Reducing Flood Inundation Hazard and Risk

Presentation to the Ministry for the Environment

Emily Lane, Sam Dean, Ryan Paulik, Paula Blackett, NIWA

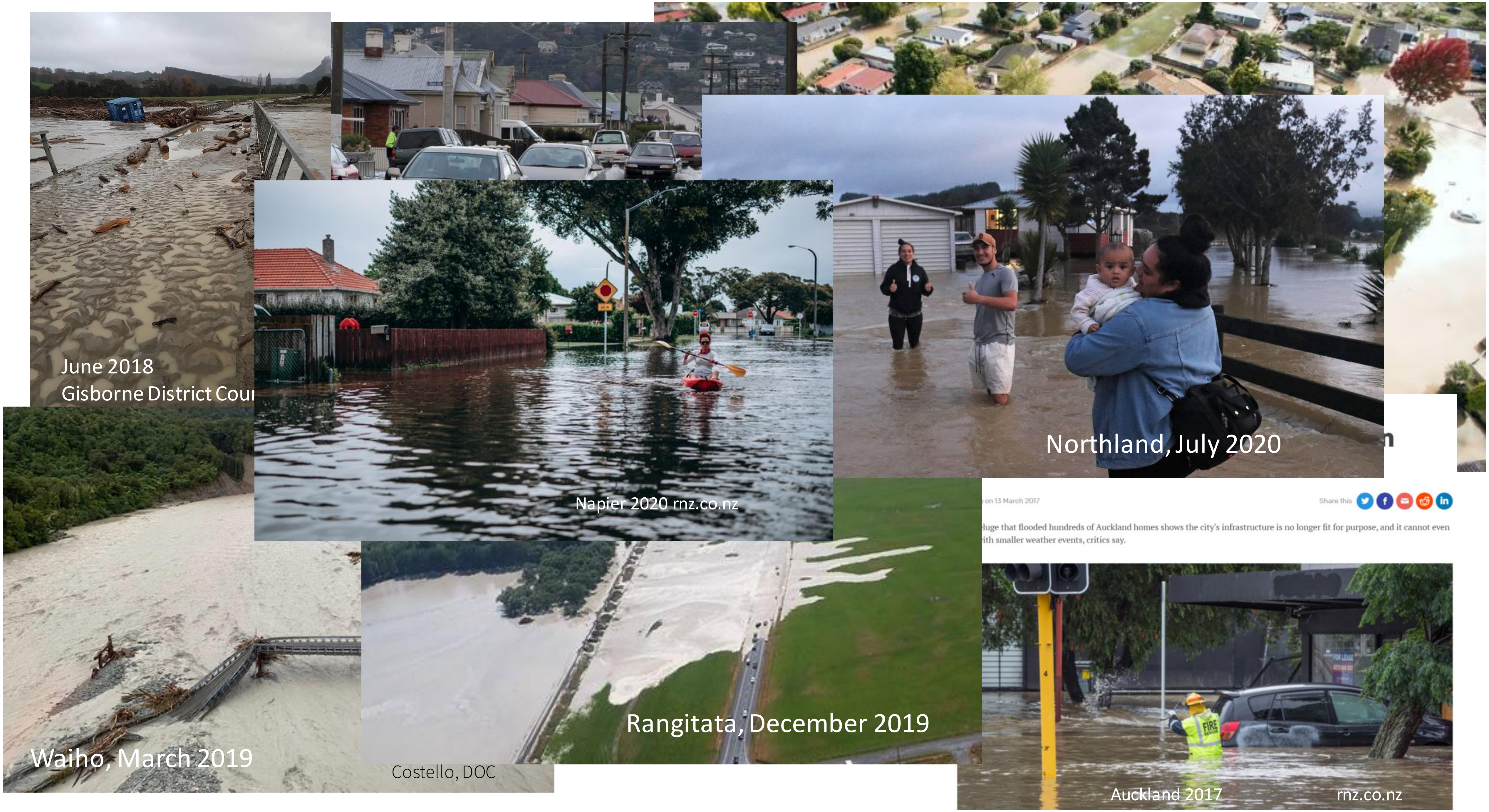
Iain White, Silvia Serrao-Neumann, University of Waikato

Matthew Wilson, University of Canterbury

- Flooding is one of the world's most frequent and destructive natural hazards. In New Zealand 16 of the 25 weather disasters tracked for insurance purposes since 2015 were floods, and they caused an estimated $200 million in insurance-claimed damage.

- Around 700,000 people and more than 400,000 buildings ($135 billion) are presently exposed to river flooding during extreme weather events

- Climate change is expected to increase flooding in NZ, but has not been well studied


June 2018
Gisborne District Cour
Napier 2020 rnz.co.nz
Northland, July 2020
on 13 March 2017
Share this
luge that flooded hundreds of Auckland homes shows the city's infrastructure is no longer fit for purpose, and it cannot even
ith smaller weather events, critics say.
Waiho, March 2019
Costello, DOC
Rangitata, December 2019
Auckland 2017
rnz.co.nz

MfE and Flooding

- The Ministry of the Environment has a key function under the Environment Act to "provide the Government, its agencies, and other public authorities with advice on the identification and likelihood of natural hazards and the reduction of the effects of natural hazards"
- The key legislation relevant to flood management in New Zealand are administered by MfE:
  - Resource Management Act,
  - Soil Conservation and Rivers Control Act
  - Climate Change Response Act

A policy to science journey

Review of Flood Management 2008, MfE:

"The current level of flood risk across New Zealand cannot be stated with any accuracy, and neither can the impact of climate change or variability be meaningfully predicted on the level of flood risk. In addition, there is no way to assess or collate comparable information around the country to make this level of analysis possible. As a result, understanding the potential flood risk requires:

- broad-scale analysis using a consistent set of parameters and approaches so flood risk can be understood across the country and hot spots identified
- understanding climate change's future effects on weather patterns in different parts of the country
- determining and accounting for uncertainty in climate change and variability, hydrological, hydraulic and economic modelling analysis."

A policy to science journey continued

- Preparing for future flooding, a guide for local government in New Zealand, 2010
- Climate projections reports 2016,18
- Adaptation Technical Working Group 2017:
- Coastal hazards and climate change: Guidance for local government, 2017
- Climate Change Risk Assessment, 2019
    - Gaps: “A lack of **consistent** hazard information at a national scale, such as flooding from rivers and surface water, results in a knowledge gap for hazard exposure”
    - Next Steps: “The national adaptation plan will respond to the priority risks, opportunities and **gaps** set out in this risk assessment”
- Inter-departmental Community Resilience Work Programme, 2020
    - Establishing baseline data sets for flood risk management for NZ and more consistent data standards for flood modelling/measurement

MBIE Endeavour 5-year Research Programme: Reducing flood inundation hazard and risk

Overall aim: A more flood-Resilient Aotearoa New Zealand

Produce a updateable nationally-consistent flood inundation hazard and risk assessment for current conditions and future scenarios under climate change.

Create a forum between science, iwi, policy-makers and stake-holders to ensure desired outcomes

Why?

National screening tool:

- Identify where the flood hazard/risk are high – especially in rural areas where there may not currently be information.
- Identify where the flood hazard/risk may increase under climate change.
- Work with local government and MfE to update guidance

Mātauranga Māori theme – Wairewa Rūnanga Case Studies

RA1: Flood Mapping
- CS1.1-2 Geofabric inputs for modelling
- CS1.3-5 Historic flood data
- CS1.5-9 Design storms
- CS1.10-12 Flood model design
- CS1.13-21 Regional and national flood mapping

RA2: Flood Risk to the built environment
- CS2.1 Dynamic flood risk tool
- CS2.2-3 Flood exposure and vulnerability assessments
- CS2.4 National flood risk assessment
- CS2.5 Uncertainty in built-environment risk
- CS2.6 Future flood risk
- CS2.7 Socio-economic costs and benefits of flood risk reduction

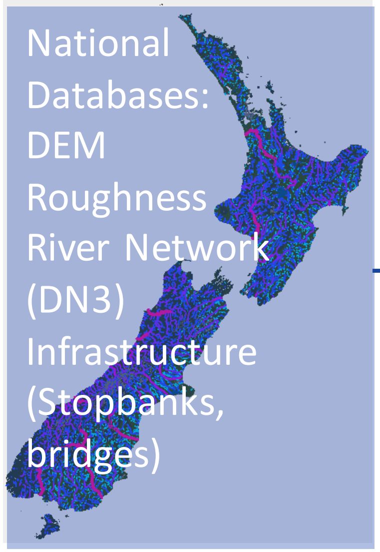
RA3: Social vulnerability to cascading events
- CS3.1-2 Case study identification and establishment
- CS3.3 Systems map of cascading impacts
- CS3.4 Exposing cascades and the existence of thresholds
- CS3.5 Useable and useful knowledge tools and practice that advance risk and vulnerability assessments

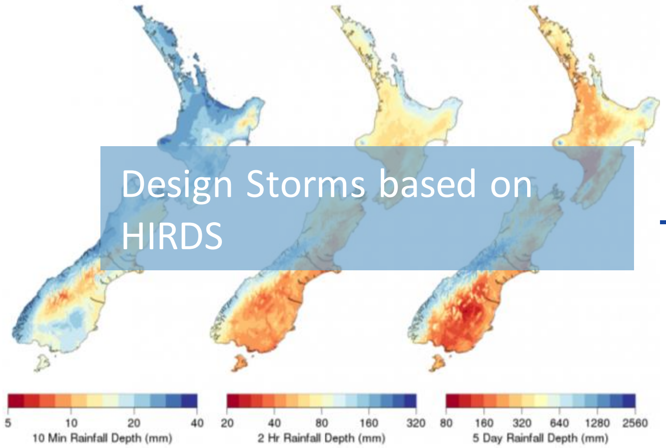
RA4: Reducing flood risk and adapting to change
- CS4.1 Establishment of the boundary organisation
- CS4.2 Science-practice roadshows
- CS4.3 Testing the usability and usefulness of information/ project outputs
- CS4.4 Designing and testing 'What if' scenarios
- CS4.5 Identifying market signals and predicting responses
- CS4.6 Developing guidance for local government
- CS4.7 Maximising the project's national long-lasting impacts

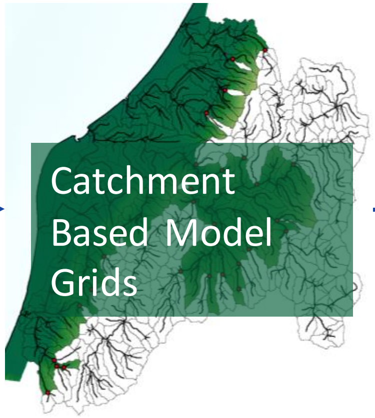
Uncertainty theme – Quantifying and communicating uncertainty

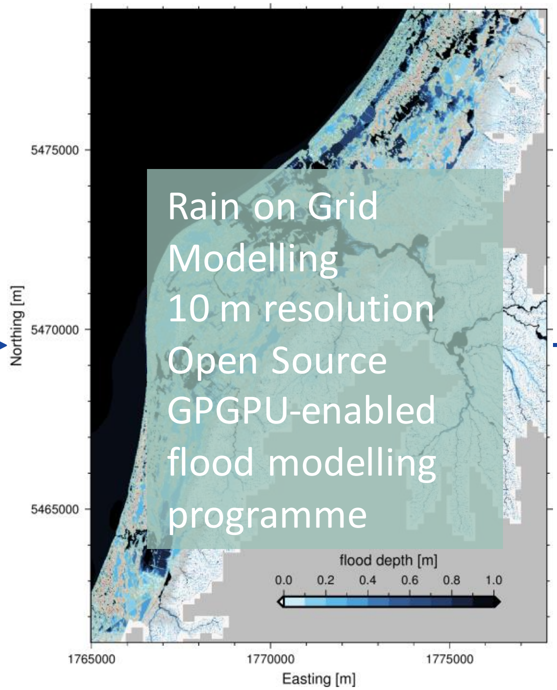
RA1 – National Flood Mapping:

Create a semi-automated system and methodology for nationally consistent flood maps for a range of design storm events, including climate change impacts, validated against a database of historical floods.



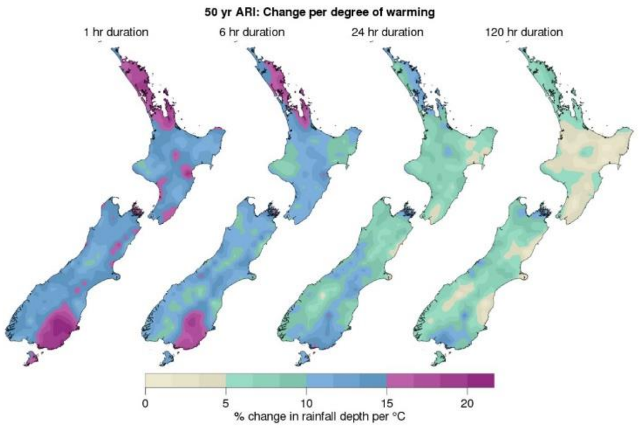


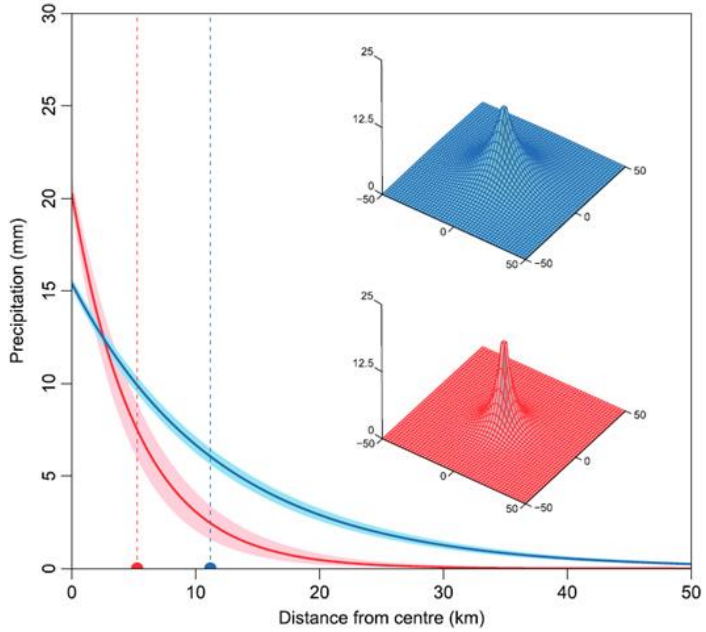




RA1 – National Flood Mapping:
Climate Change

- We live in a changing climate
- As temperatures increase, short intense rainfall events will become more frequent and 'spikier'
- These will be especially problematic in urban areas
- Sea level rise exacerbates flooding in low-lying coastal regions
- We need to understand how these changes affect our flood hazard and create a mechanism for rapid policy uptake and implementation in planning and response





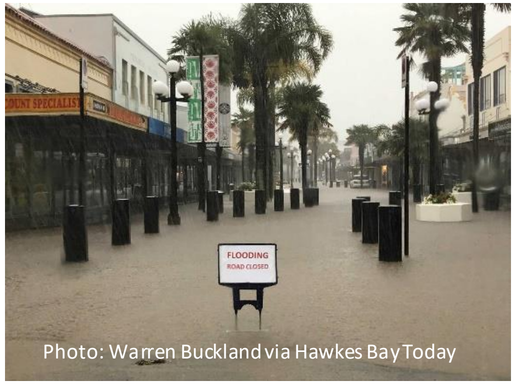
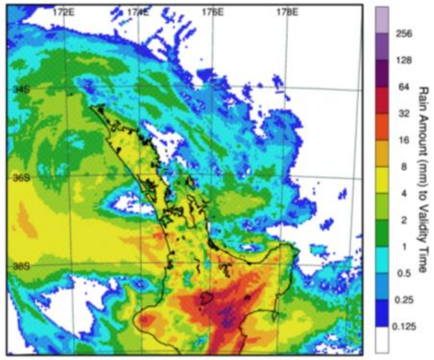
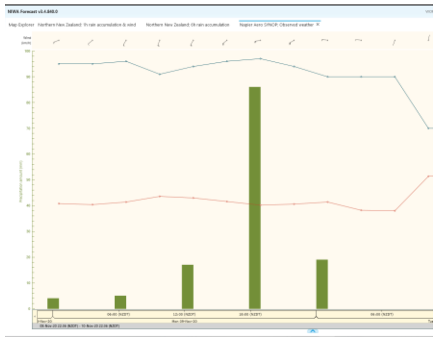


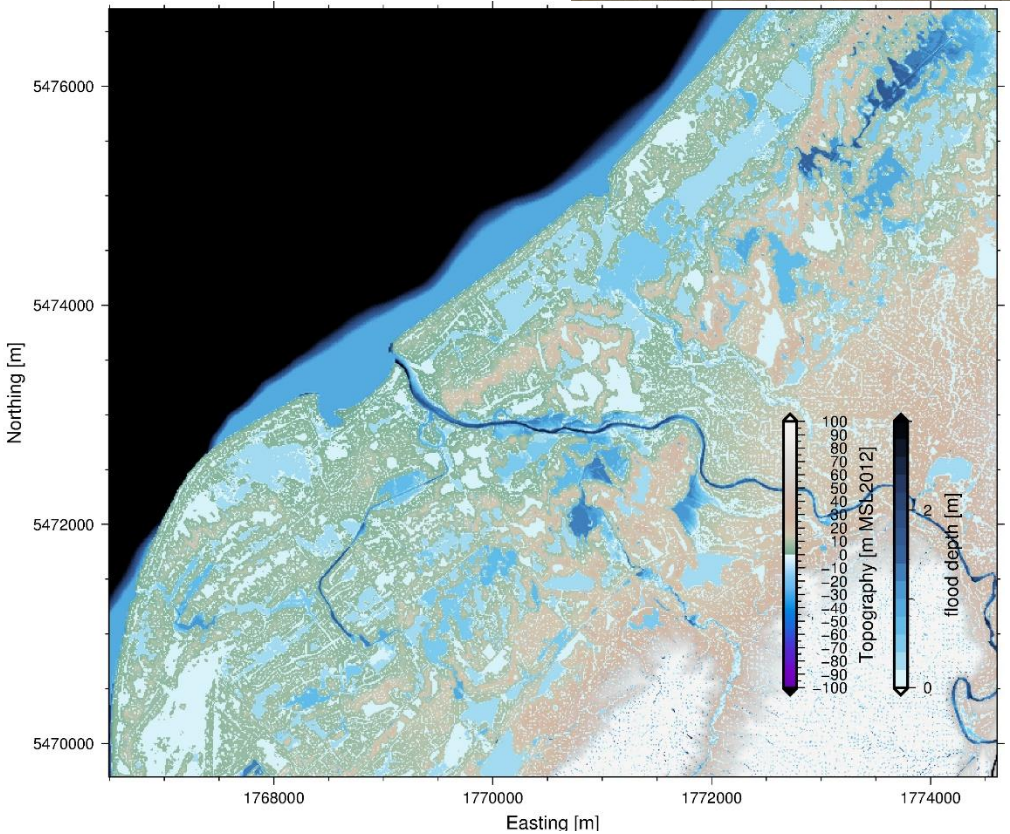
Photo: Warren Buckland via Hawkes Bay Today





RA1 – National Flood Mapping:
Flood Modelling

- Working with Local Government's River Managers Forum to ensure consistency and acceptability of approach
- Modelling will be based on catchments
- Regional prototypes will be developed first
- Both fluvial and pluvial flooding will be modelled
- BG-Flood NIWA developed model:
- GPGPU-based open-source flood model
    - Fast
    - Accurate
    - Available for anyone to use



RA1 – National Flood Mapping: Data

Flood Modelling relies on accurate underlying data:

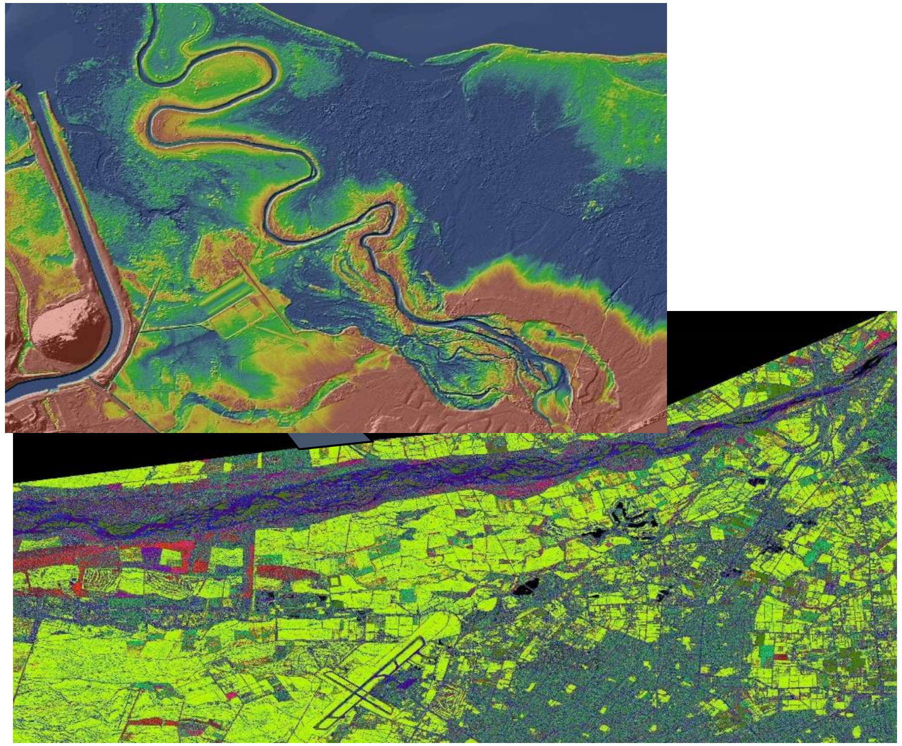
- Design storm events based on improved HIRDS (High Intensity Rainfall Design System)
- Hydraulically-conditioned Digital Elevation Model
- Roughness maps (vegetation, hard surfaces etc)
- River Networks
- Flooding Infrastructure, e.g.
    - Stopbanks
    - Bridges
    - Culverts

In conjunction with LINZ

Community Resilience work (Central-Local Government Partnership)

Historical flood events represent 'truth' and are vital to measure our modelling against:

Photo archives allow the affected public to input into science, give important context to the flood picture and are useful tools for promoting flood awareness



Vision Mātauranga

E rere kau mai te awa nui mai i te kāhui maunga ki Tangaroa, ko au te awa, ko te awa ko au.

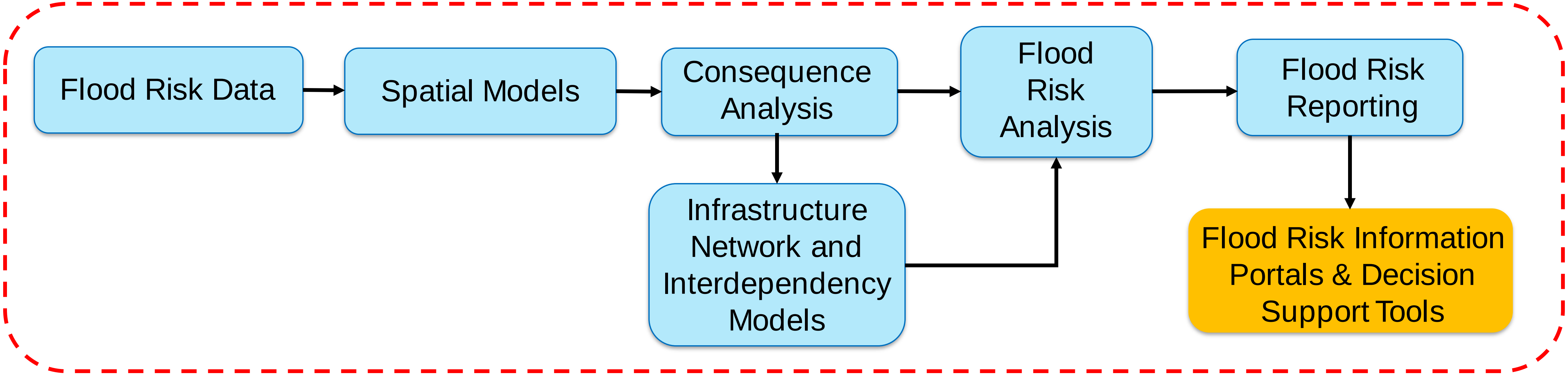
- Deep spiritual connection with the land and the rivers
- Different conceptions of risk:
  - wāhi tapu,
  - taonga species,
  - marae and other assets
- Kaupapa-Māori based solutions that enhance the mauri of the awa
- Ensuring iwi retain sovereignty of their data

Vision Mātauranga

- Working with the hapū of Wairewa Rūnanga Kāti Mako and Ngāti Irakehu
  - (Dr Benita Wakefield and Kaitiaki Advisory Group)
- Understanding knowledge of flooding from a Māori perspective
- Developing a climate change flooding strategy for the rūnanga following Te Tāhū o te Whāriki.
- More generally, developing a framework for flood risk and climate change for iwi and rūnanga across Aotearoa

Mō tātou, ā, mō kā uri ā muri ake nei

RA2 – Flood Risk to the Built-Environment



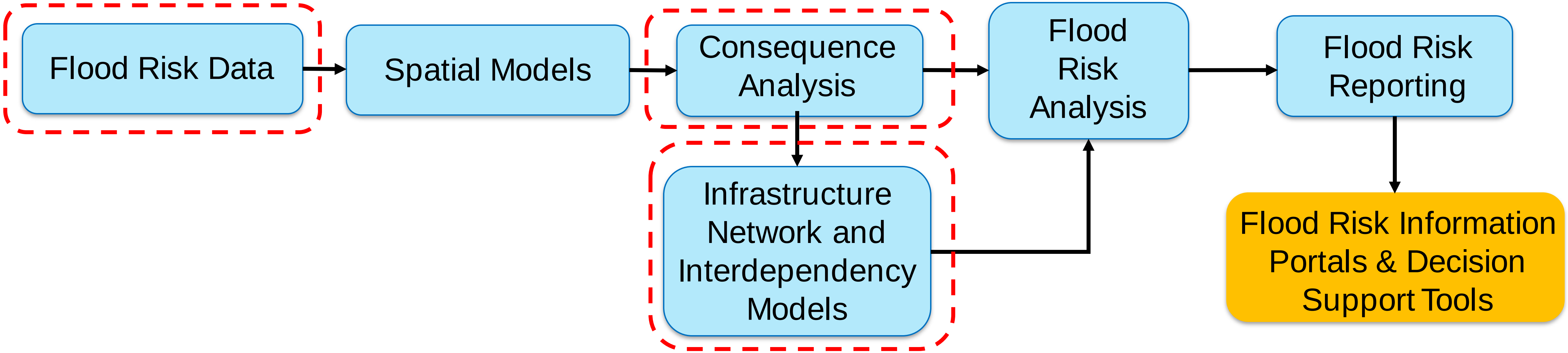
CS 2.1 Dynamic Flood Risk Tool

Key Task: Develop a flexible, user configurable modelling tool that supports socio-economic flood risk assessment in Aotearoa-New Zealand.

CS 2.5 Uncertainty in Built-Environment Risk

Key Task: Assess the effect of aleatory and epistemic uncertainties of model components and data on flood risk assessments

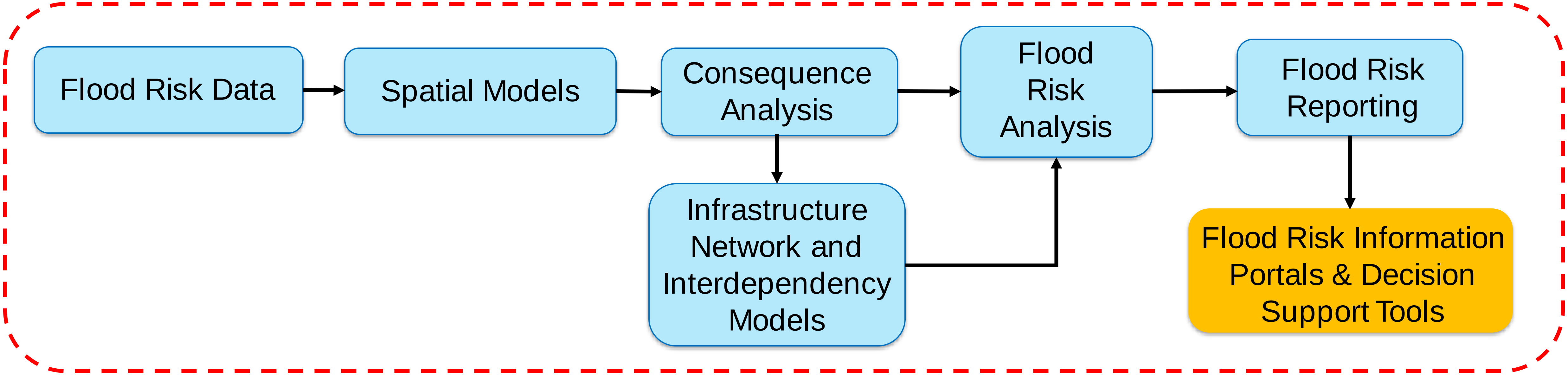
RA2 – Flood Risk to the Built-Environment



CS 2.2-2.3 Flood Exposure and Vulnerability Assessments

Key Task: Develop national-scale spatial maps and vulnerability models to assess socio-economic impacts to present-day and future built-environment land-use and structures in NZ floodplains.

RA2 – Flood Risk to the Built-Environment



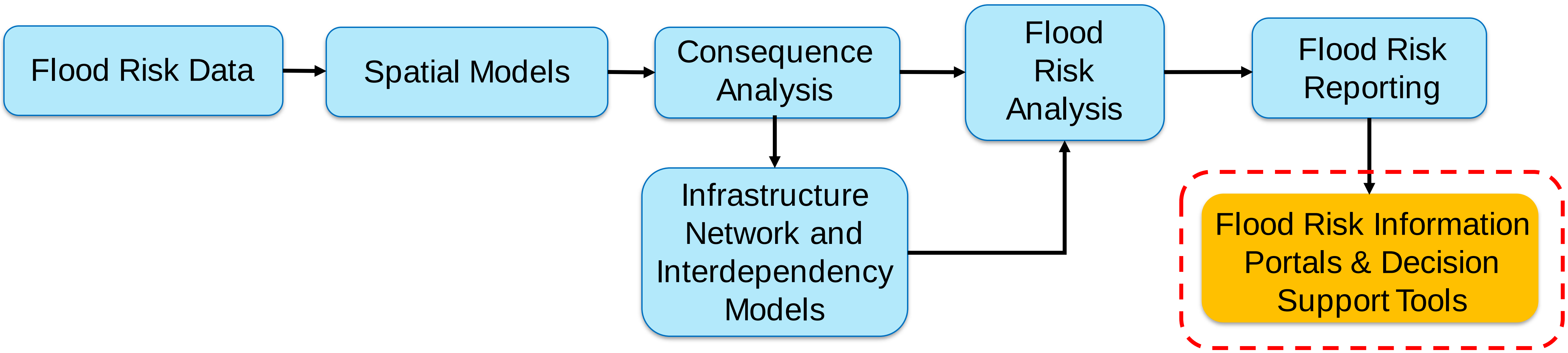
CS 2.4 National Flood Risk Assessment

Key Task: Develop a flexible, user configurable modelling tool that supports socio-economic flood risk assessment in Aotearoa-New Zealand.

CS 2.6 Future Flood Risk

Key Task: Apply the flood risk model to investigate future development scenarios along flood-prone infrastructure corridors e.g. Auckland-Hamilton-Tauranga.

RA2 – Flood Risk to the Built-Environment



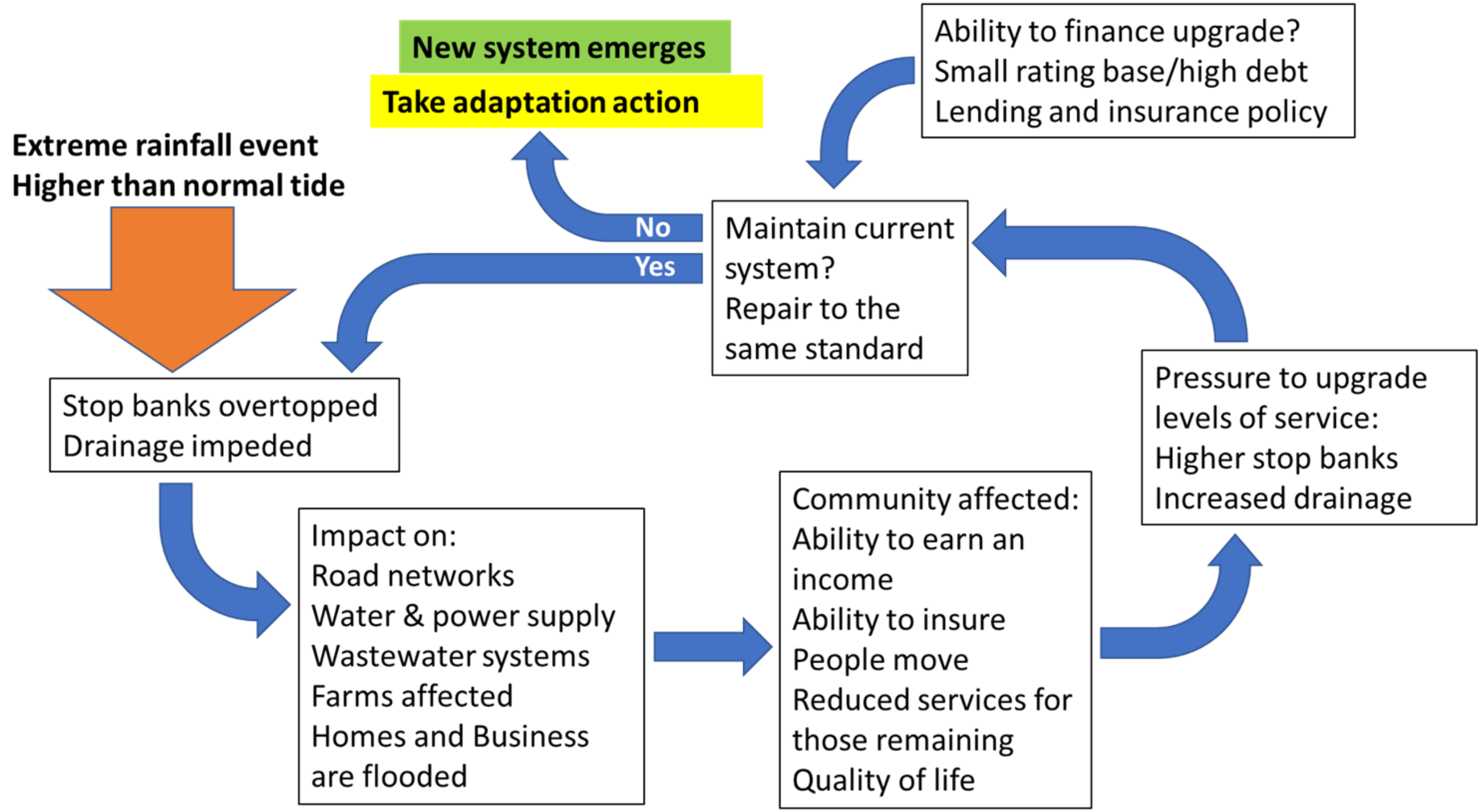
CS 2.6-2.7 Socio-Economic Costs and Benefits from Flood Risk Reduction

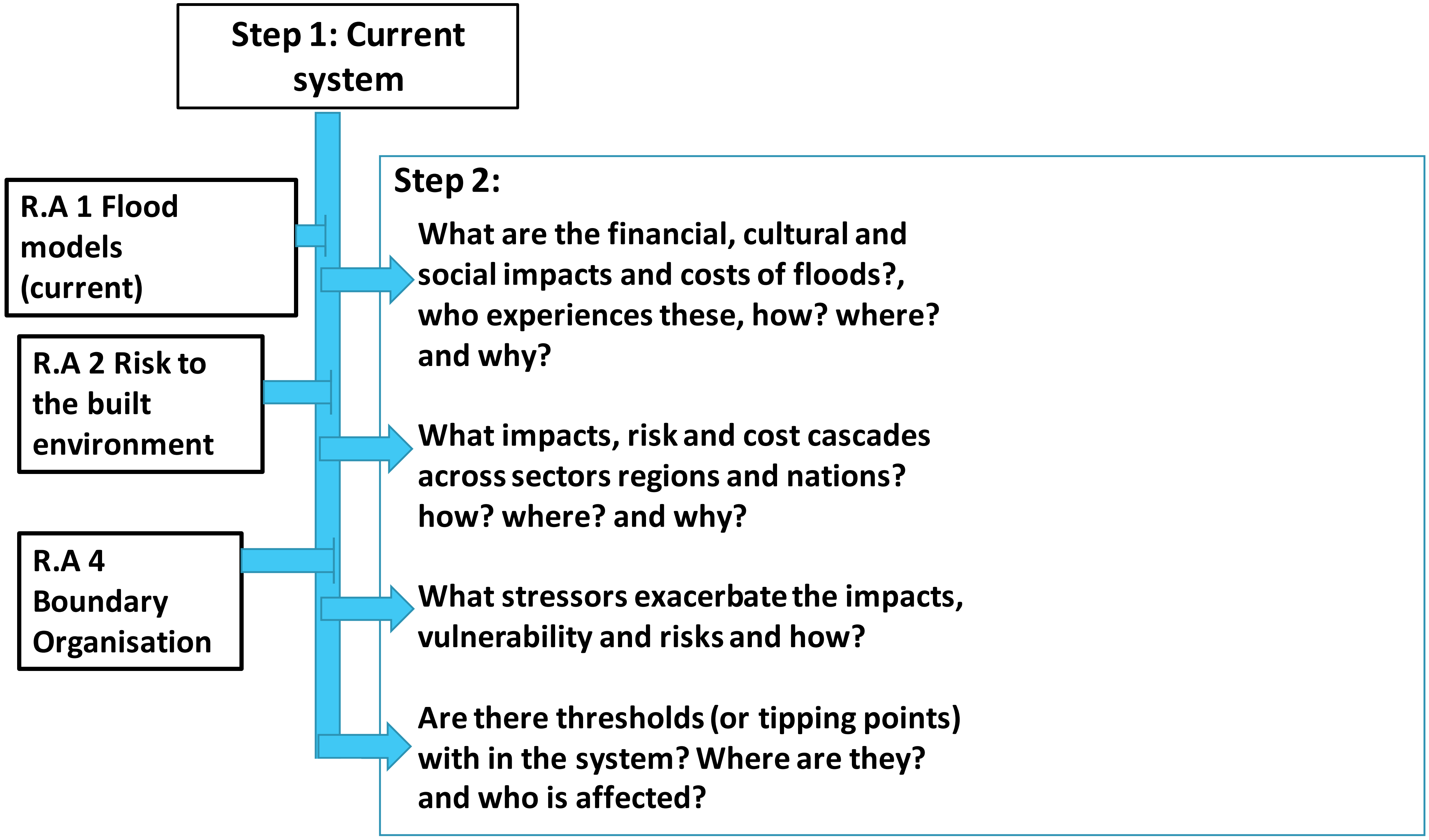
Key Task: Develop decision support tools and information portals that help practitioners test and visualise the socio-economic costs and benefits of engineering and non-engineering flood mitigation measures, or building and infrastructure design solutions that may reduce, maintain or increase flood risk for future.

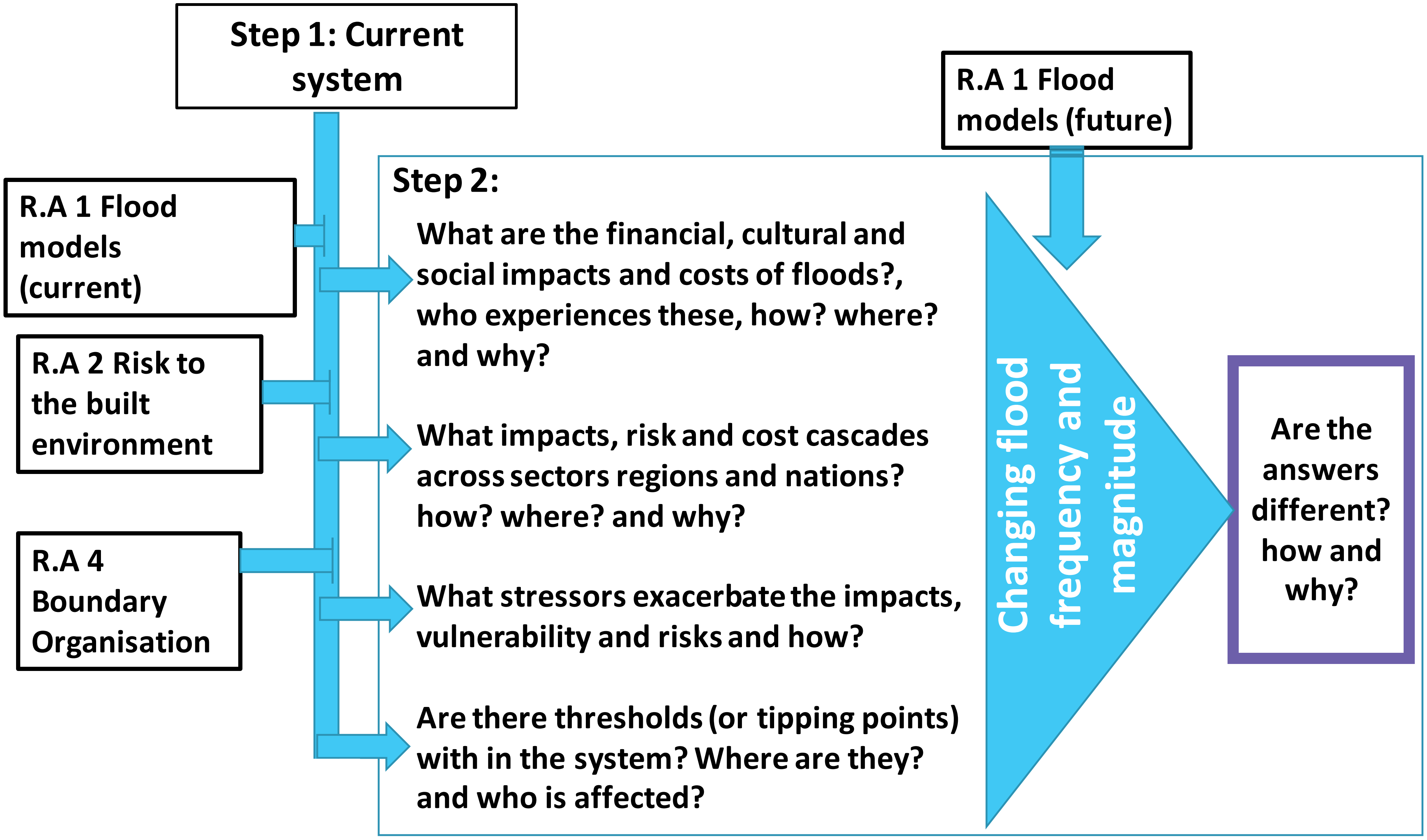
RA 3 Societal vulnerability to cascading events

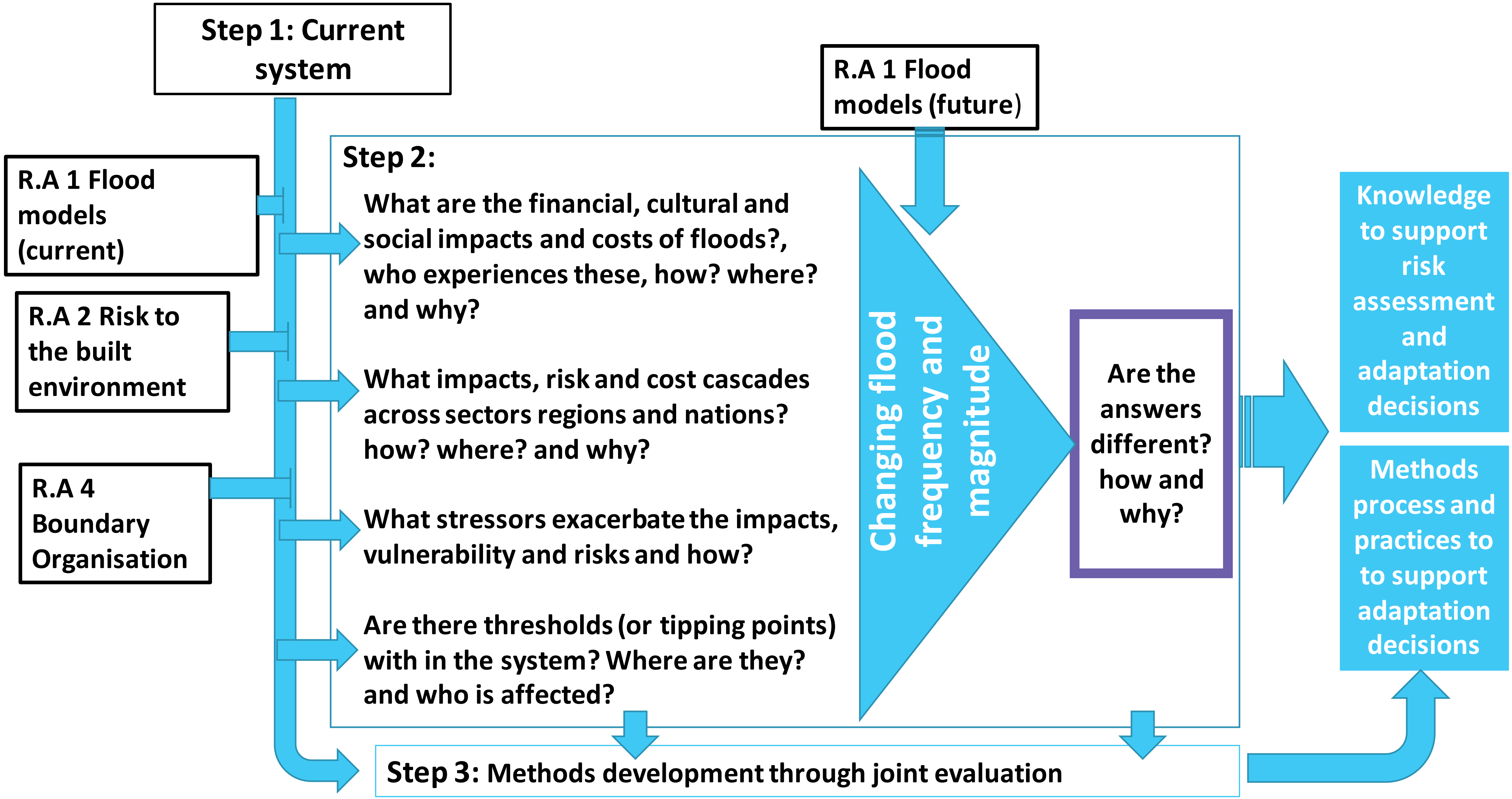
Step 1: Current system

Cascading systems loop – Stop bank breach




Step 1: Current system
R.A 1 Flood models (current)
R.A 2 Risk to the built environment
R.A 4 Boundary Organisation
Step 2:
What are the financial, cultural and social impacts and costs of floods?, who experiences these, how? where? and why?
What impacts, risk and cost cascades across sectors regions and nations? how? where? and why?
What stressors exacerbate the impacts, vulnerability and risks and how?
Are there thresholds (or tipping points) with in the system? Where are they? and who is affected?


Step 1: Current system
R.A 1 Flood models (current)
R.A 2 Risk to the built environment
R.A 4 Boundary Organisation
Step 2:
What are the financial, cultural and social impacts and costs of floods?, who experiences these, how? where? and why?
What impacts, risk and cost cascades across sectors regions and nations? how? where? and why?
What stressors exacerbate the impacts, vulnerability and risks and how?
Are there thresholds (or tipping points) with in the system? Where are they? and who is affected?
R.A 1 Flood models (future)
Changing flood frequency and magnitude
Are the answers different? how and why?



Step 1: Current system
R.A 1 Flood models (future)
R.A 1 Flood models (current)
R.A 2 Risk to the built environment
R.A 4 Boundary Organisation
Step 2:
What are the financial, cultural and social impacts and costs of floods?, who experiences these, how? where? and why?
What impacts, risk and cost cascades across sectors regions and nations? how? where? and why?
What stressors exacerbate the impacts, vulnerability and risks and how?
Are there thresholds (or tipping points) with in the system? Where are they? and who is affected?
Changing flood frequency and magnitude
Are the answers different? how and why?
Knowledge to support risk assessment and adaptation decisions
Methods process and practices to to support adaptation decisions
Step 3: Methods development through joint evaluation

RA4: Reducing flood risk and adapting to change

University of Waikato team:

Prof Iain White

Dr. Silvia Serrao-Neumann

Dr. Christina Hanna

Dr. Xinyu Fu

Image by C. Hanna 2019

Dr. Silvia Serrao-Neumann

CS4.1:What is a boundary organisation?

- **Objective**: to create and use boundary objects at the science-policy interface to solve complex societal problems (Guston 2001):

  - providing incentives and opportunities for the usability of boundary objects,
  - engaging multiple actors from the scientific and professional realms, and
  - narrowing the science-policy gap.

- In our project the boundary object is: the reduction and management of flood risks - **national flood inundation assessment**. It will provide the main platform to co-produce and co-disseminate information.

- Boundary Organisations establish collaborative arrangements and outputs at the science and policy interface to generate credible and legitimate information and outcomes

CS4.1:What is a boundary organisation?

NZ NHRP

Relevance | Legitimacy | Credibility

POLICY DOMAIN | SCIENCE DOMAIN

HYBRID BOUNDARY ZONE

- Applied science
- Demand-driven (Consultancy)
- Inter-disciplinarity
- Real time
- Timely process
- Simple information

PLATFORM DECISION-MAKING PR

1. Address national research needs
2. Research responsive to rapid change
5. Build inter-disciplinary research networks
6. End-user research engagement/uptake

Research that is responsive

'changes in policy environments

supports national response

After major hazard events, r

CRC for Water Sensitive Cities

About the CRCWSC

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) was established in July 2012. Its purpose is to help change the way we design, build and manage our cities and towns by valuing the contribution water makes to economic development and growth, our quality of life, and the ecosystems of which cities are a part.

The CRCWSC is an Australian research centre that brings together many disciplines, world-renowned subject matter experts, and industry thought leaders who want to revolutionise urban water management in Australia and overseas.

Why do we need water sensitive cities?

We exist to meet three challenges that critically affect cities and towns in Australia and across the world:

- population growth and changes in lifestyle and values;
- climate change and climatic variability; and
- challenging economic conditions.

Our vision

We envision future cities and towns, and their regions, to be sustainable, resilient, productive and liveable.

To deliver this, our mission is to:

- **research** interdisciplinary responses to water problems;
- **synthesise** diverse research outputs into practical solutions; and
- **influence** policy, regulation, and practice to promote adoption.

Our industry end users include:

- federal, state, and local governments;
- government-owned corporations, such as water corporations and utilities;
- large, privately owned companies, including the urban development sector;
- small and medium enterprises;
- training and capacity building organisations; and
- non-government and community-based organisations.

Dr. Silvia Serrao-Neumann

CS4.2: Science-Practice Road Shows

The operationalisation of the boundary organisation platform

- forum for discussion between stakeholders (e.g. government agencies, iwi) and with science partners at key times based on timelines established by CS in RAs (e.g. twice a year)
- 'Participative action translational research' (!)
- Capacity building and workshops (especially in relation to outputs from science partners)
- Validation and testing of research outputs from RA 1, 2, 3 and 4 (CS 4.4-6) for maximum credibility and legitimacy and uptake (research/ societal impact)

Possible structure

- Two-day events (with consideration to potential online delivery due to Covid-19):
- Can be used for internal purposes e.g. researchers only forum to ensure everyone knows what different research groups are doing and how it is progressing
- Presentations to stakeholders to inform what is being done and gather their feedback + other practice gaps needing attention
- Interactive workshops to discuss how research outputs can be applied in practice, inform decisions
- Mini research conferences also open to stakeholders not directly involved with the Boundary Organisations to maximise dissemination of research outputs

Dr. Silvia Serrao-Neumann

CS4.3: Testing the usability and usefulness of information/ project outputs

Primarily through Science-Practice Road Shows

Part of co-design, co-production and co-dissemination of knowledge/ information process

- The usability of research outputs for planning for reducing flood risk and adapt to change
- The enablers to the application of research outputs based on their format and readiness for use
- Future opportunities for using research outputs (how practitioners foresee any future application of outputs, especially relating to known plan/policy review cycles)
- Context (individual, organisational and/or institutional/political) in which practitioners operated that can influence the use of outputs
- Project's contribution to improving practitioner's capacity, knowledge and ability to use information
- Support for existing and future collaboration between project partners or other organisations

Professor Iain White

CS4.4: Designing and Testing 'What if' scenarios

We cannot consider future flooding and climate change as separate from future urban development. Aotearoa-NZ:

a) has a housing crisis & is experiencing huge development pressures.
b) is shifting toward more dense urban development patterns/forms
c) is changing from RMA planning to a more long-term Spatial Planning.

How can we better link climate futures with development futures? And how can we understand which development future will bring the least/most flood risk? What could we do to mitigate that?

- Working with case studies selected and designed in conjunction with other RAs (CS2.6, CS2.7, CS3.3, CS3.4) and stakeholders via the Science-Practice Roadshows, we will develop 'What if' scenarios relating to both urban and rural development options

- These will combine climate change projections with differing socio-economic scenarios to see how catchment behaviour, physical and financial exposure and risk profiles differ in response to which future land use plan is followed (e.g., differing urban densities).

- This will be a first for Aotearoa-New Zealand and provide a proof-of-concept tool for decision makers in the present to manage risk in the future; it will be particularly useful for spatial planning, infrastructure investment, and regional economy development decisions.

Dr. Xinyu Fu

CS4.5: Market signals and responses

Flood risk is rising due to climate change. There are significant implications for the real estate market because:

- 60% of local government tax income is from property tax (LGNZ)
- Over time, adaptation costs will increase and property tax income decrease (when the market prices the increasing risk of flooding)
- Exposed homes due to SLR are sold at prices 7% lower than the similar unexposed ones in the US (Bernstein et al. 2019)
- No noticeable price effect of sea-level rise in case studies in Melbourne, Australia (Fuerst and Warren-Myers 2019) and a small part of the Kapiti Coast New Zealand (Fillippova et al. 2020)

We know little about whether and to what extent the NZ market pricing will respond to the climate change risk.

1. How NZ markets price the long-run risks of climate change?

   Build models using property sales transaction data, bank lending data, and/or insurance premiums to empirically unveil market signals and trends with respect to climate change

2. What are the plausible reasons for the market (non)responses?

   Conduct surveys with property owners, government officials, bankers, insurance companies, etc. to understand risk perceptions from a variety of stakeholders and to provide contextual reasoning for market (non)responses.

3. What are the planning and policy insights and/or implications for governments?

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. Journal of Financial Economics.
Fuerst, F., & Warren-Myers, G. (2019). Sea Level Rise and House Price Capitalisation. Available at SSRN 3359289.
Filippova, O., Nguyen, C., Noy, I., & Rehm, M. (2020). Who Cares? Future Sea Level Rise and House Prices. Land Economics, 96(2), 207-224.

Dr. Christina Hanna

CS4.6: Guidance for Local Government

Aotearoa-New Zealand currently has a **fragmented risk governance system** across and between the levels of government.
There is a lack of a clear national directive, long-term planning and information gaps affecting local flood risk management.
There is a need to ensure that the findings of the project inform national and local decision making.

- Bringing together the tools and findings of RA1-RA4, we will be working collaboratively with key project partners to inform policy guidance for how the flood risk information should be used for decision-making purposes within flood policy, planning and local community engagement processes.

- This work will integrate key tools developed in CS4.4: “What if” scenarios and CS4.5:Market signals and responses

Lead: Prof Matt Wilson,
University of Canterbury

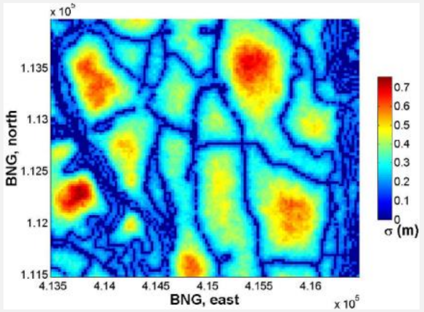
Team includes:
- 3 x PhDs, 2 x MSc
- 1 x Postdoc based at NIWA
- Full research programme team.

Uncertainty Theme

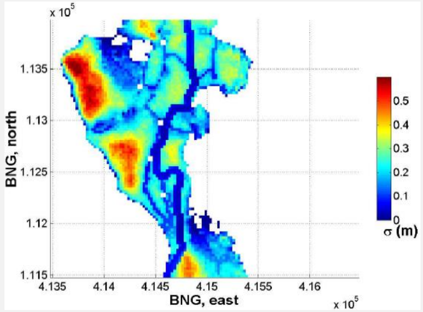
- Policy-makers need to be able to make decisions despite uncertainty in scientific predictions
- Better quantification, understanding and visualisation of those uncertainties leads to better outcomes
- Uncertainty in flood risk assessment results from many sources, e.g.:
  - **Errors in the numerous data sources**
  - **The structure and hydraulic formulations of the models**
  - Representativeness of possible futures
- Uncertainty "cascades" through the modelling/ analysis chain

***Uncertainty* is a cross-cutting theme that will assess the drivers and consequences of uncertainty and work with end-users to design, test and establish novel decision-making practices.**

Elevation data matters: uncertainty in floodplain topography leads to uncertainty in flood model predictions of depth:



Standard deviation in elevation for ~100 realisations of interpolated topographic survey data. Each realisation has equal likelihood.



Standard deviation in flood depth for ~100 simulations using these data.

Wilson, M.D. and Atkinson, P.M., 2005. Prediction uncertainty in floodplain elevation and its effect on flood inundation modelling. *GeoDynamics*, pp.185-202.

Uncertainty Theme

Quantifying and communicating uncertainty in flood risk.

RA1: Flood mapping

- *What impact does uncertainty in all components of the modelling chain have on flood predictions?*
- *How does variability in the “GeoFabric” datasets affect flooding results?*
- *How does uncertainty cascade through the modelling system?*
- *How can we optimise model inputs to deal with uncertainty using novel methods of modelling and machine learning?*
- *Can we use hybrid approaches of hydraulic modelling and machine learning for rapid scenario assessment?*

RA2: Flood risk to the built environment

- *How does uncertainty in land use and build environment assets affect our flood risk assessments?*
- *What is the uncertainty in our estimates of socio-economic impacts for present and future scenarios?*

RA3: Social vulnerability to cascading events

RA4: Reducing flood risk, adapting to change

- *How can we visualise, communicate and make the optimum planning decisions which account for uncertainty?*

Summary

- MfE is a critical stakeholder for the successful uptake of this research programme
- First workshop on working together to be held this afternoon

If you have further questions, want to receive updates, or be involved in the research programme contact Caterina Joseph or any of:

emily.lane@niwa.co.nz

sam.dean@niwa.co.nz

ryan.paulik@niwa.co.nz

paula.blackett@niwa.co.nz

silvia.serrao-neumann@waikato.ac.nz

iain.white@waikato.ac.nz

matthew.wilson@canterbury.ac.nz