



# Evaluating riverine flood policy: Land use planning trends in Aotearoa New Zealand

Christina Hanna<sup>a,\*</sup>, Pip Wallace<sup>a</sup>, Silvia Serrao-Neumann<sup>a</sup>

<sup>a</sup> Te Kura Toi School of Arts, Te Whare Wānanga o Waikato (The University of Waikato), Aotearoa, New Zealand

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## ABSTRACT

Globally, the responsibility to develop flood risk policy is often devolved to local government. However, local governments can lack the capacity to keep up with increasing and changing flood risk and information provision without external guidance and support. Central and state governments can deliver policy support and consistency by providing policy direction or standards based on best practice. Due to diverse localised modelling, plans and policies, there is often limited understanding of the nature of flood policy, the degree of variation between localities, and how authorities are improving practice and responding to increasing and changing risk. In this study, we develop and apply an evaluation tool for riverine flood planning that captures the modelling parameters, policies, and information used by regional authorities, distinguishing between traditional and emerging approaches. We examine three primary categories of regional flood policy: modelling parameters and associated planning regulations, risk-based policy approaches, and information provision processes. Our findings reveal evolving practices, policy variances, and aspects of contention, demonstrating where central and state governments can provide greater direction for policy development. Our evaluation tool therefore provides a basis to guide complex policy transitions, from static hazard-based planning towards a more comprehensive, risk-based approach.

## 1. Introduction

Land use planning is increasingly considered to be an important mechanism to reduce flood risk (Mach et al., 2022; UNISDR, 2015; Wheater and Evans, 2009). By guiding the location, nature, intensity, and staging of development, local governments responsible for land use planning can reduce susceptibility to damage and the impacts of flooding. Planning controls thus aim to achieve safer location for development by applying zoning and avoidance policies, and safer activities in the floodplain, by managing risk (Dharmavaram et al., 2017). However, flooding is a risk that frequently transcends local government administrative boundaries, requiring consistent national and regional level policy guidance. In particular, the use of ambiguous definitions, varied policy wording, parameters and strength, or divergent rules, along with local government capacity issues can affect the management of flood risk.

Historically, planning practice has mostly focused on providing certainty, with hazards defined by firm boundaries without temporal variation, using stationary lines, zones and overlays, creating a sense of

uniformity and stability in a complex environment (Lawrence, 2015). However, the limitations of static planning in a non-stationary climate continue to reveal themselves, and decision-makers are working to adjust to the dynamic realities of changing and uncertain risks (Haasnoot et al., 2024; Lawrence et al., 2021). This includes dealing with existing and anticipated climate change effects, and managing the deep uncertainty of future impacts, including those from compounding and interacting climate extremes and tipping points (Haasnoot et al., 2024). The existence of deep uncertainty highlights the inadequacies of the conventional 'predict-and-act' paradigm, including structural flood management measures, and necessitates the adoption of innovative approaches for planning and decision-making, such as Dynamic Adaptive Pathways Planning (DAPP) (Kool et al., 2024), and the consideration of multidimensional aspects of human and ecological well-being (Mach et al., 2022). Climate change also demands the reframing of the relationship between water management and land use planning, as the horizons of plans must become wider and more open to changing water conditions and uncertainty (De Vries and Wolsink, 2009; Mach et al., 2022).

\* Correspondence to: Environmental Planning Programme - Te Wānanga o Ngā Kete - Division of Arts, Law, Psychology and Social Sciences, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand.

E-mail address: [christina.hanna@waikato.ac.nz](mailto:christina.hanna@waikato.ac.nz) (C. Hanna).

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Dynamic and intensifying flood events are challenging how governments assess and communicate flood risk information and design corresponding regulatory planning instruments and tools such as land use plans and hazard maps. This paper aims to inform this by developing and applying a riverine flood policy evaluation tool, underpinned by the changing demands upon the production and application of flood hazard and risk information in the transition to a long-term, risk reduction approach to flooding in an uncertain world. Applying the evaluation tool to regional riverine/fluvial flood policy in Aotearoa New Zealand (Aotearoa), we examine three primary categories of the country's regional flood policy: modelling parameters and associated planning regulations, risk-based policy approaches, and information provision processes. The analysis reveals the scope and intent of flood policy, the degree of variation between localities, and how authorities are responding to increasing and changing risk without statutory national direction.

The paper is structured as follows. Section 2 provides an overview of the Aotearoa planning context. Section 3 describes the data collection and analysis methods. Section 4 presents the results of the analysis including detail about the various modelling parameters, land use policy, and mapping approaches applied to inform river flood planning. The paper concludes with insights for scholars and practitioners of flood policy and planning.

## 2. Flood policy and planning in Aotearoa

A history of colonial land development, clearance of indigenous vegetation, and structural protection and drainage regimes has significantly influenced flood hazard and risk in Aotearoa (Ericksen, 1986; Lawrence et al., 2021). Emergent understanding of the nature of the flooding phenomenon and attendant risk has underpinned governance responses. White and Lawrence (2020) outline the evolution of institutional hazard management in Aotearoa from 'protect and control landscapes', to 'hazardscapes', and eventually, to 'riskscapes', which enable contemplation not only of the hazard, but the conditions of the receiving environment over space and time.

In Aotearoa, avoidance of development on 'land subject to hazards' initially under the Town and Country Planning Act 1977 and followed by the integrated, effects-based regime of the Resource Management Act 1991 (RMA), have failed to 'hold the line' on further encroachment of hazardous locations, with 'high' national exposure to inland flooding (Ministry for the Environment, 2020; Paulik et al., 2019). Subsequent RMA amendments required specific consideration of the effects of climate change (2004) and the management of significant risks from natural hazards (2017). Consequently, policy attention has incrementally moved towards recognising shifting baselines, and the multi-variable nature of risk. Yet despite this recognition of the changing nature of the risk, development of flood prone land continues (Newton, 2024).

Today, flood risk governance in Aotearoa encompasses land use management and controls, community resilience planning, flood management (e.g. constructed stopbanks, water retention systems and floodways, and blue-green infrastructure such as wetland restoration), emergency response and recovery, and insurance. Land use planning is recognised as a primary tool for the management of natural hazards and significant risk (Saunders et al., 2024) and as such, is the principal focus of this paper. The RMA governs land use and the management of natural hazards. Amidst a multi-layered risk governance structure, the RMA delegates joint responsibility to regional and territorial (municipal) authorities for land use control, for the purpose of the avoidance or mitigation of natural hazards (ss 30(1)(c)(iv) & 31 (1)(b)(i)) (noting that in some cases these authorities have joined to function as Unitary authorities). These responsibilities are addressed in Regional Policy Statements (RPS), which must state which local authority is responsible for avoiding or mitigating natural hazards or any group of hazards (s 62 (1)(i)). RPS are important direction setting policy documents and

Regional and District Plans must give effect to them. As a result of urban drainage infrastructure responsibilities, territorial authorities generally undertake the majority of stormwater works and are predominantly allocated responsibility for managing the effects of pluvial flooding in urban areas (Mitchell and Knight, 2023). The mandate for the authorities is to create a policy framework via the RPS for the avoidance or mitigation of natural hazards. Natural hazard is defined by s 2 RMA to include not only the natural occurrence (such as flood) but also 'the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment'. So, avoiding or mitigating a flood thereby engages managing its impact upon human life, property and the environment, requiring examination of risk. Avoidance or mitigation are referred to in the alternative and as such no preference for one or the other is indicated. Similarly, s 6(h) elevates, as a matter of national importance, the management of significant risk from natural hazards, but leaves open direction as to stringency of approach. Without further direction from hazards-specific National Direction, implementing agencies have a broad mandate for risk management.

Land use planning that intersects with flood hazard and risk requires an evidence base to demonstrate relationships between issues, objectives, and policy responses. Various forms of knowledge and information can contribute to resource management policy, such as Indigenous and local knowledge, and scientific and observational data. There is no universal standard for flood hazard and risk identification, with various scales, data, methods, standards, and regulatory frameworks applied (Serra-Llobet et al., 2022). Local authorities often use rainfall-runoff and flood inundation models, and/or historic flood extent maps to identify flood hazard zones. In the past, one-dimensional flood models were used by authorities in Aotearoa due to the costs of detailed topographical data (Rouse, 2012) and paucity of river cross-sectional area/depth data. Keeping up with international trends (Serra-Llobet et al., 2022) two-dimensional models are becoming more widely used with large scale LiDAR surveys now captured for much of the country.

In Aotearoa, flood maps form the basis of land use zoning and regulatory controls for local flood management purposes, providing critical information to planners and the public. Internationally, there are two key types of flood maps: flood hazard maps and flood risk maps. Assessment of flood hazard indicates the probability and intensity of a possible flood in a particular location (de Moel et al., 2015). Flood hazard maps display hazard intensity parameters, most commonly including maximum flood depth and flow velocity (separately/in combination) to determine potential asset damage and human harm/life loss (Maranzoni et al., 2022). Less commonly used parameters may include flood arrival time, flood duration, flood depth rise rate, standing water depth, erosive potential of flooding, and debris or contaminant load (de Bruijn et al., 2015; Maranzoni et al., 2022; Merz et al., 2007). Duration of inundation can indicate the potential costs associated with evacuation and business interruption, and the depth rise rate can support evacuation planning and understanding potential loss of life (de Moel et al., 2009).

Many countries have produced flood maps which show values for one or two hazard parameters, such as flood depth maps for a certain probability, however, it is difficult to combine more than two parameters into one map (de Bruijn et al., 2015) unless multiple overlays are used to inform decisions. Flood hazard assessment informs flood risk assessment, which is increasingly used as part of a risk-based approach. Flood risk maps display risk parameters, combining flood hazard, exposure (presence of people, buildings, infrastructure, activities and ecosystems in floodable areas); and vulnerability (the susceptibility of exposed elements to suffer flood harm) (Maranzoni et al., 2022). Importantly, the determinants of risk and interactions across risks and responses will change through space and time, requiring adaptive decision-making, including flexibility, coordination, and public engagement in iterative, inclusive decision-making processes (Mach et al., 2022).

### 3. Material and methods

This study is part of a wider research programme, *Mā te haumarū ō ngā puna wai ō Rākaiahautū ka ora mō ake tonu* which aims to develop a consistent system to map river flood hazards and undertake risk assessment across Aotearoa, factoring in climate change projections. The programme undertakes a transdisciplinary research approach (Serrao-Neumann et al., 2020), running a series of Science-Practice Roadshows to facilitate two-way information sharing between researchers and practitioners. As a result of flood policy issues raised at practitioner workshops in 2023 (see Serrao-Neumann et al., 2024) this research investigates regional policies to ascertain how fluvial flood hazards and risks are identified and defined in the Aotearoa planning context, the use of risk frameworks, and the issue of regulatory mapping, to inform the development of national policy.

#### 3.1. Development of the riverine flood policy evaluation tool

A review of international literature and analysis of regional flood policies helped to identify the broad approach to land use planning for riverine flooding, within the remit of reducing exposure to damage and the impacts of flooding (but not mitigating the hazard itself). This includes flood hazard zoning, land use policy to avoid or mitigate flood risk, and the associated public information provision (Bergsma, 2019; De Vries and Wolsink, 2009; Dharmavaram et al., 2017; Jha et al., 2012; Mach et al., 2022). Thus, the riverine flood policy evaluation tool (see Table 1) is organised around three key categories: C1 - modelling parameters (to inform zoning); C2- land use policy; and C3- public information provision. C3 is limited to assessing the nexus between maps and policy (i.e. whether there is a regulatory connection between mapping and policy). Other international studies have already examined the accessibility and quality of flood maps for risk communication purposes (Henstra et al., 2019), examining criteria such as flood zone legibility and transparency about flood modelling limitations (Merz et al., 2007).

Assessment of regional policy and insights from the literature regarding planning for broader timeframes due to climate change (De Vries and Wolsink, 2009; Stevens and Hanschka, 2014b), incorporating land use change (Wheater and Evans, 2009) and residual risks (Serra-Llobet et al., 2022), and the transition to a risk-based approach (Van Herk et al., 2014), support the identification of policy advancements (A) beyond the baseline (B). Category one examines ‘baseline’ and ‘advanced’ modelling parameters that determine the extent and nature of flood hazard zones. Category two examines ‘baseline’ avoidance and mitigation policy and more ‘advanced’ risk-based approaches and criteria. Finally, category three delineates the various planning processes used to communicate hazard and risk information.

#### 3.2. Data collection and analysis

This study analyses publicly available, regulatory regional river flood risk management and land use planning documents for Aotearoa. This includes all 17 operative and proposed Regional Policy Statements

(or Combined Resource Management Plans for Unitary Authorities), and related planning maps or flood hazard portals (see Table 2). Content analysis (cf. Stevens and Hanschka, 2014a) was applied to describe and summarise data and to formulate additional benchmarks for the policy framework (Sheydayi and Dadashpoor, 2023). Due to the wide variance in approach and policy frameworks, two researchers reviewed and coded each RPS. First, flood hazard and risk policies from each document were reviewed and tabulated, by a full reading of each Natural Hazard chapter. The review was structured by the following key questions: ‘what are the land use planning related modelling parameters applied for flood hazard and risk mapping?’, ‘how is flood hazard and risk defined?’ and ‘how is flood hazard and risk regulated?’

Second, planning maps, hazard portals and publicly available modelling information sheets were assessed to determine key data inputs influencing hazard zones/overlays/definitions that were not explicitly detailed in policy, such as riverine flood event Annual Exceedance Probability (AEP), climate change, and urban growth influences. When the researchers had each completed a full reading and coding of all documents, results were compared, and revisions were made to the data tables. To carry out the content analysis, the original dataset was reduced into explicit spreadsheets, applying analytical codes based on interpretative themes (Hay, 2010), including avoidance terminology, policy and regulation categories, risk-based policy criteria, and specific modelling features (e.g. flood hazard probability and intensity measures) (see Tables 1–3). Finally, to ascertain the basis for unique policy approaches, plan evaluation (s 32 RMA) reports and public submissions were also reviewed for regions where the policy explanation was limited, and to ascertain the reasoning behind the mapping approach.

### 4. Results

Applying the riverine flood policy evaluation tool to the Aotearoa context enabled the heterogeneous system of regional river flood policy and mapping to be revealed and analysed. The following sections unravel the story of various modelling parameters, related planning policies, and processes of information provision in transition, and examine the opportunities and implications of these emergent and divergent practices.

Overall, our findings indicate that there is a gradual movement away from stationary hazard mapping, with climate change influences becoming more explicitly recognised in newer models and policies, increasing consideration of multiple rather than single flood event probabilities, and attention to flood intensity in zoning definitions/extent (see C1, Table 2). In the case of Auckland, the most populous city in Aotearoa, we find consideration of potential land use change (future development) in the flood model, demonstrating future-focused planning that anticipates land use change up to the permitted development baseline. One RPS (from Marlborough) explicitly maps residual risk in the event of flood defence failure. Category 2 examines the forms of land use planning policy, including risk frameworks and criteria. Avoidance and mitigation policy is present in all plans; however, the definitions and

**Table 1**  
Components of the riverine flood policy evaluation tool.

Benchmark	Category 1. Modelling parameters						Category 2. Land use policy		Category 3. Public information provision
	BASELINE (B)	ADVANCEMENT (A)					(B)	(A)	Mapping and policy nexus
Regional/ Unitary Authorities	Flood hazard mapping and policy for a single AEP*	Flood hazard mapping and policy for multiple AEPs	Policy informed by hazard intensity factors	Climate change inclusion	Land use change/intensification inclusion	Residual risk mapping	Avoidance and mitigation policy	Risk criteria/strategic risk-based framework	

\* AEP: Annual exceedance probability

**Table 2**  
Overview of riverine flood policy evaluation results.

Benchmark	Category 1. Flood hazard modelling parameters						Category 2. Land use policy		Category 3. Public information provision
	BASELINE (B)	ADVANCEMENT (A)					(B)	(A)	Mapping and policy nexus
Regional/ Unitary Authorities	Applied/ Regulated single AEP	Applied/ Regulated multiple AEPs	Policy informed by flood hazard intensity	Climate change included	Land use change/ intensification included	Residual risk mapped	Avoidance and mitigation policy	Risk criteria/ strategic risk-based framework	
Northland RPS 2016		●	●	●			Present in all plans. Wide variance in terms of subject, object and approach – see section 4.	●	●
Auckland Unitary Plan 2016	●			●	●	●		●	●
Waikato RPS 2016	●		●	●	● <sup>*C</sup>			●	●
Bay of Plenty RPS 2014		● <sup>*D</sup>						●	
Horizon's One Plan 2014	●			●					●
Hawke's Bay RMP 2006		●							●
Tairāwhiti RMP 2023			●					●	●
Taranaki RPS 2010									
Greater Wellington RPS 2013	●			●				●	●
Nelson NRMP	●		●	●				●	●
Tasman RPS 2001									
Marlborough (PMEP) 2023	●		●	●		●		●	●
Canterbury RPS 2020		●	●	●				●	●
Westland RPS 2020									
Otago Partially Operative RPS 2019		●		●				●	●
Southland RPS 2017	●		●						
Chatham Islands CIRMD 2020									

**Key:**

- = Use of singular AEPs
- = Use of multiple AEPs
- = Qualitative description of depth and velocity applied
- = Quantitative measures of depth and velocity applied
- = Additional flood hazard intensity measures applied (none)
- = Included without detailed descriptors i.e. 'climate change is taken into account'
- = Climate change scenario, timeframe and associated temperature rise provided
- = Permitted urban intensification and development inclusion
- = Residual risk is mapped
- = Quasi-risk-based approach with selective elements included in policy (e.g. consideration of residual risk, activity vulnerability)
- = Strategic risk-based policy framework with directions to reduce and manage risks according to thresholds, with specific criteria for risk assessment
- = Non-regulatory mapping
- = Regulatory mapping including statutory public engagement

**Notes:**

- \*C = variable climate change influences based on the age of models
- \*D = Dependent on risk screening outcome
- \*E = 0.5% AEP used as proxy for climate change

Regions with no data largely delegate functions to territorial authorities or leave assessment to the resource consent process.

Some plans e.g. Marlborough state that modelling will be amended according to land use changes, but only Auckland explicitly includes future development.

Nelson Plan Change 29 was used for determining the latest modelling parameters, but the C2 assessment was undertaken on the RPS.

approaches vary greatly. In terms of risk, vulnerability and consequence criteria have been included in policy, and examples of strategic risk-based planning frameworks are emerging. Finally, Category 3 highlights the varying approaches to provision of hazard information for land use planning, which depicts and translates the modelling parameters and policy to the public via statutory public engagement processes or via non-statutory information portals.

#### 4.1. Category 1: modelling parameters - defining hazard and risk in context

Defining hazard and risk in the landscape has social, cultural, economic, and environmental implications. The challenge for planning and risk management is to develop frameworks that deliver equitable outcomes whilst operating upon the best available information, and to apply assessment and decision tools that are fit for changing risk. Policy and practices often seek to define and ‘fix’ hazards and risks in space and time to provide certainty for local decision-making (White and Lawrence, 2020). The tension between providing a level of certainty and flux resonated throughout this analysis. Traditional hazard zones and planning regulations based on single probabilities obscure the dynamic nature of flooding and may create community expectations of safety outside of these regulated areas. This issue is further complicated by disparate statutory settings. The 1 % AEP is often the adopted design flood event applied for flood avoidance and mitigation policy in land use planning, likely influenced by Land Development and Subdivision Infrastructure Standard NZS4404:2010 and legacy use of Average Return Intervals (ARI) (i.e. the 1 in 100-year flood) and the at least 100-year timeframe of the New Zealand Coastal Policy Statement 2010. In contrast, for construction, the Building Regulations (1992) require a lesser threshold, ensuring surface water from an event having a 2 % AEP shall not enter housing, communal residential, and communal non-residential buildings (Clause E1.3.2). Underscoring the jurisdictional disparity between building control and managing land use activities to reduce flood risk, some authorities have introduced more stringent floor levels than those prescribed in the Building Regulations, citing resource management related purposes (Hassall et al., 2015; Independent Hearings Panel, 2016) or by recognising that “the minimum standard under the Building Act...is judged to be too low by experts” (Canterbury Regional Council, 2021, p. 172). Other authorities have had political difficulties in this space (Naish, 2021), highlighting the problem of statutory incongruence. Given land uses are generally granted in perpetuity, careful consideration needs to be had in terms of risk, beyond the 50-year timeframe of habitable and communal buildings under the Building Act (Saunders et al., 2013). As we examine next, these different probabilities highlight the conflicting statutory schemes and varied regional practice.

Whilst there are some similarities in policy structure, there are no flood design standards or methods for defining hazard areas in the regional planning provisions assessed. Some regions apply a layered system of control for flood policy (see Table 3). The **first tier**, being the determination of ‘High Flood Hazard/Risk’ is also termed ‘Intolerable’, ‘Significant’, ‘Level 3’ ‘Moderate/High’ and ‘Overlay 6 - Old River Loops.’ Across these policy areas/overlays, different probabilities are applied which influence the extent of areas affected by what is often ‘avoidance’ policies. In Waikato and Nelson, authorities regulate the 1 % AEP flood event, specifying minimum depth and velocity of floodwaters to classify the higher level of flood hazard. Whereas, in Canterbury, the 0.2 % AEP is applied, as it is assessed that floodwaters often spread out over large areas, and the difference in flood level between probabilities is relatively small—the difference in water depth in a 1 % AEP and 0.2 % AEP event is expected to be 300–400 mm or less across the region’s floodplains (Canterbury Regional Council, 2021). In contrast, Marlborough uses the 2 % AEP, and in Northland, the RPS applies the 10 % AEP to identify the areas where flood depths and velocities pose a risk to life during 1 % AEP events.

Not only does the designed flood event vary across the regions, but the flood hazard standard for water depth is irregular, with defined ‘high risk’ depths ranging from 0.3 m (Nelson), to more than 1 m (Waikato and Canterbury). The applied standard for flood water velocity is equal to or greater than 2 m/s in Nelson or greater than 2 m/s in Waikato, and in Canterbury, it is expressed as ‘water depth (m) x velocity (m/s) is greater than or equal to 1’. It appears that the newer plan (Nelson) is in line with Australian (2017b) flood hazard standards. Alternatively, in Tairāwhiti (see ‘Other’ row, Table 3), a qualitative approach provides definitions of the regulatory overlays including descriptions of the floodwaters (‘deep and fast flowing’), key planning considerations such as the need for avoidance of human habitation and diversion/blockage of floodwaters, and emergency management concerns. Whilst not conveying empirical hazard metrics, this is an approach that is accessible, conveys the reasoning behind the planning regulations, and demonstrates a quasi-risk-based approach with some vulnerability and exposure components included in the basis of the overlays.

Moving on to the **second tier** of a layered management approach, are areas defined as being ‘prone/liable to flooding’, ‘subject to inundation’, ‘flood hazard/path/ponding/river flood areas’, ‘levels 1–2’ and ‘floodplain’ and ‘flood ponding.’ Here, the 1 % AEP is commonly applied, and the depth and velocity of floodwaters are also included in some policies/overlays, with reference to: shallow, slow velocity water that is unlikely to pose a threat to life; specific standards “up to 0.3 m deep and velocity is less than 2 m/s” (Nelson); or areas where the depth/velocity is not well understood (Marlborough). Two plans using the 0.5 % AEP have different justifications for doing so. In Canterbury, “economic analysis shows that there is a positive net benefit to elevating new buildings to both 0.5 % and 0.2 % AEP flood levels” in addition to the relatively minimal difference to the 1 % AEP as discussed. Horizon’s Regional Council have moved from the 1 % AEP to the 0.5 % AEP to account for climate change (Horizons Regional Council, 2024).

The **final tier** includes areas mapped to manage residual risk. The Marlborough RPS ‘Level R Overlay’ identifies areas at risk if flood defences fail, requiring zoning and resource consent decisions to avoid locating intensive residential, commercial or industrial developments on land ‘Level R’ (Policy 11.1.11). Whilst some regional policies highlight the importance of considering residual risks, dedicated overlays for this purpose are a rare advancement.

A critical element in the definition of hazard and risk in context is climate change. Climate change is cited in all regional policy statements and unitary plans, with many authorities stating that its effects will be considered. Some state that their flood models do not currently take climate change effects into account (Hawke’s Bay) or that older flood models use different climate change scenarios to newer ones (Waikato and Auckland). Only two authorities (Auckland and Nelson) explicitly detail how climate change is incorporated into their flood models. The Auckland flood portal states that “NIWA’s latest climate projections for Auckland provide an expected temperature rise of 3.8 degrees in 100 years’ time. This has been applied for the newer floodplains.” (Auckland Council, n.d.). Whereas in Nelson, the climate change conditions applied include the Representative Concentration Pathway (RCP) 8.5 M scenario for 2130, with an associated temperature rise of 3.4<sup>0</sup> C. In contrast, Horizon’s has chosen the 0.5 % AEP as a proxy for the scale of change to the 1 % AEP. In addition to the RCPs selected, the selected planning horizon modelled and assessed determines the nature of potential climate change effects. By using an AEP incorporating an associated temperature rise over at least a 100-year time period in flood modelling, these authorities are recognising the fact that what constitutes a flood with a specific AEP may change over time, and are planning for broader timeframes.

The recent National Adaptation Plan 2022 (NAP), which authorities are required to have regard to when preparing or changing policy statements and plans (ss 61(2)(e), 66(2)(g) and 74(2)(e) RMA), directs hazard and risk screening in coastal areas and detailed hazard and risk assessments in all areas to use certain RCP scenarios to the year 2130, as

**Table 3**  
Related flood modelling and policy parameters.

Definition	0.2 % AEP (500 yr ARI)	0.5 % AEP (200 yr ARI)	1 % AEP (100 yr ARI)	2 % AEP (50 yr ARI)	10 % AEP (10 yr ARI)
<b>'TIER 1'</b> <b>High hazard/risk:</b> 'High risk' 'High Hazard' Intolerable/Significant risk, Level 3, moderate/ high hazard, old river loops	<b>Canterbury RPS: High Hazard Areas</b> water depth (metres) x velocity (metres per second) is greater than or equal to 1, or where depths are greater than 1 m, in a 0.2 % AEP flood event		<b>Waikato RPS: High risk flood zones</b> = Up to 1 % AEP with flood water (depth >1 m), (speed >2 m/s) or (flood depth x speed is >1). <b>Nelson PC29: High flood hazard</b> (1 % AEP event at 2130 is greater than or equal to 0.3 m deep and/or velocity is equal to or more than 2 m/s) <b>Wellington: Risk based approach considering</b> "magnitude and frequency, potential impacts and the vulnerability of development" with 1 % AEP as minimum standard for floor levels and access routes	<b>Marlborough RPS Level 3:</b> Land that suffers flooding of deep, fast flowing water in a flood event with an ARI of 50 years, or land in the bed of any lake or river or in any wetland.	<b>Northland RPS</b> (High Risk to life and property)
<b>'TIER 2'</b> <b>Flood prone:</b> Areas prone/liable to flooding, areas subject to inundation, flood hazard/path/inundation, river flood, levels 1–2 and R, floodplain, flood ponding,		<b>Horizon's:</b> 'Areas prone to flooding' = 0.5 %AEP Change from previous use of 1 % AEP to account for climate change.  <b>Canterbury RPS: Areas Subject To Inundation,</b> 0.5 % AEP Flood Event where the depth or velocity of flood water is not likely to be sufficient to pose a significant risk to life	<b>Nelson PC29:</b> Flood hazard (1 % AEP event at 2130 is up to 0.3 m deep and velocity is less than 2 m/ s.) Floodways (1D river channel) <b>Auckland Unitary Plan (Floodplain)</b> 1 % AEP <b>Northland RPS</b> – 1 % AEP areas <b>Hawke's Bay</b> (river flood) 1 % AEP  <b>Waikato Floodplain</b> 1 % AEP	<b>Marlborough RPS:</b> a) Level 1: Land that suffers flooding of shallow, low velocity water in a flood event with ARI of 50 yrs; (b) Level 2: Land that suffers flooding but the depth/ velocity is not well understood, or cannot easily be expressed relative to natural ground level, in a flood event with an ARI of 50 years, or land within 8 m of any lake, river or wetland; <b>Hawke's Bay</b> (floodplain) 2 % AEP	
<b>'TIER 3' Mapped Residual Risk</b>	Marlborough Level R: Residual risk areas in relation to potential failure of constructed flood defences "Policy 11.1.11 – Identify land that has potential to experience flooding of deep, fast flowing water in an extreme flood event that overwhelms stopbanks and other constructed flood defences as residual risk areas (Level R) and avoid locating intensive residential, commercial or industrial developments on land subject to a Level R flood risk... Level R indicates an extreme flood event that breaches flood protection works and is rarer than a flood with an annual recurrence interval of 1 in 100 years." (Marlborough (PMEP) 2023)				
<b>Strategic risk-based framework with multiple probability assessments</b>	Bay of Plenty RPS 1 % AEP initial assessment, 2 % AEP and 0.2 % AEP secondary analysis Otago RPS – range of likelihoods for risk assessment from 2 %AEP – 0.04 % AEP				
<b>Other approaches</b>	<b>Tairāwhiti One Plan Tier 1 - Qualitative descriptors such as:</b> a) Flood Hazard Overlay 1 (River and Floodway): These are the main routes for floodwaters (deep and fast flowing). Unsuitable for regular human occupation. * (Care needs to be taken not to alter the level of the land in a way which could divert floodwaters and cause adverse effects. Activities which could trap sediment in a flood and build up the river berms should also be avoided.) b) Flood Hazard Overlay 2 A (Moderate/High Hazard Areas) ... <b>Tairāwhiti One Plan Tier 2:</b> d) Flood Hazard Overlay 3 (Flood Ponding Areas): This contains low-lying areas or basins subject to occasional but relatively deep flooding (slow moving/ stationary water). Floodwater storage during major rainfall events. Infilling of these areas may divert and raise the level of floodwaters elsewhere... <b>Southland RPS:</b> Areas potentially at significant risk: (unprotected) areas that have flooded to a depth of more than 100 millimetres previously, spillways, secondary flowpaths and ponding areas; • areas immediately downstream of large dams (dams over 3 m in height and more than 20,000 m <sup>3</sup> in volume); • areas subject to multiple hazards, none of which in themselves would constitute a significant risk; • geomorphic floodplains of small watercourses whose flood history is unknown; • alluvial fans and river deltas especially in steep, fast flowing, dynamic watercourses; land adjacent to lakes and less than one metre higher than the previous highest lake levels.				

a minimum (Ministry for the Environment, 2020, 2022). Depending on whether detailed hazard and risk assessments are applied, this may extend the 100-year minimum planning timeframe requirement to all climate related hazards, in line with the mandatory coastal timeframe of the NZCPS for land use planning. Ideally, with progressive adherence to the NAP over time, authorities will stress-test and develop plans, policies and strategies using a range of climate change scenarios, for a minimum timeframe of 100 years, in all locations.

The variation in flood management standards, regulated flood event likelihoods and risk and climate influences examined highlights the uneven methods, criteria, and risk tolerances across the country. A further area of difference is the type of AEP applied, many of which are not clearly identified. For example, for the mapped Auckland

floodplains (low-lying areas and areas next to streams and rivers), the '1 % AEP storm' is applied, being the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year, in a given location. In other regions such as Canterbury, the AEP is based on the probability of a certain size of river flood flow occurring in a single year in a given location. Policy and mapping terminology is also inconsistent, for example, some authorities use 'hazard' and others use 'risk' and at times separation of these concepts is blurred. Although inclusion of reference to depth and speed of water may be treated in plans as a typical flood 'hazard' assessment technique, the policies are often making a connection to human vulnerability and consequences (risk to life/habitable buildings) demonstrating movement towards a more risk-based approach in policy and mapping (see 'risk-based

approach' column), discussed next.

#### 4.2. Category 2: avoidance and risk-based policy

Land use planning has an important role in defining and avoiding hazards and thereby deescalating future risk, by way of zoning and regulating use and development of land. Local authority functions to avoid and mitigate hazards shaped early natural hazard policy under the RMA and remain a distinct feature of regional policy. Express policy attention to *manage significant risk from natural hazards* (s 6 RMA), is less visible in RPS, although a recent trend towards the adoption of risk-based policy is more clearly aligned with the statutory intent. This gap potentially indicates an incompleteness or, at least, a lack of rigorous attention to statutory mandates in regional policy of the type considered in *R J Davidson Family Trust v Marlborough District Council [2018] NZCA 316* and indicates a need for overhaul of aged policy frameworks. The analysis of avoidance policies demonstrated broad variance in relation to objective, activity precluded, stringency and mitigating exceptions (see Table 4). Policies to avoid development in areas of high hazard were visible in the majority of RPS, although the *type* of development precluded was varied and included: all development, critical infrastructure, urban development, residential development, inappropriate development in residential, commercial and industrial zones, subdivision which creates demand for new structures, habitable buildings and new buildings for vulnerable activities.

What constitutes avoidance also diverged. Avoidance is understood as “not allowing” or “preventing the occurrence of” (*Environmental Defence Society Inc v New Zealand King Salmon Company Ltd [2014] NZSC 38 [24]*) and there are different means of achieving this. Most simply put, it is an outright and unqualified prohibition of the activity. Although this approach was employed in some RPS, and in instances accompanied by reference to the prohibited category, the majority of RPS employed a more nuanced approach to avoidance. Avoidance as prohibition was frequently softened by discretionary language such as “inappropriate development” and “where practicable” or by enabling mitigating qualifiers. The latter were varied in terms of purpose and included demonstration of the following:

Preventing harm to *people* and the *structures* they inhabit was the overriding concern of policy provisions using avoidance language reflecting key criteria relating to regulatory risk tolerance. Impacts to critical infrastructure and “vulnerable activities” (see Table 5) were also high priorities. Intent to avoid harm to natural processes, protect existing flood plains and avoid ecological damage, whilst not an overriding concern, was visible. This net is broadened by the example of PC29 (August 2023 version) proposed by Nelson City Council which extends its intention to avoid significant risk from flood hazard to *people, property, infrastructure and the natural environment, including social and cultural effects* (DO2.2.4). This provision as proposed is an evolution from earlier policy which accorded first priority to avoiding or mitigating hazards which threaten human life and second priority to avoiding or mitigating hazards which threaten property or other values (Nelson City Council RPS 1997 Policy DH2.3.1). The criteria described exhibit the transition towards a risk-based regulatory approach (Grace et al., 2019), but few RPS have a strategic risk-based policy framework (see Table 2).

Beyond the selective risk-based policy criteria described, and risk assessment requirements at the consenting phase, are RPS demonstrating a risk-based approach (Saunders et al., 2013) as part of their strategic planning framework. This approach includes policy directions to reduce risks to set levels, requiring assessment of risk tolerability. In Otago, the risk-assessment requirement is triggered via district plan changes/resource consents where the change of land use will/may increase natural hazard risk within ‘areas subject to natural hazards’ (HAZ-NH-M3-4). In the Bay of Plenty, Policy NH 8 A requires risk assessment during the development of land use plans and at the time of resource consent application, notice of requirement or private plan

change, where necessary. An important distinction between RPS currently applying a risk-based approach is the use of multiple likelihood scenarios. The Otago RPS allows decision makers, when considering applications for resource consent, to choose three scenarios ‘representing a high likelihood, median likelihood, and the maximum credible event (from 2 % AEP to <0.04 % AEP) using the best available information’. In contrast, the Bay of Plenty RPS requires that for flooding, the 1 % AEP is the initial starting point for risk analysis, followed by the 2 % and 0.2 % AEPs which are secondary steps of analysis (if required to demonstrate which probability represents the greatest risk). In Tauranga, the effect of the Bay of Plenty methodology is that the 1 % AEP is the only flood event probability mapped and regulated (see Tauranga City Plan Change 27), given its high-risk determination.<sup>1</sup>

Finally, policy intent and prioritisation are not only revealed through the written policies. An analysis of flood hazard mapping demonstrates that the preponderance of mapping effort and resultant flood hazard zones and overlays (to which avoidance, mitigation and risk policies connect) are located in *urban* areas or land areas of strategic importance for infrastructure and development. Similar effort has not been applied to fluvial and pluvial mapping in many rural areas (Paulik et al., 2019).

#### 4.3. Category 3: inclusion of flood maps in statutory planning processes

Flood hazard and risk maps are viewed by planners as essential planning and communication tools. As new ways of modelling, planning and regulating the present and future arise, the processes for determining which realities and futures are ‘seen’, ‘viable’, and planned for have socio-ecological consequences (Koslov, 2019). This section examines the issue of flood zone notification. Analysing the diverging mapping processes identified (see Table 2), we consider whether flood hazard and risk maps should be included in resource management plans and thus be subject to the statutory plan making process (Schedule 1 RMA).

Under the RMA, local authorities are tasked with preparing resource management plans according to functions mandated by ss 30 and 31. Where rules in a plan have a spatial quality, it is routine for interpretative maps (including connected overlays) to be included in Schedule 1 planning processes, meaning that the information can be tested by way of public submissions and eventually become part of the regulatory code. Throughout Aotearoa this applies to maps denoting a range of physical, social, cultural and spiritual characteristics such as significant landscapes, taonga (valuable objects/resources/phenomenon to Māori), habitats, infrastructure corridors and natural hazards/risks. Internationally, for flood hazard, the simplest maps will chart flood susceptibility based on topographical or geological information, or the extent of historic flood events (Merz et al., 2007). Maps become progressively more complex through the addition of flood frequency analysis and simplified flood modelling, moving through to highly complex GIS maps with multiple overlays which depict several flood probabilities. The most complex, not only include a range of modelled probabilities but also depict flood characteristics including flood extent, hazard intensity, and climate change flood scenarios. With additional vulnerability and consequence inputs, flood hazard maps can become flood risk maps (Merz et al., 2007).

Research reveals practitioner’s frustration around the slow and costly process of reviewing regulatory plans and the concomitant inability to rapidly update flood risk information (Haughton and White, 2018; Serrao-Neumann et al., 2024). In sharp contrast, it also reveals the

<sup>1</sup> See Bay of Plenty Regional Policy Statement – Appendix L – Methodology for risk assessment: “Step 5 (a) (b) Where the initial assessment results in a risk level categorisation of High: (i) (ii) No further assessment is required... (While there might be a greater risk associated with a less likely event the management approach associated with that hazard will not change.)” (Bay of Plenty Regional Council, 2014. p. 319)

**Table 4**  
Mitigating qualifiers for avoidance policies.

Mitigating qualifiers
Hazardous substances on site will not be inundated
Specific building platform, design and freeboard controls apply (including relocatable/recoverable structures)
The land use will not be subject to <i>material damage</i>
There are no risks to vehicular access
Safe evacuation routes/refuges are provided
A functional need to locate the structure or activity within such an area exists (particularly for critical infrastructure)
That it is a non-habitable structure or activity on production land
Adverse environmental effects are avoided to the extent practicable
The development is not likely to result in loss of life or serious injuries
The development is not likely to suffer significant damage/loss and is not likely to require new/upgraded hazard mitigation works
The development is ancillary to the main development
Avoidance is impossible or impractical and adverse effects are mitigated to an acceptable level
Subdivision is solely for the purpose of boundary adjustments

**Table 5**  
RPS Vulnerability definitions.

RPS	Vulnerability definitions
Auckland	'More vulnerable': Activities listed in the residential nesting table and also includes care centres, and healthcare facilities with overnight stay facilities. 'Less vulnerable': Commerce; Community, excluding care centres, and healthcare facilities with overnight stay facilities; Industry; and Rural
Waikato	HAZ-M10 – Control of use and development (high risk flood zones and areas of high coastal hazard risk) Avoiding the placement of structures or development where these would be vulnerable to a natural hazard event or would place a community at intolerable risk. These include: habitable structures; significant community infrastructure such as hospitals and emergency services; and lifeline utilities.
Wellington	Avoid inappropriate subdivision and development in areas at high risk (residential, industrial, commercial development unlikely to be appropriate) (Policy 29).
Nelson	To prohibit developments in hazard prone areas which increase the potential for loss of human life or which result in potential damage to other resources and values which can not be avoided or adequately mitigated (RPS Policy DH2.3.4).

insistence of landowners/stakeholders to interrogate the accuracy and credibility of mapped flood risk information that affects property in which they hold an interest. Commonly, rules in plans may limit activities on land identified as subject to flooding, usually through cartographic depiction. This impacts the exercise of existing property rights and may also have consequences for property insurance.

As shown in Table 2, practices have emerged whereby local authorities have opted to exclude flood risk maps (including overlays) from resource management plans to enable more dynamic review of the information (Auckland Council, 2013). In favour of this approach is greater efficiency, lower costs and rapid communication of updated flood risk information. A distinction can be drawn, however, between maps used solely for risk communication, as opposed to maps which are connected to the imposition of a regulatory constraint upon land use. Excluding the latter category from statutory planning schemes raises several issues. The maps are a cartographic depiction of the evidence establishing the risk, they demonstrate and communicate the science. The maps identify hazardous locations in the landscape and connect to land use rules which restrict activities at risk. Excluding hazard maps from statutory planning schemes weakens the evidence base for the regulation, dilutes the clarity of the spatial arrangements, and may confound the ability of the public to interrogate the accuracy and reliability of the information relied upon.

Regulatory constraints imposed by resource management plans rise and fall upon the clarity and certainty of their provisions. This certainty extends to those administering or affected by a plan provision being able to identify without difficulty the properties to which it relates (Sandstad v Cheyne Developments Ltd (1986) 11 NZTPA 250 (CA)). Even where a

rule provides an explicit formula for calculating flood hazard/risk, an interpretive map is critical to geographically translate application of the formula. A written schedule providing locational identifiers may also be applied, but these do not provide a visual translation of the hazard/risk landscape. Maps are explanatory, give meaning to plan provisions and depict the spatial impact of the rules (Wylie v Clutha DC EnvC C107/04). Without spatial translation, the locational significance of a formulaic flood provision escapes the ordinary reasonable person (Christchurch CC v Aidanfield Holdings Ltd [2010] NZRMA 92 (HC)). The planning document needs to work as a complete whole and this is lost when key interpretive material does not sit within the plan. In addition, those affected lose the ability to contest the accuracy and reliability of the flood risk assessment and provide supplemental locally specific information.

Public engagement in planning underpins the RMA, in particular, as it relates to the development of resource management policy and plans (Toomey, 2012). It is generally understood that public engagement is a traditional feature of democratic government recognising the basic human right for people to have a say in decisions that affect them (Cheyne, 2015; Warnock, 2016). Public engagement delivers better decisions due to provision of increased, locally-specific information, as well as legitimising decisions and reducing future challenges (Warnock, 2016; White et al., 2010). These rights are not unfettered and need balancing against matters such as cost, speed and public safety. Serial amendments to the RMA have addressed this balance by reducing engagement at the *consent* stage, propounding that public engagement should be front loaded in the system at the *plan making stage* (Resource Management (Simplifying and Streamlining) Amendment Act 2009, Resource Management Amendment Act 2013 and Resource Legislation Amendment Act 2017). This shift underscores the importance of retention of public input at the plan-making stage. Additional mechanisms are available to improve efficiency of engagement. The 2017 Resource Legislation Amendment Act enabled limited notification of proposed changes and variations, providing a vehicle for tailored engagement by those affected by, for instance, a plan change or variation to update flood map information (Clause 5A, Schedule 1 RMA).

Saunders and Grace (2015) conclude that maps which provide a strong link to plan objectives, policies and rules, ensure accurate matching of activity status with levels of hazard/risk, providing for more informed and transparent decision-making: "The detail in the maps is reflected in the detail in the rules, and so the policy framework for managing risk is implemented in a comprehensive way." (p.7). Furthermore, where there are concerns regarding the accuracy of maps, the application of statutory hazard awareness zones can be applied which acknowledge uncertainty (see Hurunui District Plan for example). This means that where detailed hazard analysis has not been undertaken, a broader hazard buffer zone can be applied with limited regulatory constraint, requiring a site-specific hazard analysis to be undertaken. This allows a cautious approach to using indicative maps and controlling land use near these features.

The future orientated nature of hazard/risk mapping, particularly where adjusted for climate change effects based on plausible futures (Lempert et al., 2024), further supports scrutiny by the public. Models are recognised as inherently uncertain due to the variability of natural systems combined with epistemic or knowledge uncertainty. The reliability of evidence based on predictive modelling is influenced by complex aspects of modelling best practice. Public scrutiny provides opportunity to enhance rigour and reliability (Özkundakci et al., 2018). Transparency and accountability are further enhanced where map layers based on models provide an explanation of the modelling process, including the key assumptions, parameters, limitations and the evaluation techniques applied (Özkundakci et al., 2018). In addition, resource management plans and associated maps may expressly include data confidence ranges as a mechanism for managing uncertainty (Kelly et al., 2020; Saunders et al., 2013). Kelly et al., (2020) identify distinct approaches to mapping hazard and mapping risk, underscoring the critical importance of public engagement with statutory risk mapping processes, preferably in advance of statutory notification of a plan. Kelly et al. (2020) are not as concerned with hazard mapping and public engagement due to the foundation in scientific investigation. We are not inclined to view scientific investigation (and related modelling) as a disqualifier for public engagement and take the view that where hazard mapping is associated with a rule constraining property use, then all maps should be available for public interrogation via the statutory process as explained above. As recognised by Auliagisni et al., (2022) community-informed flood mapping is critical for raising awareness and incorporating local knowledge to enhance community resilience.

Further supporting inclusion of statutory maps are additional subdivision, use and development controls in relation to natural hazards, designed to operate upon and provide the most up to date risk information and limit specific subdivision and development proposals on land subject to natural hazards (Section 106 RMA 1991; s 71 and ss 31–35 Building Act 2004, Project Information Memoranda, s 44A Local Government Official Information and Meetings Act 1987, Land Information Memorandum). Through these mechanisms, the risk profile of specific proposals may be scrutinised on current data. Councils may also mandate via a resource management plan, the use of the best-available information and likely climate change effects when assessing resource consent and plan change applications (see for instance, Hastings District Plan Policy NHP2 explanation).

Finally, the National Planning Standard 2019 mandates standards for resource management plan electronic accessibility and functionality. Clause 16 B(a)(i-iii) requires an ePlan to include a GIS viewer which includes all spatial layers of the policy statement or plan maps, enables users to search for a specific property and enables users to select which spatial layers are displayed on the viewer.

## 5. Discussion

The application of the riverine flood policy evaluation tool revealed a range of approaches to regional riverine flood policy and land use planning in Aotearoa. In terms of modelling parameters and land use policies (C1 and C2, respectively), there is some movement towards regulating multiple probabilities and longer planning timeframes, and inclusion of flood hazard (with various parameters). Risk-based criteria feature both sporadically and more systematically, with limited public communication of residual risks in mapping, but general considerations in policy. In contrast, Australia captures some of these emerging trends more comprehensively. Demonstrating a consistent national approach, flood policy guidance (AIDR, 2017c, 2017a), integrates flood extent, hazard, and probability ranges, producing multiple planning constraint categories and map overlays across a range of flood characteristics. This includes differing levels of control across a range of probabilities, covering the full floodplain, from the floodways and flood storage areas to the flood fringes, according to flood hazard, assessment of isolation from safety, and emergency management constraints. The policy

constraint criteria are flexible to allow for varying needs and flood problems, such as mapping and control of residual risks where protection measures are expected to be overtopped or fail. This approach produces maps which may outline the extents of a range of flood hazard areas with associated rules from least to most stringent, corresponding to the floodplain area and function, and the ‘relative vulnerability’ and exposure of the activity/asset.

Given the justifications for the selection of different AEPs across the RPS examined, and movement towards a risk-based approach, a policy framework such as AIDR, (2017b) could create more consistency in approach and a broader consideration of the range of effects from flood events and characteristics in Aotearoa. To address existing gaps in practice and jurisdictional disparity, flood management professionals would benefit from a national policy framework which enables collaborative work with communities and responsible authorities to set spatial, jurisdictional, and risk-based flood management interventions over a broad planning timeframe, taking multiple probabilities and climate change into account, and including the resilience benefits of using the floodplain and supporting floodplain ecosystems dependent on flood inundation. As recognised in Section 4.1, regional topography may need to inform the range of AEPs applied, rather than prescribing national standards. Where multiple hazards are at play, joint probabilities or risk assessments will be required (Stephens et al., 2018). A national model for specific flood risk management interventions is unlikely to be helpful, as this requires balanced consideration of social, cultural, economic, and environmental concerns and risk tolerances to reduce risk in a comprehensive manner. As highlighted by Saunders et al. (2024), however, software such as *Riskscape* (Paulik et al., 2023) can support context specific determination and evaluation of the interventions across the risk spectrum.

Whilst the nature of flood management interventions may be locally determined, our analysis supports the argument for national direction to enable consistent and effective policy making (Fu et al., 2023; Serrao-Neumann et al., 2024). Without a national policy statement, implementing agencies have a broad mandate for risk management. It is therefore not surprising that this analysis reveals significant disparity in policy approaches to flood hazards, and at times, tenuous approaches to risk management. Whilst ‘avoidance’ of hazards has long been a feature of planning legislation, planning practice has “largely continued along a preferred ‘mitigation’ of hazards route using ‘protection’ and ‘accommodation’ measures” (Lawrence et al., 2021, p.5). This pattern reaches beyond flood risk and is pertinent to all national risk management concerns. Without a clear planning framework, policy inconsistency and static planning measures will endure, with compounding consequences in terms of the ability to adapt to changing climate impacts, and with associated costs.

Traditional zoning and policy approaches have been criticised as being too inflexible (Lawrence et al., 2021; Saunders et al., 2024). However, flood maps which regulate and convey overlays of multiple probabilities and climate scenarios, and residual risks, may transform them into risk and uncertainty communication tools, not just decision-support tools (Haughton and White, 2018). Where there is modelling uncertainty, for example, limited historical records for determining the probable maximum event, the precautionary principle and the Australian policy stringency hierarchy described can assist.

Similarly, precaution, complemented by adaptive strategies (see Haasnoot et al., 2024), is required when addressing the deepening uncertainty of climate change (Lempert et al., 2024). This entails embedding precaution within policy frameworks, indicating areas for further site-specific analysis, or applying more limited controls, such as avoiding the development of critical infrastructure/services in the probable maximum flood (PMF) areas, and developing adaptive strategies to address existing development at risk. Alongside more dynamic mapping of flood hazards, decision-making methods need to be tailored to address deep uncertainties in modelling parameters and probabilities, moving away from static policies to a pathways approach that enables

adaptive decision making as conditions change (Haasnoot et al., 2024). Whilst authorities are already engaged in monitoring the effectiveness of policies and plans, the increasing impacts and uncertainties produced by climate change require more regular and longer-term monitoring systems (Ministry for the Environment, 2017), which approaches such as Dynamic Adaptive Pathways Planning can support. In particular, Dynamic Adaptive Pathways Planning has been tested in the river flood context in Aotearoa (Lawrence and Haasnoot, 2017) and is central to national guidance on coastal planning (Ministry for the Environment, 2024). In addition to adaptation planning, this approach could also be applied to land use policy to support dynamic spatial and temporal allocation of interventions and controls to manage flood risk over the short to long-term.

The increasing diversity of flood risk management strategies requires integration with other policy spheres beyond land use planning, especially spatial planning, conservation, adaptation planning, and emergency management (Doorn-Hoekveld et al., 2022). In relation to public information provision (C3), where there is an issue regarding statutory processes and the inclusion of updated risk information, we recommend inclusion in statutory schemes if the information triggers additional regulatory assessments and constraint on any property. Updated risk information may have significant consequences for the way in which property is used and a collaborative approach to risk definition and management is preferable. In Aotearoa, to avoid concerns relating to responsiveness of planning systems (e.g. Haughton and White, 2018) we note the existing protective capacities of using the most up to date information for subdivision and building consents (Section 106 RMA 1991; s 71 and ss 31–35 Building Act 2004, s 44 A Local Government Official Information and Meetings Act 1987). In addition, the availability of limited notification for plan changes (clause 5 A first schedule RMA) offers a more targeted process, limiting public engagement to those people directly affected. Additional opportunity could include amending s 86B(3) RMA to extend provision of immediate legal effect to a proposed rule in a plan that relates to *the management of significant risks from natural hazards* (including the relevant notations on the risk map). This enables activation of the proposed change in advance of the completion of the statutory process and would put natural hazards on the same footing as, for example, protection of water, air and soil (s 86B (3)(a) RMA). An alternative would be the development of a bespoke fast track for plan development where new information identifying risk from a natural hazard or updates on climate projections, has been released.

In summary, this research reveals the complex demands upon planners in the transition to the management of flood riskscapes. We are witnessing a move away from static susceptibility mapping and regulation towards risk-based planning assessments. While risk can be spatially defined by way of mapping, it is scenario and value dependent. The land use type, environment, flood characteristics, vulnerability, and potential mitigation measures influence the level of actual or potential risk, and selection of risk criteria requires value judgements. The way in which maps depict or exclude risk, and how they connect to land use planning, insurance, emergency management and risk communication can have large implications for society (Serra-Llobet et al., 2022). To enable a consistent approach, local governments need national policy to direct the identification and regulation of risk in land use plans. This must recognise the spatial and temporal risk legacies of land use planning, and the needs of future generations, by requiring the assessment of decisions against a range of timeframes, lifetimes of the decision, and various scenarios of the future. In particular, constant change and deepening uncertainties (Lempert et al., 2024) require a shift away from static plans and policies to dynamic, long-term planning. As the aims of flood adaptation and frameworks for assessing risk continue to evolve, the opportunities broaden, and demand attention towards what and who are valued, to deliver equitable planning decisions (Mach et al., 2022).

## 6. Conclusion

This paper aimed to inform land use planning in light of dynamic and intensifying flood events which are challenging how governments assess and communicate flood risk information, and design corresponding regulatory planning instruments and tools. For this, we developed and applied a riverine flood policy evaluation tool to the Aotearoa planning context to capture the modelling parameters, policies, and information used by regional authorities, distinguishing between traditional and emerging approaches. Our findings revealed evolving practices, policy variances, and aspects of contention, demonstrating where central and state governments can provide greater direction for policy development. Importantly, the analysis revealed that a transition from static to more dynamic river flood policy and risk communication is occurring, but national policy direction is required to help local authorities to more consistently determine flood hazard and risk, and how to use this information in land use planning decisions. This includes directions for a risk-based planning approach underpinned by a consistent framework for managing activities in the floodplain, considering dynamic flood characteristics and conditions of the receiving environment, to deliver long-term, strategic, robust, and collaborative planning.

Whilst this evaluation tool is influenced by the Aotearoa context, it has international application by providing a foundation to assess and compare riverine flood planning practices as governments move towards dealing with complexity and uncertainty in the face of increasing risks. This approach can be adapted to local contexts and updated as understanding of flood hazard and risk is refined. For example, municipal authorities may have additional policies such as floor level controls to add for comparison or additional modelling tools such as flood isolation mapping (e.g. Anderson et al., 2022).

In terms of future research, a particular area of development for this tool is Category 2 - the specific flood risk criteria and thresholds applied in practice. Where the risk-based approach is more established, this category can be expanded to include comparisons of the strategic framework and directions to reduce and treat risks (e.g. undertake planned retreat to address high risks to human life and ecosystems), plus comparison of the criteria applied such as land use compatibility, and the inclusion of factors such as evacuation route capacity. A further criterion of inclusion (evidenced by policy silence in our analysis) is criteria for risk to ecosystems, which was demonstrably less visible than risks to human life and property.

## CRedit authorship contribution statement

**Serrao-Neumann Silvia:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Wallace Pip:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hanna Christina:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

No data was used for the research described in the article.

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