Cascading coastal inundation losses on Māori taonga in the southern Marlborough district

Integrating Te Ao Māori with contemporary science to quantify compounding coastal inundation losses for adaptive resilience

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Executive Summary

This research addresses a critical gap in Aotearoa New Zealand's hazard assessment and planning processes pertaining to limited quantitative data on how extreme coastal events, compounded by sea-level rise (SLR), impact Māori taonga and whenua, as determined by them.

Te Pokohiwi o Kupe (Wairau Bar) is a site of national significance, dating to c. 1280 AD and often described as the "birthplace of the nation". For Rangitāne o Wairau this significant site is a cornerstone of their identity and whakapapa. Building on precursor research that identified that the rate of SLR is currently outpacing the natural morphological growth of the Boulder Bank at Te Pokohiwi o Kupe, this project expanded the focus to the wider Wairau area in the southern Marlborough district and explored how mātauranga Māori—informed by the needs, traditional environmental knowledge and lived experiences of Rangitāne o Wairau—could be woven with conventional science to produce more holistic and culturally responsive hazard risk assessments (Figure 1). In this context, risk is defined not solely in monetary or structural terms, but encompasses the potential for cultural disruption, ecological damage, emotional stress, and economic loss to Māori communities and their taonga as a consequence of hazard exposure.

A key outcome of this research was the development of pioneering Rangitāne o Wairau led consequence functions. These functions enable 'risk' to be modelled based on cultural, emotional, and ecological values, complementing more conventional economic and technical metrics. By integrating these functions into the RiskScape multi-hazard risk modelling platform, the project co-developed and tested a new approach to quantifying hazard risks for present and future climate scenarios in a way that responds to Māori communities and respects Māori data sovereignty.

The hazard modelling component employed the BG-Flood 2D hydrodynamic software suite, simulating tsunami scenarios from the Hikurangi subduction zone (Mw 9.0), the Wairarapa-Nicholson fault (Mw 8.6, Mw 8.1), and incremental SLR from 0.1 m to 2.0 m. These scenarios were overlaid with Rangitāne o Wairau taonga exposure layers and processed through RiskScape using the novel iwi-led consequence functions across four impact domains: Cultural Disruption, Economic Loss, Emotional Stress, and Ecological Damage.

Ultimately, this project provides a methodological exemplar for potential roll-out and upscaling in other regions and Māori communities across Aotearoa. It demonstrates that while physical landscapes face inevitable change, the kōrero (narratives) remain an enduring taonga that whānau can protect through iwi-led adaptation planning and intergenerational knowledge sharing.

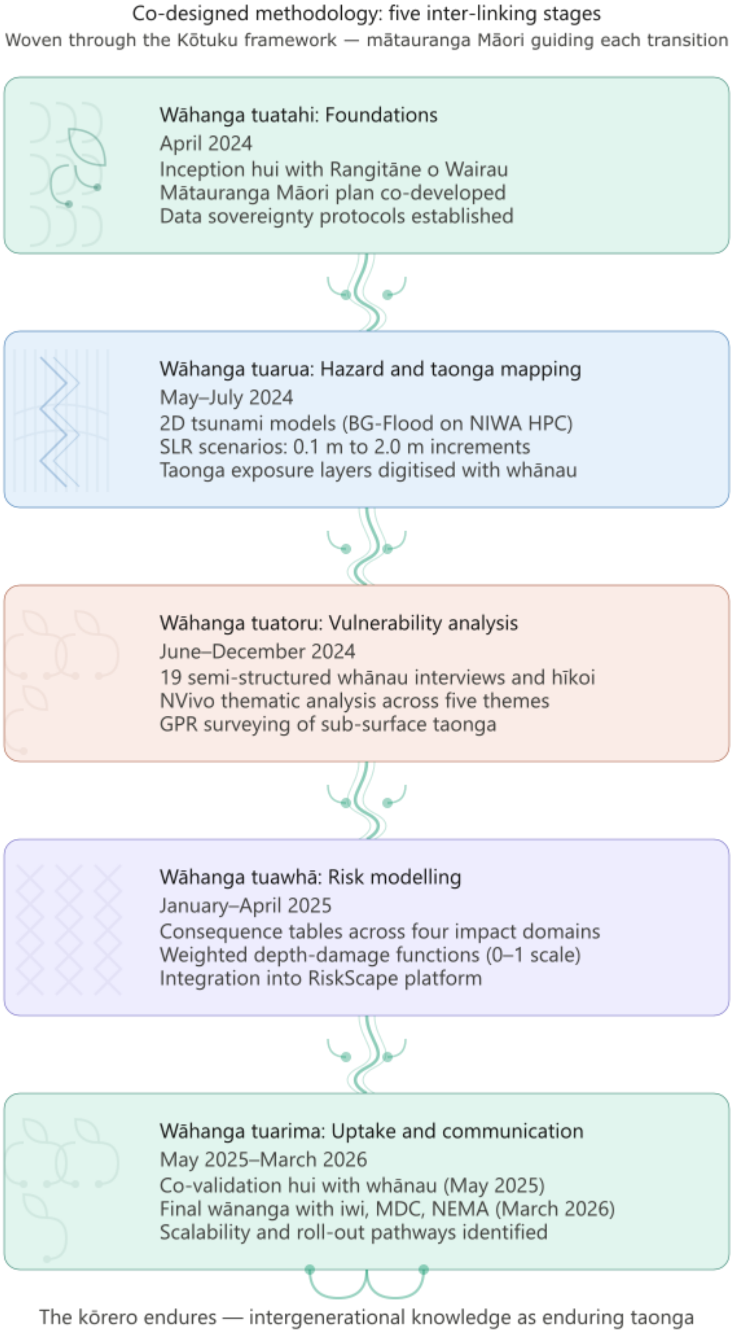

Figure 1: Five methodological stages of the co-designed research approach, connected by the awa (river) motif with koru transitions representing the inter-linking technical stages underpinning the progression of the project.

Study Aims and Objectives

This research aimed to establish a holistic, mātauranga-led pathway for integrating Indigenous knowledge systems into quantitative coastal hazard assessments. Building on precursor findings that sea-level rise (SLR) is currently outpacing the natural morphological growth of the Boulder Bank at Te Pokohiwi o Kupe, this project expanded the focus to the wider Wairau area.

Using a co-designed research framework (Figure 1), the project set out to combine 2D hydrodynamic tsunami and sea-level inundation modelling with semi-structured interviews and hīkoi involving Rangitāne o Wairau whānau members.

A key objective was to develop Aotearoa New Zealand's first iwi-led consequence functions and integrate them into the RiskScape modelling platform, to provide a baseline, scalable, template for iwi-inclusive hazard planning and smarter land-use decision-making across the country.

Prior Work

This research builds upon a precursor SLR exposure study of wāhi tapu at the Wairau Bar, which identified that SLR is occurring faster than the natural growth of the Boulder Bank (i.e., a critical threshold), which will place significant parts of the whenua at risk within our lifetimes (Williams et al., 2025; Figure 2). It also aligns with SLR assessment studies for the Marlborough district implemented by Marlborough District Council (MDC) and Earth Sciences NZ.

Previous tsunami inundation assessments for the Marlborough region used one-dimensional Level-2 attenuation-based representations (Scheele et al., 2023). A high-resolution 2D inundation model had been completed, but only for the Lake Grassmere area (Pizer et al., 2021). This project extends this work by developing 2D hydrodynamic tsunami models for the broader Wairau Plains, representing a significant advance in spatial resolution and hazard characterisation for the region.

Historical records and the National Probabilistic Tsunami Hazard Model (Power et al., 2023) confirm Te Koko-o-Kupe/Cloudy Bay is exposed to destructive tsunamis from regional sources (Hikurangi subduction zone, Wairarapa-Nicholson fault) and far-field sources (Peru subduction zone). The most significant recorded tsunami at the Wairau Bar resulted from the 1855 Wairarapa earthquake, reaching approximately 4.2 m above the high-water mark (McFadgen & Adds, 2018).

Figure 2: Location map of Te Pokohiwi o Kupe within the rohe of Rangitāne o Wairau.

Keywords

Tsunami, Sea-level Rise, Coastal Inundation, Quantifying hazards and risk, Mātauranga Māori, Climate Change, Supporting people and decisions

Introduction

Te Pokohiwi o Kupe (Wairau Bar) is a site of national significance, dating to c. 1280 AD and often described as the "birthplace of the nation”. For Rangitāne o Wairau—kaitiaki of the area—the site is a cornerstone of identity and whakapapa. Recent studies have identified the site to be at major risk to the impacts of rising sea level inundation and potential erosion (Williams et al., 2025), with detailed risk modelling required. However, conventional hazard risk modelling frameworks typically focus on quantitative economic metrics, often overlooking the relational and cultural dimensions of risk (Kaiser et al., 2025; Parsons & Jayawardena, 2026).

Building on precursor research at Te Pokohiwi o Kupe (Williams et al., 2025), the primary objective of this project co-designed by Earth Sciences NZ and Te Rūnanga a Rangitāne o Wairau, was to address critical methodological and knowledge gaps around how mātauranga Māori can be integrated into conventional hazard risk modelling assessments, through a case study exploring inundation hazards on Māori whenua and taonga across the wider Wairau region.

Flooding and coastal erosion are intensifying under climate change across Aotearoa New Zealand. Under a high-emissions scenario (SSP5-8.5), sea levels could rise by approximately 1 m by 2100 (MfE, 2024), threatening coastal infrastructure and wāhi tapu like the Wairau Bar. Furthermore, approximately 40% of Aotearoa coastline is already eroding (University of Auckland, 2025). Recent findings indicate up to 75% of Te Pokohiwi o Kupe could be inundated by 2100 under a 1 m SLR scenario (Williams et al., 2025). For Rangitāne, the degradation of wāhi tapu, disruption of mahinga kai, and erosion of urupā represent significant cultural and emotional losses that are not adequately captured by conventional risk modelling assessments (Bailey-Winiata et al., 2024 and 2025; Jones et al., 2024; Serrao-Neumann et al., 2024).

Te Pokohiwi o Kupe is one of many archaeologically and culturally significant coastal locations across Aotearoa at risk of being lost without documentation or understanding of the impacts such loss may cause (Meihana, 2022). Embedding mātauranga Māori within hazard assessment frameworks offers a pathway toward more holistic and culturally responsive methods for understanding climate risk.

Methodology

Key terms used throughout this report are defined as follows:

- **hazard** refers to the physical inundation event (tsunami or sea-level rise);

- **exposure** refers to the taonga, whenua, and assets located within the hazard zone;
- **consequence** refers to the culturally defined impact of a given hazard intensity on exposed values, as determined by Rangitāne o Wairau; and
- **risk** is the product of hazard, exposure, and consequence, quantified here through the iwi-led consequence functions integrated into the RiskScape modelling platform. For the purposes of this report, risk is defined holistically to encompass the potential for cultural disruption, ecological damage, emotional stress, and economic loss arising from hazard exposure on Māori taonga and whenua, extending beyond conventional monetary or structural metrics.

The project followed a co-designed methodology implemented across five inter-linking technical stages (Figure 1), which were as follows:

1. Foundations (April 2024):
    - Held inception hui and co-developed a Mātauranga Māori Plan to explicitly define the gathering, use, and protection of Rangitāne o Wairau mātauranga and data.
    - The Mātauranga Māori Plan also sets out how mātauranga Māori and associated data are accessed, interpreted, stored, and used both within and beyond the project, affirming Rangitāne o Wairau authority over all mātauranga shared or generated (e.g., Smith, 2012).
2. Hazard and Taonga Mapping (May–July 2024):
    - Developed 2D hydrodynamic models using the BG-Flood software suite on the Earth Sciences NZ High Performance Computer (HPC). Scenarios included tsunami events (M9.0 Hikurangi fault; M8.6 and M8.1 Wairarapa-Nicholson fault). These were used alongside SLR maps described in Williams et al., (2025).
    - Developed digitised exposure layers for wāhi tapu, buildings, and mahinga kai in collaboration with Rangitāne o Wairau whānau (Figure 3).
3. Consequence Analysis (June–December 2024):
    - Conducted 19 semi-structured interviews with Rangitāne o Wairau kaumātua and whānau members to document intergenerational connections to the Wairau awa and historical flood impacts. Guiding interview questions were co-developed with Rangitāne o Wairau. The qualitative methods used combined interviews with hīkoi, allowing for place-based storytelling.
    - Interviewees were selected by Rangitāne o Wairau kaimahi based on their whakapapa and long-standing connections to the area. Transcripts were analysed using NVivo software, with initial coding organised under multiple headings which then consolidated into five overarching themes.
    - Applied drone-based and ground-based GPR using three antennas (penetrating up

to 6 m) to map any sub-surface structures indicative of potential archaeological taonga at Te Pokohiwi o Kupe.

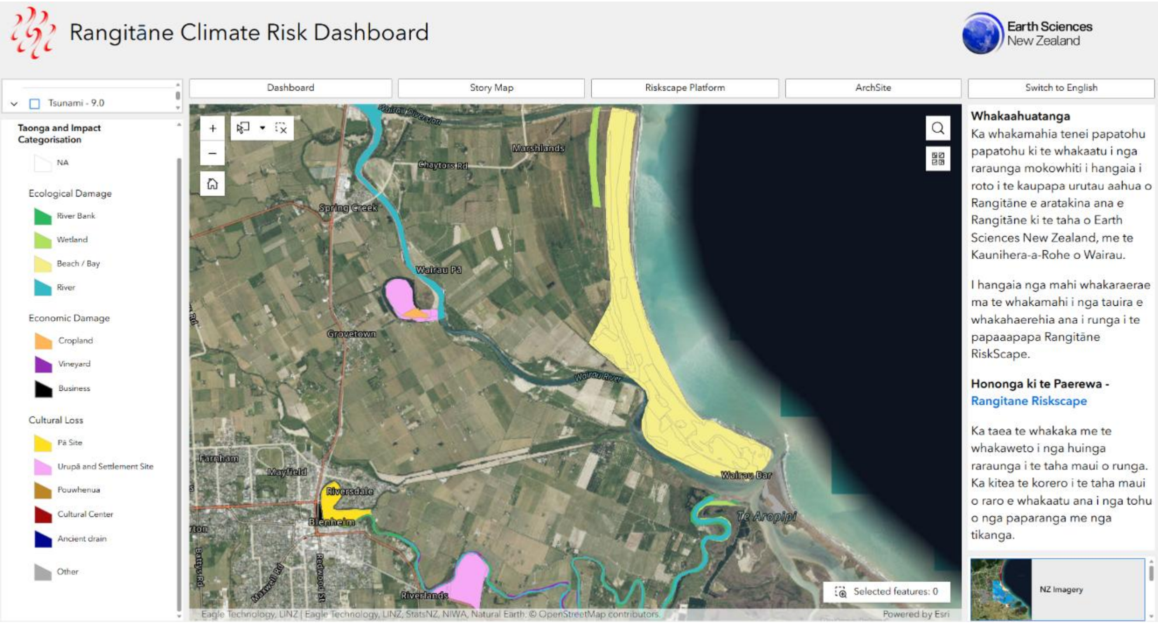

Figure 3: Taonga exposure layers co-mapped in collaboration with Rangitāne o Wairau.

4. Risk Modelling (January–April 2025):
   - Thematic analysis to classify and co-develop thematic consequence tables of flood inundation impacts across four domains: Cultural Disruption, Economic Loss, Emotional Stress, and Ecological Damage.
   - Derived weighted flood inundation depth-impact statistical relationships, codified and integrated them into the RiskScape platform (Paulik et al., 2022).
5. Uptake and Communication (May 2025–March 2026):
   - Hui with Rangitāne o Wairau kaumātua and whānau in May 2025 to validate the consequence tables developed, with a final wānanga in March 2026 to discuss the findings as well as potential scalability and roll-out with other interested iwi (e.g., Te Ātiawa), regional (e.g., MDC) and national agencies (e.g., Natural Hazards Commission Toka Tū Ake and National Emergency Management Agency).

Hazard Modelling

The 2D tsunami inundation models were developed using the BG-Flood numerical software modelling suite, which solves the non-linear shallow water equations on an adaptive computational grid. BG-Flood has been validated against standard tsunami benchmarks and previously applied to support national-scale tsunami hazard assessments in Samoa (Bosserelle et al., 2020). The model domain covered the Eastern part of Cook Strait, from Queen Charlotte's Sound to the southern Hikurangi subduction zones and from Castle Point in the north to Kaikōura in the south. The model's adaptive grid focused on Te Koko-o-Kupe/Cloudy Bay, Clifford Bay, and the Wairau Plains, with adaptive grid resolution ranging from approximately 100 m offshore to 10 m in nearshore areas of interest.

Key input datasets included: (a) the Marlborough hydraulically conditioned LiDAR DEM; (b) NIWA offshore bathymetry data; (c) co-seismic vertical displacements calculated using complex fault models (Mueller et al., 2014); (d) tide and sea-level gauge network data from NIWA and MDC; and (e) the National Probabilistic Tsunami Hazard Model of tsunamigenic seismic sources and wave heights at coasts (Power et al., 2023) (Figure 4). Land-surface roughness was assigned based on the national land-cover database.

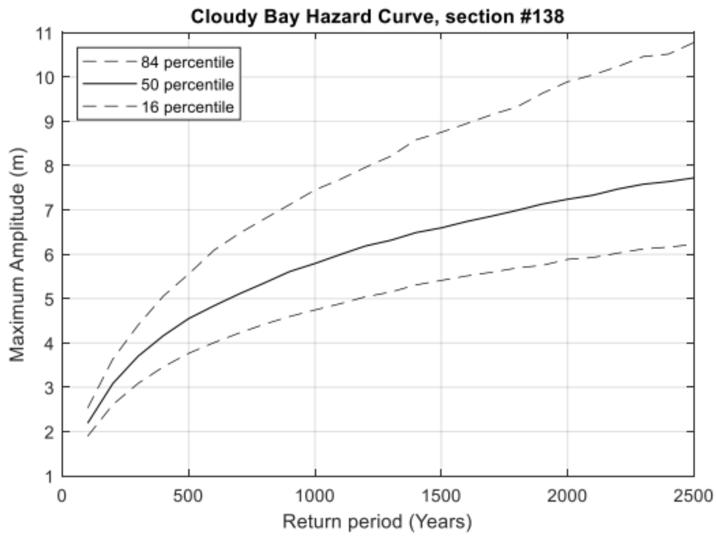

Figure 4: Tsunami hazard curve for Te Koko-o-Kupe/Cloudy Bay showing the probability-wave height relationship for regional and far-field sources (sourced from Power et al., 2023).

Tsunami scenarios were selected to represent the 2,500-year return period (84th percentile) maximum credible event for the Hikurangi subduction zone (Mw 9.0) and the Wairarapa-Nicholson fault (Mw 8.6), as well as 500-year events (Mw 8.5 and Mw 8.1, respectively) (Figure 5; Figure 6). Each scenario was simulated at present-day mean high-water springs (MHWS). Model outputs comprised geospatial maps of inundation extent, depth (D), velocity (V), and energy flux (DV) in netCDF and GeoTIFF formats.

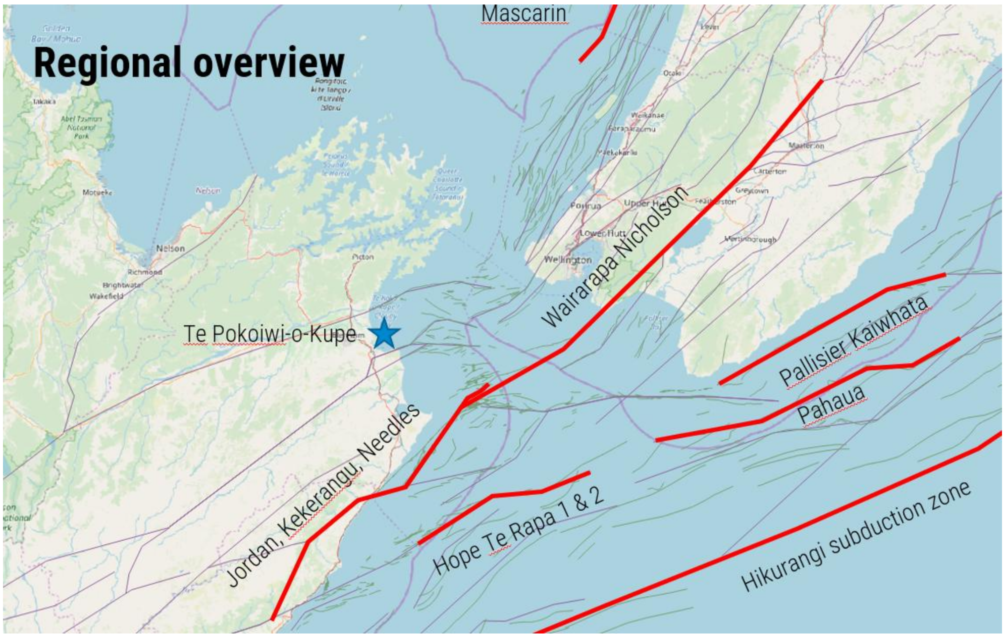

Figure 5: Simulated maximum tsunami inundation depth for the Mw 9.0 Hikurangi scenario at present-day sea level, showing extent across the Wairau Plains and Te Pokohiwi o Kupe.

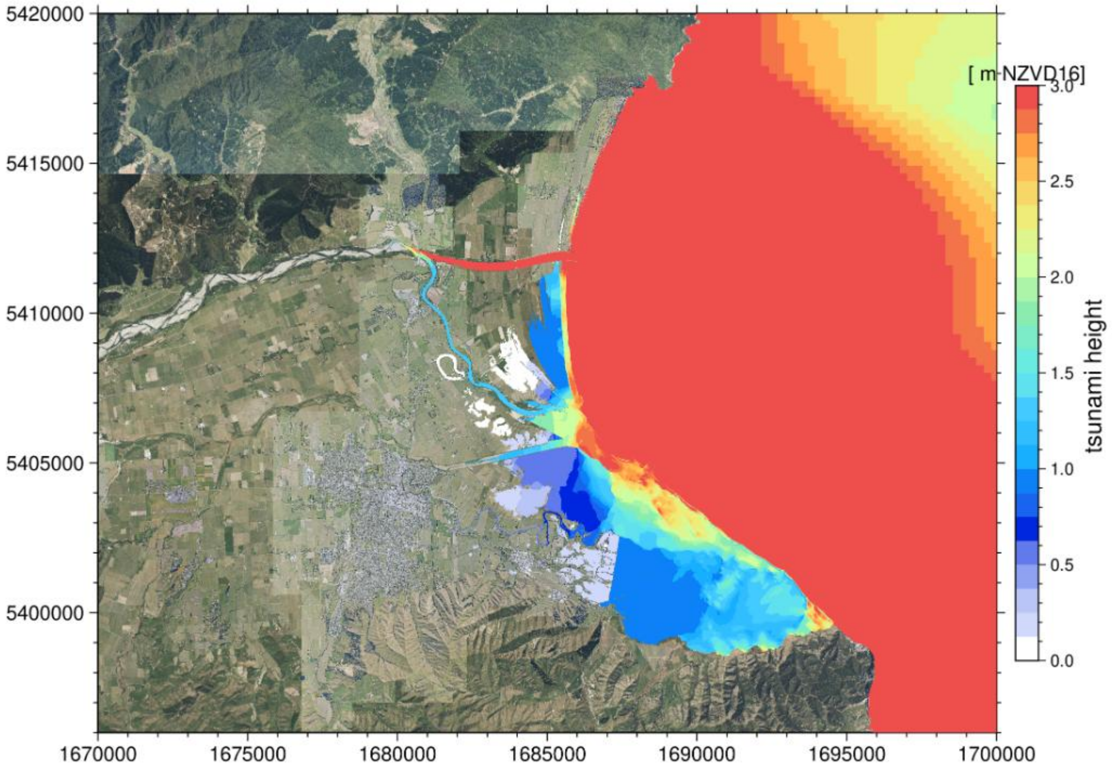

Figure 6: Simulated maximum tsunami height for the Mw 9.0 Hikurangi scenario at present-day sea level, showing extent across the Wairau Plains and Te Pokohiwi o Kupe.

For static SLR scenarios, the inundation model used a bathtub approach combined with hydraulic connectivity analysis to represent permanent spring tide layers (MHWS-10 + SLR at 0 m, 0.5 m, 1.0 m, 1.5 m, and 2.0 m) as well as 100-year storm surge events superimposed on SLR increments. These SLR scenarios were aligned with IPCC SSP mitigation pathway projections as described in Ministry for the Environment (MfE) coastal hazard guidance (MfE, 2024).

Coastal SLR and fluvial-pluvial inundation representations were also sourced from aligned collaborative work being led by MDC, ensuring consistency with regional baseline datasets. A summary distinguishing existing datasets from new project outputs is provided in Table 1.

Table 1. Distinction between existing baseline datasets/models and new outputs developed through this project.

Component	Existing (pre-project)	New (this project)
LiDAR DEM	MDC hydraulically conditioned LiDAR	Integrated into BG-Flood adaptive grid
Offshore bathymetry	NIWA national bathymetry dataset	Merged with LiDAR for coastal model domain
Tsunami scenarios	1D Level-2 attenuation zones (Scheele et al., 2023)	2D BG-Flood simulations for 5 fault scenarios × SLR increments
SLR inundation	Static inundation SLR models (via Deep South National Challenge programme)	Static inundation SLR models (Te Pokohiwi o Kupe area) – obtained from Williams et al. (2025)
Exposure layers	No cultural asset layer existed	Co-developed taonga exposure layer with Rangitāne o Wairau whānau
Consequence functions	Standard RiskScape economic depth-damage curves	Iwi-led 4-domain consequence functions
GPR subsurface data	None	Drone-based and ground-based GPR surveys at Te Pokohiwi o Kupe

Iwi-led Consequence Function Development

A central innovation of this project was the translation of qualitative mātauranga Māori into quantitative consequence functions suitable for integration into the RiskScape multi-hazard risk modelling platform. The process followed a structured workflow comprising four stages (Figure 7).

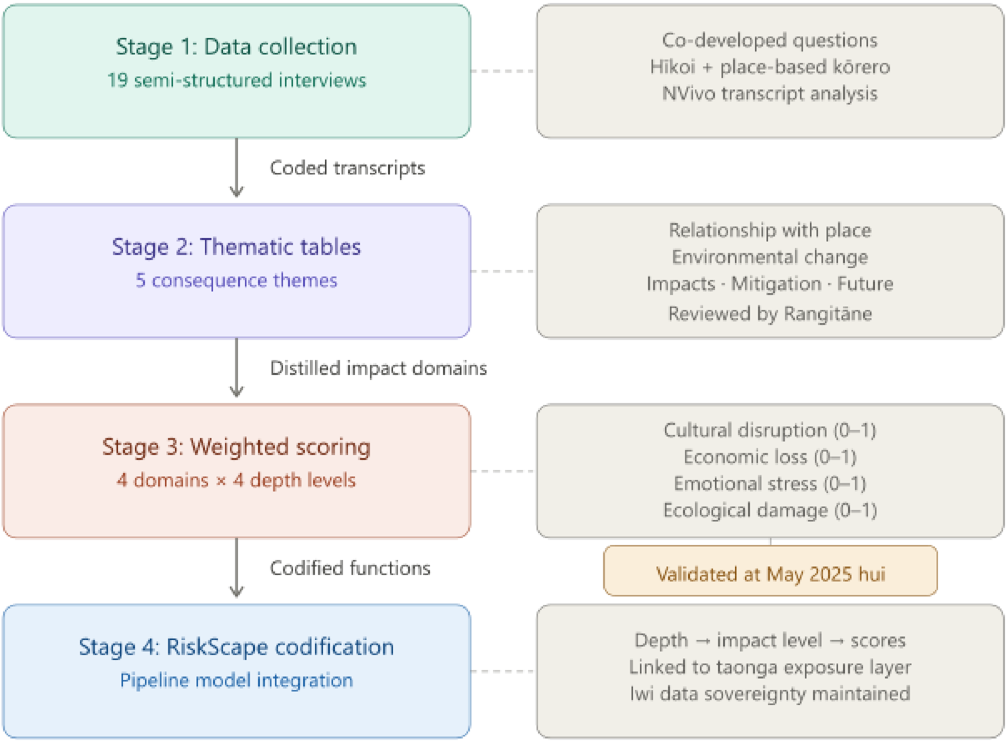

Figure 7: Workflow diagram showing the four-stage process drawing on the qualitative mātauranga shared through interviews and hikoi through to RiskScape codification and consequence function integration.

- Stage 1 – Qualitative data collection: 19 semi-structured interviews with Rangitāne o Wairau whānau, analysed using NVivo software to identify recurring themes relating to flood and coastal erosion impacts on cultural identity, environmental relationships, and intergenerational wellbeing.
- Stage 2 – Thematic consequence table development: Interview themes were consolidated into five overarching categories —Relationship with Place, Environmental Change, Impacts of Hazards, Mitigating/Living with Hazards, and Future Aspirations—then further refined into structured consequence tables (Mckenzie Sheat et al., in prep), documenting hazard types, observed impacts, consequences for Rangitāne o Wairau, and cultural significance.
- Stage 3 – Weighted impact scoring: Consequence categories were distilled into four quantifiable impact domains, Cultural Disruption, Economic Loss, Emotional Stress, and Ecological Damage (Figure 7), where:
    - Cultural Disruption captures loss or degradation of wāhi tapu, urupā, and intergenerational cultural practices,
    - Economic Loss reflects material and livelihood impacts including damage to crops, infrastructure, and productive land,
    - Emotional Stress encompasses the psychological and spiritual burden of losing

ancestral connections and place-based identity, and

- Ecological Damage covers degradation of mahinga kai, waterways, wetlands, and natural ecosystems that sustain cultural and environmental wellbeing.
- For each domain, weighted values ranging from 0 to 1 (Figure 7) were assigned qualitatively based on the perceived severity and significance of consequences at four flood depth exposure thresholds (≤0.2 m = Low; >0.2–0.5 m = Moderate; >0.5–1.0 m = High; >1.0 m = Severe). These weights were reviewed and validated by Rangitāne o Wairau whānau at a hui held in May 2025.

- Stage 4 – RiskScape codification: The weighted depth-impact relationships were codified as a consequence function pipeline compatible with the RiskScape platform. The function accepts flood depth as input, classifies it into an impact level, and returns normalised consequence scores for each domain. This function was linked to a custom exposure layer tagged with Māori land and cultural attributes (e.g., urupā, wāhi tapu, mahinga kai) co-developed with Rangitāne o Wairau whānau (Figure 7).

Worked Example: Flood Depth

To demonstrate the approach the research team went through to produce and apply the iwi-led consequence functions we have provided a worked example for flood depth.

In this example, for a flood depth of 0.7 m affecting an urupā site, the consequence function classifies this as a 'High' impact level. The resulting weighted scores are: Cultural Disruption = 0.8, Economic Loss = 0.6, Emotional Stress = 0.8, and Ecological Damage = 0.7 (Table 2). These scores indicate severe disruption to ancestral graves, significant displacement from ancestral lands, long-term cultural trauma, and substantial degradation of the surrounding ecosystem (see Figure 8).

In contrast, a consequence function in a conventional flood risk assessment approach may only report economic damage to built-assets (e.g., buildings), omitting the cultural and emotional dimensions of impacts and loss that Rangitāne o Wairau identified as most significant.

Table 2. Example of weighted iwi-led consequence scores by impact level and flood depth exposure.

Flood Depth	Impact Level	Cultural Disruption	Economic Loss	Emotional Stress	Ecological Damage
≤0.2 m	Low	0.3	0.1	0.5	0.2
>0.2–0.5 m	Moderate	0.6	0.4	0.7	0.5
>0.5–1.0 m	High	0.8	0.6	0.8	0.7
>1.0 m	Severe	1.0	0.9	1.0	1.0

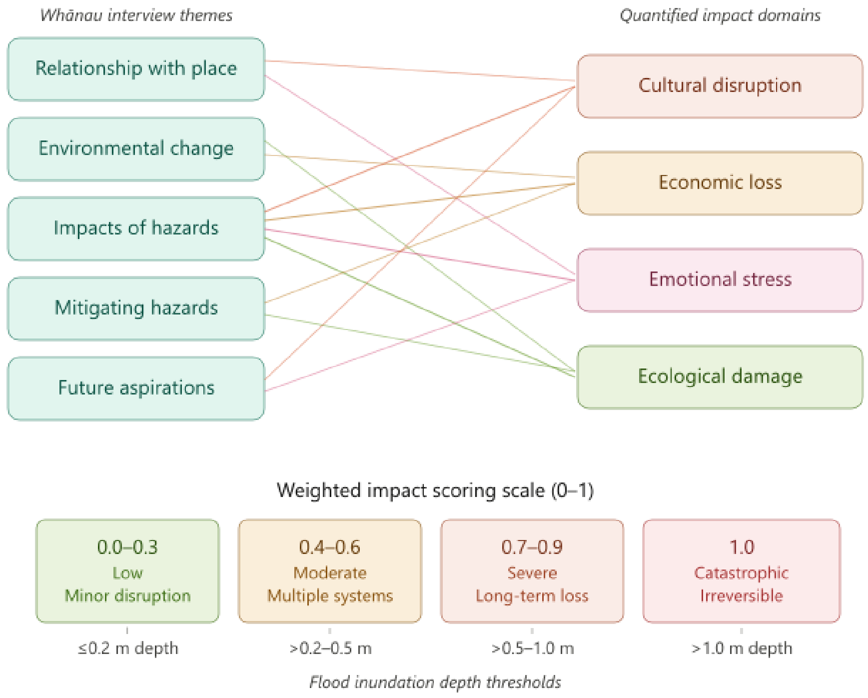

Figure 8: Rangitāne o Wairau-led thematic consequence impact schematic showing the five themes that emerged from the interviews with whānau (left) and how they informed the four impact domains (right) which were quantified and then weighted according to an impact scoring scale that ranged between 0 and 1.

Risk Modelling Workflow

The RiskScape platform was used to combine the hazard layers, exposure data, and consequence functions into a quantitative risk modelling pipeline. The workflow comprised the following steps (see Figure 9):

- Hazard input: 2D geospatial layers of maximum inundation depth from tsunami and SLR scenarios were imported as raster hazard layers.
- Exposure input: The co-developed taonga exposure layer, gridded at 1 m resolution into heritage land area polygons, was loaded as the exposure dataset. Each polygon was attributed with land-type categories (e.g., urupā and settlement sites, pā sites, cropland, vineyard, wetland, river, beach/bay) and associated impact-type classifications (Cultural Disruption, Emotional Stress, Economic Loss, Ecological Damage).
- Geospatial sampling: RiskScape performed an all-intersections geoprocessing step, spatially sampling the maximum flow depth from the hazard layer at each exposure grid cell.
- Consequence analysis: The sampled flood depth was passed through the iwi-led consequence function to classify the impact level and compute the weighted scores for each of the four domains.

- Reporting: Results were aggregated into event impact tables showing the percentage of total land area affected at each impact level, disaggregated by land type and consequence domain (Figure 9; Figure 10).

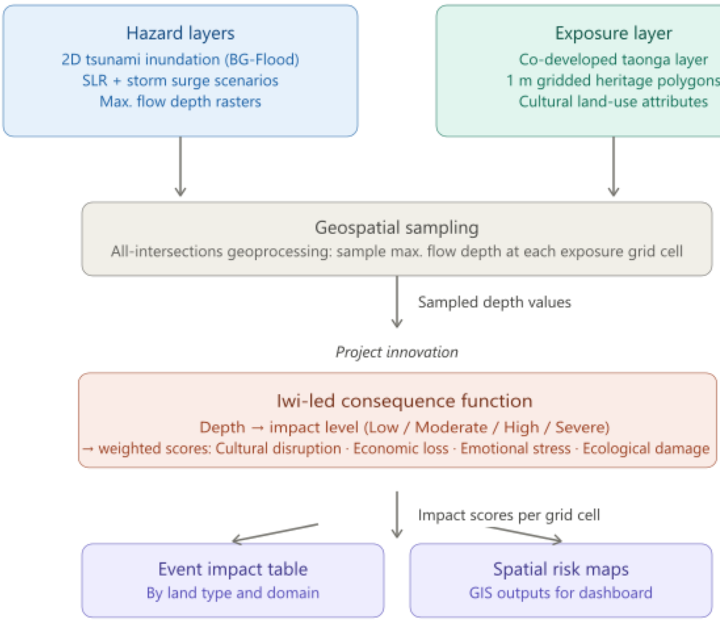

Figure 9: RiskScape modelling methodology schematic showing the data flow from hazard and exposure inputs through geospatial sampling, consequence analysis, event impact tables and output reporting.

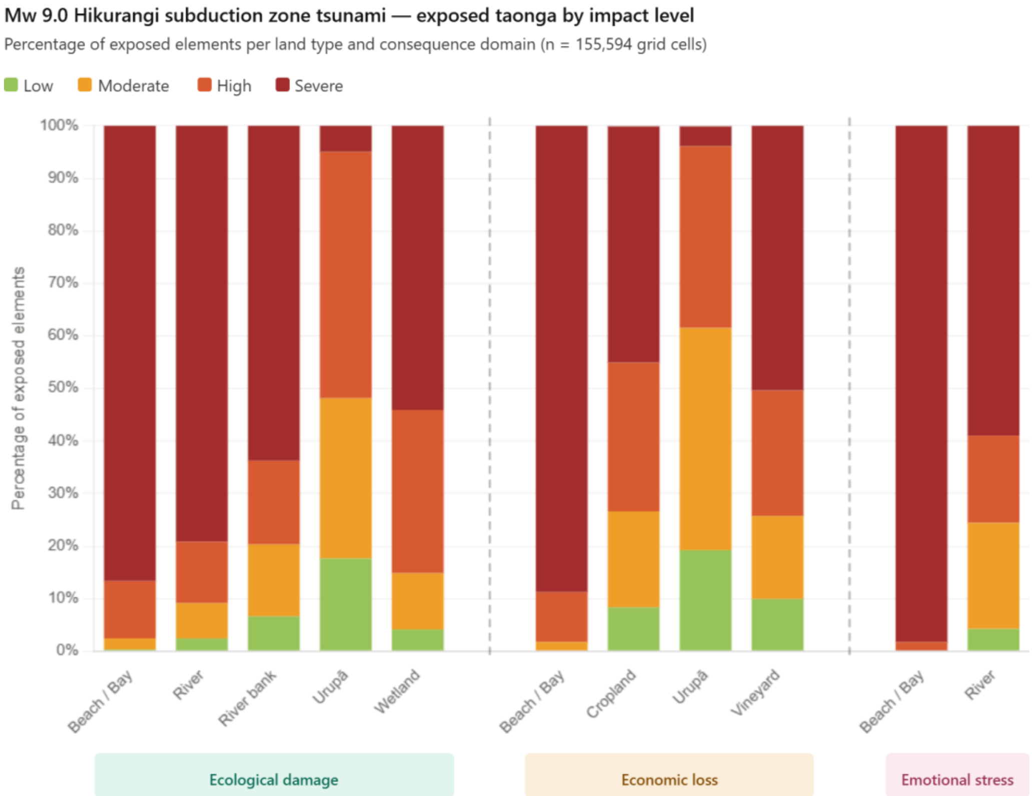

Figure 10: Example RiskScape processed output – bar chart showing percentage of total land area affected by impact level (Low, Moderate, High, Severe) across Ecological Damage, Economic Loss, and Emotional Stress domains for the Mw 9.0 Hikurangi tsunami scenario. The chart illustrates that Ecological damage is dominated by Severe impact across Beach/Bay (86.8%), River (79.3%), and Wetland (54.1%). Urupā and Settlement Sites are the exception, showing the highest proportion at High impact (46.9%) with relatively low Severe (5.1%), likely because these sites sit at slightly higher elevations with shallower inundation depths. Economic loss shows Beach/Bay at 88.8% Severe, while Vineyard and Cropland have a more distributed spread across levels. Urupā sites again have a distinctive profile (42.3% Moderate and 34.6% High), reflecting their elevated but still exposed position. Emotional stress is the most extreme domain: Beach/Bay reaches 98.3% Severe, reflecting the consequence function's high weighting for emotional/spiritual impacts of coastal inundation on ancestral landscapes.

Results and Discussion

Key project findings are described below in the context of thematic insights, technical hazard quantifications, and the development of the methodological exemplar for iwi-led risk definition.

Thematic Insights from Whānau Interviews

Analysis of the 19 whānau interviews and hīkoi identified five core themes: Relationship with Place, Environmental Change, Impacts of Hazards, Mitigating and Living with Hazards, and Future Aspirations. Whānau reported that floods are becoming less frequent but more severe, compounded by infrastructure that often misaligns with natural river behaviours. A critical finding was how inundation and erosion impacts experienced by Rangitāne o Wairau whānau, wāhi tapu and taonga are cumulative, place-based, and interlinked with broader processes influencing environmental change as the Wairau River and lagoons have been reshaped through past and present land-use changes, nutrient loading, and increasing sediment loads, which have impacted access to wāhi tapu and resources, which in turn affect cultural practices and intergenerational transfer of knowledge.

Rangitāne o Wairau whānau expressed their significant intergenerational connections to Te Pokohiwi o Kupe and the Wairau River, describing these places as ancestral homelands and sites of cultural continuity that are essential to Rangitāne o Wairau identity and whakapapa. Environmental changes observed over multiple generations including river sedimentation, reduced water quality, decline in traditional kai species, and aquifer salinisation were attributed to a combination of catchment land-use changes, river management interventions, and climate-driven pressures. The reduced water levels and shallowing of the Wairau River was of particular concern, with whānau linking this to sediment runoff from forestry, reduced dredging, and increased water extraction for viticulture.

Hazard impacts were described not primarily in economic terms but through emotional, cultural, and intergenerational lenses. Rangitāne o Wairau whānau identified the loss and degradation of wāhi tapu, the exposure of kōiwi, decline in mahinga kai, and the disruption of mātauranga and intergenerational relationships with place as the most significant consequences of flooding and coastal erosion - impacts that conventional hazard frameworks do not consider and are unable to quantify.

In response to these hazards, adaptation strategies put forward by Rangitāne o Wairau whānau reflected deep local and practical knowledge and included knowing when to evacuate the Pā and what routes to take, using tractors for rescues, maintaining food stores, and undertaking native riparian planting to stabilise riverbanks. These responses also reflect a strong ethic of kaitiakitanga and collective action.

Iwi-led Consequence Functions

A major outcome of this project is the co-development of iwi-led consequence functions that can be accommodated into the RiskScape platform. Using thematic and consequence analysis, the research derived weighted impact scores relating hazard intensity (inundation/flood depth) to four specific domains: Cultural Disruption, Economic Loss, Emotional Stress, and Ecological Damage. For example, flood depths exceeding 1.0m were classified as "Severe," representing catastrophic disruption to ancestral graves and potential irreversible cultural trauma. These functions provide a tool for iwi to explore and define "risk" through a cultural lens rather than from a purely economic perspective.

The weighting methodology followed a structured scoring framework. Weighted values (ranging from 0 to 1) were assigned qualitatively, based on the perceived severity and significance of each consequence at different flood impact levels. The scoring scale was: 0.0 = no measurable impact; 0.1–0.3 = mild, short-term disruption with limited consequence; 0.4–0.6 = moderate disruption affecting multiple whānau members or systems; 0.7–0.9 = severe damage or long-term loss with significant cultural/emotional strain; and 1.0 = total or irreversible disruption catastrophic to cultural integrity or ecological systems (Figure 8). These scores were validated by Rangitāne o Wairau whānau at a hui in May 2025, ensuring the quantification appropriately reflected their lived experiences and cultural values.

Shifting Perspectives: Kōrero as Enduring Taonga

At the final wānanga, Rangitāne o Wairau whānau discussed how their physical sites, like urupā, will have a finite lifespan due to inevitable extreme weather events which will be compounded by SLR.

The application of conventional science tools (such as LiDAR, GPR, and hazard modelling) assisted Rangitāne o Wairau whānau to learn more about their cultural landscape, whakapapa and history in ways that reinforced their perspectives and helped to relieve some of the long-standing impacts of historical dispossession.

Rangitāne o Wairau whānau emphasised the significance of communicating, recording and preserving their knowledge (and more broadly within iwi and hapū across Aotearoa), with urgency, as a means of safeguarding and strengthening whakapapa and identity as the cultural landscape changes due to climate-related hazards - protecting the kōrero associated with these significant sites as an enduring taonga.

Scalability and Methodological Exemplar

As a methodological exemplar, this project demonstrates a scalable approach for other iwi, coastal wāhi tapu and regions. NEMA representatives have expressed an interest in using the framework and learnings from the study to help inform/refine national catastrophic criteria, noting that the current metrics they use often fail to meet the needs of Māori communities. By building cultural/Māori-informed assessment approaches into conventional science modelling tools such as RiskScape, iwi/Māori are able to consider and articulate risks through a cultural lens to inform various governance and policy contexts. This project provides other iwi, such as Te Ātiawa, with a demonstrated process to combine their own cultural mapping with hazard data to inform and support their adaptation journeys.

At the March 2026 wānanga breakout sessions involving wider Te Tau Ihu iwi and agencies, several pathways were identified to increase the transferability and scale of the approaches demonstrated in this project. Regions that already have hazard data would primarily require the cultural mapping and impact layer to be added, while those already undertaking cultural mapping would need the hazard data fed in. MDC noted the value of understanding consequences beyond purely monetary terms. Key constraints identified included funding and capacity, concerns around sharing information about wāhi tapu, and the need for transparent tikanga-based processes to build trust with iwi who are starting new research relationships.

Validation, Confidence, and Limitations

This section addresses the uncertainty, validation, and limitations associated with the hazard modelling, consequence function development, and risk modelling outputs, as recommended for technical reproducibility and transparency.

Hazard modelling confidence

The BG-Flood software has been validated against international tsunami benchmarking standards and applied for national-scale hazard assessments in Aotearoa. The tsunami source scenarios are grounded in the National Probabilistic Tsunami Hazard Model (Power et al., 2023) and co-seismic displacement models (Mueller et al., 2014), which represent the current best available science for the region. However, limitations exist in the representation of nearshore bathymetry resolution, surface roughness parameterisation, and the omission of morphodynamic feedback (i.e., the model does not simulate erosion or sediment transport during inundation events). SLR scenarios rely on static superposition of sea-level increments onto present-day topography, which does not account for future geomorphological adaptation of the Boulder Bank or surrounding coastal landforms.

Consequence function limitations

The iwi-led consequence functions represent a qualitative-to-quantitative translation based on the lived experience and cultural knowledge of 19 Rangitāne o Wairau whānau. While these were validated through semi-facilitated hui, the project focused on a specific place-based context with one iwi and applied a subjective weight determination (e.g., Kizielewicz et al., 2024). No sensitivity testing of the weighting values has been undertaken. Therefore, the consequence functions co-developed and tested in this project should be understood as an initial, baseline framework that can be refined through further engagement and, if desired, expanded to include additional impact domains or adjusted thresholds to reflect the relational and cultural dimensions of risk relevant to another iwi and rohe.

RiskScape Integration

The RiskScape workflow in this study is deterministic for a given hazard scenario—results are directly determined by the selected hazard layer, exposure data, and consequence function parameters. No probabilistic or uncertainty analysis was performed. The 1 m grid resolution of the exposure layer introduces spatial generalisation, and the binary classification of land types may not capture the full complexity of cultural landscape use. Nonetheless, the project model workflow data and functions are fully reproducible and the RiskScape platform retains all model configurations for future refinement or re-execution by Rangitāne o Wairau.

Overall Confidence

The hazard modelling outputs provide a robust representation of regional inundation hazard exposure consistent with national-standard methods. The consequence functions represent a meaningful first-generation framework for quantifying cultural dimensions of risk, validated by the community whose knowledge underpins them. Results should be interpreted as indicative rather than predictive, and users should recognise that the consequence scores are context-specific to Rangitāne o Wairau. The framework's primary value lies in demonstrating a replicable methodology for integrating mātauranga Māori into quantitative risk models, rather than producing definitive loss estimates.

Conclusions

The project successfully established a template for iwi-led quantification of inundation hazard risks to support their climate resilience and adaptation decision-making. Key conclusions include:

- The framework provides an evidence base that strengthens iwi to represent cultural impacts within conventional science models, helping to support iwi-led climate and disaster resilience planning.
- The 2D hydrodynamic tsunami models developed through this project represent a significant advance over previous 1D Level-2 attenuation-based assessments for the Marlborough region, providing higher-resolution hazard data suitable for both cultural risk assessment and broader regional planning.
- The development and application of iwi-led consequence functions that explicitly integrate relational and cultural dimensions of loss into conventional science-based tools such as RiskScape, provide a new approach for quantifying cultural, emotional, and ecological dimensions of flood and inundation risk for Māori communities, complementing conventional economic depth-impact curves.
- By weaving mātauranga Māori with quantitative hazard modelling, the project established a mātauranga-led methodological exemplar and replicable/scalable template for potential refinement and roll-out to other regions/contexts, helping to support inclusive hazard risk and adaptation planning.

Rangitāne o Wairau retain authority over all mātauranga shared or generated, ensuring that this hazard research conducted in their culturally significant landscapes respects their on-going governance and intergenerational equity obligations (Meihana, 2022).

Research Benefits and Potential Future Directions

Key benefits of the research include:

- Supported Rangitāne o Wairau to define risk through a cultural lens;
- Contributed to the Te Rūnanga a Rangitāne o Wairau Taiao Strategy and supported their governance capacity through the Control and Management Agreement for Te Pokohiwi o Kupe signed with DOC on 27 February 2026 (Te Rūnanga a Rangitāne o Wairau & DOC, 2026a; 2026b);
- Demonstrated a co-developed and co-delivered hazards research approach that has been recognised by external agencies as a strong exemplar for more widespread adoption;
- Offered a potential roll-out template for other regions;
- Provided NEMA with an example model to support national 'catastrophic criteria'.

Potential future directions include:

- Finalising GPR results to inform future Rangitāne o Wairau decision-making;
- Exploring "self-determined insurance" models to protect taonga ignored by commercial insurers;
- Developing digital platform tools for knowledge sharing across hapori Māori.
- Extending the framework to incorporate additional hazards (e.g., alpine fault earthquakes, liquefaction, landslides) and hazard interaction/amplification effects;
- Investigating groundwater movement, vineyard water extraction impacts on aquifer systems, freshwater resources and downstream water quality;
- Investigating long-term downstream effects of tsunami on Marlborough wastewater infrastructure;
- Using hazard and LiDAR data to identify priority areas and actions to increase resilience (e.g., native vegetation plantings, sediment binding, and bank reinforcement);
- Socialising the outcomes of this project with MfE to help shape how cultural risk and mātauranga Māori is incorporated into national hazard risk and climate change guidance and policy frameworks and working with NEMA on how cultural impact modelling can inform national catastrophic criteria.

Publications and Research Outputs

A list of key research outputs from the project is provided in the table below.

Output Type*	Date Published/ Completed	Author/s	Title	DOI or Link
Conference (poster) – NZ Coastal Society 2025	Nov 2025	R. Mckenzie Sheat, P. Meihana, C. Hebberd, S. Williams, C. Bosserelle, J.	Iwi-led consequence modelling of inundation hazards: a case	10.13140/RG.2.2.28196.33923

		Battersby, J-M. Woolley, R. Paulik, J. Hepi, A. Lorrey	study at Te Pokohiwi o Kupe | Wairau Bar	
Conference (oral presentation) – Adaptation Futures 2025	Oct 2025	Meihana, P., Hebberd, C., Williams, S., Mckenzie Sheat, R., Bosserelle, C., Paulik, R., Battersby, J., Hepi, J., Lorrey, A., Bind, J., Woolley, J.-M.	Assessing spatiotemporal flooding impacts on Māori cultural heritage in Aotearoa New Zealand: the Wairau experience	[Adaptation Futures Conference 2025]()
Webinar (oral presentation)	Aug 2025	R. Mckenzie Sheat, P. Meihana, C. Hebberd, S. Williams, C. Bosserelle, J. Battersby, J-M. Woolley, R. Paulik, J. Hepi, A. Lorrey	Co-developing methods to embed te ao Māori into coastal risk assessments: a case study at Te Pokohiwi o Kupe	[NZCS Webinar 2025]()
Conference (poster) – NZ Coastal Society 2024	Nov 2024	R. Mckenzie Sheat, P. Meihana, S. Williams, C. Hebberd, J. Hepi, D. Johnson, C. Bosserelle, A. Lorrey, J. Battersby	Integrating mātauranga Māori into science-based flood risk models	10.13140/RG.2.2.36089.68961
Journal article	In prep (pending submission in May-2026)	R. Mckenzie Sheat, C. Hebberd, P. Meihana, S. Williams, D. Johnson, J. Hepi	Towards mātauranga-led flood risk modelling assessments	In prep

Communications and Dissemination

A list of weblinks to media, and other communications (e.g., project website, social media posts) is provided in the table below. This includes supplementary materials and tools that support the technical content of this report which are available from the project team or through the secured platforms indicated.

Output Type*	Date Published/ Completed	Author/s	Title	DOI or Link
Media – Social (LinkedIn)	Mar 2026	Earth Sciences NZ; Rangitāne o Wairau	Aotearoa's Wairau Bar Climate Impacts Assessed	Aotearoa's Wairau Bar Climate Impacts Assessed | Earth Sciences New Zealand posted on the topic | LinkedIn

Web Tool – Information Dashboard	Jan 2026	Earth Sciences NZ; Rangitāne o Wairau	Rangitāne Climate Risk Dashboard	(Closed/Secured site access): Dashboard - Te Reo Maori | Rangitane Prototype Risk Dashboard - October 2025
Web Tool - RiskScape Platform	Nov 2025	Earth Sciences NZ; Rangitāne o Wairau	Coastal Inundation Losses on Taonga	(Closed/Secured site access): riskscape.nz/projects/niwa/te-runanga-a-rangitane-o-wairau/coastal-inundation-losses-on-taonga/models
Function Code – Iwi-led consequence model	Nov 2025	S. Williams, R. Paulik, C. Hebberd, P. Meihana, R. Mckenzie Sheat, J. Battersby	Iwi-led consequence function pipeline model for use in the RiskScape software tool	(Closed/Secured site access): riskscape.nz/projects/niwa/te-runanga-a-rangitane-o-wairau/coastal-inundation-losses-on-taonga/models
Internet publication	Oct 2025	R. Mckenzie Sheat (compiler)	Te Ao Māori in Coastal Risk Assessments	Story Map 2025
Media – The Conversation	Jul 2025	P. Meihana, C. Hebberd, S. Williams	Rising seas threaten to swallow one of NZ's oldest settlement sites – new research	https://doi.org/10.64628/AA.7jh4aw46s
Media – Social (Facebook)	Mar 2024	Rangitāne o Wairau	Tini whetū ki te rangi ko Rangitāne nui ki te whenua! Check out this dream tīma!	Tini whetū ki te rangi ko Rangitāne... - Rangitāne o Wairau | Facebook

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  - Peter Meihana, Trustee, Rangitāne o Wairau. Project role: Kaupapa Māori Specialist.

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