case study: Alpine Fault Earthquake Impacts

Leader: Brendon Bradley | Deputy Leader: Tom Wilson

This case study focused around an Alpine Fault earthquake rupture scenario in order to contextualise each aspect of the earthquake resilience 'pipeline', the expertise for which resides within the Flagships themselves. This project, aligned to the "Project AF8" programme funded by the National Resilience Fund seeks to apply the latest research understanding for impacts of Alpine Fault earthquakes, and through end-user engagement, use the results of this project toward tangible improvements in Aotearoa New Zealand earthquake resilience. Notably, this case-study project will learn from the Kaikōura Earthquake to better understand the impacts of future Alpine Fault Earthquakes.

Earthquake Case study: Wellington Earthquake Resilience Collaboratory

Leader: Ken Elwood

The Wellington Earthquake Resilience Collaboratory Project was started in 2019 and uses the dynamic natural environment and proactive earthquake-risk mitigation activities in Wellington City and region, to provide a unique setting for cross-disciplinary research. Bringing researchers together to consider the key challenges facing Wellington city and region in a major earthquake provides a unique environment in which to understand the different facets of earthquake resilience.

Special Project

Spatially–distributed Infrastructure

Leader: Liam Wotherspoon | Deputy Leader: Industry Representative: Roger Fairclough

This Special Project is a joint research initiative with the National Science Challenge 10: Resilience to Nature's Challenges. The programme is developing tools to assess the performance of spatially-distributed infrastructure networks subject to extreme natural hazards.

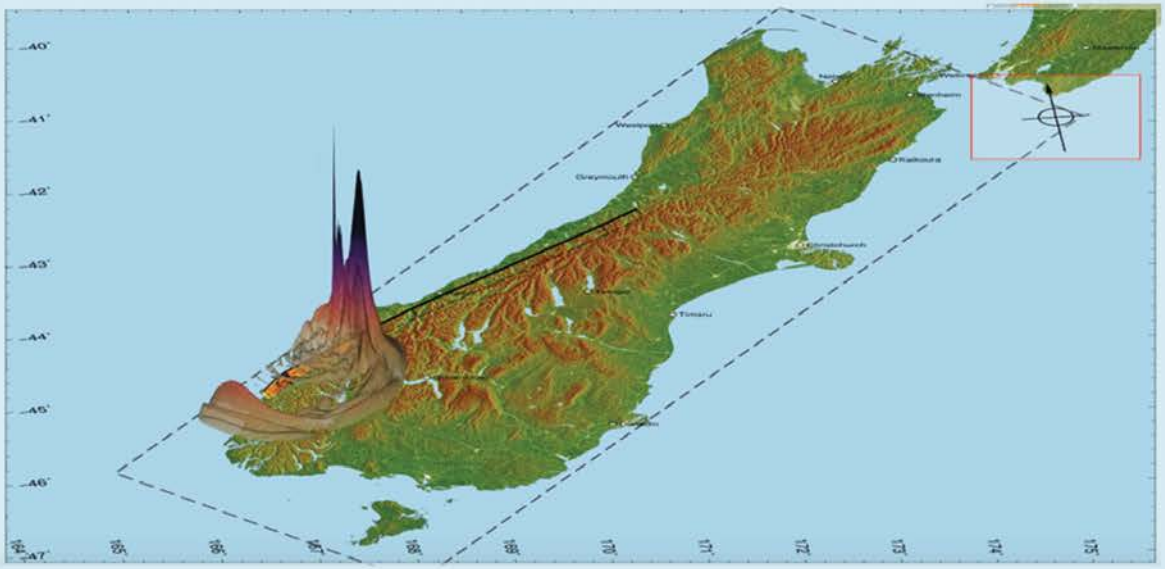
Moving Ground

When the ground moves beneath our feet there is a fun-park of physics at play: pressure, friction, energy, speed, distance, time – all interacting to produce a unique felt experience for each earthquake. With so many factors to ground shaking how do we ensure people will be safe? How do we make sensible land use plans? What engineering design standards are appropriate? Enter the field of ground motion prediction where there is change afoot…

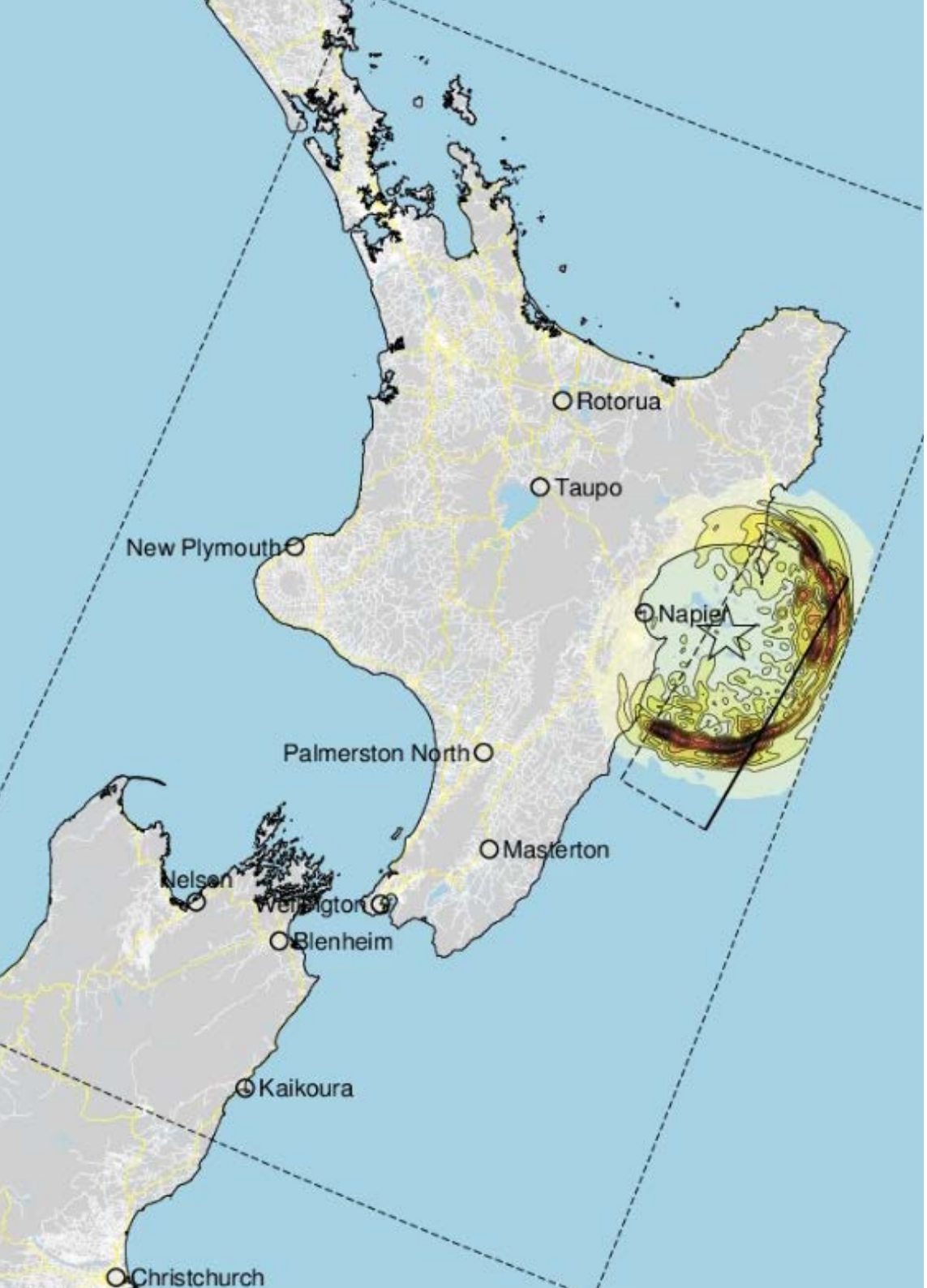
Ground motion prediction has traditionally relied on past observations to estimate what will happen in future earthquakes. Principal Investigator of Te Hiranga Rū QuakeCoRE's Ground Motion Simulation and Validation Programme, Brendon Bradley, recalls feeling like he was using a blunt instrument when he started studying site-specific ground motions from the 2010-2011 Canterbury Earthquake Sequence. That's when he decided to bring physics-based ground motion simulations, showing promise overseas, to Aotearoa New Zealand.

Ground motion simulations use a 3D model of the earth's crust with different soil and rock types and characteristics of known faults. Based on what is known about seismic waves and how they travel, such simulations can predict how the ground will move at a given site in any earthquake. With supercomputers and ever-more-detailed crustal models, the improvement over old empirical methods is that shaking can be estimated with confidence for conditions we haven't experienced before.

QuakeCoRE researchers have been improving the prediction capabilities of ground motion simulations by testing results against thousands of real earthquakes. New Zealand contributed to this validation work in a unique way – by having a large, complicated earthquake at the outset of the research programme. The 2016 Kaikōura Earthquake, with a magnitude of 7.8, ruptured over 20 faults in 2 minutes and, at a big picture scale, ground motions simulated by QuakeCoRE were close to measured ground motions.



Magnitude 8
Alpine Fault Simulation



Always moving to improve seismic hazard knowledge, QuakeCoRE researchers have now simulated earthquakes from faults in New Zealand's National Seismic Hazard Model. These simulations make up Cybershake, an initiative started in California to harness the predictive power of physics-based ground motion simulations for the benefit of seismic hazard analysis. Lessons from Cybershake NZ will be incorporated into the National Seismic Hazard Model as part of an update due in 2022.

There is more ground to cover, but Brendon can see a time when 3D simulations replace empirical methods entirely. QuakeCoRE is iteratively bringing New Zealand closer to having no surprises when a large earthquake strikes. We will know what ground shaking to expect and, with uptake by policy-makers, planners, and engineers, we will have prepared accordingly – thereby making New Zealand more resilient.

Magnitude 8.6 Hikurangi Subduction Simulation

QuakeCoRE meets Rūaumoko

Ka mate whare tahi, ka ora whare rua
With one house we are weak, with two houses we are strong

"Using just our own minds we are weak. However, if we use our minds combined with the minds of the community and those from other worldviews, we expand our horizons and become stronger." This is how Nona Hohepa-Taute explained the above whakatauki at the 2019 Pacific Conference on Earthquake Engineering. Nona, who is a lecturer and PhD student at the University of Auckland's Engineering Faculty, and thoroughly immersed in his Māori culture, demonstrates the advantages in using both mātauranga Māori and Pākehā science to make Aotearoa New Zealand a better place to live.

Nona's research explores the benefits that arise when non-Māori engineers have an understanding of Māori cultural values and include Māori at the conceptual stage of projects. The trust and respect that stems from mutual understanding increases the likelihood that engineering projects will be successful. Bicultural projects not only improve resilience to natural hazards and the sustainable use of natural resources, but also provide solutions that uphold and strengthen Māori connection to their culture and environment.

As a starting point, Nona encourages non-Māori earthquake engineers in Aotearoa New Zealand to learn about Rūaumoko – the Māori god of earthquakes, volcanoes and geothermal activity. This may seem a far cry from learning formulas to calculate building strength – he is not suggesting mātauranga replaces the Western discipline of engineering – but rather, that by expanding horizons to incorporate mātauranga, all of society benefits. Learning about Rūaumoko's relevance to Māori opens the door to understanding the interconnectedness that Māori culture has with natural forces and resources – beneficial to New Zealand as a whole.

Te Hiranga Rū QuakeCoRE Principal Investigator Jason Ingham recalls the early days of QuakeCoRE as very white and very male. To fulfil funding obligations to mātauranga Māori he wanted to work on seismic resilience of marae buildings but he wasn't sure how to start. Jason has now learnt: first you build relationships then you build a research plan. From learning his pepeha to doing the Rūaumoko haka, Jason has been thoroughly enriched and made close colleagues with whom he can now do truly collaborative, multicultural, interdisciplinary research.

QuakeCoRE research into seismic assessment of marae buildings is following a kaupapa Māori approach. A predominantly Māori team of building experts have laid out the justifications and recommendations for changes to building status, methods and capabilities that will ensure culturally appropriate treatment of earthquake-prone marae buildings. There is more to come, but this work, published in the Philosophical Transactions of the Royal Society, is a clear illustration that when it comes to resilience to Rūaumoko's rumblings, the more worldviews, the better.

Previous page: Nona Hohepa-Taute. Photo credit: Stephen Hussey

Jason Ingham. Photo credit: Stephen Hussey

Stronger Bridges

Aotearoa New Zealand, with its mountainous terrain and numerous rivers, is a land of many bridges. Thousands of bridges not only keep communities connected but also carry essential services like water, power and communication cables. Many New Zealand bridges were built before modern design codes so we don't know how they'll perform in large earthquakes. Te Hiranga Rū QuakeCoRE researchers are making the most of a novel opportunity to find out.

Associate Investigator Lucas Hogan is always on the hunt for old bridges. So, for Lucas and his engineering colleagues at the University of Auckland, the proposed demolition of the original Whirokino bridge was an exciting discovery. The 1.2-kilometre-long trestle bridge, spanning the Manawatū River and floodplain south of Foxton, was deemed too narrow for today's traffic and has now been replaced. The old bridge represented a rare chance to test a long bridge after 80 years of service and with its piles still in the ground.

To replicate strong ground shaking, piles of the old bridge were pushed and pulled using a hydraulic jack to see how they would perform and what sort of damage they would experience. Columns will be tested in a similar way in the lab later this year. Key to the value of this research is that the old Whirokino bridge was built in 1939 to standard design and construction techniques. Therefore, test results will be useful for exploring the strength of many similar-aged structures.

Whirokino bridge. Photo credit: Lucas Hogan

The fate of the bridge piles was of great interest to Waka Kotahi NZ Transport Agency, who are responsible for maintaining more than 4,500 bridges to keep New Zealand roads open. Close collaboration was also essential between the researchers and bridge demolition contractors. The research was funded by EQC and QuakeCoRE.

The good news is that the piles held strong in the face of powerful forces. This bodes well for many similar bridges. Once column testing is complete, there will be a detailed prognosis of bridge strength with insights into assessment techniques and retrofitting needs. Fragility modelling is underway to estimate the vulnerability of this bridge type to different levels of earthquake hazard.

With this kind of knowledge, it becomes easier to appropriately prioritise bridge strengthening or replacement. And from a risk management perspective, it becomes possible to identify the weak links in the roading network and make plans to minimise isolation of communities before the next damaging earthquake.

Preparing the loading system for testing.
Photo credit: Pavan Chigullapally

Collaboration for Impact

Knowing Our Hazards

The first step towards managing our risks effectively and making Aotearoa New Zealand a safe place to live, is to know our hazards. The National Seismic Hazard Model (NSHM) is a way of encapsulating what scientists know about the location of active faults in New Zealand, the probability of earthquakes occurring away from known faults, the magnitude and frequency of earthquakes and how much the ground will shake in different parts of the country over varying time periods. It provides an estimate of earthquake hazard.

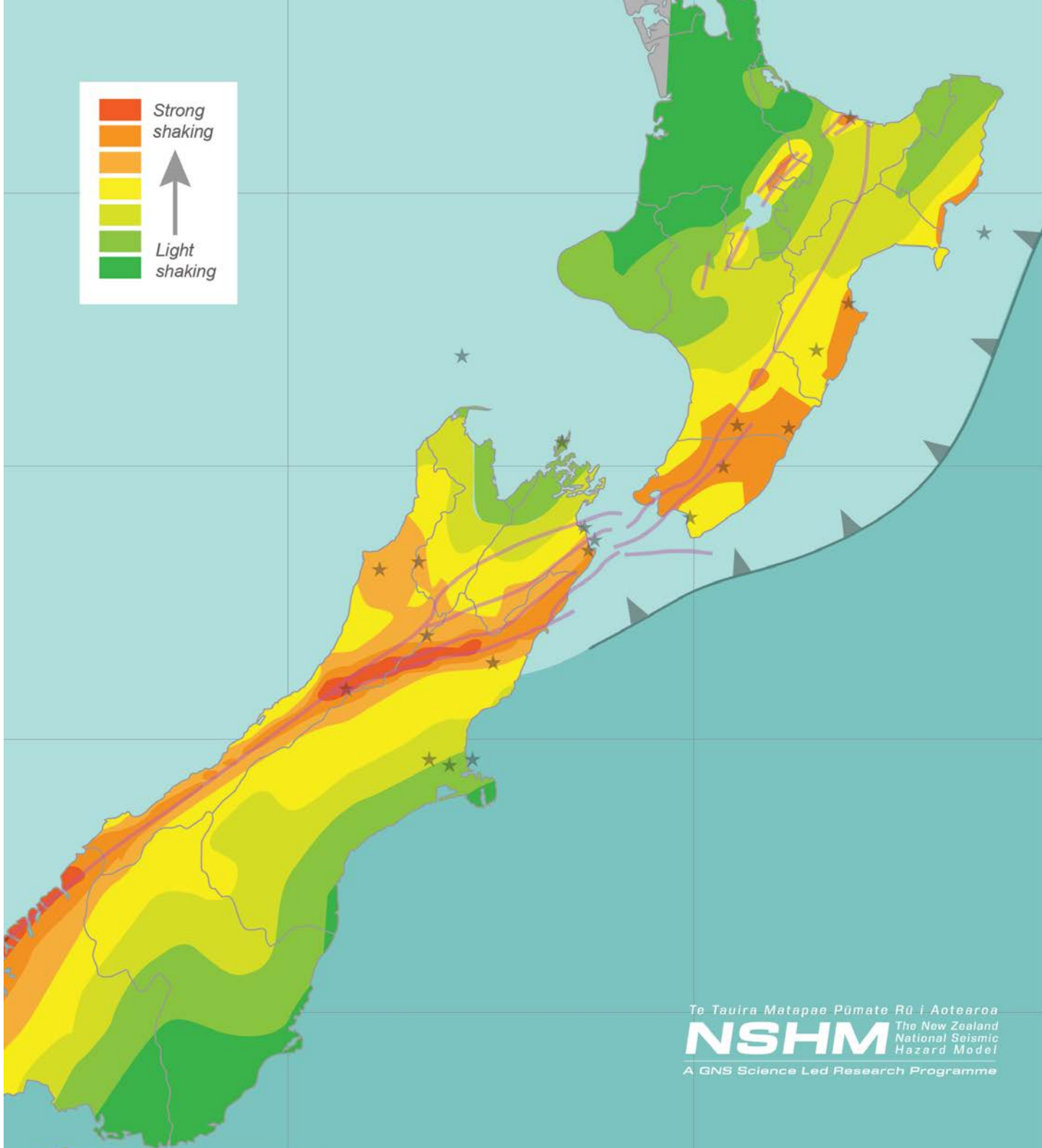
Even at a glance, maps from the NSHM show us that Northland and eastern Southland are less shaky places than the rest of the country. At a more detailed level, the NSHM provides the basis for policy making and land use planning by central and local government, risk assessments for the insurance industry and guidance for setting engineering design standards.

Given New Zealand's stark experience of earthquakes over the last decade and rapid advances in technology, there is a lot of new data, understanding, and modelling capability, that is not incorporated in the 2010 version of the NSHM. In 2019 the Ministry for Business, Innovation, and Employment (MBIE) and EQC commissioned GNS Science to revise the NSHM. Te Tauira Matapae Pūmate Rū i Aotearoa, a GNS-led research programme, will be completed in August 2022. GNS Principal Scientist Matt Gerstenberger is leading the programme with about 50 national and international researchers contributing. Matt says there is an integrated involvement of end users – for the first time for a seismic hazard model internationally, insurance brokers, policy makers, engineers are part of the Technical Advisory Group.

Many Te Hiranga Rū QuakeCoRE researchers are involved with the revision. As New Zealand's Centre for Earthquake Resilience, QuakeCoRE is keen to support uptake of the NSHM and is well-placed to facilitate engagement with the engineering community in particular. QuakeCoRE started this process by hosting a NSHM workshop at the QuakeCoRE Annual Meeting in 2020 with another planned for the 2021 meeting.

A new initiative to compliment this NSHM revision is MBIE's Seismic Risk Working Group (SRWG). This is a think tank of industry and academic experts, many from the QuakeCoRE community, who are working in tandem with the NSHM update to provide advice on how to take hazard outputs and put them into engineering practice. In particular, this advice will give direction on how to update the building code and it will enable MBIE to act quickly to make change.

As Matt says, "There will always be uncertainty in our knowledge of how the earth works but right now we're in the process of producing a model that best reflects our current understanding and capabilities. A modern NSHM is crucial for making decisions that matter, and the SRWG provides a vehicle for us to get the NSHM science into practice in an appropriate manner."



National Seismic Hazard Model (NSHM)Map

Safer Buildings

There are few sights more chilling after an earthquake than that of multistorey buildings with collapsed floors – a pile of concrete pancakes between which people used to work and live. Building failures are not restricted to developing countries or old buildings; the 1994 Northridge Earthquake in California had many examples and New Zealand witnessed collapses in the 2011 Christchurch Earthquake and partial collapse of a very modern building in the 2016 Kaikōura Earthquake

Failure of precast concrete floors is a concerning issue for New Zealand because such floors have been used extensively in mid-rise buildings all around this seismically active country. The ReCast Floors (REtrofit of preCAST FLOORS) Project, initiated in late 2018, has found solutions for making them safer. With increased urgency due to the damage sustained in the Kaikōura Earthquake, researchers have developed methods for retrofitting precast concrete floors in existing buildings to improve their performance in earthquakes.

Not satisfied with theoretical solutions alone, the project team put their designs to the test. At the University of Canterbury's Structural Engineering Laboratory, parts of buildings were pushed and prodded as if they were in the Kaikōura or Northridge earthquakes. This "super-assembly" testing, among the largest in the Southern Hemisphere, involved a full-scale replica of one quarter of a single storey from a 10-storey office building with different retrofit designs installed

Large-scale Precast Floor Experimental Testing.
Photo credit: Corey Blackburn

for different tests. Smaller "sub-assembly" tests (using only beams and precast floor units) were carried out at the Structures Testing Laboratory at the University of Auckland.

One of QuakeCoRE's founding concepts – to share expertise and facilities for the benefit of New Zealand – has been realised in the ReCast Floors Project. BRANZ was the major funder with additional support from EQC, QuakeCoRE, and the Concrete New Zealand Learned Society. The project team included researchers, laboratory technicians, practitioners, and students. Collaboration with the structural engineering industry was at the core of the work. As Principal Investigator Ken Elwood expressed, "It might be simpler to do research on your own but outcomes are much more useful if you interact with industry along the way."

A big gap has been filled by this project: engineers now have guidance on how to retrofit precast concrete floors in existing buildings. Further safety assurance has been provided by full scale testing. The collaborative approach has ensured that the recommended retrofit solution is widely applicable – increasing its uptake and ultimately leading to safer buildings sooner and fewer lives lost in the next big earthquake.

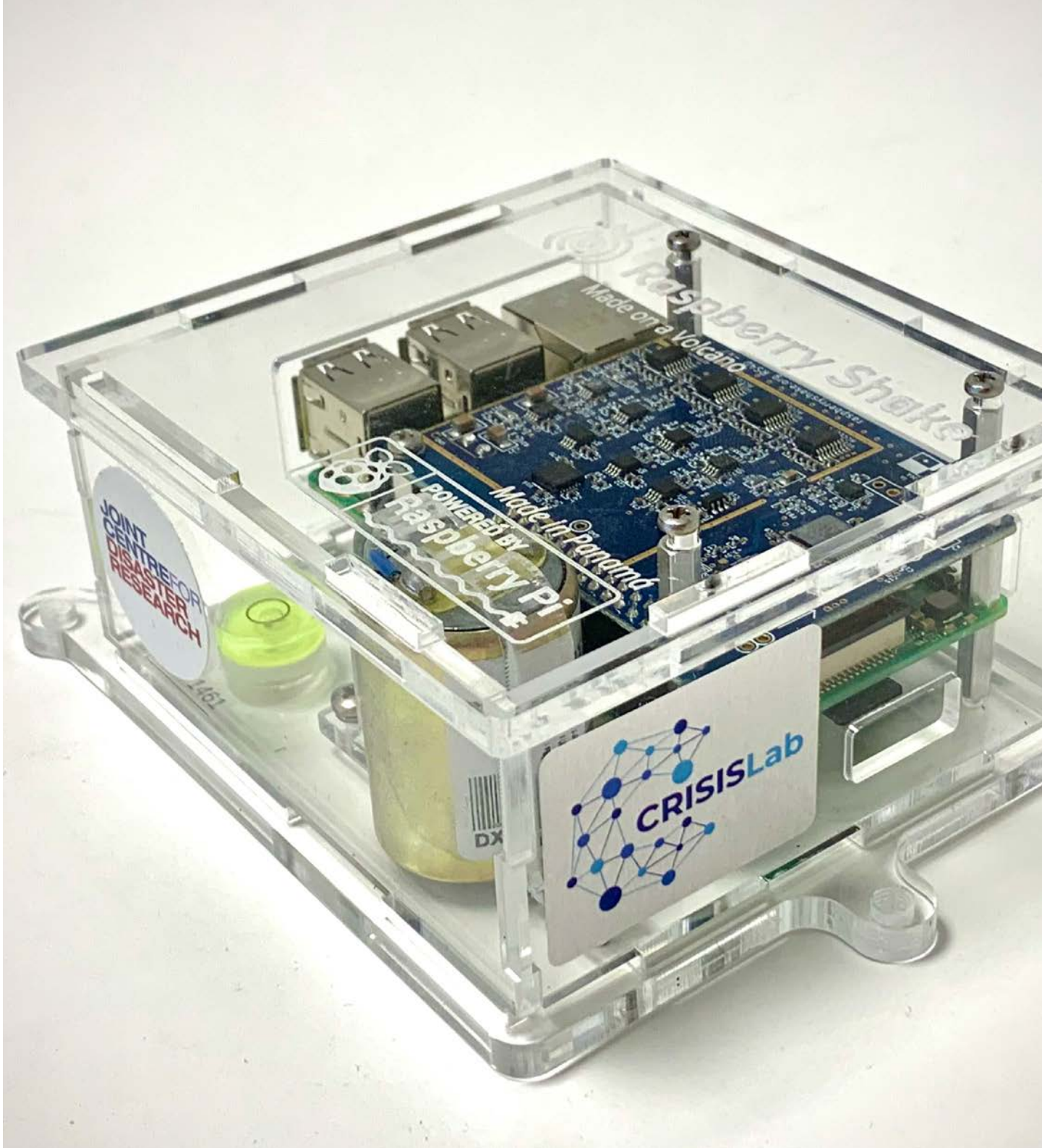
Inspecting Damage Following Experimental Testing.
Photo Credit: Corey Blackburn

Seismometers in Schools

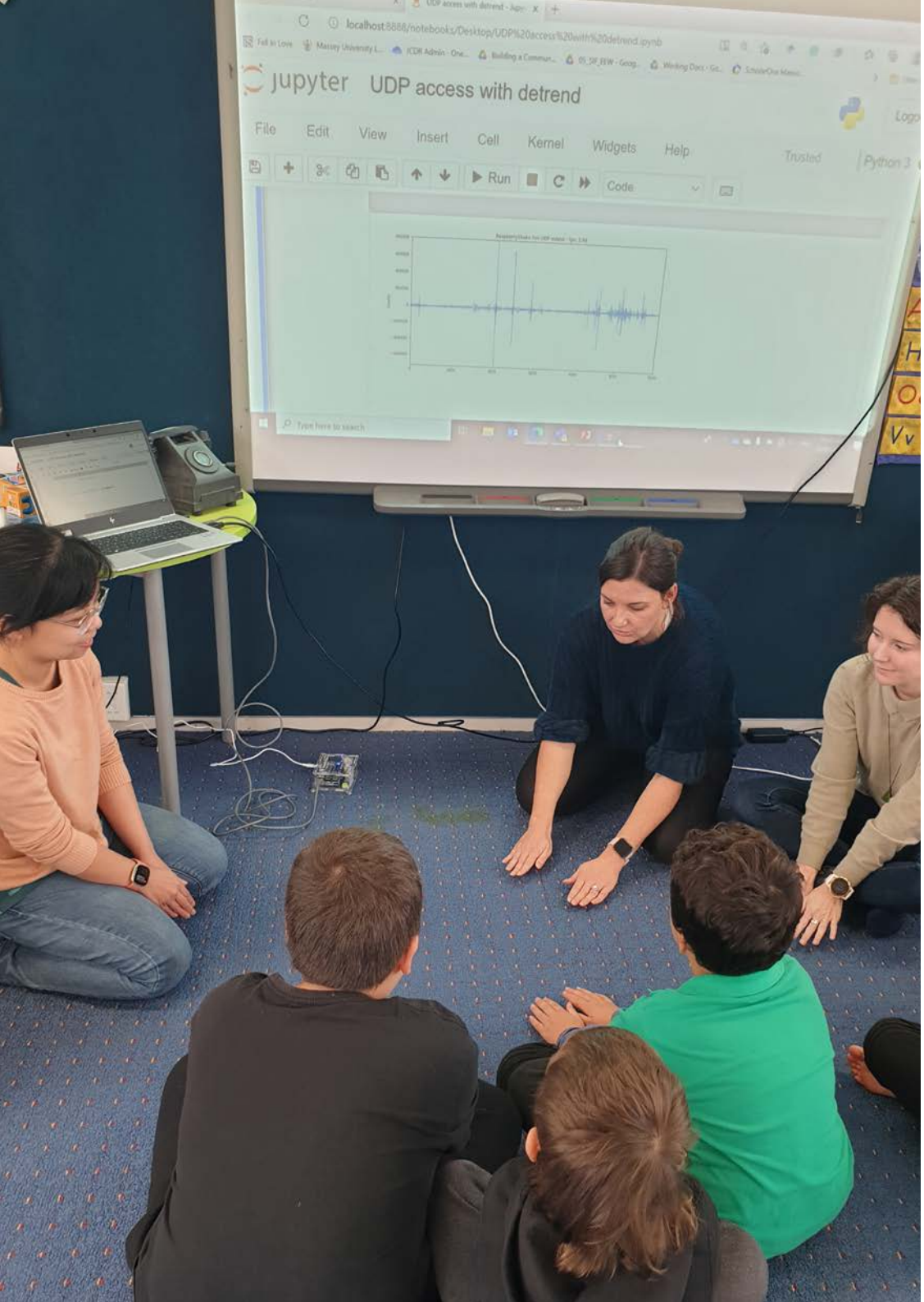
When the magnitude 8.1 Kermedec Earthquake occurred on 5 March 2021, the children of Matatā Public School knew what to do. Although there was no strong shaking on the mainland of Aotearoa New Zealand, they knew it was time for a tsunami hīkoi – time to get to high ground in case of waves inundating their school.

The school was highly prepared because, as well as their regular drills, they had hosted the national earthquake drill and tsunami hikoi – ShakeOut – in October 2020. Civil defence officials and scientists joined the children to "drop, cover, and hold" in a livestreamed exercise in which 670,000 New Zealanders practised their earthquake response. The school had also been given their own seismometer to monitor earthquakes.

Te Hiranga Rū QuakeCoRE researchers have installed seismometers in 11 schools so far with plans to expand. Giving seismometers to schools is not a new idea, but technological advances, such as those provided by Raspberry Shake



Raspberry Shake Seismometer.
Photo credit: Alicia Cui



(who make seismographs powered by raspberry pi computers), are making it easy for schools to become part of a global seismic monitoring network. However, as Principal Investigator David Johnston explains, "It's not all about the instruments. The seismometers are a starting point for building relationships and having conversations about natural hazards."

Scientists from Massey, Canterbury, and Victoria Universities, and GNS Science are introducing natural hazard activities into schools as part of the seismometer roll-out. Interaction with scientists can help children prepare for events, improve their understanding of natural hazards, contribute to science advances, and be aware of different careers. Children are also likely to take preparedness knowledge into homes. Connecting with the school's stakeholders and leaders, particularly the principal, board of trustees and mana whenua, has been critical to success. Working with schools aligns with QuakeCoRE's vision of a resilient country where communities are prepared for disasters and the preparation has been informed by excellent research.

QuakeCoRE is collaborating with other research programmes to maximise the potential of school-based seismometers. Bay of Plenty schools are helping monitor seismic activity of the Taupō supervolcano for the programme ECLIPSE (Eruption or Catastrophe: Learning to Implement Preparedness for future Supervolcano Eruptions). Wellington schools are helping pilot a move towards citizens monitoring cities in the Resilience to Nature's Challenges Programme.

After the ShakeOut exercise at Matatā School in 2020, teachers reported that some children were unsettled by the idea of a big earthquake or tsunami. However, when the real event struck in March 2021, children faced it with calm confidence because they had practised. As David reflects, "This is exactly the outcome we're hoping for after running preparedness exercises – not only will children be physically safe but they'll also feel empowered by the knowledge they have."

Students test the Raspberry Pi Seismometer through floor vibration. Photo credit: David Johnston

Human Capability Development

Academic Opportunities

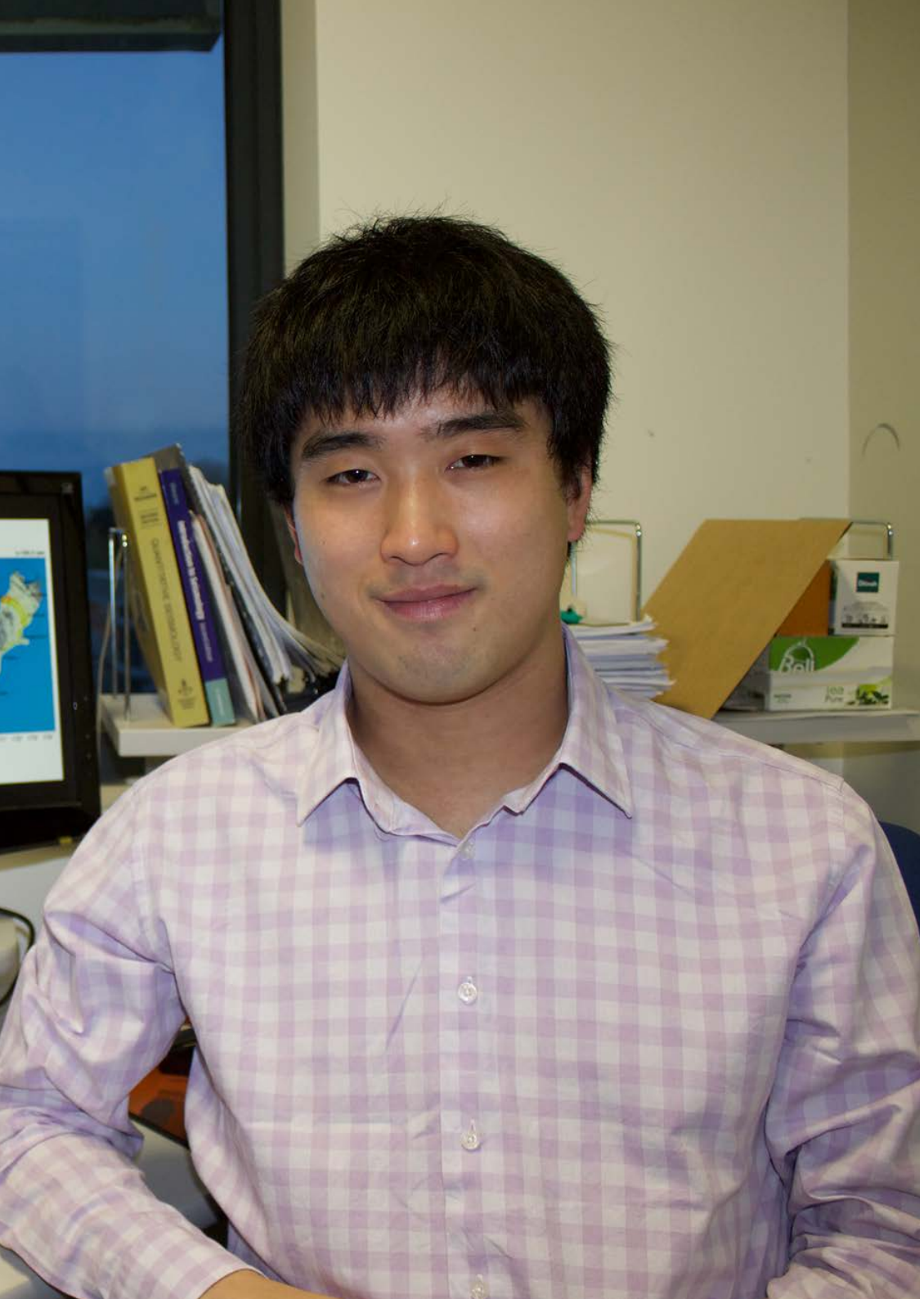
Te Hirangi Rū QuakeCoRE is developing the next generation of researchers by funding PhD scholarships and bridging gaps between PhD, postdoctoral fellowships and academic positions. QuakeCoRE has a strong mentoring ethos and the multi-institutional community provides diverse opportunities for students. QuakeCoRE is pleased to see some of its original students continuing their research in academic careers.

Shannon Abeling is a born and bred QuakeCoRE Scholar. She came from California in the first round of QuakeCoRE PhD scholarships to study the behaviour of unreinforced masonry buildings in the Canterbury Earthquake Sequence. Her supervisor, QuakeCoRE Principal Investigator Jason Ingham encouraged her to do extra-curricular activities. This led her to being a founding member of the QuakeCore Emerging Researchers Chapters (QERC) in 2016. She was president of the Auckland chapter for two years, then vice-president and outreach officer. Shannon is now underway with postdoctoral research into resilient buildings. "QuakeCoRE opened up opportunities to talk with researchers outside my field. Winning the Director's Award in 2019 raised my profile and ultimately led to new collaborations and a postdoctoral opportunity".

Photo credit: Stephen Hussey

Marion Tan also came from overseas to do her PhD in New Zealand. QuakeCoRE made her experience less daunting because she joined an existing research community with good connections to industry. She was involved with the Wellington Chapter of QERC and became its president in 2017. Marion recently received a QuakeCoRE Proposal Development Grant enabling her to do groundwork for her next academic endeavour. She is applying for funding to develop a best practice framework for programs that place seismometers in schools. Marion aims to continue researching user-centric perspectives on technology that keeps people safe, because, as she argues, "technology is only useful if users know how to use it".

Photo credit: Alicia Cui



Robin Lee is a lecturer in Earthquake Engineering at the University of Canterbury. He credits his position to the mentorship and good working relationship he has with QuakeCoRE Director Brendon Bradley. Robin started his PhD before QuakeCoRE but his research on ground motion simulations was well aligned and quickly folded into the programme. Robin says "QuakeCoRE allowed me to collaborate with top researchers, both nationally and internationally, and provided me with an unprecedented opportunity to grow and establish myself as a researcher." QuakeCoRE Proposal Development Grants have supported Robin with his recent Marsden Fast-Start application.

By supporting researchers such as Shannon, Marion and Robin, QuakeCoRE is ensuring a succession of academics dedicated to understanding more about earthquakes and how to live safely in a seismically active country.

Photo credit: Susie Zhu

Bridge to Industry

As a Centre of Research Excellence, Te Hiranga Rū QuakeCoRE contributes to Aotearoa New Zealand's development in various ways, not least by providing pathways for QuakeCoRE scholars to find employment in industry.

Cuong Nhu Nguyen, motivated by the typhoon disasters he witnessed in Vietnam, and with a Master's degree in economics from the University of London, came to New Zealand in 2016 to study the economics of disaster recovery and earthquake insurance. He did an EQC-funded PhD supervised by Ilan Noy, Chair in the Economics of Disasters and Climate Change at Victoria University of Wellington. For Cuong, QuakeCoRE provided an insight into the wide range of earthquake-related topics being addressed in New Zealand and the annual conferences were a chance to meet a lot of key players.

The skills he gained during his PhD – like tackling the big dataset of Canterbury earthquake insurance claims – have enabled him to contribute to solving pressing problems as he's moved into government jobs. At the Ministry of Business Innovation and Employment he produced forecasts (and even nowcasts) of the economic impacts of Covid-19 lockdowns. Cuong is now at the Reserve Bank where he is running stress tests on risks as diverse as climate change, cyber-attacks and rising house prices.

Photo credit: Victoria University Wellington

After a PhD and postdoctoral research at the University of Canterbury, Sarah Barrett has been pleased to discover that the learning, researching and problem-solving of academia can continue into industry jobs. Sarah is enjoying working at BECA where she is able to apply her liquefaction research in ways that directly impact people's lives. She also appreciates opportunities to branch out into other fields such as slope stability and debris flow modelling and helping councils with natural hazard assessments.

Photo credit: QuakeCoRE

Ananth Balachandra went straight into consulting as a Geotechnical Engineer after gaining a Civil Engineering degree in 2011. In this role, he enjoys working on and bringing to life roading, building and other infrastructure projects. It was a QuakeCoRE Masters project that encouraged Ananth to make some time for research in addition to working full time at Tonkin and Taylor. His thesis topic was to validate numerical simulations of buildings interacting with liquefiable soils against centrifuge experiment results. The QuakeCoRE postgraduate experience enabled him to pursue his interest in geotechnical earthquake engineering and delve deeper into a topic than is possible under the commercial imperatives of the workplace. Ananth is now involved in providing industry guidance as the New Zealand Geotechnical Society's representative for updating the Earthquake Geotechnical Engineering Modules.

As these experiences illustrate, the greater the ebb and flow of knowledge between academia and industry, the greater the benefits to New Zealand.

Photo credit: Tonkin + Taylor

Lockdown Opportunities

"In the middle of difficulty lies opportunity". Einstein's words have been ringing true for international students recently. Since the Covid-19 pandemic led to travel restrictions, students have had to adapt to changing circumstances. Te Hiranga Rū QuakeCoRE has had to get smarter about operating as a virtual organisation and providing a sense of community from a distance.

Shakti Raj Shrestha came to Aotearoa New Zealand in 2018 to do a PhD on the cordons that get erected around damaged zones after earthquakes. As Shakti got deeper into his topic, he realised that the web of legal, economic, ethical and political considerations he was addressing were unfolding around him in daily life. "Cordons are like inside out lockdowns. Authorities want to protect the public; after a while people just want to get on with life."

Shakti has been locked down in Nepal and New Zealand. Caroline Orchiston and Shakti's other supervisors were supportive and inventive about where he worked so a cordon case study from Nepal became part of his thesis. Although Shakti found it hard to be productive while isolated, lockdowns have resulted in a stronger international perspective to his research.

Photo credit: Carsten Dortans

Ryo Kuwabara is researching earthquake-damaged buildings to clarify when they can be re-occupied or if they need to be repaired or demolished. Ryo received a PhD scholarship from the University of Auckland in 2020 but has had to stay in Japan. With the help of supervisors Ken Elwood and Lucas Hogan, Ryo made the most of being in the "wrong" place at the right time. Collaboration between the University of Auckland and the Earthquake Research Institute at the University of Tokyo enabled Ryo to join the project team for a full-scale test of building strength using the world's largest shake table. Data from this test will now be key to Ryo's thesis.

Ryo says the most important aspects to studying while isolated are to communicate regularly and manage your schedule to stay motivated. He has found QuakeCoRE's online events useful but is looking forward to joining the community in person.

Photo credit: University of Tokyo

Ren-Jei Tsai has had to stay in Taiwan since starting his New Zealand PhD. He is investigating engineering solutions for making buildings safer in earthquakes. He aims to develop a procedure that makes coupled wall systems more ductile. Fortunately, Ren-Jei's supervisor Rick Henry had links with Taiwan's National Centre for Research on Earthquake Engineering. Ren-Jei has benefitted from this collaboration to learn from experts abroad and join useful experiments.

As QuakeCoRE students and supervisors seize opportunities that arise out of restrictions, they are simultaneously strengthening international collaborations and broadening research horizons.

Photo credit: National Center for Research on Earthquake Engineering (NCREE)

Recognition Highlights

Lucy Kaiser
(GNS Science)

Lucy Kaiser won the GNS Science Excellence in Early Career Achievement Award in October 2020. This award recognises her important work using a kaupapa Māori approach to developing seismic and tsunami hazard education activities for kura ākonga (school students). Lucy also carried out collaborative work exploring the role of wāhine Māori researchers in the field of seismic research and made recommendations for alleviating some of the challenges to encourage more wāhine Māori into the physical sciences. The mahi was funded through partnerships between Te Hiranga Rū QuakeCoRE, Resilience to Nature's Challenges, East Coast LAB and Massey University.

Photo credit: GNS Science

Greg MacRae

(University of Canterbury)

Greg MacRae won the Steel Construction New Zealand (SCNZ) Chair's Award in November 2020. This award recognises individuals who have made a significant and lasting contribution to Aotearoa New Zealand's structural steel industry. Greg is a University of Canterbury Te Hiranga Rū QuakeCoRE Associate Investigator. His work to improve structural resilience and implement low-damage design has been used in the Christchurch rebuild, throughout New Zealand and in other earthquake-prone countries. Frank Van Schaijik, SCNZ's Chair, said, "Greg has… demonstrated a clear focus on finding the best structural solutions for both the community and the industry using safe, strong and resilient structures."

Photo credit: SCNZ (Steel Construction New Zealand)

Financials, Community & Outputs

Financials

Data covers the period from 1 January 2020 to 30 June 2021

Category	Total ($000s)
CoRE Funding	6,245
Total Revenue	**6,245**
Directors and Principal Investigators	478
Associate Investigators	0
Postdoctoral Fellows	265
Technology Platform Staff & Research Technicians	1,224
Others	416
Total Salaries & Salary-related Costs	**2,383**
Overheads	1,496
Project Costs	2,066
Travel	212
Postgraduate Students	1,326
Equipment Depreciation / Rental	0
Subcontractor(s)	1,671
Total Other Costs	**6,771**
Less: Host ad Partner Support	(185)
Total Expenditure	**8,969**
Net Surplus / (Deficit)	**(2,724)**

2020 at a glance

Data covers the period 1 January 2020 to 30 June 2021

Category	Detailed category	FTE	2020
People	Principal Investigators	1.81	9
	Associate Investigators	0.15	52
	Postdoctoral Fellows	3.38	6
	Technology Platform Staff/ Research Technicians	11.74	19
	Administration/Support	6.50	6
	Research Students	116.85	101
	Total	**140.43**	**193**
Peer-reviews research outputs	Journal Articles		142
	Conference Papers		85
	Total		**227**
Value of external research contracts awarded	Vote Science and Innovation Contestable Funds		$7,521,634
	Other NZ Government		$758,576
	Domestic – Private Sector Funding		$59,004
	Overseas		$65,059
	Domestic – Other Non-government Funding		$5,000
	Total		**$8,409,273**
Students studying at CoRE	Doctoral Degree		86
	Other		15
	Total		**101**
Number of students completing qualifications	Doctoral Degree		15
	Other		5
	Total		**20**
Immediate post-study graduate destinations	Further study in NZ		2
	Further study Overseas		0
	Employed in NZ		12
	Employed Overseas		4
	Other		2
	Total		**20**
Commercial activities	Invention disclosures		0
	Patents granted		0

Community

61
Investigators

33
Industry Affiliates

18
Affiliate Organisations

Board

Dean Kimpton (Chair)	Tuhura Consulting
Mary Comerio	University of California, Berkeley
Jan Evans-Freeman	University of Canterbury
John Hare	Holmes Consulting Group
Bryony James	University of Auckland
Mike Mendonça	Wellington City Council
John Reid	Ngāi Tahu Research Centre
Tā Mark Solomon	

International Science Advisory Panel

Mary Comerio (Chair)	University of California, Berkeley
Jack Baker	Stanford University
Tom O'Rourke	Cornell University
Ellen Rathje	University of Texas at Austin

Leadership Team

Brendon Bradley (Director)	University of Canterbury
David Johnston (Deputy Director)	Massey University
Ken Elwood (Research Director)	University of Auckland
Misko Cubrinovski	University of Canterbury
Caroline Orchiston	University of Otago
Wendy Saunders	GNS Science
Tim Sullivan	University of Canterbury
Liam Wotherspoon	University of Auckland

Principal Investigators

Brendon Bradley	University of Canterbury
Misko Cubrinovski	University of Canterbury
Ken Elwood	University of Auckland
Anthony Hoete	University of Auckland
Jason Ingham	University of Auckland
David Johnston	Massey University
Erica Seville	Resilient Organisations
Tim Sullivan	University of Canterbury
Liam Wotherspoon	University of Auckland

Associate Investigators

Julia Becker	Massey University
Deidre Brown	University of Auckland
Reagan Chandramohan	University of Canterbury
Alice Chang-Richards	University of Auckland
Gabriele Chiaro	University of Canterbury
Charles Clifton	University of Auckland
Toni Collins	University of Canterbury
David Dempsey	University of Canterbury
Rajesh Dhakal	University of Canterbury
Dmytro Dizhur	University of Auckland
Olga Filippova	University of Auckland
Connor Hayden	University of Auckland
Richard Henry	University of Auckland
Lucas Hogan	University of Auckland
John Hopkins	University of Canterbury
Nick Horspool	GNS Science
Emma Hudson-Doyle	Massey University
Matthew Hughes	University of Canterbury
Christine Kenney	Massey University
Robin Lee	University of Canterbury
Minghao Li	University of Canterbury
Tom Logan	University of Canterbury
Quincy Ma	University of Auckland
Gregory MacRae	University of Canterbury
Chris Massey	GNS Science
John McClure	Victoria University of Wellington
Christopher McGann	University of Canterbury
Mark Milke	University of Canterbury
Hugh Morris	University of Auckland
Nirmal Nair	University of Auckland
Katharina Naswall	University of Canterbury
Ilan Noy	Victoria University of Wellington
Caroline Orchiston	University of Otago
Rolando Orense	University of Auckland
Alessandro Palermo	University of Canterbury
Michael Pender	University of Auckland
Suzanne Phibbs	Massey University
Raj Prasanna	Massey University
Santiago Pujol	University of Canterbury
Geoffrey Rodgers	University of Canterbury
Vinod Sadashiva	GNS Science
Wendy Saunders	GNS Science
Allan Scott	University of Canterbury
Mark Stirling	University of Otago
Mark Stringer	University of Canterbury
Bridgette Sullivan-Taylor	University of Auckland
SR Uma	GNS Science
Chris Van Houtte	GNS Science

Bernard Walker	University of Canterbury
Colin Whittaker	University of Auckland
Thomas Wilson	University of Canterbury

Industry Affiliates

Richard Apperley	Aurecon
Jawad Arefi	Beca
Hamish Avery	Canterbury Seismic Instruments
Sarah Barrett	Beca
Jeff Bayless	AECOM
Nicholas Brooke	Compusoft Engineering
Dave Brunsdon	Kestrel Group
Des Bull	Holmes Consulting
Nigel Colenso	ABI Piers
Patrick Cummuskey	Auckland Council
James Dismuke	Golder Associates
Michael Drayton	Risk Management Solutions
Roger Fairclough	Neo Leaf Global
Helen Ferner	NZSEE
Matt Fox	Beca
Jeff Fraser	Golder Associates
Reza Jafarzadeh	Auckland Council
Weng Yuen Kam	Beca
Jared Keen	Beca
Angela Liu	BRANZ
Alan McMahon	Colliers International
Rebecca McMahon	Beca
Gareth Morris	Holmes Consulting
Dan Neely	WREMO
Matt Ogden	Tonkin + Taylor
Aasha Pancha	Aurecon
Didier Pettinga	Holmes Consulting
Dario Pietra	Holmes Consulting
Aimee Rhodes	Opus International Consultants
Andreas Skarlatoudis	AECOM
Paul Somerville	AECOM
Richard Voss	Warren and Mahoney Architects
Rick Wentz	Wentz Pacific

Postdoctoral Fellows

In addition to the postdoctoral fellows listed below, there are a number of additional postdoctoral fellows that are part of the QuakeCoRE Community but funded with aligned funding.

Giovanni De Francesco	University of Canterbury
Adnan Djeffal	University of Canterbury
Trung Dung Nguyen	University of Canterbury
Max Stephens	University of Auckland
Marion Tan	Massey University
Lauren Vinnell	Massey University

Students

In addition to the students listed below that received direct support towards their postgraduate studies, there are a significant number of additional aligned students that are funded with external funding.

Prestige Scholarship Recipients

Our Prestige Scholarship Recipients have been awarded Te Hiranga Rū QuakeCoRE Scholarships as outstanding students to support PhD research under the supervisor of a QuakeCoRE Investigator.

Shannon Abeling	University of Auckland
Pavan Chigullapally	University of Auckland
Chris de la Torre	University of Canterbury
Riwaj Dhakal	University of Canterbury
Tom Francis	University of Canterbury
Francisco Gálvez Gonzalez	University of Auckland
Martín García Cartagena	Massey University
Anna Kowal	University of Otago
Vahid Loghman	University of Canterbury
Nikolaos Ntritsos	University of Canterbury
Eyitayo Opabola	University of Auckland
Mehdi Sarrafzadeh	University of Auckland

Students

In addition to the students listed below that received direct support towards their postgraduate studies, there are a number of aligned students that are funded with aligned funding.

Mohammadtaghi Aghababaei	University of Auckland
Itohan Aigwi	Massey University
Marufa Akther	University of Otago
Fransiscus Arifin	University of Canterbury
Mohammad Bagher Asadi	University of Auckland
Tyler Barton	University of Canterbury
Vishvendra Bhanu	University of Canterbury
Muhammed Bolomope	University of Auckland
Frank Bueker	University of Auckland
Ashley Cave	University of Waikato
Danny Chan	University of Auckland
Jackson Chen Yu	University of Auckland
Max Chirapattanakorn	University of Canterbury
Lucia Danzi	University of Otago
Pavithran Devananthan	University of Canterbury
Wenchen Dong	University of Canterbury
Thomas Dudek	Victoria University Wellington
Michael Dupuis	University of Canterbury
Cameron Eade	University of Canterbury
Saeed Eyvazinejad Firouzsalari	University of Auckland
Davide Forcellini	University of Auckland
Kevin Foster	University of Canterbury
Amin Ghasemi	University of Auckland
Rosa Gonzalez Espinel	University of Auckland
Lesley Gray	University of Otago

Yujia Han	University of Auckland
Sara Harrison	Massey University
Kieran Haymes	University of Canterbury
Asher Herrmann	University of Canterbury
Rangika Hewa Algiriyage	Massey University
Thoa Hoang	Victoria University Wellington
Arman Kamalzadeh	University of Auckland
Saanchi Kaushal	University of Auckland
Shreedhar Khakurel	University of Canterbury
Eseta Le'au	Massey University
Shong Wai Lew	University of Auckland
Robert Malcolm	Massey University
Lisa McClaren	Massey University
Romain Meite	University of Auckland
Catalina Miranda	University of Auckland
Richard Mowll	Massey University
Gonzalo Muñoz Arriagada	University of Auckland
Sunil Nataraj	University of Auckland
Sarah Neill	University of Canterbury
Amirhossein Orumiyehei	University of Canterbury
Moriah Osborne	University of Otago
Michael Parr	University of Canterbury
Marie Claire Pascua	University of Auckland
Jacob Pastor	Victoria University Wellington
Bruce Pepperell	Massey University
Kiran Rangwani	University of Canterbury
Ebad Rehman	University of Auckland
Aimee Rhodes	University of Canterbury
Julian Rincon Gil	University of Canterbury
Ana Sarkis Fernandez	University of Canterbury
Sulaiman Sarwary	University of Canterbury
Subhechha Sharma	University of Auckland
Shakti Shrestha	University of Otago
Hossein Soleimankhani	University of Canterbury
Tomomi Suzuki	University of Auckland
Yasir Syed	Massey University
Laura Tilley	University of Canterbury
Qing Tong	University of Auckland
Christiana Torricelli	Massey University
Ren-Jie Tsai	University of Auckland
Clare Wilkinson	University of Canterbury
James Williams	University of Canterbury
David Wither	University of Otago
Mohsen Yazdanian	University of Auckland
Majid Zakerinia	University of Auckland

Other staff

Research Technicians

In addition to the Research Technicians listed below, there are a number of additional related roles that are supported with aligned funding

Sung Eun Bae	University of Canterbury
Richard Ball	Resilient Organisations
Emily Campbell	Massey University
Alicia Cui	Massey University
Alexandra Davis	University of Canterbury
Yen-Ko Huang	University of Canterbury
Lucy Kaiser	Massey University
Emily Lambie	Massey University
Yiqiu Lu	University of Auckland
Matt Luani	Massey University
Jason Motha	University of Canterbury
Sally Owen	Victoria University of Wellington
James Paterson	University of Canterbury
Claudio Schill	University of Canterbury
Dong Son	University of Canterbury
Andrew Stolte	University of Canterbury
Ethan Thompson	University of Canterbury
Tomas Uher	University of Auckland
Syed Yasir Imtiaz	University of Auckland

Support Staff

Ruth Hartshorn	Operations Manager
Brandy Alger	Outreach Coordinator
Amy McGeddie	Administrator
Siew Lee O'Brien	Senior Finance Administrator
Rosemary Walton	Research Coordinator

Affiliate Organisations

Building Research Institute (BRI)	Tsukuba , Japan
Copenhagen Centre for Disaster Research (COPE)	Copenhagen, Denmark
DesignSafe	Austin, USA
EPICentre	London, UK
EU Centre	Pavia, Italy
Geotechnical Extreme Events Reconnaissance Association (GEER)	Atlanta, USA
International Joint Laboratory of Earthquake Engineering (ILEE)	Shanghai, China
Korea Institute of Science and Technology Information (KISTI)	Daegu, Korea
Liquefact	Chelmsford, UK
National Center for Research on Earthquake Engineering (NCREE)	Taipei, Taiwan
National Hazards Center (NHC)	Boulder, USA
National Hazards Engineering Research Infrastructure (NHERI) @UTexas	Austin, USA
National Hazards Engineering Research Infrastructure (NHERI) SimCenter	Berkeley, USA
Pacific Earthquake Engineering Research Center (PEER)	Berkeley, USA
Quake Centre	Christchurch, New Zealand
Research Centre for Integrated Disaster Risk Management (CIGIDEN)	Santiago, Chile
Southern California Earthquake Center (SCEC)	Los Angeles, USA
Smart Structures Lab, Swinburne University of Technology	Melbourne, Australia

Partners

University of Canterbury (Host)
BRANZ
GNS Science
Massey University
Resilient Organisations
University of Auckland
University of Waikato
Victoria University of Wellington

Publications

227
Peer-reviewed Outputs

97
Annual Meeting Posters

Journal Publications (Direct Peer-Reviewed)

Abbott, E., **Horspool, N.**, Gerstenberger, M., Huso, R., Van Houtte, C., McVerry, G., & Canessa, S. (2020). Challenges and opportunities in New Zealand seismic hazard and risk modelling using OpenQuake. *Earthquake Spectra,* **36 (1),** 210 – 225

Abeling, S., & **Ingham, J.** (2020). Volume loss fatality model for as-built and retrofitted clay brick unreinforced masonry buildings damaged in the 2010/11 Canterbury earthquakes. *Structures,* **24,** 940 – 954

Abeling, S., **Horspool, N.**, **Johnston, D.**, **Dizhur, D.**, Wilson, N., Clement, C., & **Ingham, J.** (2020). Patterns of earthquake-related mortality at a whole-country level: New Zealand, 1840–2017. *Earthquake Spectra,* **36 (1),** 138 – 163

Aigwi, I., **Filippova, O.**, **Ingham, J.**, & Phipps, R. (2020). Unintended consequences of the earthquake-prone building legislation: An evaluation of two city centre regeneration strategies in New Zealand's provincial areas. *International Journal of Disaster Risk Reduction,* **49,** 101644

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Aigwi, I., **Ingham, J.**, Phipps, R., & **Filippova, O.** (2020). Identifying parameters for a performance-based framework: Towards prioritising underutilised historical buildings for adaptive reuse in New Zealand. *Cities,* **102,** 102756

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Arifin, F., **Sullivan, T.**, & **Dhakal, R.** (2020). Experimental investigation into the seismic fragility of a commercial glazing system. *Bulletin of the New Zealand Society for Earthquake Engineering,* **50 (3),** 144 – 149

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Asadi, M., Asadi, M., **Orense, R.**, & **Pender, M.** (2020). Small-strain stiffness of Natural Pumiceous Sand. *Journal of Geotechnical and Geoenvironmental Engineering,* **146 (6),** 6020006

Barton, T., Beaven, S., Cradock-Henry, N., & **Wilson, T.** (2020). Knowledge sharing in interdisciplinary disaster risk management initiatives: Cocreation insights and experience from New Zealand. *Ecology and Society,* **25 (4),** 1 – 18

Basharati, S., Ardagh, M., Deely, J., **Horspool, N.**, **Johnston, D.**, Feldmann-Jensen, S., Dierckx, A., & Than, M. (2020). A research update on the demography and injury burden of victims of New Zealand earthquakes between 2010 and 2014. *Australasian Journal of Disaster and Trauma Studies,* **24 (1),** 65 – 73

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Arifin, F., De Francesco, G., **Sullivan, T.**, & **Dhakal, R.** (2020) Developing guidelines for the seismic assessment of glazing systems. *New Zealand Society for Earthquake Engineering Conference.*

Arifin, F., **Sullivan, T.**, & **Dhakal, R.** (2020) Experimental investigations into the fragility of commercial glazing systems in New Zealand. *17th World Conference on Earthquake Engineering.*

Arifin, F., **Sullivan, T.**, & **Dhakal, R.**, (2021) Performance comparison of standard and seismic glazing systems. *New Zealand Society for Earthquake Engineering Conference.*

Bagheri, H., Hashemi, A., Zarnani, P., Quenneville, P., Yan, Z., **Clifton, G.**, & **MacRae, G.** (2020) Full-scale shaking table testing of a low-damage steel structure using Resilient Slip Friction Joint. *New Zealand Society for Earthquake Engineering Conference.*

Bagheri, H., Hashemi, A., Zarnani, P., Quenneville, P., Yan, Z., **Clifton, G.**, **MacRae, G.**, **Dhakal, R.**, Zhao, X., Jia, L., & Xiang, P. (2020) A Low-Damage Steel Structure using Resilient Slip Friction Joint for a Full-Scale Shaking Table Test. *17th World Conference on Earthquake Engineering.*

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Rodgers, G., Vishnupriya, V., Chase, J., & Zhou, C. (2020) Upper and lower bounds of device force capacity in high force to volume (HF2V) device design. *17th World Conference on Earthquake Engineering.*

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Soleimankhani, H., **MacRae, G.**, & **Sullivan, T.** (2020) Effects of hysteretic behaviour on inelastic response of single story systems with torsional response. *17th World Conference on Earthquake Engineering.*

Soleimankhani, H., **MacRae, G.**, & **Sullivan, T.** (2021) Simple design methods to make allowance for building inelastic torsion. *New Zealand Society for Earthquake Engineering Conference.*

Sullivan, T. (2020) How would changes to serviceability limit state design criteria impact likely repair costs. *New Zealand Society for Earthquake Engineering Conference.*

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Tan, M., **Prasanna, R.**, **Becker, J.**, Brown, A., Stock, K., **Kenney, C.**, Lambie, E., **Johnston, D.**, & De Alwis, D. (2021) Outlook for earthquake early warning for Aotearoa New Zealand: Insights from initiating a community-of-practice.. *New Zealand Society for Earthquake Engineering Conference.*

Vazquez-Colunga, S., Lee, C., & **MacRae, G.** (2020) Brace end flexibility effects on the stability of buckling restrained braced frame. *17th World Conference on Earthquake Engineering.*

Vinnell, L., **Becker, J.**, & **Johnston, D.** (2021) Evaluation of the ShakeOut earthquake drill and use of protective actions in Aotearoa New Zealand. *New Zealand Society for Earthquake Engineering Conference.*

Vishnupriya, V., Chase, J., **Rodgers, G.**, & Zhou, C. (2020) Finite element method for designing HF2V device force capacity. *New Zealand Society for Earthquake Engineering Conference.*

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Yan, Z., Bagheri, H., **Clifton, G.**, Quenneville, P., Ramhormozia, S., **MacRae, G.**, **Dhakal, R.**, Zhao, X., Jia, ., & Xiang, P. (2020) Shake table testing of a near full scale three-storey friction based low damage steel structure: Structural design and detailing. *New Zealand Society for Earthquake Engineering Conference.*

Yan, Z., Bagheri, H., **Clifton, G.**, Quenneville, P., Ramhormozian, S., & **MacRae, G.** (2021) Three-storey configurable steel framed building incorporating friction based energy dissipaters: Structural configuration and instrumentation. *New Zealand Society for Earthquake Engineering Conference.*

Yan, Z., Ramhormozian, S., **Clifton, G.**, Bagheri, H., **MacRae, G.**, Quenneville, P., **Dhakal, R.**, Xiang, P., Jia, L., & Zhao, X. (2020) Shaking table testing of a three storey steel frame building incorporating friction-based connections: Structural design and detailing. *17th World Conference on Earthquake Engineering.*

Yang, Q., **Henry, R.**, & Lu, Y. (2021) Wall-to-floor connection behavior in a low-damage concrete wall building. *New Zealand Society for Earthquake Engineering Conference.*

Yu, F., Huang, R., & **Sullivan, T.** (2020) Estimating deformation demands on steel EBF systems. *New Zealand Society for Earthquake Engineering Conference.*

QuakeCoRE Annual Meeting Posters

97 posters were presented at the Te Hiranga Rū QuakeCoRE Annual Meeting in Whakatū Nelson from 8 – 10 December, 2020.

Aigwi, E., **Filippova, O.**, **Sullivan-Taylor, B.**
Public perception of heritage buildings in Invercargill's city centre

Alger, B., Midwood-Murray, A., Midwood-Murray, B., Kaiser, L., Lake-Hammond, A., Boersen, K.
Te Hiranga Rū QuakeCoRE Quake Centre Outreach Programmes

Algiriyage, N., **Prasanna, R.**, Stock, K., **Doyle, E.**, **Johnston, D.**
Real-time Disaster Event Extraction from Unstructured Text Sources

Allen, N., **Wilson, T.**, Kennedy, B., Scott, A., Stewart, C.
Multi-Volcanic Hazard Impact assessment for Residential Buildings in the Auckland Volcanic Field, New Zealand

Avendano-Uribe, B., Milke, M., Beaven, S., **Hughes, M.**
The use of Participatory Modelling to integrate social and infrastructure resilience-building.

Bae, S., Huang, J., **Bradley, B.**, Polak, V.
Web Interfaces for Earthquake and Ground Motion Simulation Visualisation

Barnhill, D., **Wilson, T.**, **Hughes, M.**, Beaven, S., Schoenfeld, M., Chandratilake, S., Jack, H.
Informing tsunami evacuation modelling by evacuation dynamics from Christchurch and Banks Peninsula during the 2016 Kaikōura earthquake

Bebbington, M., Weir, A., **Wilson. T.**
Quantifying systemic vulnerability to critical infrastructure systems

Bhanu, V., **Chandramohan, R.**, **Sullivan, T.**
Earthquakes: Are we ready for a LONG one?

Bolomope, M., **Filippova, O.**
The relationship between building lifecycle of commercial properties and seismic adaptation in Wellington CBD

Boston, M., Kurata, M., Kawamata, Y., Gipson, J., Kanao, L., Otsuru, S., Matsuo, S., Fujita, K., Aida, S., Tsutsumi, T., Cho, K., Kojima, K.
Integrated Complex Structural / Non-Structural Assessment on Steel Hospital Building

Calderon, R., **Wilson, T.**, Leonard, G.
Potential hazard scenarios from Taupo Volcanic Zone: Geological and historical records of large silicic systems

Carradine, D.
Determining the Seismic Performance of Structural Insulated Panels for New Zealand Buildings

Chandramohan, R., Dashti, F., **Dhakal, R.**, **Elwood, K.**
Seismic performance of a 9-storey pre-1970s reinforced concrete wall building in Wellington

Chigullapally, P., **Wotherspoon, L.**, **Hogan, L.**
Pushover Testing of Isolated Piles of the Whirokino Trestle

Crawford, M., **Saunders, W.**, Leonard, G., **Hudson-Doyle, E.**, **Johnston, D.**
A Review of Natural Hazard Risk Governance in New Zealand: Complexity, inertia and options for moving forward

Darling, M., **Wilson, T.**, **Orchiston, C.**, Adams, B., **Bradley, B.**
Safety does not take a holiday: Towards real-time indicators of population exposure for disaster risk assessments

de la Torre, C., **Bradley, B.**, **McGann, C.**
Modelling Soil Heterogeneity and Wave Scattering in Geotechnical Site Response Analysis

Dempsey, D., Eccles, J., Huang, J., Nicolin, E., Stolte, A., **Wotherspoon, L.**, **Bradley, B.**
Ground Motions Simulation of Hypothetical Earthquake Sources in the Upper North Island, New Zealand

Deng, T., **Henry, R.**
Numerical modelling of tall reinforcement concrete wall designed with the minimum vertical reinforcement limits

Dhakal, R., **Cubrinovski, M.**, Bray, J.
Liquefaction Assessment of Reclaimed Land at CentrePort

Dudek, T.
Examining the Association of Personality with Insurance Decisions

Dupuis, M., Schill, C., **Lee, R.**, **Bradley, B.**
A neural network for ground motion quality classification from New Zealand earthquakes of variable magnitudes and tectonic types

Eade, C.
From Disaster to Resilience: A Comparative Study of Legal Models for Regulating Seismic Risk of Existing Buildings

Evans, A., **Wilson, T.**, **Hughes, M.**, Nilsson, D.
Assessing the evacuation capacity of remote rural communities highly exposed to tsunami hazard: a case study of Wairarapa coastal communities

Faulkner, H., **Hopkins, J.**, **Collins, T.**
Regulating for Resilience: The Wellington Case Study

Filippova, O., Tong, Q., **Ingham, J.**
Can regulatory intervention be successful? Review of the Unreinforced Masonry Securing Fund

Forcellini, D.
The role of location in the seismic assessment of Wellington CBD buildings

Francis, T., **Sullivan, T.**
Seismic Isolation of Light Frame Wood buildings in New Zealand

Ghasemi, A., Stephens, M., **Elwood, K.**
Wellington Building Inventory: Rapid Earthquake Response Framework

Gonzalez, R., Stephens, M., Toma, C., **Elwood, K.**, Dowdell, D.
Holistic Evaluation of Resilient Structures: The Environmental Performance of Beyond New Zealand Building Code Structures.

Gray, L.
Explicit, implicit and internalised: Bias and large bodies in disaster risk reduction - a multi-method study

Gurung Shrestha, S., **Chandramohan, R.**, **Dhakal, R.**
Using Genetic Algorithms to Select Ground Motions for conducting HC-IDA

Harrison, S., Potter, S., **Prasanna, R.**, **Doyle, E.**, **Johnston, D.**
Accessing, Sharing, and Using Impact Data in New Zealand for Disaster Risk Reduction

Hashemi, A., Zarnani, P., Quenneville, P.
Resilient Slip Friction Joint (RSFJ): Completed and ongoing projects in research and practice

Hoang, T., **Noy, I.**
The effects of managed retreat (red zoning) on the relocated households in New Zealand

Hogan, L.
Improved panel-to-foundation connections for low-rise precast concrete buildings

Holden, C., Sklowdowska, A., Gueguen, P.
Testing advanced seismological methods towards a better understanding of the built environment response to earthquakes in New Zealand

Horsfall, S., Hatton, T., **Collins, T.**, Brunsdon, D.
Earthquake Risk Reduction Behaviours in Organisations: Understanding what organisations are doing to stay safe in New Zealand's seismically active environment.

Horspool, N., **Elwood, K.**, Gerstenberger, M.
Risk targeted hazard spectra for seismic design in New Zealand

Hudson-Doyle, E., Paton, D., **Johnston, D.**, Smith, R.
Effective communication of model uncertainty: moving towards decision-relevant communications

Kahandawa, R., Domingo, N., Chawynski, G., **Uma, S.**
Post earthquake cost estimation model for damage repair work

Kaiser, L.
Investigating Tangata Whenua Views and Responses to Climate Change

Kaushal, S., **Ingham, J.**, **Dizhur, D.**
Using Machine Learning techniques to predict seismic damage in Dunedin

Kowal, A., Jeong, S., **Wotherspoon, L.**, **Stirling, M.**
Ground motion simulations for the Dunedin - Mosgiel area

Lake-Hammond, A., **Orchiston, C.**, Scally-Irvine, K.
Evaluating the relevance and effectiveness of AF8 since the project began in 2016

Lee, R., **Bradley, B.**, Graves, R., Paterson, J., Motha, J., Huang, J., Schill, C., Polak, V., Bae, S.
Source Considerations for Moderate Magnitude Earthquake Ground Motion Simulation Validation

L'Hermitte, C., **Wotherspoon, L.**
Resilient and adaptable transport across modes: key enablers and existing barriers in New Zealand

Lin, A., **Wotherspoon, L.**, Blake, D., **Bradley, B.**, Motha, J.
Liquefaction exposure and impacts across New Zealand State Highways

Logan, T.
Resilience as a function of equitable access to services and essentials - integrating infrastructure and community resilience approaches

Loghman, V., **Bradley, B.**, **Chandramohan, R.**, **Lee, R.**, **McGann, C.**
Validation of ground-motion simulations using Advanced Intensity Measures - New Zealand small magnitude events

Miranda, C., **Becker, J.**, **Johnston, D.**, Toma, C., **Elwood, K.**
Future seismic performance expectations of the wooden-framed houses by homeowners

Mostafa, M., Bueker, F., Parr, M., Jenkins, M., **Hogan, L.**, **Elwood, K.**, Bull, D., Brooke, N., **Henry, R.**, **Sullivan, T.**, Liu, A.
Seismic assessment and retrofit development of precast prestressed hollow-core floors

Motha, J., **Bradley, B.**, Paterson, J., **Lee, R.**, Thompson, E., Tarbali, K., Bae, S., Huang, J., Schill, C., Polak, V., Lagrava, D.
Cybershake NZ v20.8: New Zealand simulation-based probabilistic seismic hazard analysis

Mowll, R.
Infrastructure emergency levels of service for the Wellington region

Muñoz, G., **Henry, R.**, **Elwood, K.**
Repairability of earthquake damaged RC walls

Naguit, M.
GeoNet strong motion data products - modernizing & future-proofing our services

Neill, S., **Bradley, B.**, **Lee, R.**
Ground motion simulation validation with explicit uncertainty incorporation for small magnitude earthquakes in New Zealand

Nguyen, T., **Lee, R.**, **Bradley, B.**, Graves, R.
Full Waveform Seismic Tomography for geophysical velocity model in South Island region, New Zealand based on Adjoint-Wavefield method

Nicolin, E., **Dempsey, D.**
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