TSUNAMI VULNERABILITY: DEVELOPING TOOLS FOR INFRASTRUCTURE IMPACT ASSESSMENT

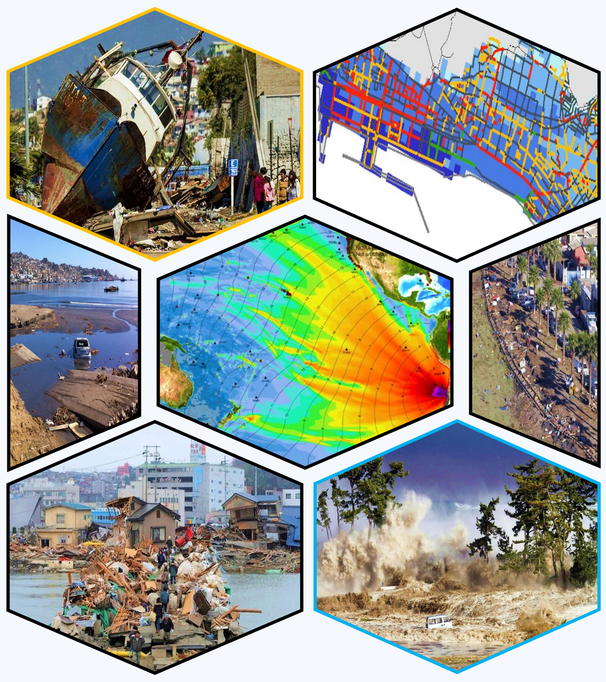
James H. Williams[1], Colin Whittaker [2], Liam Wotherspoon [2]

[1] Department of Geological Sciences, University of Canterbury; [2] Department of Civil and Environmental Engineering, University of Auckland

AIMS AND OBJECTIVES

Develop a holistic framework for tsunami vulnerability assessment of critical infrastructure

- Develop vulnerability models for tsunami impacts on infrastructure which consider a range of:
  - Lifeline networks and components
  - Hazard intensity measures
  - Impact types
- Apply synthesised vulnerability functions to a New Zealand-based case study



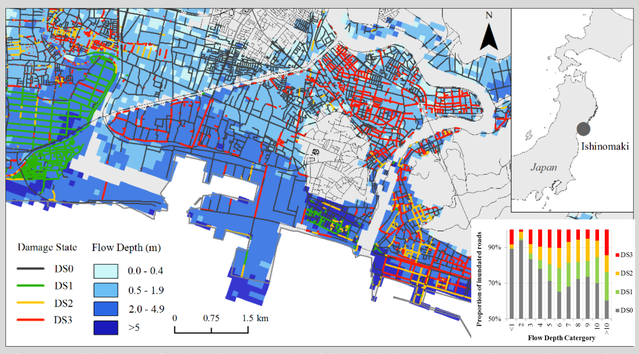
BACKGROUND

Impact assessment is important for proactive tsunami risk management. However, research on tsunami vulnerability of infrastructure lifelines is largely under-developed.

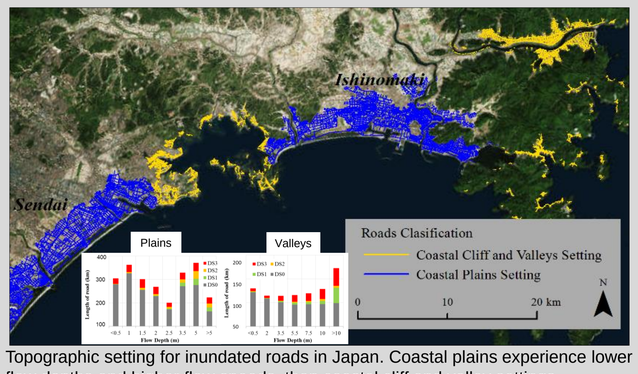
Tsunami vulnerability functions typically use depth as a proxy for direct damage. We aim to develop new functions which consider construction standards (material etc.) multiple hazards (depth, speed, loading) and impact types (direct damage, functionality, outage time).

METHODOLOGY AND FRAMEWORK

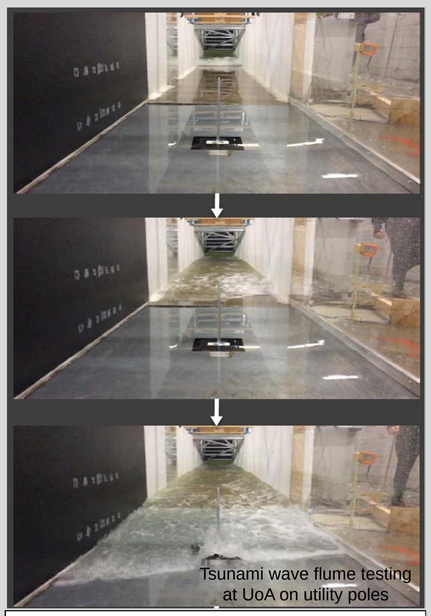
POST-EVENT SURVEYS + REMOTE SENSING + PHYSICAL MODELS → VULNERABILITY FUNCTIONS



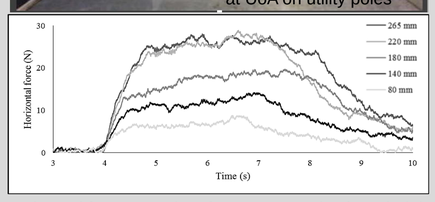
Surveyed damage for inundated roads, 2011 Tohoku Earthquake and Tsunami, Japan



Topographic setting for inundated roads in Japan. Coastal plains experience lower flow depths and higher flow speeds, than coastal cliff and valley settings



Tsunami wave flume testing at UoA on utility poles



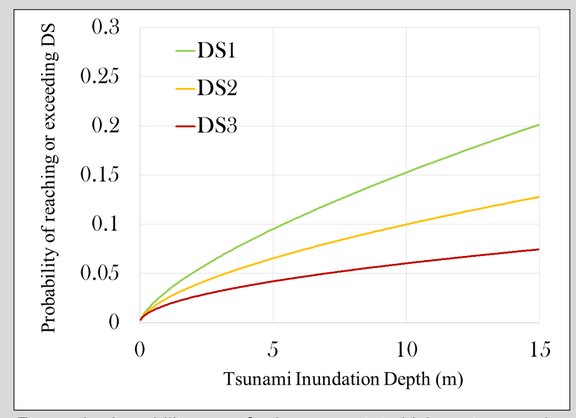
Horizontal force over time for representative bore heights

Asset Standards: Construction type, material, dimensions etc.

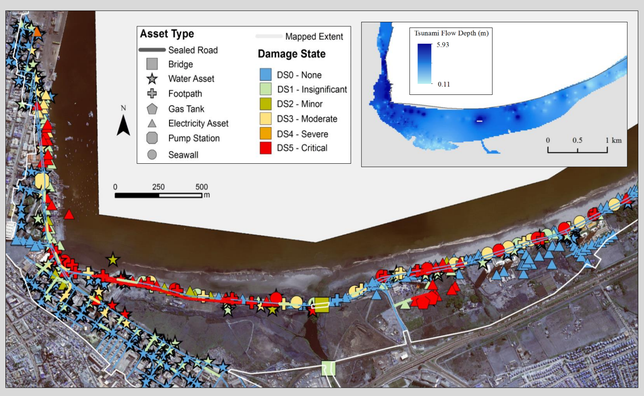
Hazard Intensity Measure: Flow velocity, inundation depth, hydrodynamic loading

Impacts: Direct damage, functionality

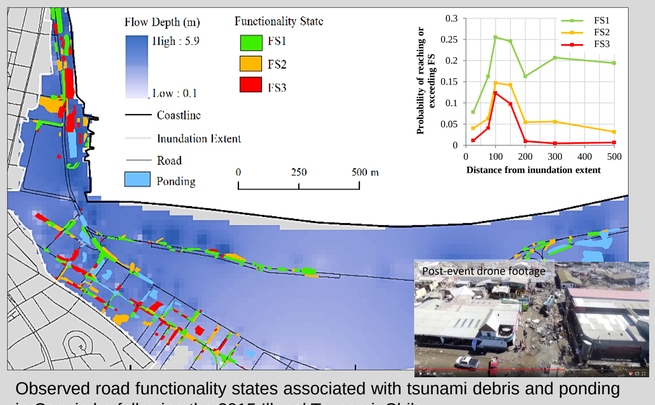
Impact Enhancements: Debris potential, interdependency



Tsunami vulnerability curve for Japanese state highway-type roads for the 2011 Tohoku Tsunami, using post-event survey and remote sensing data.

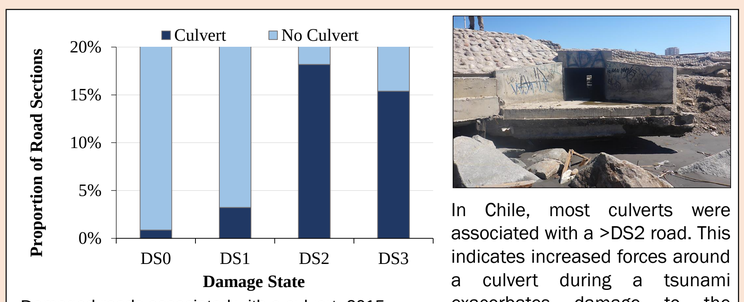


Surveyed damage for inundated infrastructure assets, 2015 Illapel Tsunami, Chile



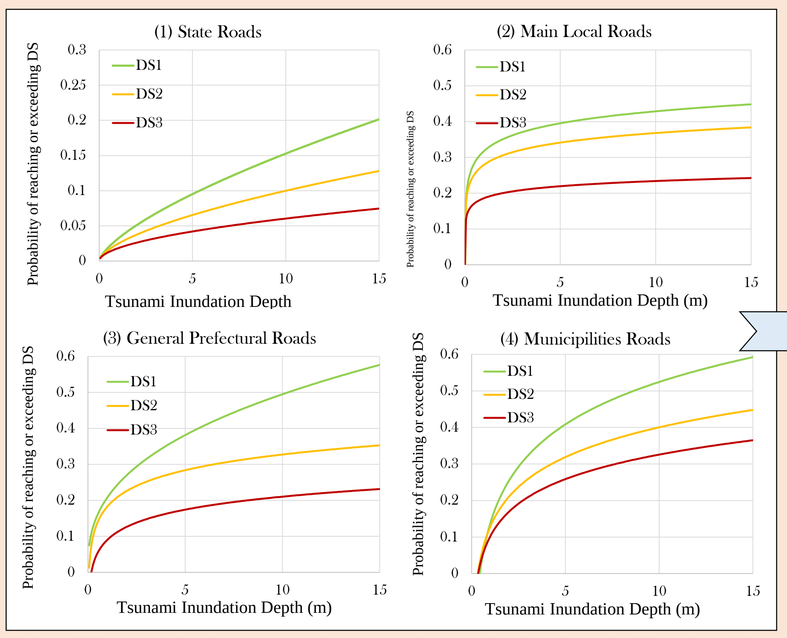
Observed road functionality states associated with tsunami debris and ponding in Coquimbo following the 2015 Illapel Tsunami, Chile.

RESULTS

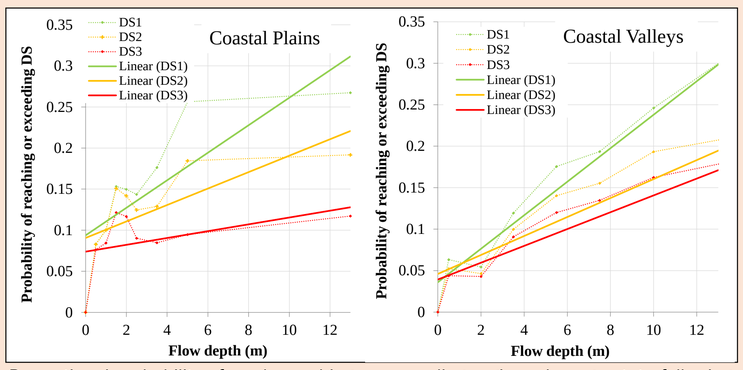


Damaged roads associated with a culvert, 2015 Illapel Tsunami, Coquimbo, Chile.

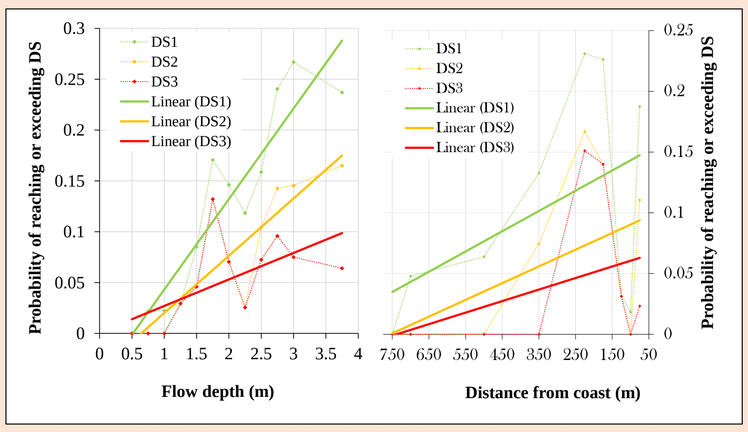
In Chile, most culverts were associated with a >DS2 road. This indicates increased forces around a culvert during a tsunami exacerbates damage to the surrounding subgrade material



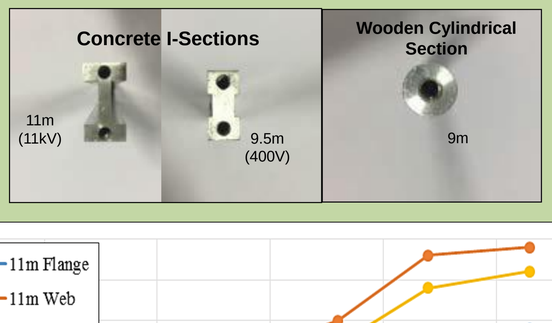
Vulnerability curves for Japanese road use-type classes, showing the probability of reaching or exceeding a given damage state following the 2011 Tohoku Tsunami, Japan.

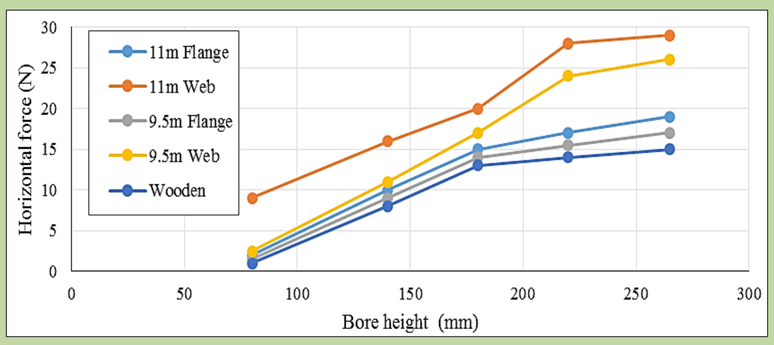


Proportional probability of roads reaching or exceeding a given damage state following the 2011 Tohoku Tsunami. This indicates the higher flow speeds associated with flatter land (plains) result in higher initial damage at lower depths, whereas greater inundation depths in steep topography (cliff & valleys) results in more DS3 (complete damage) roads comparatively.



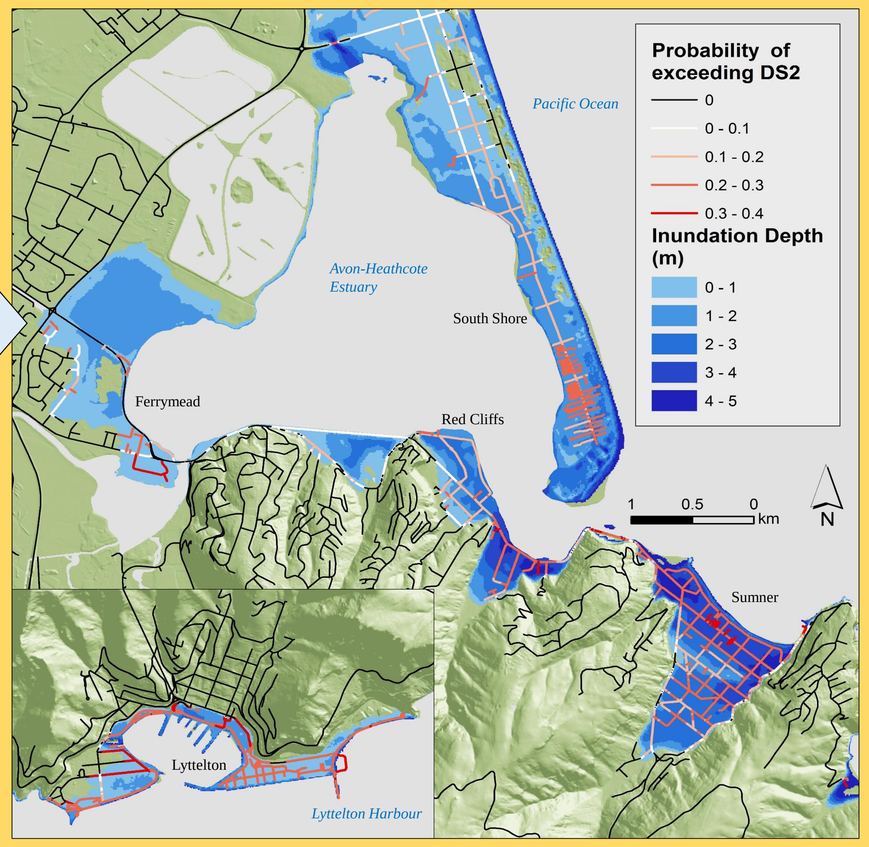
Cumulative probability for tsunami flow depth (left) and distance from coastline (right) defining the probability of roads reaching or exceeding DS1-DS3, for the 2015 Illapel Tsunami. This indicates a relationship between damage and distance from the coast which could be used as a proxy for decreasing flow speed further inland.





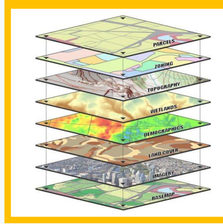
Effect of cross-section and orientation (for concrete I-sections) on horizontal force exerted by tsunami bore on model-scale utility poles.

APPLICATION



The probability of roads reaching or exceeding Damage State 2 (complete damage to one or more lanes) has been modelled for Christchurch. This uses 2014 NIWA tsunami models based on a Mw 9.485 Peru subduction zone earthquake source and vulnerability functions for Japanese road use-type classifications from the 2011 Tohoku Earthquake and Tsunami, Japan. Future work will look to apply a level of service, network outage and recovery time for infrastructure lifelines.

FUTURE WORK



- Check physical modelling against available field surveys
- Develop and apply a framework for loss of service and recovery time
- Collect and analyse future tsunami impact data

QuakeCoRE NZ Centre for Earthquake Resilience Te Hiranga Rū

GNS SCIENCE TE PŪ AO

NIWA Taihoro Nukurangi