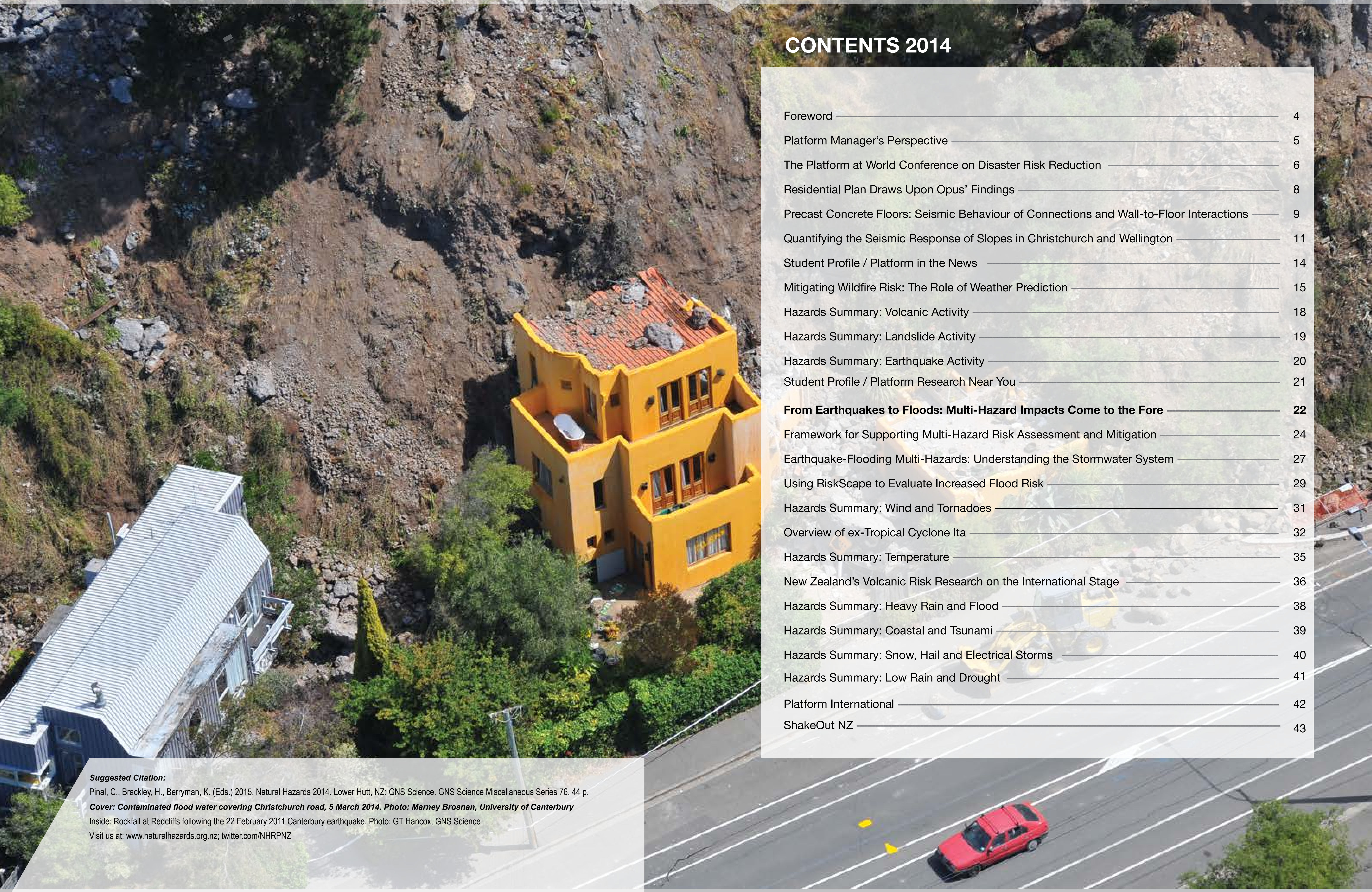
Natural Hazards 2014

Earthquake to Flood: Multi-Hazard Impacts

GNS Science Te Pū Ao
Massey University
UC University of Canterbury
The University of Auckland New Zealand Te Whare Wānanga o Tāmaki Makaurau
Opus
NIWA Taihoro Nukurangi



CONTENTS 2014

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Cover: Contaminated flood water covering Christchurch road, 5 March 2014. Photo: Marney Brosnan, University of Canterbury

Inside: Rockfall at Redcliffs following the 22 February 2011 Canterbury earthquake. Photo: GT Hancox, GNS Science

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Foreword

Good science and research are fundamental to disaster risk management (DRM). This has long been recognised in New Zealand, together with the importance of collaboration and partnerships.

There is an international dimension to this. Offshore collaboration enriches our domestic DRM expertise, not only in the underlying science, but also in policy, planning and practice across the four "Rs" of risk reduction, readiness, response and recovery.

International collaboration on DRM has also become an important part of New Zealand's world profile. We have a long history of supporting countries affected by disasters, especially in the South Pacific, East and South East Asia and more widely through the United Nations. It is about New Zealand being a good international citizen. It also very much reflects our friendships and responsibilities in our part of the world. DRM is an area where New Zealand's domestic experience and expertise are relevant and valued offshore.

Historically much of the international collaboration centred on readiness and response. The importance of risk reduction and recovery is now being recognised and embraced.

Countries in the South Pacific are increasingly providing leadership around disaster planning, especially the link with climate change. Similarly there is very innovative thinking in East and South East Asia on issues such as the role of the private sector in helping prepare for and respond to disasters and get recovery under way.

The recent United Nations World Conference on Disaster Risk Reduction in Sendai, Japan, was an important event in bringing together international experience and building better understanding of disaster risk reduction, its management, the value of investing in science and research, policy planning and practice to build resilient communities.

The Conference adopted a new Framework for Disaster Risk Reduction through until 2030. This sets out goals, action priorities, targets and stakeholder roles at the international, regional and national levels.

New Zealand made a substantial contribution to the Framework both in preparatory meetings over the last two years and also in the final negotiations in Sendai. Throughout this process in shaping how New Zealand could most effectively contribute, officials drew on a wide range of stakeholders including the Natural Hazards Platform for advice and input.

Similarly the New Zealand delegation at the Conference, led by Hon Gerry Brownlee spanned cental Government, the wider research community, non-governmental organisations and local government representatives. This "joined up" approach was a powerful demonstration of the value of collaboration and partnerships.

It was clear at the Conference that there is continuing offshore interest in the lessons to be learned from our Christchurch experience. The Sendai Framework also provides impetus for ensuring a more resilient New Zealand.

I well recall in Christchurch the impact and emotions when the USAR teams and help from Australia, the United States, Japan, China, Singapore, the United Kingdom and others started to arrive. A lesson not to be forgotten. International collaboration and partnerships are essential. When natural disasters strike, they know no boundaries. We are all in it together.

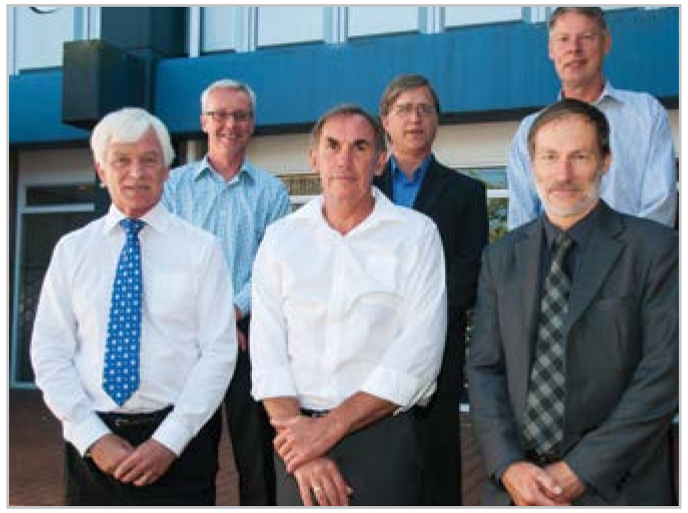
Phillip Gibson

Special Envoy Disaster Risk Management

Ministry of Foreign Affairs and Trade

Platform Manager's Perspective

Evolution, expectations, events, challenges and connectedness are key words for 2014 and into 2015. With respect to evolution I mean science priority settings and new initiatives such as the National Science Challenges and recent announcement of the 'QuakeCore' as a Centre of Research Excellence, a significant boost to earthquake engineering in New Zealand. I say expectations because in 2014 the Platform was involved in a broad New Zealand-wide partnership involving significant preparation, dialogue and planning for the Sendai Framework for Disaster Risk Reduction. Events in 2014 – there were plenty - including flooding in Christchurch from rainstorms in March, April and June exacerbated by tectonic subsidence and liquefaction. Platform researcher Dr. Sonia Giovinazzi (University of Canterbury) gathered a research team to investigate multi-hazard impacts in Christchurch and some of their findings are reported in this issue.



The Platform Management Group. Back row (l-r): Peter Benfell, Opus; Pierre Quenneville, U. Auckland; Jarg Pettinga, U. Canterbury; Front row (l-r): Murray Poulter, NIWA; Kelvin Berryman, Platform Manager, GNS Science; Terry Webb, GNS Science. Absent: Peter Kemp, Massey University

Early in 2014 the Platform was reviewed by MBIE to examine progress over its first four years (2009-13). Reviewers identified that (i) Our performance exceeded contractual expectations; (ii) Delivered value for money; and (iii) Provided a mechanism for the science sector to respond quickly to external events. As always there are things to improve upon, but it was recognised that the existence of the Platform was critical to providing a coordinated response during the Canterbury earthquakes, a model mirrored during the Tongariro eruption.

The *'Resilience to Natures Challenges'* (National Science Challenge) was in development over 2014. Once advanced, the Platform and RNC will dovetail their strategy, science management and stakeholder arrangements so as to maximise benefits for New Zealand. Our aim is to keep stakeholders engaged though these new initiatives and rearrangements.

Platform has been involved in a wide range of international collaborations. This includes participation in the recent 3rd World Conference on Disaster Risk Reduction. Engagement in the Sendai Framework was, personally, the highlight of the year. The depth of engagement, trust in advice provided, and teamwork with MFAT and other agencies demonstrated the excellent opportunity we have as a nation in taking substantial steps forward in reducing the impacts of future natural hazard events in New Zealand.

Lastly, the management group of the Platform has also changed in the past year: Terry Webb (GNS Science) and Murray Poulter (NIWA) have retired; and Jarg Pettinga (University of Canterbury) has stepped down from the management team to focus on research activities. I would like to thank Terry, Murray and Jarg for their major contribution to the success of the Platform. All three were founding members and their continued advice and support has been much appreciated.

Kelvin Berryman, Platform Manager

More information:

QuakeCore - https://beehive.govt.nz/release/four-more-centres-research-excellence-funded

Sendai Framework for Disaster Risk Reduction - http://www.wcdrr.org/preparatory/post2015

The Platform at World Conference on Disaster Risk Reduction

Platform researchers played an active role in the World Conference on Disaster Risk Reduction (WCDRR) from 14 to 18 March 2015 in Sendai Japan. Representatives from 187 UN member States adopted the first major agreement of the Post-2015 development agenda, a far-reaching new framework for disaster risk reduction with seven targets and four priorities for action. The World Conference was attended by over 6,500 participants, including 2,800 representatives from 187 governments. The Public Forum had 143,000 visitors over the five days of the conference.

The new Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven global targets to be achieved over the next 15 years: a substantial reduction in global disaster mortality; a substantial reduction in numbers of affected people; a reduction in economic losses in relation to global GDP; substantial reduction in disaster damage to critical infrastructure and disruption of basic services, including health and education facilities; an increase in the number of countries with national and local disaster risk reduction strategies by 2020; enhanced international cooperation; and increased access to multi-hazard early warning systems and disaster risk information and assessments.

The Post-2015 Framework for Disaster Risk Reduction makes a strong call for science to support the understanding of disaster risk and to promote risk-informed decisions and risk sensitive planning from local to global levels. It also calls for the coordination of existing networks and scientific research institutions at all levels, all regions and between countries. The goal is to strengthen the evidence-base in support of the implementation of the new framework. The Platform recognises that if we want to continue to deepen our understanding of evolving risks, the root causes of disasters and their impact on development, we need actionable research that is useful, usable and used. Scientists and researchers must work with policy-makers and practitioners to co-design and co-produce research that can be used effectively. The global science and technology community can support better monitoring and forecasting, help develop scenarios and identify options to manage risk (including related to climate change), propose resilient and sustainable development pathways and test potential solutions to assess their effectiveness and viability.

The Platform supports the global scientific and technological community's call to strengthen the implementation and monitoring of the Framework in multiple ways. These include:

Assessment. Science can provide analytical tools to assess and advance our knowledge of hazard, risk, and underlying risk drivers. It can also evaluate the need for a regular, independent, policy-relevant international assessment of available science on disaster risk reduction, resilience and transformation to achieve a more comprehensive view of disaster risk.

Synthesis. To facilitate the uptake of scientific evidence in policy-making, we need to synthesise it in a timely, accessible and policy-relevant manner.

Scientific advice. To translate knowledge into solutions, the science community can provide advisory capabilities integrating all fields of science, technology and innovation in collaboration with practitioners and policy-makers.

Monitoring and review. The science and technology community is ready to support the development of science-based indicators, common methodologies and processes to harness data and information, to promote their availability and use at different scales.

Communication and engagement. We need to build closer partnerships between policy and research and among researchers themselves. We need to improve the communication of scientific knowledge to facilitate evidence-based decision-making at all levels of government and across sectors of society.

Capacity building. Risk literacy needs to be promoted through curricular reform, professional training and life-long learning across all sectors of society.

Caption: From left, David Johnston (GNS Science/Massey Univ), Phillip Gibson (see Foreword), and Christine Kenney (Massey Univ) contribute to the 2nd Preparatory meeting for the 3rd WCDRR. Photo: YouTube, https://www.youtube.com/watch?v=EZS34TTS5wc

Statement prepared by the Science & Technology Major Group to the Third World Conference on Disaster Risk Reduction, Sendai Japan

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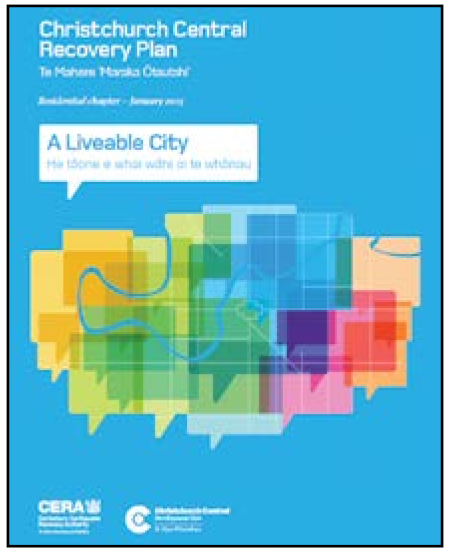
Main photo: Resilience Dialogue at the 3rd World Conference on Disaster Risk Reduction. Photo: Hannah Brackley, NHRP

Residential Plan Draws Upon Opus' Findings

What will it take for the central city of Christchurch to be a successful place to live?

Developing a vibrant central city is a critical but challenging component of Christchurch's vision for recovery from the 2010/11 earthquakes. To help the city, the natural hazards team at Opus Research has been developing a robust, timely and local evidence base to guide rebuild and recovery decisions. Findings from Opus' Central City Living Study continue to inform Christchurch City Council, Canterbury Earthquake Recovery Authority (CERA), health, transport, and housing authorities, as well as private sector developers and consultants, and inform public discussion in the media.

One debate has been whether people would want an urban lifestyle not traditionally offered in Christchurch. Such uncertainty poses a major risk to the recovery, with developers unwilling to invest without evidence of demand, and authorities needing to know which projects would best support a vibrant central city (such as public space and amenities). We asked potential residents what it would take for them have a good quality of life if they were to move to the central city at different stages



in the rebuild. Developed by Opus' urban and behavioural psychology experts, the study used sophisticated multimedia Computer Assisted Personal Interviewing (CAPI) methods to generate responses to simulated neighbourhood amenity and housing options. Rather than simply capturing unrealistic 'wishlists,' the method allows researchers to test real life trade-offs.

Those individuals willing to move into an incomplete central city can play a vital role in the recovery, not least by providing a local market for the emerging commercial sector. Most findings were in line with researchers' knowledge about urban environments, but some results proved surprising, such as the one-fifth of respondents with school-aged children who were prepared to move into the central city early in the rebuild.

Throughout the project, Opus engaged widely. The study itself provided a forum to discuss and debate how to rebuild the central city and provide opportunities for everyday activities.

CERA's 2015 residential chapter, *A Liveable City*, sets out initiatives to stimulate residential recovery in the central city through changes to planning regulations and processes. It is positive to see a number of our key findings represented in the chapter. These include recognition that recovery of the commercial and residential sectors can help each other, the need to support an urban lifestyle through managing land use and transport, and the importance of encouraging early residential rebuild projects. We will continue to observe impacts of the initiatives introduced to better understand their effectiveness at aiding recovery.

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Precast Concrete Floors: Seismic Behaviour of Connections and Wall-to-Floor Interactions

Floor diaphragms play an important role in the seismic response of buildings by transferring forces to lateral and vertical load-resisting systems. However, the demands on floors during earthquakes can result in damage that compromises their connection to other elements in the building, and in extreme cases may result in the collapse of the floor. In New Zealand, floor diaphragms in multi-storey buildings are typically constructed using precast concrete floor units. Research in the past 20 years has highlighted a number of vulnerabilities in the connections of precast concrete floor systems that have resulted in significant changes to design standards and construction practice.

The Canterbury earthquakes reconfirmed several of the previously identified vulnerabilities in precast concrete floors and also raised new concerns that hadn't previously been considered (Fig. 1). The Canterbury Earthquakes Royal Commission made a number of recommendations related to loads and connection design in precast concrete floors, as well as a need to develop greater understanding of the interactions between structural elements.

This research project is focused on improving the seismic performance of connections in precast concrete floors and investigating the interaction between floor and wall systems as buildings deform during earthquakes.

Figure 1: Damage to precast floors during the Canterbury earthquakes

Support connections

Experimental testing has been conducted to investigate the seismic behaviour of deep hollowcore precast units that use recommended support connection details. Additional testing is in progress to understand the seismic behaviour of precast concrete rib with timber infill floor systems that use typical pre-Canterbury earthquake detailing, as well as detailing recommended by the Structural Engineering Society (SESOC) after the Canterbury earthquakes.

The outcomes of these precast unit tests have resulted in recommendations that were used to support amendments currently proposed to the New Zealand Concrete Structures Standard (NZS 3101).

Wall-to-floor interaction

The Canterbury earthquakes further highlighted the need to consider earthquake-induced deformations on buildings and the interaction between different structural and non-structural systems. For example, the deformation of reinforced

The research team takes a break from seismic testing of a hollowcore floor unit at Stresscrete. From left are Sandra Yassi, James Daniels, Sam Corney, and Rick Henry.

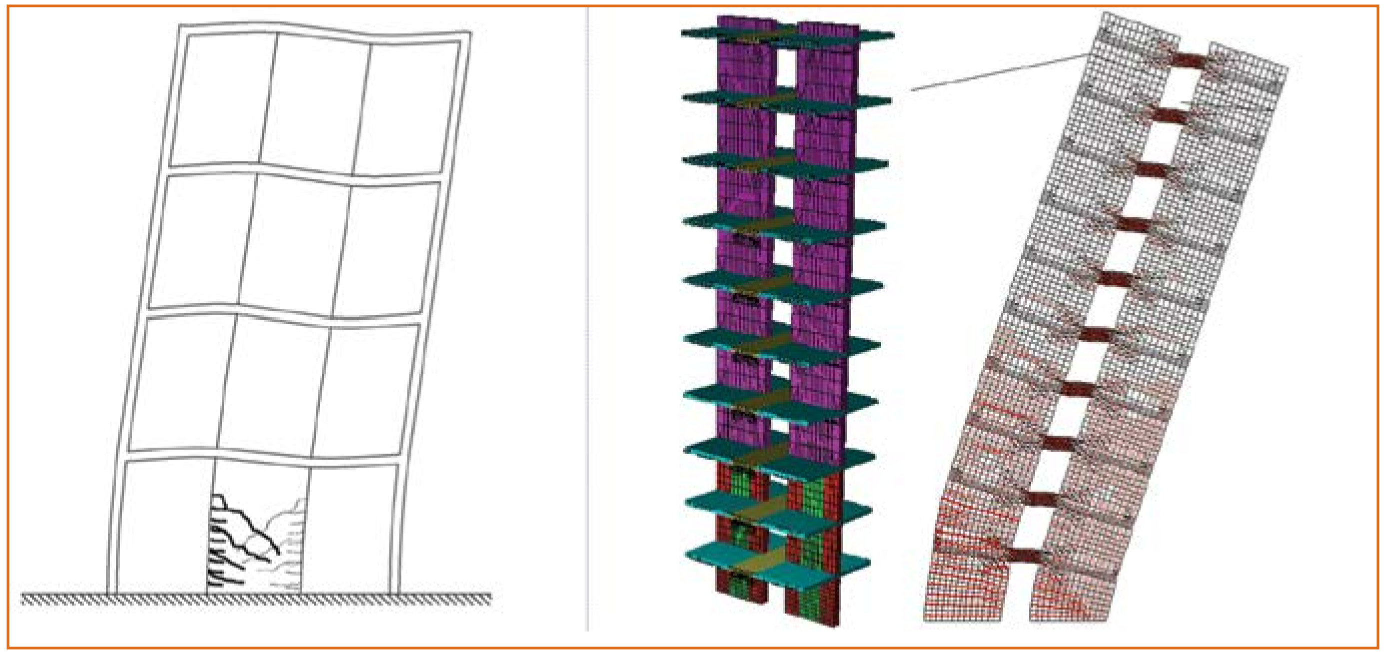

Figure 2. Structural interaction between wall and floor systems. Left, a single cantilever wall. Right, a coupled wall system.

concrete walls can be restrained by the floor diaphragms (Fig. 2). Numerical models are being used to understand how the deformations induced in the floor and the restraint provided to the wall may alter the seismic loads on parts of the building and its overall behaviour during earthquakes.

Low-damage systems

Low-damage concrete systems can provide a more resilient building by minimising damage during large earthquakes. Rocking concrete walls can provide excellent low-damage systems, but new wall-to-floor connections need to be developed to ensure that the floors are not damaged and to maximise the likelihood that the building can be reoccupied post-earthquake. A novel isolating connector has been developed and a large-scale test of a rocking wall with a section of floor was recently completed by collaborators in the United States (Fig. 3).

Project team

The project team includes Dr Rick Henry and Prof. Jason Ingham (University of Auckland), PhD students Sam Corney, Ericson Encina and Jonathan Watkins, and ME students Andy Ahn and Richard Malcolm. The coupled wall analysis included collaboration with Prof. Des Bull (Holmes Consulting Group and University of Canterbury), and the low-damage wall tests were conducted in collaboration with Prof. Sri Sritharan (Iowa State University) and Prof. Cathy French (University of Minnesota).

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Figure 3. Low-damage rocking wall system test at the University of Minnesota.

Quantifying the Seismic Response of Slopes in Christchurch and Wellington

The 2010/11 Canterbury earthquakes triggered mass movements in the Port Hills including rockfalls, debris avalanches, landslides and cliff-top cracking. The most abundant mass movements with the highest risk to people and buildings were rockfalls and rock/debris avalanches. Over 100 residential homes were impacted leading to the evacuation of several hundred residents.

Our research looks at the effects that slope geometry, geology and earthquake source have on amplifying ground shaking leading to slope failure. This research was primarily focused on the effects of the 2010/11 Canterbury earthquakes on slopes, ranging from steep rock cliffs to shallow soil slopes in the Port Hills of Christchurch. The methods used and the lessons learned from Christchurch were then applied to some major slope types in Wellington to test the results and identify differences.

Results from the Port Hills cliffs

For the debris avalanches and rockfalls of the Port Hills (Fig. 1), observations and monitoring showed that the higher and steeper cliffs produced more debris, as one might expect. The higher cliffs also suffered larger amounts of cliff-top cracking than smaller cliffs (Fig. 2).

Our data have shown that amplification of shaking did not increase linearly with increasing height, but instead reflected changes mainly in the cliff geology. Local topography, such as sharp breaks in slopes, can also amplify ground shaking. However, an important factor in amplifying ground shaking is contrasting geological materials, which in the Port Hills cliffs are quite variable.

Figure 3 shows a schematic of the locations where we sampled the

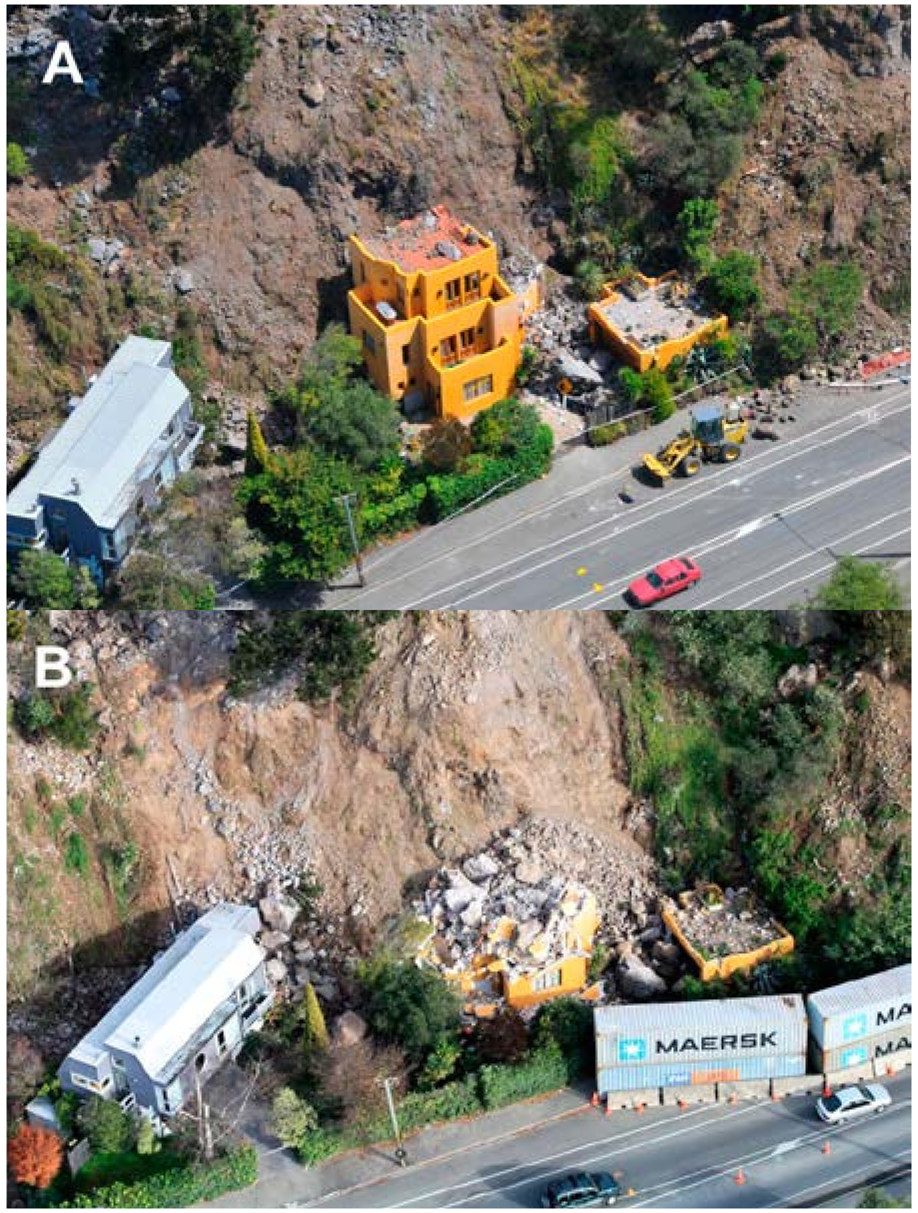

Figure 1. A) The northern end of the Redcliffs site, taken shortly after the 22 February 2011 earthquakes. B) The same site at Redcliffs, taken after the 13 June 2011 earthquakes. Photos: G.T. Hancox (GNS Science).

modelled accelerations (ground motions). AMAX represents acceleration at the top of the cliff "crest", AFF represents accelerations at the bottom "toe" of the cliff, and KMAX represents the average accelerations along a number of simulated slide surfaces (along which the displaced mass can move) within the rock mass forming the cliffs.

For slope-stability assessments, characterising the shaking in terms of KMAX is more representative than just using the accelerations measured from a single point at the cliff top (AMAX) (Fig. 3). Amplification ratios of peak ground acceleration (PGA) between the cliff crest and cliff toe were on average 2.0 (AMAX and AFF, respectively), and 1.5 (KMAX and AFF) for Port Hills slopes between 10 and 100 metres high and steeper than 60 degrees. That means the peak acceleration ('ground motions') experienced at the top of the slope could be two times greater than that at the bottom.

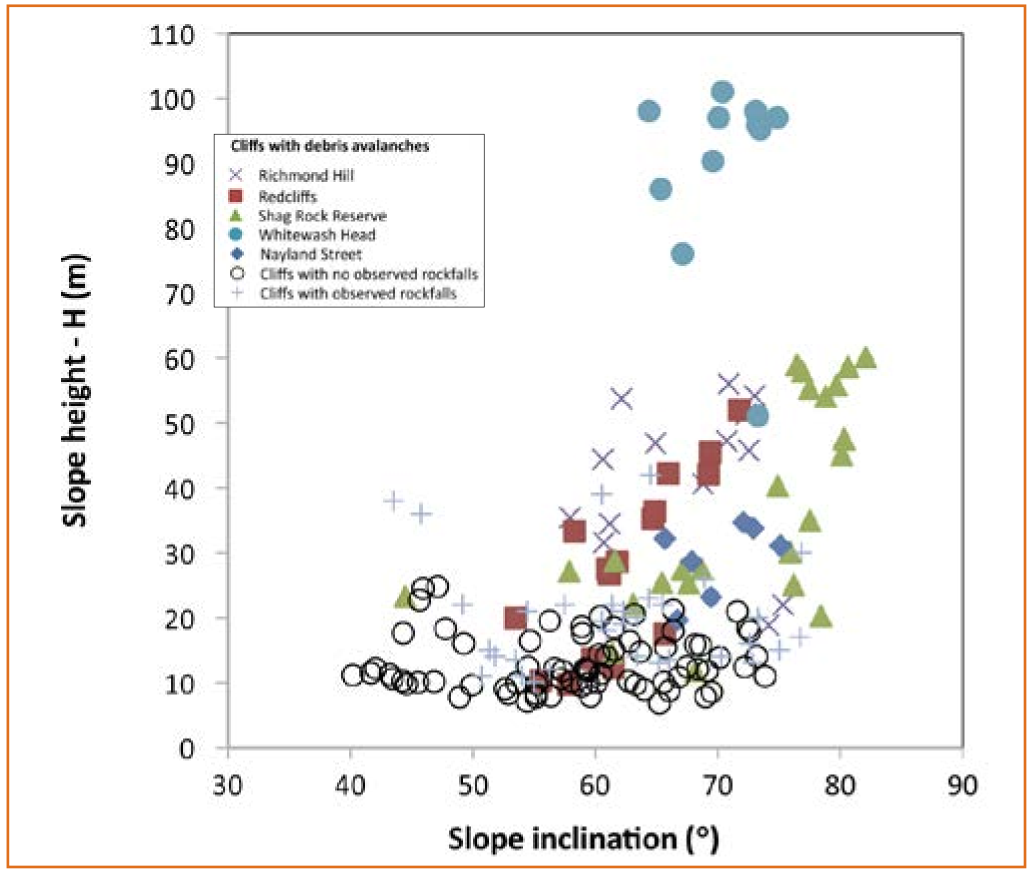

Figure 2. Relationships between slope height, inclination and extent of cliff-top cracking for cliffs in the Port Hills affected by the 2010/11 Canterbury earthquakes.

Thus, the well documented Port Hills case histories, involving site-specific assessments, can provide more certainty in seismic landslide assessments, in general. The results suggest that the ground motions used for assessing the stability of steep and tall cliffs in Christchurch (slopes greater than 60 degrees and more than 10 metres in height) should include an amplification factor to take into account the effects that slope shape and local geology have in amplifying shaking. However, for the design of structures located near the edge of steep slopes, the maximum acceleration at the slope crest (AMAX), may be a more useful parameter.

Preliminary assessment of field and model data from slopes in Wellington, taking into account the differences in earthquake sources, geology and topography in Wellington compared to those in the Port Hills, suggest similar results. That is, tall and steep slopes, contrasting geological materials and sharp breaks in slope cause measurable increases in ground accelerations compared to those at the slope toe. The magnitude of amplification is currently difficult to quantify in Wellington because there is very limited subsurface information available from the Wellington hill slopes, and so more work will be needed in this area. Our findings in the Port Hills were used by regulatory authorities as one of the inputs to developing land zoning policy. The lessons from Christchurch are influencing decision-making across the country.

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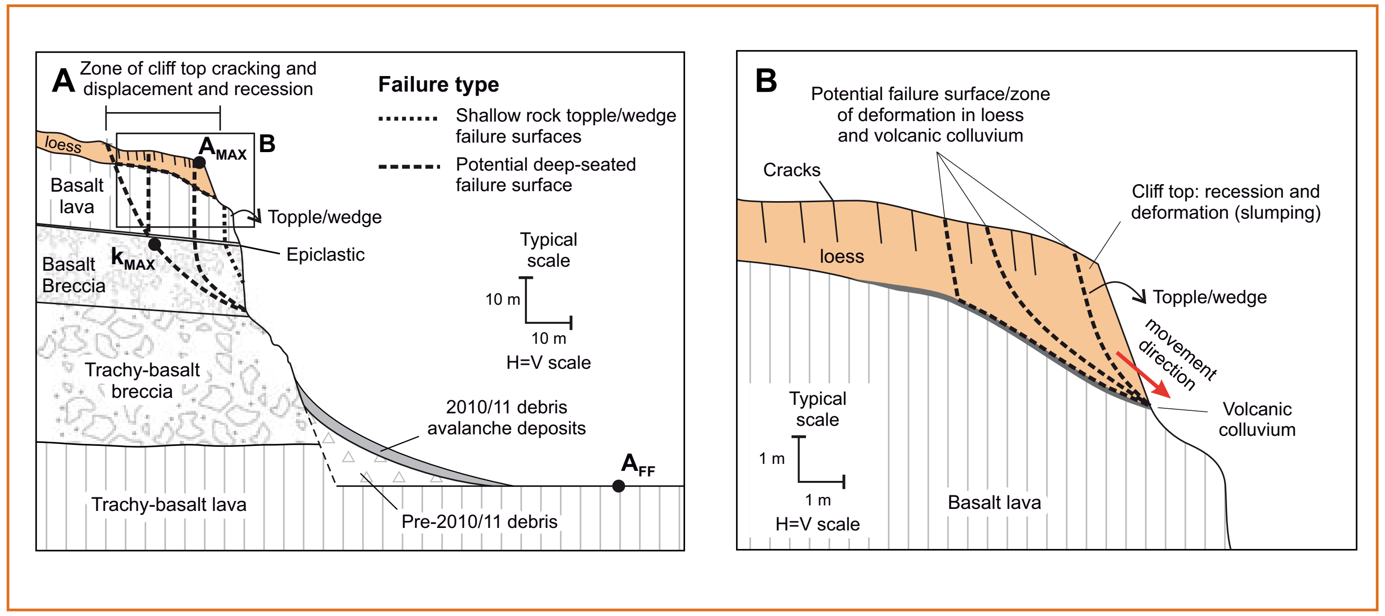

Figure 3 A-B. Schematic cliff failure modes in the Port Hills that occurred during the 2010/11 Canterbury earthquakes. Shown are locations corresponding to acceleration sampling points at the crest (AMAX) and free field (AFF), and average accelerations in the failure zone (KMAX).

Platform-funded Students

Lukáš Janků is studying towards a PhD in Engineering Geology at the University of Canterbury, co-supervised by Drs Marlène Villenueve (University of Canterbury) and Chris Massey (GNS Science).

Lukáš is part of the 'Quantifying seismic response of slopes...' team, contributing towards understanding the stability of hills around Wellington. With the installation of temporary seismic stations, quantification and numerical modelling can be undertaken to create 2D seismic models of the sites, while the seismic records can be used for calibration of the models.

Platform in the News

- **Researchers from Resilient Organisations invited to the '100 Resilient Cities Centennial Challenge' forum in New York.** Resilient Organisations researchers John Vargo and Erica Seville gave a presentation on 13 June to the Rockefeller Foundation. The Foundation launched the 100 Resilient Cities Centennial Challenge to enable 100 cities to improve their urban resilience over the next three years. Christchurch and Wellington are receiving support from the Rockefeller Foundation to create and implement a resilience plan. http://www.comsdev.canterbury.ac.nz/rss/news/?feed=news&articleId=1339
- **Radio NZ** interviewed Tony Bromley and Mike Revell (NIWA) on the joint NIWA-Opus Research project investigating wind speed over complex terrain. Their observations in the field and the **Opus Research Wind Tunnel** will contribute to how buildings are designed to withstand environmental factors. http://www.radionz.co.nz/national/programmes/afternoons/audio/2599123/measuring-wind-speed-across-complex-terrain
- **University of Canterbury engineers simulate large earthquakes to test low damage design.** Stefano Pampanin's research team simulated high magnitude earthquake shaking based on recent global earthquakes. Their simulation study included adding components of low damage design. http://www.nzherald.co.nz/technology/news/article.cfm?c_id=5&objectid=11226229

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Mitigating Wildfire Risk – The Role of Weather Prediction

Photo: Scion

The NIWA-Scion fire weather system (FWSYS) provides practitioners and emergency managers with information that alerts them to potentially dangerous conditions and provides access to information to understand fire risk in the rural landscape and how that risk is expected to change over time.

This new FWSYS builds on weather prediction research and tool development carried out in the Weather Hazards theme, and a strong collaboration with Scion.

Estimating Fire Risk: The New Zealand Fire Danger Rating System

The Fire Weather Index system uses observations of temperature, relative humidity, wind speed and rainfall to infer the effects of fuel moisture and weather on ignition potential and probable fire behaviour (Fig.1).

The five fire danger classes (Low to Extreme) that we see on the side of highways are the outcome of the Head Fire Intensity (HFI) predictor for each of three major land classifications: Forest, Scrub and Grassland. HFI indicates the intensity of the head of a fire, which takes account of rate of spread and land attributes acting as fuel. HFI can inform responders and/or decision-makers about the effectiveness of different types of suppression resources in containing a fire.

The FWSYS computes rate of spread and head fire intensity for each land cover class separately, and as an integrated product that takes account of land classification type. As an example for Grasslands, the FWSYS can take account of the initial spread index and the degree of grassland curing, a measure of the proportion of dead grass material present reflecting the stage of seasonal grass die-off.

The current fire danger class as well as the FWI codes and indices are calculated daily from data supplied

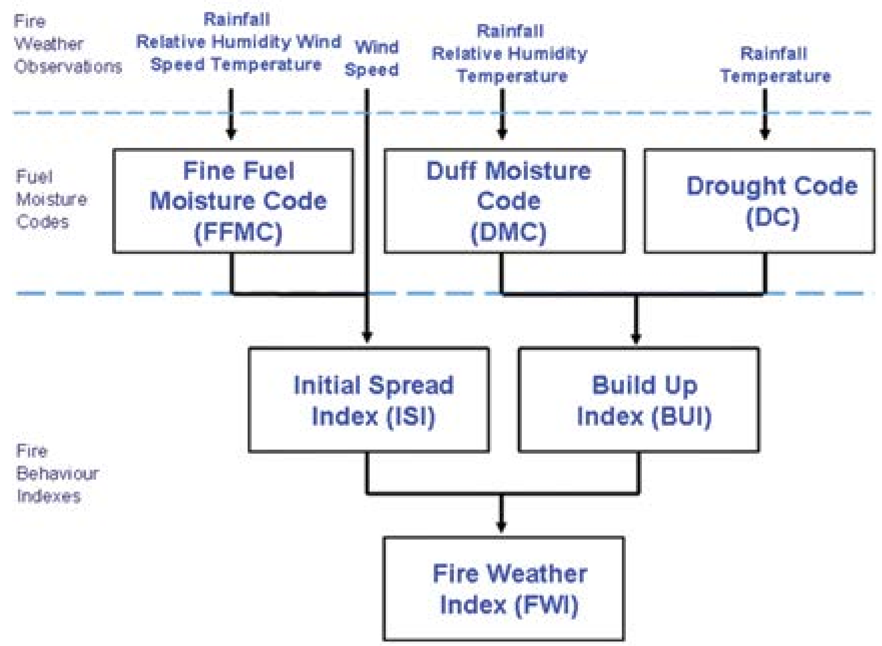

Figure 1. New Zealand Fire Weather Index (FWI) System: Four weather inputs, three fuel moisture codes and three fire behaviour indices. Higher code and index values indicate more severe fire potential.

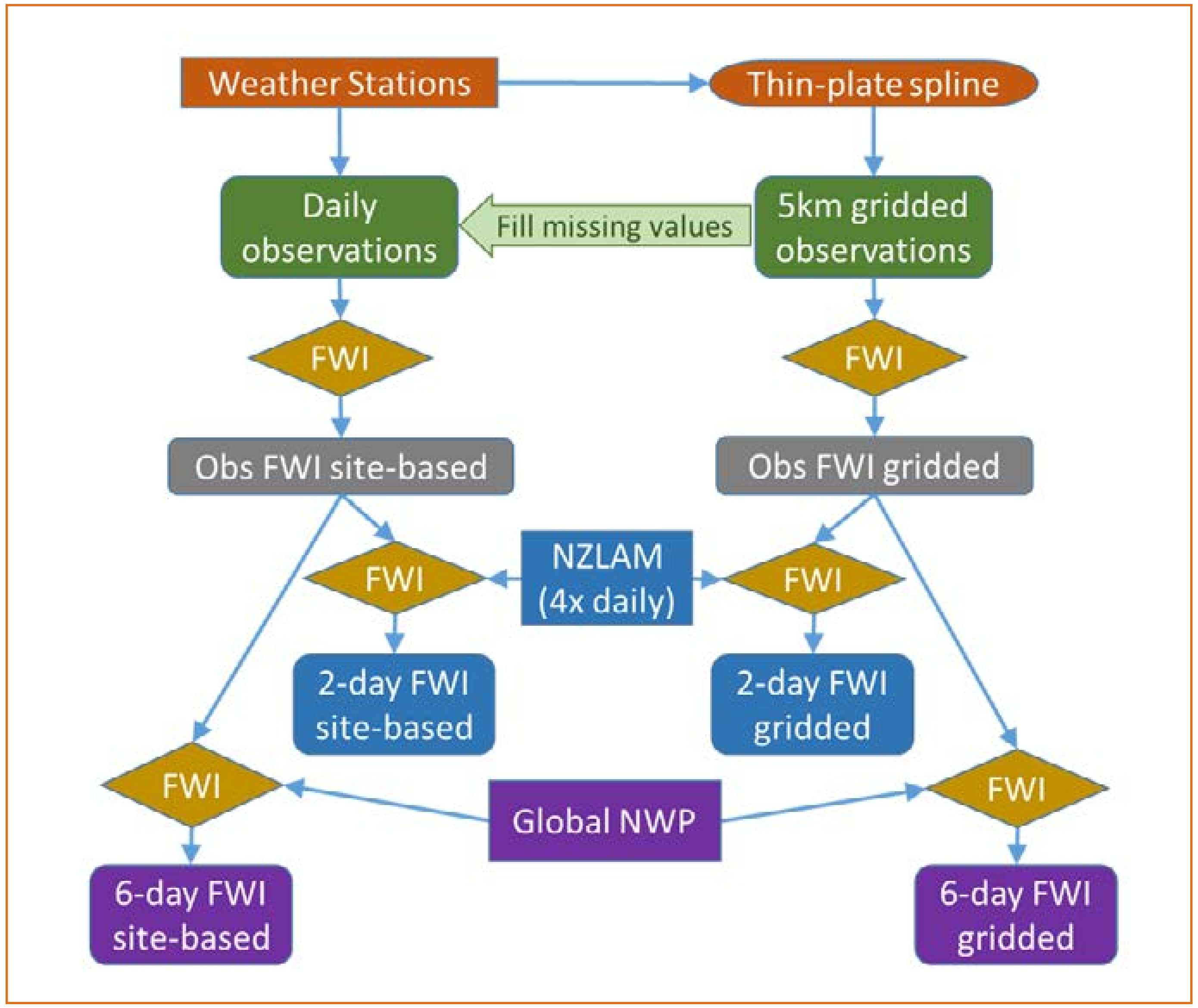

Figure 2. The implementation of the NZFDRS within EcoConnect. The diamonds containing "FWI" denote the system which generates the moisture codes, fire indices and danger classes from input weather variables.

from around 200 automatic weather stations spread across the country. Using geospatial processing techniques (thin-plate spline, above) these site-specific data are interpolated onto a 5 km grid that covers the whole country, allowing estimates of current fire danger to be provided for any location.

Forecasting the Future Risk

Using numerical weather prediction (NWP) models, forecasts of FWI codes and indices, and of Fire Danger Class can be estimated, up to six days ahead.

Two different NWP models lie behind these calculations: NZLAM (the New Zealand Limited Area Model) is used to provide a high spatial resolution (12 km) forecast of weather conditions out to two days ahead, then a global NWP model with 20 km spatial resolution, to extend the forecast conditions out to six days ahead (Fig. 2). The NZLAM-based fire danger forecasts are expected to be the most accurate over the first 2 days, and then the Global model based forecasts for the following 4 days.

Figure 3 shows example forecasts of national Fire Danger Class. Figs. 3a-c show the observed values for the days of 7,9,11 February 2015 ; Figs. 3d-e show the forecast Fire Danger Class

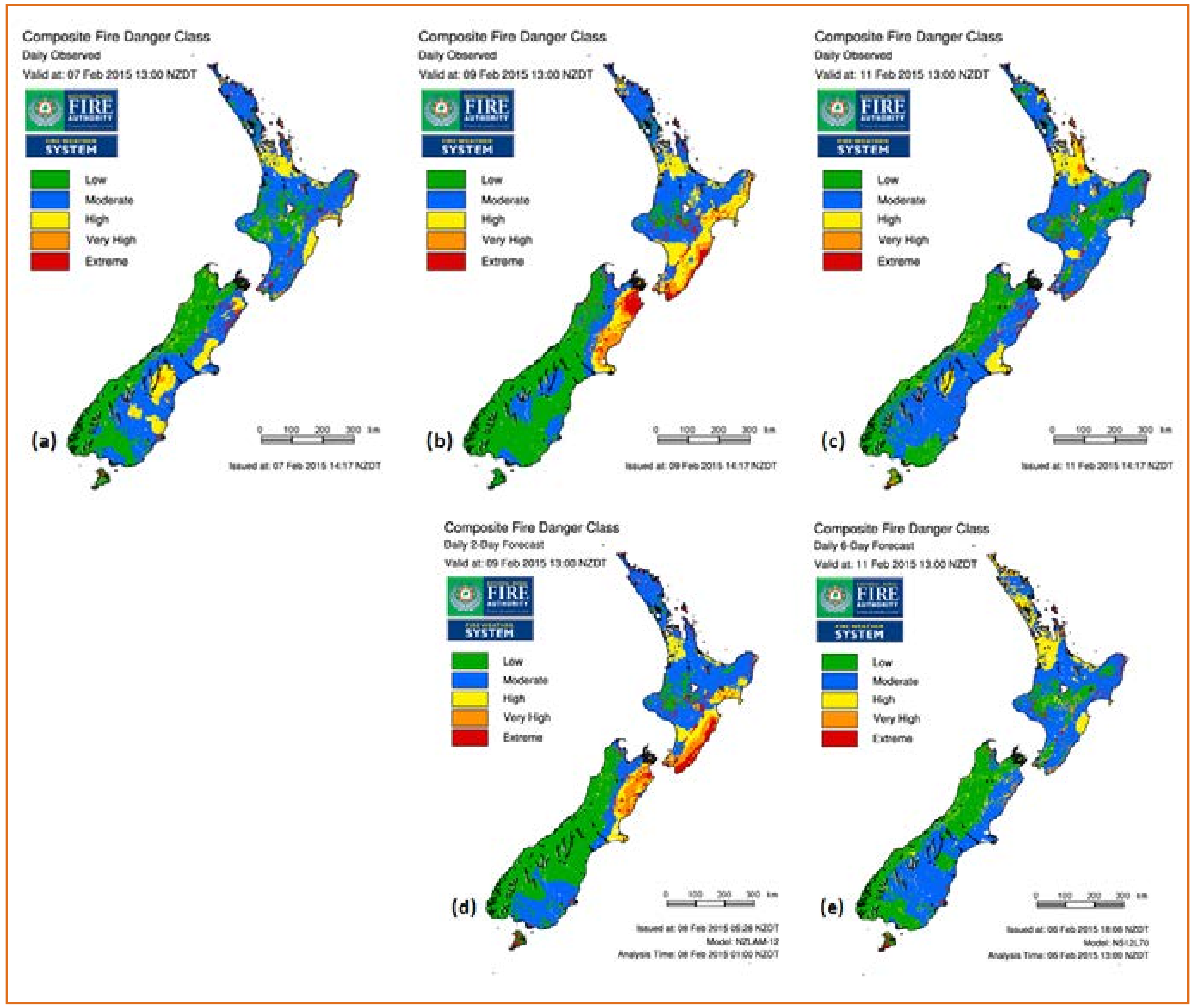

Figure 3. Observed Fire Danger Classes for (a) 07-Feb-2015, (b) 09-Feb-2015 and (c) 11-Feb-2015 as derived from the Remote Automatic Weather (RAWS) network, and forecast Fire Danger Classes for (d) 09-Feb-2015 and (e) 11-Feb-2015 from forecasts initiated on the 07-Feb-2015.

using forecasts initiated on the 7 February (and available to end users on that date). The forecast for 9 February (d) is based on a 2-day weather forecast from NZLAM, while that for 11 February (e) is based on a 4-day forecast from the Global model. Accordingly Fig. 3a-c show what actually happened, and Fig. 3d-e show the forecast fire danger class up to 4-days ahead. The forecast and actual fire danger classes are encouragingly similar, demonstrating the value of the forecast data to mitigate fire risk through management decisions in advance of days with forecast high (or low) fire danger.

Decision Tool

Using the EcoConnect FWSYS PC application, users can access a large range of information to monitor fire weather conditions, determine when to carry out fire prevention publicity efforts, set fire season restrictions, decide whether to issue burning permits, and set readiness levels for fire suppression resources.

The new FWSYS is flexible and automatically leverages advances in publicly funded research on increasingly more accurate weather prediction models. This will lead to even greater accuracy of both current and forecasted fire danger estimates in future.

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Volcanic Activity

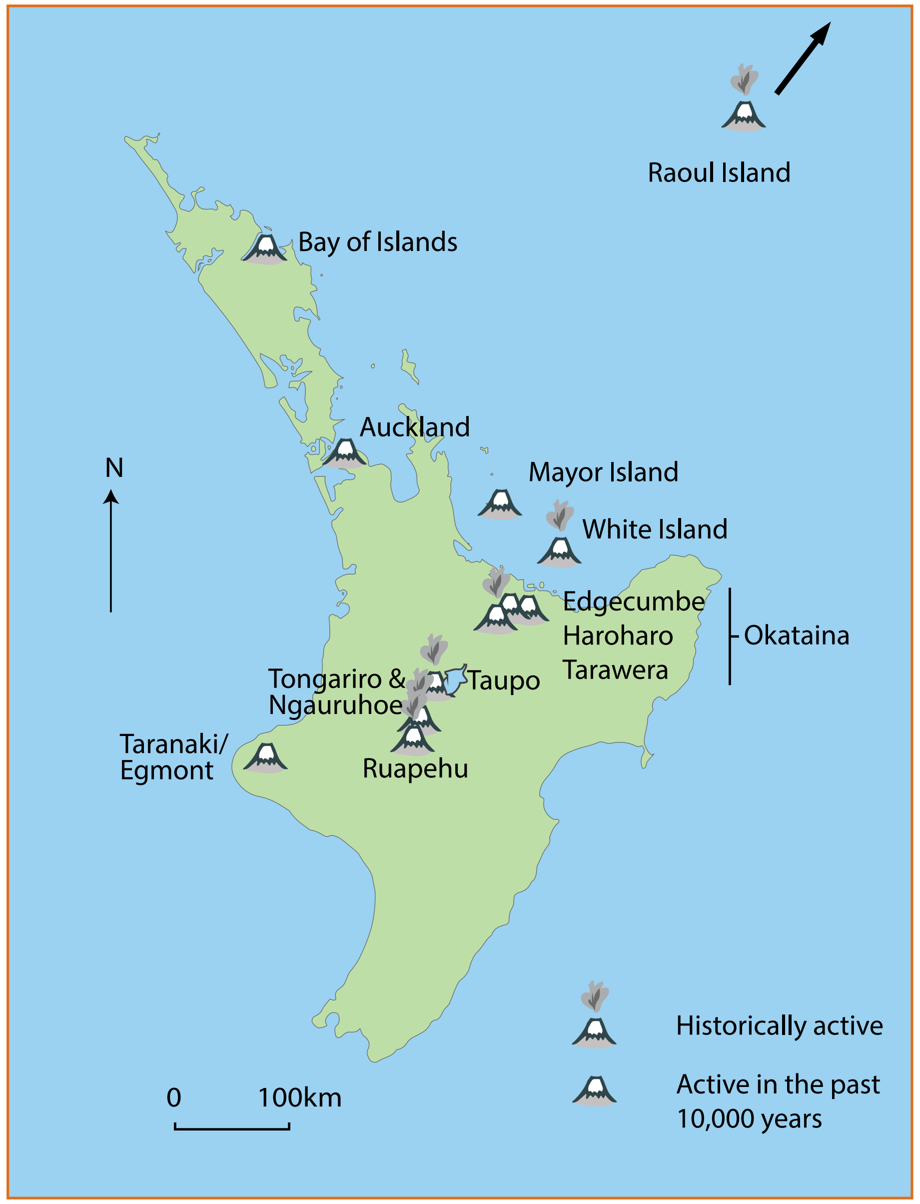
In contrast with 2012 and 2013, which were busy years with eruptions at Tongariro and White Island, 2014 was on the quiet side, with no eruptions to report.

In early December, Ruapehu Crater Lake cooled down and reached a minimum of 15 degrees C before heating up again, as it has many times before.

Tongariro was very quiet, with very little seismic activity and a general decline of gas emissions and fumarole temperature at the Te Maari vent.

Except for a short swarm of earthquakes in August, activity at White Island also remained at a low level, allowing monitoring work to be carried out at the crater floor, and 3-monthly crater floor surveys and crater lake sampling to resume. We also took the opportunity to increase the level of continuous monitoring on the island with the installation of an additional webcam on the western crater rim, providing unprecedented views of the crater floor to everyone, and of a GPS station near the factory, in the crater floor. Several remote sensing technologies were also tested to measure gas concentrations in the plume from a distance (laser diode, FTIR).

2014 also marked a change in the New Zealand Volcanic Alert Level (VAL) system. This system is used by GNS scientists to characterise and convey the level of activity at New Zealand volcanoes to the authorities, stakeholders and general public. Changes in the new system include having just one system for all New Zealand volcanoes, restructuring the system with an additional level for 'moderate to heightened volcanic unrest' (instead of just one level for all volcanic unrest), and adding information about the most likely hazards accompanying each level of activity.



Data: GeoNet

Landslide Activity

GNS Science recorded over 500 landslides in 2014, some of which damaged roads, houses and other infrastructure. The majority of these landslides followed heavy rainfall, however a significant earthquake near Eketahuna triggered about 100 landslides. There was one fatality and a near-miss incident as a result of rockfall.

Significant rainstorms that triggered landslides occurred in Christchurch in March, over much of the North Island in April, and in Northland in July.

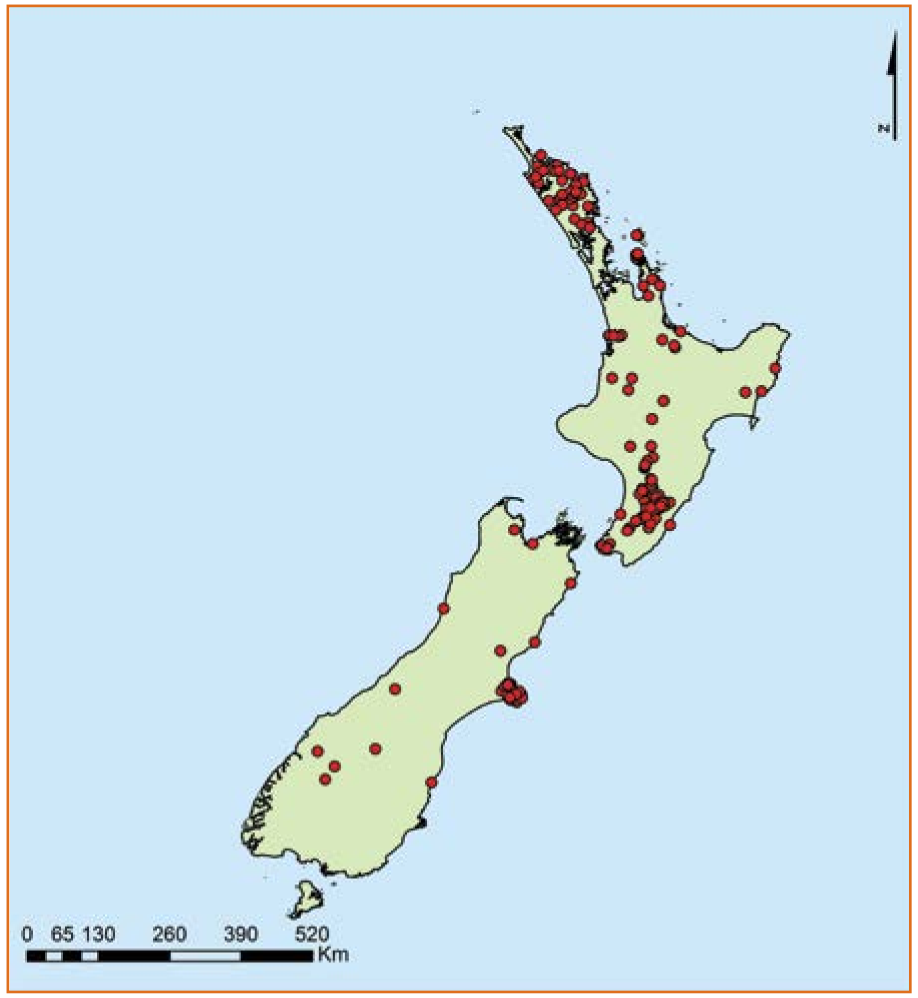
On 6 January a landslide on Tarewa Road, Gisborne, severed the water pipe that feeds Gisborne's main water supply. The Gisborne district was faced with a water supply crisis for four days while the landslide was stabilised and the pipeline repaired.

On 20 January, the M6.2 Eketahuna earthquake triggered landslides and rockfalls, with several large landslides on the eastern Puketoi foothills. Rockfalls were reported from as far away as Parapara Road, Wanganui, and on the Rangitikei River cliffs at Mangaweka.

Heavy rain on 4-5 March caused a moderate-sized slip in Lyttleton (about 2,000 cubic metres), which damaged a house and a fuel tank below, and forced the evacuation of 19 houses while the stability of the hillside was assessed. The same storm caused several slips on Wellington's south coast.

On 16-18 April, ex-tropical Cyclone Ita brought heavy rain throughout New Zealand. Many roads were closed or affected by landslides from the Bay of Plenty to Marlborough.

On 23 May, heavy rain caused an 8,000 cubic metres slip on SH 73 near Arthur's Pass, closing the popular tourist route for four days.



Significant landslide events across New Zealand

On 10 June extreme rainfall in the northern part of Coromandel triggered debris flows, resulting in damage of more than $1 million to roads and infrastructure. The same storm also triggered landslides on Great Barrier Island and in Northland, Waikato, Bay of Plenty, Gisborne, Wairarapa, and North Canterbury regions.

In Northland, heavy rain from 8-14 July caused widespread flooding and landslides, including a washout near Kawakawa that closed SH1 for seven days. On 19-20 July a second period of heavy rain struck the Far North and caused further damage.

On 15 July, a large rock avalanche on Mount Cook/Aoraki engulfed a climber's hut. A section of the South (Hillary) Ridge collapsed and swept across the Hooker Valley, nearly taking out Gardiner Hut. The 900,000 cubic metre rock avalanche was the third rock avalanche to hit the area in the last 18 months.

In September, a slow-moving landslide on Hill Rd, Gisborne, damaged a house and put two further houses under threat. The three houses were evacuated by the Council.

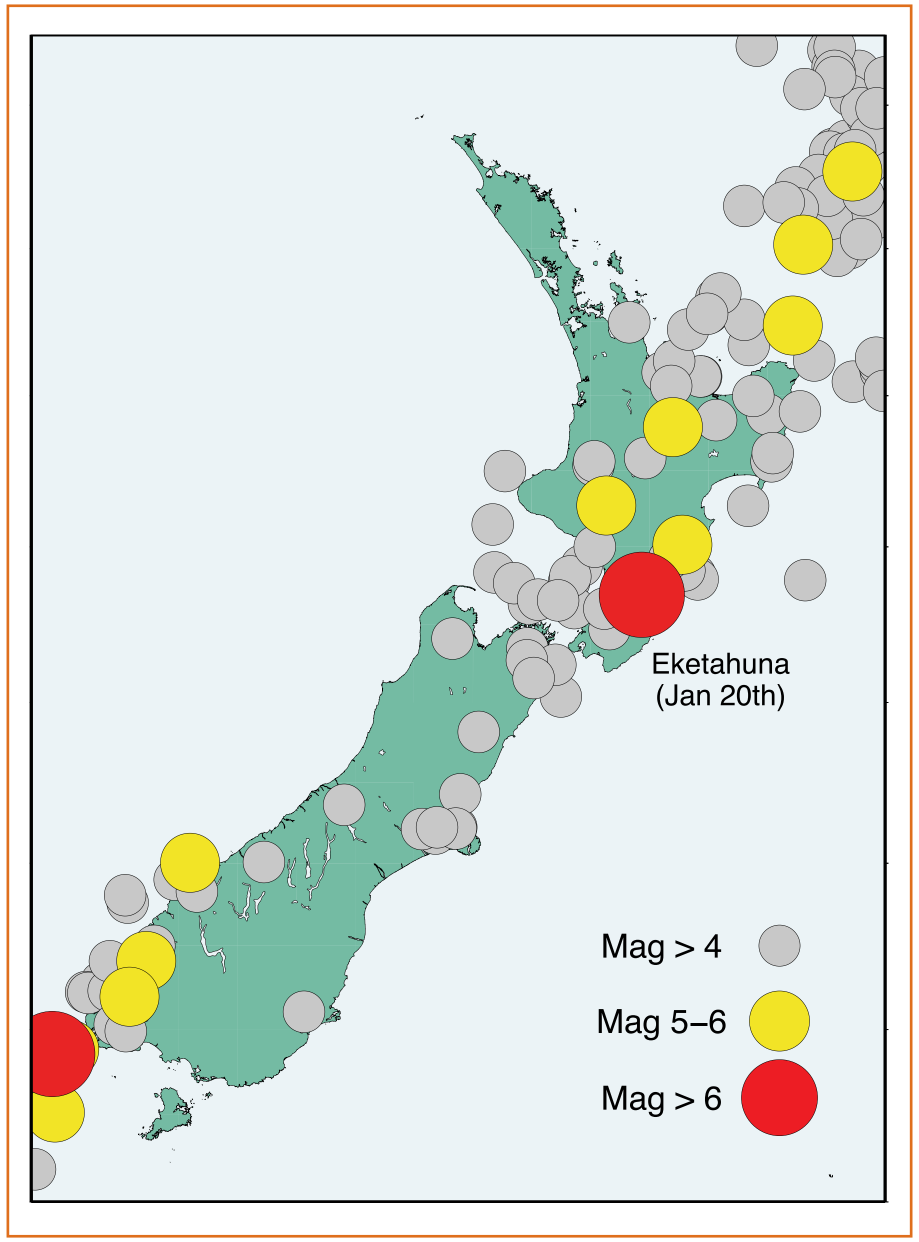
Data: GeoNet

Earthquake Activity

The most significant earthquake of the year was the M6.2 Eketahuna earthquake of 20 January. It was centred 14 km east of Eketahuna and was 34 km deep inside the crust of the subducting Pacific Plate. This was the most widely felt earthquake of the year and the only one to register any reports of heavy damage, attracting 9,448 'felt it' reports on the GeoNet website.There were more than 4,600 aftershocks, with 18 of those greater than magnitude 4 and two over magnitude 5.

Earthquakes greater than magnitude 5.0 occurred in the central North Island on 31 March (centred near Waipukurau), 6 June (near Ohakune), 23 September (northeast of Eketahuna, near Pahiatua) and 6 October (near Murupara). The Ohakune quake was the second most widely felt of the year, with 5,887 'felt it' reports on the GeoNet website, although most (5,167) reported it as 'light'. It was 106 km deep and was a magnitude 5.1. On 23 May and 20 October, quakes of just over magnitude 5.0 occurred in Fiordland. Both were centred within 50 km of Te Anau but only a single "strong" report was registered on the GeoNet site. The 23 May shake, which was 80 km deep, attracted just seven "moderate" reports to GeoNet. On 20 October, the 134 km-deep quake was reported "moderate" by three and "light" by 308. A magnitude 6.5 quake on 17 November had only six "strong" reports and 62 "moderate", but did get 2,648 'light' reports. It was centred about 220 km northeast of Gisborne and was about 32 km deep.

"Slow slip" earthquakes are recognised to be occurring along the Hikurangi subduction zone, and are



usually identified by examination of the continuous GPS data recorded by GeoNet. These "slow slip" earthquakes usually occur over weeks to months, rather than in seconds, and are not felt by people. In September 2014 there was a Magnitude 6.8 slow slip event off the Gisborne coast, which occurred over two weeks and which was successfully 'captured' by recording instruments onshore, as well as by ocean-bottom research seismometers on the seafloor off Gisborne. These offshore seismometers were placed there as part of an international research project "Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) to capture the slow slip, in order to improve our understanding of this phenomena.

Data: GeoNet

Platform-funded Students

Vicki Johnson recently completed her doctorate at Massey University, Wellington, supported by GNS Science and the Joint Centre for Disaster Research. Vicki's thesis, entitled "Evaluating Disaster Education Programs for Children,' aimed to generate new theories on how to evaluate the outcomes and societal impacts of disaster education programs for children. Based on the finding that few evaluations examined program theories, models were developed for two original evaluations of disaster education programs for children in the U.S. and New Zealand, which served as case studies. Vicki is now living in San Francisco with her husband and son, and is a Policy and Government Affairs Manager for the San Francisco Public Utilities Commission.

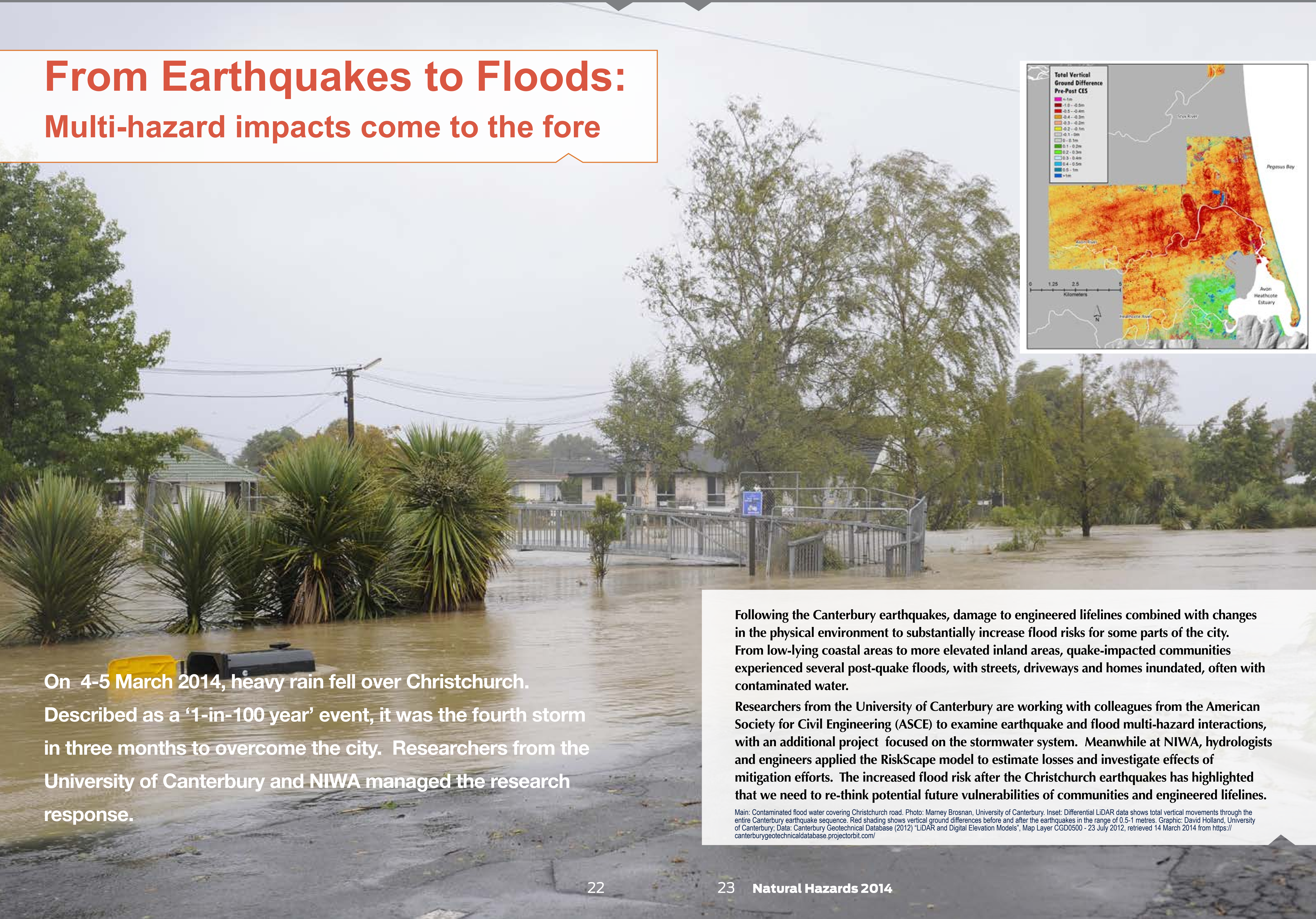
Platform Research Near You

- **Scientists map Auckland volcanic zone.** A new, geology-based approach has predicted just how susceptible various areas of Auckland are for explosive volcanic activity – with Three Kings and Māngere identified as potentially high-risk areas. The project team includes Gábor Kereszturi (Massey Univ), Jon Procter (Massey Univ), Shane Cronin (Univ Auckland), Mark Bebbington (Massey Univ), Mr Mike Tuhoy, Karoly Nemeth (Massey Univ) and Jan Lindsay (Univ Auckland). Link: http://www.massey.ac.nz/massey/about-massey/news/article.cfm?mnarticle_uuid=B0092F68-C296-2BA4-DE29-AAAC292CCCCB
- **NIWA** develops and tests a first generation flood-inundation model for the Karamea River.
- **A GNS Science study on tsunami risk in Napier has been incorporated into the region's hazards planning.** In work led by PhD student Stuart Fraser and GNS scientist William Power, earthquake and inundation scenarios, and vertical evacuation options were developed for Napier and incorporated into hazards planning by the Hawkes Bay Regional Council. Link: http://www.stuff.co.nz/dominion-post/10120115/Napier-centre-at-risk-of-tsunami.
- **'Resource Management Act, Emergency Management and Infrastructure Resilience.'** Wendy Saunders (GNS) and Roger Fairclough (National Infrastructure Unit) gave presentations on the topic in Nelson, Taranaki and Wellington.

For more news and updates visit our website at **www.naturalhazards.org.nz**

From Earthquakes to Floods:

Multi-hazard impacts come to the fore



On 4-5 March 2014, heavy rain fell over Christchurch. Described as a '1-in-100 year' event, it was the fourth storm in three months to overcome the city. Researchers from the University of Canterbury and NIWA managed the research response.

Following the Canterbury earthquakes, damage to engineered lifelines combined with changes in the physical environment to substantially increase flood risks for some parts of the city. From low-lying coastal areas to more elevated inland areas, quake-impacted communities experienced several post-quake floods, with streets, driveways and homes inundated, often with contaminated water.

Researchers from the University of Canterbury are working with colleagues from the American Society for Civil Engineering (ASCE) to examine earthquake and flood multi-hazard interactions, with an additional project focused on the stormwater system. Meanwhile at NIWA, hydrologists and engineers applied the RiskScape model to estimate losses and investigate effects of mitigation efforts. The increased flood risk after the Christchurch earthquakes has highlighted that we need to re-think potential future vulnerabilities of communities and engineered lifelines.

Main: Contaminated flood water covering Christchurch road. Photo: Marney Brosnan, University of Canterbury. Inset: Differential LiDAR data shows total vertical movements through the entire Canterbury earthquake sequence. Red shading shows vertical ground differences before and after the earthquakes in the range of 0.5-1 metres. Graphic: David Holland, University of Canterbury; Data: Canterbury Geotechnical Database (2012) "LiDAR and Digital Elevation Models", Map Layer CGD0500 - 23 July 2012, retrieved 14 March 2014 from https://canterburygeotechnicaldatabase.projectorbit.com/

Framework for Supporting Multi-Hazard Risk Assessment and Mitigation

Many strategies and policies for the mitigation of natural hazard risks consider the majority of hazards as discrete, isolated events. The 2011 Canterbury earthquakes and the Tohoku earthquake-tsunami sequence demonstrated a different reality. After any significant disaster, multi-hazard interactions and cascading effects may alter the risk to impacted communities from other hazards (Fig. 1).

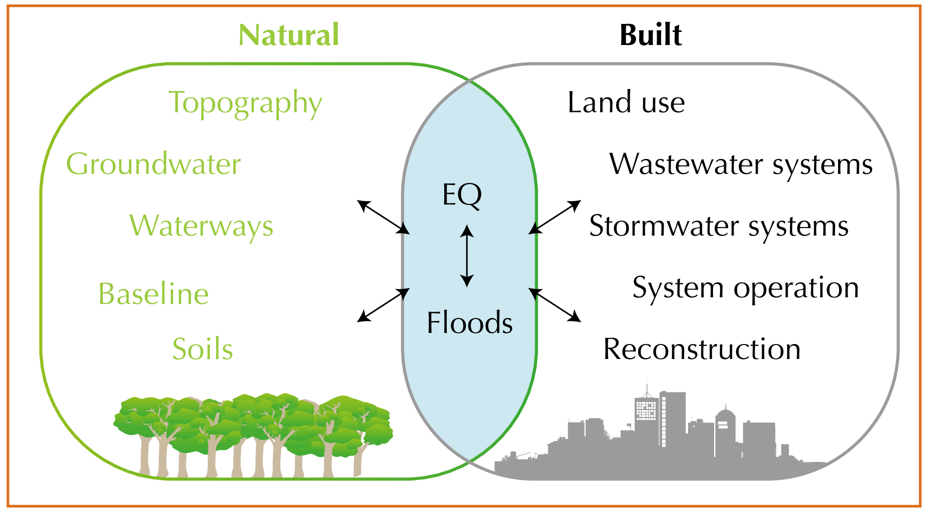


Figure 1. Components of the natural and built environment that could be affected by an earthquake and modify subsequent flood potential.

Thanks to initial support from the Natural Hazards Research Platform and co-funding by stakeholder agencies, a team of engineers and geographers is investigating these issues in New Zealand and Japan. A collaboration initiated in New Zealand in 2012 between the University of Canterbury (UC) and the Infrastructure Resilience Division (IRD), a technical group of the American Society of Civil Engineers (ASCE), and supported by Environment Canterbury,* is allowing us to develop a risk assessment framework applicable to the analysis, mitigation and management of complex multi-hazard scenarios, using earthquakes and floods as a case study.

Our aim for the framework is to create a matrix for the identification of earthquake-flood interactions and causative factors within an urban environment, followed by clarifying the needs and recommended approaches for investigating the identified earthquake-flood interactions.

Photo: Su Young Ko is a PhD candidate in in civil and natural resources engineering at the University of Canterbury

We have so far completed a comprehensive review of the current state of knowledge for urban environments, and identified the components of the natural and built environment that can be affected by and contribute to multi-hazard interactions and cascading effects for earthquake-flood scenarios. We have also developed a conceptual model representing the mechanisms that result in modification of different types of flood risks after an earthquake.

The main earthquake-flood interactions are summarized in the Tables (p. 26). For each one, there is a succinct explanation of the key changes to the natural and built environment brought about by the multi-hazard interactions, and the main factors influenced by cascading effects. Table 1 shows a list of all factors affected by each identified multi-hazard link; Table 2 illustrates an example related specifically to the "Topography-Groundwater" interaction.

Simplified conceptual diagrams summarizing the relationships are in development. Below is one such example representing the possible flood risk effects of two consequences of earthquakes: damage to buildings and damage to the stormwater system.

By Su Young Ko, Deirdre Hart, Tom Cochrane and Sonia Giovinazzi

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**The NZ team with Marion Gadsby (ECAN) investigated the 5 March flooding alongside the Geotechnical Extreme Events Reconnaissance (GEER) team. See our Report: http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Christchurch_Flood_2014/index.html.*

IRD was formerly the Technical Council on Lifeline Earthquake Engineering, TCLEE. The IRD team for this project is led by Dr. Craig Davis and Alex Tang.

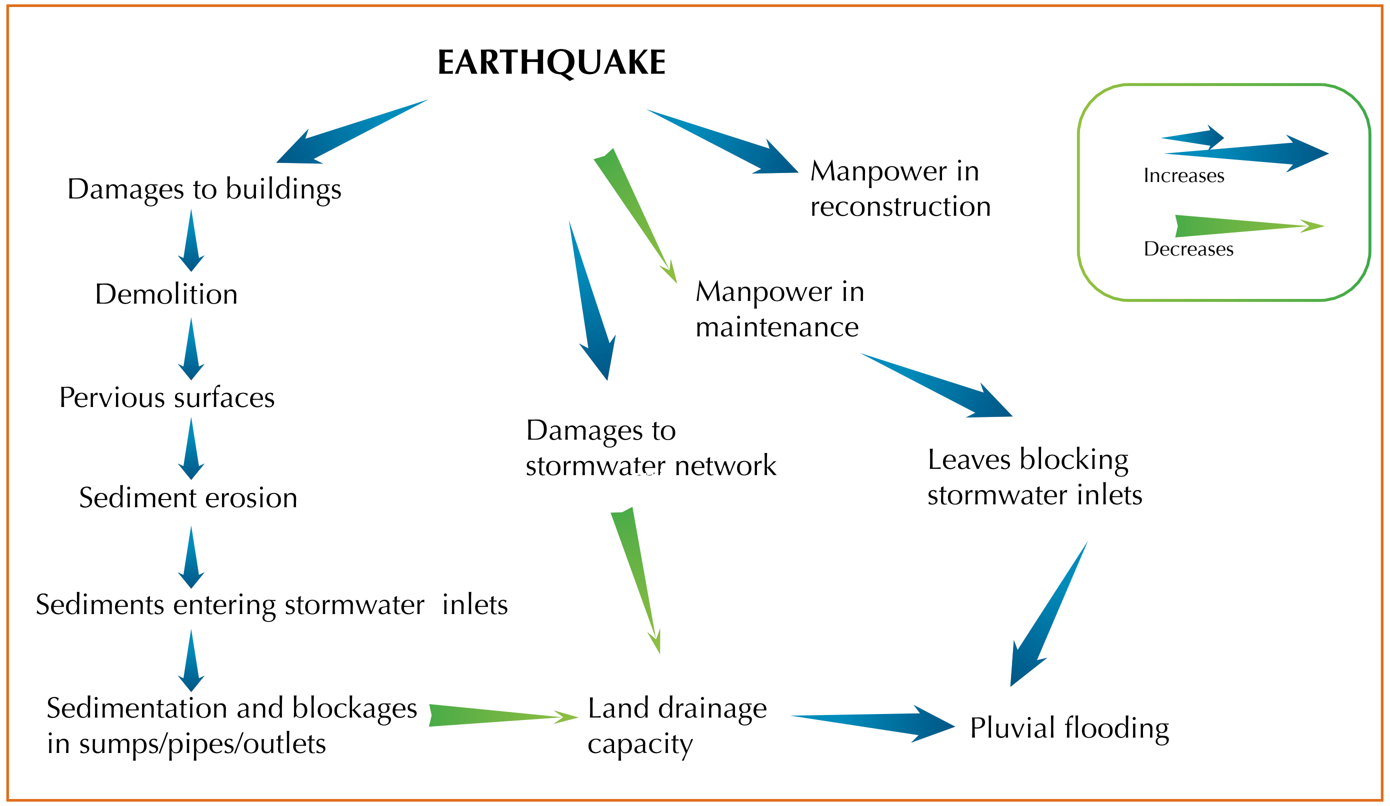


Figure 2. Sequence of cascading effects initiated by earthquake-induced damage to buildings and to the storm-water system that could possibly affect flood risk.

Main multi-hazard interactions	Exposed/Affected Factors	ID
A) Topography - Groundwater	Wetland characteristics	a1
	Stormwater retention basin capacity	a2
	Soil water storage capacity	a3
	Surface ponding from groundwater	a4
B) Topography - Stormwater (SW) System	SW catchment area	b1
	SW system capacity	b2
	Surface ponding from runoff	b3
C) Waterways/Open Channels - SW	Water storage capacity	c1
	Water transport capacity	c2
	Water transport capacity	c3
	Water transport capacity	c4
	Back water effect upstream	c5
D) Waterways/Open Channels - Ocean	Tidal influence	d1
E) Reconstruction - SW System	Infiltration	e1
	SW capacity	e2
F) Reconstruction - Groundwater	Soil water storage capacity	f1
G) SW System - Soils	Soil moisture and infiltration	g1
H) SW System - Groundwater	Groundwater table	h1
	Stormwater drainage capacity	h2
I) Wastewater System - Groundwater	Groundwater table	i1
L) Operational - SW System	Tree leaves and debris blocking	l1

Table 1. Main multi-hazard interactions between components of the natural (green) and built (blue) environments that could be simultaneously exposed to and/or causative factors for multi-hazard earthquake-flooding interactions and cascading effects.

A) Topography - Groundwater

Explanation on the main multi-hazard interaction	Key changes	Affected factors in relation to flooding
Changes in the vertical land elevation means the relative depth to the groundwater table is changed. Changes in hydrogeology (movement of groundwater) could mean surface flooding from groundwater or newly emerged springs. Previously existing springs could disappear.	Depth to ground-water table	Wetland characteristics **(a1)**
		Stormwater retention basin capacity **(a2)**
		Soil water storage capacity **(a3)**
	New springs	Surface ponding from groundwater **(a4)**

Table 2. Details on "Topography-Groundwater" interaction.

Earthquake-Flooding Multi-Hazards: Understanding the Stormwater System

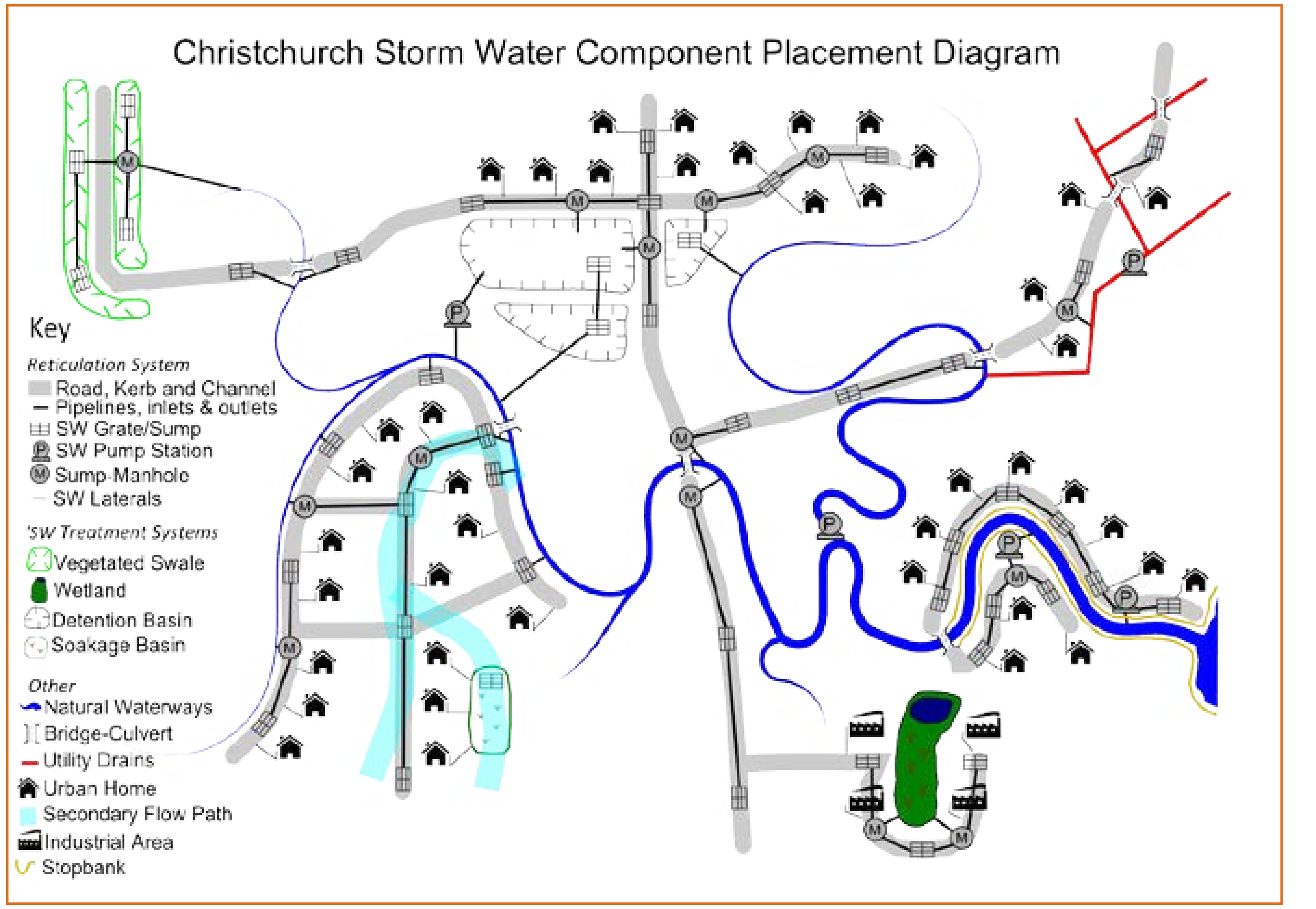
Earthquake-induced damage to potable water, wastewater, roading and other lifeline systems has been well documented following recent earthquakes worldwide, but there has been little research into understanding the effects on the stormwater system.

One reason might be that, while the importance of available drinking water and functioning wastewater post-event is clear, people may not be aware of the importance of assuring the correct level of stormwater protection.

Our research addresses how the seismic vulnerability of a stormwater system could affect post-earthquake flood risk.

Our aim is to help lifeline end-users understand and manage stormwater system multi-hazard impacts. End-users can adopt our methodology as a tool to help manage lifeline systems and further lifeline system resilience.

Understanding the system, its components and their purpose is crucial to recognising damage sustained post-event.



A stormwater system taxonomy was developed, and we designed a simplified stormwater system placement diagram. This links the components in the taxonomy to a simplified graphic representation. The role of each component can be viewed at a glance within the system. This is the first time this approach has been adopted in New Zealand. A combined taxonomy and layout diagram ensures a prompt and systematic model that can be clearly understood by the relevant end-users and stakeholders in the involved communities.

Currently, damage and changes to each system component are being assessed, with limited prior research in this area. Understanding the damage caused to each system component and documenting the findings using the taxonomy framework will markedly improve management of stormwater system multi-hazard resilience.

Using our methodology, stormwater asset managers will be able to identify data that are critical to collect and have on hand to facilitate pre-event mitigation strategies and post-event system assessment and recovery decision-making.

This taxonomy-based approach will aid in the identification of elements and/or areas in a stormwater system that could be vulnerable to flooding because of underlying interlinked environmental factors.The proposed format will provide a roadmap of possibilities for emergency management and asset managers and can be used to help inform communities nationwide.

By David Holland, Deirdre Hart and Sonia Giovinazzi

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Giovinazzi, Ko, Holland and team are grateful for the support and useful discussions with Canterbury CDEM, EQC, Christchurch City Council, Waimakariri District Council, Selwyn District Council, Environment Canterbury, Chorus, Orion, Contact Energy and the UC Quake Centre.

Photo: David Holland is pursuing his Master's of Engineering degree at the University of Canterbury

Using RiskScape to Evaluate Increased Flood Risk

Following the 4-5 March event, NIWA hydrologists set out to measure the floodwaters and map the worst-affected suburbs with the added help of 'citizen science.' Using local and social media, residents were asked to email photos they had of the flooding, especially peak water levels.

In the space of a few days, more than 600 photos were received and work began on refining a flood map of the event using some of the evidence provided by residents.

The first step was to establish the exact location of each photograph (many cameras and smartphones now record time and location information within the digital image files). Then the water level on relevant photographs was calculated. Often the water level could be determined (using position co-ordinates of the water's edge) from ground level information given by post-earthquake, airborne laser surveys. In locations where photos did not permit clear identification of water levels, field visits were carried out to make supplemental measurements. Information was collated from all photos, surveys and records of emergency callout locations and the resulting point data were interpolated to derive flood depth maps.

Once a flood hazard map was available, it was used in conjunction with the "RiskScape" model to calculate economic costs of the flooding.

Using the provisional flood maps, RiskScape forecast that homes in Mairehau would cost $1.28 million to repair, with $900,000 lost in content damage. When the cost of the clean-up was added in, the cost of house flooding in Mairehau totalled about $2.2 million.

Total subsidence*

200-400 mm at Mairehau
400-1000 mm at Burwood

Rainfall 4 March 2014

123 mm at Riccarton
153 mm at Lyttelton
*Total subsidence includes subsidence as a result of tectonic forces and liquefaction.

RiskScape can also be used to evaluate mitigation options. By using the RiskScape programme, floor levels could be artificially raised to see how much damage would be reduced. This is particularly useful for deciding on priorities for flood protection measures. In the Mairehau suburb, RiskScape predicted that if floor levels of the vulnerable buildings had been raised by only 10cm, the cost of house flooding would have been halved; if floor levels had been raised by up to 45cm there would have been no house-related flood damage.

Since the Canterbury earthquake sequence, more end-users have included RiskScape in their hazards mitigation programme. RiskScape is a joint venture between GNS Science and NIWA.

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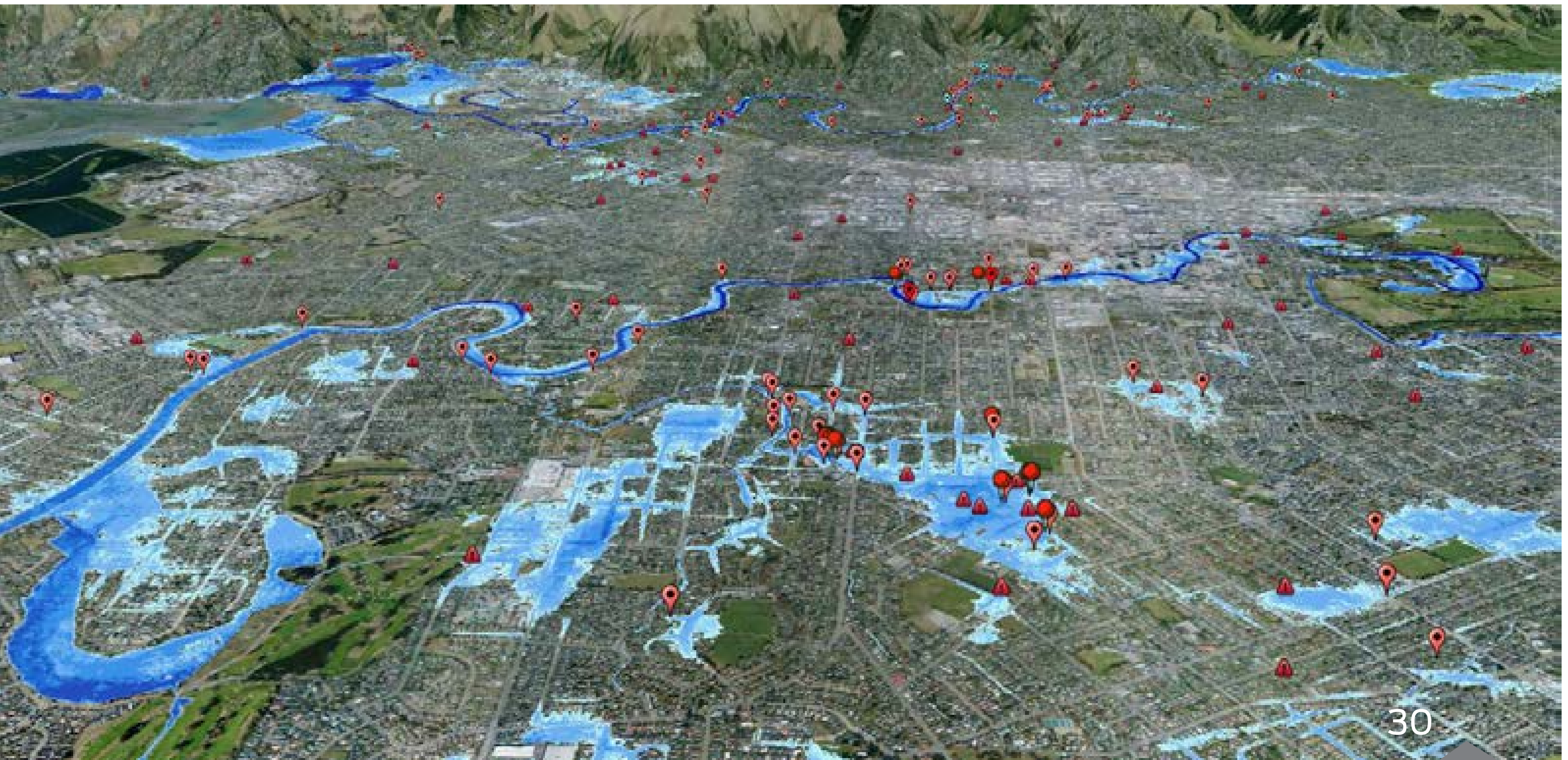
Left: NIWA hydrologists at work.

Christchurch under water: flooded areas shown in blue; emergency callouts and field measurement locations also shown. Note the darker the blue, the greater the flooding. Data: NIWA.

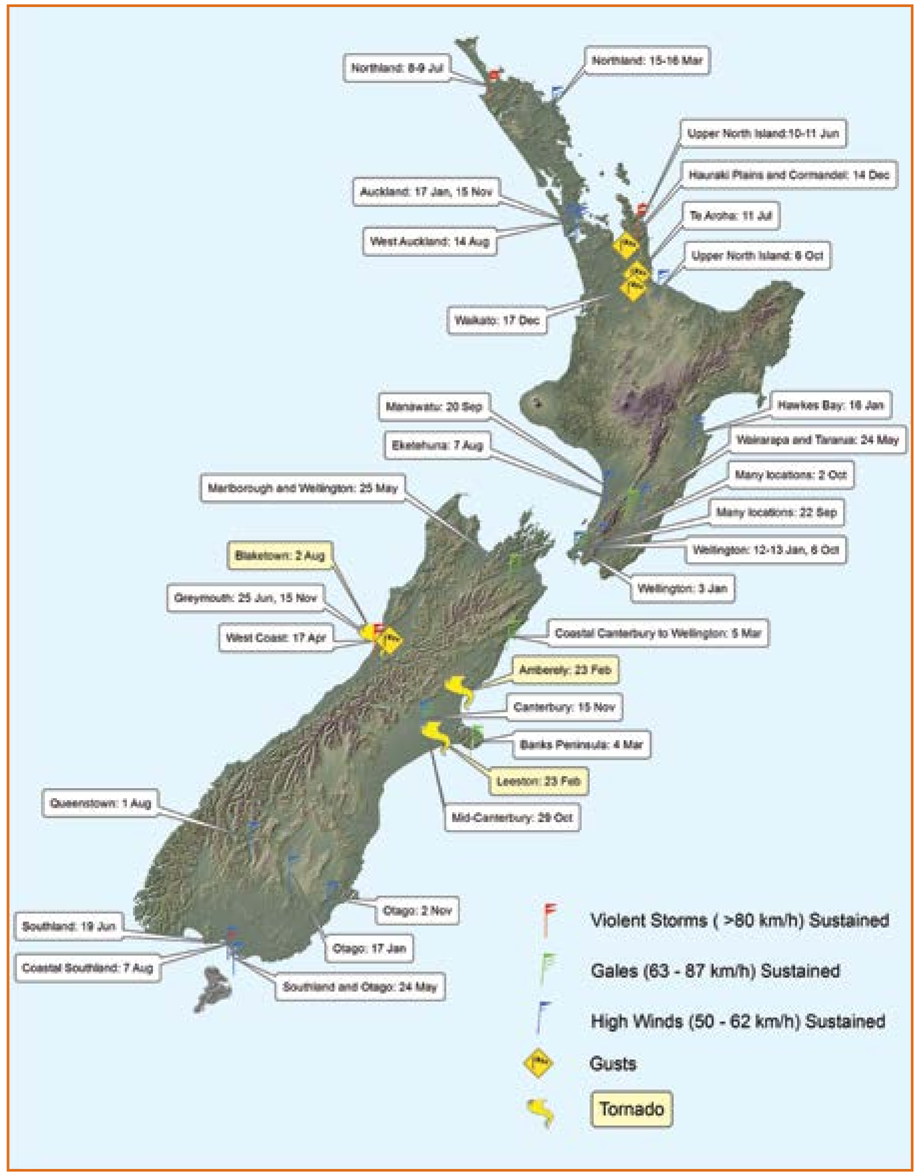


Wind and Tornadoes

Insured losses from extreme winds in 2014 totalled over NZ$130 million, a similar amount to that of 2013. Both years were the worst since 1968, the year of the Wahine storm. The bulk of the insured losses came from three violent storm events, the worst of which caused $55 million in losses on 17 April when ex-Tropical Cyclone Ita re-intensified rapidly as it tracked southward, west of the North Island. Eight stations recorded their highest ever wind-gust speeds on this day. On 10 and 11 June, very strong winds struck many parts of the upper North Island and power was lost to 90,000 Auckland homes ($38 million). On 8 and 9 July, damaging winds struck many parts of the upper North Island ($19 million) with widespread damage occurring in Northland; record gusts (122 kilometres per hour) occurred at Kaitaia during this storm. Damaging winds were reported for thirty-eight other days throughout the year.

There were only three tornadoes reported through 2014. Tornado events that lead to property damage were reported at Amberley on 23 February and at Greymouth on 2 August. A tornado was also spotted at Leeston on 23 February, but this did little damage. A waterspout moving ashore caused damage at Raumati South on 26 January.

The highest recorded wind gust was 217 kilometres per hour at Mt Potts on 6 October.



Overview of ex-Tropical Cyclone Ita

Former Tropical Cyclone (TC) Ita, which swept south through the Tasman Sea during April 2014, was among the most powerful storms of the past 100 years.

Ita was comparable in intensity to some of the most notable New Zealand storms: A great unnamed storm (also a former Tropical Cyclone) in February 1936 that did much damage in the North Island; the Wahine storm (former TC Giselle) of April 1968, and the Bola storm of March 1988. Bola was also a former Tropical Cyclone but was not as intense as Ita (central pressures near North Cape were around 980 hPa) and was very slow moving.

The greatest impacts from Ita were on the relatively sparsely populated West Coast. There it caused approximately $55 million in insured losses, mainly to houses in the Greymouth suburbs of Cobden and Blaketown. It also caused considerable (un-costed) damage to large tracts of native forest and conservation areas on the West Coast. In parts of the Buller region, foliage was stripped from trees, especially on the ranges inland from Karamea. Here, gusts of at least 170 kilometres per hour – equivalent to a Category 3 Tropical Cyclone (Australian Classification) – were estimated, and these were consistent with forecasts from NIWA's ultra-high resolution New Zealand Convective Scale Model (NZCSM).

Our ability, using the New Zealand Limited Area Model (NZLAM) to represent the atmospheric processes and latent heat exchanges with the sea-surface over a large area, is a pre-requisite to accurately forecast the re-intensification and development of this intense storm. The higher resolution offered by NZCSM is required to further capture the fine-scale topographic and mountain wave effects to accurately forecast the intensity and areas affected by the winds over land and offshore.

Figure 1 shows a surface pressure map with wind speeds 10 metres above ground level at 9 am on 17 April as forecast 3 hours ahead by NZLAM, and 36 hours ahead by NZCSM. The strength of the storm system is indicated by the low central pressures (< 970 hPa at 38°S) and the large area of surface wind speeds over the sea, which exceeded 100 kilometres per hour. The tight-spacing of the contours over the Southern Alps and the Arthur and Kahurangi ranges indicate that strong downslope winds were likely, and these certainly eventuated. The NZCSM forecast model captured the re-intensification and the details of the potentially damaging nature of Ita 36 hours ahead of time.

FACT BOX

A former tropical cyclone is a storm that originated as a cyclone in the tropics but which has migrated southwards and evolved into a mid-latitude cyclone.

In the tropics, the cyclone has a symmetric structure with a central 'eye' of mostly calm weather surrounded by an eyewall of more severe weather. It's main energy source is latent heat available from the warm seas.

As the storm moves southward over cooler waters, the main energy source becomes the latitudinal (i.e., north to south) gradient in temperature. The winds decrease in intensity (but can still be damaging) and spread out to cover a much larger area. The storm becomes asymmetric and loses its central eye.

Wind damage to Greymouth house during Tropical Cyclone Ita, 17 April 2014. Photo: NIWA.

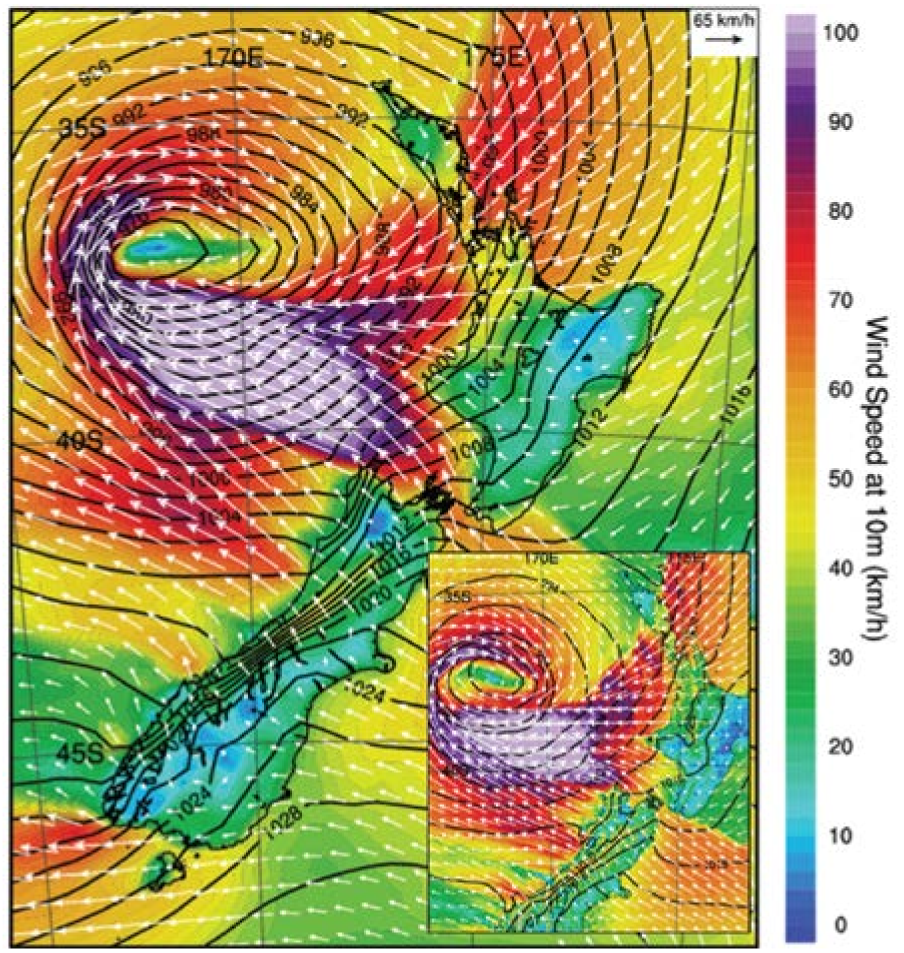


Figure 1. The situation at 9 am on 17 April 2014 as forecast by the mesoscale resolution (12 km grid) NZLAM model. The isobars are indicated as Black contours and have a spacing of 2 hPa, the 10 m (above the surface) wind speed as colour (Km/h) and the wind direction as arrows (the length of the arrow is also related to wind speed). The inset shows the 36 hour NZCSM forecast valid at this time.

Figure 2 shows the maximum daily wind speeds for 17 April at 133 metres above ground level, as forecast by NZCSM. Also shown are observed daily maximum gusts for available locations. Vertical cross-sections (i.e. through the atmosphere) from this model revealed that very strong amplitude wave motions caused by the strong easterly flow associated with the intense low-pressure would have been responsible for the very strong winds along the West Coast. They also explain why certain parts of the West Coast were worse affected by Ita than other parts. In addition, local effects of terrain, such as channelling through gaps in hills, would also have acted to produce even stronger localised gusts in places such as Blaketown.

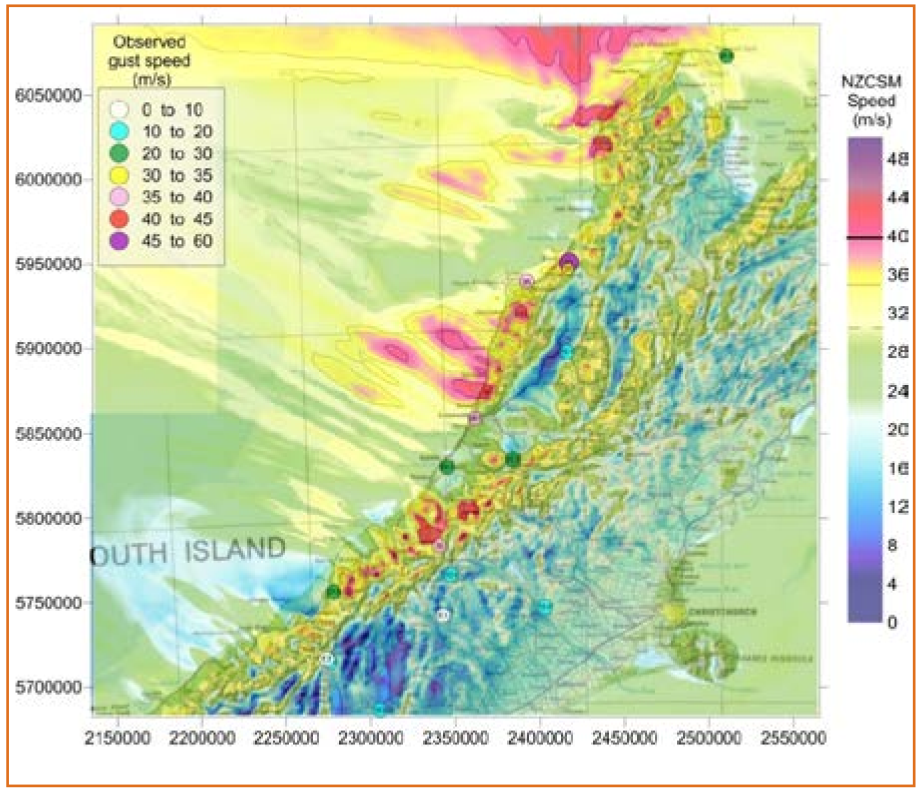


Figure 2. The maximum daily wind speeds for 17 April 2014 at 133 metres above ground level (which is an indicator of likely gust strength at the surface), as forecast by NIWA's NZCSM model, which uses a fine 1.5 km resolution grid spacing.

In July 2008, Greymouth experienced a severe downslope easterly storm that caused damage to houses mainly in the suburb of Cobden. On that day the peak gust at Greymouth Airport was 104 kilometres per hour, but for Ita the peak gust was 142 kilometres per hour. Much stronger gusts would have been likely in Cobden and Blaketown due to the channelling effect of the Grey River gorge.

NIWA conducted damage surveys for both events and found that the April 2014 event was much more severe, with over 150 damaged properties surveyed, compared with 75 in July 2008. Additionally, the more widespread nature of the damage following Ita meant that damaged properties in Westport, Karamea, or Whataroa were not able to be surveyed.

By Michael Uddstrom and Richard Turner

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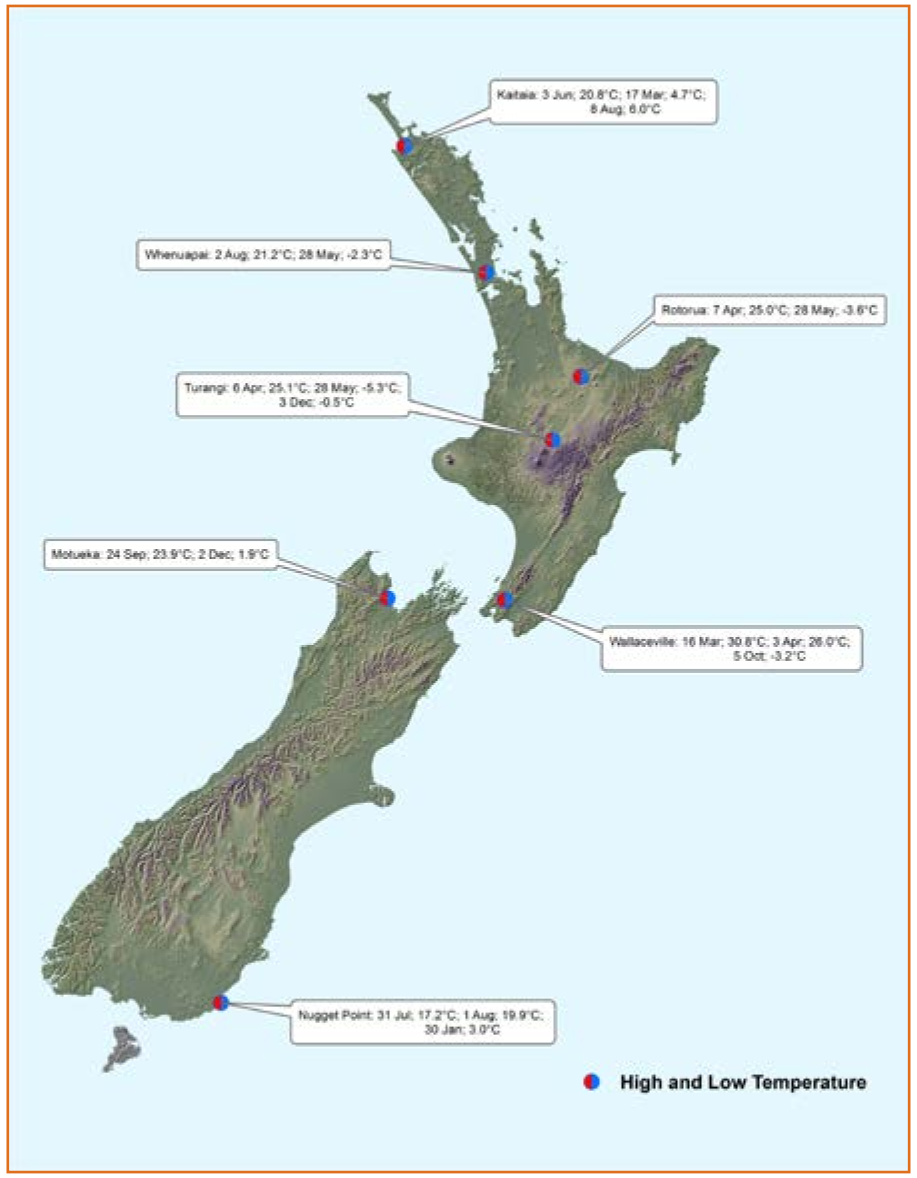
Temperature

Annual temperatures were near average across much of New Zealand in 2014, and extreme high or low temperatures were not especially prevalent. The nationwide average temperature was 12.8°C (0.2°C above the 1981-2010 annual average), using NIWA's seven-station temperature series which begins in 1909*. According to this series, 2014 was the equal-23rd-warmest year since 1909. 2014 had five 'warmer than average' months, two 'cooler than average' months, and five 'near average' months.

The highest mean annual temperature for 2014 was 16.1°C, recorded at Whangarei. The lowest mean annual temperature for 2014 (excluding high altitude alpine sites) was 7.9°C, recorded at Chateau Mt Ruapehu. The highest air temperature for 2014 was 35.7°C at Clyde on 20 February, and the lowest air temperature for the year was -9.8°C at Lake Tekapo on 17 July.

**These locations were chosen because they provide broad geographical coverage and long records (with measurements at all sites started by 1909).*

Source: NIWA's National Climate Centre Monthly and Annual Summaries.



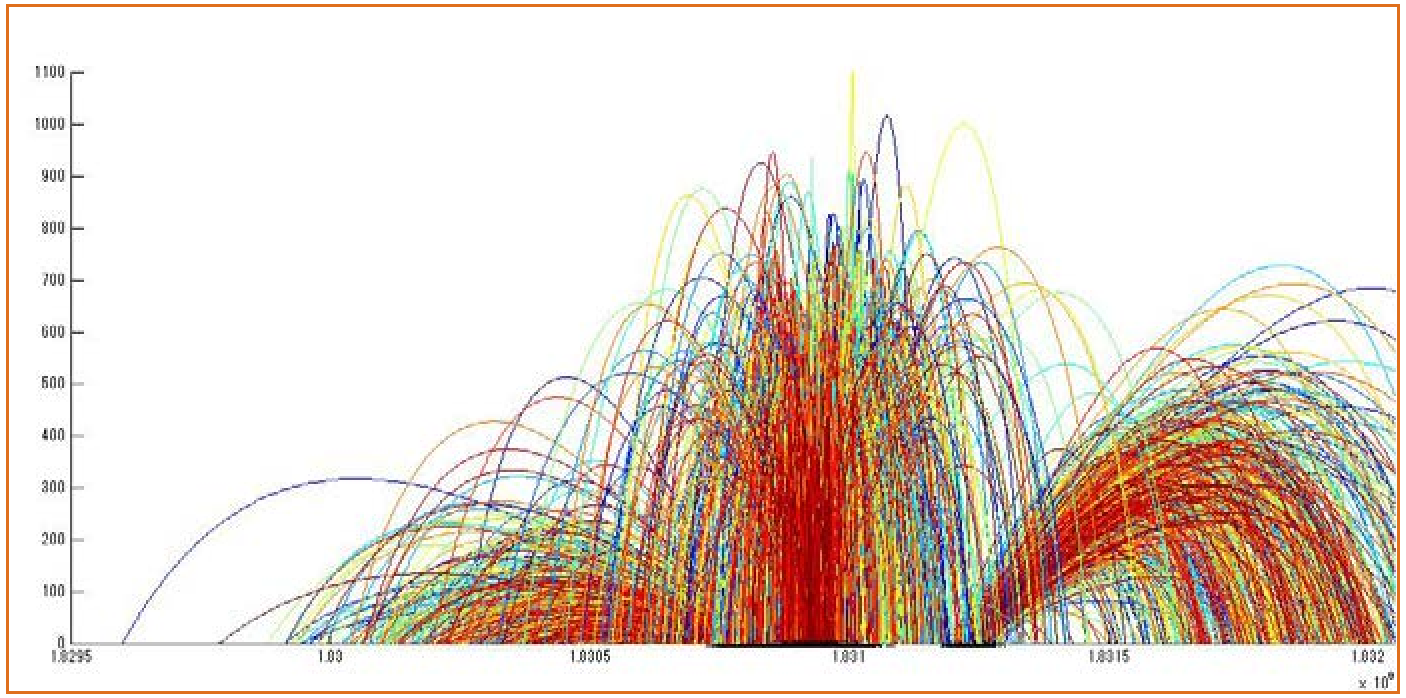
New Zealand's Volcanic Risk Research on the International Stage

The 27 September 2014 eruption of Ontake Volcano in Japan was a wake up call for scientists and emergency personnel faced with managing the risk posed by small, fast-onset volcanic eruptions. We were lucky in the 2012 Te Maari eruption that the event happened on a winter night when no one was using the Tongariro Alpine Crossing track or Ketetahi Hut. Both were impacted by ballistics (flying rocks) and pyroclastic density currents (PDCs) from the eruption. This kind of activity can potentially happen at any time from Ruapehu, Ngauruhoe and Tongariro, and Platform partners are working closely with the international science community to share and improve methods for volcanic risk management.

New Zealand is quite advanced in the calculation of life safety for staff and the public to inform decisions about safety distances during eruptions. The calculation was developed collaboratively between GNS Science and the Department of Conservation around the Te Maari eruption. It was published along with discussion of the wider multi-agency coordinated response in a paper in the 2014 special issue of the International Journal of Volcanology and Geothermal Research. The special issue was edited by Art Jolly (GNS Science) and Shane Cronin (Massey University), and includes papers on ballistics, PDCs, meteorological monitoring of ash, seismology, ash characterisation, impacts and the development of hazard maps.

Damage to Ketetahi Hut following the Tongariro eruption. Photo: Brad Scott, GNS Science.

A wide group of Platform partners produced a suite of maps before and during the 2012 eruption, and recognised that some things could have been done better. We are now helping lead a hazard map working group for the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), tasked with developing an international guideline for volcanic hazard



A ballistics trajectory model developed from the 2012 Tongariro eruption. Data: Rebecca Fitzgerald, University of Canterbury. https://www.youtube.com/watch?v=7SYwbEYemAU&feature=youtu.be

Laboratory simulations of pyroclastic density currents. Photo: Massey University

maps. The working group had its first workshop as part of the Cities on Volcanoes Conference in Yogyakarta, Indonesia in September 2014.

The University of Canterbury and GNS Science have initiated a PhD study by Rebecca Fitzgerald on ballistics linking the deposits from Ontake and Te Maari to computer models and calculations of life safety for improved hazard zones for future hazard maps. This will involve collaborative field work with scientists at Mount Ontake. Graham Leonard of GNS science was sponsored by the Geological Survey of Japan to present New Zealand and IAVCEI hazard mapping initiatives as part of a workshop on hazard risk reduction at the 3rd World Conference on Disaster Risk Reduction in Sendai (see Foreword).

There is also Platform effort around PDC models and PDC experiments underway that will also inform hazard map zones. This includes primary field research as part of the DEVORA project in Auckland, and simulating Ontake and Tongariro style PDCs on the pyroclastic flow machine at Massey University (above). The size of ballistic and flow hazard zones on hazard maps is a critical issue, which should be linked to acceptable life safety.

Finally, Platform partners have been working closely with the Global Volcano Model, to produce the first inclusion of an estimate of global volcanic risk in the United Nations UN-ISDR Global Assessment of Risk Report published in March 2015 (GAR 2015). New Zealand team expertise around the impacts of volcanic ash and strategies for collaborative risk reduction were used and highlighted in the report.

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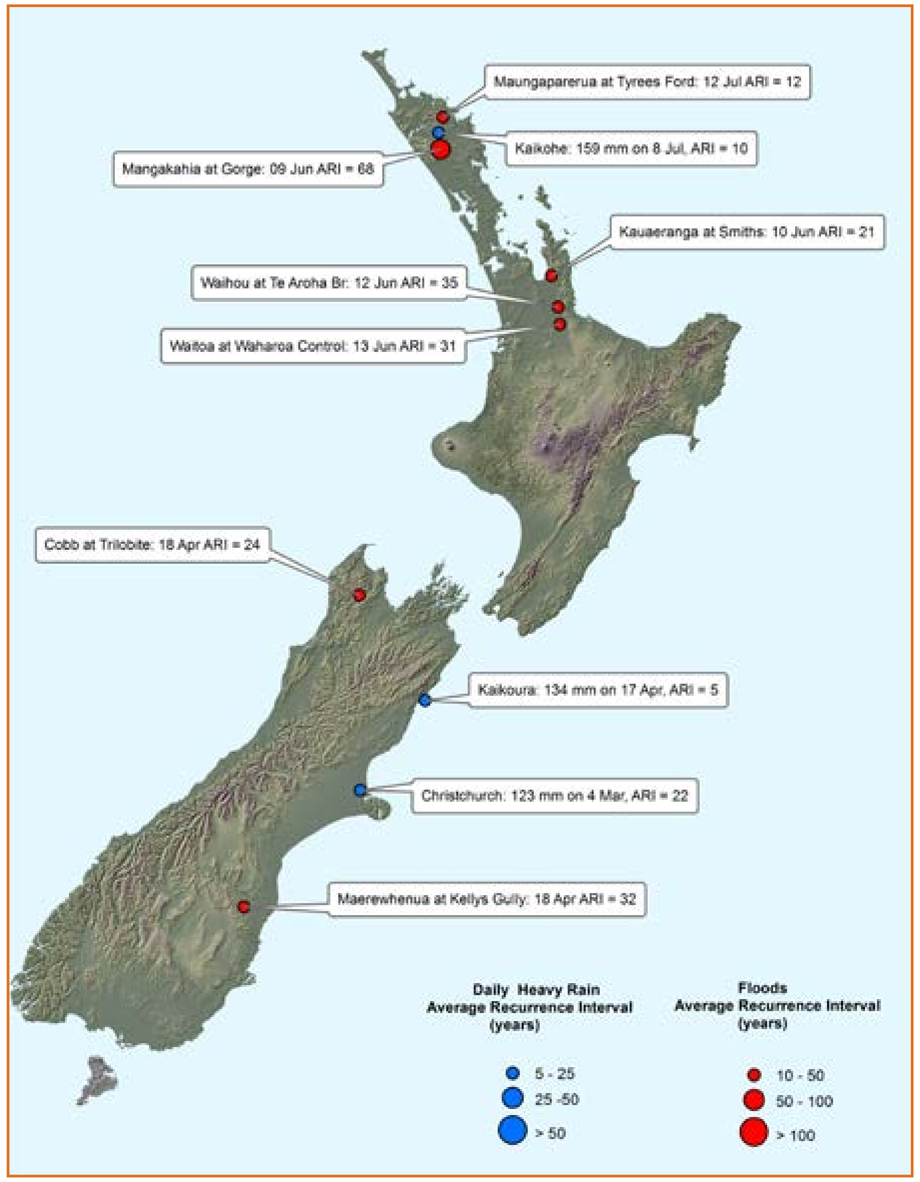
Heavy Rain and Flood

No location in New Zealand received record or near-record annual rainfall totals in 2014. However, some locations did receive record or near-record monthly rainfall totals. March and April were particularly wet in Christchurch: parts of the city recorded 71% of the average annual rainfall during those two months alone. In addition, it was Christchurch's wettest March and second-wettest April on record. Kaikohe received 586 mm of rain in July (311% of normal) which is the highest July rainfall total for this location.

On 4-5 March, heavy rain caused flooding throughout Christchurch and surrounding areas. Christchurch recorded its second-highest 1-day rainfall total (123 mm) since records began in 1873. At least 100 homes were inundated with water, and flooding caused road and school closures. Akaroa and Sumner were temporarily isolated.

On 10 June, flooding occurred throughout North Canterbury. Many schools were closed and a rest home was evacuated. SH 1 between Amberley and Waikuku was closed.

From 8 to 12 July, heavy rain fell in parts of the Far North, resulting in widespread surface flooding and road closures. Kaikohe recorded 328 mm of rainfall over three days: this has an average recurrence interval of 82 years.



Map shows single days with the highest rainfall.

Source: National Climate Database, High Intensity Rainfall Design System (HIRDS), and National Climate Centre Monthly and Annual Summaries (all NIWA).

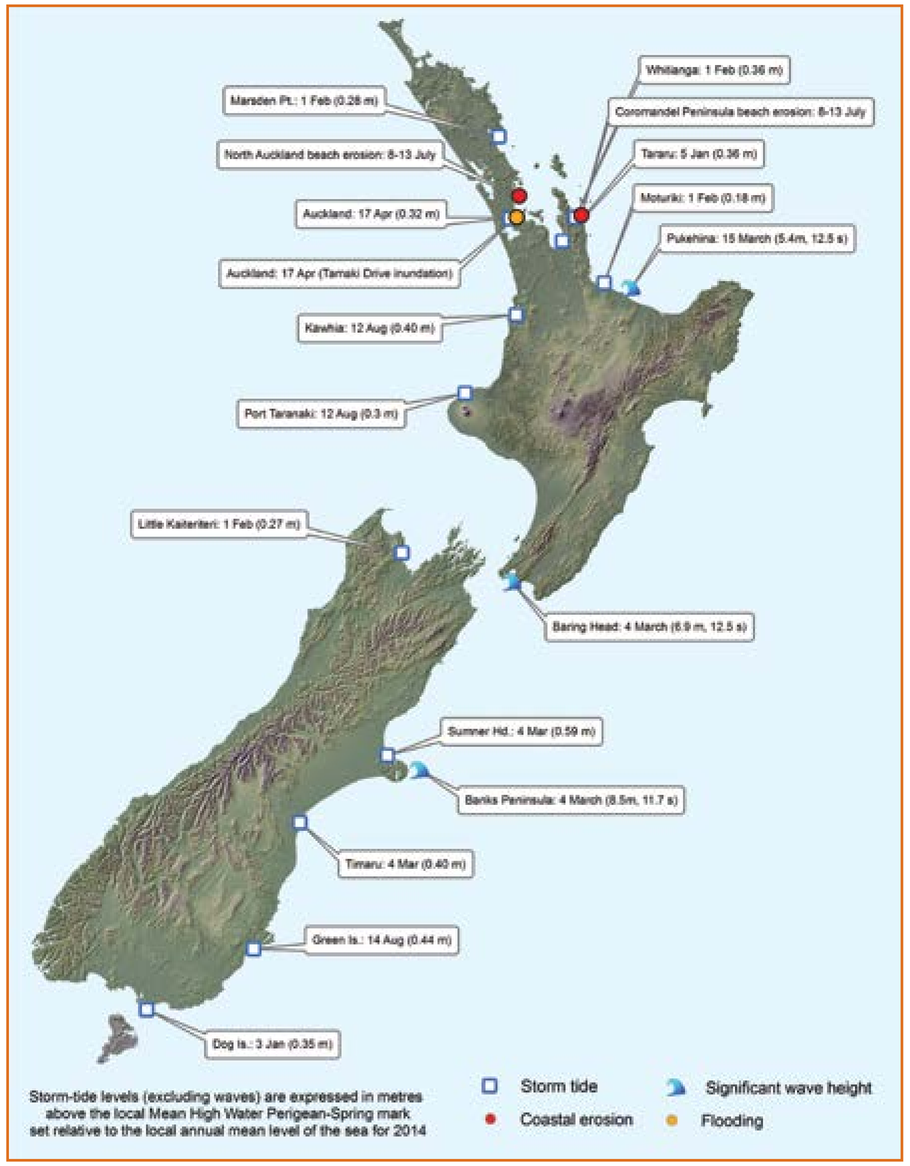
Coastal and Tsunami Hazards

Coastal Hazard - At both Banks Peninsula and Baring Head, the largest significant wave heights for 2014 were recorded on 4 March, with waves coming from the south west. The maximum individual wave height during that storm was 12.0 metres at both sites. However, a 17.5 metre wave was measured at Baring Head in another storm on 15 August.

The highest storm tide level of 0.59 metres was recorded at Sumner Head on 4 March, when a deep low to the east produced gale force southerlies and high rainfall caused flooding in Christchurch.

Most of the mapped, highest storm-tide events for 2014 coincided with a high perigean-spring tide (predicted by NIWA as a red-alert tide day*). This is not unusual in New Zealand, where typically modest storm surges mean that large storm-tide events usually require these higher tides. One exception occurred on 17 April when ex-Tropical Cyclone Ita generated a strong north-easterly airflow over New Zealand. The resulting storm-tide in Auckland (0.32 metres above mean high-water perigean spring) from wind set-up plus wave overtopping on a normal high tide caused substantial coastal inundation of Tamaki Drive and adjacent buildings.

Data sources: NIWA, Waikato Regional Council, Environment Canterbury, Port Taranaki, PrimePort (Timaru), Otago Regional Council, Ports of Auckland Ltd., Bay of Plenty Regional Council.*http://www.niwa.co.nz/our-science/coasts/tools-and-resources/tide-resources Caption: Map shows significant wave heights. During the 4 March storm, maximum wave height was 12 metres at Banks Peninsula and Baring Head.



Tsunami Hazard - There was only one notable tsunami event to affect New Zealand in 2014. The Mw 8.2 Iquique earthquake in Chile, South America on 1 April 2014 generated a tsunami with waves of up to 2.4 metres on the Chilean coast that propagated across the Pacific. The Geonet Tsunami Experts Panel issued an advisory for New Zealand coasts, and the possibility of strong or unusual currents.

Observations indicated that tsunami waves of up to about 30 cm were present at the Chatham Islands, and up to about 20 cm elsewhere in New Zealand. These waves arrived in New Zealand on 3 April (local time). Unusual tsunami-caused wave and current activity at Tutukaka in Northland caused difficult conditions for yachts over a period of several hours starting from 9am on 3 April.

Data: GeoNet

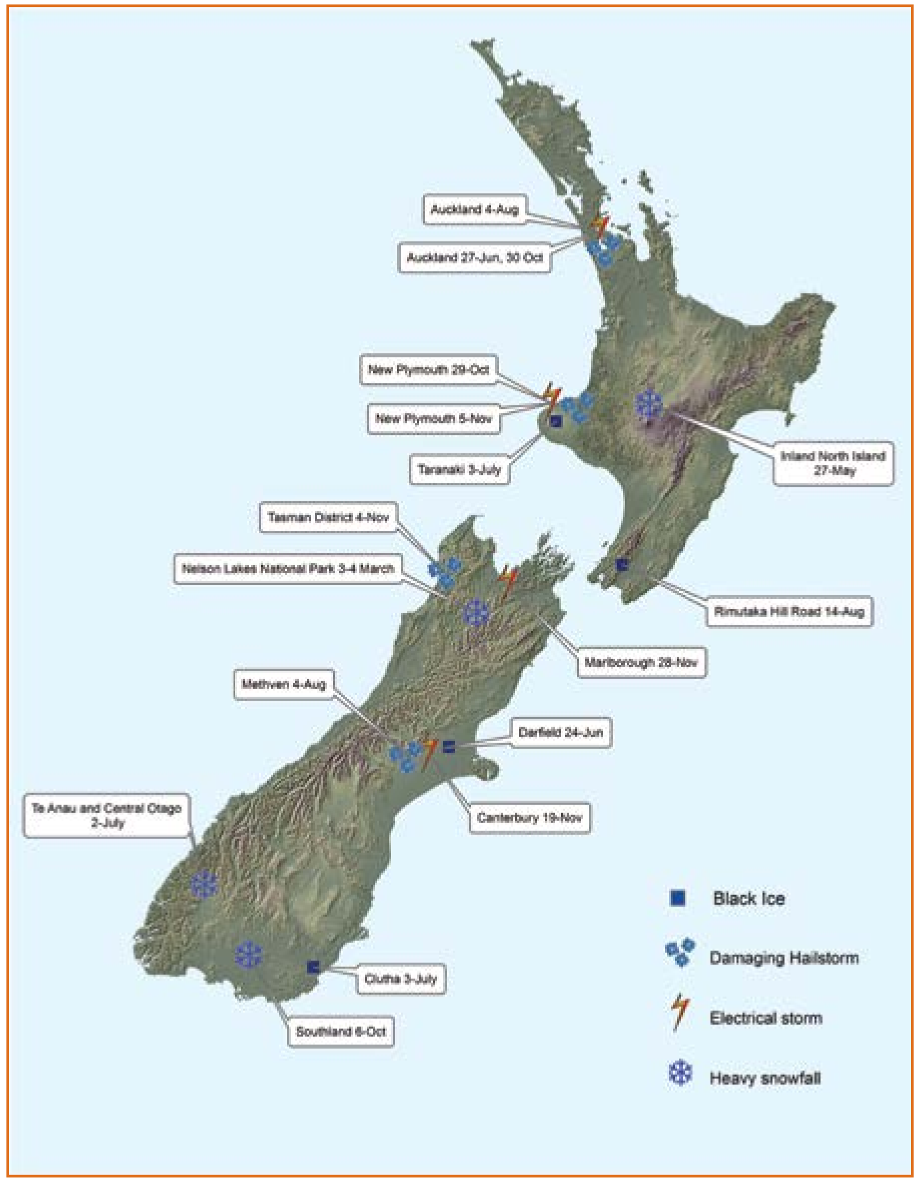
Snow, Hail and Electrical Storms

Between 24 June and 14 August 2014, black ice on roads was associated with 38 car accidents resulting in one fatality. Snow on 27 May and associated frosts were responsible for a number of car accidents in inland North and South Island, and disruptions to services in Otago and Southland. A number of subsequent low elevation events in Canterbury-Otago and Southland resulted in service and sporting event disruption (2 July, Otago and Canterbury; 7 August, Otago; 6 October, Southland). In addition, a number of uncharacteristic snow events affected the Southern Alps outside of the typical snow season.

On 4 November, a thunderstorm struck parts of the Tasman District resulting in severe damage to orchards, while on 12 November hail accumulated up to 30 cm near Methven. Two severe thunderstorms resulted in surface flooding due to blocked drains (4 August - Auckland and 5 November - New Plymouth).

On 29 October, Northland and Auckland experienced a number of thunderstorms resulting in 16,000 lightning strikes, including one on an aircraft in flight, and temporary power faults (Northland). Further lightning events occurred on 30 October (Auckland - 600 strikes) and 19 November (Canterbury-19 strikes). On 28 November, lightning strikes in Marlborough (Port Underwood) started a forest fire.

Source: National Climate Centre Monthly and Annual Summaries Data: NIWA



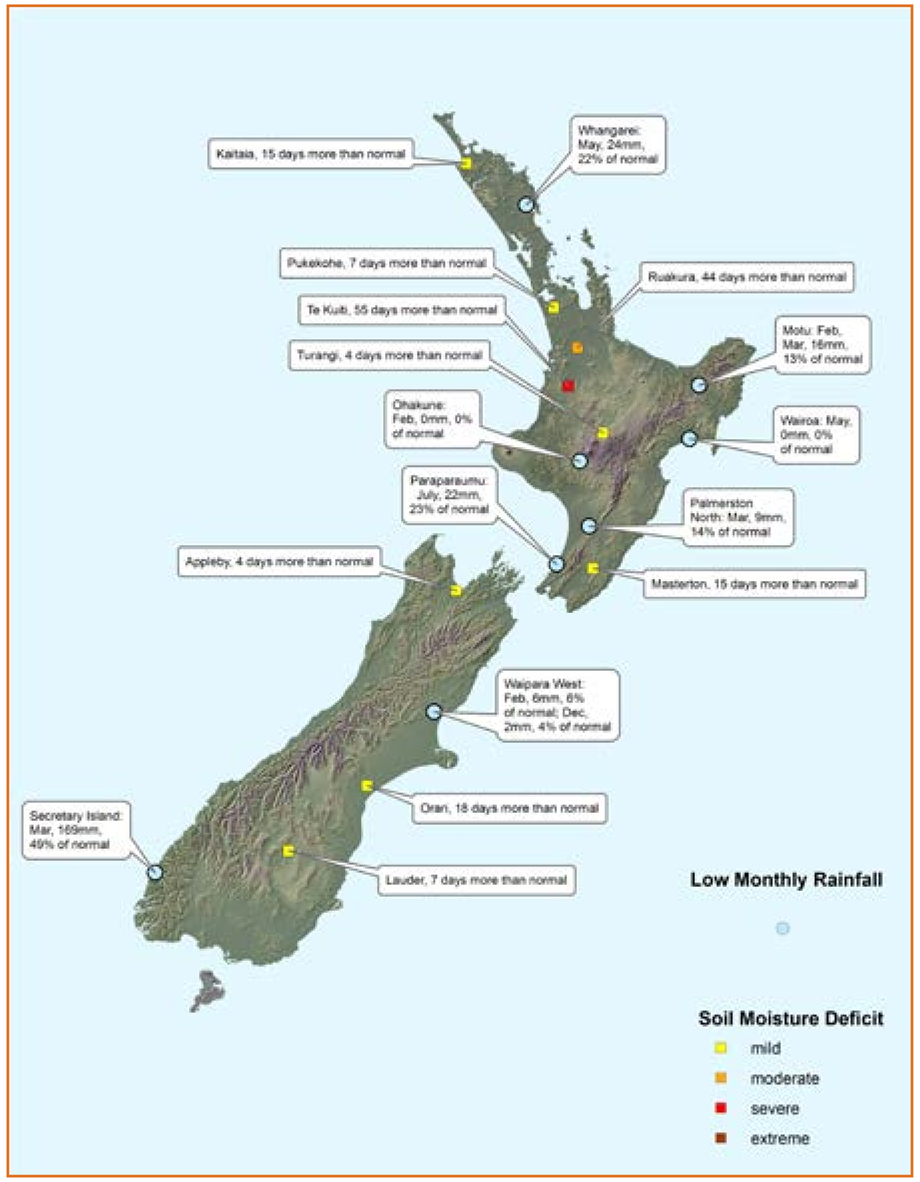
Low Rain and Drought

Annual rainfall totals for 2014 were near normal (within 20% of the annual normal) for most of the country. However, annual rainfall was below normal (50-79% of annual normal) for parts of the central North Island and Central Otago. It was the second-driest year on record for Turangi and Dannevirke, with these locations recording just 69% and 72% of the normal annual rainfall, respectively. The driest location in New Zealand for 2014 was Alexandra with 305 mm of rainfall.*

In 2014, soils of the central and northern North Island experienced wilting conditions (WCs) more frequently than normal. For instance, in a normal year, the soils at Te Kuiti experience WCs for 44 days, but in 2014, WCs were recorded for 99 days. South Canterbury and Central Otago soils also experienced more days under WCs than normal, though the conditions were not as dire as in the central North Island.

Source: NIWA's National Climate Centre Monthly and Annual Summaries.

*Note: Even though Alexandra was the driest location in NZ for 2014, the rainfall total was not extreme by Alexandra standards. Rainfall in Alexandra was near normal at 96% of its annual normal rainfall, which is why it does not appear on the map.



Platform International

- **Sendai Framework.** Provided support to the Ministry of Foreign Affairs and Trade in the preparation and negotiation of the Sendai Framework adopted at the 3rd World Conference on Disaster Risk Reduction.
- **NIWA's Deepwave Experiment**, a collaboration between NZ, USA, German and UK scientists to observe and investigate deeply propagating gravity waves in the atmosphere. These waves transport large amounts of energy within the atmosphere and can affect the accuracy of weather forecasts. Deepwave will lead to improved understanding of this phenomena, and improved accuracy of weather forecasts and climate model simulations. Link: http://www.niwa.co.nz/news/deepwave-project-measures-gravity-waves-in-the-atmosphere
- **GEM Foundation.** New Zealand participation in the Global Earthquake Model. Link: http://www.globalquakemodel.org/
- **GAR Reports.** Engagement and review of Global Assessment Reports (GAR) for the United Nations International Strategy for Disaster Reduction (UNISDR). See 'New Zealand Volcanic Risk Research' (p.37). Link: http://www.preventionweb.net/english/hyogo/gar/2015/en/home/index.html
- Ongoing dialogue with the global reinsurance industry.
- **Closer ties with the Bushfire and Natural Hazards CRC** in Australia. Link: http://www.bnhcrc.com.au/

The Natural Hazards Research Platform

The Natural Hazards Research Platform was formed by Government in September 2009 to provide secure long-term funding for natural hazards research, and to help research providers and end-users work more closely together. The Platform is hosted by GNS Science and includes NIWA as an anchor organisation and University of Canterbury, Massey University, Opus International Consultants, and University of Auckland as partners.

www.naturalhazards.org.nz

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