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Innovative land use planning for natural hazard risk reduction: A consequence-driven approach from New Zealand

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ABSTRACT

The traditional land use planning approach for addressing natural hazards in New Zealand has been based on the likelihood of an event occurring, with little consideration of the consequences associated with natural hazard events. This has led to decisions that place developments and communities at risk. Local government planning authorities who want to transition to risk-based planning face a number of challenges, including: how to satisfactorily define acceptable, tolerable and intolerable risk; how to incorporate the views of stakeholders and affected communities; and how to ensure that potentially controversial decisions over land use options are robust and defensible.

This paper describes a practical innovation in land use planning that assists local and regional scale planners incorporate risk into land use planning decisions. Termed the 'Risk-Based Planning Approach' (RBPA), the objective of this framework is to provide local government planners with a process that responds to the key challenges they face in adopting a risk-based approach. It includes strategies to guide engagement and communication with key stakeholders both across local government and with affected communities; it supports a full assessment of the consequences, as well as likelihood, of natural hazard events; and it enables natural hazard policies to be monitored for their effectiveness in either holding-the-line or in reducing risks.

In this paper we review how the RBPA provides for innovation in land use planning. In particular we note how its development with input from planners has ensured its applicability and consistency with statutory planning requirements and we examine an early case of its use in practice. This case demonstrates how a regional planning agency further innovated based on the RBPA, to provide robust and defensible decisions around acceptable, tolerable and intolerable levels of risk for their region.

1. Introduction

Land use planning is a major tool for reducing risks from natural hazards, in turn aiding sustainability and increasing resilience [2,17]. Risk-based planning provides an opportunity to move beyond planning for a natural hazard only (i.e. the likelihood of an event), to planning for the consequences of an event. This involves assessing the land use, and having planning provisions that become more restrictive as the risk increases. There are a number of challenges in moving towards a risk-based approach which are not unique to New Zealand. Firstly, in planning there is traditionally an over reliance on assessing the probability of an event, and an under capacity to assess and quantify the possible consequences of events beyond annual fatality. In situations where likelihood of events is deemed low, this has led to decisions that have placed developments and communities at risk.

Secondly, at the heart of risk-based planning is the ability to delineate between different levels of risk (such as acceptable, tolerable or intolerable), and link these to suitable land use policies. An acceptable level of risk needs to be based on measurable indicators that allow risk levels to be monitored over time, enabling towns and cities to undertake sustainable development that does not exceed acceptable levels of risk- and may even act to mitigate existing risk. It also makes it possible to track the efficacy of efforts to reduce existing risks.

In this paper we present an innovative, practical framework for risk-based land use planning to support the inclusion of natural hazard risk assessments in land use decisions. The objective of this framework is to provide local government planners with procedures and resources that respond to the key challenges they face in adopting a risk-based approach to policy development. Termed the 'Risk-based planning approach' (RBPA), it is available either as an online toolkit[1], or as a report [23], and includes strategies to guide

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[1] Available at: http://www.gns.cri.nz/risk-based-planning.

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engagement and communication with key stakeholders within both local government and affected communities. Developed with input from planners to ensure its applicability, the RBPA allows a full assessment of the consequences, as well as likelihood, of natural hazard events. Natural hazard policies can thus be monitored for their effectiveness in either holding-the-line or in reducing risks.

This paper first outlines what innovation is within a land use planning context, and summarises the physical and governance context of natural hazards management in New Zealand. The five-step RBPA framework is then presented, which includes a matrix for assessing the potential consequences of natural hazard events. By reviewing how the framework works in practice, we show that robust and defensible decisions around acceptable, tolerable and intolerable levels of risk can be determined. The paper reviews the design criteria of the RBPA, tested through action research and development methods. This approach ensured the RBPA could be of practical value within known resource and capacity limitations, and the imperfect knowledge that characterises natural hazard risk decision-making.

2. Innovation in land use planning

Innovation within the context of land use planning and natural hazard risk reduction is defined as an opportunity to plan for positive social, economic, and environmental outcomes in a new way, based on old and new planning principles within planning theory and practice. It requires a vision, leadership, and belief which extends beyond political cycles; is comprehensive and integrated with policies and plans from different sectors; and involves the active and meaningful participation of the community [21].

Davila et al. [3] categorise innovation in business (i.e. the market) according to three generic categories:

Incremental innovation brings out as much value as possible from existing products or services without making significant changes or major investments. Incremental innovation represents constrained creativity, where only small changes are feasible at any one time; it often becomes the dominant form of innovation and crowds out other potentially more valuable changes.

Semi-radical innovation involves substantial change to either the business model or technology of an organisation – but not to both. Often change in one dimension is linked to change in the other, although the parallel change may not be as dramatic or disruptive.

Radical innovation is a significant change that simultaneously affects both the business model and the technology of a company. Radical innovations usually bring fundamental changes to the competitive environment in an industry.

While it is often thought that innovation is about making something new, these three types of innovation include a mixture of old and new. Sternberg et al. [31] expand these three generic categories of innovation to eight distinctive types of innovation, reflecting variations in the nature of the creative contribution each represents (see Table 1). Similarly, innovation in the planning profession, within practice or theory, can be categorised as any one – or a combination of these types depending on of the creative contribution that planning is making. It can be internal to the governance processes and systems that administer the planning, or external to those who use the planning system.

Risk-based planning can fall into all of these innovative categories, depending on the state of planning in a particular area. The New Zealand planning system is briefly outlined below.

3. The need for an innovative approach to risk-based planning in New Zealand

Located on the active boundaries of the Pacific and Australian plates, New Zealand is subject to a wide variety of geological natural hazard events (see Fig. 1). It is also susceptible to extreme meteorological events due to its mountainous topography in the path of moisture-bearing winds. While flooding is the most frequently occurring natural hazard [6], communities also face risks from landslides, coastal storms and erosion, severe winds, snow, drought and the potentially catastrophic impacts of earthquakes, tsunami and volcanic eruptions. As rapid development has occurred along the coast, the exposure to coastal storms and erosion has increased. Increased climate variability and change will likely compound the risks many communities face, especially those on floodplains and along low-lying coastal margins, as sea level, and intensity and frequency of storms increase [7].

As New Zealand is susceptible to so many natural hazards, it is nearly impossible to have zero risk. Avoidance, while useful in extreme risk locations, is not always possible. Mitigation efforts can ironically increase risks to others (e.g., deflecting flood waters), and can increase residual risk (e.g., increased development behind flood control structures). Natural hazards must thus be managed in a way that allows for smarter, risk-aware development.

3.1. Land use planning in New Zealand for natural hazards

No one agency is responsible for natural hazard management in New Zealand. Rather, a number of organisations, including: the Ministry for the Environment (provides national regulatory and non-regulatory guidance); regional councils (responsible for regional or catchment scale policy frameworks); territorial authorities (i.e. city and district councils responsible for specific land use designations and decisions); civil defence emergency management groups (disaster preparedness and response); and engineering lifeline groups (infrastructure management), hold complimentary responsibilities. Co-operation between these agencies is essential to ensure a streamlined and holistic national approach to planning for natural hazards and disasters.

There are four key statutes that contribute to natural hazard

Table 1
Three categories of business innovation [3] with eight types of innovation (based on [31]).

Category	Type
Incremental innovation	*Replication* – the field is where it should be *Redefinition* – to redefine the field; a new point of view
Semi-radical innovation	*Forward incrementation* – moves the field in the direction it is heading, takes the field to a point with others *Advance forward incrementation* – moves the field in the direction it is heading, moving beyond where others are ready to head
Radical innovation	*Redirection* – moves the field toward a new and different direction *Reconstruction/redirection* – moves the field back to where it once was, so it can again move forward in a different direction *Reinitiation* – moves the field to a different and not yet reached starting point, and then moves in a new direction *Integration* – moves the field by combining past contributions that were distinct or opposed.

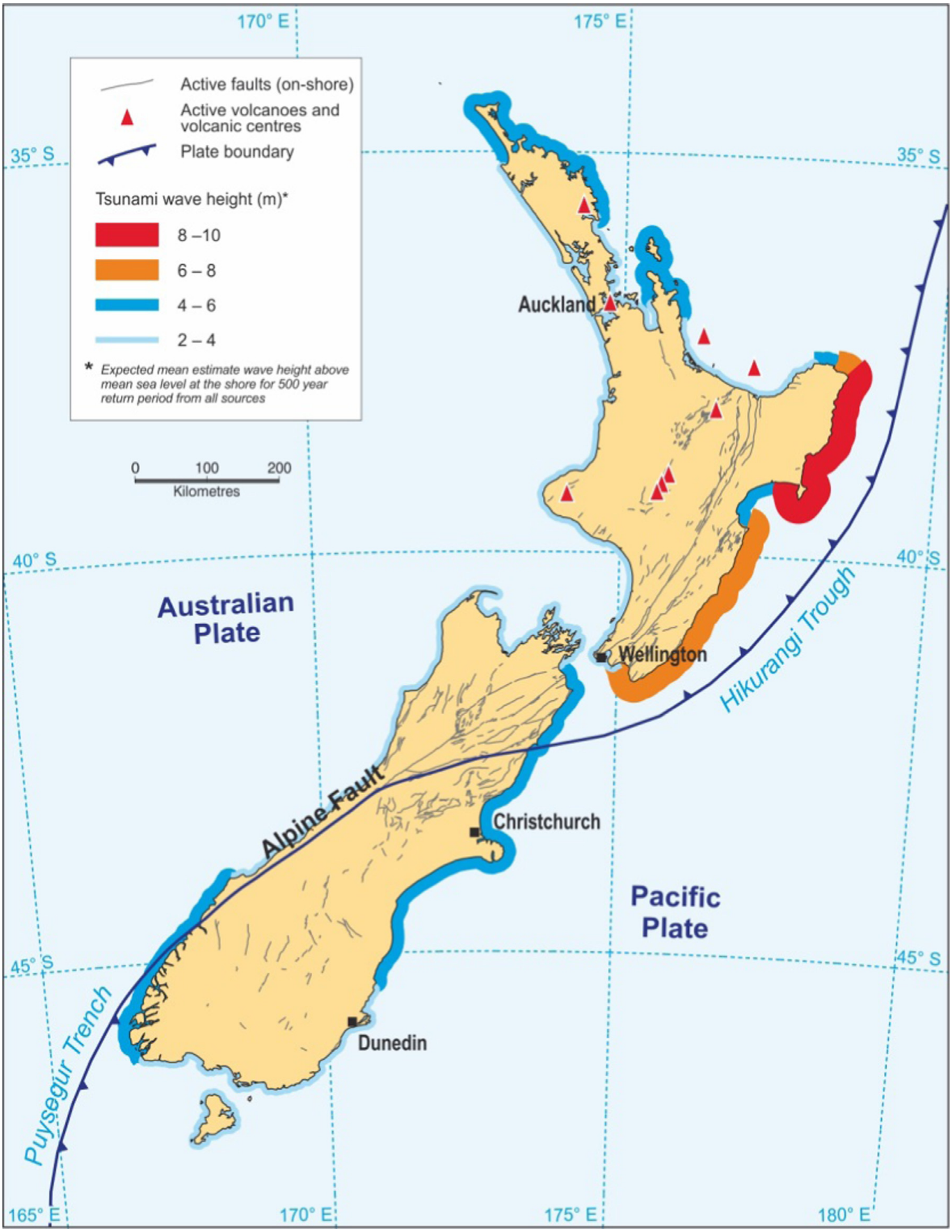

Fig. 1. The New Zealand geological setting (adapted from [6,p. 680]).

management: the Resource Management Act 1991(RMA), Building Act 2004, Civil Defence Emergency Management Act 2002, and the Local Government Act 2002. These are intended to be integrated, which is reflected in their common purposes and shared focus on sustainability. The RMA is the primary legislation for controlling land use, with its purpose to promote the sustainable management of natural and physical resources. Under the RMA, sustainable management means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while sustaining the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations.

Three levels of governance in New Zealand administer these Acts: at national, regional, and territorial scales. The roles of each in natural hazard management are summarised in Table 2; further detailed information can be found in Glavovic et al. [6].

Risk-based planning assists both regional and territorial authorities to mitigate the effects of natural hazards through land use plans. Currently, mitigation measures required by territorial

Table 2
Summary of roles for managing natural hazards in New Zealand.

Level of government	Example	Function	Natural hazard management
Central	Ministry for the Environment	Provide National Policy Statements, non-regulatory guidance	Currently developing National Policy Statement on natural hazards and risks
	Department of Conservation	Provide and administer the New Zealand Coastal Policy Statement	Coastal hazard risks, over at least 100 years, are to be assessed
	Ministry of Civil Defence & Emergency Management	Provide emergency readiness, response and recovery for large scale events	Promotes sustainable management of hazards; encourages communities to achieve acceptable levels of risk
Regional	Regional Councils, Unitary Authorities	Administer the RMA through regional policy statements (RPS) and regional plans	Control and use of land for the purpose of the avoidance or mitigation of natural hazards
		Provide emergency readiness, response and recovery for regional scale events	In respect of any coastal marine area in the region, the avoidance or mitigation of natural hazards
Territorial	District and City Councils, Unitary Authorities	Administer the RMA through district/city/unitary land use plans	The control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards.
		Provide emergency readiness, response and recovery for local scale events	District/City plans must beconsistent with provisions in the RPS

authorities under the RMA do not necessarily result in a reduction of risk; only in a reduction of the hazard [24]. Risk terminology in many land use plans is weak [22], allowing for developments where the risk is acceptable to the applicant (e.g. the developer, and often for a short time), but not to the greater community or officials. In addition, while the RMA promotes a consultative, co-operative approach to land use planning [5], talking to stakeholders such as infrastructure providers and affected communities about risks can be challenging. This is particularly so for local government agencies, who often lack appropriate risk communication and engagement frameworks and resources.

The online RBPA toolkit aids current planning practice by providing explanations of hazard and risk, outlines an adaptable risk-based framework, includes examples of engagement practices and risk-based planning in practice, and general hazard and risk information relevant for planning. It provides an improvement on current practice by presenting a transparent framework for decision making based on risk, rather than just hazard. This subtle change in natural hazard management is incrementally innovative for many councils in New Zealand, and the implementation of the RBPA is considered to be radically innovative for many. This toolkit provides an extension of current practice by having hazard and risk information specific to land use planning in one online location; reduces the repetition of policy development between councils in New Zealand; utilises current science to underpin the framework, and outlines consequences in a scalable and quantitative way.

With climate change, the context for managing natural hazards is changing. Extreme weather events, increased magnitude of flood events, sea level rise, coastal erosion, along with the shocks of major geological events (such as earthquakes), and pressure for increased urban development, will change the way natural hazards are managed. Regional and territorial agencies have to adapt ahead of this changing environment, and require tools to assist them in planning for the future. The RBPA is therefore a timely intervention, providing a robust framework that is well supported by a widely recognised need for change – moving beyond where current practice is.

4. A risk-based approach to land use planning for natural hazards

Risk-based planning is encouraged by the UNISDR [32], who highlight the role of land use plans to control or prevent development in extreme risk areas, and to mitigate risk in existing developments. More recently, the Sendai Framework for Disaster Risk Reduction has further prioritised the strengthening of disaster risk governance to manage disaster risks [33].

Despite these international trends, local government agencies in New Zealand have shown some reluctance to widen the consideration of natural hazard events as part of land use planning, fearing implications for development and growth. Arguably, a risk-based approach supports smarter development (not necessarily no development), allowing long-term potential impacts and costs to be factored into development choices. It provides local government planners and elected governance officials with a vehicle for deliberating future land use options based on the potential social and economic costs of a natural hazard event. Importantly, it allows local government agencies to determine, in discussions with their communities, what is an acceptable level of risk. Once determined, reference to levels of risk can be included in land use plans.

A risk-based planning assessment can be used to address the effects of a particular natural hazard, either in its own right, with other hazards at the same location (i.e., cumulative), or with cascading hazards (e.g. an event such as an earthquake can trigger other hazards such as liquefaction, tsunami, and landslides). It ensures that the economic, social, cultural, infrastructure, and health and safety consequences of a specific development are explored and quantified as part of future planning decisions [21].

Variations of risk-based land use planning is being used in many countries including: United Kingdom, European Union, Canada, Australia, USA and Hong Kong [1,8,9,11,15,19,20]. During the development of this RBPA (between 2007 and 2013), a number of other countries were developing similar risk-based frameworks, for example: the Queensland Reconstruction Authority in Australia, who published their risk-based approach to flooding in 2012; and the Geological Survey of Canada, who published their risk-based land use guide for hazard risk assessment in 2015. In contrast to these risk-based planning approaches, the framework presented here directs planners and policy makers to focus first on the social, cultural, built, economic and health and safety consequences of a natural hazard event, followed by analysis of likelihood. For many New Zealand regional and territorial councils, this is a semi-radical innovation-moving beyond the current practice of planning for hazard, to planning for risk (i.e. likelihood and consequences). Typically, primary consideration is given to the probability of an event, for example, the often used and misconstrued '1-in-100 year flood', and focuses only on the time period, rather than on the implications for communities in terms of disruption to livelihoods, health, infrastructure and economies.

This focus on a return period makes it difficult for technical experts and political decision-makers to be adequately forward thinking, particularly where decisions are required on what appear to be unlikely events.

4.1. Development of the RBPA

The project to develop the RBPA used Participatory Action Research (PAR) to ensure its applicability and relevance for planning practice [12,14,16]. Rather than undertaking research independent of the practical end users (i.e., local government agencies), which could lead to results that have no support or cannot be implemented, the PAR approach directly involved users within the research. A combined researcher and stakeholder steering group was formed which included regional and territorial government agencies (i.e. two regional councils, one unitary authority, one district council), as well as risk and land use planning national agencies (i.e. Ministry for the Environment, Ministry of Civil Defence Emergency Management, Earthquake Commission, Local Government New Zealand), an academic and a consultant. As well as this stakeholder group, workshops were undertaken with other council representatives across New Zealand.

4.2. Outline of the RBPA framework

The RBPA framework is consistent with international risk management best practice (e.g. [28]). Fig. 2 compares the standard risk management process with the risk-based planning approach, and shows that each step of the risk-based approach is consistent with the risk management standard.

The RBPA is based on five steps:

1. Know your hazard;
2. Determine the severity of the consequences;
3. Evaluate the likelihood of an event;
4. Take a risk-based approach and;
5. Monitor and evaluate.

Each step has options enabling stakeholders and affected communities to participate in the risk analysis, evaluation and decision making process. While presented as five distinct steps, the process is not strictly linear. Sometimes likelihood may drive the consequence assessment, or Step 1 may need to be revisited in light of an outcome (for example, more detailed modelling of a hazard may be required). While it is important to recognise areas of uncertainty and the implications of incomplete information, the approach can enable decisions to progress on the basis of current knowledge.

In the RBPA, risk communication and engagement is fundamental to risk assessment and decision-making. At each phase, communication and engagement activities support the risk assessment tasks and contribute to the individual parts of the RBPA (see Fig. 2 and Table 3). With phases of awareness raising, information assessment, and reflection, the communication and engagement activities of the RBPA act to stimulate complex discussions about risk acceptability, within both the agencies and the wider affected community.

The five steps for the risk-based approach are explained in more detail in Table 1.

The RBPA is designed to work within typical constraints on local government resources and skills, while at the same time

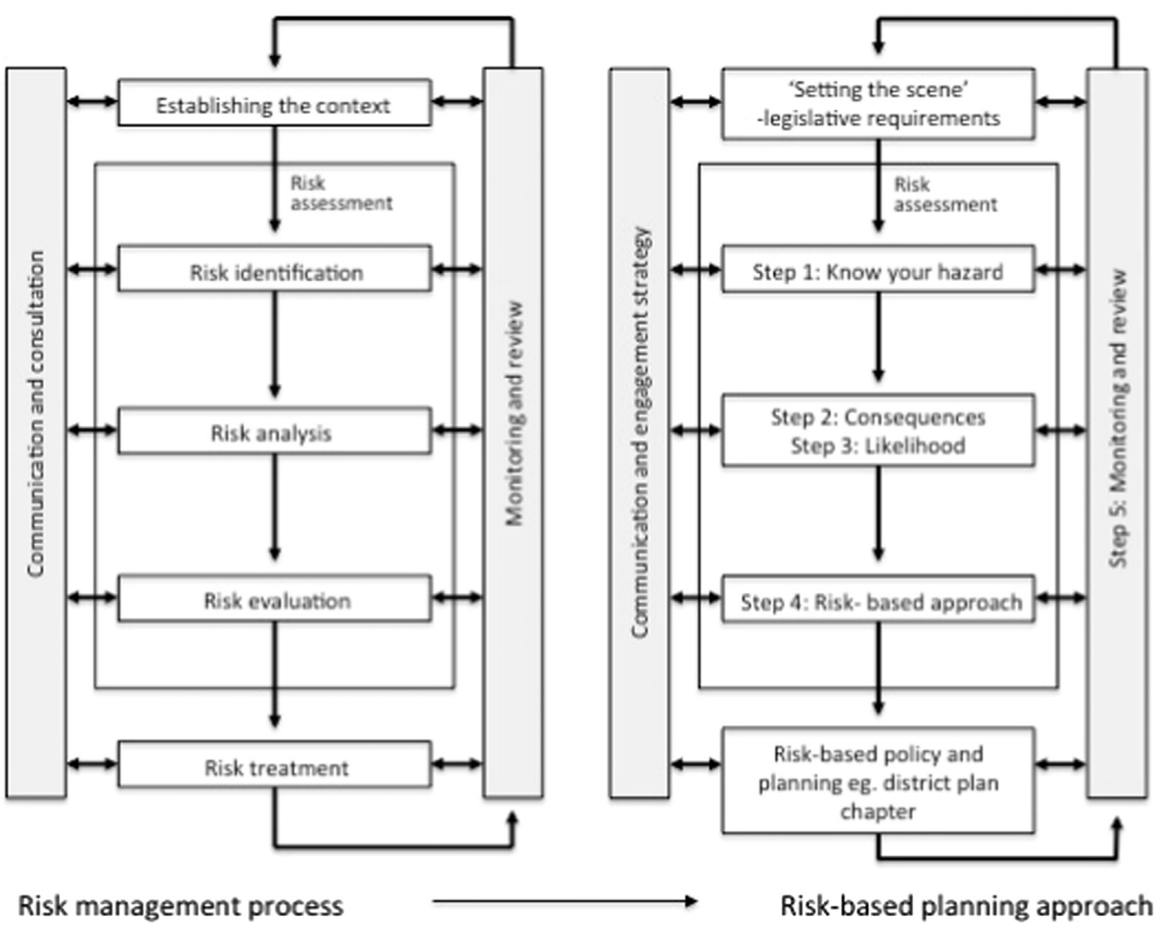

Fig. 2. Relationship of risk-based planning approach to the risk management process.

Table 3
Summary of risk-based approach showing parallel risk analysis and risk communication and engagement activities [23].

Step 1 – Know your hazard	**Risk analysis tasks**	**Risk communication tasks**
The purpose of this step is to determine the scope of the issue to be addressed, to identify the team of professionals and experts whose input will be needed, and to cover the important base elements of a public engagement strategy. The second stage of this step is to assemble hazard information for analysis and review, and to prepare materials for engagement with affected parties and/or discussion by expert panels or representative groups.	Scoping – 1. **Establish problem/decision parameters** (e.g., what is the information (e.g., plan change, growth strategy?) How will the information inform policy? What scale is the information required at? What is the time frame for the decision? What are the risk outcomes sought (e.g., risk reduction, not increasing existing levels of risk)? 2. **Identify team and resource needs** (e.g., what expert information is required and who is available to provide it? Who is able to provide useful local context information? Preliminary assessment and information preparation 3. **Identify hazard information gaps and uncertainty**, gather further information where existing information is lacking or does not meet requirements. 4. **Gather background information** for consequences analysis (e.g., inundation maps, fragility curves, regional GDP figures, land use plans). 1. **Agree on an information management system** to store, retrieve, and access hazard information.	1. **Prepare an** engagement approach including stakeholder analysis, context analysis, and assessment of existing perceptions. 2. **Begin** internal communication within local government agency including public representatives, and other departments. 3. **Begin** external communication (e.g., early notification of upcoming decisions). 4. **Identify hazard information gaps and uncertainties** Identify useful information for sharing with stakeholders; clarify areas of uncertainty, note gaps and likely areas of contention. Also consider hazard complexity. 5. **Update engagement approach** – following a hazard information review (new stakeholders may become apparent)
Step 2 – Determine severity of consequences The purpose of this stage is to build a picture of the possible consequences of a natural hazard event. Natural hazard information, coupled with information about the proposed development and existing land use is used to undertake an assessment of consequences. Information about the natural hazard consequences and the development is confirmed through engagement with specialists, those with local knowledge, and stakeholders.	**Risk analysis tasks** 1. **Determine** consequences for a) individual and b) cascading hazards and assess against a consequence table (see Fig. 3). 2. **Determine** severity of consequences for the hazard event with the highest severity of impact to set the consequence level.	**Risk communication tasks** 1. **Validate hazard information:** Use the engagement approach identified earlier to share, review and update information about natural hazards and potential consequences. 2. **Update stakeholder analysis** (following consequences analysis new stakeholders may become apparent). 3. **Assess engagement approach** – is it still right for the situation? 4. **Record decisions and assumptions** for transparency.
Step 3 - Evaluate likelihood of an event The purpose of this stage is to assess the likelihood of any event that will result in the consequences outlined in Step 2.	**Risk analysis tasks** 1. **Assess the likelihood** of individual and cumulative hazard events (cascading hazards are addressed against the trigger hazard). 2. Cumulative hazards may result in an increase in **likelihood**, e.g., three cumulative hazards which are 'possible' may increase overall likelihood to'likely'. 3. In some instances the **likelihood** will be required for modelling and assessing the hazard (Step 1).	**Risk communication tasks** 1. **Record decisions and assumptions** about likelihood and occurrence for transparency and use in communication at Step 4.
Step 4. Take a risk-based approach This is the stage where stakeholder acceptance of the calculated levels of risk and associated consent categories (and the implications of these) are assessed. It is also when ideas about risk mitigation may emerge – particularly in relation to areas of greatest contention. Discussions with stakeholders and affected parties will include whether the risk categories and/or consent levels are appropriate, and what trade-offs might be made between extra margins of safety, possible benefits, and costs of mitigation.	**Risk analysis tasks** 1. **Determine** levels of risk for policy. 2. **Determine** resource consent activity status based on levels of risk. 3. **Assess** against assessment criteria and anticipated environmental outcomes. 4. **Identify** and consider risk mitigation options.	**Risk communication tasks** 1. **Validate levels of risk for policy and consent categories with stakeholders** – i.e., confirm and check for perverse outcomes. 2. **Engage stakeholders in identifying and reviewing risk mitigation options**. 3. **Update stakeholder analysis and engagement approach** (after mitigation options new stakeholders may appear). Hold forums/meetings/public events in accordance with engagement strategy, e.g., with representative groups, expert panels or communities. (See 'key points for public forums on local hazards and their impacts').
Step 5 Monitor and evaluate While evaluation and monitoring have taken place throughout at this final stage, the outcomes of the process and the process itself are assessed to determine any further necessary actions.	**Risk analysis tasks** 1. **Evaluate risk-reduction effectiveness**, i.e., risks are not increased. 2. **Plan to change or revisit strategy** if required to ensure risk outcomes are being achieved.	**Risk communication tasks** • **Evaluate** acceptance of mitigation options. • **Evaluate** acceptance of residual risks. • **Evaluate** communication and engagement strategy. • **Communicate** risk outcomes with stakeholders and community and review policy if required.

building capacity for risk based planning, and including public input into decisions that involve risk. There are important components to implementing the RBPA at each step, which extend existing land use planning practice. Some of these aspects were built into the RBPA through the project's grounded research and development process; others have emerged as local government agencies have begun to take up the approach – notably the Bay of Plenty Regional Council who have used it in the development of their regional policy on land use and natural hazards, and the Thames-Coromandel District Council who have used the RBPA to guide restrictions on land development. The framework is adaptive – it provides a process that councils can adjust it to their own needs, and those of their communities.

4.3. Step 1: know your hazard

In traditional planning this information gathering and scoping stage is largely the province of planners and in-house technical experts. The RBPA asks planners and policy makers to source information more widely by encouraging a cross agency, cross expertise approach. For example project team members can include: internal council staff from the areas of communications; emergency management; planners (both policy and regulatory); elected members; and scientists with expertise in the area; as well as neighbouring local government agencies that share jurisdictional and hazard boundaries (e.g. active faults that traverse across jurisdictional boundaries). A review of use of uptake science information in local government [26], found that local government agencies are not fully utilising scientific information that they currently hold. Widening the sources of information can help to counter this. Furthermore, while it is not usual practice to have public engagement at this stage, the RBPA recognises that discussions with external stakeholders (i.e. researchers, community members, businesses and infrastructure providers), can provide useful information at the start of the process, rather than stakeholders responding to decisions and options. Ideally, the approach need not be resource intensive and can be based on existing information.

4.4. Step 2: determine severity of consequences

The aim of Step 2 is to examine a range of possible consequences of a natural hazard event and involves several aspects that are innovative in current risk-based planning.

In the RBPA, consequences of a natural hazard event are calculated using a consequence matrix (Fig. 3), based on the mapped hazard extents identified in Step 1 (e.g., flood extents, coastal erosion lines, active fault setbacks, tsunami inundation zones, landslide susceptibility areas); and the known land uses within the hazard zones (e.g., residential, commercial, industrial, recreational). As the assessment is directly linked to the assets within a given mapped hazard extent (rather than averaged over an area such as a town), there is no dilution of consequences over an area where they may have no impact.

The consequence matrix offers an innovative framework for reviewing consequences across multiple community well-beings, as identified in key land use planning legislation [24]. The matrix is an example of semi-radical incremental innovative, in that it moves beyond the typically life safety and economic metrics to include qualitative and quantitative measures of social, cultural, and built environment metrics. A consequence table such as that shown in Fig. 3 had not been developed to this extent prior to this project. The impact metrics chosen in the RBPA consequence matrix were based on sources readily available and applicable to local government. It is underpinned by the metrics in the Risk Management Guidelines [27]; the measures within the table could be debated and expressed differently in different national and cultural settings. These guidelines have similar columns for economic, health and safety, and social/cultural heritage. The guidance provided in the Risk Management Guidelines was adapted for land use planning. For example, in the RBPA consequence matrix, measures are based on percentages rather than nominal numbers. This allows for the scale of the population at risk to be taken into account (an important feature as many local government regions have communities of widely differing population density); and negates the need to revise the dollar value of economic measures over time.

In assessing consequences, the final overall level of impact is determined by the consequence category with the highest severity. For example, a natural hazard event may have a ‘moderate’ severity of impact across all of the categories, with the exception of critical buildings category, for which it has a ‘major’ severity of impact. The overall impact of the hazard event would then be regarded as ‘major’. This first-past-the-post method avoids

Severity of Impact	Built				Economic	Health &Safety
	Social/Cultural	Buildings	Critical Buildings	Lifelines		
Catastrophic (V)	≥25% of buildings of social/cultural significance within hazard zone have functionality compromised	≥50% of affected buildings within hazard zone have functionality compromised	≥25% of critical facilities within hazard zone have functionality compromised	Out of service for > 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for > 6 months (affecting < 20% of the town/city population)	> 10% of regional GDP	> 101 dead and/or > 1001 inj.
Major (IV)	11–24% of buildings of social/cultural significance within hazard zone have functionality compromised	21–49% of buildings within hazard zone have functionality compromised	11–24% of buildings within hazard zone have functionality compromised	Out of service for 1 week – 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for 6 weeks to 6 months (affecting < 20% of the town/city population)	1–9.99% of regional GDP	11–100 dead and/or 101–1000 injured
Moderate (III)	6–10% of buildings of social/cultural significance within hazard zone have functionality compromised	11–20% of buildings within hazard zone have functionality compromised	6–10% of buildings within hazard zone have functionality compromised	Out of service for 1 day to 1 week (affecting ≥20% of the town/city population people) OR suburbs out of service for 1 week to 6 weeks (affecting < 20% of the town/city population)	0.1–0.99% of regional GDP	2–10 dead and/or 11–100 injured
Minor (II)	1–5% of buildings of social/cultural significance within hazard zone have functionality compromised	2–10% of buildings within hazard zone have functionality compromised	1–5% of buildings within hazard zone have functionality compromised	Out of service for 2 hours to 1 day (affecting ≥20% of the town/city population) OR suburbs out of service for 1 day to 1 week (affecting < 20% of the town/city population)	0.01–0.09 % of regional GDP	<= 1 dead and/or 1–10 injured
Insignificant (I)	No buildings of social/cultural significance within hazard zone have functionality compromised	< 1% of affected buildings within hazard zone have functionality compromised	No damage within hazard zone, fully functional	Out of service for up to 2 hours (affecting ≥20% of the town/city population) OR suburbs out of service for up to 1 day (affecting < 20% of the town/city population)	<0.01% of regional GDP	No dead No injured

Fig. 3. Consequence matrix.

Level	Descriptor	Description	Indicative frequency
5	Likely	The event has occurred several times in your lifetime	Up to once every 50 years
4	Possible	The event might occur once in your lifetime	Once every 51–100 years
3	Unlikely	The event does occur somewhere from time to time	Once every 101–1000 years
2	Rare	Possible but not expected to occur except in exceptional circumstances	Once every 1001–2,500 years
1	Very rare	Possible but not expected to occur except in exceptional circumstances	2,501 years plus

Fig. 4. Likelihood scale.

meaningless averaging across wellbeing categories, and the difficulty of determining one wellbeing category as more important than another. Finally, the consequence table allows for cumulative hazards (e.g. unrelated hazards that affect the same location), and cascading hazards (e.g. a trigger event that results in many hazards, such as an earthquake that, in addition to ground shaking, can result in a tsunami, liquefaction, subsidence, and landslides), to be considered.

4.5. *Step 3: likelihood*

Step 3 of the RBPA is the determination of likelihood for individual and/or multiple hazards. It involves technical input by qualified hazard analysts. Similar to the consequence table (Fig. 3), the frequencies may differ in other national and cultural settings. For New Zealand the likelihoods provided are based on typical planning timeframes (i.e. 50 and 100 years), as well as on timeframes under the New Zealand Building Act 2004, where a 2500 year timeframe must be assessed for critical buildings. Fig. 4 shows the likelihood scale used.

Assessing the consequences in Step 2 and the likelihood in Step 3 may be interchangeable (and can even occur simultaneously). However, the RBPA recommends carrying out consequence analysis prior to likelihood analysis, to shift the focus from timeframe and probability to impact.

4.6. *Step 4: take a risk-based approach*

Overall levels of risk are established at this step – using outcomes from Steps 2 (severity of impact score), and 3 (likelihood level). Levels of risk are at the very centre of the risk-based planning approach, where risk is determined as a function of consequences multiplied by likelihood (Fig. 5). This gives a risk range from 1 (extremely low) to 25 (extremely high).

For land use planning this quantified level of risk must be further translated into thresholds of acceptable, tolerable or intolerable, and

	Consequences				
Likelihood	**1**	**2**	**3**	**4**	**5**
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Fig. 5. Quantifying consequences and likelihood.

actively linked to public policy outcomes. Table 4 outlines important questions to consider when qualifying levels of risk.

Once levels of risk have been determined, the matrix is then colour-coded. The colours can be used as descriptors for different land use controls, which become more restrictive as risk increases. The colours shown in Fig. 6 are considered standard colours for this type of approach [29].

The land use control levels in Fig. 6 reflect the levels in New Zealand resource management law, where the level of control increases with the level of risk. In Fig. 6, non-complying (which is still allowed with rigorous assessment), and prohibited (which is not allowed), are merged together, even though the former allows for development, while the latter avoids development. This is to allow high consequence activities to take place in high-risk areas that cannot be avoided, e.g. a port that has to be located on the coast.

4.7. *Step 5: Monitoring and Evaluation*

Monitoring changes to risk exposure allows the policies to be evaluated and improved if required. One challenge of monitoring natural hazard policies is measuring their effectiveness – particularly if there has been no event [25]. Using the RBPA, where consequences are limited to a specific hazard zone, it is possible to assess whether the exposure to risk has increased, reduced, or remained constant within that zone by reviewing the change to the risk profile brought about by different land uses (such as additional housing development). The ability to monitor policies – regardless of whether there has been an event or not – provides an innovative solution to a challenging aspect of planning.

5. Innovation in the RBPA

The majority of the innovations provided by the RBA are semi-radical advance forward incrementation. In particular, the consequence table and monitoring abilities are provide an opportunity for planning practice to move beyond current practice, to an advanced planning process that leads to robust and transparent decision making.

The consequence matrix is the underpinning innovative step in the framework. The purpose of the matrix is to provide decision makers with a robust and transparent framework for assessing and measuring risk, with a focus on consequences. Potential users of the RBPA and the steering group involved in the development of the RBPA created a list of requirements for the consequence matrix, shown in Table 5.

Based on those requirements, the consequence matrix was

Table 4
Questions to be considered when determining levels of risk (adapted from [29,p. 82]).

Acceptability	Is the risk reduction option likely to be accepted by relevant stakeholders?
Administrative efficiency	Is this risk reduction option easy to implement or will it be neglected because of difficulty of administration or lack of expertise?
Compatibility	How compatible is the risk reduction option with others that may be adopted?
Continuity of effects	Will the effects be continuous or only short term? Will the effects of this risk reduction option be sustainable? At what cost?
Cost effectiveness	Is it cost effective? Could the same results be achieved at a lower cost by other means?
Economic and social effects	What will be the economic and social impacts of this risk reduction option?
Effects on the environment	What will be the environmental impacts of this risk reduction option?
Equity	Are risks and benefits distributed fairly e.g., do those responsible for creating the risk pay for its reduction?
Individual freedom	Does the risk reduction option deny any basic rights?
Jurisdictional authority	Does this level of organisation or government have the authority to apply this option? If not, can higher levels be encouraged to do so?
Leverage	Will the risk reduction option lead to additional benefits in other areas?
Objectives	Are organisational objectives advanced by this risk reduction option?
Regulatory	Does the risk reduction option (or lack of option) breach any regulatory requirements?
Political acceptability	Is it likely to be endorsed by the relevant government authority? Will it be acceptable to communities?
Risk creation	Will this risk reduction option introduce new risks?
Timing	Will the beneficial effects be realised quickly?

	Consequences				
Likelihood	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Level of risk	Level of land use control
Acceptable	Permitted
Acceptable	Controlled
Tolerable	Restricted Discretionary
Tolerable	Discretionary
Intolerable	Non complying, prohibited

Fig. 6. An example of levels of risk and associated levels of land use control. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article).

Table 5
Steering Group requirements of the consequence table.

It must be: simple, easy to understand, and fit on one page (any longer and decision makers were perceived to find it unworkable).
It should provide a nationally consistent means of assessment using metrics readily attainable and applicable to different local government provinces.
It should be applicable for multiple hazards i.e., specific hazard consequence matrices are not required.
It must be scalable (i.e., for different population sizes and regional or local planning and policy development contexts).
It should be adaptable by agencies with differing resources, communities and natural hazards.

developed along 'SMART' principles, which have historically been used to guide achievable goal setting in management [4]. The principles – of being specific, measureable, attainable, realistic, and timely – were used to ensure the consequence matrix met practitioner needs. In addition, two further principles of scalability and adaptability were added in response to the Steering Groups requirements. Using SMART principles is an example of incremental innovation – reinforcing that policy development should be consistent with these principles. Table 6 outlines how the consequence matrix meets these principles

6. Practical application of the RBPA

The risk-based approach framework was tested through desktop exercises using a number of previous natural hazard events, in addition to scenarios for potential future hazard events. It was also immediately applied to regional and district level planning and policy projects by the Bay of Plenty Regional Council (BOPRC) and the rural based Thames-Coromandel District Council (TCDC). The TCDC included the consequence table in their district plan to assist in understanding levels of risk; while the BOPRC worked through the RBPA in entirety for the development of the natural hazards chapter of their regional policy statement in entirety, adapting it to their context, resources, and policy development challenges.

6.1. Testing of the RBPA

Desk-top testing ensured the risk-based approach would not result in perverse outcomes, where the risk was under- or overstated. Testing against natural hazard events ensured the various levels of severity of impact for the different categories (e.g., consequence descriptors) are measurable and comparable relative to one another. More than ten natural hazard events and scenarios were tested, including earthquakes, debris flows, tsunami, flooding, and liquefaction.

When the testing revealed a problem or a perverse outcome, the cause was reviewed and a solution was identified. For instance, a change might be needed to the thresholds for one or more of the wellbeing categories in the consequence table, in which case expert opinion was sought to make the adjustment. Once a solution was identified, the scenario was retested to see whether the risk outcomes were appropriate. If the results were appropriate, several further scenarios were tested to ensure that no other perverse outcomes resulted from the revised approach.

Testing against past natural hazard events also revealed what scale of development the RBPA can be applied to. The RBPA worked well for large-scale development or for local council policies such as growth plans, district plans, and regional policy statements.

In addition to input from the practitioners on the steering group, the RBPA framework and consequence table were workshopped with local government agencies and reviewed at several forums attended by land use planners and local government policy developers from around New Zealand. Two facilitated workshops were undertaken to test the framework and receive feedback, involving staff from a mix of backgrounds—regional and territorial authorities, planning and emergency management. The workshops reviewed:

- The ease of use of the risk-based approach.

Table 6
SMART(SA) principles of RBPA.

***S**pecific*	Uses quantitative measures of impacts
***M**easurable*	When based within mapped hazard extents, consequences can be measured and monitored. For example, x houses within a flood extent can be counted, and the increase in housing (and resulting impact on the level of risk) can measured over time.
***A**ttainable*	Mitigation actions can reduce the level of consequence e.g., an activity could be deemed moderate, but with mitigation measures may be reduced to minor.
***R**ealistic*	The wellbeing metrics used in the consequence matrix have been tested on past events to ensure they are realistic and likely to occur.
***T**imely-*	The wellbeing metrics are not tied to a point in time. For instance, economic consequences are expressed as a percentage of GDP, which can be assessed at current dollar value (e.g., \$1 million in 2014 is not comparable with \$1 million in 2004).
***S**calable*	By using percentages, the table is scalable for large urban cities to smaller rural-based towns. The only exception to this is the health and safety column, where a death and/or injury are actual numbers[a]. However, as the approach is adaptable, this does not preclude decision-makers from including an annualised probability of death.
***A**daptive*	The consequence matrix can be modified if more detailed information is provided. For example, if district GDP figures are available (or a similar measure of economic effects), these could be used within a district context instead of regional GDP. The entire five-step process is a framework only, and is intended to be adapted for different communities – particularly with the associated engagement approach. Councils may choose to use only some of the columns, or may add columns to the table (on the proviso they meet the SMART plus principles). Terminology can also be adapted, for example the terms acceptable, tolerable and intolerable could be replaced with low, medium and high levels of risk.

[a] Following discussions with end users and experts, it was decided not to use the annual probability of death as a metric, for two reasons: (i) a 'life is a life' principle, where all life is valued the same regardless of the population, and (ii) a number, such as 1×10^{-5} (and its equivalent 0.00001) can be confusing for decision makers not familiar with this representation. For example, is this number considered a death, or not?

- Whether the thresholds and the descriptions in the consequence table were appropriate.
- Whether the final risk outcome was appropriate and why or why not this might be the case; and
- How risk communication and public input on risk assessment could be integrated within the risk-based approach.

It was particularly important at these meetings to understand how applicable the approach was across the different hazards and planning scales that local government agencies in New Zealand regularly deal with. It was also important to understand how easily the RBPA would mesh with existing land use planning practice. Facilitating an easy transition to the new approach was a primary goal of the RBPA project. Information from these interactions with potential users of the RBPA was used in the development of the online toolkit.

6.2. Environmental impacts

The consequence table does not include a column for assessing natural hazard impacts directly on the environment. This issue was considered a number of times at steering group meetings, workshops and meetings with potential users of the RBPA during its development and testing. The decision to not make separate consideration of environmecee factors:

1.The RBPA has been designed for land use planning and thus considers the interaction between human habitation and natural hazards. Local government agencies are largely unable to plan for interactions among natural processes. For example, if a large earthquake uplifted an estuary, no land use planning options could be implemented to prevent this from occurring.

2.The RBPA concentrates on the primary (immediate) effects associated with natural hazards. There can be many secondary effects of an initial natural hazard event (e.g. blocked roads, pollution to drinking supplies), but the severity of the event based on the consequences can be adequately - and most directly - assessed using the primary effects.

3.It was important that the RBPA be in line with international best practice, and other international natural hazard impact analyses do not include the environment as a separate category (e.g. [10]).

This does not preclude councils from developing their own metric for environment, taking into account the SMART principles. If an environment column was to be included, there is guidance available from Standards New Zealand [29] on what measures could be included. Options include: measures of ecosystem functionality (e.g. moderate, short term effects versus serious, long term impairment of ecosystem functions); or environmental outcomes of various types (for the user to determine) [30]. Other national guidance available in New Zealand from the Ministry for the Environment include a consequence table including environment [18], however similar to the metrics included in other standards, they do not meet SMART(SA) principles, and are therefore of little value for land use planning purposes.

6.3. The BOPRC application of the RBPA examples of implementation of the RBPA

The Bay of Plenty region is affected by a wide range of natural hazards including earthquake, tsunami, volcanic eruption, flood, landslide, coastal erosion, and land subsidence. The BOPRC were represented on the steering group for the RBPA project which coincided with the BOPRC's own need for a supportive risk analysis framework on which to base proposed changes to the natural hazards component of their proposed regional policy statement (PRPS). In particular, BOPRC wanted to extend the analysis of natural hazard impacts beyond current provisions, which relied on mortality indicators, and to take a risk-based approach to land use policy. As part of this they hoped to find a valid mechanism to assess the regional community's tolerance to natural hazard risk that would lead to robust and defensible planning recommendations through transparent process.

The BOPRC followed the five steps of the RBPA. At each stage the BOPRC sought input from multiple institutions and in house expertise groups combining skills from planning and policy, community development, Māori[2] liaison and communication, regional, city and district agencies. They also sought input from internal and external experts with technical natural hazards expertise and affected stakeholders. In particular, the BOPRC used the framework provided by the consequence matrix to design an innovative, locally relevant scenario based public engagement process [13], which has been of considerable interest to other local government agencies facing similar challenges involving their communities in decisions on acceptable levels of risk. Fig. 7 shows the qualified levels of risk used in the engagement process by the BOPRC in applying the RBPA to their regional policy development. Notably they included colloquial definitions of acceptable, tolerable and intolerable risk that were used in public communications.

[2] Maori are the tangata whenua (indigenous people) of New Zealand, and have recognised independent status in resource management law.

Acceptable risk: Risk level 1-9	**Definition:** Risk that people are prepared to live with knowing that no measures will be taken to reduce it.
	Everyday description: *Part of daily life – these things happen*
	Policy: All future activities should fit within this threshold
Tolerable Risk: Risk level 10-19	**Definition:** Risk that people are prepared to endure because of the benefits of the activity but expect measures to be taken to reduce it.
	Everyday description: *when it's awful but you know that your family and community can recover from it in time*
	Policy: measures should be taken to reduce the risk for existing activities that fit within this threshold.
Intolerable Risk: Risk level 20-25	**Definition**: Risk that people are not prepared to endure regardless of the benefits of the activity.
	Everyday description: *NO WAY – risk is so great that it can't be justified.*
	Policy: Activities will not be permitted within this threshold except in limited unpreventable circumstances (e.g., port location)

Fig. 7. An example of qualifying levels of risk from Fig. 5 [13].

This process captured participant's views on risk acceptability across all natural hazards and enabled them to consider both the likelihood and consequences of events in making their judgements. It also produced information that could be directly and transparently integrated alongside technical risk threshold assessments provided by internal and external experts. The resulting risk thresholds, judgements on risk acceptability and policy outcomes were incorporated into the decision making process on levels of risk.

The RBPA consequence table has also been used by the Bay Of Plenty Civil Defence Emergency Management Group to aid their assessment and prioritisation of risks.

7. Conclusions

The RBPA offers a semi-radical innovation to existing land use planning and risk management practices in New Zealand. It provides a framework for decision-makers that is innovative from typical natural hazard management, moving the practice of planning for natural hazards forward from where it currently is.

The novelty of the approach lies in both the underpinning logic of the framework, and in the practicality of its implementation. The RBPA Project Steering Group set criteria for the approach to be simple, easy to understand, applied nationally, applicable for multiple hazards, scalable, and adaptable. Taking these criteria into account, a key resource within the RBPA - the consequence matrix - was developed around legislatively defined well-beings (covering life and livelihood, critical infrastructure, and social and economic impacts), and used language that is familiar to decision-makers, not just to risk and hazard technical experts. Because consequences can be limited to mapped hazard extents, and are not diluted across a larger geographical area, the consequence table meets SMART principles (i.e., specific, measureable, attainable, realistic, and timely), while also being scalable and adaptable. It is these factors that contribute to a semi-radical innovative approach to risk-based land use planning in New Zealand.

As well as providing a five step adaptive framework, the RBPA allows for much-needed capability building for risk based planning. It enables decisions to progress on the basis of current knowledge, shifts emphasis from likelihood to consequences, and extends the understanding of impacts beyond fatality risk. Working through the procedures as recommended in the RBPA fosters a multi-disciplinary approach, particularly within and across agencies; and leads planning towards international best practice in public engagement on risk. It also promotes information use and management that will boost resources for local government agencies making risk based decisions in the future.

To ensure its relevance to planning practice, the RBPA development project employed participatory action research. Cycles of development and testing through workshops with potential end users resulted in amendments, and were followed by further testing. As a result of this close engagement with practitioners, two councils (one regional and one territorial) have incorporated aspects of the RBPA into their land use plans within 12 months of the approach being available. This is a good level of early uptake considering the usual lengthy time periods taken to alter land use planning policy. In the case of the BOPRC the flexibility of the RBPA enabled this agency to innovate further to meet their specific needs for seeking public input on risk acceptability. RBPA is not only innovative in itself, but as it is adaptive (e.g. it does not preclude councils from developing their own metric for environment, taking into account the SMART principles), it enables agencies to innovate further to meet their specific needs.

Each step in the RBPA is designed to link common land use planning practices to risk analysis and management and new opportunities for communication and engagement. The result is rational land use planning process based on risk-based decision making for land use. While developed to compliment New Zealand planning legislation, the RBPA is highly related to international risk analysis and risk management and as a framework and set of principles is adaptive to different cultural and legislative environments with wide application in other settings. Examples include improving community and government capacity to assess and plan for climate change impacts and pre-planning for natural hazards.

The use of the RBPA consequence table by the Bay Of Plenty Civil Defence Emergency Management Group to aid their assessment and prioritisation of risks is had the benefit of creating consistency in approaches between land use planning and emergency management – something that has been lacking in New Zealand.

The RBPA provides a robust, transparent and participatory framework for decision makers to determine levels of risk. Policies can be written that support a risk-based approach, can be evaluated through time, and can result in risk reduction for people and property. Importantly the RBPA takes into account both theoretical and practical challenges commonly faced in adopting a risk based approach to land use planning.

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