An Overview of GNS's Recent Research on the Risk & Resilience of Infrastructure

ShengLin Lin, Team Lead – Risk Engineering
and Others

GNS SCIENCE
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Our science

***NHR Theme Vision*:**

Aotearoa is a disaster resilient nation that acts proactively to manage risks and build resilience in a way that contributes to the wellbeing and prosperity of all New Zealanders

***Within the Theme*:**

- **GeoNet (inc NGMC)**
- **HRM SSIF**
- **NSHM, RiskScape, RNC2**
- **Endeavour, Marsden**
- **…**

Society & Infrastructure Department

- **Risk Engineering**
- **Risk Science**
- **Planning & Policy**
- **Hazard & Risk Social Science**
- **Environmental Social Science**

Risk Engineering Team

Sheng-Lin Lin

Team Lead, Senior Risk Engineer

Timely and accurate intelligence saves lives

Vinod Sadashiva

Senior Risk Engineer

Improving understanding of impact from natural hazards

Uma Ashok

Senior Risk and Resilience Engineer

Risk and resilience beyond natural hazards

We use engineering knowledge and experience to understand built environment responses to natural hazards, and to minimise impacts.

Yasir Syed

Natural Hazard and Risk Scientist

Useful and useable decision support and visualisation tool

Sarah Inglis

Exposure Data Modeller

Standardised and efficient exposure model management

Jose Moratalla

Risk Engineer

Connecting seismology, structural and geotechnical engineering

Currently working on right now:

Exposure model development, vulnerability functions for tsunami and landslide events, infrastructure dependence, recovery and resilience modelling

Methods we use in research:

Field reconnaissance, numerical simulation, GIS, engagement and collaboration

Risk Science Team

Christina Magill

Team Lead, Senior Risk Specialist

Exploration of cascading and systemic disaster risk

Nick Horspool

Senior Risk Specialist

Developing tools and workflows to quantify risk

Nico Pondard

Senior Disaster Risk Management Specialist

Reducing risk by building capacity

Victoria Miller

Senior Disaster Risk Management Scientist

End-to-end solutions for reducing disaster risk

Finn Scheele

Risk Specialist

Understanding population displacement and household impacts

Jacob Pastor-Paz

Natural Hazards Risk Modeller

Collection, analysis and dissemination of risk data

Risk analytics to inform preparedness, response and recovery

Currently working on:

RiskScape™ software development, quantifying economic and health impacts of disasters and climate change

Methods we use in research:

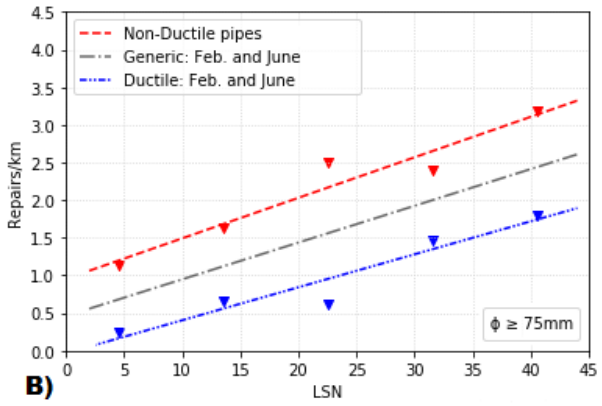
End-user focus, probabilistic modelling, scenario development, agent-based modelling, spatial science

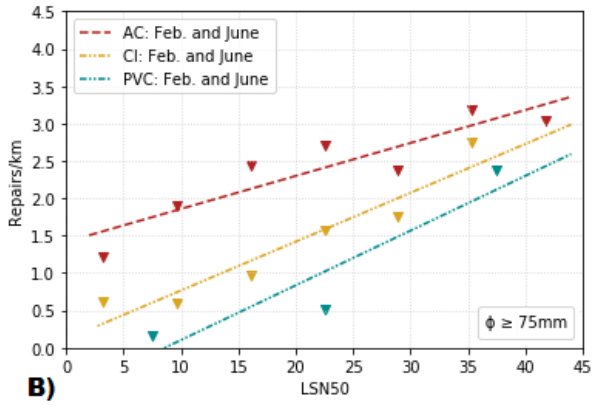
HRM SSIF - Built Environment & Performance Project (P1.6)

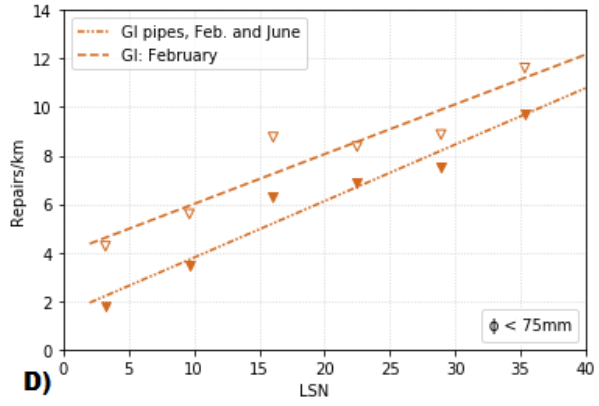
Development of LSN-based pipe repair rate models utilising data from the 2011 Christchurch earthquakes

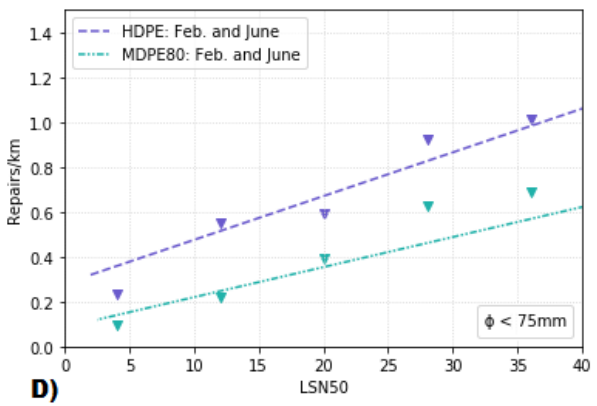
J.M. Moratalla & V.K. Sadashiva
GNS Science, Lower Hutt.

- Models developed for estimating repair rate (RR) for water supply pipes
- Based on repair data from 22nd February and 13th June 2011 Christchurch earthquakes
- Liquefaction Severity Number (LSN) maps from T&T Ltd.









Moratalla, J.M.; Sadashiva, V.K. 2022. Development of LSN-based pipe repair rate models utilising data from the 2011 Christchurch earthquakes. Bulletin of the New Zealand Society for Earthquake Engineering.
Sadashiva, V.K.; Nayyerloo, M.; Sherson, A.K. 2019. Seismic performance of underground water pipes during the Canterbury earthquake sequence. Underground Utilities – Seismic Assessment and Design Guidelines. Water NZ.

Fragility models developed – another example

Seismic Performance of Buried Electricity Cables during the Canterbury Earthquake Sequence

Sheng-Lin Lin[1], Mostafa Nayyerloo[2] and ZhaoXuan(Hins) Zhang[3]

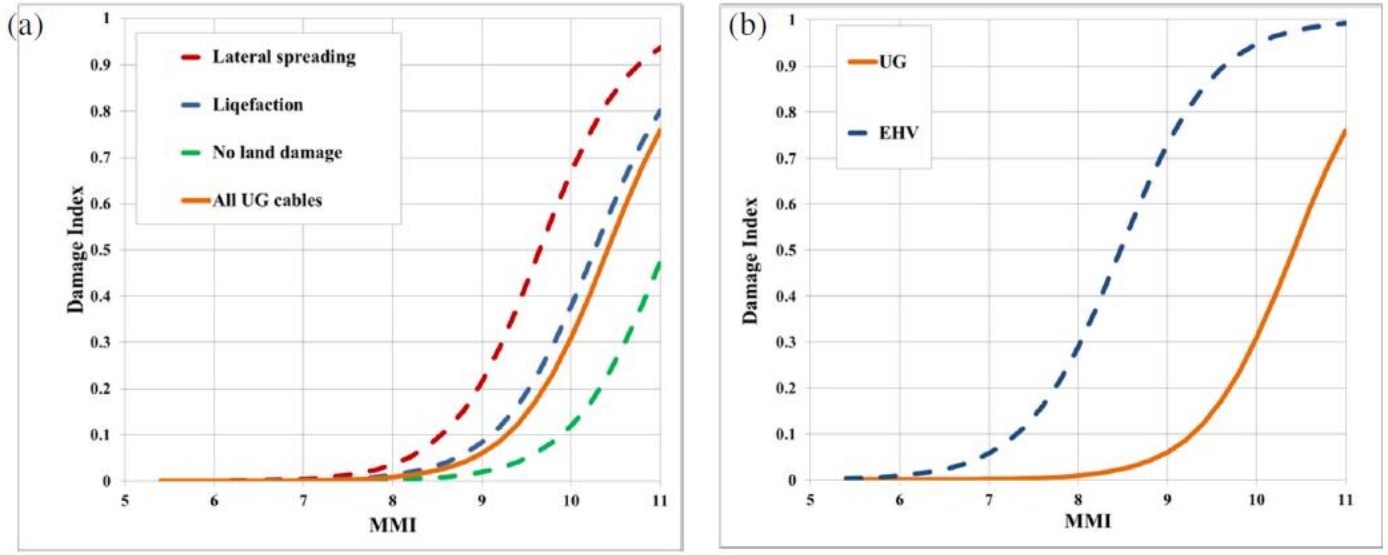
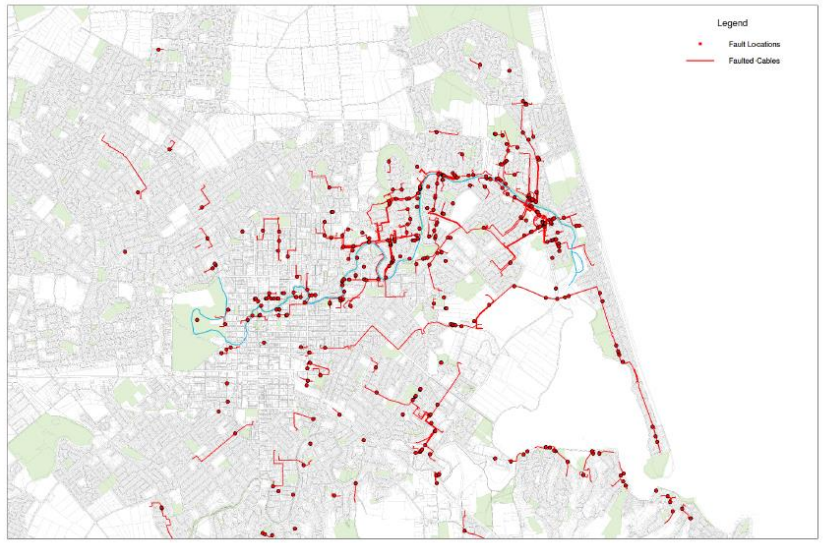


Figure 3. The derived damage index curves for (a) UG cables in different ground deformation categories, and (b) UG and EHV cables given MMI values for February earthquake

HV cable faults from Feb 22nd aftershock



gure 2. fault locations of HV (i.e.11 kV) cables during the February earthquake

Lin, S.L.; Nayyerloo, M.; Zhang, Z.X. 2016. Seismic performance of buried electricity cables during the Canterbury earthquake sequence, Proceedings of the Australian Earthquake Engineering Society Conference, Melbourne, Vic, Nov 25-27.

Damage modelling for Wellington Water's bulk water pipelines

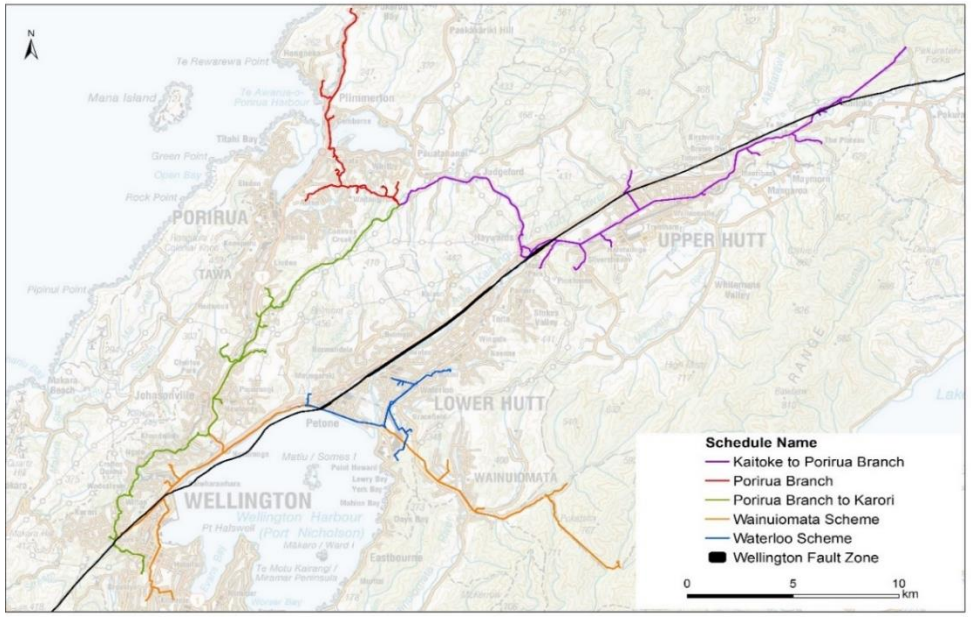


Table 4. Estimated numbers of failures to bulk water pipelines (discretized into 12 m segments) following a Wellington Fault earthquake. "SD" refers to Standard Deviation.

Pipe branch	Number of pipe failures				
	Shaking and secondary perils*				Fault rupture#
	MAX**	Mean + 1SD	Mean	Mean - 1SD	
Kaitoke to Porirua Branch	19	9	6	3	107 (10)
Porirua Branch	19	8	6	4	0
Porirua Branch to Karori	26	13	10	7	81 (5)
Wainuiomata Scheme	51	33	28	23	86 (6)
Waterloo Scheme	29	14	11	8	17 (1)
All above together (i.e. whole network analysed as one set)	96	70	62	54	291 (22)

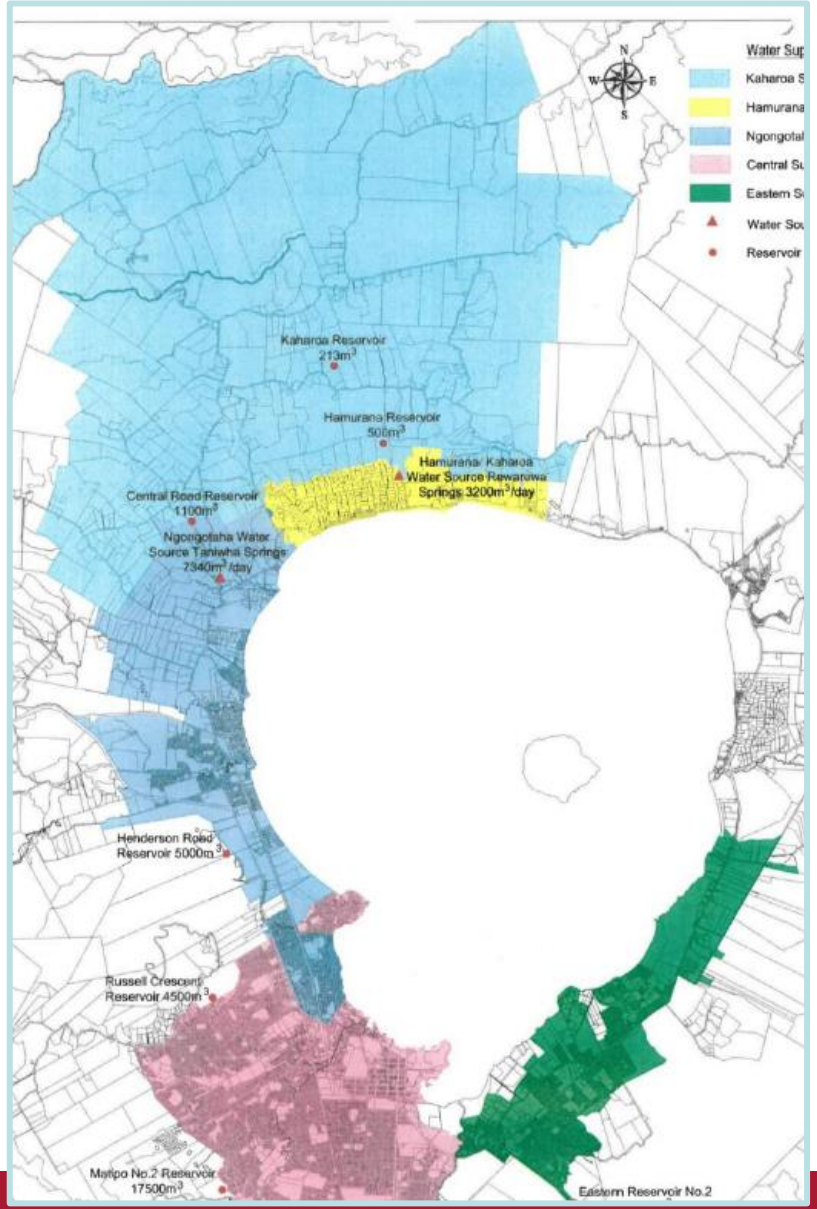
* Results based on 50,000 simulation runs
** Maximum number of pipe failures from a simulation run (out of 50,000 runs)
# value outside the brackets represents the potential (max.) number of failures and the value within the brackets represent the minimum number of failures expected

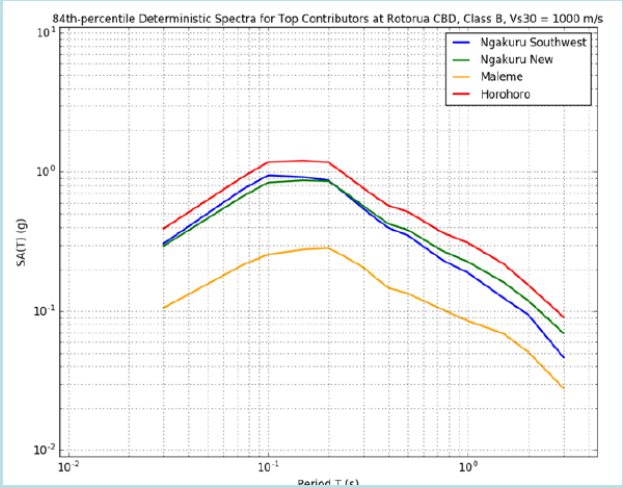
Outputs used by WW to:

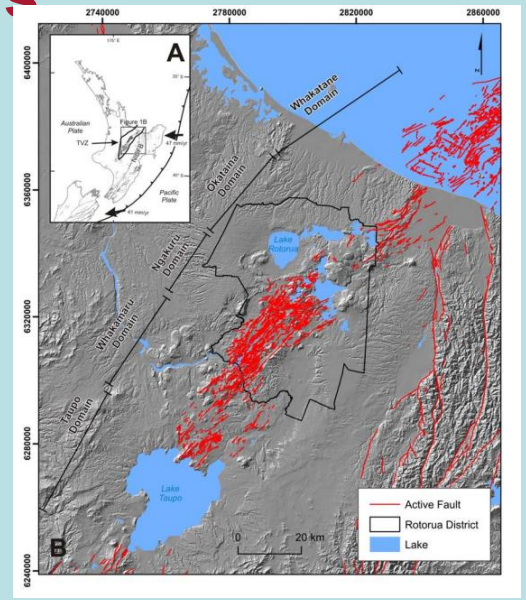
- Gain better understanding of the vulnerable sections in the network
- Prioritize pipeline replacement/upgrade projects to increase the network resilience
- Develop response plans
- Review quantity of material stock held against the stock likely needed for repairing the network following the event
- Estimate time and resources required to recover the service
- Estimate the maximum probable loss

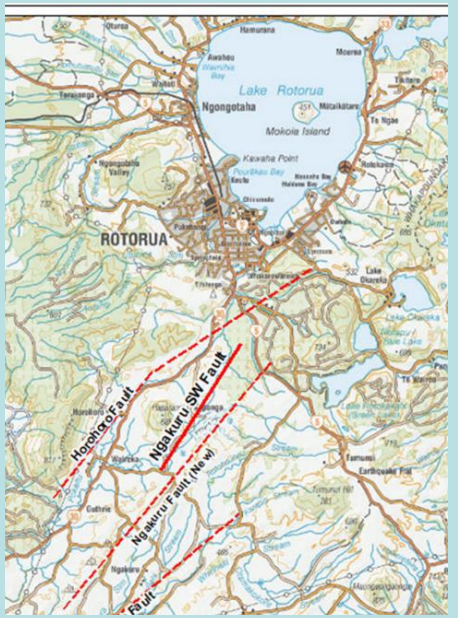
Sadashiva, V.K.; Heron, D.W.; Dellow, G.D.; Duggan, J. 2019. Impact of a major earthquake on bulk water pipeline network in four cities of Wellington region in New Zealand. Paper 322. ICONHIC 2019 : 2nd International Conference on Natural Hazards & Infrastructure, Chania, Greece.

Planning for resilience of Rotorua Lakes Council's water networks

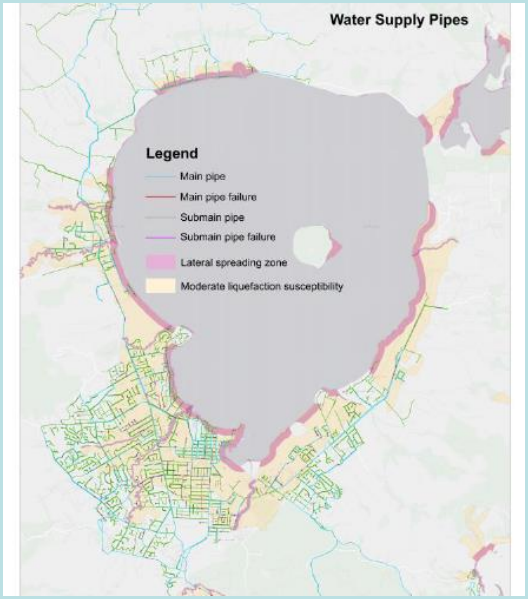




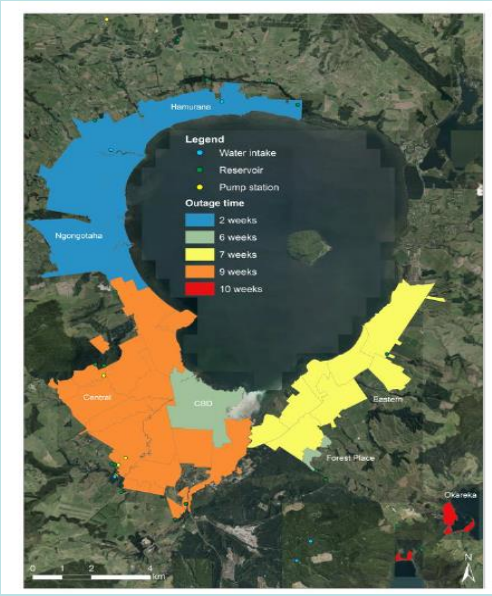




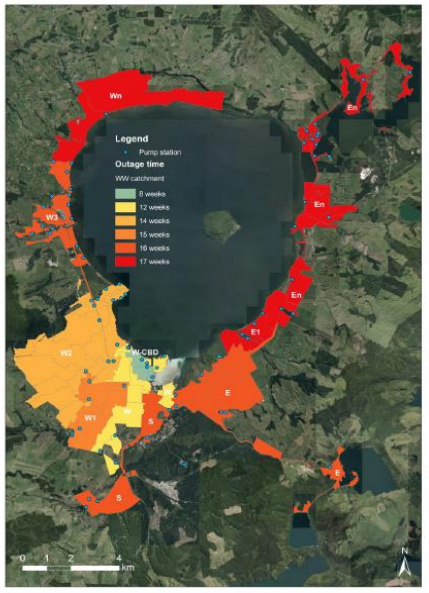
Hazard identification



Damage modelling

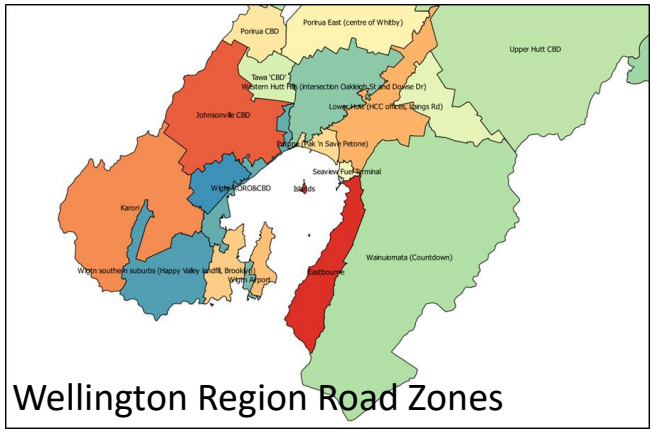


WS Outage modelling

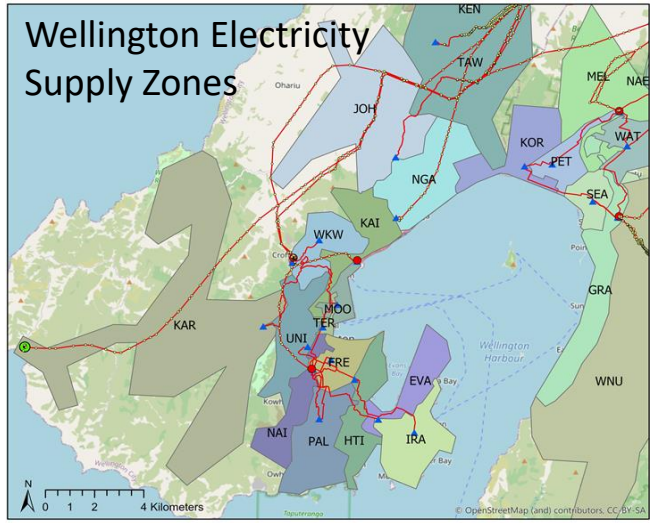


WW Outage modelling

HRM SSIF P1.6. research on modelling interdependencies



Wellington Region Road Zones



Presentation tier	Business logic tier	Data tier
User interface layer	**Application Processing Layer**	**Data and knowledgebase layer**
Front-end for the Decision makers	Application and Web server containing ASP.net engine, C# Source code and JavaScript files	Database server containing the database, knowledgebase and the DBMS
View module of the MVC	**Controller** module of the MVC	**Model** module of the MVC

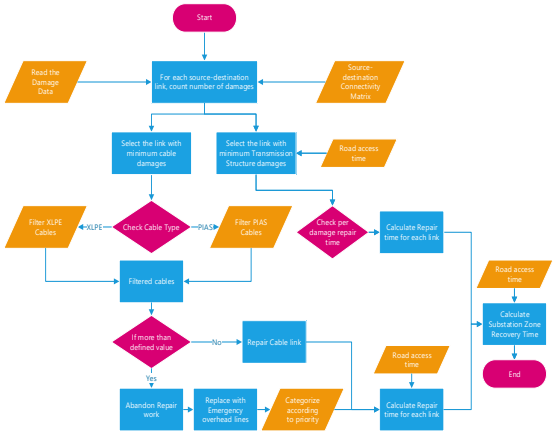
Web Server

Application Server

Database Server

User Interactive - Decision Support System Architecture

"What if" scenarios comparison

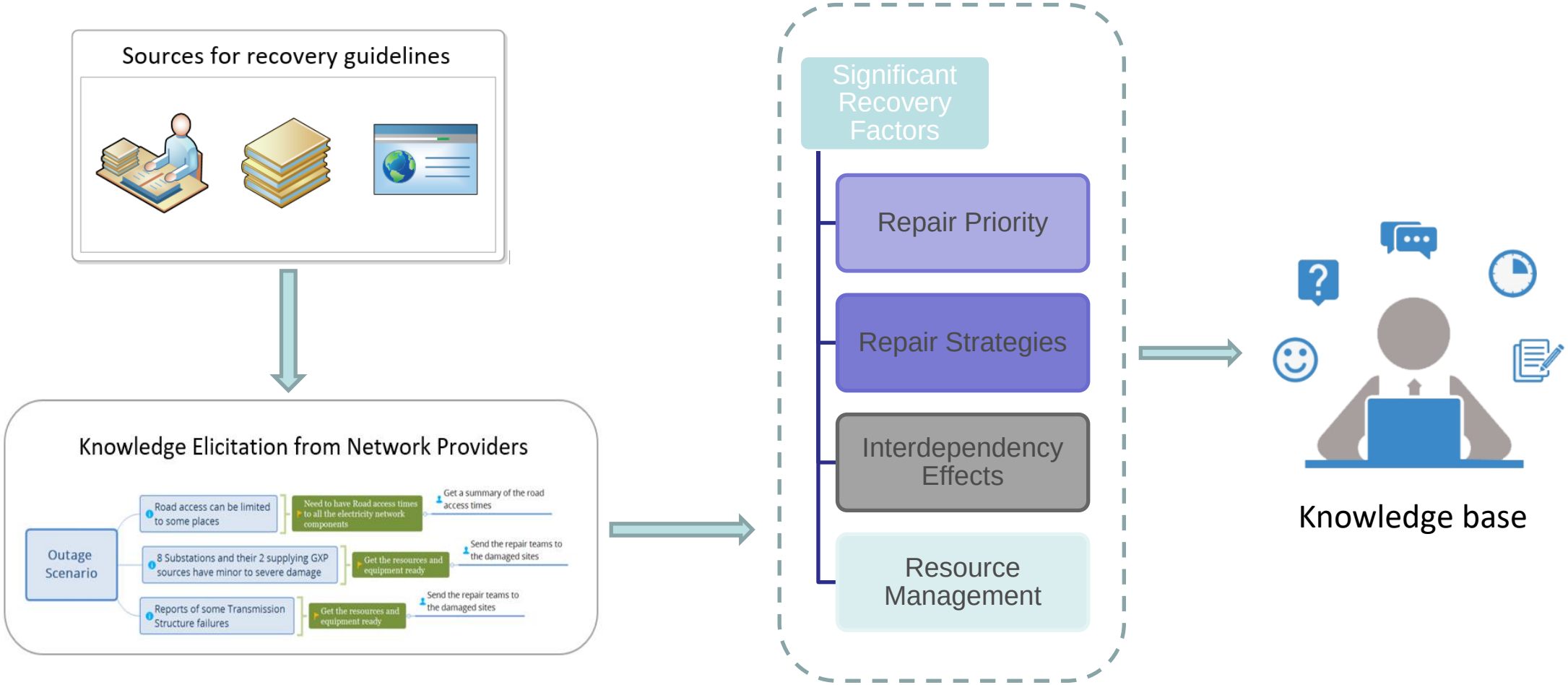


Recovery strategies

Uma SR, Syed Y, Karalliyadda SC, Prasanna R. 2020. Modelling interdependencies of critical infrastructure network recovery using a decision support system. Lower Hutt (NZ): GNS Science. 42 p. (GNS Science report; 2020/18). doi:10.21420/Y46F-GJ02

Syed, Y., Uma, S. R., Prasanna, R., & Wotherspoon, L. (2021). 'End to end' linkage structure for integrated impact assessment of infrastructure networks under natural hazards. Bulletin of the New Zealand Society for Earthquake Engineering, 54(2), 153–162. https://doi.org/10.5459/bnzsee.54.2.153-162.

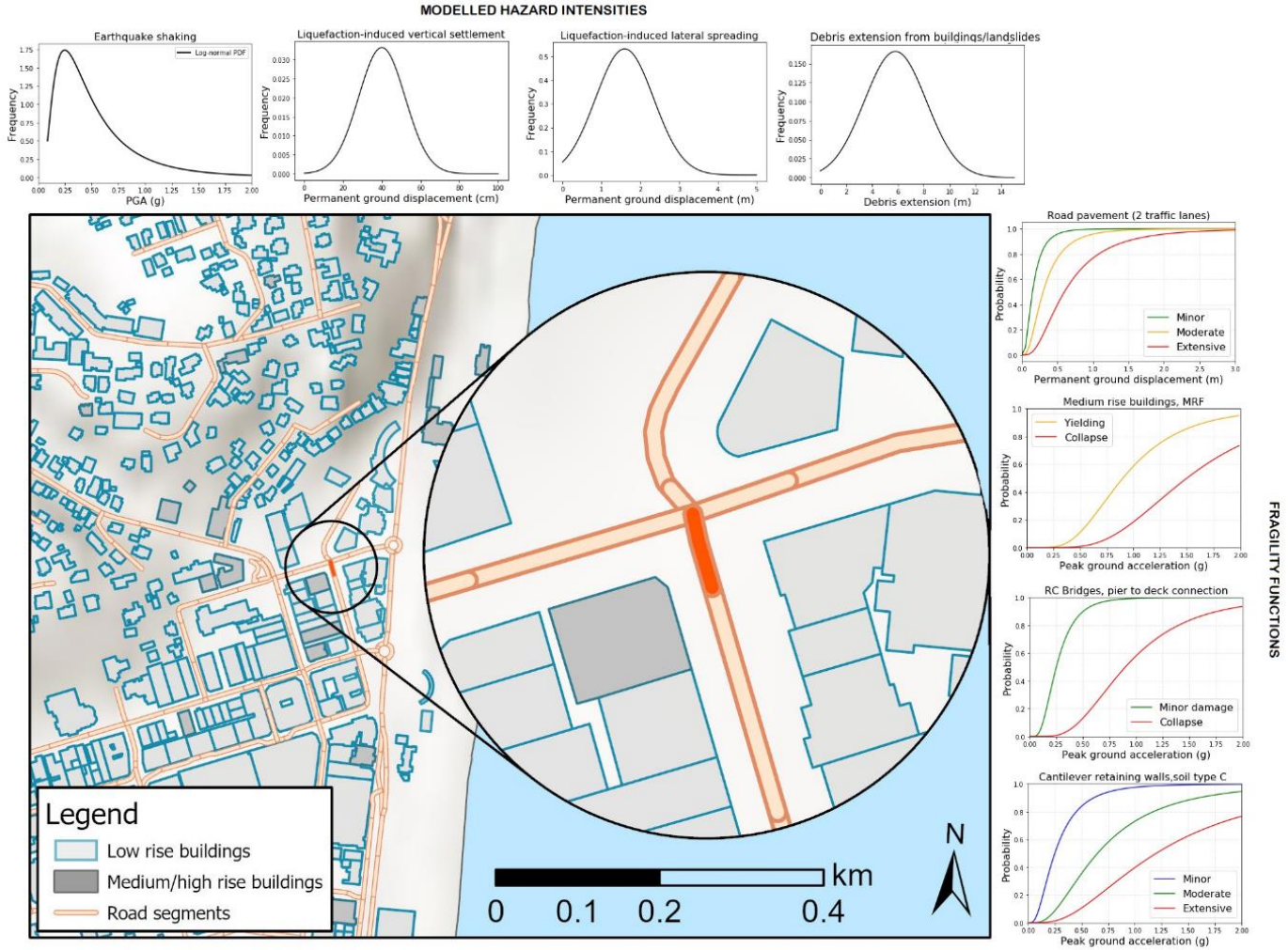
P1.6 work recently completed - Identification of significant factors for recovery of infrastructure networks

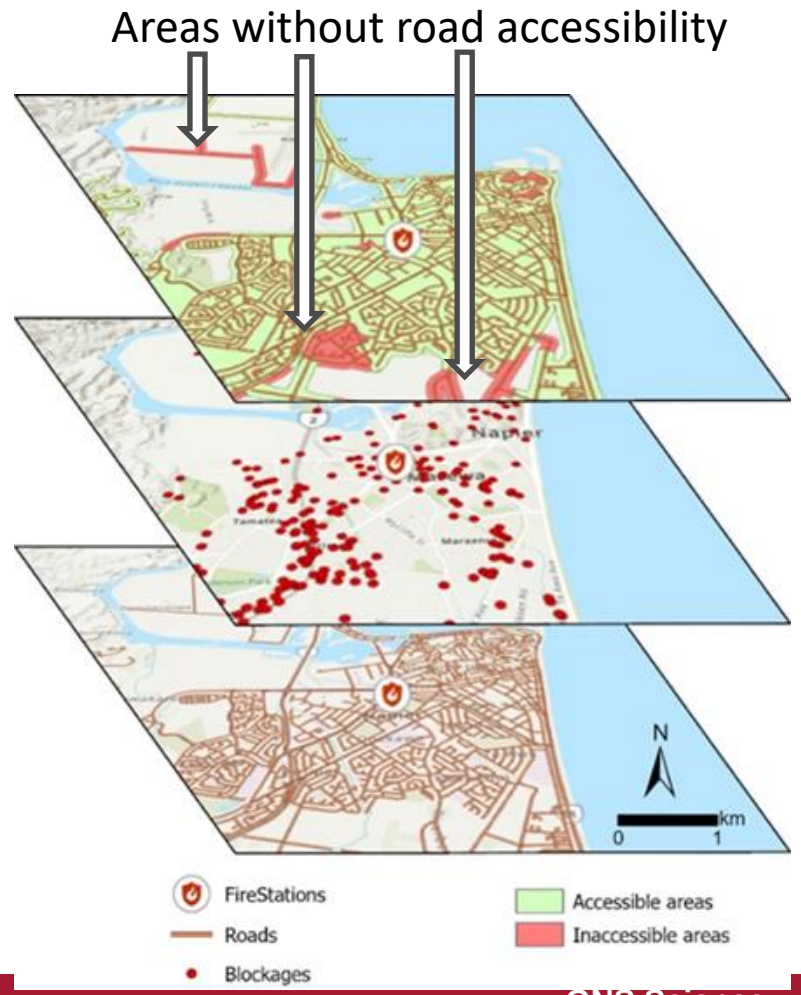


Syed, Y. I., Uma, S. (2022). Identification of significant factors for the recovery of distributed infrastructure networks through knowledge elicitation processes. Journal paper under review.

P1.6 work recently completed - Probabilistic assessment of road accessibility under cascading hazards

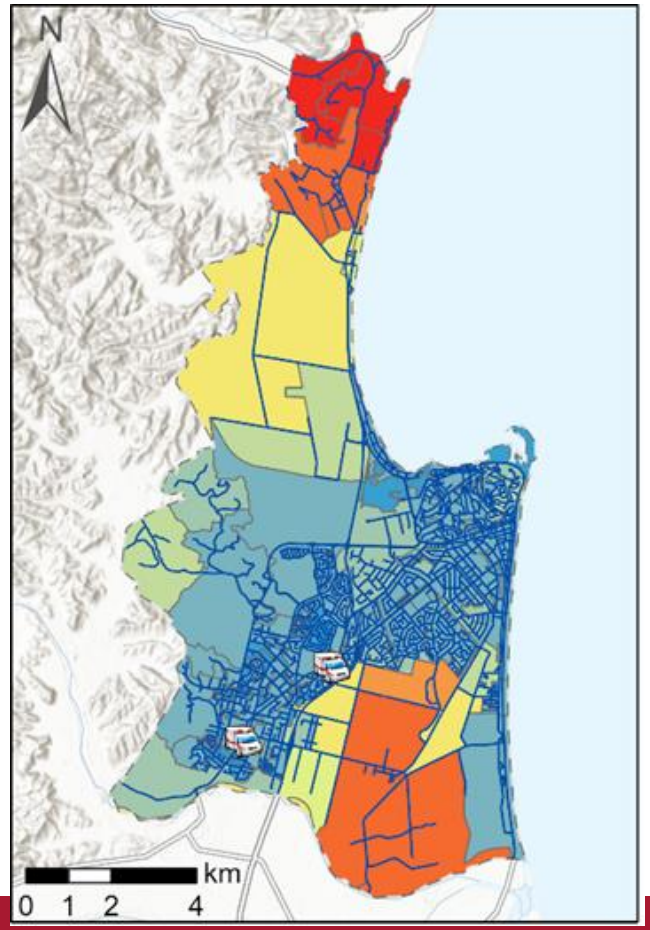
- Impact of **ground shaking** and cascading hazards (**liquefaction, lateral spreading, landslide and debris from collapsed buildings**) on road assets and accessibility analysis for emergency services (**firefighting stations and ambulance centres**)

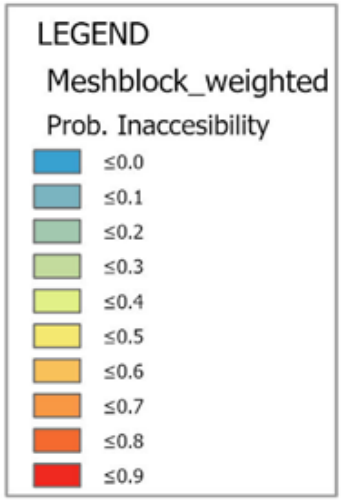


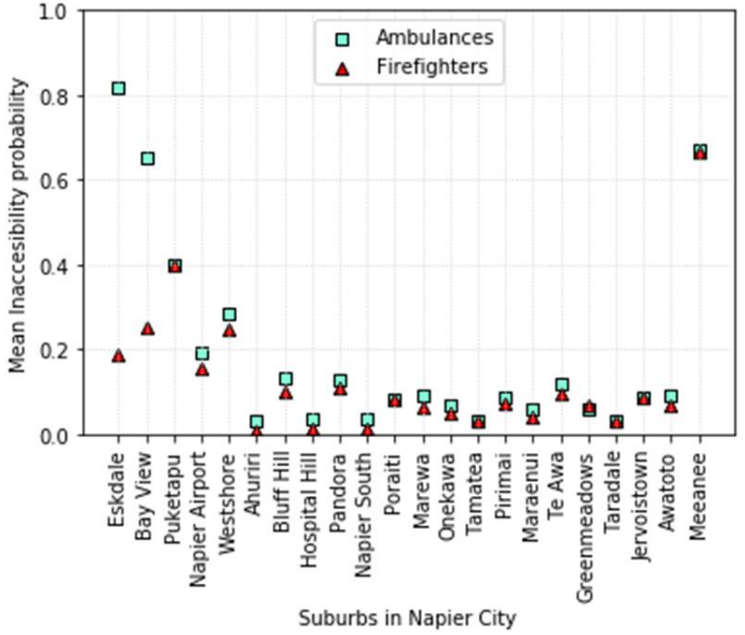


Results

- 10000 different damage scenarios → 10000 accessibility scenarios
- Results aggregated and presented as Probability of inaccessibility (POI) for ambulance centres and firefighting stations
- POI presented at a suburb level and at a road segment level
- **Case study:** a Mw8.4 Hikurangi SZ event affecting Napier City

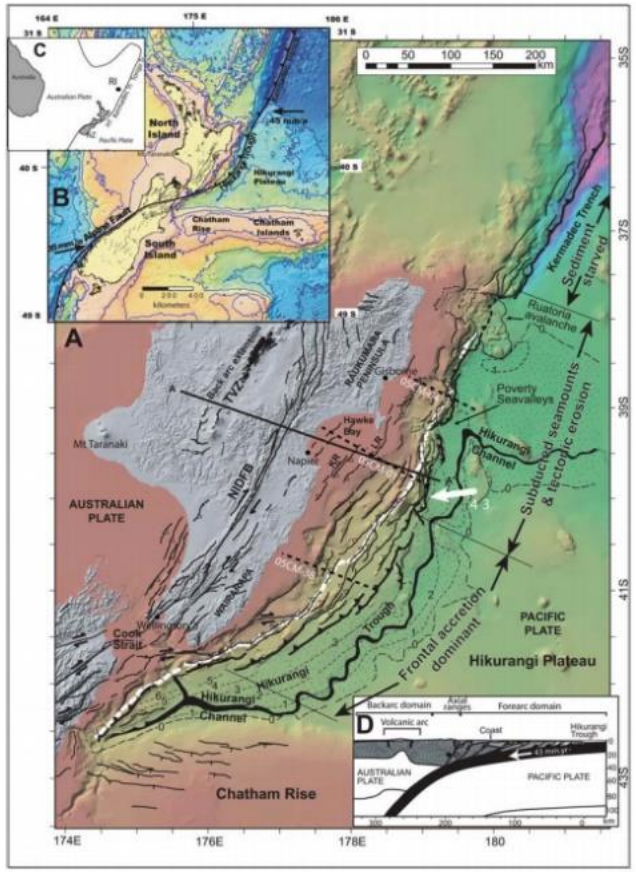


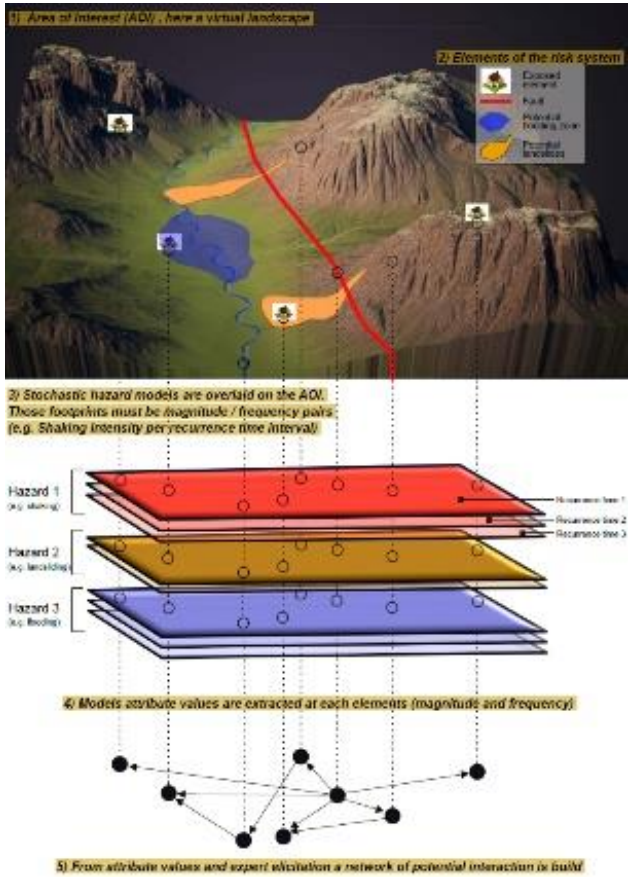




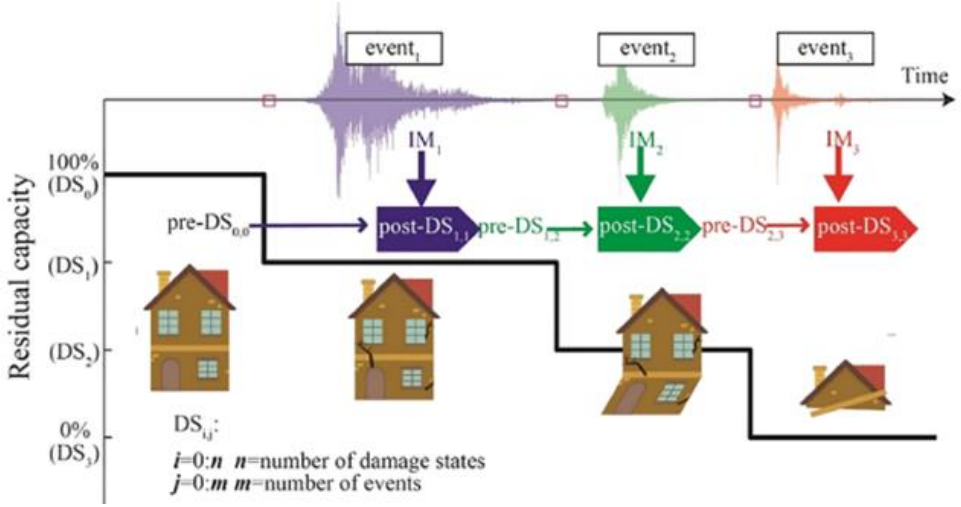
HRM SSIF: End-to-End Framework Flagship Project

We are working on quantifying the cascading risk from a rupture on the Hikurangi fault. The hazards would include shaking, tsunamis inundation, liquefaction and landsliding.





Links to research from other projects, e.g SSIF P1.6, RiskScape

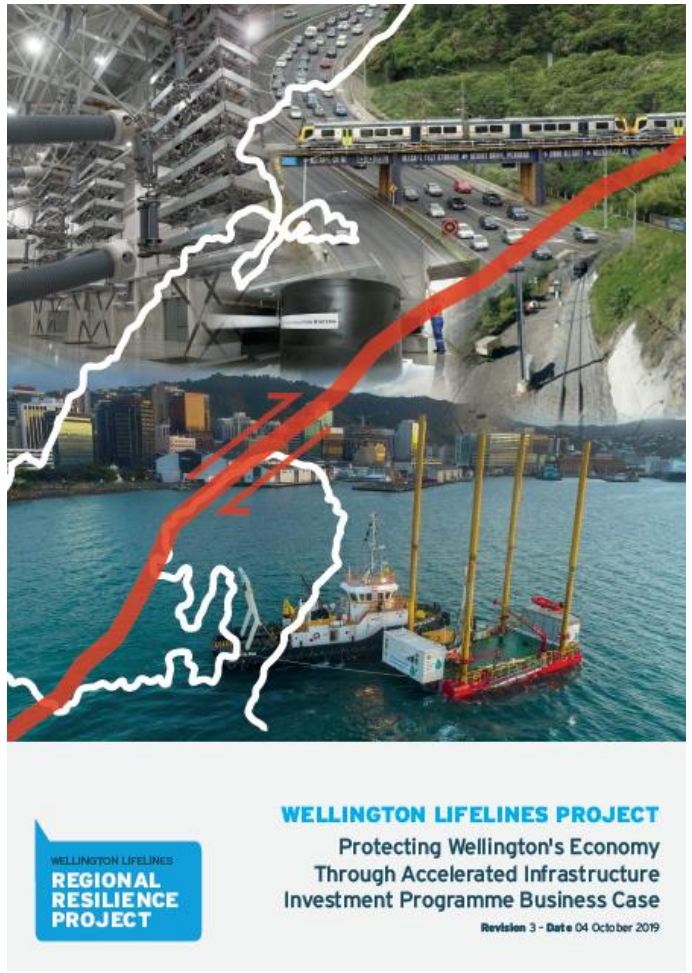


Multi-Hazard: A set of hazard ensembles are created to assess stochastically the total risk from the hazard system

Wellington Lifelines Project

Since public release of the report, dissemination of project details have continued via. national and international research forums and technical articles:

- Sadashiva, V.K.; Mowll, R.; Uma, S.R.; Lin, S.-L.; Heron, D.W.; Horspool, N.A.; Nayyerloo, M.; Williams, J.; Syed, Y.; Buxton, R.; King, A.B.; Lukovic, B.; Berryman, K.R.; Daly, M.C. 2021. Improving Wellington region's resilience through integrated infrastructure resilience investments. Bulletin of the New Zealand Society for Earthquake Engineering, 54(2): 117-134; doi: 10.5459/bnzsee.54.2.117-134
- Mowll, R.; Sadashiva, V.K.; Delaney, A.; Wilde, F.;, Crampton, C.; Wiertsema, A.; Muirhead. C. 2022. Understanding The Consequences Of Wellington's Infrastructure Vulnerability To A Major Earthquake. ASCE/IRD UCLA Lifelines Conference, Los Angeles
- Sadashiva, V.K.; Nayyerloo, M.; Williams, J.; Heron, D.W.; Uma, S.R.; Horspool, N.A.; Buxton, R.; Lin, S.-L.; Lukovic, B.; King, A.B.; Berryman, K.R.; Daly, M.C. 2020. Potential benefits of implementing water network resilience projects in Wellington region of New Zealand. paper 11a-0011 IN: 17th World Conference on Earthquake Engineering, 17WCEE 2020, Sendai, Japan.
- Brown, C.; McDonald, G.; Uma, S.R.; Smith, N.; Sadashiva, V.K.; Buxton, R.; Grace, E.S.; Seville, E.; Daly, M.C. 2019. From physical disruption to community impact : modelling a Wellington Fault earthquake. Australasian Journal of Disaster and Trauma Studies, 23(2): 65-75.
- Sadashiva, V.K.; Mowll, R.; Heron, D.W.; Lukovic, B. 2020 Reducing infrastructure outages through integrated infrastructure resilience investment programme. paper 11a-0010 IN: 17th World Conference on Earthquake Engineering, 17WCEE 2020, Sendai, Japan.
- Sadashiva, V.K.; Heron, D.W.; Williams, J.; Nayyerloo, M.; Mowll, R. 2021 Reducing disaster impact by targeted infrastructure resilience investments: a case study involving the water and wastewater networks in Wellington, New Zealand. Sustainable and Resilient Infrastructure. doi: 10.1080/23789689.2021.1925400



Thank you & Questions?

s.lin@gns.cri.nz