How Risk Informs Natural Hazard Management:

A study of the interface between risk modelling for tsunami inundation and local government policies and procedures

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We care a lot!

We care a lot!

About disasters, fires

Floods and killer bees

...

We care a lot!

About you people 'cause we're

Out to save the world!

Yeah!

...

Well it's a dirty job but

Someone's gotta do it

Said, it's a dirty job but

Someone's gotta do it

Faith No More, (1985). We Care a Lot

Abstract

The impact of natural hazards on society and the environment continues to increase, resulting in intolerable and unsustainable financial and social costs. The traditional approach of responding to the hazard once it has occurred is no longer acceptable because it hasn't always raised awareness of the hazard or allowed communities to pre-emptively take action to protect themselves and their property. It is now more important than ever for governments and communities to proactively understand and prepare for natural hazard risks before hazards occur, so that our vulnerability and exposure to them is reduced when they occur. The costs-benefits of following a proactive approach, rather than a reactive approach are clear, bringing about a change in the way natural hazards are managed, as exemplified by the risk management focus of the Sendai Framework for Disaster Risk Reduction (2015).

Despite considerable research and effort in this area, natural hazard risk management struggles to be applied at global, national, and local scales. This illustrates a need to better understand how natural hazard risk is perceived and understood, and how it influences the development of policy frameworks for natural hazard management. In particular, questions remain regarding how risk modelling influences perception of natural hazard risk and application of risk reduction measures at the community level.

This research explores how risk informs natural hazard management in Aotearoa New Zealand's local government. It focusses on how the RiskScape risk modelling tool is used to communicate natural hazard risk for influencing risk awareness and the perceptions of practitioners. It specifically focusses on a tsunami hazard generated in the Hikurangi Subduction Margin as tsunami is Aotearoa New Zealand's least likely but most significant natural hazard risk. However due to its infrequent occurrence, tsunami is perceived as less risky than other hazards.

Focus group sessions and semi-structured qualitative interviews were held with natural hazard risk practitioners within local government, primarily across the Gisborne, Hawke's Bay, and Wellington regions of Aotearoa New Zealand. The focus groups and interviews explored practitioners' perceptions on the value of risk modelling tools, particularly 'RiskScape', for communicating risk and influencing policy development, as well as their thoughts and opinions on natural hazard risk management policy development in general,

and with a specific focus on tsunami. These results were then corroborated through document analysis of risk-based tsunami policy and procedure for the regions studied.

This research found that while practitioners understand the value of risk modelling for communicating tsunami risk for developing risk awareness and influencing perceptions, RiskScape is not employed widely within local government to achieve risk-based policy and practice. This is partly attributed to trust in risk modelling outputs as well as developmental problems with the RiskScape software. However, the larger part is due to challenges for natural hazard risk management within local government. Local Government's challenges include lack of guidance, mandate, and collaboration for hazard management; limited risk leadership, understanding and awareness; lack of funding, capacity, and capability; and unavailability of quality data. Underlying each of these challenges are more fundamental challenges relating to the disconnect of the 'science-policy-practice' interface, and the interrelated complexity of the challenges which limit the effectiveness of solutions. Along with the limited use of risk modelling, risk-based policy and procedure for tsunami remains scarce. Of the 58 national and local policy documents analysed as part of this research, only three contain specific tsunami risk-based policy.

This research proposes the use of 'systems thinking' to better understand this complex system of challenges as a whole. This approach can identify intervention points, which can interrupt the system's dynamics and better apply natural hazard risk management in local government. The science-policy-practice interface is identified as an intervention point; however, tensions for collaboration across this interface limit its effectiveness. A formalised structure, which is mandated by integrative research frameworks, is recommended for how collaboration across the science-policy-practice interface can be improved.

An improved science-policy-practice interface would enable the application of further recommendations for overcoming challenges for local government natural hazard risk management. These include developing awareness of natural hazard risk and the cognitive biases that influence risk perceptions; improved understanding of the value in using established risk management approaches; and greater capacity and capability for collecting, managing, and using natural hazard risk data. The outcome would enable bottom-up co-development of risk modelling, which is trusted and used within local government to better develop risk-based policy and procedure.

Through greater use of risk modelling in local government, tsunami risk can be better communicated, and risk-based tsunami policy and procedure can be better achieved. This will reduce tsunami-related losses and enable greater community resilience.

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you for always pushing me, for always testing me, for always expecting me to succeed. It was tough but I did it, and it was worth it.

To quote John Lennon, “Life is what happens to you while you're busy making other plans.” In 2016, my second son, Darcy was born with a rare and almost unknown condition called Tetrasomy 9p, meaning Darcy will have severe and lifelong physical and mental challenges. Darcy’s condition was not diagnosed until shortly after his birth, which at that point suddenly changed my family’s life course. New and unanticipated obstacles emerged, which significantly impacted on our needs. Darcy’s condition took time for us to mentally process and include into our new way of life. However, Darcy is a ray of light in our lives, and we wouldn’t change a thing. Naturally, my PhD journey then took a new course. Darcy’s special needs meant that I needed to spend more time away from my research helping at home. I also needed to enter back into the workforce on a full-time basis. As such, my PhD journey has now taken six years where the usual PhD timeframe is three years. Throughout this period, I have been truly humbled by the care and understanding of my family, friends, and supervisors, who have kept me to task when I have wavered and have protected me from pressures that would have otherwise caused me to pull-out from finishing this journey.

I dedicate this thesis to my son, Lachlan, who has been keenly observing my PhD journey. Thank you for being interested in it, thank you for keeping me grounded, and thank you for being the driving force behind my research. As I write this you are nine years old with all of life’s challenges and wonders still ahead of you. The future will be a more difficult place to live in than it is now, and the reason for me undertaking this PhD is to try and make that future less difficult for you. As has been the case with completing this PhD, nothing of true value in life is ever achieved without hardship, self-belief and perseverance. I hope my PhD journey helps encourage you to strive for value and not shy away from the struggles that it entails. Those struggles will be rampant and complex and take hard work to manage. However, by facing them head on, you will do important things, meet wonderful people, and become a deeper, fuller person for it.

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1 Introduction

Risk management has increased in public profile in the past decade as social, environmental and technological consequences have impacted on the world causing losses for people, communities, organisations, and governments on an intolerable scale. People, communities, organisations, and governments are increasingly aiming to reduce their losses by proactively managing the uncertainties associated with these consequences and applying measures to control their likelihood and impact before they occur, rather than reacting to them once they have occurred. Whilst it is understood that risk management can reduce the likelihood and impact of hazards or threats in general, it is challenged by issues relating to perception, communication, and motivation to act. This in turn affects the value and success of policies and procedures employed for the application of risk management.

This thesis focusses on natural hazard risk management, specifically on how risk modelling for tsunami inundation informs the development of risk management policy and procedure within local government in Aotearoa New Zealand. As such, it studies the interface between:

1. destructive tsunami – a severe but unlikely hazard risk that is difficult to perceive and internalise;
2. natural hazard risk governance – primarily applied by local government; the coalface for managing natural hazard risk for Aotearoa New Zealand; subject to a complex system of challenges that limit its effective application; and
3. risk modelling – a communication tool for risk management; beset with its own assumptions and uncertainties.

While this research will focus primarily on tsunami risk, the insights gained from this research could be applied to a range of social, technological and natural hazard risks. Improved understanding of the challenges and solutions for risk management is significant because it has the potential to develop resilience and reduce loss for people, communities, and organisations.

1.1 Overview of this chapter

This chapter provides the background for this thesis. It introduces natural hazards and their impact on our global society. It then introduces the tsunami hazard, a specific focus of this research because of their devastating impact and consequences. However, due to the low likelihood of destructive tsunami, they remain an underrated hazard mainly due to the perception that their infrequency does not present significant risk compared to other natural hazards. The chapter then introduces the concept of risk, how it can be managed, and how risk perceptions challenge the application of natural hazard risk management. From here, the chapter introduces the international governance context for how natural hazard risk is managed and introduces risk modelling as a tool for communicating natural hazard risk within this setting. The chapter ends with the rationale for the research and the structure of this thesis.

1.2 Natural hazards

Physical phenomena occur frequently in nature; however, they only become natural hazards when they have the potential to impact on human systems, or society. As Kates (1971) defines in the following citation, they are considered hazards when they impact on both the natural and human systems to a point where they cause harmful effects:

> *"A natural hazard is an interaction of man [sic] and nature, governed by the coexistent state of adjustment in the human use system and the state of nature in the natural events system. In this context, it is those extreme events of nature that exceed the capabilities of the system to reflect, absorb, or buffer that lead to the harmful effects, ofttimes dramatic, that characterise our image of natural hazards"* (Kates, 1971, p. 438).

In its recent review of hazard definitions and classification, the United Nations Office of Disaster Risk Reduction (UNDRR, 2020) clustered natural hazards into:

- Meteorological and hydrological – including tropical cyclones, drought, riverine floods, and heatwaves.
- Extra-terrestrial – including asteroid and meteorite impacts and solar flares.
- Geohazards – including earthquakes, tsunamis, lava flows, rockfalls, ashfalls, and coastal erosion.

- Environmental – relating to degradation of the natural systems (e.g. due to climate change) upon which humanity depends, including biodiversity loss, land salination, and loss of permafrost.
- Biological – insect/animal plagues, pathogenic microorganisms, and toxins and bioactive substances that occur naturally causing disease epidemics.

Natural hazards are often associated with events that have rapid onsets, for example, earthquakes, volcanic eruptions, and tsunamis (noting that distal / regional tsunamis come with hours to many hours of warning time). They can also have a slow onset, particularly those exacerbated by climate change (e.g. sea level rise). The United Nations Institute of Disaster Reduction (UNIDR, 2015a) has reported that the frequency of geophysical hazard events remained broadly constant between 1994 and 2013. However, a sustained rise in environmental related hazards, occurring due to climate change, has significantly increased total occurrences of natural hazard related disasters. Since 2000, the Emergency Events Database (EM-DAT) has recorded an average of 341 climate-related disasters per annum, up 44% from the 1994-2000 average and well over twice the level in 1980-1989 (UNIDR, 2015a).

Figure 1-1 shows that the global cost of natural hazard related disasters is increasing. In 2020 alone, there were $210 billion of losses as several countries battled hurricanes, floods, and wildfires (Munich Re, 2021). While the cost of natural hazard related disasters is increasing, it is offset by increasing global wealth. As such, loss from disasters, as a share of global gross domestic product (GDP), remains relatively constant. However, as shown in Figure 1-2, global deaths from natural hazard related disasters continue to grow, reaching an average of more than 99,700 deaths per year between 2004 and 2013.

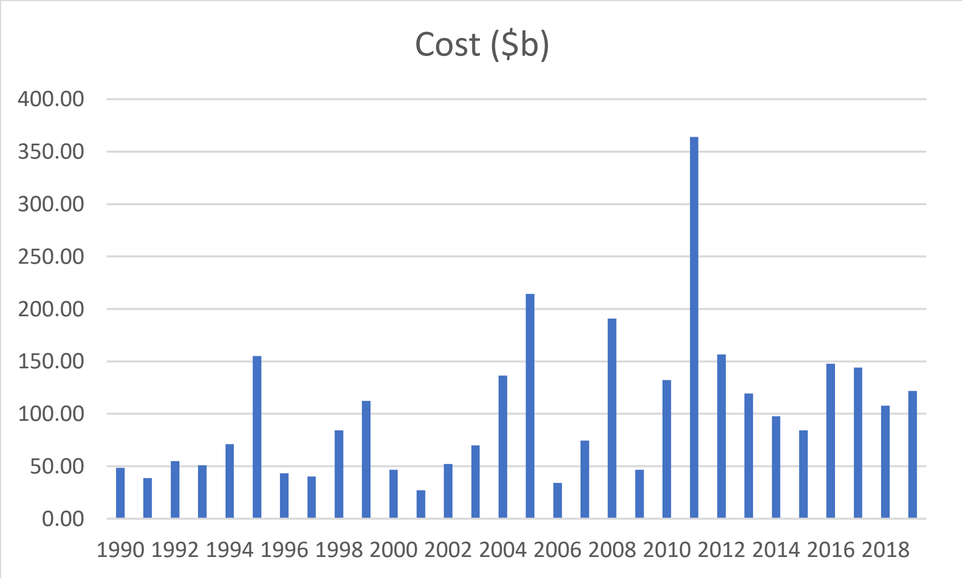

Table 1-1: Global damage cost from disasters cause by natural hazards 1990 – 2019
Source: Our World in data. Natural Disasters. Last revised in 2019. Accessed 02/07/21

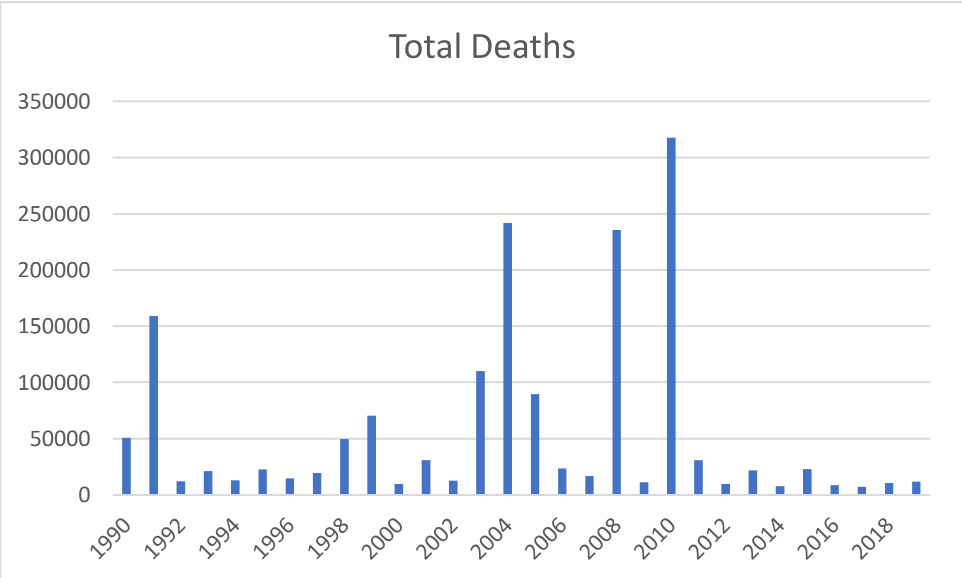

Table 1-2: Global deaths from disasters cause by natural hazards 1990 – 2019

Source: Our World in data. Natural Disasters. Last revised in 2019. Accessed 02/07/21

Of note are the spikes in both graphs for 2005, 2008 and 2010. The spike for 2005 was caused by a record number of Atlantic hurricanes, including Hurricane Katrina in 2005; the spike for 2008 was caused by Cyclone Nargis and the Great Sichuan earthquake; the spike for 2010 was caused by the Haiti earthquake and Russian heatwave.

Increasing deaths from natural hazard related disasters are partly explained by global population rise (almost doubling in the last 45 years), resulting in more people exposed to the impact of natural hazards. However, increasing deaths are also highly correlated with the vulnerability of people in low-income demographic brackets. EM-DAT data shows that on average, more than three times as many people died per disaster in low-income countries (332 deaths) than in high-income nations (105 deaths) (UNIDR, 2015a).

As such, population growth and patterns of economic development are more important than the progressive impact of climate change for explaining increasing natural hazard related deaths. Not only is increased development and intensification occurring in areas exposed to natural hazards, but increased numbers of people are vulnerable to their impact. This, in turn, increases the risk that a natural hazard becomes a disaster.

1.2.1 Tsunami

This research specifically focuses on destructive tsunami because its low frequency compared to other natural hazards means that it is not as directly experienced, which limits its risk perception, resulting in an underestimation of the risk (Bronfman et al., 2020). The deadliest tsunami in history was the Indian Ocean tsunami in 2004, which impacted on the coastal communities of numerous countries, including the Nicobar Islands, Burma, Indonesia, and parts of Sri Lanka. The total tsunami death toll was approximately 227,898 people (Athukorala & Resosudarmo, 2005). The losses from such an event, and others like it, are too high for them to be acceptable and therefore need to be managed. However, because destructive tsunamis are relatively infrequent, they are perceived by individual public and community decision makers as less risky compared to other hazards (Bryant, 2014). Thus, preparatory actions to reduce tsunami risk have not adequately progressed to reflect the significance of the risk.

A tsunami is a series of waves in a water body caused by the displacement of a large volume of water. The water displacement that causes these waves can be generated by a number of naturally occurring events, including earthquakes, volcanic eruptions, landslides, glacier calvings, and meteorite impacts. Large, destructive tsunamis are most often generated by earthquakes occurring at subduction interfaces (Clarke et al., 2019; Mueller et al., 2015; Priest et al., 2017) where the collision of tectonic plates can cause a sudden vertical deformation or 'thrust' to large areas of ocean floor, displacing the overlying water and generating tsunami.

Tsunami sources are often defined as 'local', 'regional' or 'distal', depending on the distance from where they are generated to the coastline that they impact upon (Downes et al., 2017; Garside et al., 2009; Johnston et al., 2014). A local source tsunami is generated within 100 kilometres or less than one hour's travel time from the impacted coastline. These can result in a significant number of casualties due to little warning time for people to evacuate. A regional source tsunami is generated within 1000 kilometres or one to three hour's travel time from the impacted coastline. A distal source tsunami is generated more than 1000 kilometres or over three hour's travel time from the impacted coastline. Distal source tsunamis are also referred to as 'ocean-wide' (Gusman et al., 2015; Heidarzadeh et al., 2018) because the waves continue to travel across an entire ocean basin, impacting on multiple coastlines. While there is more time to evacuate distal source tsunami, they have all been generated by major earthquakes (CTIC, n.d.) and have potential to cause large scale casualties and destruction for the coastlines they impact upon.

The simplest form of tsunami wave shape is sinusoidal and is described by three main parameters: crest to trough wave height (H), wavelength (L) and water depth (d), which relate to each other by three ratios: H : L, H : d, L : d (Komar, 1998), see Figure 1-1.

Figure 1-1: Change in tsunami wave shape relative to bathymetry and shoreline.

H = crest to trough wave height, L = wavelength, d = water depth, H_o = crest to trough wave height at source, h = crest height above the seabed, ŋ = crest height above mean sea level, H_t = crest to trough wave height at the toe of the shelf, H_s = crest to trough wave height at shore, H_r = wave runup height above mean sea level. Source: Bryant (2014)

While the magnitude of its generating event influences tsunami wave height, its location and the depth of the water column through which the wave travels also influence wave heights. Tsunami generated by earthquakes in deep water would normally be under 40 cm in height (Wiegel, 1970), have a wavelength between 10 and 500 km, a wave period of 1.6 – 33 minutes, and travel at speeds of 600–900 kilometres per hour (Bryant, 2014).

When a tsunami that has been generated in deep water approaches the shore and interacts with shallower bathymetry, its energy is progressively concentrated into a smaller volume of water. It slows down to around 36 kilometres per hour (Bryant, 2014), its wavelength decreases and the wave height increases. The shallower bathymetry also causes part of the wave to reflect and interact with the following waves in the tsunami wave train. This can cause the waves to resonate and amplify, depending on which part of the sinusoidal curve they interact at, causing the second and third waves to be larger, and have a bigger impact, than the first wave (Pudjaprasetya, Adytia, & Subasita, 2021). Following the first few waves in the tsunami wave train, waves heights will typically taper off exponentially in height over four to six hours (Bryant, 2014).

Once they impact upon a coast, tsunami can inundate many kilometres inland, causing devastation to people, property, ecosystems, and the landscape in their inundation zone. Their most significant impact is on people and the built environment, destroying buildings, infrastructure networks, and other structures, which create debris that act to further destroy other buildings, networks, and structures. People caught within a tsunami are not only vulnerable to the wave of water, but also the debris and contamination carried in the wave, causing an average of 79 deaths for every 1,000 people affected (UNISDR, 2015a). The most significant cause of death due to tsunamis is drowning, but also includes deaths due to fire, asphyxiation (excluding drowning), and injuries to the head; however, in many cases the cause of death is unknown (Seto & Imamura, 2020).

The impact of destructive tsunami can then cause cascading disasters (Kelman, 2020; Pescaroli & Alexander, 2015), primarily for health, the natural environment, technology, and economies. Tsunami survivors are often left wounded, without access to potable water, food, and shelter causing health disasters due to unavailability of community health services exacerbated by destruction of potable water and sewerage networks (Morgan, Ahern, & Cairncross, 2005). Environmental disasters occur due to destruction of flora and fauna and the landscapes that support them (Srinivas & Nakagawa, 2008). Technological disasters or 'Natechs' – natural hazard triggered technological disasters – occur due to the release of hazardous materials resulting from natural hazard impacts, for example, the Fukushima Daiichi nuclear disaster in 2011 (Krausmann & Cruz, 2021). Economic disasters occur due to death or injury to working populations, the destruction and contamination of primary production, and the community's ability to recover (Athukorala & Resosudarmo, 2005). Furthermore, the consequences of destructive tsunami and cascading disasters is exacerbated by sea level rise due to climate change (Nagai et al., 2020; Sepúlveda et al., 2021).

Historical recordings of destructive tsunami indicate a low frequency of occurrence, with 13 major tsunamis recorded over a time span of 115 years from 1849 throughout 1964 (SMS Tsunami Warning, n.d.). However, with better recording frameworks, and with an increased population living in areas exposed to the tsunami hazard, destructive tsunami are now being recorded more frequently. Table 1-3 shows that since 2000 eight major tsunamis have occurred causing significant death.

Date	**Location**	**Generation**	**Wave height**	**Deaths**
2004	Indian Ocean	Earthquake (9.3 MM)	33m	≈227,898
2006	South of Java Island	Earthquake (7.7 MM)	6m	800+
2007	Solomon Islands	Earthquake (8.1 MM)	12m	52
2009	Samoa	Earthquake (8.1 MM)	14m	189+
2010	Sumatra	Earthquake (7.7 MM)	3m	435
2011	Japan	Earthquake (9.0 MM)	10m	18,550
2018	Sulawesi	Earthquake (7.5 MM) and underwater landslide	7m	≈1,234
2018	Java and Sumatra	Volcanic-eruption-triggered landslide	13m	426

Table 1-3: Major tsunami occurring since 2000. Source: Wikipedia, List of Tsunamis, 2000s – Present. Accessed 12/08/21

In 2018, The United Nations Office for Disaster Risk Reduction (UNISDR) called attention to deaths and economic losses from recorded tsunami events over the preceding twenty years. A review of available data from tsunami events between 1998 – 2017 put these losses at a total of 251,770 deaths (mostly attributed to the Indian Ocean Tsunami) with costs of US$280 billion (UNISDR, 2018).

This is a significant increase in reported losses compared to between 1978 – 1997, which reported 998 deaths and costs of US$2.7 billion (UNISDR, 2018). Furthermore, recorded financial losses are primarily drawn from physical damage and loss of earning potential. Indirect losses from natural hazards, such as impact on mental health and lost education, are rare and harder to quantify (Dottori at al., 2018; Merz et al., 2020). Considering this, total losses from destructive tsunami are much greater than recorded.

While awareness of the tsunami related hazards and consequences has grown over the past thirty years, their relative infrequency compared to other hazards means that they are not as directly experienced, which limits their risk perception (Bronfman et al., 2020). As such, the risk of destructive tsunami is underrated compared to other natural hazards. Consequently, the history of tsunami losses has not been effectively translated into preparedness and response (Bryant, 2014). For example, the 2004 Indian Ocean Tsunami revealed weaknesses in early warning systems (de León, 2006) and the 2011 Tohoku Tsunami revealed flaws in risk perception and preparation (Komendantova & Mochizuki, 2016; Sun & Sun, 2019).

With most of the world's population living on the coastline, if a large, destructive tsunami were to occur today, the death toll would be in the tens of thousands and the damage would exceed that of any historical disaster (Bryant, 2014). Considering this, the risk of tsunami needs to be better understood, along with how communities and governments perceive and manage their risk, in order to reduce their impact (Løvholt et al., 2019).

The increasing losses from tsunami and other natural hazards are unacceptable. This is not only because of the significant loss of life and impact on economies and community health, but also because these losses can be reduced through risk management. However, as stated earlier in this section, perceptions of risk (in this case tsunami risk) challenge how natural hazard risk management is achieved. Risk and risk perceptions are explained further in sections 1.3 and 1.4.

1.3 What is risk?

Life is risky. People, communities, organisations, and governments exist in a world where social, technological and natural processes are sometimes hazardous. At these times, there are several choices for taking action (contingency), and these choices can have consequences. People, communities, organisations, and governments think about risk because they want to decide on the best choice of action to manage the uncertainty of these consequences, which may have negative (or positive) effects (Eiser et al., 2012; Renn, 2008).

There are many definitions of risk. This is because the concept of risk is abstract, as well as transdisciplinary, and as such is a "symbiosis of natural and human sciences, of everyday and expert rationality, of interest and fact" (Healy, 2001, p. 39). Aven et al. (2011) list some examples of the range of risk definitions, including:

1. Risk equals the expected loss.
2. Risk equals the expected disutility.
3. Risk is a measure of the probability and severity of adverse effects.
4. Risk is the combination of probability and extent of consequences.
5. Risk refers to uncertainty of outcome, of actions and events.
6. Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain.
7. Risk is an uncertain consequence of an event or an activity with respect to something that humans value.
8. Risk is the effect of uncertainty on objectives.
9. Risk is equal to the two-dimensional combination of events/consequences and associated uncertainties.
10. Risk is uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that humans value.

Given the variation in risk definitions, the understanding of risk is dependent on the discipline and culture within which it is applied. In addition, risk comes with a plethora of associated terminology, which is "jargon-filled and opaque, using probability estimates and abstracted impacts" (Manning et al., 2015, p. 588). The result is considerable confusion and substitution, by both lay-people and experts over the concepts of risk, hazard, susceptibility, vulnerability, resilience, exposure, risk tolerance/acceptance, risk awareness, and risk management (Kelman, 2018).

In the natural sciences, the simplest definition of risk is defined as: $R = F \times D$ (Power, 2013); where R is risk, F is the frequency or likelihood of an event occurring, and D is the damage or consequences. The damage or consequences (D) can be further broken down into two factors: exposure (E) and vulnerability (V). This breakdown is reflected in the most common definition of risk where frequency (F) has been replaced with hazard (H) to define: Risk = Hazard × Exposure × Vulnerability (Wisner et al., 2004; Pondard & Daly, 2011; Power, 2013; Purdy, 2010). In this sense, natural scientists use risk to quantify the likelihood and magnitude of a hazard and the consequences of its impact on tangible assets, given the exposure to the hazard and how vulnerable we are to it. The result is usually expressed as loss in financial terms or number of casualties. As such, natural scientists commonly view risk objectively, assessing it through risk frameworks and quantifying it through the use of risk models.

However, risk cannot be defined as only an objective quantification of what is happening 'out there', independent of our minds and cultures. This is because risk calculates the chance that something may happen in the future, which has not yet happened and is therefore an idea rather than a reality. As such, the idea is constructed 'in here' in our minds and is susceptible to how humans subjectively qualify it (Burgess, 2015; Dake, 1992; Oliver-Smith et al., 2017). In the social sciences additional meaning is given to the uncertainties of risk, incorporating considerations such as doubt, dread, catastrophic potential, controllability, equity, and risk to future generations. Risk is therefore considered a symbiosis, straddling the divide between the natural and social sciences (Donovan & Oppenheimer, 2015; Healy, 2001; Renn, 2008; Slovic, 2001). But this symbiosis is an untidy state, with discontinuities between scientific 'fact' and human 'values' for communicating risk, where natural science resists the link with social construction, and social science sees this resistance as weak and idealistic (Healy, 2001; Stirling, 2007).

Consequently, there is a need for a standard risk management approach for how risk is assessed objectively and also evaluated subjectively, which enables explicit and shared understanding for how risk can be managed. One option for achieving this is through the ISO 31000 Risk Management Standard.

1.3.1 The ISO 31000 risk management approach

The ISO 31000 Risk Management Standard (ISO, 2018) spans the natural and social environments by combining risk assessment based on likelihood and consequence, with risk evaluation based on human and cultural factors. It is a standard developed by the International Organization for Standardization (ISO) through “the distilled wisdom of people with expertise in their subject matter and who know the needs of the organizations they represent” (ISO, n.d.).

The ISO 31000 Risk Management Standard is used globally across a range of disciplines and technologies including occupational health and safety (Santos & de Oliveira, 2019; Wilbanks & Byrd, 2020), business management (Almeida et al., 2019; Rampini, Takia, & Berssaneti, 2019), ITC security (Banowosari & Gifari, 2019), and infrastructure networks (Rød et al., 2020; Häring et al., 2021). The value of the ISO 31000 approach is that it works “to develop a risk management culture where employees and stakeholders are aware of the importance of monitoring and managing risk. Implementing ISO 31000 also helps organisations see both the positive opportunities and negative consequences associated with risk, and allows for more informed, and thus more effective, decision-making” (Tranchard, 2018, p. 181).

Figure 1-1 sets out the ISO 31000 system. This comprises of how the principles of risk management interact with its risk management process and risk management framework. This ensures that risk information is assessed using a structured and comprehensive approach, while also taking into account the influence of risk perceptions. Fundamental to the success of the ISO 31000 risk management framework is leadership and commitment, i.e. the support of decision makers, to understand the value of risk management, enable its process, and ensure it is regularly applied by practitioners within organisations.

Figure 1-2: The ISO 31000:2018 risk management system.

The links between the principles for how risk management should be implemented, the process for how risk management is assessed, treated and reported, and the framework for how risk management is supported and sustained within an organisation. (https://www.iso.org/obp/ui/#iso:std:iso:31000:ed-2:v1:en, Accessed 10/11/21)

The United Nations guidelines for national disaster risk assessment (UNISDR, 2017) refer to the ISO 31000 standard as the most commonly used approach to risk management. These guidelines set out four components of the risk management process:

1. Establishing context – understanding the risk management context and engaging with stakeholders to define criteria for decision making.
2. Risk identification – using the knowledge and experience of stakeholders, as well as data from past events to draw initial conclusions on the significance of the natural hazard risk. This includes consideration of exposed assets and known vulnerabilities as well as whether the risk event is extensive (frequent, low- impact) or intensive (occasional, high-impact).
3. Risk analysis – obtaining a more detailed understanding of the disaster risk, including hazard analysis, exposure analysis, vulnerability analysis, and capacity analysis. It also includes assessing the level of uncertainty or likelihood for the hazard's occurrence and consideration of its consequences, including effectiveness of existing capacities to manage them.
4. Risk evaluation – using likelihood and consequence, adjusted by understanding of capacities, risk perception, and risk acceptance, to prioritise oversight and immediacy of risk treatment (UNISDR, 2017).

Further steps in the ISO 31000 risk management process that aren't included in the United Nations guidelines are 'risk treatment', 'communication and consultation', and 'monitoring and review' as defined below:

5. Risk treatment – iteratively selecting risk treatment options, implementing the treatment, assessing the effectiveness of the treatment, deciding whether the residual risk is acceptable and, if not acceptable, repeating the treatment process. Common treatment options include risk avoidance, removing the risk source, changing the likelihood, changing the consequences, sharing the risk and/or retaining the risk by informed decision (ISO, n.d.).
6. Communication and consultation – assisting stakeholders in understanding the risk in order to aid decision making. Consultation should take place throughout all steps of the risk management process with the aim of gathering different expertise in the process, ensuring all views and perceptions are considered, providing sufficient information for decision making, and building inclusiveness and ownership for

managing risk (ISO, n.d.). Section 1.4 sets out the challenges for risk communication; however, section 1.6 sets out how communication can be assisted with risk modelling (even though it has its own challenges).

7. Monitoring and review – including planning, gathering, and analysing information, recording results, and providing feedback to assure and improve the quality and effectiveness of process design, implementation, and outcomes (ISO, n.d.). When applied to natural hazard risk management, Thomas (2018) states that it is "important to monitor changes in the environment (e.g. new risk reduction initiatives, changes in politics, demographic changes, a hazardous event, development of new assets and new hazard information) that may change the context or the risk itself" (Thomas, 2018, p. 15). She adds that monitoring changes in the environment also helps identify any emerging risks.

In summary, a standardised and structured risk management approach enables the severity of the risk to be assessed, evaluated, and communicated for shared risk awareness and understanding. Ultimately, this risk information is used to influence decision makers to enable proactive management to reduce risks before they occur, rather than respond to events once they have occurred.

1.4 Natural hazard risk perceptions, communication, and disaster preparedness

1.4.1 Perceptions

The economic benefits of proactively acting to reduce natural hazard risk before a disaster occurs are clear. Mechler (2016) provides a cost benefit of disaster risk reduction (DRR), where he found that despite limited evidence, the benefits of investing in DRR outweigh the costs by about four times in terms of avoided and reduced losses. Shreve and Kelman (2014) add to this by stating that while there is solid evidence to support the economic effectiveness of DRR, cost-benefit ratios differ depending on the influence of culture on the hazard, vulnerability, risk, and disaster.

Despite the economic benefits being clear, the application of natural hazard risk management continues to be challenged by perceptions of risk. This is because risk is a subjective idea, a difficult concept to grasp, and people have a low understanding of it (Burgess, 2015; Donahue et al., 2014; WSS Fellows on RIA, 2014; Doyle et al., 2014;

Edwards et al., 2012; Henrich et al., 2015; King, 2015; Manning et al., 2015; Oliver-Smith et al., 2017). Further risk perception challenges include: contrasting perceptions between ‘authoritative / scientific’ experts and ‘inexperienced’ lay-people leading to conflict and inaction (Barnes, 2001; Donahue et al., 2014; Slovic, 2001); damage to trust between scientists and stakeholders due to wrong interpretations of risk data (Doyle et al., 2014); misunderstanding of the ‘technical’ framing for risk communication by people without technical knowledge (Barnes, 2001; Doyle et al., 2014); ineffective traditional educational approaches for increasing risk perception (Paton & Johnston, 2001); a complicated communication environment for risk given the distribution of risk perceptions through society (Paton & Johnston, 2001); and how different risk perceptions cause people to respond to risk in unexpected or seemingly illogical ways (WSS Fellows on RIA, 2014).

1.4.2 Communication

When communicating natural hazard risk, the factors that affect its perception and understanding include framing, likelihood, past experience, warning fatigue, and political and economic factors. In Doyle et al.’s (2014) investigation into how verbal or numerical framing of probabilities affect risk perception and decision making, they found that numerical framing prompted more of a response than verbal framing. Despite this, people tend to have a poor understanding of numerical values for low likelihoods (Doyle & Potter, 2015; Shoemaker, 1980; Slovic, Fischoff, & Lichtenstein, 1982). As such, Henrich, McClure, and Crozier (2015) found that describing earthquake risk in a 50-year time interval rather than as a return period (e.g. 500-year) and using frequencies of fatalities, rather than the probability of death from an earthquake, was most effective.

Similarly, Slovic, Fischoff, and Lichtenstein (1982) found that people are insensitive to differences in very low probabilities and that below a certain threshold, low probabilities are perceived as the same and tend to zero. Shoemaker (1980) stated that people either ignore low probabilities or are unable to make rational decisions involving low probabilities. Slovic et al. (2004), LGNZ (2014), and Bryant (2014) outline how unlikely but catastrophic events are perceived as less risky than more frequent, lower magnitude risks and how this low likelihood lulls us into a false sense of security. Past experience that an individual has had for a hazard can contribute to heightened perception of risk and increased efficacy for preparedness (Donahue et al., 2014; Lawrence et al., 2014; Paton & Johnston, 2001), as well as decreased risk perception and optimism bias particularly if outcomes were not as severe as those forecasted (Mileti & O’Brien, 1992; Solberg, Rossetto, & Joffe, 2010). Fraser et al. (2016), Mileti and O'Brien (1992), and Solberg, Rossetto, and Joffe (2010) referred to how warning fatigue and normalisation bias can drive people to underestimate the risk of natural hazards. Underestimation or misperception of these risks can also be influenced by political agendas where natural hazard risk management is seen as a barrier to development and economic growth (Lawrence & Manning, 2012; Lawrence et al., 2015).

It is important to be aware of the multi-faceted and complex nature of perspectives when communicating risk information and in turn influencing stakeholder and decision-maker perceptions to use and act on that information (WSS Fellows on RIA, 2014; Eiser et al., 2012; Lawrence et al., 2014; Slovic, 2001). When risk communication fails to influence stakeholder and decision-maker perceptions, the result is a misappropriation of time and resource into preparing for risks with minor implications, over more serious risks with severe implications.

1.4.3 Preparedness

Preparedness for natural hazard related disasters is typically understood as consisting of measures that enable individuals, households, organisations, communities, and societies to respond effectively and recover more quickly when disasters strike (Sutton & Tierney, 2006). Common preparation measures include developing contingency or risk management plans, developing skills needed for response, collecting and storing survival items, implementing actions to reduce vulnerability and exposure, getting involved with wider community preparedness initiatives, and thinking about recovery-based response planning (Becker et al., 2012; Paton et al., 2013). Yet while large amounts of time and resource are invested by governments and other organisations in disaster preparedness, especially around public awareness and education, efficacy for disaster preparedness remains limited (Becker et al., 2012; Donahue, 2014; Laurence et al., 2014; Vinnell et al., 2021).

While it is easy to assume that low levels of preparedness are because people, communities, and organisations are ignorant of 'the facts' or irrational in how they interpret information, this is a misconception (Eiser et al., 2012). Studies have shown that variances in efficacy for disaster preparedness are influenced by a range of factors: different perspectives of risk, previous experience, education, income, social relationships, attitudes, beliefs, political will, decision processes, gender, and race (Edwards et al., 2012; Eiser et al., 2012; Donahue et al., 2014; Paton & Buergelt, 2019). Eiser et al. (2012) explain that efficacy for disaster preparedness is not an all-or-none process but a spectrum ranging from where some people are aware of the hazard but decide not to prepare, to the other end of the preparedness spectrum with those who have acted without being aware of a specific hazard.

Even though action to prepare for disasters remains low, the literature also suggests that communicating risk can increase motivations to act. Paton et al. (2013) discuss that, among other things, it is how people interpret their risk that determines what people do. Similarly, Donahue (2014) suggests that risk perceptions influence support for preparedness capabilities and programmes.

While the relationship between risk perceptions and motivation to act for disaster preparedness is growing, knowing the risk and knowing how to prepare for the risk are not the same (Eiser et al., 2012; Odiase, 2020). As such, there remain broad gaps in the link between understanding what motivates people to prepare (Donahue, 2014) and the provision of risk information for preparedness (Paton & Johnston, 2001).

1.5 Governance of natural hazard risk

Governance is a complex concept that is subject to varying definitions depending on its context and how it is applied (Robichau, 2011). To understand natural hazard risk governance, the different governance concepts that combine to make it need to be defined. These are a definition of governance and its shift to 'new governance'; a definition of how governance is applied to managing risk; a definition of how governance is applied to the environment; and how these concepts are incorporated to define disaster risk governance.

1.5.1 Governance and 'New Governance'

The Commission on Global Governance (1995) defined governance as:

> *…the sum of the many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and co-operative action may be taken. It includes formal institutions and regimes empowered to enforce compliance, as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interest* (The Commission on Global Governance, 1995. Chapter One, The Concept of Global Governance, para. 2).

A key characteristic of this definition is that since the 1980's, a neoliberal agenda has shifted governance practices away from centralised, bureaucratic and rigid hierarchical systems of state governance (Bulkeley, 2010; Goldsmith & Eggers, 2004). There has been a shift to 'new governance', hallmarked by the absence of coercive state power and in its place a dependence on co-existent networks of multiple agents, institutions, and arrangements (Bevir & Rhodes, 2011; Paavola, 2007; Rodes, 1996). These networks acknowledge the complexity of governance and promote both vertical and horizontal cooperation across actors, which act to close the policy gaps across levels of government and promote collaboration in providing the best service (Kita, 2017).

Two forms of governance network are relevant to natural hazard risk governance in Aotearoa New Zealand and are further reviewed in section 2.3. They are:

- A joined-up government network, where different government agencies coordinate their efforts and share information (Goldsmith & Eggers, 2004).
- A third-party government network, where non-state actors are used to deliver public services (Goldsmith & Eggers, 2004). This is referred to as 'hollowing out of the state', where governance functions are directed towards special-purpose bodies and outwards to agencies (Rhodes, 1997).

1.5.2 Risk governance

Risk governance links the fields of 'risk management', including risk analysis and communication, with 'governance', which collectively binds decisions associated with regulation (Klinke & Renn, 2021). Renn (2008) defines risk governance as an activity that:

> *…requires consideration of the legal, institutional, social, and economic contexts in which a risk is evaluated, and involvement of the actors and stakeholders who represent them. Risk governance looks at the complex web of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analysed, and communicated, and how management decisions are taken.* (Renn, 2008, p. 9).

While risk governance originally applied to the quantification and management of unwanted consequences in the engineering and economic disciplines, it has evolved as the unintended consequences of modernisation have resulted in new and complex forms of risk that pose a challenge to pre-existing social and political processes (Beck, 1992; Bulkeley, 2001). Three key traits have contributed to this evolution: complexity, uncertainty, and ambiguity:

1. Complexity – As social, environmental and technological influences have become more interrelated in the modern world, risk governance has needed to acknowledge the complexity of causal links for limiting how risk can be assessed based on the knowledge of the system elements and the assumptions about these elements (Johansen & Rausand, 2014; Van Asselt & Renn, 2011).
2. Uncertainty – In the context of risk assessment, human knowledge is always incomplete and selective and cannot be completely resolved. This means that we make uncertain assumptions, assertions, and predictions, which put the validity of risk assessment results into question (Renn, 2008).
3. Ambiguity – Over the past three decades the influence of social sciences has driven risk governance to incorporate the non-technical and non-linear concepts of risk perception and characterisation, which are shaped by values, beliefs, political systems, and cultural factors (Klinke & Renn, 2021; Slovic et al., 2004). Some sociologists, such as Beck (1992) and Giddens (1999), have proposed socio-culturally constructed risks as the driving forces initiating the reorganisation of risk governance in the post-industrial society.

As such, risk governance cannot simply be calculated as a function of probability and effect. Social context is also an important contributor, which in turn creates challenges for the development and application of policy.

1.5.3 Environmental governance

Challies and Newig (2019) define environmental governance as:

> *… the totality of interactions among societal actors aimed at coordinating, steering and regulating human access to, use of, and impacts on the environment, through collectively binding decisions. Environmental governance arrangements may be directed towards a range of causes – including conservation and environmental protection, spatial and land use planning, (sustainable) management of natural resources, and the protection of human health – and operate across scales to address local and global environmental problems.* (Challies & Newig, 2019. What is ‘environmental governance’? A working definition, para. 7)

Environmental governance is intended to improve accountability, accessibility, and a voice for local people and their representatives (Batterbury & Fernando, 2006). This has been reflected in the new governance agenda where decentralisation of decision-making powers from the state, outwards and downwards towards local institutions, NGOs, and communities, is an important feature of the environmental governance approach (Savage, Hudson, & Osborne, 2020). However, it is important to acknowledge 'the tragedy of the commons' (Hardin, 1968) for decentralised environmental governance. The tragedy of the commons is where groups are logically motivated to exploit a common resource that is open to all, such as the environment, without limit even though that resource is limited. Herein lays Hardin's tragedy, which is the inability of groups to sustainably manage a common resource. Powerful influences from special interest groups to bend the rules (Croley, 2009) can perpetuate a tragedy of the commons, resulting in varied success for decentralisation of environment governance mechanisms (Batterbury & Fernando, 2006).

In response to this, the concept of 'good governance' has emerged, which aims to ensure that policy mechanisms for the governance of public goods, including the environment, are accountable, stable, effective, and resistant to corruption (Graham, Plumptre & Amos, 2003; Rothstein, 2012). Good governance acknowledges that policies to govern public goods cannot be managed by the state alone, but that in many cases there is a need for collaboration with business and/or voluntary organisations. For decentralisation of environmental governance to work, centralised government regulations are needed in collaboration with alternative, non-state policy approaches (Rothstein, 2012; Young, 2017), where accountable institutions at all levels of government can secure autonomous decision making and rule making at the local level (Ribot, Agrawal & Larson, 2006; Epstein, 2017).

1.5.4 Disaster risk governance

Over the last thirty years, disaster risk governance has incorporated the concepts as defined earlier for 'new governance', 'risk governance', 'environmental governance', and 'good governance'. Disaster risk governance acknowledges the decentralisation, or 'hollowing out' of the state, where implementation of disaster risk management policies has moved away from being solely developed and administered by central government. The United Nations Development Programme (UNDP) defines disaster risk governance as:

> *the way in which the public authorities, civil servants, media, private sector, and civil society coordinate at community, national and [international] levels in*

order to manage and reduce disaster and climate related risks (UNDP, 2013, Disaster Risk Reduction and Governance, para. 4).

This has resulted in three dimensions for the distribution of influence and responsibility in disaster risk governance (Jones, Manyena, & Walsh, 2015):

1. An upward dimension where governments are becoming more accountable to international institutions and transnational networks;
2. An outward dimension, requiring different sectors to integrate disaster and development into their activities to develop better prevention and preparedness; and
3. A downward dimension empowering local communities to formulate realistic and implementable prevention, preparedness, response, and recovery plans.

The redistribution of state functions upward to the international level in disaster governance has led to the creation of the United Nations International Strategy for Disaster Risk Reduction (UNISDR) in 1999. The UNISDR was set up as a focal point for the coordination of disaster reduction activities of governments, UN agencies, and organisations across international regional and civil society organisations to guide, monitor, and report on the progress of disaster risk reduction (DRR) measures implemented by member states. Progress for DRR is coordinated by what the UNISDR refers to as National Disaster Management Organisations (NDMOs) against frameworks such as the Sustainable Development Goals, Paris Agreement (UNFCC, 2015) and the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015b). While weaknesses have been noted for how NDMOs have implemented their DRR measures in accordance with international frameworks (UNISDR, 2011; Raju & da Costa, 2018), there is growing recognition of the importance for reporting to UNISDR, which has gradually become the institution of practice and a constitutive element of disaster governance (Jones, Manyena, & Walsh, 2015).

Despite the agenda of new governance to ‘hollow out’ the influence of the state, NDMOs are still called upon to integrate DRR internally throughout their government’s administrative levels, requiring a joined up, coordinated government network. This calls for both vertical and horizontal cooperation across the state’s organisational structures, such as health, natural resource management, and economic development, where DRR is linked across policies and practice. However, it has been found that many NDMOs are not adequately resourced to fulfil this function due to complexity of issues, scarcity of funding, limited expertise, and limited ability to influence (Rajan, 2002; UNISDR, 2013). Nationally formulated DRR policies and plans have not achieved widespread systemic change in local practices, creating a void which has largely been filled by development partners from non-state actors including non-government organisations (NGOs) (e.g. the International Federations of Red Cross and Red Crescent), community organisations, the private sector, academia, and voluntary groups (Lassa, 2018).

As such, the distribution of disaster risk governance has moved outwards from NDMOs and is shared with non-state actors. Non-state actors are seen as more effective and efficient than government because of their pursuit of community-based participatory approaches, their principled motivations, clear mission and objectives, organisational flexibility and adaptability, progressive development agendas, and lower overhead costs (Izumi & Shaw, 2012; Jones, Manyena, & Walsh, 2015; Lassa, 2018). While the participation of non-state actors in DRR has risen markedly over the last thirty years, the literature is also critical of their legitimacy as vehicles for disaster risk governance. This includes non-state actors being more accountable to donors than to their beneficiaries, being self-interested, and causing fragmentation and duplication (AbouAssi & Trent, 2016; Lister, 2003; Suleiman, 2013; Uddin & Belal, 2019).

Given that the allocation of resources for DRR has the potential to be misappropriated, the concept of 'good governance' has been applied as a framework for accountability in achieving DRR (Choudhary & Neeli, 2018; Planitz, 2015). However, good governance for DRR has turned out to be a challenging undertaking at the community level, especially in countries with weak or corrupt governance systems (Planitz, 2015; Uddin, Haque & Khan, 2020).

While disasters impact at a national scale, disaster risk is always experienced locally (Scott & Tarazona, 2011; Gaillard & Mercer, 2012). This has led to the redistribution of disaster risk governance downward to the community level, where local government and community-based organisations cooperate to apply disaster risk management. The value of community-based approaches, which are often developed or supported by non-state actors, is that they focus on 'grassroots' community involvement and ownership and are based on identifiable local needs and priorities (Izumi & Shaw, 2012; Manyena & Walsh, 2015; Shaw, 2012).

These approaches, commonly referred to as 'community-based disaster risk reduction' (CBDRR), empower the capacity of communities to undertake pre-emptive, bottom-up approaches to DRR, that focus on the root causes of vulnerability rather than isolated disaster events (Allen, 2006). However, while non-state actors (NGOs) often initiate CBDRR programmes of work, problems arise when funding for these programmes ends, and they withdraw from the field. This leads to two major challenges: sustainability of effort at the community level and incorporation of CBDRR issues at the policy level (Shaw, 2012). To be effective over time, CBDRR needs the involvement of local government, ensuring that expertise and good practice developed through participatory, community-based approaches is captured and sustained through existing governance structures for policy, planning, and budgeting (Shaw, 2012; Manyena & Walsh, 2015). Furthermore, good practice in CBDRR needs to be recognised and captured within national and international governance frameworks. This is currently reflected in the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015b) which, while advocating disaster risk governance at the national, regional and international level, also calls for empowerment of local authorities and communities through resources, incentives, and decision-making responsibilities as appropriate.

1.6 Risk modelling for communicating natural hazard risk

Up until the availability of modelling, the common practice for communicating risk for natural hazard risk governance was with a hazard map detailing the location of assets, for a single return-period (e.g. 1 in 250 years). If the hazard was less frequent (e.g. a 1 in 1,000 year event), there was a limited understanding of what the consequences would be from such an event, or whether stakeholders were ready to accept the associated risk if they knew what it was (Pondard & Daly, 2011). As such, the demand for risk modelling has significantly increased over the last few decades (The World Bank, 2014). Researchers, policy makers, and practitioners are increasingly using risk modelling to scope the consequences for hazards scenarios that they know they are exposed to, but have no historical information about, particularly low-frequency, high-magnitude events such as destructive tsunami (UNISDR, 2015; Donovan & Oppenheimer, 2015; Eiser et al., 2012). By giving a visual representation of risk, as well as tabulated data on impact and loss, risk models provide decision makers with a starting point for how they balance the cost and benefits of associated risk reduction measures (Edwards et al., 2012; Stein & Stein, 2014).

Risk models come with a number of limitations. A model is a representation of 'reality' which we cannot fully understand and is therefore defined by a series of assumptions. These assumptions are fuelled by scientists being uncertain about their knowledge and data, incomplete information, inadequate understanding of the processes involved, and undifferentiated alternatives (Baven et al., 2018; Doyle et al., 2019).

Each of the components within the risk model has its own set of associated uncertainties. Van Asselt (2000) outlines four types of modelling uncertainty:

1. Technical – from the quality or appropriateness of the input data used to describe the system, from aggregation (temporal and spatial) and simplification, as well as from lack of parameters from data and approximations.
2. Methodological – due to uncertainty in equations and model structures.
3. Epistemological – uncertainty in levels of confidence and model validity.
4. Model operation uncertainties – due to hidden flaws in technical equipment and/or accumulation of uncertainties propagated through the model.

As these uncertainties compound, the model output may move further away from 'accuracy'. For example, a risk model might appear to produce an output detailing that 21,689 people will be affected, but in reality the accuracy of the model and input data may provide only an order of magnitude estimate, e.g. in the thousands – ≈22,000 (GFDRR, 2014). While the experts developing these models are aware of their uncertainty and assumptions, the policy and decision makers using this risk information are less aware (Donovan & Oppenheimer, 2015; GFDRR, 2014; Stein & Stein, 2014).

Furthermore, there has been little assessment of the uncertainties in risk modelling or of how well models predict future events. Stein and Stein (2014) propose two approaches to change this situation:

1. The uncertainties in models should be clearly communicated to users in a manner that suits their needs, enabling them to decide how much credence to place in the modelling outputs. Doyle et al. (2019) find that a shared understanding of decision-maker perspectives, values, and judgements is needed so scientists can more effectively communicate and increase decision makers' tolerance for model uncertainty.

2. The modelled outputs should be tested objectively against null hypotheses outputs to compare their predictions. So, while models have a role in communicating risk to policy and decision makers, “as soon as they are used in this way their vulnerability as representations of nature is exposed” (Donovan & Oppenheimer, 2015, p. 153).

Models have the potential to support decision makers with natural hazard risk information. This involves a two-way communication process, where the feedback from stakeholders also informs the usability of the model and how it is applied (Komendantova et al., 2014). This is very important for the communication of risk from science to policy and vice versa. However, there is a scarcity of research in this area. A review of 101 papers on risk modelling for natural hazard risk reduction (Newman et al., 2017) found that only 13 papers referred to end-user involvement in model design, with fewer in regard to end-user involvement in specifying decision criteria, and none that reported on the success of natural hazard modelling over the long or short term.

As such, while modelling is increasingly being used to communicate the impact and losses from natural hazards, the use of risk modelling is compromised by unavailability of hazard data along with modelling uncertainties. Furthermore, there is limited understanding of how modelled information is received and valued by stakeholders and how models can be improved to better inform their natural hazard risk preparedness measures. Currently there is no clear recommended approach to address how modelling uncertainty is communicated to stakeholders (Doyle et al., 2019) and more research is needed to better understand how natural hazard modelling is used by decision makers to inform the governance and management of natural hazard risk.

1.7 Rationale for the research

As presented in this introduction, global losses caused by natural hazards are significant and unacceptable. Yet these losses continue to increase. The risk of natural hazards can be reduced through risk management, with structured risk management approaches, such as ISO 31000, enabling organisations to do this. However, complex and subjective perceptions of ‘risk’ challenge how natural hazards are governed. These perceptions are influenced by the frequency of the event, where low-likelihood natural hazards such as tsunami are perceived as less risky. Effective governance of natural hazard risk requires decision makers and practitioners to be risk aware, for risk to be managed via consistent, structured approaches, and for risk management to be connected between government and community actors. One option for achieving this is through risk modelling tools, which have been increasingly used to help communicate natural hazard risk for different audiences with different perceptions.

Given this background, this research seeks to better understand how natural hazard risk is communicated and managed in Aotearoa New Zealand. It focusses on local government because that is where natural hazard risk management is primarily applied. It specifically focusses on destructive tsunami because despite the significance of its consequences, its low likelihood causes the risk to be misperceived and underrated. The research then focusses on how risk modelling is used for communicating tsunami risk in local government to aid the development of policy and procedure for natural hazard risk management. However, the adoption of risk modelling is challenged by model uncertainties and further research is needed for how they are perceived by end users.

1.8 Thesis structure

This thesis consists of a mixture of conventional chapters and manuscripts that have been submitted for publication in peer-reviewed journals, as follows:

1. Chapter 2 reviews the literature specific to natural hazard risk management in Aotearoa New Zealand, with a specific focus on tsunami risk governance in local government and the use of risk modelling. It concludes with the key research areas and questions that this thesis seeks to answer.
2. Chapter 3 sets out the philosophy, methods, ethics, and areas studied for this research.
3. Chapters 4, 5, 6 and 7 are presented as manuscripts and explore the research questions. They are set out in Table 1-4, followed by a brief summary of each manuscript.
4. Chapter 8 concludes the thesis with a synopsis of the literature review presented in Chapter 2, a summary of the research undertaken and the results, implications of the research, and opportunities for future research.

The manuscripts in Chapters 4 to 8 are presented in Table 1-4 along with the research questions (RQs) they aim to answer and are explained further in the following paragraphs.

<table>
<tr><th>Chapter 4 –
1st Manuscript</th><th>Chapter 5 –
2nd Manuscript</th><th>Chapter 6 –
3rd Manuscript</th><th>Chapter 7 –
4th Manuscript</th></tr>
<tr><td>Explores how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk in Aotearoa New Zealand local government.</td><td>Think piece exploring how risk modelling is perceived and used by the policy making, land-use planning, and emergency management functions within Aotearoa New Zealand local government.</td><td>Explores the thoughts and opinions of natural hazard risk practitioners regarding tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development.</td><td rowspan="7">Explores the complex system of challenges for the application of natural hazard risk management within local government as a whole and how the science-policy-practice interface can interrupt the complex system's overall dynamic.</td></tr>
<tr><td colspan="3">RQ1. How is risk communicated, perceived, and acted upon by government bodies?</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">RQ2. How is risk modelling informed by natural hazard management?</td></tr>
<tr><td rowspan="3"></td><td></td><td></td></tr>
<tr><td colspan="2">RQ3. How are natural hazard management policies and procedures informed by risk modelling?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="4">RQ4. What are the risk communication barriers and enablers that limit or contribute to efficacy for risk management for local government?</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">RQ5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?</td></tr>
</table>

Table 1-4: Manuscript Positionality in Relation to Research Questions

Chapter 4 (the first manuscript) draws on focus group sessions with natural hazard risk practitioners in Aotearoa New Zealand local government to explore how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk. The manuscript discusses that while there is definite interest and engagement in the use of risk modelling from emergency management and other natural hazard risk management practitioners within local government, the use of risk modelling to better understand and communicate natural hazard risk continues to be challenged by the disconnect across the science-policy interface and resulting practice. The conclusion summarises these challenges and makes recommendations to span the science-policy interface and enable risk modelling as a communication tool to better develop policy and procedure for natural hazard management.

Chapter 5 (the second manuscript) continues from Chapter 4, drawing from the original focus group sessions, as well as follow-up interviews with natural hazard risk practitioners in Aotearoa New Zealand local government, contributing to the scarcity of research on the perception and use of natural hazard risk modelling tools, specifically RiskScape. It is a think piece that explores how risk modelling is perceived and used by different natural hazard practitioners within local government, focussing on functions for strategic policy making, land-use planning, and emergency management. The research finds differences in how risk modelling is perceived and used by each function and goes on to provide opinions on why this is the case. It concludes with recommendations for developing end-user perceptions of risk modelling and better enabling its use for natural hazard risk management.

Chapter 6 (the third manuscript) shifts the focus away from the challenges of applying risk modelling in Aotearoa New Zealand local government and explores risk perception as a cause of these challenges. It focusses on risk perception for tsunami risk because tsunami is Aotearoa New Zealand's most significant natural hazard risk but is also the least likely. It explores how low-likelihood influences the development of tsunami risk management policy, the barriers and enablers that limit or contribute to this, and briefly how risk modelling (RiskScape) can help communicate risk to influence risk perceptions. The research reinforces the literature, finding that low likelihood presents a significant challenge for the development of tsunami risk management policy in Aotearoa New Zealand. The result is a paucity of tsunami risk management policy. The manuscript goes on to explore cognitive biases as a cause for this and makes recommendations to overcome the low-likelihood challenge for tsunami risk management policy. The research recognises that these challenges arise from more fundamental issues relating to how natural hazard risks are governed in Aotearoa New Zealand. These issues are complex, interrelated, and entrenched within local government and result in the limited success of natural hazard risk management approaches.

Chapter 7 (the fourth manuscript) picks up from the end of the third manuscript to explore the challenges for natural hazard risk management within local government in Aotearoa

New Zealand. It views these challenges as a complex system, consisting of feedback loops, which inhibit the effective resolution of the challenges. It is proposed that these challenges remain unresolved because they are elements within a complex system. This complex system is explored using a systems-thinking approach and identifies the science-policy-practice interface as an intervention point which can interrupt the complex system's overall dynamic. The manuscript concludes with recommendations for further research into the use of systems thinking for exploring these challenges, as well as how collaboration across the science-policy-practice interface can be improved to apply natural hazard risk management more effectively within local government.

2 Literature Review

2.1 Overview of this chapter

This research focusses on how risk perceptions of natural hazards influence the development of policy and procedure in Aotearoa New Zealand. It specifically focusses on tsunami risk as, despite its destructive consequences, its low likelihood influences practitioners and decision makers to misperceive and underrate the risk, resulting in them being less prepared for tsunami than for other natural hazards. The research pulls the global context for natural hazard risk management, including tsunami (presented in Chapter 1), into the national context for Aotearoa New Zealand. It presents a brief overview of the natural hazard setting in Aotearoa New Zealand and reviews the literature for how the management of these hazards is governed. The chapter then focusses on tsunami risk management, reviewing the literature on how it is applied within local government. It then reviews the literature on the application of RiskScape for communicating natural hazard risk within this setting and concludes by setting out the key research areas and questions for this research.

2.2 Natural hazards in Aotearoa New Zealand

Aotearoa New Zealand is an island nation in the southwest Pacific. Figure 2-1 shows that the country lies across the boundary of the Australian and Pacific tectonic plates. The figure shows that to the east of the North Island, the Pacific Plate is being subducted under (pushed under) the Australian Plate. To the southwest of the South Island the opposite is happening — the Australian Plate is being subducted under the Pacific Plate.

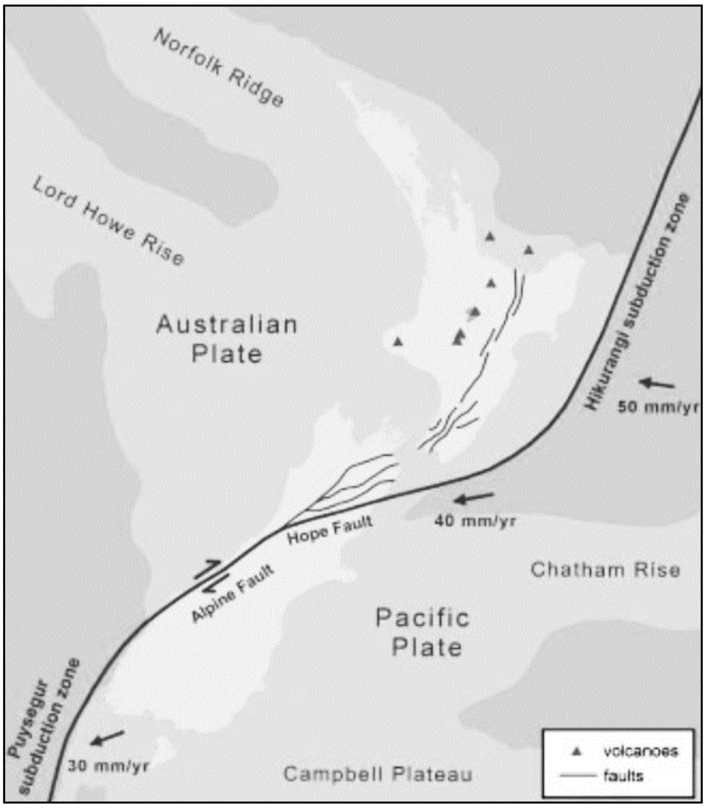

Figure 2-1: The tectonic setting of Aotearoa New Zealand showing the generalised plate boundary between the Australian and Pacific tectonic plates (DPMC, 2007)

Its position straddling two plate boundaries results in Aotearoa New Zealand being susceptible to geophysical hazards including volcanic eruption, land instability, earthquake and tsunami related disasters (please refer to Section 2.5 for more on the tsunami risk management in Aotearoa New Zealand). Its position as an isolated landmass in the Pacific Ocean results in it being susceptible to maritime weather patterns, including storm, flooding, and drought related disasters, which are exacerbated by climate change. These hazards occur with sufficient frequency and intensity that substantial damage and loss of life results (King & Bell, 2006). Furthermore, Lloyd's (2018) placed Aotearoa New Zealand as the second most vulnerable economy in the world for annual expected disaster related losses as a percentage of gross domestic product (GDP). Since 2000, the financial losses caused by natural hazards in Aotearoa New Zealand is $1,830,630,000 (NZD) (ICNZ, n.d.), or approximately 1% of the country's annual GDP. Given the increase in occurrence of natural hazard events (as explained in Chapter 1), the costs from natural hazards in Aotearoa New Zealand will continue to increase unless there is effective governance of natural hazard risk.

2.3 The framework for natural hazard risk governance in Aotearoa New Zealand

Governance for natural hazard risks in Aotearoa New Zealand reflects the structure presented for disaster risk governance in section 1.5.4, where it is accountable:

- upwards to international institutions and frameworks;
- outwards across National Disaster Management Organisations (NDMOs) located within central government; and
- downwards to local government and community-based organisations.

2.3.1 Upwards

Aotearoa New Zealand is 'upwardly' accountable to international institutions and frameworks for natural hazard risk governance, primarily the Sendai Framework for Disaster Risk Reduction 2015–2030 (Sendai Framework) (UNISDR, 2015b). The Sendai Framework takes into account the experience gained through the implementation of its predecessor - the Hyogo Framework for Action 2005–2015 (Hyogo Framework) (UNISDR, 2005) because it shifts the focus from managing disasters to managing disaster risk. The framework states a need for focused action within and across sectors at local, national and global levels in the following four priority areas:

- Priority 1: Understanding disaster risk.
- Priority 2: Strengthening disaster risk governance to manage disaster risk.
- Priority 3: Investing in disaster risk reduction for resilience.
- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction.

Priority 2 of the Sendai Framework specifically relates to governance, calling for a strengthening of disaster risk governance to manage disaster risk, including a clear vision, plans, competence, and guidance. It also calls for effective and efficient management of disaster risk 'outward' at the national level and 'downwards' to the local level. As part of this, it calls for coordination within and across sectors and participation from relevant stakeholders.

Under these priorities, the framework sets seven global targets for improved disaster risk reduction, which signatory nations are asked to report on annually. The targets are:

1. Substantially reduce disaster mortality by 2030, aiming to lower average per 100,000 mortality between 2020–2030 compared with 2005–2015.
2. Substantially reduce the number of affected people by 2030, aiming to lower the average figure per 100,000 between 2020–2030 compared with 2005–2015.
3. Reduce disaster economic loss in relation to gross domestic product (GDP) between 2020–2030 compared with 2005–2015.
4. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.
5. Substantially increase the number of countries with national/local disaster risk reduction strategies by 2020.
6. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of [the] framework by 2030.
7. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

Historically, international frameworks concerning disaster risk and its reduction have been poorly acknowledged in Aotearoa New Zealand, with the Hyogo Framework (UNISDR, 2005) largely ignored (Basher, 2016). However, the Sendai Framework is now specifically referenced in Aotearoa New Zealand's National Disaster Resilience Strategy (MCDEM, 2019). This strategy has incorporated the targets listed in the Sendai Framework into the strategy's objectives, with the aim to report, on a biennial basis, progress against goals and objectives, resilience, and impacts.

The National Emergency Management Agency (NEMA) is developing a national loss and impact database, which will be used to report losses and impacts to the UNDRR in fulfilment of the Sendai Framework. However, Harrison et al. (2021) note that development of the database is slow as NEMA is continuously busy responding to other events. Furthermore, Saunders et al. (2020) specifically explore the progress that Aotearoa New Zealand is making in changing its governance measures to meet the commitments made to international frameworks. Saunders et al. (2020) found that the Sendai Framework's shift in focus from managing disasters to managing natural hazard risk is incorporated into current emergency management planning but is lacking in reference and refinement in strategic and statutory documents that guide land-use planning. They give four recommendations to further implement these international accountabilities within natural hazard governance in Aotearoa New Zealand: (1) take into account international agreements during the development and implementation of all legislation; (2) build awareness, capability, and capacity within central, regional and local governments to support implementation; (3) actively evaluate the progress of implementing initiatives designed to reduce vulnerability and strengthen resilience; and (4) ensure that more weight and value are given to indigenous planning documents.

As such, Aotearoa New Zealand is working to meet its obligations ‘upwards’ to the Sendai Framework; however, acknowledgement of the framework is not evenly distributed across legislation for natural hazard risk management, and national reporting has been disrupted by other events, for example, the Covid-19 pandemic. While Saunders et al. (2020) have provided a starting point for how government is meeting these obligations, further research is needed to understand how the Sendai Framework is used as a driver for natural hazard risk governance both ‘outwards’ and ‘downwards’, across all levels of government, and how our natural hazard governance system can best enable them.

2.3.2 Outwards

Governance for natural hazard risk in Aotearoa New Zealand is shared ‘outwards’ across national disaster management organisations (NDMOs) within central government. The primary agencies responsible for administration of natural hazard governance legislation and policy are:

- The Department of Internal Affairs (DIA), which administers the legislation for local government management.
- The National Emergency Management Agency (NEMA), which administers the legislation for civil defence emergency management;
- The Ministry for Environment (MfE), which administers legislation for sustainable land-use management and climate change; and
- The Ministry of Business, Innovation and Employment (MBIE), which administers legislation and regulations for building control, as well as funding for collaborative research (e.g. the National Science Challenges).

These central government agencies administer the acts of legislation for natural hazard risk governance in Aotearoa New Zealand, as well as provide implementation support for organisations to collaborate in the research and application of natural hazard risk governance. An example of this collaboration is the Resilience to Nature's Challenges (Resilience Challenge), which is one of the National Science Challenges funded through MBIE. The Resilience Challenge formally involves Crown Research Institutes, Crown Entities, universities, and private research consultancies (or NGOs) (e.g. WSP, Resilient Organisations and Market Economics), which work together to co-create research solutions to inform how New Zealand will build a transformative pathway toward natural hazard resilience (Resilience to Nature's Challenges, 2018). Another example is the Earthquake Commission, which is a Crown Entity established under the Earthquake Commission Act 1993, investing in natural disaster research and education and providing insurance to residential property owners (EQC, n.d.).

Crawford et al. (2019) recognise four key central government acts of legislation (Acts) under which natural hazard risk is governed within Aotearoa New Zealand. They are the Local Government Act (New Zealand Government, 2002b); the Resource Management Act (New Zealand Government, 1991); the Civil Defence Emergency Management Act (New Zealand Government, 2002a), and the Building Act (New Zealand Government, 2004). Saunders et al. (2020) add to this list of key legislation with the Climate Change Response (Zero Carbon) Amendment Act (New Zealand Government, 2019).

These Acts are part of a plethora of central government legislation, national strategies, plans, policies, regulatory codes, and practices supporting natural hazard risk management outcomes, including:

- Soil Conservation and Rivers Control Act 1941
- Local Government Official Information and Meetings Act 1987
- Earthquake Commission Act 1993
- The Public Finance Act 1989
- New Zealand Coastal Policy Statement 2010
- National Civil Defence Emergency Management Plan Order 2015
- Building Regulations 1992
- National Tsunami Advisory and Warning Supporting Plan 2016

- National Disaster Resilience Strategy – Rautaki ā-Motu Manawaroa Aituā 2019.

These Acts and policy instruments provide a framework for sharing responsibility for natural hazard risk governance 'outwards' across a number of central government agencies and supporting organisations, and also 'downwards' for application by local government and community organisations. However, the breadth of interrelationships across these policies has resulted in issues for its application. In its think piece, 'Managing Natural Hazard Risk in New Zealand', Local Government New Zealand (LGNZ) argued that natural hazard management sits within a complex legislative environment that requires the many players to work together in a coordinated way and consists of high-level, disconnected and widely-interpretative policy guidance (LGNZ, 2014). It found there was no formal approach for how natural hazard risk management is achieved, or how it is applied 'downwards' within local government and community organisations. This finding is supported in later research (Basher, 2016; Crowley & Crawford, 2018a; EQC, 2019; Kilvington & Saunders, 2019), which found that local government and community organisations are currently left to individually manage natural hazard risk with varying degrees of success.

This lack of guidance has been acknowledged within central government through a 2020 review of the Resource Management Act, titled 'New Directions for Resource Management in New Zealand' (MfE, 2020). The review recommended that the RMA is repealed and replaced with three new Acts called the 'Natural and Built Environments Act'; the 'Strategic Planning Act'; and the 'Managed Retreat Act' (now referred to as the 'Climate Adaptation Act'). The 'Natural and Built Environments Act' would be the primary replacement for the RMA and proposes greater use of mandatory national direction and nationally coordinated data management with a focus on climate change and reduction of risks from natural hazards. The 'Strategic Planning Act' would integrate 'outwards' with other legislation relevant to development and set long-term funding and planning processes for strategic spatial planning. The 'Climate Adaptation Act' would provide the framework for managed retreat resulting of sea level rise brought about by climate change.

While the recommendations in 'New Directions for Resource Management in New Zealand' (MfE, 2020) provide structure 'downwards' for local government natural hazard risk governance, it also takes some responsibility away from local government bodies for developing their own, fit for purpose, community-focussed measures for managing natural hazard risk. As such, the redistribution of responsibility back to central government for managing natural hazard risk contradicts the neoliberal governance agenda as explained in section 1.4. The recommendation to shift more natural hazard risk governance to central government, along with the complexity of central government legislation in the first place, exposes a gap in research for better understanding the system of natural hazard risk governance in Aotearoa New Zealand, and how this system can best enable local government to apply natural hazard risk governance.

2.3.3 Downwards

As noted in the previous section, central government policy is devolved 'downwards' for application in local government. There are two tiers of local government:

- The first tier is regional councils, with responsibilities including: sustainable regional well-being; managing the effects of using freshwater, land, air, and coastal waters; managing rivers; mitigating soil erosion and flood control; and regional emergency management and civil defence preparedness (Department of Internal Affairs, Councils' roles and functions web page, n.d).
- The second tier is territorial authorities (district and city councils), with responsibilities including: sustainable district well-being; the provision of local infrastructure, including water, sewerage, stormwater, and roading; controlling the effects of land use (including hazardous substances, natural hazards, and indigenous biodiversity), noise, and the effects of activities on the surface of lakes and rivers; building control; and district emergency management and civil defence preparedness (Department of Internal Affairs, Councils' roles and functions web page, n.d).

In six cases, the responsibilities of regional councils and territorial authorities have been combined under a 'unitary authority'. These have been developed for areas in Aotearoa New Zealand which could not support both regional and territorial authorities (Morgan-Williams & Macdonald, 1999), or because separated regional and territorial authorities did not fit the governance framework desired for an area's development. Examples of unitary authorities are Gisborne District Council and Auckland Council.

Local government in Aotearoa New Zealand currently consists of seventy-eight councils: eleven regional councils; sixty-one district and city councils and six unitary councils (LGNZ, n.d.). The seventy-eight councils have about 1600 local politicians, who are elected every three years in accordance with the Local Government Act (New Zealand Government, 2002b) by voters within their communities. These local politicians, consisting of a mayor and a body of councillors, typically meet monthly to decide on the preferences of their communities, the commitments of previous councils, central government requirements, and the policy platforms they were voted in on. The mayor employs a chief executive to run the everyday business of the council. The chief executive then employs all other council staff, who implement council decisions in compliance with Acts and other legislative instruments.

As stated in section 2.3.2, Crawford et al. (2019) recognise four key central government Acts under which natural hazard risk is governed within Aotearoa New Zealand. Saunders et al. (2020) add to this list, including the Climate Change Response (Zero Carbon) Amendment Act. These Acts and a brief description of their natural hazard risk governance responsibilities are set out in Table 2-1. Their provisions for managing natural hazard risk are further explained in the following sections.

Legislative Act	**Natural hazard risk governance responsibilities**
The Local Government Act (New Zealand Government, 2002b)	A local authority must manage risks to infrastructure from natural hazards (section 101B(3)(e)).
The Resource Management Act (New Zealand Government, 1991)	A local authority shall manage significant risks from natural hazards for the use, development, and protection of resources (section 6(h)).
The Civil Defence Emergency Management Act (New Zealand Government, 2002a)	A local authority shall encourage and enable communities to achieve acceptable levels of risk (section 3(b)).
The Building Act (New Zealand Government, 2004)	A local authority must manage consent for construction or alteration of buildings subject to natural hazards (section 71).
The Climate Change Response (Zero Carbon) Amendment Act (New Zealand Government, 2019)	A local authority may be required to report a description of the processes that it uses to identify, assess, and manage the risks and opportunities arising from climate change (section 5ZW(1)).

Table 2-1: Key legislative Acts in Aotearoa New Zealand for local government natural hazard risk management

2.3.3.1 The Local Government Act (LGA)

The LGA provides the framework for local government to promote the social, economic, environmental and cultural well-being of their communities, taking a sustainable development approach. It provides the overall setting, including funding arrangements, for which local government can achieve its natural hazard risk management objectives through various types of legislation and policy instruments. The primary document produced under the LGA is the long-term plan (LTP), which is the key planning tool for councils. The purpose of the LTP is to:

- describe the council's activities in meeting outcomes focussed on the current and future needs of communities for good-quality local infrastructure, local public services, and performance of regulatory functions;
- provide integrated decision making and coordination of the resources, as set out in section 93(6)(c) of the Act;
- provide a long-term focus;
- show accountability to the community;
- provide an opportunity for participation by the public in council decision-making processes.

LTPs cover a 10-year period and are reviewed every three years, when local government is required to consult with their communities and other stakeholders, who are invited to submit their views on how the LTP meets the local outcomes in which they are interested. While LTPs cover a 10-year timeframe, section 101B of the LGA sets requirements for local authorities to prepare and adopt infrastructure strategies that cover at least 30 consecutive financial years. One of the matters that must be taken into account in preparing the strategy is the need to "provide for the resilience of infrastructure assets by identifying and managing risks relating to natural hazards and making appropriate financial provision for those risks". The Draft New Zealand Infrastructure Strategy (NZIC, 2021) refers to the uncertainties from climate change and other natural hazards over the next 30 years and recommends that government agencies, including local government, be required to develop and publish capital investment plans for a minimum period of 10 years.

LTPs set provision for management of natural hazard risk through land-use planning, emergency management, building control, and climate change. However, specific actions and outcomes for governing natural hazard risk management are primarily focussed through legislation that works alongside the LTP, specifically the Resource Management Act (1991), the Civil Defence Emergency Management Act (2002), the Building Act (2004), and the Climate Change Response (Zero Carbon) Amendment Act (2019). Plans, strategies, and other policy instruments are then developed under these Acts, and these are discussed further in the following sections.

2.3.3.2 The Resource Management Act (RMA)

The provision for environmental management is devolved through the RMA by way of National Policy Statements (NPSs), National Environmental Standards (NESs), Regional Policy Statements (RPSs), regional plans, district plans, and resource consents.

The purpose of NPSs is to state objectives and policies for matters of national importance (s6) that are relevant to achieving the purpose of the RMA (RMA, s45). Specifically, "when determining whether it is desirable to prepare a national policy statement, the Minister may have regard to anything which, because of its uniqueness, or the irreversibility or potential magnitude or risk of its actual or potential effects, is of significance to the environment of New Zealand" (RMA, s45(2)(g)).

NESs are regulations issued under section 43 of the RMA, which can prescribe technical standards, methods, or other requirements nationally. Current examples of NESs are standards for air quality, drinking water, and assessing and managing soil contamination. Each regional, city or district council must enforce the same standard, or impose stricter standards.

Currently, there are no NPSs or NESs that set any standards for the management of natural hazard risk, though some progress towards natural hazard risk management is recognised in the New Zealand Coastal Policy Statement (NZCPS). The NZCPS sets out objectives and policies in order to achieve the objectives of the RMA in relation to the New Zealand's coastal environment and makes provision for "activities in the coastal environment [that] are susceptible to the effects of natural hazards such as coastal erosion and tsunami, and those associated with climate change" (NZCPS, 2010). The NZCPS includes policies on the subdivision, use, and development of land in areas of coastal hazard risk, as well as strategies for protecting existing development from coastal hazard risk.

RPSs are a particularly useful instrument for coordinating RMA policy across a region because of the requirement for regional and district plans to 'give effect' to them. It is important that to be effective, RPSs integrate with other natural hazard risk management measures in the region, particularly CDEM risk reduction aspirations (Saunders et al., 2015).

Under the current RMA, every regional council has a responsibility to control the use of land, coastal marine area, or bed of a water body for the purpose of the avoidance or mitigation of natural hazards (RMA, s 30). A regional council can prepare a specific natural hazard regional plan but, because of the interrelated nature of hazards with other environmental features or effects, these planning provisions are usually distributed across different sections of other regional plans, for example, CDEM plans (the RMA Quality Planning Resource, n.d.).

Territorial authorities need to be aware of measures outlined in the regional plan when reviewing their district plans for the purpose of stating:

- the objectives for the district;
- the policies to implement the objectives; and
- the rules (if any) to implement the policies.

However, if no direction is provided through the RPS, there is no requirement for the district plan to include risk-based measures to control the use of land to avoid or reduce the effect of natural hazards.

A local authority should provide:

- clear direction through plans and other means on the hazard information that needs to be included in any resource consent application;
- policies within the plan giving clear guidance on the matters addressed during consideration of a resource consent and the desired outcome sought in managing hazard risk.
- methods on how policies will be implemented, such as through rules.

A resource consent is the authorisation given to certain activities that would otherwise contravene the policies of the regional or district plan. Resource consent applications must be accompanied by an assessment of environment effects (AEE), where an assessment of an activity's effects on the environment must address any risk to the neighbourhood, the wider community, or the environment through natural hazards (RMA – Schedule 4(7)(1)(f)). The Quality Planning website (n.d.) lists a number of aspects for the AEE to consider, including:

- risk to life, property, and the environment posed by the natural hazard;

- likely frequency and magnitude of the hazard event;
- type, scale, and distribution of any potential effects from the natural hazard.

However, while these considerations are integral to natural hazard risk management, they are listed as potential good practice rather than a requirement.

2.3.3.3 The Civil Defence Emergency Management Act (CDEMA)

Natural hazard risk governance under the CDEMA is framed around the four 'Rs', being:

- Reduction – involving the identification and analysis of risks to life and property from hazards, taking steps to eliminate those risks if practicable, and, if not, reducing the magnitude of their impact and the likelihood of their occurrence to an acceptable level.
- Readiness – involving the development of operational systems and capabilities before an emergency happens, including arrangements with emergency services, lifeline utilities, and other agencies, and developing self-help and response programmes for the general public.
- Response – involving the actions taken immediately before, during or directly after an emergency to save lives and property and to help communities begin to recover.
- Recovery – involving the co-ordinated efforts and processes used to bring about the short, medium and long-term holistic regeneration and enhancement of a community after an emergency (MCDEM a., n.d.).

This approach starts with recognising the hazards New Zealand faces and the vulnerability of communities and infrastructure to those hazards. By addressing what these hazards could do, the focus can move to measures for reducing the risks and for managing the impacts when they occur.

Guidance for how the four 'Rs' are applied is led by the National Emergency Management Agency (NEMA), and the CDEMA requires the formation of Regional CDEM Groups, which are consortia of representatives from the regional, territorial or unitary authorities. The location of current CDEM Groups in Aotearoa New Zealand, with participating councils is shown in Figure 2-2.

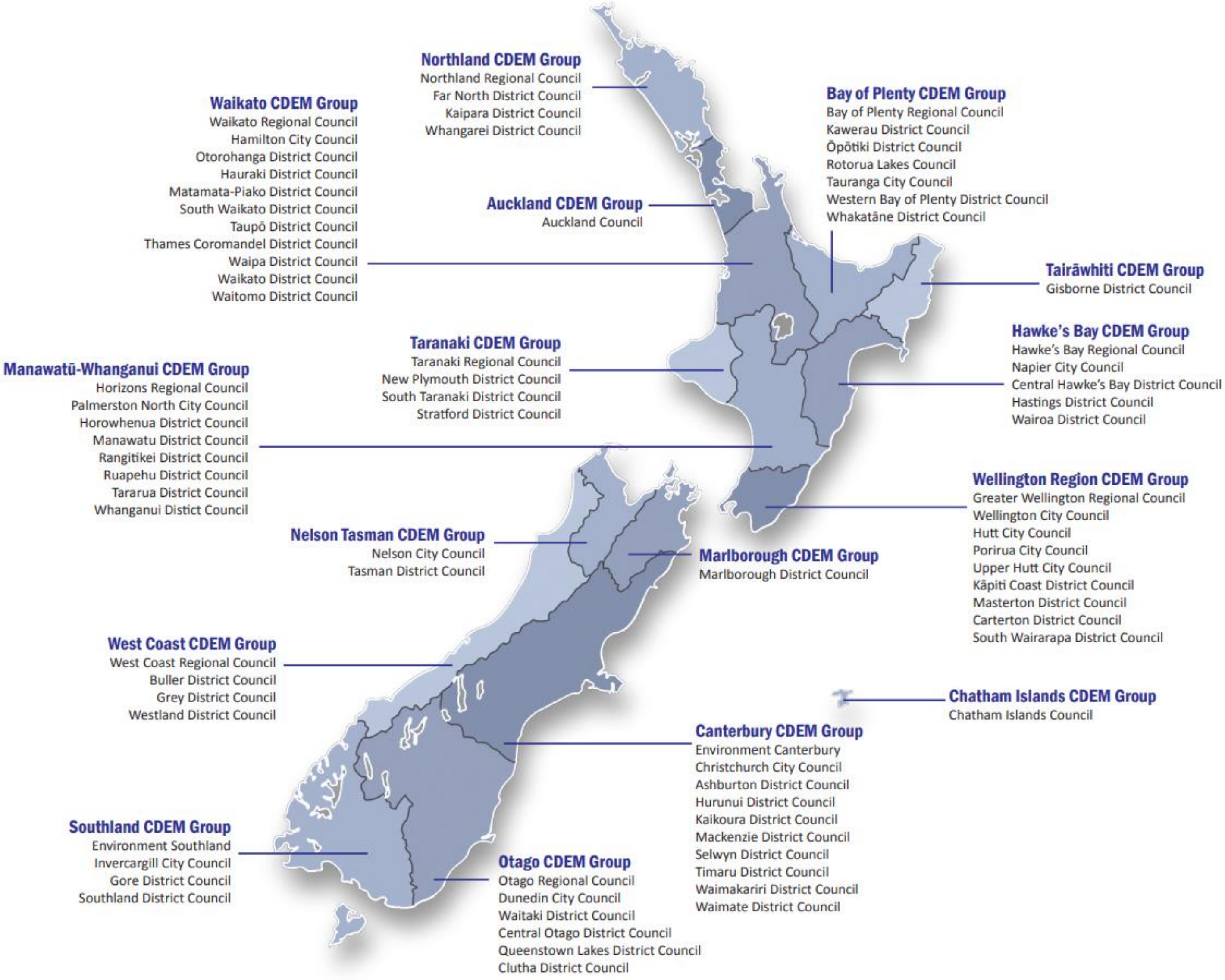

Figure 2-2 Location of Civil Defence Emergency Management (CDEM) Groups, with participating councils in Aotearoa New Zealand (NEMA, n.d.)

The national level policy document under which all CDEM Groups administer natural hazard risk management is the National Disaster Resilience Strategy – Rautaki ā-Motu Manawaroa Aituā (2019). The strategy sets three priorities to improve our nation's resilience to disasters:

1. Managing risks – what we can do to minimise the risks we face and limit the impacts to be managed if hazards occur;
2. Effective response to and recovery from emergencies – building our capability and capacity to manage emergencies when they do happen; and
3. Enabling, empowering and supporting community resilience – building a culture of resilience in New Zealand so that everyone can participate in and contribute to communities', and the nation's, resilience.

The strategy is given effect through regional CDEM Group Plans, which enable effective, efficient and coordinated CDEM delivery at a group level. Each member of a CDEM Group has a responsibility to support and promote the principles underlying the CDEM Act 2002. These principles include:

- promoting the sustainable management of hazards;
- encouraging and enabling communities to achieve acceptable levels of risk;
- providing for planning and preparation for response to, and recovery from, emergencies;
- co-ordinating programmes and activities, and encouraging co-operation and joint action among agencies across the areas of reduction, readiness, response, and recovery; and
- providing the basis for the integration of local with national CDEM policies, processes, and operations (MCDEM, 2018).

CDEM Groups are encouraged to use a risk-based approach when developing their Group Plans, which is "[t]he requirement to practise sound risk management is implicit throughout the CDEM Act. CDEM Groups are required to apply risk management to their planning and activities. Whilst planning is not a linear process and may involve many iterative steps, it is expected to follow a risk management based approach" (MCDEM, 2002, p. 17).

2.3.3.4 The Building Act (BA)

The Building Act governs the building sector and sets out the rules for the construction, alteration, demolition, and maintenance of new and existing buildings in Aotearoa New Zealand. It does this through the Building Code, which is a set of regulations defining clear standards and expectations to ensure that the intended use of a building is safe, healthy, and durable for everyone who visits or lives within them. Plans for building work are assessed by building consent authorities (BCAs), usually the council, to ensure the proposed building work will comply with the Building Code. When the BCA is satisfied, it will issue a building consent for the work to proceed.

Section 71(1) of the Building Act requires the territorial authority to refuse a building consent for building work if the land is subject to one or more natural hazards, or if the building work will accelerate or worsen the adverse effects because of the natural hazard on that land or other property. Rather confusingly, section 71(2) goes on to state that section 71(1) need not apply if an applicant can satisfy the territorial authority that the land and building will be protected from the hazard. Section 71(3) defines a list of natural hazards, including erosion, falling debris, subsidence, inundation (including flooding, overland flow, storm surge, tidal effects, and ponding), and slippage. However, section 71(3) does not include inundation from tsunami, nor does it address issues associated with the land under buildings (e.g. earthquake or geothermal activity) (ICNZ, 2014; LGNZ, 2014).

Section 72 of the Act adds to this confusion where it states that despite section 71, a territorial authority must grant a building consent if the building consent authority considers that building work will not accelerate, worsen, or result in a natural hazard; the land is subject, or is likely to be subject to one or more natural hazards; and it is reasonable to grant a waiver or modification of the Building Code in respect of the natural hazard concerned. As such, it appears that section 72 negates section 71(1) even though the land may be subject to one or more natural hazards (out of an incomplete list of natural hazards). It is at the discretion of the BCA to decide what is reasonable in waiving requirements with regards to the Building Code and the natural hazard(s) concerned.

2.3.3.5 The Climate Change Response (Zero Carbon) Amendment Act

In May 2019, in response to commitments made under the Paris Agreement (UNFCC, 2015), central government enacted the Climate Change Response (Zero Carbon) Amendment Act (New Zealand Government, 2019). One of the main drivers for development of the Act was through Generation Zero, a youth-based NGO that had been active on climate issues since 2010 to lobby for more ambitious climate policy in Aotearoa New Zealand (Bailey et al., 2021). The involvement of non-government actors in creating this legislation reflects the 'hollowing out of the state' as described in section 1.4, where development and implementation of disaster risk management policies has moved away from being solely developed and administered by central government.

The Climate Change Response (Zero Carbon) Amendment Act created a Climate Change Commission responsible for advising government-led policies. This commission is responsible for preparing a National Climate Change Risk Assessment and a National Adaptation Plan. These link with international natural hazard risk governance frameworks, primarily the Paris Agreement, to limit the global average temperature increase to 1.5 °C above pre-industrial levels and allow Aotearoa New Zealand to prepare for and adapt to the effects of climate change. The National Adaptation Plan must be prepared in response to a national climate change assessment where the Government must consider "the distribution of the effects of climate change across society, taking particular account of vulnerable groups or sectors" (section 5ZS(4)(b)). In anticipation of their inclusion into this planning, some authorities within local government have developed non-regulatory plans for how their regions are addressing climate change risk and response. Saunders et al. (2020) have stated that early indications of local government involvement in this process are positive and include action from Auckland Council, Nelson City Council, Wellington City Council, and Christchurch City Council.

2.4 Challenges (and solutions) for local government natural hazard risk governance

Given these responsibilities, local government practitioners for natural hazard risk management range across a number of disciplines and functions, including policy making, environmental science, land-use planning, building control, emergency management, asset management, engineering, and hazard modelling. These practitioners interact 'upwards' and 'outwards' to gather, communicate and apply natural hazard risk information:

- 'upwards' with central government through working groups for reviewing/developing policy and specific initiatives requiring local government input; and

- 'outwards' with CRIs, universities, local-level NDMOs (including the Police, Fire and Rescue Service, District Health Boards, Ambulance), the private sector through public-private partnerships (PPPs), council-controlled organisations (CCOs) (including airport and marine port authorities), and community organisations.

However, as highlighted in section 2.3.2, there is not yet any formal approach for local government to apply natural hazard risk management. Local government is left to individually manage how these 'upwards' and 'outwards' interactions are achieved resulting in varying degrees of success (Basher, 2016; Crowley & Crawford, 2018a; EQC, 2019; Kilvington & Saunders, 2019; LGNZ, 2014).

Within this setting, this research identifies four broad challenges for the application of natural hazard risk management within local government in Aotearoa New Zealand:

1. Lack of guidance, mandate, and collaboration;
2. limited risk leadership, understanding, and awareness at the national and local government levels;
3. lack of funding, capacity, and capability; and
4. unavailability of quality data and information.

Underlying each of these themes are a further two fundamental challenges for natural hazard risk management: 1) the disconnect of science to policy to practice, and 2) the complex system of challenges for natural hazard risk management. These challenges are reviewed in the following sections.

2.4.1 Lack of guidance, mandate, and collaboration

2.4.1.1 Guidance

An absence of clear and concise national government guidance for natural hazard risk management was recognised by Glavovic, Saunders, and Becker (2010) who focussed on the ability of land-use planning for coordinating natural hazard risk management within local government. They identified a need for local government to take more proactive steps for managing the risk of hazards rather than managing them through an ad hoc, response and recovery basis. Among other recommendations, they called for "nationally consistent practical steps to improve the safety and sustainability of at-risk communities" (Glavovic, Saunders, & Becker, 2010, p.697). Kilvington and Saunders (2013) identified that guidance for managing natural hazards through land-use planning appeared independent and not located in a conceptual hierarchy, such as a national to local scale. They stated that in the absence of clear, directive guidance material from central government, the trajectory for natural hazard management was being primarily directed by RMA case law.

Kilvington and Saunders (2016) stated that while there was (and still is) no national policy statement (NPS) or national environmental standard (NES) that could be used for local government natural hazard risk guidance, an impending amendment to section 6 of the RMA was expected to strengthen provisions around natural hazards. This amendment was inserted as section 6(h) into the RMA in 2017 (New Zealand Government, 1991), identifying 'the management of significant risks from natural hazards' as a matter of national importance which decision makers must recognise and provide for in making decisions. However, evidence for how this has enabled stronger national direction for local government natural hazard risk management is yet to emerge. The recent review of the Resource Management Act, titled 'New Directions for Resource Management in New Zealand', listed the management of significant risks from natural hazards as a "gap in national direction" (MfE, 2020, p. 197). Furthermore, it identified guidance around the effects of climate change as a notable omission from national direction. This is despite section 7(i) of the RMA requiring those making decisions under the statute 'to have particular regard to the effects of climate change' (New Zealand Government, 1991).

The lack of national level guidance for climate change echoes Manning et al.'s (2015) analysis of Aotearoa New Zealand's adaptive capacity for climate change risk. This stated that at that time no national adaptation strategy had been developed, which resulted in limited development or application of local government climate change policy (Lawrence et al., 2015; Hanna, White & Glavovic, 2017). Guidance has since been developed for local government management of coastal hazards and climate change (MfE, 2017), as well as climate change risk management (MfE, 2019; MfE 2021). Local government has been a participant in the development of climate change risk assessment measures (MfE, 2017; MfE, 2019), and climate change plans have recently been developed, or are under development within local government (WCC, 2020; CCC, 2021), as well as nationally. They are in the early stages of application, and evidence for how they are managing climate change risk is yet to emerge.

It is of interest to note the dominance of climate change over other natural hazards for the development of national level guidance. While climate change guidance is important and needed within local government, it may have come at the expense of guidance for other natural hazards that do not possess the same profile that climate change currently does, for example, tsunami risk management.

2.4.1.2 Lack of mandate for collaboration

Lack of mandate for intra and inter-council collaboration for natural hazard risk management was recognised in Local Government New Zealand's think piece on managing natural hazard risk (LGNZ, 2014). They noted that within councils there was a lack of interaction mainly between local government's land-use planning and emergency management functions, stating that RMA planning and CDEM planning operate in a more 'silo-ed' manner. Despite ongoing research into how natural hazard risk management can be better achieved through the RMA and CDEMA in New Zealand (Saunders et al., 2007; Saunders et al., 2011; Saunders & Beban, 2012; Saunders et al., 2013; Saunders et al., 2014; Saunders & Becker, 2015), Saunders et al. (2015) found that while the links between land-use planning and emergency management had improved over time, collaborations across different natural hazard practitioner roles were not commonly encouraged for sharing information, good practice, and understanding of roles.

Collaboration across natural hazard risk management functions is also affected by its perceived importance. CDEM is often perceived as a lesser function compared to policy making and land-use planning (LGNZ, 2014; Lawrence et al., 2015; Crawford et al., 2018b) and has been missed out of natural hazard risk management planning in the past. The literature indicates that it is the personal strengths and capability of the people employed within CDEM that influence its inclusion within broader council natural hazard risk management planning (Glavovic, Saunders, & Becker, 2010; Crowley & Crawford, 2016; Crawford et al., 2018a).

As such, the depth of CDEM involvement in broader local government natural hazard risk management is varied across planning documents developed within councils at different times, as well as inconsistent across councils throughout Aotearoa New Zealand. Lack of consistency in natural hazard risk management across councils was recognised by Saunders and Beban (2012), who stated "there is a lack of consistency in how the natural hazards and associated risk are addressed. One council may have strict planning requirements pertaining to a natural hazard, whereas the neighbouring council has a lesser requirement that allows for development that increases the risk" (Saunders & Beban, 2012, p. 18). This is despite the benefits of a combined, multi-council natural hazard risk management approach, which are recognised as acting to reduce duplication and costs associated with researching hazards and developing policy, along with consistent and easier understanding of natural hazard provisions from stakeholders (Saunders, Beban & Coomer, 2014a).

Outside of intra and inter-council collaboration, Basher (2016) noted the limited mandate for collaborating with communities, where natural hazard risk management arrangements did not properly engage civil society actors or recognise their interests in and capacities for disaster risk reduction. The Civil Defence Emergency Management Act (New Zealand Government, 2002a) does not specifically refer to collaboration with non-government actors even though it makes provision for private sector 'lifelines utilities', such as telecommunications and energy networks and providers, to establish planning and operational relationships with local CDEM Groups. CDEM's engagement with Lifelines Groups, an informal collaboration between infrastructure providers, scientists, emergency managers, and other professionals, has progressed over that time and is supported with guidance for how CDEM and Lifelines Groups engage (MCDEM, 2014).

More recently, the National Disaster Resilience Strategy (MCDEM, 2019) takes a strong community focus for action, including putting in place organisational structures and identifying necessary processes – including being informed by community perspectives – to understand and act on reducing risks. This includes interaction with iwi, the private sector, not-for-profits, and other community representatives. In stating this, the National Disaster Resilience Strategy (MCDEM, 2019) recognised that communities and organisations still needed to be better joined up and that more effective ways of tackling challenges are required to transcend sector barriers.

2.4.1.3 Solutions for lack of guidance and mandate for collaboration

While this is not specifically mentioned within the National Disaster Resilience Strategy (MCDEM, 2019), an avenue for engaging with local government and communities to build guidance and improve collaboration for natural hazard risk management is through integrative research collaboratives as introduced at the beginning of section 2.3.2. Examples of integrative research collaboratives include the Resilience to Nature's Challenges National Science Challenge (Resilience to Nature's Challenges, 2018), as well as the East Coast LAB (Life at the Boundary) and AF8 (Alpine Fault Magnitude 8). The objective of these collaborations is "to build shared understanding of natural hazards and risks and to develop practical risk reduction solutions" (Woods et al., 2017, p. 330). An example of this is the 'Napier Natural Hazards Resilience Workshop: Initial Options Report' (Crawford, Eady, & Pearse, 2019) produced through East Coast LAB. This provides options for how local government can engage community stakeholders, with the aim of increasing community resilience to natural hazards. While focused on Napier City, the report has lessons for all of Aotearoa New Zealand.

2.4.2 Limited risk leadership, understanding, and awareness

2.4.2.1 Leadership

In 2015, a Local Government Risk Agency (LGRA) project was started through Local Government New Zealand (LGNZ, n.d.). The intention of the project was to pool and coordinate local government resources to lower the risk and cost of disaster. This was pertinent at the time, given calls for a central agency to provide leadership, expertise, and consistent terminology and processes for local government risk management (Basher, 2016; LGNZ, 2013). However, government confirmation of the LGRA project's initial business case, which was expected in 2017, has not yet come to pass.

With the limited national level leadership and guidance provided at that time, there had not been the driver for local government to develop and apply risk awareness and understanding. This was reflected in the Local Government New Zealand think piece on Managing Natural Hazard Risk in New Zealand, which found that "while New Zealand is a strong performer in terms of response and recovery, it is less so in terms of risk reduction and readiness. Particular concerns are expressed about our effectiveness in risk reduction" (LGNZ, 2014, p.34).

2.4.2.2 Understanding

Glavovic, Saunders, and Becker (2010) proposed that for land-use planning, poor performance in natural hazard risk management was because many Aotearoa New Zealand communities typically prioritised issues of immediate and direct impact, rather than taking steps to reduce hazard risks. Similarly, for emergency management, this was because district, regional and national levels of emergency management focused more predominantly on emergency event response and recovery than on risk reduction (Glavovic & Smith, 2014; Garrido & Saunders, 2019).

In their evaluation of land use and emergency plans for local government natural hazard risk management, Saunders et al. (2015) identified a number of challenges for understanding and applying risk management, including:

1. The term 'risk' is often not defined or that the definition changes across legislation and resultant plans. As such there is little strategic leadership or consistent approach to risk management.
2. The quality and dissemination of risk information is not well developed, and there are issues with the availability of natural hazards information for decision making.
3. Communities are not appropriately engaged, using a risk-based approach, to contribute to determining levels of risk.

Further challenges identified in understanding and applying natural hazard risk management for local government in Aotearoa New Zealand include:

4. Risks are predominantly characterised as static, assuming that future risks will be the same as the past, and decision-making practices have become implicitly dependent on certainty. Consequently, there is difficulty over making decisions on changing risks (Lawrence et al., 2015; LGNZ, 2014; Manning et al., 2015; White & Haughton, 2017).
5. There is no one set of risk assessment methodology or standards of acceptable risk, leading to a wide variation in practice and a low level of quantified risk assessment (LGNZ, 2014).
6. The communication of risk and uncertainty, between scientists and stakeholders, is open to misinterpretation and misperception (Doyle & Paton, 2017).
7. Risks are underestimated, especially climate change and low-likelihood (destructive tsunami) risks, due to differing timeframes within which different practitioners and decision makers operate, e.g. the short three-year electoral cycle for local politicians, combined with different planning cycles for land-use planning, asset management, and long-term plans (Lawrence & Manning, 2012; Lawrence et al., 2015).

2.4.2.3 Awareness

It is important at this point to clarify the difference between 1) natural hazard awareness, 2) natural hazard risk awareness, and 3) natural hazard risk perception. This research defines them as:

1. Natural hazard awareness – recognition of the magnitude or extent of a hazard and its physical impact on natural, built and social environments (as defined in section 1.2).
2. Natural hazard risk awareness – recognition of the potentiality or likelihood of occurrence for a certain magnitude natural hazard and the consequences of its impact on exposed and vulnerable populations, environments, and built networks.
3. Natural hazard risk perception – subjective perception of natural hazard risk influenced by factors including likelihood, past experience, background knowledge, severity, level of uncertainty, political and economic factors, etc (as defined in section 1.3.1).

Natural hazard awareness is well developed in Aotearoa New Zealand as a result of a number of national and international natural hazard events and is represented through a breadth of literature (Blake et al., 2018; Dhellemmes et al., 2021; ICNZ, 2014; Johnston, 2018; Kool et al., 2020; LGNZ, 2014; Pinal & Coomer, 2019) and natural hazard risk perception (Becker et al., 2013; Doyle et al., 2011; Henrich, McClure, & Crozier, 2015; McClure et al., 2016; Vinnell, Milfont, & McClure, 2021). However, the research primarily focusses on natural hazards and their risk perception for community and household preparedness, with less research on natural hazard awareness within local government.

The literature that does exist for natural hazard awareness in local government includes Saunders, Beban, and Coomer (2014), who state that 83% of councils promoted awareness of natural hazards for new planners; and Saunders, Beban, and Kilvington (2013), who called for planners to "know your hazard" as the first step in applying a risk-based approach for natural hazard risk reduction (Saunders, Beban, & Kilvington, 2013, p. 18). However, the literature on local government hazard awareness is practitioner focussed, leaving a gap in knowledge on decision maker, i.e. local politician, hazard awareness.

The literature is scarce on risk awareness within local government. This could be because risk awareness is understandably included as an aspect of risk perception. However, the literature on risk perception within local government is also scarce. Saunders and Beban (2012) stated that high-consequence, low-likelihood events (e.g. destructive tsunami) are difficult for practitioners and decision makers to manage, due to a lack of understanding and awareness of their consequences. Similarly, Crawford et al. (2019) found that while practitioners understood the impact of destructive tsunami hazard, the likelihood of destructive tsunami was so remote that its risk was hard for them to internalise. While Crawford et al. (2019) refer to how these risk perceptions could also impact on local politicians' motivation to approve specific tsunami risk-based policy, no local politicians were interviewed as part of the research. Similarly, Lawrence et al. (2015) address the climate change risk perceptions of local politicians, stating that political willingness to act on climate change risk was perceived as "it isn't a problem", or at least "not in my term of office" (Lawrence et al., 2015, p. 313). However, these perceptions were reported by practitioners, not by the politicians themselves.

In their research on communicating the uncertainties of natural hazards for decision making, Doyle et al. (2011) found that there was a need to identify the different ways in which local government practitioners understood and used uncertainty and probabilities, which may have been affected by their perceptions of the likelihood of the event. This research was extended by Doyle et al. (2014), who found that practitioners underestimated the chance of an event likelihood 'today' compared to 'tomorrow', due to interpretive bias which skewed their perceptions on the likelihood of occurrence. Similarly, White and Haughton (2017) refer to the 'tyranny of the present' for risk awareness, where governance arrangements are bound by policy makers' biases towards developing policy based on what is certain and known about now compared to the future. White and Haughton (2017) and White and Lawrence (2020) acknowledge that there is need for growing scientific awareness on uncertainty of natural hazard risks over time and space, which needs to be matched by policy that can better recognise and cope with the dynamism, uncertainty, and ongoing change for natural hazard risk into the future.

2.4.2.4 Solutions for limited risk understanding and awareness

As introduced in section 1.3.1, the ISO 31000 risk management approach has been referred to in a breadth of literature focussed on structuring local government's awareness, understanding, and management of natural hazard risks in Aotearoa New Zealand. The literature includes coastal hazard and climate change (Bell et al., 2017); civil defence emergency management (UNDRR, 2020; UNISDR, 2017); a risk-based approach under the

RMA (Beban & Saunders, 2013; Saunders & Beban, 2013; Saunders, Beban, & Kilvington, 2013; Tonkin & Taylor, 2016b), natural hazard risk communication (Auckland Council, 2014), and the use of the 'RiskScape' risk modelling software (Thomas et al., 2020).

While some parts of local government have successfully applied the ISO 31000 approach to planning for natural hazards, for example, the engagement on risk thresholds as part of Bay of Plenty Regional Council's Regional Policy Statement (Kilvington & Saunders, 2015, 2019), adoption of a consistent risk management approach in local government remains scarce. The status report on disaster risk reduction in New Zealand (UNDRR, 2020) highlights that, despite central government support of the ISO 31000 approach, many local authorities use a range of risk assessment approaches depending on their capacities, resources, and risk perceptions. The status report goes on to highlight the expected publication of risk assessment guidance for CDEM Groups to improve how risk is managed (UNDRR, 2020). While ISO 31000 risk assessment guidance has been provided within guidelines for CDEM Group planning (MCDEM, 2018), the provision of specific risk assessment guidance, expected to be published by the National Emergency Management Agency (NEMA) in early 2020, has yet to emerge.

Another avenue for increasing risk awareness and influencing perceptions is through the use of risk modelling as a natural hazard risk communication tool. The use of risk modelling for communicating natural hazard risk to increase awareness for decision making and action is a focus of this research. The benefits of risk modelling were introduced in section 1.6 and the use of the RiskScape risk modelling tool is presented in section 2.6. Further research for how RiskScape is applied and valued within local government is presented in Chapters 5, 6 and 7.

2.4.3 Lack of funding, capacity, and capability

2.4.3.1 Funding

In the Ministry of Civil Defence and Emergency Management progress report on Aotearoa New Zealand's implementation of the Hyogo Framework for Action, Hamilton (2013) recognised that, despite New Zealand's exposure and vulnerability to natural hazard risks, the country's relatively small economy limited the total available investment in hazard and disaster research and management. Hamilton (2013) went on to state that "competing priorities within tighter economic conditions can create challenges for public and stakeholder groups in recognising a return on investment from [natural hazard] risk reduction programmes. These challenges not only concern the direct costs of programmes, but also perceived lost opportunity due to restrictions on development within high hazard risk prone areas" (Hamilton, 2013, p. 12).

As such, funding for natural hazard risk management is a contentious subject; natural hazard risk management is an integral aspect of sustainable social and environmental wellbeing of communities as per section 10(1)(b) of the Local Government Act (New Zealand Government, 2002), while at the same time potentially limiting the economic wellbeing of communities, which is called for under the same section of the Act (New Zealand Government, 2002). This is reflected in the National Disaster Resilience Strategy (MCDEM, 2019), which states that perceptions of risk reduction for limiting economic development and business growth are a barrier to resilience. Similarly, 'New Directions for Resource Management in New Zealand' (MfE, 2020) states that planning for climate change and natural hazards often limits what people can do with their land and impacts property values. While this might not fully explain the lack of central government support for natural hazard risk management in local government, funding from central government has been focussed on emergency response (Faafoi, 2019; UNDRR, 2020) rather than being aimed at reducing natural hazard risks and adapting to climate change (MfE, 2020).

Without dedicated central government support, funding for natural hazard risk management has been the responsibility of local government. Local government budget allocations for natural hazard risk management are determined by a property-based rating system. If a region has a low population, they are less able to provide funding through rates, and there is less budget available for natural hazard risk management, regardless of the size of the region or its exposure to natural hazard risk. Funding for natural hazard risk management is pulled from a finite pool, where budget allocation can be limited due to other local government imperatives taking precedence over natural hazard risk management because other functions (e.g., three waters management) are perceived as more urgent or important, or more politically acceptable (Lawrence & Manning, 2012; Manning et al., 2015; Crawford et al., 2019). Furthermore, the increased frequency and severity of natural hazard events, driven by climate change, has added to pressures on how local government can fund natural hazard risk management. This was recognised by The New Zealand Productivity Commission (2019) that councils are struggling to deal with some big pressures including climate change, where they recommended changes in funding and financing. In its recent review of the Resource Management Act, the Ministry for the

Environment (MfE, 2020) identified that funding to cover the scale of response required for natural hazard risk management and climate change was ultimately likely to be beyond the means of local authorities.

'New Directions for Resource Management in New Zealand' (MfE, 2020) states that the success of the new resource management system depends critically on the capacity and capability of all those involved in it, and that failure to provide sufficient resources to build capability has been one of the more important reasons for past failures. As such, provision of funding is closely linked with developing capacity and capability for natural hazard risk management. However, a legacy of insufficient funding within local government has resulted in limited capacity and capability.

2.4.3.2 Capacity and capability

Glavovic, Saunders, & Becker (2010) found that targeted and systematic training was required to develop local government capacity and capability for natural hazard risk management across a number of different activities:

1. For land-use planners to improve their understanding about the nature of hazards, and to ensure that hazards are 'mainstreamed' into their daily work.
2. For emergency managers to develop a better understanding about the role of land-use planning in reducing hazard risks.
3. For local politicians to develop hazard awareness and understanding given their critical decision-making responsibilities.
4. For planners, emergency managers, developers, and other professionals to work together more effectively.
5. For local government practitioners and disaster scholars to improve their dialogue on natural hazard risk.
6. For local government practitioners to build natural hazard awareness for citizens and community leaders.

Sinclair et al. (2012) stated that the ad hoc approach to emergency management training and evaluation provided no guarantee that emergency response capability was being increased. LGNZ (2014) noted that many smaller territorial authorities resource the emergency management function at well below one full-time-equivalent (FTE), which limits its capability to reduce risk, and that there was limited human and intellectual risk management capability. Saunders, Beban, and Coomer's (2014) survey of council capability and capacity for managing natural hazards through land-use planning found, rather concernedly, that only 47% of respondents with natural hazard responsibilities had undertaken training in natural hazards. They found that without qualified natural hazard advice there is potential for incorrect decisions regarding natural hazards and their associated risk. Manning et al. (2015) stated that there was limited funding for local government risk assessment and reduction, and there was little climate change expertise and capacity. Basher (2016) highlighted that local government had limited capacity to generate funds for natural hazard risk reduction and had limited access to technical expertise. Crawford (2018b, Chapter 5) proposed that due to stretched resources, there has not been the drive or capacity for land-use planners to learn different approaches for natural hazard risk management. MCDEM (2019) noted gaps in emergency response capability and capacity, predominantly around the capacity of response organisations and the powers of those authorities to act.

Limited funding, capacity, and capability has also impacted on local government's use of risk modelling for understanding and communicating natural hazard risk. Crawford et al. (2018b, Chapter 5) identified a lack of practitioner understanding of the capability and value of risk models, especially within land-use planning. Crawford et al. (2019, Chapter 6) found that, in general, local government did not have spare capacity to develop in-house capability for natural hazard risk modelling. Similarly, EQC (2019) noted that skilled resources are lacking in natural hazards science modelling, and some models and modelling capability are not optimised.

2.4.4 (Un)availability of quality data and information

Data and information on natural hazards has traditionally been gathered by local government as part of their duties, under section 35 of the RMA (New Zealand Government, 1991), to gather information, monitor, and keep records of natural hazards to the extent that the local authority considers appropriate for the effective discharge of its functions (s 35(5)(j)). In addition, the monitoring of natural hazards is deemed important for ensuring accurate information is used as the basis for decision making (Saunders et al., 2015).

2.4.4.1 Unavailability of data

Generally, the natural hazard information that has been collected has been peer reviewed, robust, and included appropriate recommendations (Saunders, Beban & Coomer, 2014). However, it has been widely agreed that there is insufficient monitoring and collection of data and information on environmental pressures (MfE, 2020). Furthermore, Harrison et al. (2021) suggested conflicting priorities and a lack of motivation or interest in data creation and data maintenance was a barrier for how well natural hazard risk data is collected and used.

Over time, the literature has commonly referred to the unavailability of quality natural hazard data and information as a challenge for local government natural hazard management. Lawrence and Manning (2012) highlighted general fragmentation and unnecessary inconsistencies in climate change data. Their later research supports this, where they referred to limited data quality, the complex forms it can take (Manning et al., 2015), and variable data quality within and across local government regions (Lawrence et al., 2015). Bremer and Glavovic (2013) stated that a reason for this was that most local government regions do not have the capacity to monitor a large number of natural hazard indicators. They go on to state that the scientific data that could supplement local government information was poorly disseminated, was often in an unusable form, had been lost through poor information management, or was held by private organisations and research institutes. Saunders, Beban, and Coomer (2014) identified lack of information on the extent and risk presented by the various natural hazards in a council's jurisdiction, the prohibitive cost of obtaining natural hazard risk information, and limited information quality and reliability, particularly for low-probability, high-consequence natural hazards (such as destructive tsunami). Doyle, Paton, and Johnston (2015) noted the lack of networking across the scientific community (in this case, volcanologists), which limited the use of scientific data for local government emergency management.

MWH (2016) referred to the high variability in the nature, comprehensiveness, and consistency of information on different natural hazards held by councils. Similarly, Tonkin and Taylor (2016) stated that the level of detail and how information is presented, including maps, as highly variable around the country and across different types of hazards. They also note the prohibitive costs associated with obtaining information and also in maintaining it. Bell et al. (2017) highlighted that limited data was a barrier for accurately calculating the frequency and magnitude of rare events (such as climate change or destructive tsunami) for local government land-use planning. Crawford et al. (2018a, Chapter 4) noted that unavailability of data, and the expense of developing it, as barriers for local government use of risk modelling. Crawford et al. (2018b, Chapter 5) added to this when they found that risk data for natural hazard modelling was not widely available for emergency management, with challenges for emergency management to generate their own data. Furthermore, Crawford et al. (2019, Chapter 6) highlight the scarcity of data in a usable format and quality for local government natural hazard risk modelling. MCDEM (2019) stated that availability of information was crucial at the local level to enable local governments and communities to identify and prioritise the use of resources for emergency management. However, they go on to state that challenges remain in increasing the availability of information and assessments to the people and planners across all levels of government.

Despite general awareness on the unavailability of natural hazard data and information, the UN status report on disaster risk reduction in New Zealand (UNDRR 2020) highlighted that information on disaster risk reduction was still difficult to track down in government documents and policies, with minimal cross-referencing between agencies. Most recently, Harrison et al. (2021) noted that the personal interests of key staff within an organisation appear to either inhibit or enable data collection and creation, and that “it just depends on who’s here and who’s leading the team” (Harrison et al., 2021, p. 17).

Considering these findings there is a need to improve how natural hazard data and information is collected, maintained, governed, and used. This has been recognised in the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015b), with one of its targets being to “[s]ubstantially increase the availability of and access to … disaster risk information and assessments to the people by 2030” (UNISDR, 2015b, p. 12). This target is reflected in Aotearoa New Zealand’s National Disaster Resilience Strategy (MCDEM, 2019), where one of its objectives is to “[i]mprove the information and intelligence system that supports decision-making in emergencies to enable informed, timely, and consistent decisions by stakeholders and the public (MCDEM, 2019, p. 30).

MCDEM’s (2019) objective echoes recommendations made in the literature over time. Manning et al. (2015) recommended the use of consistent methodologies for collecting natural hazard data, decision-relevant local information, and frequent updates that reflect changing climate risk. Saunders et al. (2015) recognised the need for an enhanced and more integrated approach to making natural hazards information available, which would help overcome existing issues with information quality and dissemination, as well as information for decision making. Crawford et al. (2018a, 2018b) recommended that local government capacity and capability is built for collecting, managing, and using natural hazard risk data so that it is open, shared, usable, and used. UNDRR (2020) recognised that easily accessible disaster information could lead to more comprehensive, detailed, and tangible risk and vulnerability assessments at the regional and local level. However, they go on to state that this would require increased capacity and capability (technical and human resources) for implementation. Harrison et al. (2021) recommended that support and buy-in from decision makers and upper management was needed to influence priorities and increase motivation for data collection.

2.4.4.2 Solutions for improving availability of quality data and information

Common amongst recommendations for improving the availability of natural hazard data and information has been for a centralised natural hazard information system (Basher, 2016; Glavovic, Saunders, & Becker, 2010; Hamilton, 2013; ICNZ, 2014; Lawrence & Manning, 2012; Lee, 2010; LGNZ, 2014; MfE, 2020; UNDRR, 2020). A centralised system could combine various existing platforms and databases to harmonise and synergise available information in terms of loss data and to support decision making, prioritisation, and funding needs projection (UNDRR, 2020). The information system would be comprised of high-quality data (ICNZ, 2014). This would improve efficiency and ensure consistency and fairness in application of natural hazard risk management activities around the country (Lawrence & Manning, 2012; MfE, 2020) and stakeholders would benefit from a comprehensive natural hazards information database bringing together existing information to aid decision making (LGNZ, 2014). While a national loss and impact database is being coordinated by the National Emergency Management Agency (NEMA), resource pressures have meant that development of the database has been slow (Harrison et al., 2021).

2.4.5 The disconnect of the science-policy-practice interface

The science-policy-practice interface is defined as the “social processes and relations between scientific experts, policy makers, and other actors in the domain of policy making which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making” (Albris, Lauta, & Raju, 2020, p. 3). However, this interface is fraught with challenges, where the processes, interactions, and roles at the interfaces between science, policy, and practice can be complex, fuzzy, and inappropriate, with scientific knowledge being misused or rejected (van der Hove, 2007; Wyborn et al., 2017).

2.4.5.1 Challenges for the science-policy-practice interface

The challenges that can act to disconnect the science-policy-practice interface for natural hazard risk management include:

- Lack of trust – Interaction between stakeholders, at different timeframes and often in autonomy, without mutually understood and developed tools leads to uneven power relationships, non-contextual, outsider influenced processes and lack of trust in scientific knowledge (Gaillard & Mercer, 2012). This can also lead to the politicisation of scientific knowledge and a tendency from some community members to oppose the perceived authority of the science (Albris, Lauta, & Raju, 2020).
- Absence of space for dialogue – Low priority accorded to DRR by those most at risk due to other pressing concerns, the limited time, resources, and space afforded DRR by local actors, and 'participation fatigue' or competition from other key issues which local actors face (Gaillard & Mercer, 2012).
- Intangibility of culturally specific knowledge – Strategies which are applicable to DRR may not be identified as such by community members, as they are embedded within community life and therefore not tangible to outside stakeholders. Cultural and language difficulties compound these problems of access and present difficulties in attempts to integrate the two knowledge types (Kelman et al., 2011; Gaillard & Mercer, 2012).
- Lack of scientific skill – Traditional hazard assessments are no longer adequate for accounting for more complex social and economic vulnerabilities. Scientists need to broaden their skill-base and approaches for providing information that is appropriate for DRR policy (Albris, Lauta, & Raju, 2020). Correspondingly, there is a lack of capability outside of the scientific disciplines for deciphering scientific knowledge (Gaillard & Mercer, 2012) and there is a need for 'mediators of science' or 'knowledge brokers' to act as translators between science and policy (Albris, Lauta, & Raju, 2020; Gluckman, 2013; Meyer, 2010).
- Difficulties in communicating science – Not only is scientific terminology difficult to interpret for non-scientists (Albris, Lauta, & Raju, 2020), but so are the visualisations, i.e. maps (Gaillard & Mercer, 2012). When applied to natural hazard risk

management, there is a difference in understanding of technical, jargon-filled risk terminology that underpins disaster risk assessments, which makes it difficult to communicate risk-informed scientific knowledge not only to policy makers but also other scientists (Kelman, 2018). Furthermore, personal perceptions of risk also influence how scientific risk information is received (Doyle & Paton, 2017; Crawford et al, 2019), which can result in policy makers adopting strategies based on idiomatic, conceptual understandings (Albris, Lauta, & Raju, 2020).

- Institutional differences – Common visions for the science-policy-practice interface are rare at the national and local levels (Albris, Lauta, & Raju, 2020). There are a lack of platforms, arenas, and opportunities to enable dialogue between scientists, policy makers and community stakeholders (Albris, Lauta, & Raju, 2020; Gaillard & Mercer, 2012), which can be further limited by the specific intent for which scientific knowledge is being sought by policy makers and the limitations of static policy-making frameworks.

While there is an abundance of research on natural hazard risk management in Aotearoa New Zealand, turning that theory into practical action is challenging (Bremer & Glavovic, 2012; Glavovic, Saunders, & Becker, 2010; Lawrence & Manning, 2012; MCDEM, 2019). Kilvington and Saunders (2016) reveal six likely problem areas on the role of science in local government policy making in Aotearoa New Zealand:

1. Information dissemination and management practices
2. Institutional capacity
3. Mutual misunderstanding and incompatibility
4. Timely, targeted information
5. Science and values in decision making, and
6. Clarity on where to target improvements.

Each of these problem areas is expanded upon below:

1. Information dissemination and management practices – The scientific data and information that does exist is poorly disseminated, often unusable, has been lost, or is restricted by private organisations and research institutes (Bremer & Glavovic, 2013). There is a lack of awareness that scientific material exists, as well as difficulty and prohibitive costs associated with gaining access to it (Kilvington & Saunders

2013). There are inconsistent mechanisms for storage, retrieval, and raising awareness of the existence of information, and practitioners are often reliant on the memories of staff (Kilvington & Saunders, 2013).

2. Institutional capacity – There is not always the capability within government to seek out scientific information and appropriately translate it to a policy question (Gluckman, 2013). At the local government level, there is a lack of scientific skill to undertake research, or to interact with the science for it to be interpreted for local scale and context (Kilvington & Saunders, 2013). Lack of local government scientific skill results in a heavy reliance on commissioning work. In Saunders et al.'s (2014) survey of capacity and capability of councils for natural hazards management across New Zealand, it was found that 49% of councils outsource their natural hazards advice, itself contingent on the scientific skill of those outsourced organisations. Inhouse resource competition also reduced local government capacity for natural hazards science in practice, where topics of high contention and public interest (such as freshwater management) were likely to take precedence (Kilvington & Saunders, 2016).

3. Mutual misunderstanding and incompatibility – For scientists and researchers, this has been described as "naïve[ity] in assuming that policy follows directly from evidence" (Gluckman, 2013, p. 4). Correspondingly, local government policy makers can find the nonlinear and alternating evolution and revolution processes, by which science knowledge is developed, to be frustratingly protracted (Kilvington & Saunders, 2016). Doubt attached to scientific information is not well regarded by policy makers, who want incontestable evidence for robust decision making (Kilvington & Saunders, 2016; Lawrence & Manning, 2012). As such, it is important for scientists to effectively communicate the levels of scientific uncertainty to non-scientists (Doyle et al., 2019; MFE, 2016). The relevance of scientific research to the needs of stakeholders is a significant component of environmental research programmes (Thompson et al., 2015). However, the processes for enabling the science-policy-practice interface in Aotearoa New Zealand remain largely informal (Barton et al., 2020; Woods et al., 2017). If this process is not made clear amongst policy makers and scientists from the outset, there is a risk that the resulting scientific data and information is not appropriate for decision making.

4. Timely, targeted information – Kilvington and Saunders (2016) state that the guidance for producing scientific information is set at a national level and not

specific to regions or districts, which creates challenges for policy makers to develop provisions at a local level. Furthermore, different timescales between research programmes and policy frameworks make it difficult to ensure natural hazard risk management provisions are updated to reflect the latest research findings. Land-use planning timelines are notoriously pressured (Kilvington & Saunders, 2016), and the capacity of policy makers to ensure that current and relevant science is used is highly variable across local government. Consequently, inappropriate scientific information can be used to develop policy, which is locked in for the duration of the policy document.

5. Science and values in decision making – While scientists perceive their scientific knowledge and information as having a neutral value, in practice it competes with the social norms and values of the communities in which it impacts (Doyle, Paton & Johnston, 2018; Linnerooth-Bayer et al., 2016). Consequently, the use of science to support policy making and resultant practice in local government is potentially subject to contestation, "taking the form of doubt in the findings, interpretations, and occasionally even the research process or researcher themselves" (Kilvington & Saunders, 2016, p. 10). Scientific information can be 'politicised', where its value is accepted only if it adds legitimacy to the visions already held by decision makers. Correspondently, scientific advice is derived from the collective values held by the research community, which may advocate for certain precautions or decisions to be made regardless of the interests or 'visions' of the society that it impacts. As such, Kilvington and Saunders (2016) call for further research in how values are acknowledged across the science-policy-practice interface, thereby enabling any contest to be focussed on the values rather than the validity of research.
6. Clarity on where to target improvements – Actions taken by research institutions can be made in isolation meaning that significant players in the system may be overlooked (Kilvington & Saunders, 2016). The importance of knowledge brokers for enabling this is acknowledged (Gluckman, 2013); however, in practice individuals or groups that perform this role are not always recognised. Furthermore, approaches for exchanging knowledge across the science-policy-practice interface in Aotearoa New Zealand are ad hoc (Thompson et al., 2017; Barton et al., 2020). More systemic approaches are needed that aren't solely driven by research programmes and institutions, that improve societal understanding and

reflection of the theory, methods, and experience used to connect scientific knowledge with policy and practice (Kilvington & Saunders, 2016).

2.4.5.2 Solution for the disconnect across the science-policy-practice interface

A solution for communicating natural hazard risk across the science-policy-practice interface is through using collaborative, participatory approaches. Participatory approaches are fundamentally a collective, self-reflective inquiry including researchers and participants, “so they can understand and improve upon the practices in which they participate and the situations in which they find themselves” (Rogers et al., 2016, p. 77). It offers a democratic model of who is able to produce, own and use knowledge across all stages of the research process and encourages face-to face discussion, pooling of skills, and working together (Whitman et al., 2015). It enhances mutual awareness of compatibilities in participants’ interests and skills and builds trust between participants to facilitate communication and effective knowledge transfer (Rogers, 2016).

Collaborative, participatory approaches have been used to explore risk communication (Gurabardhi, Gutteling, & Kuttschreuter, 2005; Bidwell, 2009), for natural hazard risk management (Evers et al., 2016; Scolobig & Pelling, 2016), and for spanning the science-policy-practice interface (Karl, Susskind, & Wallace, 2007; Scolobig & Pelling, 2016; Spruijt et al., 2014). Furthermore, they have increasingly been used to span the science-policy-practice interface for local government in Aotearoa New Zealand (Barton et al., 2020, Bremer & Glavovic, 2012; Thompson et al., 2017; Vallance, 2015). In Bremer and Glavovic’s (2012) exploration of the science-policy-practice interface for coastal management in Aotearoa New Zealand, they found that increased use of participatory approaches reflected:

- an increasing experience and maturity relative to the coastal management regime and the restrictions of the statutory decision-making process, leading to more creativity beyond core functions;
- an emphasis on co-management in some regions;
- recognition of the impediments to mobilising science; and
- an increasing tendency to base decisions in a fuller understanding, that extends to evidence from other knowledge systems (Bremer & Glavovic, 2012, p. 116).

However, the practice of participatory collaboration in spanning the science-policy-practice interface is not a 'silver-bullet' for informing high quality research and relevant, effective outcomes. In many cases the practice of participation in environmental research and policy making is shallow, where participatory approaches focus "simply on including relevant stakeholders or having an underlying agenda of building trust in science or policy-making" (Whitman et al., 2015, p. 622). This was earlier identified by Bremer and Glavovic (2012), who noted that at that time participatory initiatives were not normal practice in Aotearoa New Zealand local government, with most consultation with the wider community still limited to the statutory minimum.

Furthermore, Gaillard and Mercer (2012) stated that local government institutions and scientists are reluctant to seriously consider both the participatory approaches themselves and the knowledge they produce for improving policies. This is because participatory approaches are not primarily geared towards producing quantitative data which are of primary importance for government decision makers and scientists (Gaillard & Mercer, 2012). This is reflected by Barton et al. (2020), where they stated that balanced, co-designed participatory approaches between scientists and policy makers would better enable the co-creation of knowledge for interdisciplinary disaster risk management in Aotearoa New Zealand. However, they went on to state that this approach was a substantial departure from the precedent set by the science-to-policy-to-practice collaborative style that had developed in the preceding five years.

As such, there is a gap in research for how participatory approaches can be formally applied to span the science-policy-practice interface with local government, especially for how the uncertain and often qualitative knowledge can be accepted and valued by policy and decision makers. These challenges are acknowledged in Chapter 7 of this thesis, which focuses on how a formalised structure could improve collaboration across the science-policy-practice interface for local government in Aotearoa New Zealand.

2.4.6 The complexity of challenges

The challenges listed above for natural hazard risk management are interconnected, creating a complex system where challenges are impacted upon by other challenges, creating feedback cycles with no end point, which impede their effective resolution (Ladyman & Wiesner, 2013; Siri et al., 2016; Young, 2017). For example, funding for natural hazard risk management in Aotearoa New Zealand is limited by the country's relatively small economy and by perceptions of natural hazard risk reduction for limiting economic development and business growth. Lack of funding then limits the development of guidance and mandate for natural hazard risk management and the capacity and capability of local government to apply that guidance, gather data, use scientific approaches, and develop local-level policy. Lack of capacity and capability in local government then limits how policy makers and other practitioners work with each other and with scientists in spanning the science-policy-practice interface to develop risk awareness, understanding, and knowledge. Finally, limited risk awareness, understanding, and knowledge cycles back to impact on decision makers' perceptions of the natural hazard risk and their motivations to fund and develop capacity and capability for natural hazard risk management. Figure 2.2 shows how these challenges are inter-connected and cycle back to impact on other challenges.

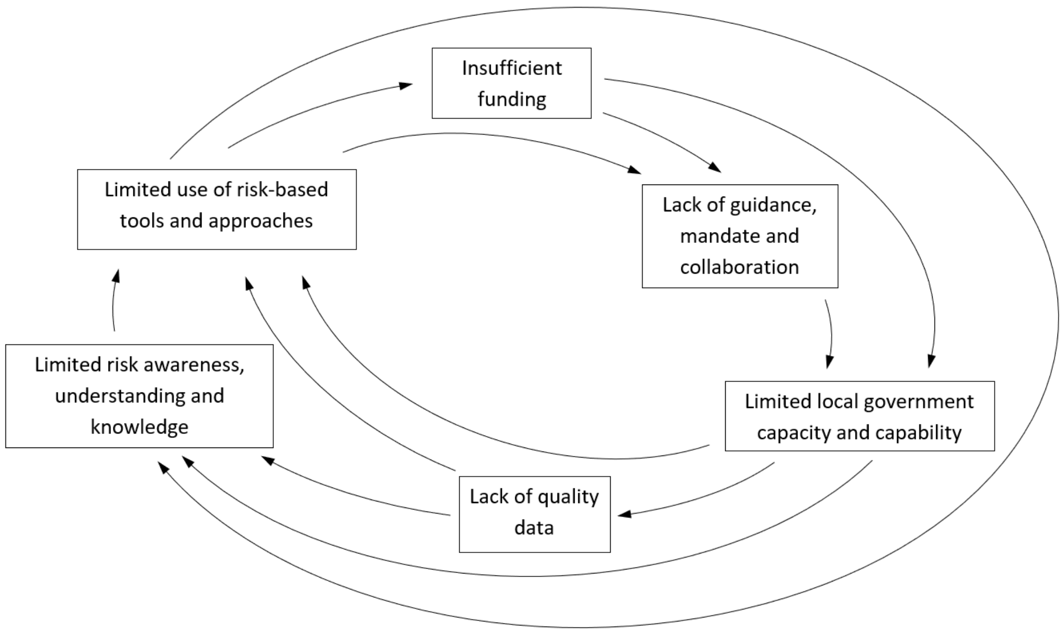

Figure 2-3: A cycle of the interconnected challenges for local government natural hazard risk management

The complex relationship between natural hazards, sustainability, and society has been recognised across a breadth of literature. This includes the increased frequency and interaction of natural hazards causing cascading and complex disasters (Cutter, 2018; Hariri-Ardebili, 2020; Pourghasemi et al., 2020), the complexities of economic, cultural and political linkages with the natural environment and social vulnerability (Cutter & Finch, 2008; Dwyer et al., 2004; Kaniasty, 2020), complexities in communicating and governing risk (Eiser et al., 2012; Johansen & Rausand, 2014; Khan et al., 2017; Renn, 2008; Renn, Klinke, & Schweizer, 2018; Slovic, 2001; WSS Fellows on RIA, 2014) and institutional complexity in developing natural hazard policy (Bolognesi & Nahrath, 2021; Kita, 2017; Spruijt et al., 2014; Subroto, 2012; Young, 2017; van der Hove, 2007; Wyborn et al., 2017).

The complexities of natural hazards themselves, natural hazard data, communicating natural hazard risks, natural hazard policy, natural hazard response, and the impact of natural hazards on society are widely acknowledged as a challenge for decision making, policy development, and community engagement for natural hazard risk management in Aotearoa New Zealand (Blake et al., 2018, Crawford et al., 2019; Doyle, Paton, & Johnston, 2015; Fraser, Leonard, & Johnston, 2013; Kwok et al., 2016; Jolly et al., 2014; LGNZ, 2014; Kilvington & Saunders, 2016; Lawrence, 2016; Manning et al., 2015; MfE, 2020; Power, 2013; Saunders & Becker, 2014; Thomas et al., 2020; White & Haughton, 2017). However, the literature is scarce for viewing these complexities as a whole, and how their inherent challenges can be holistically overcome.

2.4.6.1 Solution for managing the complexity of natural hazard risk management challenges

An approach for holistically viewing the complex systems of challenges for local government natural hazard risk management in Aotearoa New Zealand is through the use of systems thinking. Systems thinking is a way for people to understand systems where traditional, siloed, reductionist approaches for dealing with complexity have failed to produce apparent or effective solutions (Aronson, 1996; Siri et al., 2016). Its fundamental feature is that it takes a holistic view of a system while identifying the interrelated, non-linear properties and behaviours that are internal and external to the system (Jaradat, Keating, & Bradley, 2017; Lee & Green, 2015). The benefits from using a systems-thinking approach are that the dynamics of a complex system can be mapped out using cyclic feedback loops. Cyclic feedback loops, for example, the cycle of the interconnected challenges for local government natural hazard risk management shown in Figure 2-2, enable people to compare and share mental models for the connections and feedback relations between seemingly isolated agents within a system (Haraldsson, 2004; Toole, 2005), as well as identify intervention points, which can then be used to change the system's overall dynamic (BeLue et al., 2012).

Application of systems thinking is a novel approach for better understanding the complex systems of challenges for natural hazard risk management in local government. Initial research into this, and the science-policy-practice interface as an intervention point, is presented as a manuscript awaiting publication in Chapter 7.

2.5 Tsunami risk management in Aotearoa New Zealand

Within this context of challenges for the effective local government governance and management of natural hazards in Aotearoa New Zealand sits tsunami risk management. The National Hazardscape Report (DPMC, 2007) states that Aotearoa New Zealand's tsunami risk is comparable to, or larger than its earthquake risk. It highlights that the area of greatest hazard from any tsunami source, combining local and distant-source hazard information, is the east coast of the North Island. The report goes on to acknowledge that despite growing recognition of the potential effectiveness of tsunami risk reduction, there has been little progress in implementing risk reduction measures in Aotearoa New Zealand because of the infrequency of damaging tsunamis and because of its low density of population exposed to tsunamis.

Actions to understand and reduce tsunami hazard and risk in Aotearoa New Zealand grew after the Indian Ocean Tsunami in 2004 and were further driven by the Samoa Earthquake and Tsunami in 2009 and the Tohoku Earthquake and Tsunami in 2011. The increase in the production of tsunami hazard and risk research included:

- a review of tsunami risk knowledge (Power, 2008; Power, 2013; Horspool, 2015; Gill, 2015; Webb, 2005);
- a review and development of tsunami warnings and alerts (Johnston et al., 2008; MCDEM, 2008a; MCDEM, 2010);
- investigations of community awareness, perceptions, and preparedness for tsunami risk (Couling, 2014; Dhellemmes, Leonard, & Johnston, 2016; Fraser et al., 2016; Gill, 2015);
- tsunami response behaviour and evacuation (Fraser et al., 2012; Fraser et al., 2013; Fraser et al., 2016; Johnston et al., 2016; Leonard et al., 2008; MCDEM, 2008b);
- the use of risk modelling for clearer understanding and communication of tsunami risk (Fraser et al., 2013; Horspool et al., 2015; King, 2015; King & Bell, 2009; Pondard & Daly, 2011; Power et al., 2008; Power, 2013; Schmidt et al., 2011); and
- guidance on incorporating tsunami modelling into land-use planning (Saunders et al., 2011; Saunders et al., 2015).

In 2016, the magnitude Mw 7.8 Kaikōura earthquake occurred in Aotearoa New Zealand generating a tsunami with wave oscillations measuring between 1.2 metres below and 2.45

metres above mean water level. A maximum run-up height of 5.5–6.9 metres was recorded at Goose Bay, 20 kilometres southwest of Kaikoura, with tsunami inundation beyond the high tide mark reaching some 250 metres up the Oaro River and 170 metres in Goose Bay (Power et al., 2017). While this was a moderate event with minimal property damage and no casualties, the experience of the tsunami in Aotearoa New Zealand further drove scientific efforts to understand and manage tsunami hazard risk. This included:

- tsunami hazard modelling (Crowell, Melgar, & Geng, 2018; Lemoine et al., 2018; Power et al., 2018; Williams et al., 2019; Williams et al., 2020);
- tsunami vulnerability and impact modelling (Downes et al., 2017; King et al., 2018; Paulik, Craig, & Popovich, 2020; Scheele et al., 2020; Williams et al., 2021);
- tsunami hazard awareness, perception, and preparedness in communities (Blake et al., 2018; Dhellemmes et al., 2021; Lane et al., 2020) including in Māori (Johnston, 2018; Kaiser & Boersen, 2020);
- tsunami risk communication (Bailey & Māhutonga, 2021);
- evacuation from tsunamis (Blake et al., 2018; Payne, Becker & Kaiser, 2019; Tilley et al., 2020);
- participatory tsunami risk science with iwi, hapu, and communities (Doyle et al., 2020; Thomas, 2018); and
- coordinated tsunami scientific response (Lane et al., 2020; Woods et al., 2017).

The literature reviewed above represents a breadth of scientific knowledge on tsunami hazard, risk awareness, and response. Many of these articles include recommendations for central and local government to use this knowledge to develop tsunami risk reduction policy; however, a much smaller bracket of literature reviews how this knowledge is applied across the science-policy-practice interface for managing tsunami risk within local government.

This smaller bracket of literature includes Webb's (2005) review of Aotearoa New Zealand's preparedness for tsunami hazard, where he explained that while all tsunami risk can be managed through land-use planning arrangements, land-use planning was unlikely to provide effective mitigation for the entire risk. As such, management of tsunami risk has historically been perceived as best achieved through emergency management using a 'readiness and response' approach of public education, warning, and evacuation measures

(Garside et al., 2009; Johnston et al., 2008; King, 2015; Leonard et al., 2007, 2008; MCDEM, 2008a, 2008b, 2010; Saunders, Prasetya, & Leonard, 2011; Webb, 2005; Wright et al., 2013). However, emergency management's traditional tendency to focus on 'response' over 'risk reduction' has resulted in a lack of policy to proactively plan for tsunami and reduce future risks (Johnston et al., 2014).

Given the focus on emergency management rather than land-use planning for tsunami risk management, Glavovic et al. (2010) found that at that time there were no land-use planning tools available for planners to deal with tsunami risk, despite tsunami being referenced to varying degrees in Regional Policy Statements and district plans. In response to this, guidance for land-use planners was developed on incorporating modelled tsunami inundation maps into land-use planning documents (Saunders et al., 2011).

Further literature reviewing how emergency management, land-use planning, and building control was incorporated with tsunami risk management revealed a lack of, or unclear definitions of tsunami risk in the policy (Saunders & Beban, 2012); that tsunami modelling may not be set at a level adequate for land-use planning purposes (Saunders, Beban, & Coomer, 2014b); and a low identification of consequences and/or likelihood of tsunami risk within the Regional Policy Statements (RPSs) and district plans (Saunders, Beban, & Coomer, 2014a). Saunders, Beban, and Coomer (2014a) found that 43.8% of Regional Policy Statements and 82.6% of district plans contained no description of either the consequences and/or the likelihood of tsunami. This is consistent with later research on destructive tsunami policy in Aotearoa New Zealand local government (Crawford et al., 2019, Chapter 6), which found that of the 58 central and local policy documents analysed across the Wellington, Hawke's Bay, and Gisborne Regions, only three contain specific tsunami risk-based policy.

The paucity of tsunami risk policy in Aotearoa New Zealand reflects international literature that due to perceptions of their infrequency, tsunamis do not present significant risk compared to other natural hazards (Bryant, 2014) and that tsunami risk management policies and actions need to garner political support in order to be implemented (Kuriyama et al., 2020). As stated in section 1.6, the risk needs to be clearly communicated in a way that influences decision makers to enable preparatory action. One option for communicating tsunami risk to influence the development of tsunami risk management policy in Aotearoa New Zealand is through the use of the risk modelling software called 'RiskScape'.

2.6 The use of RiskScape in Aotearoa New Zealand local government

RiskScape was first introduced to local government in Aotearoa New Zealand in 2006, having received funding in 2004, through collaboration between National Institute of Water and Atmospheric Research Ltd (NIWA) and the Institute of Geological and Nuclear Sciences (GNS). It was introduced as a national multi-hazard impact model that presents relative risks and community exposure to five natural hazards – flood (river), earthquake, volcano (ash), tsunami, and windstorm (King & Bell, 2006). At that time, it was a prototype still under development, which aimed to provide hazard exposure information into the likely impacts for a region, for example, damage and replacement costs, casualties, economic losses, disruption, and number of people affected. This hazard exposure information was intended to be presented in a way that was usable and aided decision making for non-technical end users within local government, such as emergency managers and land-use planners (King & Bell, 2006; Reese, Bell & King, 2007).

The difference between RiskScape and other hazard exposure models at that time was that RiskScape proposed a modular, integrated, multi-risk assessment framework, which was capable of deriving risks for different hazards and asset bases and deliver useful tools to compare various hazards impacting on an asset base (or one hazard impacting on multiple asset bases) (Schmidt et al., 2011). Figure 2-3 presents how the RiskScape model combined asset data (buildings, infrastructure, etc.) and hazard models (defining the hazard model to be used), with fragility functions to produce a range of economic and social consequences. However, the system was only capable of modelling and comparing multiple independent risk scenarios; it was not able to model compounding or cascading hazards, based on interaction between multiple hazards and assets in a risk scenario (Schmidt et al., 2011).

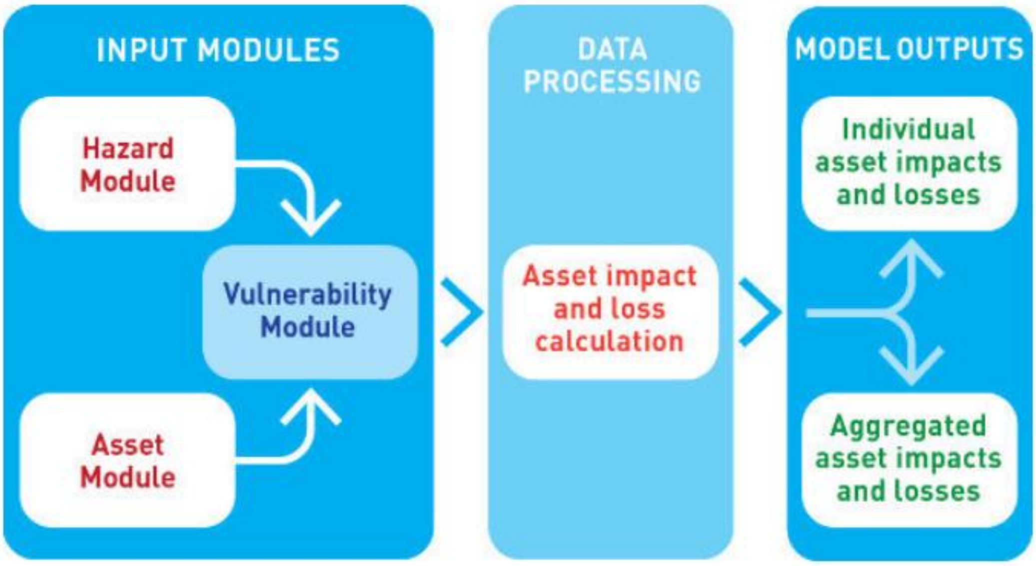

Figure 2-4: The RiskScape Model Framework. (RiskScape, n.d.) https://riskscape.niwa.co.nz/how-it-works 08/06/16

The RiskScape model was trialled in three geographically disparate pilot regions – Christchurch, Hawke’s Bay, and Westport, each exposed to a different mix of natural hazards (Stirling & King, 2010). At that time, Stirling and King (2010) proposed that phase two in the development of RiskScape would include more hazards (e.g. landslides, storm surges, pyroclastic flows and lahars, and climate change effects) and would advance the software into providing probabilistic-based solutions.

Trialling and development of RiskScape over the following years included implementation in volcanic risk assessment (Deligne et al., 2013; Deligne & Wilson, 2015; Kaye, 2008); application for seismic performance of transportation networks, electric power systems, potable water systems, and other infrastructure (Giovinazzi & King, 2009; Ragued et al., 2014); earthquake vulnerability assessments for different building types (Giovinazzi et al., 2018; Uma et al., 2008, 2011; Walsh 2014); social vulnerability indicators (Kwok, 2016), and tsunami hazard and impact assessment (Williams at al., 2018, 2020; Williams et al., 2021).

While the literature listed above highlights considerable effort in developing hazard models and fragility functions, less was known about how RiskScape was received by its intended end users within local government. Due to a recognised slow uptake in the use of RiskScape in the emergency management sector, Crowley and Crawford (2016) sought to better understand the needs of the New Zealand Civil Defence Emergency Management (CDEM) sector within local government for risk modelling and how RiskScape could be developed to better suit those needs. They found that unavailability of usable data limited how CDEM could use RiskScape, and that further development was needed for RiskScape to provide real-time impacts and consequences, specifically for tackling infrastructure assets, service repair time, wellbeing, as well as multi-hazard scenarios. Among other things the report recommended targeted engagement and training with specific user groups to grow understanding and use of RiskScape.

Following on from this research, Crawford et al. (2018a) and Crawford et al. (2018b) reviewed how risk modelling (RiskScape) was applied within local government in Aotearoa New Zealand, with their findings set out in Chapters 4 and 5 of this thesis. Both Crawford et al. (2018a) and Crawford et al. (2018b) recommended that: 1) greater clarity and mandate was needed for how natural hazard risk management was achieved to enable better collaboration, knowledge sharing, and data development across the different local government natural hazard risk management functions, and 2) that greater capacity and capability was enabled for co-developing, collecting, managing and using natural hazard risk data for use in risk modelling.

In 2017 RiskScape underwent an external review, finding that the modelling software was challenged by the old architecture of the system, which impacted on RiskScape's usability and adding complexity to updating the software for future releases (Thomas et al., 2020). A programme of work was instigated to redevelop RiskScape's core engine with a focus on workflow functionality, optimisation, performance enhancement, and an improved user interface. The result will be 'RiskScape 2.0', as presented in Figure 2-9, which builds on previous RiskScape versions to enable greater uptake with end users.

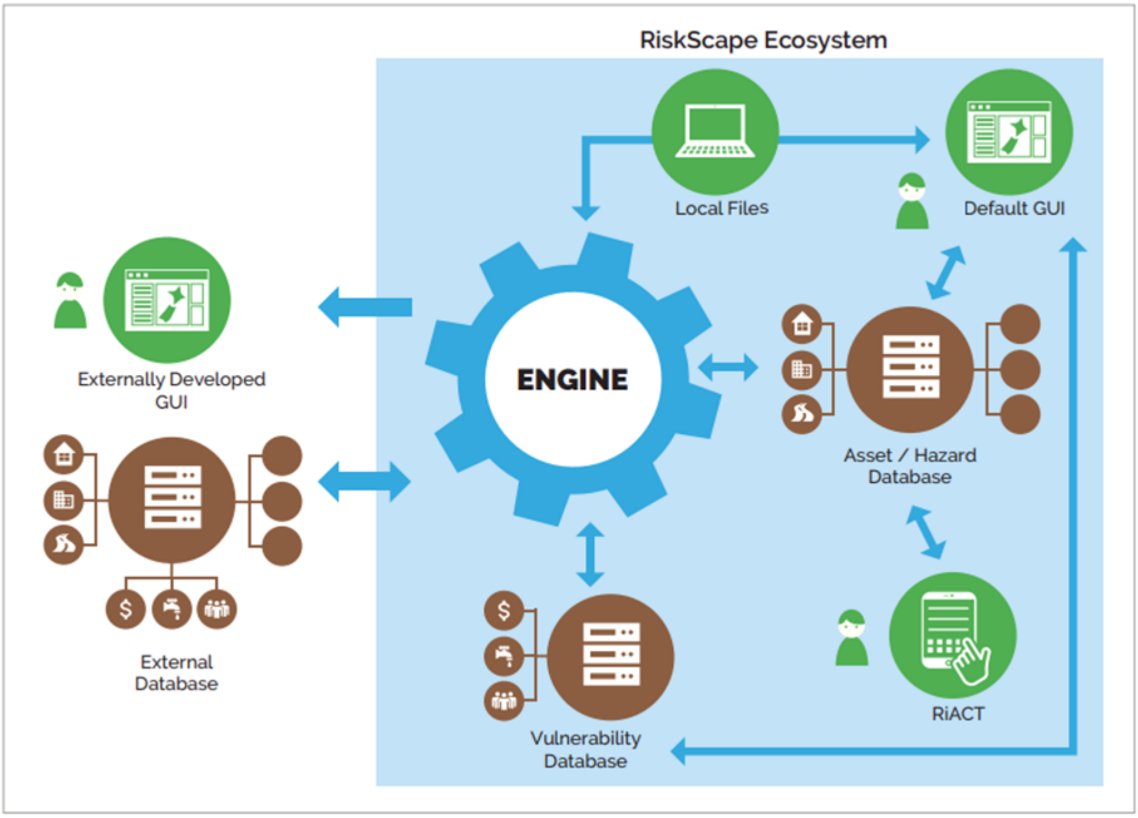

Figure 2-5: RiskScape version 2.0. Source: Natural hazards 2018 (Pinal & Coomer, 2019).GUI stands for graphical user interface and RiAct stands for Real-Time Asset Capture Tool, a tool which provides and receives asset data to/from RiskScape

As part of the programme of work to develop 'RiskScape 2.0', an online survey was carried out and workshops were run with natural hazard risk management practitioners and researchers in local government, and with other parts of the public and private sectors to seek feedback on user needs. It found that only 10% of survey respondents had used RiskScape (Thomas et al., 2020), with most respondents instead preferring to use Geographical Information Systems (GIS) or Microsoft Excel to assess risk. Consistent with the findings from Crawford et al. (2018a) and Crawford et al. (2018b), the majority of respondents (69%) reported that they would need further access to data before they could operate RiskScape, with local government respondents calling for more national datasets and data standards for natural hazard risk assessment. Consistent with Crawford et al.'s (2018) findings was local government respondents calling for greater risk literacy in local government, including in those making decisions (Thomas et al., 2020).

Despite RiskScape working since 2006 to present hazard exposure information in a way that was usable and aided decision making for non-technical end users within local government, the literature reveals that there are a number of current challenges for RiskScape to be useful, usable, and used (or desirable) for policy making within local government (Aitsi-Selmi, Blanchard, & Murray, 2016). Tools that are 'useful, usable and used' are defined by EQC (2019) as:

Useful: tools that can identify and fill data gaps to build knowledge.

Usable: tools that can translate and transform data to create meaning and new insights.

Used: tools that influence uptake and implementation within local government.

Thomas et al. (2020) presented an extensive list for what local government practitioners still wanted from the RiskScape software. This included for RiskScape to:

- be robust, credible, and easy to use, with minimal training required;
- incorporate the user's own data, as well as access a data pool with vulnerability models;
- produce outputs that are in formats that can easily be imported into spreadsheet software (Excel) as well as GIS software;
- be transparent, including how probabilities are calculated and impact the result, and have a clear display of limitations, assumptions, and uncertainty;
- have varied user interfaces for emergency management and/or land-use planning;
- generate immediate assessments based on real-time data and to forecast impact;
- provide more models (e.g. population movement, climate change, cascading and secondary hazards, slow-onset hazards, social vulnerability, volcanos, complex hazards, infrastructure outage);
- quantify resilience based on risk, impact, consequence, and loss.

While there is a desire from local government practitioners to use RiskScape as a tool to better understand and communicate natural hazard risks, almost twenty years later RiskScape is still not widely used to aid decision making for non-technical end users within local government as originally intended by King and Bell (2006). This is partly because of developmental problems with the RiskScape software. However, the larger part is due to the challenges for natural hazard risk governance, as detailed in section 2.4, creating an environment where it difficult for RiskScape to be applied. As stated in section 2.4.6, further research on Aotearoa New Zealand's system of challenges for natural hazard risk governance is needed to better understand how these challenges can be overcome to enable effective application of tools, such as RiskScape.

2.7 Key research areas and questions

The literature reviewed sets out the governance framework and challenges for local government management of natural hazard risks in Aotearoa New Zealand. It highlights that there is need to better understand how natural hazard risk (especially tsunami risk) is understood and perceived, which builds on previous research for how risk information can be communicated to more effectively enable the development and application risk-based policy and procedure. Three key areas for research are identified:

1. The use of RiskScape, a risk modelling tool for communicating natural hazard risk, where the end-user experience for risk modelling is not well understood and is scarcely covered in the literature.
2. Perceptions of, and motivation to, manage destructive tsunami risk. While it is Aotearoa New Zealand's most significant natural hazard risk, local government policies and procedures to manage tsunami risk are scarce and not well defined.
3. Governance for natural hazard risk management. The policy environment for natural hazard risk management in Aotearoa New Zealand local government is beset with challenges impacting on how risk management is applied. The interrelationship of these challenges is complex, and gaps in understanding remain for how these challenges can be overcome.

To address these areas, the research questions are:

- How is natural hazard risk modelled information perceived and acted upon by local government?
- How is risk modelling informed by natural hazard management?
- How are natural hazard management policies and procedures informed by risk modelling?
- What are the risk communication barriers and enablers that limit or contribute to efficacy for natural hazard risk management in local government?

- What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?

Consequently, this research attempts to improve our understanding for how initiatives, such as the RiskScape risk modelling tool, can be used to span the science-policy-practice interface for more effective governance and management of natural hazard risk, specifically tsunami risk, within local government in Aotearoa New Zealand. Chapter 3 (Research philosophy and methods) discusses how the research was designed and carried out.

3 Research philosophy and methods

3.1 Overview of this chapter

Chapter 2 reviewed the literature, considered how natural hazard risks are governed and managed in Aotearoa New Zealand and identified areas for further study, which are addressed in this research. This chapter presents the philosophical framework for undertaking the research, methods for how the research was conducted, ethical considerations, and the study area in which the research took place.

3.2 Philosophical framework

When looking at how to do research, there is need to appreciate a much more profound question – why research? The answer to this question is based on the researcher's assumptions concerning the interrelated concepts of ontology, epistemology, and human nature (Holden & Lynch, 2004). Ontology and epistemology are both important elements of the philosophy of knowledge. They often overlap and there is sometimes confusion over what their difference is (Bryman, 2008; Creswell, 2007; Patton, 2015). However, there is a clear distinction:

- Ontology is about our assumptions about how the world is made up, the nature and relationship of things, and what is fundamentally 'real'.
- Epistemology is about our beliefs on how one might discover knowledge about the world, and the way we give meaning to and know things.

As such, the epistemology is framed by the ontology. The ontology involves the philosophy of reality and what fundamentally is real. The epistemology addresses our relationship with that reality, what counts as knowledge, and how we come to know it (Krauss, 2005).

Further to the ontology and epistemology is the methodology. Methodology is "an articulated, theoretically informed approach to the production of data" (Ellen, 1984, p. 9). It informs how data is produced and how that data is studied, and consists of a strategy, plan of action, process, or design that informs one's choice of research methods (Rehman & Alharthi, 2016).

When combined, the ontology, epistemology, and methodology determine the 'research paradigm'. The research paradigm is "a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalisations and the experiments performed in support of them are formulated" (Merriam-Webster's Learner's Dictionary, 2016). Choosing a research paradigm is a very personal aspect of the research context. It reinforces the researchers' reasons for the question – why research? as well as providing value around where the research takes them (Bryman, 2008; Creswell, 2007; Patton, 2015).

Research paradigms are classified and defined in a range of ways across, and within, disciplines (Patton, 2015). Common research paradigms include:

- Positivist – Knowledge is discovered and verified through direct observations or measurements of phenomena, and facts are established by taking apart a phenomenon to examine its component parts (Krauss, 2005). It makes claims of knowledge based on precision, objectivity, standardisation, deductive reasoning, and replicability (Kaushik & Walsh, 2019). Positivists separate themselves from the world they study, while researchers within other paradigms acknowledge that they have to participate in real world life to some extent so as to better understand and express its emergent properties and features (Healy & Perry, 2000).
- Pragmatist – Knowledge is established based on an objective reality that exists apart from human experience. However, this reality is grounded in the environment and can only be encountered through human experience (Morgan, 2014). If the positivist and constructivist research paradigms were located on a continuum, they would be located at its two opposite ends, where the pragmatist research paradigm bridges the gap between them (Kaushik & Walsh, 2019).
- Constructivist – Knowledge is established through the meanings attached to the phenomena studied; researchers interact with the subjects of study to obtain data; inquiry changes both researcher and subject; and knowledge is context and time dependent (Krauss, 2005). Constructivist research is shaped from the bottom up, through individual perspectives to broad patterns, to gain broad understandings (Creswell & Clark 2017). It differs from positivism by disputing that the world cannot be known directly, "but rather by the construction imposed on it by the mind" (Young & Collin, 2004, p. 375).

Given that perceptions and understandings of natural hazard risk are constructed in the mind and given meaning through social interaction, this research has adopted the constructivist paradigm over other paradigms including the positivist or pragmatist paradigms, as further outlined below.

3.2.1 The constructivist paradigm

Sections 1.3 and 1.4 acknowledge how perceptions and understandings of natural hazard risk are subjective to people, communities, and organisations based on framing, likelihood, past experience, warning fatigue, and political and economic factors. These perceptions and understandings incorporate considerations such as uncertainty, doubt, dread, catastrophic potential, controllability, equity, and risk to future generations. As such, perceptions and understandings of natural hazard risk are constructed in the mind (Young & Collin, 2004). Furthermore, meaning for risk can only be built through social interaction with other people's perceptions and understanding of contingency and loss (Burgess, 2015; Oliver-Smith et al., 2017).

This research has adopted the constructivist paradigm over other paradigms because the meaning behind risk perceptions can only be derived through human experience, requiring interaction between the researcher and the participants being studied (Krauss, 2005). As such, the positivist paradigm's approach to research, where positivists separate themselves from the world they study, has not been deemed as suitable for this research. Furthermore, perceptions of risk are subjective as opposed to objective. As such, the pragmatist paradigm's approach to reality, where knowledge is established based on an objective reality, has also not been deemed as suitable for this research.

Within the constructivist paradigm, 'constructivism' has been chosen as the ontology for the research and 'social constructionism' as the epistemology. There has been some confusion over the ambiguity between these terms, where both social constructionism and constructivism have been bundled under the term constructivism (Young & Collin, 2004). This is reflected by the mix of conflicting definitions for the two albeit very similar philosophies, defined as:

- Constructivism – People construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences.
- Social constructionism – Understanding is constructed jointly (rather than individually) forming shared assumptions about reality. Human beings give meaning

> to their experience by creating models of the social world and share and realise these models through language (Young & Collin, 2004).

Creswell (2007) uses a term that is a mix between the two – social constructivism, which is used in this research, explained as:

> *… subjective meanings are negotiated socially and historically. In other words, they are not imprinted on individuals but are formed through interaction with others (hence the social constructivism) and through historical and cultural norms that operate in individuals' lives. Rather than starting with a theory (as in post-positivism), inquirers generate or inductively develop a theory or pattern of meaning* (Creswell, 2007, p. 20–21).

3.3 Consideration of methods

Because different paradigms rest on different assumptions about the nature of the world, they require different methods to find or generate the type of data desired (Ochieng, 2009). The different methods used for producing and studying data are quantitative, mixed methods, and qualitative.

Quantitative research methods are empirical in nature (Ochieng, 2009). They are confirmatory and expressed numerically, where validity of research is derived through clear, replicable, structured processes and the testing of predetermined hypotheses (Goertzen, 2017; Patton, 2015). Quantitative methods most commonly support the deductive reasoning based within the positivist paradigm (Kaushik & Walsh, 2019).

Mixed methods research does not privilege ontology or epistemology over the methods that are most appropriate to address the research question (Kaushik & Walsh, 2019). As such, they employ both quantitative and qualitative methods which enable the researcher to test hypotheses as well as generate data (Goldkuhl, 2012; Morgan, 2014). This results in mixed methods being most commonly used within the pragmatist paradigm, which is typically associated with abductive reasoning that moves back and forth between deduction and induction (Kaushik & Walsh, 2019).

Qualitative research methods examine the 'why' and 'how' of decision making (Patton, 2015) seeking information about the values, interests, behaviours, and opinions of groups in society and to explain behaviour (Smith & Smith, 2018). Creswell (2007) lists the characteristics of qualitative research methods where:

1. data is collected at the source via interviews, focus groups, or case studies;
2. the researcher is the key instrument – collecting the data in person;
3. there are multiple sources of data – interviews, observations, and documents;
4. understanding/theory is built inductively – from the bottom up, through interactive collaboration and development of themes;
5. research is focussed on learning the meanings that participants hold about an issue, not the theories that research hold over the issue;
6. the research process is emergent and can change from initial plans as the research progresses; and
7. the research is a form of inquiry where researchers develop a complex picture of the problem or issue under study from multiple perspectives. "The research is not bound by tight cause and effect relationship but rather by identifying the complex interactions of factors in any situation" (Creswell, 2007, p. 38–39).

As such, qualitative methods are typically associated with the constructivist paradigm (Kaushik & Walsh, 2019) and have been deemed as appropriate to generate data and learn meanings from participants' perceptions and understanding of natural hazard risk.

The research paradigm and qualitative methods used in this research are set out as research design in Table 3-1, which also sets out the sampling strategy, data collection, and analysis methods. These will be further explained in the following sections.

	Type:	Descriptions:	My reasons / defence:
Epistemology:	Social Constructionism	Our understanding of the world is 'constructed' rather than existing 'objectively'. We build our internal models in a pseudo-shared way in response to our perceptions of perceived constructs we receive from others. Constructivism can thus be seen as a social process whereby constructs (and hence 'reality') emerge from ongoing conversations and interactions.	Risk is an intangible, flexible construct where its meaning can only be built through social interaction with other people's perceptions and understanding of contingency and loss.
Methodology	Qualitative	Exploratory: used to gain an understanding of underlying reasons, opinions, and motivations, to uncover trends in thought and opinions, and dive deeper into a problem.	• Fits with my epistemology and personal values. • The research questions best suit a qualitative method. • Understandable, teachable, and usable for a participatory approach.
Sampling Strategy:	Purposive Sampling – homogenous sampling	Selection of similar cases to study the characteristics they have in common.	The project specifically focuses on natural hazard risk management within local government, so sampling is purposefully directed towards a small group of practitioners and decision makers in that field.
Data Collection Methods:	Focus Groups – multi-category design	Different groups with the same focus.	The project will work with different groups in CDEM, land-use planning, building control, engineering and policy development all focussing on natural hazard risk management.
	Interviews – semi-structured	Open interview style that follows a loose interview guide. Allows new, tangential ideas to be brought up during the interview as a result of open-ended interview questions.	• Supports qualitative enquiry. • Encourages participants to communicate how they think, feel, and understand (perceive).
	Document Analysis – public records	The official, ongoing records of an organisation's activities.	Local government measures for natural hazard risk management are recorded in public records: national legislation, annual plan and strategy documents, Long Term Plans (LTP), National/Regional/Coastal Policy Statements, Resource Management Plans, CDEM Plans, by-laws.
Analysis:	Inductive – Constant comparative analysis Thematic	Data is compared to all other pieces of data that are either similar or different looking at what the data different and/or similar to other pieces of data.	Supports the social constructivism approach, where knowledge and understanding emerge from the collaborative process.

Table 3-1: Research Design Framework

3.3.1 Qualitative methods

There are a variety of methods of data collection in qualitative research, where the most common are document analysis, observations, semi-structured interviews, and focus groups (Russell & Gregory, 2003; Shenton, 2004).

This research employs three of the four qualitative methods referred to above, set across three phases, to collaborate with local government natural hazard practitioners and corroborate results. Phase 1 uses a focus group research method, Phase 2 uses a semi-structured interview research method, and Phase 3 uses a document analysis research method. Each of these methods is further explained in sections 3.3.1.1 to 3.3.1.3.

The three different phases along with their respective data sources and qualitative research methods have been used because they triangulate the research. Triangulation, within qualitative research, refers to the use of multiple methods or data sources to develop a comprehensive understanding of phenomena (Carter et al., 2014; Patton, 2015). It corroborates the findings from other methods (Bowen, 2009; Carter et al., 2014) and enables saturation of data (Fusch & Ness, 2015; Patton, 2015), when there is enough information to replicate the study and when further coding is no longer feasible.

The mixing of qualitative methods allows for different perspectives that may otherwise be overlooked (Morse, 2009). For example, data captured from focus groups produce multiple stories and diverse experiences (Brown, 1999), whereas data captured from qualitative interviews stimulate discussion on different and more sensitive topics than focus groups (Powell & Single, 1996; Kaplowitz, 2001). Carter et al. (2014) added that use of multiple qualitative methods allows for participants to be involved in the study who were unable to participate when other methods were used (i.e. in a previous phase of research), and to ‘member check’, “a procedure largely associated with qualitative research whereby the researcher submits material relevant to an investigation for checking by the people who were the source of those materials” (Lewis-Beck et al., 2003, p. 663). This ensures that the data gathered, and assumptions derived, from previous use of other methods was relevant.

Table 3-2 gives an overview of each phase, the objective, the qualitative research technique used, and the reason for employing that technique, which are further explained in the following sections.

Phase:	Objective:	Research method:	Reason for use:
Phase 1: RiskScape CDEM Focus Groups	Research on how risk information is shared across councils and how risk is modelling tools, such as RiskScape, can be used for Civil Defence Emergency Management (CDEM) decision-making and risk assessment.	Focus groups	Interactive group setting where participants are free to talk with other group members producing data and insights that would be less accessible without the interaction.
Phase 2: Follow-up interviews	• Renewing the relationship between me and the participants. • Reviewing previous research results. • Introducing tsunami inundation risk modelling as the specific focus. • Exploring views on natural hazard risk management policy and procedure.	Interviews	The use of an individual approach to member check how risk modelling informs natural hazard risk management policy and procedure and how natural hazard risk management policy and procedure inform risk modelling.
Phase 3: Planning and policy analysis	Analysis of national legislation and council policies and procedures with a specific focus on tsunami risk management.	Document analysis	A review of the literature which triangulates with findings from the previous phases about where the researcher and participants think the barriers and enablers are for the communication, perception, and efficacy for natural hazard risk management in their council.

Table 3-2: Overview of research phases

3.3.1.1 Focus groups (Phase 1)

A focus group is a type of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs, and attitudes towards something in an interactive group setting where participants are free to talk with other group members (Patton, 2015). It stimulates the identification and sharing of various perspectives on the same topic (Morgan, 2014). Participants can hear each other’s responses and provide additional comments that they might not have made individually (Carter et al., 2014), and it "produces data and insights that would be less accessible without the interaction found in the group" (Flick, 2006, p. 197).

One to ten focus groups sessions are generally sufficient for most studies depending on the nature and complexity of the research, with each session lasting between 90–120 minutes (Powell & Single, 1996) and consisting of between six and ten participants (Patton, 2015). The facilitator of focus group sessions ideally shares the participants' characteristics and background (Powell & Single, 1996; Dilshad & Latif, 2013). Facilitation should be relaxed and non-judgemental and achieved via a non-prescriptive, semi-structured interview schedule. The semi-structured interview schedule is based on pre-prepared focus areas, which enable researchers to clarify a topic or explore participants' answers in greater detail (Powell & Single, 1996).

Focus groups are a relatively easy and inexpensive method to gain access to information on interactions in a given group (Busetto, Wick, & Gumbinger, 2020) and tend to be less costly in time than other qualitative methods, especially semi-structured interviews (Carter et al., 2014). However, the time and effort required to analyse the focus group data may ultimately negate any time savings (Mansell et al., 2004). Further disadvantages of focus groups include limited control over the process, where some participants may vocalise their perspectives more than others. Power dynamics between group members also need to be carefully managed to ensure all perspectives are equally acknowledged. Aligned with this is the emergence of 'groupthink', a common disadvantage of focus groups (Chuka-Maduji, 2021), where people set aside their own personal beliefs to adopt the opinion of the rest of the group. As such, focus group sessions require experienced facilitation (Busetto, Wick, & Gumbinger, 2020); however, experienced facilitators may not be involved or available.

Section 3.5.1 sets out how the focus group research method was applied, including how disadvantages were managed. Limitations for this method are also discussed in section 3.7.

3.3.1.2 Semi-structured interviews (Phase 2)

Qualitative interviews are "a conversation with a purpose" (Smith & Smith, 2018, p. 72) and are one of the most powerful tools for gaining an understanding of human beings and exploring topics in depth (Fontana & Frey, 2000). The defining characteristic of qualitative interviews is the use of questions to understand the thoughts, feelings, beliefs, and behaviour of people (Grant, Rohr, & Grant, 2012). Edwards and Holland (2013) add that the negotiation of the participants in the interview situation – the researcher and the researched – is what creates knowledge and understanding of social life.

Types of qualitative interviews range from being structured and controlled, increasing in flexibility towards being unstructured and fluid. The primary difference between them is the amount of control the researcher has over how the interview progresses and how interview aims are met (Stuckey, 2013). The different types of qualitative interview are summarised below:

- Structured interviews follow a predetermined set of questions with a limited number of response categories, for example, a survey (Sarantakos, 2005). Questions are asked verbatim, and researchers do not deviate from that format (Mueller & Segal, 2014). They allow for larger numbers of participants to be studied, with answers recorded according to a to a pre-set coding scheme (Stuckey, 2013).
- Semi-structured interviews set an outline for the topics covered and employs open-ended questions to cover them. The researcher has more latitude to follow up on the participants' responses (Mueller & Segal, 2014), which determines the way in which the interview is directed. This requires the researcher to be knowledgeable about the topic being covered, whereas structured interviews can be completed by interviewers not familiar with the research (Mueller & Segal, 2014).
- Unstructured interviews have no pre-set parameters for the topic being researched and depth of conversation. It is more of a free-flowing conversation where the researcher is responsible for determining the specific questions that are needed to successfully cover the topic (Mueller & Segal, 2014). As with semi-structured interviews, the researcher is required to be knowledgeable about the of the topic being covered. The lack of structure in unstructured interviews, compared to semi-structured interviews, can potentially result in the researcher not gathering all the information needed to meet the research aims.

This research has adopted the semi-structured interview because the number of participants in the local government areas being researched are not large (twenty-three participants) and therefore doesn't require structured interviews. Furthermore, the aim of the research is to co-create knowledge and understanding of participants' thoughts, feelings, and perceptions of natural hazard risk, which requires latitude in interview questioning that is more suited to semi-structured or unstructured interviews. However, semi-structured interviews were adopted over unstructured interviews to reduce the risk that relevant information was not gathered.

Edwards and Holland (2013, p. 3) defined the common features of semi-structured qualitative interviews as:

- The interactional exchange of dialogue between two or more participants, in face-to-face or other contexts.
- A thematic, topic-centred, biographical or narrative approach where the researcher has topics, themes, or issues they wish to cover, but with a fluid and flexible structure.
- A perspective regarding knowledge as situated and contextual, requiring the researcher to ensure that relevant contexts are brought into focus so that the situated knowledge can be produced. Meanings and understandings are created in an interaction, which is effectively a co-production, involving the construction or reconstruction of knowledge.

Potential disadvantages of semi-structured interviews are that nuance is lost due to inability to have in-person conversations (Kakilla, 2021), instead using technology to hold interviews (e.g. Skype or Zoom), which is pertinent in this time of the Covid-19 pandemic. Further disadvantages are language barriers resulting in questions being lost in translation and limited ability to probe answers (Kakilla, 2021), limited participant understanding or inadequate response to the topic (Kakilla, 2021), inability of the researcher to build rapport with the participants or actively listen to the participants' responses and engage in the interview (Mueller & Segal, 2014; Kakilla, 2021), time pressures that limit the availability of participants (Kakilla, 2021), and the costs in time and effort to gather and analyse the data (Carter et al., 2014).

Section 3.5.2 sets out how the semi-structured interview research method was applied, including how disadvantages were managed. Limitations for this method are also discussed in section 3.7.

3.3.1.3 Document analysis (Phase 3)

Document analysis is a systematic procedure for reviewing or evaluating documents. When used qualitatively, this method requires data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). Approaches for the analysis of documents appear in a variety of forms, with the most common being document study, content analysis, and text analysis (Sarantakos, 2005). Each of these methods is summarised below:

- Document study is a basic method which focusses on description, identification of trends, frequencies, and interrelationships, producing summaries of factual information (Sarantakos, 2005).
- Content analysis is a more sophisticated analysis focusing on manifest or latent content within documents, which allows for conclusions to be made on meanings that are beyond the text and the language (Sarantakos, 2005). It compresses text across whole documents into a few content categories based on criteria or rules of coding (Stemler, 2000).
- Text analysis approaches text as a 'virtual reality', using methods such as semiotics, discourse analysis, and hermeneutics to provide in-depth analysis beyond the level that other methods can reach (Sarantakos, 2005).

This phase employed the content analysis approach for analysing documents to gain an overview of patterns and meaning of tsunami risk management content within national legislation and local strategy and planning policy documents. This was done to corroborate the findings from the other qualitative methods used in this research. Indeed, document analysis is often used in combination with other qualitative research methods as a means of triangulation (Bowen, 2009).

Document analysis is a is less time-consuming than other methods because it requires data selection, instead of data collection (Bowen, 2009; Sarantakos, 2005). Documents are often publicly available without need for permission and are free to access (Bowen, 2009, Davie & Wyatt, 2021). Documents are 'unobtrusive' and 'non-reactive' (Bowen, 2009) and therefore moderate reflexivity (i.e. the researcher's contribution to the construction of meaning) inherent to in other qualitative research methods. Documents are also context and time specific, providing details on knowledge and understanding for a time and place. Within the document analysis method, the content analysis approach allows for consideration of explicit and implicit discourses (Davie & Wyatt, 2021), where the researcher has some control over the scope of the content being analysed. It is systematic (Stemler, 2000), based on explicit rules of coding, and is able to be replicated (Sarantakos, 2005).

Potential disadvantages of document analysis are that documents may be out of date or don't contain the detail needed for the research aims (Bowen, 2009; Sarantakos, 2005). Documents may be unavailable, inaccessible, or missed from being gathered for analysis (Bowen, 2009; Davie & Wyatt, 2021; Sarantakos, 2005). Some documents gathered may be biased or not representative of their kind and therefore influence generalisations and/or the interpretation of meaning (Davie & Wyatt, 2021; Sarantakos, 2005). Within the document analysis method, Stemler (2000) identifies two fatal flaws for the content analysis approach – faulty definitions of categories and non-mutually exclusive and exhaustive categories.

Section 3.5.3 sets out how the content analysis approach to the document analysis research method was applied, including how disadvantages were managed. Limitations for this method are also discussed in section 3.7.

3.4 Ethics

The ethical issues relating to this research pertain to the nature of harm that the research may cause for the participants involved, and their ability to consent to providing information. These ethical issues were assessed with reference to the Massey University 'Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants' (Massey University, 2017) and were discussed with colleagues and supervisors.

Discussions with colleagues and supervisors primarily focussed on whether the research was ethically 'high risk' or 'low risk'. High-risk ethics relates to research undertaken with participants whose competence to exercise informed consent is in doubt (i.e. children or people with learning difficulties); participants who may not be socially able to exercise unfettered informed consent (i.e. prisoners, asylum seekers or family members of the researcher); and participants whose circumstances may unduly influence their decisions to consent (i.e. people who anticipate personal benefits from participation). Given that this research did not engage these types of participants, and because the nature of the harm was minimal and no more than was normally encountered in daily life (Massey University, n.d.), it was agreed amongst colleagues and supervisors that the ethical issues relating to this research were ‘low risk’.

Low-risk ethics was then sought and approved by the Massey University Ethics Committee to cover Phase 1 and Phase 2 of this research (see Appendices A and B). No ethics approval was required for Phase 3 of the research as document analysis is an ‘unobtrusive measure’ (Davie & Wyatt, 2021). Information sheets were developed for Phases 1 and 2 of the research, containing all the information that potential participants needed to make an informed decision about whether or not they wished to consent to participate in the research (Appendices C and D). I emailed these to potential participants prior to the focus group sessions and interviews, at the same time as I sent calendar invites to book participants’ time. The information sheets were written in the form of a customised letter of invitation using language suitable for participants, avoiding unnecessary specialist terminology. They were set out in accordance with the standard format for Massey University information sheets and included the following sub-sections: (i) the researcher’s personal introduction; (ii) a description of the project and an invitation to participate in the research; (iii) details of participant identification and recruitment; (iv) a concise description of each of the research procedures and the overall time commitment; (v) an explanation of how data will be gathered, stored, used, and disposed of; (vi) a list of participants’ rights; (vii) researcher and supervisor contact details; and (viii) compulsory statement(s).

At the time of the meetings, I provided consent forms for participants to fill in before the focus groups or semi-structured interviews had started. A consent form is the equivalent of a legal document that has been signed by the participants agreeing to participate in the research as described in the information sheet. This was an important legal protection for me and for Massey University, as well as for participants. The consent forms for Phases 1 and 2 have been safely kept by me for the duration of this research and are available on request.

3.5 Application of qualitative methods in this research

Phases 1, 2 and 3 of this research were applied between November 2015 and August 2018, between 6 ½ and 4 years ago. It is acknowledged within the constructivist paradigm that the thoughts and opinions on natural hazard risk, as well as development of natural hazard policy, is based on human experience, which will have developed in the intervening years. Intervening events, such as the Whakaari / White Island eruption in 2019 and the Covid-19 pandemic beginning in 2020, will have influenced risk perceptions and impacted on actions within local government. Policy development, especially in the climate change space, has also occurred. As such, the findings from application of Phases 1, 2 and 3 between 2015 and 2018 may not be representative of findings, using the same methods, from research applied now.

3.5.1 Focus groups (Phase 1)

This phase of my research collaborated with researchers from GNS Science and NIWA, where the data was collected jointly for a report prepared by the National Institute of Water and Atmospheric Research (NIWA) (Crowley & Crawford, 2016) and to inform this research. The research team included me, Doctor Sally Potter from GNS Science, and Doctor Kate Crowley from NIWA.

Focus groups were run with five local authorities across Aotearoa New Zealand to gather data for how risk modelling tools, such as RiskScape, can be used for Civil Defence Emergency Management (CDEM) decision-making and risk assessment. While the sessions focussed on CDEM, emergency management is a holistic role that works with other parts of the council to manage natural hazard risk. As such, participants in other council roles (e.g. land-use planners, engineers, GIS technicians, building controllers) were also encouraged to contribute.

Potential participants were recruited through a ‘homogenous sampling’ strategy. This strategy it is a type of qualitative sampling that brings together people of similar backgrounds and experiences to participate in a focus group, identifying common issues, characteristics, and circumstances (Patton, 2015). Homogenous sampling was adopted over other sampling methods (i.e. convenience sampling or quota sampling) because its specific focus on a certain group of participants eliminates variation (noise) associated with a wider participant sample base and improves the accuracy and quality of the resultant data (Bornstein, Jager & Putnick, 2013).

Emails were sent to local government natural hazard risk management practitioners in management positions, who were contacted because of their ability to act as a ‘gate keeper’. A gate keeper is a person who is able to transfer information from the external environment to colleagues within their organisation, with a primary interest in personal use of the information gathered (Macdonald & Williams, 1993). The gate keepers were also already known to different members of the research team, were willing and able to be involved, and were capable of encouraging other people within their councils to participate.

The five local authorities that participated in the focus group sessions are listed in Table 3-3:

Council visited	**Date visited**	**Participant numbers**
Bay of Plenty Regional Council	19/11/15	12
Wellington Regional Emergency Management Office (representing the Wellington region and its districts)	23/11/15	7
Tasman District and Nelson City Council	17/03/16	5
Hawke’s Bay Regional Council (and districts)	04/04/16	6
Environment Canterbury (and districts)	23/05/16	15

Table 3-3: Councils and participant numbers for focus group sessions

Before the sessions started, participants were given an oral introduction on the purpose of the research, provided with further information sheets, reminded of their participant rights, and asked to sign a participant consent form as part of the ethics process.

Initially, the focus groups were controlled via facilitator-led discussions around key questions interspersed with group activities; however, after two sessions it became apparent that this method of data collection was not conducive to encouraging free talk as this approach led the participants to focus more on delivering the activity rather than the discussion. The remaining three sessions removed the activities and facilitated the sessions using a semi-structured question guide (as per Table 3-4), which encouraged participant-led discussion over broad themes. Sometimes open-ended questions were used to guide discussion for further clarity, or if the participants remained off-topic for too long.

Scene setting: • Introduction to why we were there and the aims. • Highlight that RiskScape is more easily applied. **Establish Context:** • How does CDEM works in this region, and what roles and responsibilities participants have? **Data and pathways:** • How does this group links with other departments and the wider natural hazards management within the council? • How is hazard information communicated and decided upon across councils and within CDEM? • What information do you use? Where does it come from? Do you withhold your own information? **Examples:** • Encourage discussions around examples of risk decision making, or response? What went well in terms of information requirements? What information was missing or what are the information gaps? • How would you like to receive or share hazards information? • Select particular hazards to discuss – let the discussion flow naturally around CDEM needs and expectations. Thirty minutes before end of session (at least), wrap up discussion and present RiskScape tool version 1. Explain main features and outputs, explain a little about how these could be used. Ask what do they think? Could this be used by the CDEM Group? What for? What would they need?

Table 3-4: Semi-structured question guide for focus group sessions

Each focus group session lasted up to two hours with data captured via notes taken during the focus group sessions and through dictaphone recordings. The transcriptions and notes were analysed to identify themes through thematic analysis. Thematic analysis is a common form of analysis in qualitative research and was chosen over other types of analysis (i.e. narrative or content analysis) because it emphasises pinpointing, examining, and recording patterns (or 'themes') within data. Braun and Clarke (2006) recommend thematic analysis as it "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006, p. 5). Themes were identified using an inductive, 'bottom up' approach (Patton, 2015), where patterns of meaning were reflexively interpreted through the lens of the researcher (Braun & Clarke, 2006). Resultant themes were independently coded within two qualitative analysis software packages – NVivo was used by me and QDA Miner 4 Lite was used by Doctor Kate Crowley (being the qualitative analysis software available to her). Following the thematic analysis, the individually-identified codes were explicitly considered and discussed (Braun & Clarke, 2006) by Doctor Kate Crowley and myself and regrouped into mutually agreed themes during a one-day analysis workshop.

Analysis of the data informed the development of the NIWA technical report – 'Risk Tool and Data Needs: Civil Defence and Emergency Management in New Zealand' (Crowley & Crawford, 2016), the journal article – 'Risk Modelling as a tool to support natural hazard risk management in New Zealand local government' (Crawford et al., 2018a) in Chapter 4, and partly informed the conference proceedings – 'End-user perceptions of natural hazard risk modelling across policy-making, land-use planning, and emergency management within New Zealand local government' (Crawford et al., 2018b) in Chapter 5.

3.5.2 Semi-structured interviews (Phase 2)

Compared to Phase 1 where focus groups were run in five locations across the North and South Islands, this phase focussed on the specific study areas for this research: Wellington, Hawke's Bay, and Gisborne (see the study areas in Chapter 3.6). Interviews were held individually with the same natural hazard risk management functions as identified in Phase 1 for the regions of Wellington and Hawke's Bay, and with previously identified participants in Gisborne who were unable to attend the focus group session in Hawke's Bay. Five local authorities participated in the semi-structured interviews as set out in Table 3-5

Council Visited	Date visited	Participant numbers
Wellington Regional Council	17th of May 2017 16th of June 2017	4
Hawke's Bay Regional Council	22nd – 23rd of September 2016	5
Napier City Council	22nd of September 2016 26th of June 2017	3
Hastings District Council	27th of June 2017	3
Gisborne District Council	26th – 27th of September 2016 28th – 29th of May 2017	8

Table 3-5: Councils and participant numbers for semi-structured interviews

Emails were sent to the participants in the Wellington and Hawkes bay regions that participated in Phase 1, as well as new participants in Gisborne. The emails provided a brief introduction of the purpose and benefits of being part of the follow-up interviews, as well as an information sheet describing the interview purpose. Twenty-three participants were individually interviewed between September 2016 and June 2017, covering functions for strategic policy making, land-use consent planning, and emergency management, as well as other roles including environmental science, building control, asset management, engineering, and hazard modelling. Two series of interview sessions were held with practitioners in Hawke's Bay and Gisborne regions to ensure participants were interviewed that were unavailable at the time of the previous interview series.

The interviews lasted between 1–2 hours and were held in a private space. Before the sessions started participants were given a brief introduction on the purpose of the interview, provided with a further information sheet, reminded of their participant rights, and asked to sign a participant consent form.

The purpose for each interview was:

1. To renew the relationship and review my research – using a fluid and unstructured interview approach, I reintroduced myself and talked about how I thought the communication of risk for natural hazard management policy and procedure was an

important subject. Throughout this process I encouraged participants to relate to what I said and provide their own views and experiences.

2. To review the report from Phase 1 and member check – where I referred to the NIWA report from Phase 1 (Crowley and Crawford, 2016) and checked whether it aligned with participants' views and experiences. This procedure gave credibility to the research and also served to alleviate any anxieties I might have held in my capacity to understand the social context of the other participants.
3. To introduce tsunami inundation risk modelling as the specific focus – in the first interview I attempted to use the RiskScape risk modelling tool to run an all-of-boundary earthquake and tsunami event originating from the Hikurangi Margin on my lap-top computer. However, while practice runs of the model had worked previously, the modelling run-time was too slow for the interview timeframe of 1 – 2 hours, potentially because of a poor guest Wi-Fi connection at the interview location. To avoid this issue in the following interviews, I described the intended capabilities of the RiskScape model and presented pre-prepared outputs of what the modelled scenario would be for the region where I was interviewing participants. I asked them what they thought and how they felt about this information. Following on from that, I asked participants what they thought the barriers and enablers were for the communication and perception of this risk, and how this influenced motivation to act on risk information.

As with the focus group sessions, a semi-structured interview guide was developed to help steer the course of the interviews as set out in Table 3-6:

Thoughts, feelings, and experiences on how natural hazard risk management policy works in that Council:

- Its level of importance.
- How often policy is developed.
- How policy is applied.
- Links across council for natural hazard risk management.
- The local governance environment/mandate for policy development.
- Risk-based policy.

Views on the use of risk modelling software:

- Whether it changes the way participants perceive natural hazard risk.
- Whether it better communicates the risk, why, and why not.
- Whether it is better at creating efficacy for developing more risk informed policy and procedure.
- What participants think are the barriers for the communication, perception, and efficacy for natural hazard risk.
- What participants think are the enablers for the communication, perception, and efficacy for natural hazard risk.

Table 3-6: Semi-structured Interview Guide

Data was captured through dictaphone recordings and then transcribed. Transcriptions were thematically analysed as it "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006, p. 5). As with Phase 1, themes were identified using an inductive, 'bottom up' approach (Patton, 2015), where patterns of meaning were reflexively interpreted through the lens of the researcher (Braun and Clarke, 2006). The NVivo software package was used to assist with the analysis, categorisation, and organisation of the data into main themes with contributing sub-themes.

Analysis of the data informed the development of the conference proceedings paper – 'End-user perceptions of natural hazard risk modelling across policy-making, land-use planning, and emergency management within New Zealand local government' (Crawford et al., 2018b) in

Chapter 5. It partly informed the development of the journal article 'The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government' (Crawford et al., 2019) in Chapter 6, and also informed the development of the manuscript 'A cycle of challenges for natural hazard risk management for local government in Aotearoa New Zealand – and how it could be interrupted' (unsubmitted manuscript) in Chapter 7.

3.5.3 Document analysis (Phase 3)

New Zealand national legislation along with local strategy and planning policy documents were analysed for their provisions relating to natural hazards, risk management, and tsunami. The documents selected were required to be operational at the time of analysis and refer to natural hazard risk management within the Wellington, Hawke's Bay, or Gisborne regions.

Fifty-eight national and local policy documents were identified via a combination of internet searches and documents provided by participants. Examples include the New Zealand Coastal Policy Statement (Department of Conservation, 2010), the Hawke's Bay Regional Council – Long Term Plan 2012–2022 (Hawke's Bay Regional Council, 2012), and the City of Lower Hutt District Plan (Hutt City, 2016). A full list of the documents is provided in Appendix E.

The documents were analysed using content analysis in accordance with pre-determined criteria (Sarantakos, 2005; Stemler, 2001). Previous analyses of New Zealand local government natural hazard policy were considered in determining criteria (Becker & Johnston, 2000; Glavovic et al., 2010; Kilvington & Saunders, 2016; Lawrence & Haasnoot, 2017; Saunders & Beban, 2012), with the criteria for this analysis primarily aligned with Saunders et al.'s (2015) evaluation of the use of land use and emergency management policy documents for natural hazards in New Zealand local government. In their analysis, a plan was considered to be best practice based on eight indicators including hazard identification, the inclusion of hazard specific rules, and the use of risk management language (e.g. consequence and likelihood). The analysis used in this research adapted Saunders' et al. (2015) best practice indicators to explore four objectives – the pattern of natural hazards policies in general, the pattern of tsunami policies specifically, the pattern of risk-based policies in general, and the pattern of tsunami risk-based policies specifically. Table 3-7 sets out these four objectives along with the pre-determined criteria which inform each of them.

Criteria	Objectives
The document analysed:	
• has a section on natural hazards • has a definition for natural hazard • includes natural hazard policies	Explores patterns generally associated with natural hazard management policies.
• lists tsunami as a natural hazard • refers to tsunami as potentially affecting that district/region • includes tsunami policies • refers to tsunami inundation maps	Explores patterns specifically focussing on tsunami hazard management policies.
• has a definition of risk • sets out a risk-based management model • includes risk-based policies • links to risk management policies in other documents	Explores patterns generally associated with risk-based policies.
• refers to tsunami risk – e.g. likelihood and consequences of certain magnitude events • includes tsunami risk-based policies	Explores patterns specifically focussing on tsunami risk-based policies.

Table 3-7: Document analysis criteria with objectives

Analysis of the data partly informed the development of the journal article – 'The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government' (Crawford et al., 2019) in Chapter 6.

3.6 Study areas

This research focusses on three regions, as defined by local government boundaries, exposed to the impact of an all-of-boundary tsunami generated in the Hikurangi Subduction Zone. The Wellington, Hawke's Bay, and Gisborne Regions were chosen, as they have been recognised as being exposed to the greatest risk from any tsunami hazard source (DPMC, 2007). The most significant tsunami to impact on this area is a local source tsunami generated in the Hikurangi Subduction Zone. The Hikurangi Subduction Zone is shown in Figure 1- 5, located to the east of Aotearoa New Zealand's lower North Island, and can be divided into three segments – the northern, central, and southern, each with their own seismogenic characteristics and a specific likelihood of rupture (Power, 2013; King, 2015).

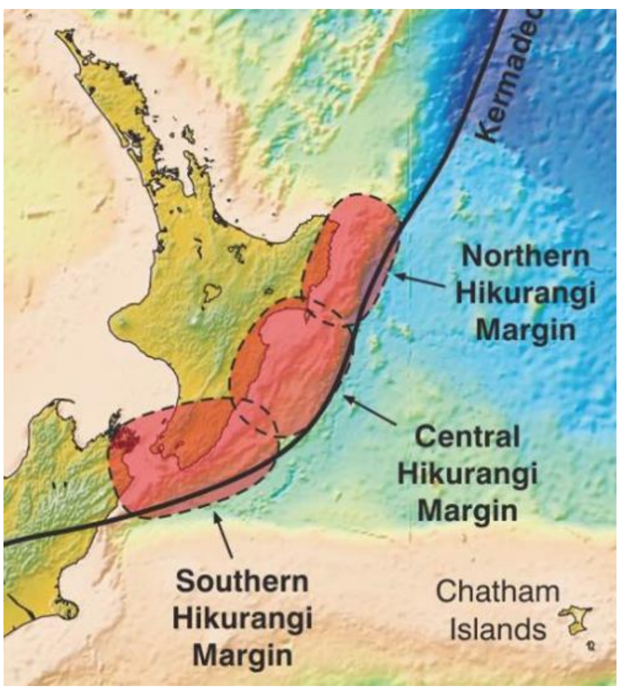

Figure 3-1: The Hikurangi Subduction Zone separated into its northern, central, and southern segments (Geonet, n.d.)

The Hikurangi Subduction Zone can produce an 'all-of-boundary' mega-thrust earthquake, where all three segments of the subduction zone rupture as part of the same event, with a magnitude corresponding to Mw = 9.0 (Power, 2008). If a rupture of this size were to occur, the resultant tsunami would be one of the most destructive Aotearoa New Zealand is likely to encounter over a 1000-year time frame (Power, 2008), affecting 200–300 km or more of the nearby coast, with large run-ups and severely damaging waves (Power, 2013). One scenario for a 9.0 Mw rupture on the Hikurangi subduction interface modelled wave heights of 7.4m at Wellington, 8.4m at Hawke's Bay, and 8.0m at Gisborne, which are similar to the wave height of 10m recorded for the 2011 Tohoku Tsunami. Modelled deaths and injuries from an all-of-boundary tsunami in the Hikurangi subduction interface total 3,990 in Wellington, 8,647 in Hawke's Bay, and 1,811 in Gisborne (Gill, 2015). If a disaster like this was to impact on Aotearoa New Zealand, it would cause huge loss of life and severely affect the national economy with an estimated financial loss of $20,280 million NZD (Gill, 2015).

The Hikurangi subduction interface is not the only tsunami generating margin in New Zealand, there are also the Kermadec Trench (extending further north of the Hikurangi trench), and the Puysegur Trench (to the south of the South Island); however, the Hikurangi subduction interface is preferential compared to the Puysegur or Kermadec Trenches as it holds the highest risk (Power, 2008) and is located around where I live and study (in Wellington). The findings from this project will not be restricted to tsunami risk management specific to the Hikurangi subduction interface but can be applied for tsunami (and natural hazard) risk management anywhere.

Each of the three case study areas are outlined in the following sections.

3.6.1 Case study area 1: The Wellington Region

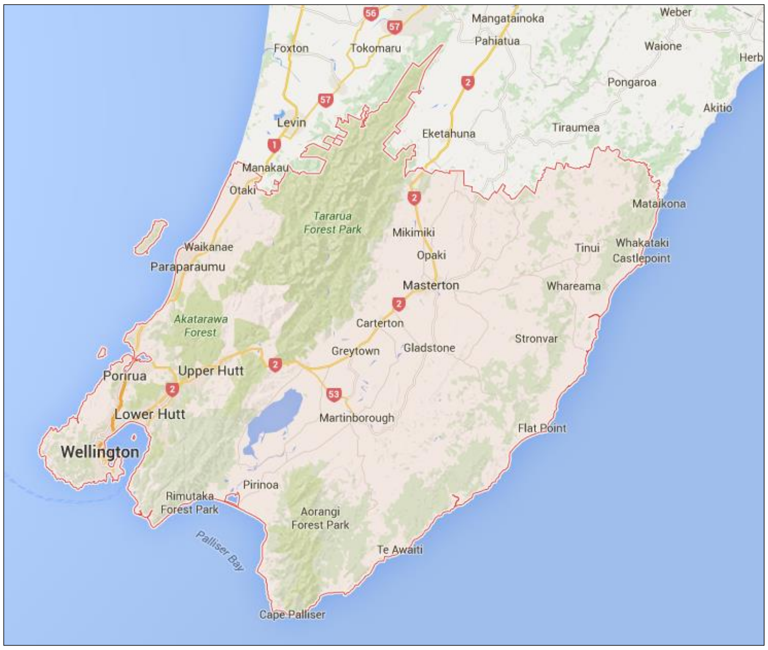

Figure 3-2: Wellington Regional Map. Source: Google maps – Wellington region. https://www.google.co.nz/maps/place/Wellington/@-41.0342341,174.3211995,8z/data=!3m1!4b1!4m5!3m4!1s0x6d3f5205bd43cf57:0xf7ade3e9c48078c2!8m2!3d-41.0299323!4d175.4375574. 6/07/16

The Wellington Region covers an area of 8,049 square kilometres and hosted a population of approximately 506,814 counted in the 2018 census (Stats NZ, n.d.). It is home to New Zealand's capital city of Wellington and the cities of Lower Hutt, Porirua and Upper Hutt. The region also includes the Kapiti Coast District and three rural districts containing most of the Wairarapa, covering the towns of Masterton, Carterton, Greytown, Featherston, and Martinborough. Wellington's economy is based on knowledge, with central government and nine of New Zealand's top 20 companies headquartered there. It is also home to the New Zealand Stock Exchange. Wellington's economic strength lies in the service sector with information technology, film, and education (Wellington Chamber of Commerce, n.d.). The Wellington region has 497 kilometres of coastline, much of it exposed to tsunami generated in the Hikurangi Margin. Wellington City's southern coast and harbour and the Wairarapa coast are most exposed to tsunami risk from the southern segment of the Hikurangi Margin, which is the most likely segment of the margin to rupture and could result in tsunami waves arriving at Wellington within five minutes of the earthquake (Fraser et al., 2016).

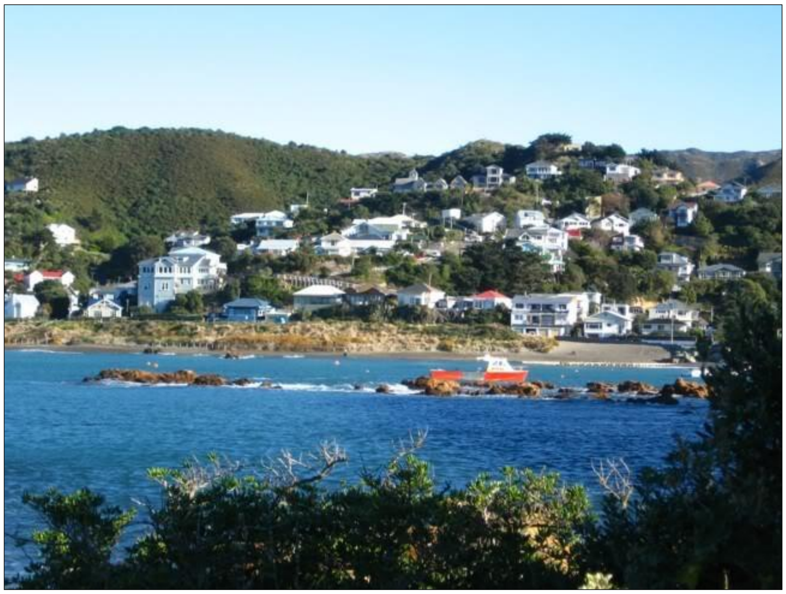

Figure 3-3: Island Bay, Wellington. Source: The Island: Island Bay, Wellington, New Zealand. http://nztravelbloque.blogspot.co.nz/2007/06/26-island-island-bay-wellington-new.html. 27/06/16

The region's natural hazard management is administered through the Greater Wellington Regional Council, via the Wellington Region Emergency Management Office (WREMO)[1] as well as through land-use planning and hazard policy development functions within the regional council and its constituent territorial authorities.

[1] Wellington Region Emergency Management Office (WREMO) – http://www.getprepared.org.nz/. 07/07/16

3.6.2 Case study area 2: The Hawke’s Bay Region

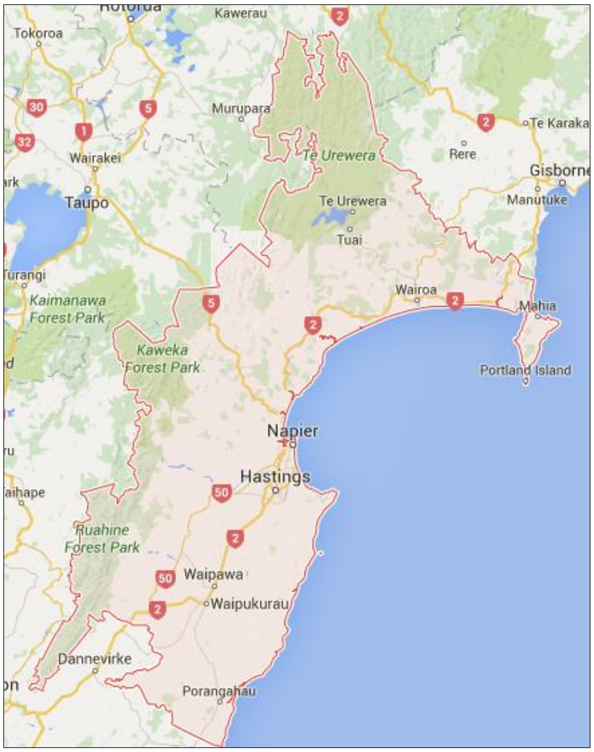

Figure 3-4: Hawke's Bay Regional Map

Source: Google maps – Hawke’s Bay region. https://www.google.co.nz/maps/place/Hawke's+Bay/@-39.302624,175.7947779,8z/data=!3m1!4b1!4m5!3m4!1s0x6d69b343861c81c1:0x454e29826582867!8m2!3d-39.7711616!4d176.7416374. 6/07/16

The Hawke’s Bay Region covers an area of 14,200 square kilometres and hosts a population of approximately 166,368 (Stats NZ, n.d.), with approximately 130,000 living in its major centres – the cities of Napier and Hastings. Local government in the region consists of the Hawke’s Bay Regional Council, Wairoa District, Hastings District, Napier City, and its southernmost district, the Central Hawke's Bay District. The region is renowned for its horticulture, with large orchards and vineyards on the plains. In the hilly parts of the region sheep and cattle farming predominates, with forestry blocks in the roughest areas. Hawke's Bay is the country's oldest winemaking region and is New Zealand's leading producer of red wine and is also home to a significant concentration of Art Deco architecture. The Hawke’s Bay region has over 350km of coastline, all of it exposed to tsunami generated in the Hikurangi Margin. In an all-of-boundary event, tsunami inundation is expected to travel 4 km inland, with a flow depth of up to 3 m in Napier city centre (Fraser et al., 2014). The region’s natural hazard management is administered through Hawke’s Bay Regional Council, via the Hawke’s Bay Emergency Management Group[2] as well as through the land-use planning function via district plans and the Regional Policy Statement (RPS). The Group’s website states that it reduces natural hazard risk thorough: “hazard research, land use planning and educating the community about hazards so they can reduce the risk they face” (HBEMG, 2016b). The Group’s primary hazard risk management initiative is the ‘Hawke's Bay Hazard Information Portal’[3], a web-based GIS data viewer, which aims to make information on the nature and location of hazards more accessible, in order to assist people and organisations make better risk management decisions (HBEMG, 2016a).

3.6.3 Case study area 3: The Gisborne Region

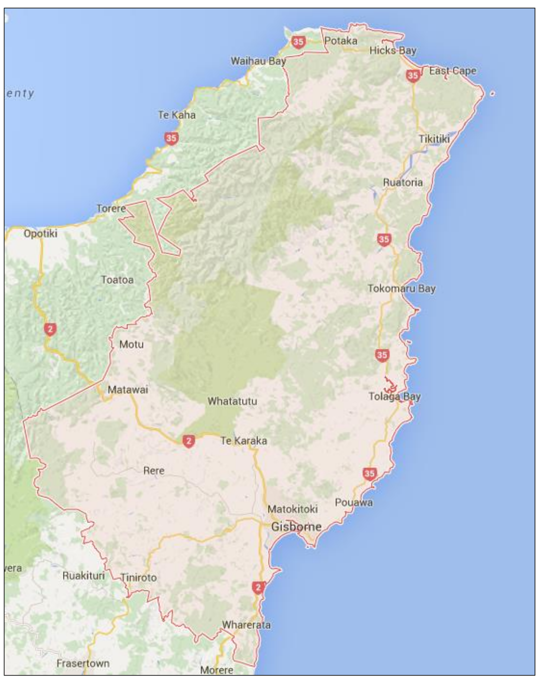

Figure 3-5: Gisborne Regional Map Source: Google maps – Gisborne region. https://www.google.co.nz/maps/place/Gisborne/@-38.2508563,177.3457326,9z/data=!4m5!3m4!1s0x6d65be53821b0acb:0xccabbe7b4ce8f81e!8m2!3d-38.1309688!4d178.0118473. 6/07/16

[2] Hawke’s Bay Emergency Management Group – http://www.hbemergency.govt.nz/. 07/07/16
[3] Hawke's Bay Hazard Information Portal – http://www.hbemergency.govt.nz/hazards/portal. 07/07/16

The Gisborne Region covers an area of 8,386 square kilometres and hosts a population of approximately 47,517 (Stats NZ, n.d.), with approximately 35,700 living in its only main centre, the city of Gisborne. Local government in the region is administered by Gisborne District Council, a unitary territorial authority, as described in section 2.3.3. Agriculture has been the most important industry since earliest settlement. However, agriculture has diversified over the years and now includes forestry, viticulture, and horticulture, which are now the backbone of the district's economy. Gisborne sits at the northern section of the Hikurangi Margin in an area of more moderate subduction than further south, yet has a history of tsunami events. In 1947, the Gisborne region experienced two tsunami with run-ups of up to 10 and 6 metres respectively. Power et al. (2008) suggest that these tsunami may recur in the Gisborne region as frequently as ~70–80 years.

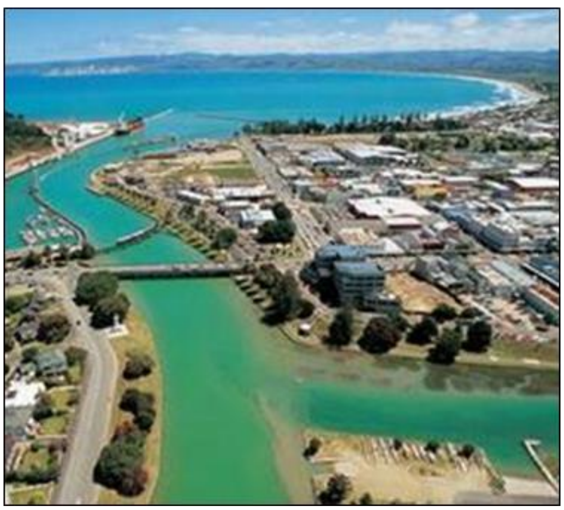

Figure 3-6: Coastline in front of Gisborne City. Source: Gisborne, New Zealand. http://www.internnzoz.com/human-resources-internships-in-new-zealand.html. 27/06/16

3.7 Limitations of methods used

Some participants were unable to attend either focus group sessions (Phase 1) or semi-structured interviews (Phase 2), due to work requirements at the time that these phases were conducted. This was managed through the use of multiple qualitative methods in this research, as well as two series of semi-structured interviews in the Hawke's Bay and Gisborne areas, which allowed for participants to be involved in the research who were unable to participate previously.

Participants may have felt uncomfortable revealing certain information in Phases 1 and 2. This was addressed across all phases with participants being provided with information sheets that explained the purpose and aims of the research and being reminded of their right to withdraw from participation at any time. They were also assured that all data collected was anonymous and pooled across locations in the study areas. Participants seemed comfortable providing information and no one withdrew from participating in the research.

It is important to acknowledge my own positionality in conducting qualitative research within a constructivist paradigm. I adopted the position of 'participant as observer' (Bryman, 2008), where I interacted with the participants and expressed my own thoughts and opinions. My position as the researcher, coming from a perceived position of scientific knowledge and therefore authority or power, may have influenced participants' views, the conversations we had with each other, and the data that was collected. I was careful to (re)introduce myself at the beginning of Phases 1 and 2, and explained my background having worked in local government natural hazard risk management. This built rapport with participants and enabled comfortable, free flowing conversation. Furthermore, conversations were kept on track using the semi-structured question guides in Phase 1 (Table 3-4) and in Phase 2 (Table 3-5).

There was potential that participant numbers for the focus group sessions (Phase 1) would be too small, that one participant might dominate the discussion, or that participants wouldn't adequately represent the focus of the research. None of these issues presented themselves; however, in one focus group session only emergency management practitioners were present. This was not an issue as the focus of the research was on the CDEM role, but the lack of integration with other natural hazard management roles within the council was noted.

Presenting a working RiskScape tool was a major aspect of the qualitative interviews (Phase 2) for gaining an understanding of participant views on the value of the tool for communicating risk and influencing perceptions. However, at the time that the qualitative interviews were undertaken, the RiskScape risk modelling software was not able to run tsunami scenarios on my lap-top computer within the 1–2 hour interview timeframe. I addressed this in interviews by describing the intended capabilities of the RiskScape model and showing pre-prepared outputs of what the modelled scenario would be for the region in which I was interviewing participants. Participants were able to provide their thoughts and opinions on the use of risk modelling. However, an interview about the use of risk modelling without actually being able to use a risk model may have influenced the balance and quality of data that was gathered.

Decision makers, i.e. local politicians, were not invited to the focus group sessions (Phase 1) or qualitative interviews (Phase 2). This was because the focus of the research was on practitioners' thoughts and opinions of risk modelling and natural hazard policy in local government. However, the participation of decision makers in the qualitative interviews would have improved data quality, especially for how risk modelling influenced them to enable the development of risk-based policy procedure.

There was potential that the categorisation used for content analysis of the documents in Phase 3 was faulty (Stemler, 2000). This was managed through consideration of criteria used in previous analyses of New Zealand local government natural hazard policy and by aligning the criteria used in this research with criteria previously used by Saunders et al. (2015) in their evaluation of the use of land use and emergency management policy documents for natural hazards in New Zealand local government.

Relevant policy documents or references within the documents may have been missed in the document analysis for Phase 3. This was addressed by me asking participants, who I had previously developed a relationship with through Phase 1 and 2, to send me relevant policy documents. I also conducted an additional internet search within respective council websites for documents that may have been overlooked by participants. All documents were required to be operational at the time of content analysis and refer to natural hazard risk management within the Wellington, Hawke's Bay, or Gisborne regions. The number of documents analysed (58 documents) was considered to have reached the point of saturation (Fusch & Ness, 2015;

Patton, 2015) where no new information was discovered in the data analysis, and that any missed documents or references would not have significantly altered the results.

My personal biases will have influenced my analysis and interpretation of the data, which challenges the validity of the findings and subsequent discussions within my research manuscripts. The influence of personal biases is acknowledged with regards to the validity of qualitative research (Galdas, 2017; Morse et al., 2002) and can never be removed. The validity of this qualitative research has been addressed through the rigour of the research methods used across all three phases and through triangulation and member checking. It was also validated through explicit consideration and discussion of themes between Doctor Kate Crowley and myself for Phase 1, and through review and moderation by my PHD supervisors for Phases 2 and 3.

4 [1st manuscript] Risk Modelling as a tool to support natural hazard risk management in New Zealand local government

4.1 Overview of this chapter

This manuscript draws on focus group sessions with natural hazard risk practitioners in Aotearoa New Zealand local government to explore how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk. The manuscript discusses that while there is definite interest and engagement in the use of risk modelling from emergency management and other natural hazard risk management practitioners within local government, the use of risk modelling to better understand and communicate natural hazard risk continues to be challenged by the disconnect across the science-policy interface and resulting practice. The conclusion summarises these challenges and makes recommendations to span the science-policy interface and enable risk modelling as a communication tool to better develop policy and procedure for natural hazard management.

Table 4-1 positions this manuscript in relation to the other manuscripts within this thesis and the research questions that it has aimed to answer.

<table>
<tr><th>Chapter 4 –
1st Manuscript</th><th>Chapter 5 –
2nd Manuscript</th><th>Chapter 6 –
3rd Manuscript</th><th>Chapter 7 –
4th Manuscript</th></tr>
<tr><td>Explores how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk in Aotearoa New Zealand local government.</td><td>Think piece exploring how risk modelling is perceived and used by the policy making, land-use planning, and emergency management functions within Aotearoa New Zealand local government.</td><td>Explores the thoughts and opinions of natural hazard risk practitioners regarding tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development.</td><td rowspan="4">Explores the complex system of challenges for the application of natural hazard risk management within local government as a whole and how the science-policy-practice interface can interrupt the complex system's overall dynamic.</td></tr>
<tr><td colspan="3">RQ1. How is natural hazard risk modelled information perceived and acted upon by local government?</td></tr>
<tr><td colspan="3">RQ2. How is risk modelling informed by natural hazard management?</td></tr>
<tr><td></td><td colspan="2">RQ3. How are natural hazard management policies and procedures informed by risk modelling?</td></tr>
<tr><td colspan="4">RQ4. What are the risk communication barriers and enablers that limit or contribute to efficacy for risk management for local government?</td></tr>
<tr><td></td><td></td><td colspan="2">RQ5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?</td></tr>
</table>

Table 4-1: Positionality of the first manuscript to the thesis

4.2 Manuscript preparation and publication

I prepared this manuscript following development of the NIWA Report – Risk Tool and Data Needs: Civil Defence and Emergency Management in New Zealand (2016), jointly authored by Dr Kate Crowley, Dr Sally Potter, and myself. I conducted the data collection and analysis with Dr Kate Crowley, which then contributed to this manuscript. I prepared the manuscript as the primary author with Dr Kate Crowley, Dr Sally Potter and my supervisors, Dr Wendy Saunders and Dr David Johnston, as co-authors. The co-authors provided guidance on the systematic review analysis, gave insights into patterns in the data collected, and offered feedback on the content and structure of the manuscript. I prepared the final manuscript for submission to the journal. The manuscript, published in 2018 by the International Journal of Disaster Risk Reduction, was accepted with minor revisions by the journal (Crawford et al., 2018a).

4.3 Abstract

Due to New Zealand's exposure and vulnerability to natural hazards, it is important for local government to have tools that enable effective use of its natural hazard risk information. This manuscript explores the use of risk modelling as a tool that can support local government to better understand, manage, and communicate natural hazard risk. Focus group sessions were held with emergency management and other natural hazard practitioners in councils across New Zealand to understand their perceptions on the value of risk modelling tools, particularly 'RiskScape'. While practitioners see the value in the use of risk modelling relating to communication, decision making, planning, and emergency response purposes, they also see a number of challenges. Challenges identified for the use of risk modelling relate to how emergency management and natural hazard risk is perceived and managed, issues with connecting information and developing data, and the capability of risk modelling software. Underlying these challenges is the recognition that while risk modelling can help span the science-policy interface, it is the problems with this interface that slow its development. However, with ongoing mutual engagement, risk modelling can become an effective tool to communicate natural hazard risk and better inform natural hazard policy and procedure.

4.4 Introduction

> *'Sometimes it does us a power of good to remind ourselves that we live … where two tectonic plates meet, in a somewhat lonely stretch of windswept ocean just above the roaring forties. If you want drama – you've come to the right place'* (Sir Geoffrey Palmer, cited in MCDEM, 2004, p. 2).

New Zealand is an island nation in which events such as earthquake, volcanic activity, tsunami, flooding, storm, and landslides occur with sufficient intensity that substantial damage and loss of life results (King & Bell, 2006). Given the severity of natural hazard risks, it is an increasingly important focus for national and local government to ensure natural hazards are understood and managed effectively. However, local government's understanding and management of natural hazard risk is fraught with challenges, including uncertainty over how natural hazards should be managed (LGNZ, 2014; Saunders et al., 2015), scarce data on natural hazards (MWH, 2016; Tonkin &Taylor, 2016), and limited appreciation of natural hazard risks (LGNZ, 2014; Tonkin &Taylor, 2016).

Underlying these challenges is the disconnect of 'science to policy'. While scientists, policy makers, and practitioners agree on the importance and value of science-informed policy and practice, bridging the science to practice gap is not a simple task and depends on a mutual spirit of partnership and interest between the scientific and practice communities (Vogel, 2007). Kilvington and Saunders (2016) reflect on this in their review of how natural hazard science is incorporated in land-use planning in New Zealand, recognising that "despite genuine and ongoing efforts to improve the relationships between science information users and producers, research agencies still struggle in many ways to fully transition their communication practice towards new ideals" (Kilvington & Saunders, 2016, p. 4).

Along with this, the need for improved risk communication between science, policy, and practice has been increasingly recognised (Jönsson et al., 2016; Kuhlicke & Demeritt, 2014; WSS Fellows on RIA, 2014). However, much of the research has focussed on the tenets and mental models of risk communication (Bostrom et al., 2008; Fischhoff et al., 1993; Khan & Kelman, 2012; Lindenfeld et al., 2014) and, while there has been a call for the use of tangible heuristics and models to support decisions for effective risk management (The World Bank, 2014; WSS Fellows on RIA, 2014), little is known about how effective risk models are as a communication tool for natural hazard risk management.

The term 'risk modelling' can be applied to many frameworks and guidance. Within this paper, we focus on risk modelling as a software application, based on a risk assessment framework, to assess the consequences of a natural hazard event. Risk modelling is important as understanding the impacts and consequences of a natural hazard event is an essential building block for resilience (Crowley, Feaeff, Macara & Duncan, 2017). This paper explores the perception and use of risk modelling, with specific reference to the 'RiskScape' model, as a tool to support local government in New Zealand to better understand and communicate natural hazard risk.

This paper begins by explaining the structure for how natural hazard risk management is applied within New Zealand local government. It details the role of emergency management, known in New Zealand as CDEM (Civil Defence Emergency Management), within that natural hazard risk management function, and recognises the complicated legislative environment in which this takes place. We then describe risk modelling as a tool to support natural hazard risk management and introduce the RiskScape modelling tool. From here we explain our use of focus groups to gather data on how natural hazard risk practitioners perceive risk modelling and examine three key themes that emerged from analysis of the results: 1) ‘CDEM within and across councils’; 2) ‘drivers and needs for risk modelling’; and 3) ‘risk data sources and pathways’. We discuss our findings, setting out the challenges and opportunities for the use of risk modelling, and how these are driven by the existing disconnect across the science-policy interface. We conclude by giving recommendations for how the science-policy interface can be improved in local government, to better enable its use of natural hazard risk modelling, which can then inform improved natural hazard risk policy and procedure.

4.5 Local government natural hazard risk management

The responsibility for natural hazard risk management in New Zealand is devolved from central government legislation to local government for application, with local government operating under a 3-tiered structure of regional and district councils. Regional councils manage a larger geographic area and are comprised of between one to ten district councils. As such, regional councils play more of a directing role, developing regional policy which the district councils comply with.

Figure 4-1: Map of New Zealand with Regional Council Boundaries. Source: New Zealand Regions (n.d.)

While regional and district councils have slightly different functions, both tiers of local government fulfil responsibilities including:

- sustainable well-being;
- environmental management;
- emergency management and civil defence preparedness;
- infrastructure, including roads, water, sewerage, and stormwater;
- environmental health matters, including building control, public health inspections; and
- controlling the effects of activities (including hazardous substances, natural hazards, and indigenous biodiversity), noise, and the effects of activities on the surface of lakes and rivers (DIA, n.d.).

Natural hazard risk management is spread across all of these responsibilities and is achieved through a combination of national and local policies, plans, and strategies. It requires many council roles to work together in a coordinated way and consists of high-level and widely-interpretative policy guidance (LGNZ, 2014). Given the breadth of natural hazard policies and the differences in how they are managed, there is no formal approach for how hazard risk management is achieved, or which council function owns it (LGNZ, 2014; Basher, 2016).

Within this complicated policy environment sits Civil Defence Emergency Management (CDEM). CDEM in New Zealand promotes the sustainable management of hazards and encourages communities to manage natural hazard risk via a framework of Reduction, Readiness, Response, and Recovery, known as the 4Rs. By addressing the consequences of these hazards, the focus can move to measures for reducing the risks and for managing the impacts when they occur. The framework for how the 4Rs are applied is led by the Ministry of Civil Defence & Emergency Management (MCDEM) through the CDEM Act, via CDEM Groups (Lee, 2010). CDEM Groups are a partnership of the district and regional authorities across a region, in conjunction with emergency services, utilities, management groups and other government departments to identify hazards and risks. CDEM Groups develop Group Plans to manage those hazards and risks following a risk-based approach:

> *The requirement to practice sound risk management is implicit throughout the CDEM Act. CDEM Groups are required to apply risk management to their planning and activities. Whilst planning is not a linear process and may involve many iterative steps, it is expected to follow a risk management based approach (MCDEM, n.d. a).*

MCDEM is also the national focal point for New Zealand's implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015b; MCDEM, n.d. b). This involves providing leadership within a multi-sectoral, holistic approach to implementing disaster risk reduction and coordinating progress reporting, as required under the monitoring regime of the new framework.

4.6 Natural hazard risk modelling

Natural hazard risk modelling involves combining hazard impact scenarios with exposure data and vulnerability functions. The output is an estimate of loss, depicted in various ways including economic cost, human casualties or fatalities, building damage states, societal disruption, and other types of consequence given the severity of the hazard.

Demand for natural hazard risk modelling has significantly increased over the last few decades (The World Bank, 2014). Researchers, policy makers, and practitioners increasingly seek to use risk modelling to scope the consequences for hazard scenarios they know people are exposed to but have little historical information about. Pondard and Daly (2011) illustrate how risk modelling can give a more comprehensive insight into natural hazards and their socioeconomic consequences, setting out three key benefits:

1) a clearer overview of geographical concentrations of natural hazard risks, across different frequencies and magnitudes;
2) quantification of potential physical damage, business interruption, and casualties; and
3) identification of key risk drivers.

As such, a clearer, more comprehensive picture of the uncertainties and consequences of natural hazards provides policy makers and decision makers with a better starting point to communicate and decide on how they manage the cost and benefits of risk reduction measures (Edwards et al., 2012; King & Bell, 2006; Newman et al., 2017; Pondard & Daly, 2011; Stein & Stein, 2014). However, risk models also come with a number of limitations relating to the development and modelling process itself and their uptake and application by users. A model is only a representation of reality and is therefore defined by a series of assumptions. These assumptions are informed by imperfect historical records, our incomplete knowledge of natural processes, limitations in how the model describes those natural processes, as well as perceptions around exposure and vulnerability. Furthermore, each of the components within a risk model has its own set of associated uncertainties. Table 4-2 outlines these components as set out by Van Asselt (2000) in her figure – 'Uncertainty in the modeller's and decision-maker's view':

1.	Technical – from the quality or appropriateness of the input data used to describe the system, from aggregation (temporal and spatial) and simplification, as well as from lack of parameters from data and approximations.
2.	Methodological – due to uncertainty in equations and model structures.
3.	Epistemological – uncertainty in levels of confidence and model validity.
4.	Model operation uncertainties – due to hidden flaws in technical equipment, and/or accumulation of uncertainties propagated through the model.

Table 4-2: Four components of modelling uncertainty

As these uncertainties compound, the modelled output may move further away from 'accuracy', providing only an order of magnitude estimate (GFDRR, 2014), which may not give much assurance for stakeholders and decision makers. Also, the application of risk modelling tools relies on sound data being available in a format that can be input into the model; the technical capacity to employ the modelling tool to produce results that are relevant and accessible; trust from users in the validity of the results; and mandate from decision makers to use the tool (The World Bank, 2016). If any aspect of this is inhibited, then confidence in the practice of risk modelling can be diminished.

The RiskScape risk modelling tool has been developed over the last ten years in New Zealand through a joint venture between GNS Science and the National Institute of Water and Atmospheric Research (NIWA) (King and Bell, 2009). RiskScape is designed to meet demand for a natural hazard impact and loss modelling tool for New Zealand conditions. It creates direct and indirect loss estimates for a number of hazards, for all types of assets, networks, and populations. Figure 4-2 sets out how RiskScape combines hazard, asset and vulnerability modules through a data selection process, producing both individual and aggregated outputs quantifying a range of economic and social consequences (RiskScape, n.d.).

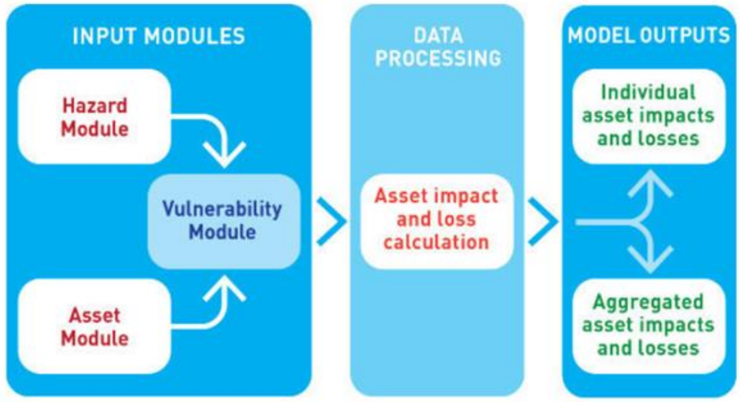

Figure 4-2: The RiskScape Model Framework. Source: RiskScape model framework (n.d.)

RiskScape's aim is to support the investigation, planning and response activities of councils and stakeholders by providing decision makers with information on direct and indirect socio-economic losses and casualties across the spectrum of natural hazard threats facing a region. This information is then used to assist the council or organisation in developing natural hazard risk management policy and procedure, as well as in responding to actual events (King & Bell, 2009). Recent disaster risk management projects using RiskScape include: The Pacific Risk Tool for Resilience project (PARTneR), developing real-life case studies that address the impact of natural hazard risks for land-use planning and emergency response needs (Crowley & Crawford, 2016), as well as building damage assessments and loss estimates following the 2016 Kaikoura Earthquake.

Reducing the uncertainty within the risk modelling process has been a focus of natural hazard science for many years (de Moel & Aerts, 2011; Douglas, 2007; Merz et al., 2010; Nilsen & Aven, 2003; The World Bank, 2016). However, less consideration has gone into how stakeholders perceive and apply such tools. This is supported by Komendantova et al. (2014) who discuss that while models have the potential to support decision makers with risk information, this is a two-way communication process, where the feedback from stakeholders also informs the usability of the model and how it is applied. As such, the focus of this study is to explore how CDEM practitioners perceive the value of risk modelling tools, such as RiskScape, to support natural hazard risk management, rather than on the uncertainties of the physical modelling process.

4.7 Method

Engaging across the science-policy divide requires an understanding of not just the policy for applying natural hazard risk management in local government, but the motivations, challenges, and ethos of that sector (Vogel et al., 2007). As such, the research team selected the use of focus group discussions. A focus group is a qualitative research method which quickly enables a group of people to discuss their perceptions, opinions, beliefs, and attitudes on the use of the RiskScape risk modelling tool for natural hazard risk management. This method provides an interactive group setting where participants are free to talk with other group members, enabling open and creative discussion and producing data and insights that would be less accessible without the interaction found in the group (Flick, 2006).

Five CDEM Groups participated in the research, each with varied attributes relating to the size of the region for which the CDEM Group has responsibility, CDEM Group management structure, and the regional hazard landscapes. Focus group sessions were held, one at each of the following regions:

- Wellington
- Hawke's Bay
- Canterbury
- Nelson/ Tasman (combined CDEM Group)
- Bay of Plenty.

Each session had six to fifteen participants attending, including those from CDEM roles as well as from other natural hazard risk management roles across the council spanning land-use planning, policy writing, engineering, hazard analyst, and GIS technician roles. The participants were identified and invited by a 'gate keeper' in each region. A gate keeper is a person who is able to transfer information from the external environment to colleagues within their organisation, with a primary interest in personal use of the information gathered (Macdonald & Williams, 1993). The gate keepers were all council staff and were a CDEM officer, land use-planner, or hazards advisor.

Participants were encouraged to discuss the use of risk modelling via a semi-structured approach framed by guiding questions as set out in Table 4-3. However, once conversation was stimulated, most focus group sessions did not need prompting from the guiding questions as they were automatically covered within the richness of discussion.

Understanding the context: • What is the structure of CDEM here? • How does CDEM operate within council? **Understanding information management:** • How is this group linked with other departments and wider natural hazards risk management within the council? • How do you communicate risk and hazard information and make decisions across the council and within CDEM? • What information do you use? • Where does it come from? • Do you create or provide your own information? • How would you like to receive or share risk and hazard information? **Discussion based on examples:** • Do you have any examples of risk-informed decision making or response? • What went well in terms of information requirements? • What information was missing or what were the information gaps?

Table 4-3: Focus Group Guiding Questions

It is important to recognise the influence of the researchers' position, power, and perceived role on this process (Landström et al., 2011; Whitman et al., 2015). In this case the research team were positioned as 'participant-as-observer' (Bryman, 2008), where the three researchers fully participated in the discussions, with the other members of the focus group having been informed, at the beginning of the focus group session, of the research team's backgrounds spanning natural hazards, disaster risk reduction, emergency management, and risk management.

Data were captured through notes taken during the focus group sessions and through dictaphone recordings. The data was then transcribed and thematically analysed to pinpoint, examine, and record its patterns or 'themes'. Thematic analysis was used because it "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006, p. 5). Themes were individually identified or 'coded' by the research team using an inductive, bottom-up approach, where the themes emerge from the data itself (Patton, 2015). Two qualitative analysis software packages were used for this – NVivo and QDA Miner 4 Lite. Following the analysis, the individually identified themes were reviewed and regrouped into mutually-agreed themes. This approach is based on content analysis, a process of organising information into categories (Bowen, 2009). Content analysis is mainly used to analyse subjective viewpoints (Flick, 2006), and as such is an appropriate method for this research. The goal of content analysis is to reduce the material; for this research it meant that less relevant themes were skipped and then the remaining similar themes were bundled and summarised.

Potential issues considered for this focus group method were that participant numbers would be too small, that one participant might dominate the discussion, or that participants wouldn't adequately represent the focus of the research. None of the issues presented themselves; however, in one focus group session only emergency management practitioners were present. This was not an issue as the focus of the research was on the CDEM role, but the lack of integration with other natural hazard management roles within the council was noted and is expanded upon in section 4.8.1.

4.8 Results

The themes that emerged through analysis of the focus group discussions are: 1) 'CDEM within and across councils'; 2) 'drivers and needs for risk modelling'; and 3) 'risk data sources and pathways'. These themes interact and influence each other and are examined in turn.

4.8.1 CDEM within and across councils

Given the lessons from the literature highlighted in section 4 focussing on the uptake, application, and mandate for the use of risk modelling tools, it was important to understand the context, role, and structure of each CDEM Group. It appeared that their perceived and real role within the council influences their depth of engagement with risk-reduction decision making and the receiving and provision of risk information. The groups discussed the perception that CDEM are just for response and yet they all agreed that CDEM must work across each relevant council department in order to address the 4 Rs:

> *… usually civil defence is the 'gimp', if you remember that movie, usually they sit in a box and they only bring the gimp out when things get really, really bad…when it's over they put civil defence back in the box. So I think the challenge is for civil defence to be out of the box all the time and actually be working with other parts of local authorities.*

Some groups recognised the confusion of CDEM being responsible for natural hazard risk management and yet it being a shared function across most departments and groups across council. There was disagreement within each of the focus groups between raising the profile of CDEM within council decisions and discussions that require a risk-informed approach versus labelling natural hazard risk management as a CDEM process alone:

> *We are all doing it and this is where some confusion comes from…just because it has not got a CDEM label on it, it is sometimes not classed as CDEM work. But it is all going on and what we need to do is look at what is going on and make sure that we include it in this, e.g. flood mapping is part of EM [emergency management] and weather forecasting as well.*

Entry points for CDEM to engage in natural hazard risk management across council were a common point of discussion. There were a spread of approaches ranging from complete integration of CDEM across council, which naturally provided easy access to important discussions and decisions, through to issues where CDEM remained isolated and had to push their way into discussions that they were able to find out about. The ease of integration across council appeared to stem from the influence of key individuals within the group, either in terms of a specially designated 'knowledge broker', people that create connections between researchers and their audience (Meyer, 2010), or through gate keepers with their ability to influence colleagues to connect to, use, and share external knowledge.

Most participants described their CDEM function as engaging with others within and across councils through a subcommittee structure. Multiple subcommittees on specific areas, such as ‘Readiness and Recovery’ and ‘Communications’, provide an opportunity for staff to meet and share natural hazard information. Despite this positive engagement there remained an undercurrent of opinion that the CDEM function is often isolated from certain decisions, in particular land-use planning and natural hazard policy development.

In summary, the key influencers on CDEM’s role in council natural hazard risk management are the misconception of its role, uncertainty over how it works with other council roles to manage natural hazard risk, and its level of integration across council functions. These influencers impact on CDEM’s ability to engage in decision making, drive and develop relevant risk data and information, and access risk information for their needs.

4.8.2 Drivers and needs for risk modelling

Participants identified a range of regulatory and non-regulatory activities which would be supported by natural hazard risk modelling. These include:

- Communication to the public and decision makers
- Real-time event response
- Exercise development
- Contingency planning
- Generic plans, such as land-use and civil defence plans
- Policy development, such as Regional Policy Statements.

The two most frequently discussed activities focussed on risk communication and real-time event response. However, cutting across these activities were common threads relating to uncertainty, external influencers, and experience. Each of these is discussed in further detail below.

4.8.2.1 Risk Communication

The complex policy setting for natural hazard management in local government drives the need for CDEM to communicate risk to at least two distinct audiences – the public and council decision makers. The need to effectively communicate risk requires CDEM staff to understand the risk in their region.

While the CDEM function is integrally linked with protecting the community from the effects of natural hazards, this is not just in a response capacity. Communicating natural hazard risks was recognised not only for increasing hazard awareness, but also as a mechanism for gaining input and agreement for council policies designed to reduce community exposure and vulnerability:

> *[It] would be a huge benefit for us to be able to show [RiskScape results] to our politicians, to our community members, so they could understand what the impacts of these events might be so that they are encouraged to take those mitigation options that we believe they need to take now.*

Participants discussed the importance of communicating risk information, specifically economic loss information, for influencing decision making on future development:

> *Managing development …making sure that we don't develop in risky places. Being aware and making sure the right rules are in place.*

> *If you've got an economic reason to be resilient, you're more likely to get the support for that.*

Real-time information participant discussions separated 'real-time' information needs from pre-event or preparedness information needs, concentrating on the need for rapid and updateable information for both the multi-hazard environment and social vulnerability and capacities of the community. The speed of data access, analysis, and interpretation was a critical discussion point, with most participants agreeing that the ability to gather or produce real-time information during a crisis would be beneficial:

> *In terms of CDEM we need information that is as up to date as possible. We can use it as a response tool as long as the data is available.*

4.8.2.2 Uncertainty

Underlying and giving context to all discussions was a theme focussing on uncertainty. While it was acknowledged that risk is a measure of uncertainty and that modelling produces uncertain results, participants were not necessarily concerned with knowing the detailed uncertainty of the modelling. Rather, they were concerned with the order of magnitude of the uncertainties for decision-making processes:

> *The need [from science and researchers] is around what is uncertain and what is not uncertain.*

4.8.2.3 External Influences

All focus group sessions included a reference to an external influence and/or personal experience as a driver for better understanding and assessing natural hazard risk. Predominant among these were references to the 2011 Great East Japan Earthquake and the 2010-ongoing Canterbury Earthquake Sequence, for example:

> *It could be just knowledge of Christchurch occurring, tsunamis overseas, and you see the damage to Japan, and of course the properties are very similar to here. And suddenly that brings it to the forefront of your mind that it could actually happen here…. And we need to think about that a little bit.*

Understandably, this was most felt by the Canterbury participants, who are still engaged with the recovery from the 2010-ongoing Canterbury Earthquake Sequence. The link between disaster experience and preparedness is well documented, where people's deliberations about preparedness are not only attributed to individual cognitive processes but are also influenced by their interactions with wider society (Becker et al., 2012; Becker et al., 2013; Donahue et al., 2014; Paton, 2003). This heightened awareness of risk and preparedness was not only reflected in the Canterbury Region but has boosted changes across all five regions visited, with CDEM instigating risk assessments and reassessing how CDEM Groups are structured and coordinated.

In summary, participants presented a proactive and pragmatic view on the 'drivers and needs for risk modelling' theme. It was implicitly agreed that risk data was valuable for communication and decision-making purposes with participants also seeing a strong need for its use in a real-time, emergency response capacity.

4.8.3 Risk data sources and pathways

Essential to discussions was CDEM's ability to access natural hazard risk data and the relevance of information available. In most cases, the CDEM Groups described themselves as 'gatherers' rather than 'generators' of risk information, and therefore reliant on a range of external information sources from other parts of the council as well as from outside agencies:

> *We pull this information from various consultancies, research, local authority information and science.*

As a result, all the groups reported similar challenges arising from lack of data where neither the council nor outside agencies had seen it as their responsibility to collect the data. Participants also reported a lack of knowledge of what data their council held, adding that even if they knew of its existence it was often in a format that could not be used outside of its original context. For example:

> *Various [councils] have asset databases – I guess we have. It's important that we know if the information is modelled or surveyed.*

> *[The data] was never really designed for CDEM. We can use it … as long as the data is available.*

Another challenge lay in the cost of data collection or management, where the cost of collecting data for cross-council use did not meet the benefits and was abandoned:

> *Feedback from the planners was that it was very expensive inputting data and that there was other ways that they could make those calculations.*

In light of the challenges in accessing and using natural hazard risk data, some CDEM Groups have seen the need to become proactive instigators for developing natural hazard risk data and are organising forums in isolation in an attempt to share information:

> *The strength is also about the process. Getting everyone together and having a discussion and sharing ideas on what we are not doing and where we are going in the future…should identify information for the gaps that we are now addressing.*

Additionally, those CDEM Groups that are taking the lead in risk information generation are also considering how they will manage and share this information at a regional level, for example:

> *The hazard portal is a one stop shop, so it's an authoritative source for hazard information in the region. So instead of someone in a district grabbing an old book and thinking this is my flooding risk, they know that actually if I want to know the most current information, this is where I go. So if an update is done by one of the engineers it's automatically on the website and reflecting the current picture.*

In summary, while proactive measures towards managing natural hazard risk are developing across a number of the CDEM Groups visited, results show a challenging environment for CDEM's use of risk modelling as a tool to better understand and manage natural hazard risk. This is not only because of confusion over CDEM's role and its limited influence for decision making, but also because of lack of data availability and suitability. As such, results show that there appears to be no standard approach to generating or sourcing risk data and there is no simple pathway for its communication.

4.9 Discussion

There is definite interest and engagement in the use of risk modelling from CDEM and other natural hazard risk management practitioners within local government. The outputs from risk modelling are seen as beneficial for managing emergency events, increasing natural hazard awareness for the public, and also for communicating risk to decision makers for cost-benefit analysis, risk reduction, and land-use development measures. As such, participants agreed that risk modelling tools, like RiskScape, can help span the communication gap across the science-policy interface, providing information that better enables decision makers to develop improved natural hazard management policy.

Yet the use of risk modelling to better understand and communicate natural hazard risk continues to be challenged by the disconnect across the science-policy interface and resulting practice. Even though the risks are acknowledged by the scientists and practitioners, there is a disconnect between them, the decision makers, and resultant policies and procedure. Drawing on the core themes from the focus groups and literature set out in section 4.8 (Results), we discuss the key contributors to this disconnect.

4.9.1 Misperceptions of the CDEM role within council

Goal Two of the National CDEM Strategy (MCDEM, 2007) aims to reduce the risks from hazards to New Zealand, achieved by:

- improving the co-ordination, promotion, and accessibility of CDEM research;
- developing a comprehensive understanding of New Zealand's hazardscape;
- encouraging all CDEM stakeholders to reduce the risks from hazards to an acceptable level; and
- improving the co-ordination of government policy relevant to CDEM (MCDEM, 2007, p. 11).

However, the results in section 4.5.1 show that CDEM in New Zealand is often misperceived as solely having a emergency response role. Emergency management's bias for emergency response has long been known (Britton & Clark, 2000; Petak, 1985; Waugh & Streib, 2006), where the employment background of CDEM practitioners in response-focussed military or police roles can result in a greater tendency to focus on CDEM response activities over risk reduction. Donahue et al. (2014) add that elected officials support this by investing more on emergency response than risk reduction because electoral payoffs are higher if they do so. Furthermore, while CDEM practitioners can see the value in risk management, the benefits of risk management are uncertain, which lessens their willingness to give action to risk-reduction measures (Edwards et al., 2012; Manning et al., 2015). As such, with the value of CDEM seen more easily through its emergency response activities, CDEM is marginalised as mainly a response role, with that marginalisation inadvertently supported by the CDEM practitioners themselves.

The need to better understand the impact of organisational culture and mental models for CDEM is recognised by Doyle et al. (2015), where they recommend the use of 'shared mental models' to overcome misconceptions of other people's roles. A shared mental model requires an understanding of each other's knowledge, skills, roles, anticipated behaviour or needs, and can be developed a number of ways, including inter and intra-team networking, exercising, and role-swapping (Doyle et al., 2015). By building shared mental models, CDEM and other natural hazard risk practitioners can improve the understanding of their function, better coordinate their roles, and break down misconceptions.

4.9.2 Communicating uncertainty

The uncertainties associated with risk data has traditionally been recognised as a challenge, where compounding assumptions have the potential to misrepresent the risk, as well as mislead practitioners (Donovan & Oppenheimer, 2015; GFDRR, 2014; Stein & Stein, 2012). However, as related in section 4.5.2, this was not an issue for the participants. The participants wanted some communication on the uncertainty associated with the modelling process but not in a detailed probabilistic/mathematical sense. As with Doyle et al. (2011), Doyle et al. (2014) and Henrich et al. (2015), participants were more interested in the uncertainties being framed in a way that they could apply to their decision-making needs. RiskScape's ability to spatially depict consequences is one option for achieving this, where depicting the uncertainty of the risk in map form is beneficial for decision makers (Kunz et al., 2011; Mason et al., 2016; Spiegelhalter et al., 2011). However, as Thompson et al. (2015) point out, "conveying such complicated data on a static map image without careful consideration of user perspectives or context, may result in contrasting interpretations, misunderstandings, or aversion to using the map" (Thompson et al., 2015, p. 1)

4.9.3 Immaturity of risk modelling and its data

Another challenge is due to natural hazard risk modelling still being a new application. The results in sections 4.5.2 and 4.5.3 support that, while work is ongoing to further develop risk models, they cannot yet compute multi-hazard events or cascading consequences, and cannot be used to their fullest extent due to unavailability of data and expense of developing it. Even though practitioners see the benefits in risk modelling, they’re reluctant to invest in its development due to resource pressures (time, capability, and money), as well as the limited assurance that decision makers would appreciate its value.

It’s a ‘Catch-22’ (Heller, 1961); there is not the level of capability or data availability to enable risk modelling to be realised as a valuable risk management tool for local government, yet without realisation of its value, there is limited investment into collecting natural hazard data, developing the software, or developing the capability to use it. Investment in risk modelling is sorely needed with the cost-benefit advantages of investing in risk-reduction measures being well documented (Shreve & Kelman, 2014; Špačková & Straub 2015), and with wide consensus across geo-social science disciplines that natural hazard related disasters are increasing in magnitude, frequency, and cost.

4.9.4 Uncertainty over council natural hazards management

Figure 4-3 sets out the complexity of the environment for natural hazard management legislation and how it contributes to a network of policy and procedural measures.

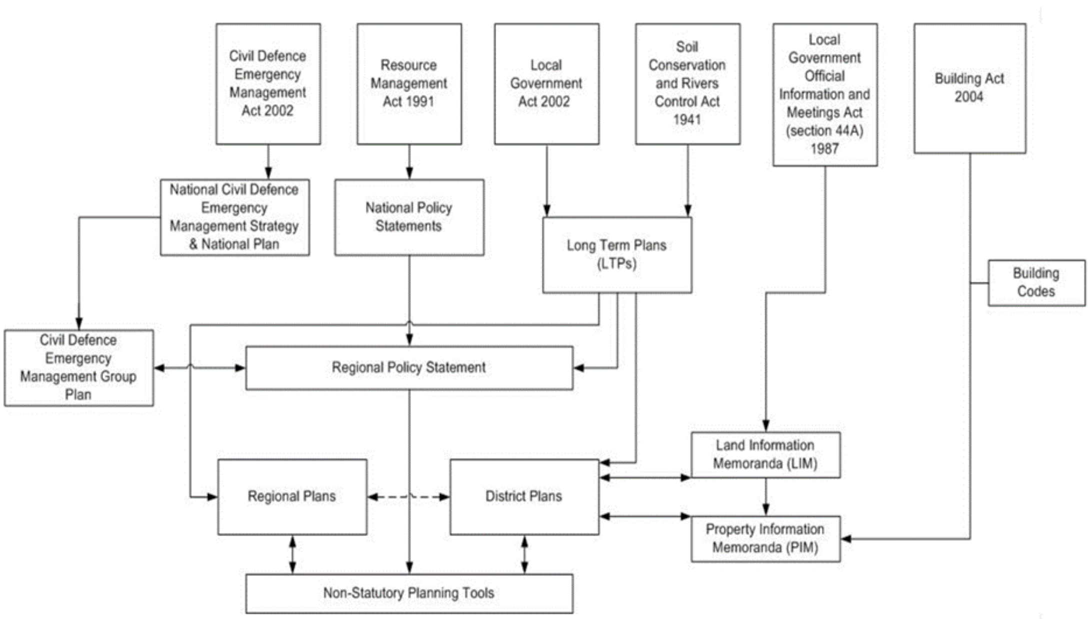

Figure 4-3: Relationships between key legislation for natural hazard management. Source: The RMA Quality Planning Resource (n.d.)

In its current state, the connections across the legislative environment for natural hazard management are difficult to coordinate, and there is no mandated structure for how natural hazard risk assessment and communication can be achieved (LGNZ, 2014; Saunders et al., 2015). This difficulty in coordination and lack of mandated structure leads to confusion and a lack of will to invest in natural hazard risk management activities, including the use of risk modelling. While this lack of national coordination is a challenge for local government natural hazard risk management, section 6.3 shows that some councils have independently recognised the need to share information on natural hazard management and have developed forums to achieve this. However, the participants discussed how these forums are isolated, with no standard operating model, and have varying degrees of support from decision makers in senior and political positions. While these forums are making progress towards good natural hazard risk management, they are small, have limited funding, and are not currently focused on the development and use of risk modelling. This is a significant challenge given that cross-government sharing and collection of data is crucial for risk assessment. This is not a unique challenge for New Zealand but has been highlighted internationally (The World Bank, 2016).

4.9.5 Limited use of 'knowledge brokers' and 'gate keepers'

'Knowledge brokers' are people that can move knowledge around and create connections between researchers and their audience (Meyer, 2010). Similar to the 'knowledge broker' role are 'gate keepers', who are people that can integrate external knowledge with different roles within an organisation (Macdonald & Williams, 1993). Knowledge brokers and gate keepers are beneficial because they act as the link between science and policy and can enable the appropriate information translation in an organisation. However, of the five councils visited, the knowledge broker and gate keeper roles were effective in only two, with those two councils being the most proactive and dynamic for how CDEM was integrated with cross-council natural hazard management. Figure 4-4 outlines the spectrum of integration or connectivity that was identified during the analysis, with each of the five CDEM Groups visited at a different point across the spectrum from 'isolated' to 'integrated'. This is particularly relevant to the theme of enabling effective data pathways across councils as outlined in section 4.8.3.

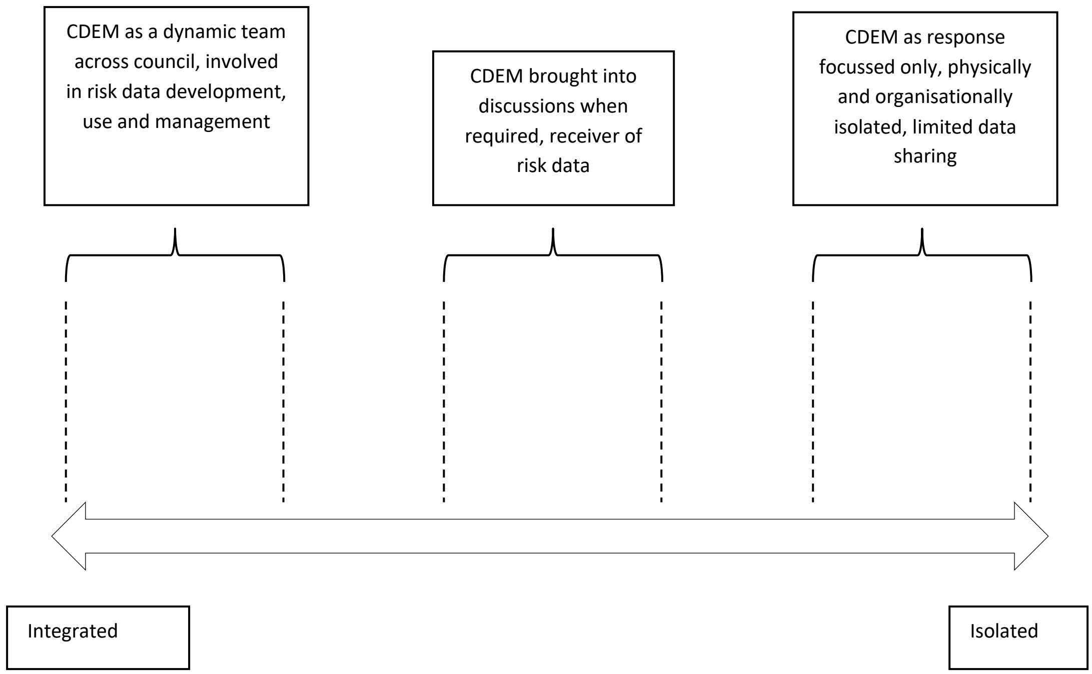

Figure 4-4: A spectrum of connectivity identified from the focal group discussions. Source: Crowley & Crawford (2016)

While some progress towards integrated natural hazard risk management has been achieved through knowledge brokers and gate keepers, the use of risk modelling has not been a focus for local government natural hazard management.

4.10 Recommendations and Conclusion

Common across both researchers and natural hazard practitioners is that, even though they are aware of the challenges for applying risk modelling tools, they have yet to overcome them. This points to a deeper, more fundamental challenge – while it is agreed that risk modelling can contribute to improving the disconnect across the science to policy interface for natural hazard management, it is the problems with this interface that impede the development of natural hazard risk modelling tools.

The disconnect between science and policy for natural hazard management is well documented. Write et al. (2013) point out that the language barrier between science and policy is large and often underestimated. Landström et al. (2011) and Nursey-Bray et al. (2014) reflect this, stating how different knowledge discourses between scientific knowledge and local knowledge limit its integration with policy. Gaillard & Mercer (2012) refer to the need for participatory, integrative processes for linking knowledge to action; however, Le De et al. (2015) and Mercer et al. (2008) warn of the difficulties of using participatory approaches, questioning the accountability of academics for ensuring an open and transparent process. Glasgow & Emmons (2007) refer to the need for more inter-connectedness across contributing programmes, and Finewood & Porter (2010) point out conflicting pressures between environmental and economic development as the disconnect, rather than between scientists and decision makers.

Gluckman (2011) takes a New Zealand government perspective, referring to the challenges of the science-policy disconnect for developing knowledge-informed policy. Challenges include a lack of interaction between academia and the public service, a haphazard structure for internal scientific advice, limited use of external scientific advice, conflicts of interest with Crown Research Institutes, and how the deprecation of social science can undermine good policy development. Kilvington and Saunders (2016) add to this with their review of the role of science in -use planning within New Zealand's local government. They refer to a mixture of factors contributing to the disconnect between science, policy, and practice, including limited information dissemination and information management, differing time-frames between research and practice, limited institutional capacity, unavailability of knowledge brokers, and social and political pressures.

Given these challenges, we make the following recommendations to span the science-policy interface and enable risk modelling as a communication tool to better develop policy and procedure for natural hazard management:

- Legislate greater mandate for how natural hazard risk management is achieved in New Zealand local government, with clarity on which local government natural hazard role is the lead for the function across the council. The silos between the existing natural hazard roles can be more easily crossed with a recognised lead for the natural hazard management function.
- Enable greater capacity and capability building for collecting, managing, and using natural hazard risk data so that it is well known, available, and usable, where its value is obvious to policy and decision makers through collaborative risk modelling approaches.

- Support and enable the movement of knowledge for natural hazard risk management through the development of shared mental models via knowledge broker and gate keeper roles that give greater connectivity, advocacy, and significance to natural hazard management initiatives across different council roles.
- Adopt effective and meaningful participatory approaches for developing natural hazard risk management policy. While participatory approaches are useful for democratising the exchange of knowledge between science, policy, and practice, they need to be managed carefully so that the process doesn't become a 'box-ticking' exercise that remains ineffectual.

In conclusion, given the severity of natural hazards in New Zealand, it is important for local government to be able to understand and manage them effectively. Risk modelling, specifically RiskScape, is a tool that can help support local government to do this through communicating natural hazard risk to better inform policy and procedure. However, research on the perception and use of risk modelling is scarce. As such, this research gains a practitioner perspective on how the RiskScape risk modelling tool can be used to support local government natural hazard risk management. Participants identified the value in risk modelling for managing emergency events, increasing natural hazard awareness for the public, and also for communicating risk to decision makers for cost-benefit analysis, risk reduction, and land-use development measures. However a number of challenges were also identified – misperceptions on the salience of emergency management for natural hazard risk management, uncertainty over how natural hazards are managed within New Zealand local government, issues with connecting information from outside organisations and across council functions, the capability of risk modelling software, and limited availability of natural hazard risk data. Underlying these challenges is the recognition that while risk modelling can help span the science-policy interface, it is the problems with this interface that slow the development of risk modelling. These challenges continue to limit the efficacy of research, not just for risk modelling and natural hazard risk management, but across a number of academic disciplines interacting with government and private organisations. However with mutual partnership and ongoing engagement across the science-policy interface, along with the recommendations listed above, risk modelling can be enabled as an effective tool, not only to communicate natural hazard risk and inform better natural hazard policy and procedure, but also for other disciplines spanning social and technological hazards.

5 [2nd manuscript] End-user perceptions of natural hazard risk modelling across policy making, land-use planning, and emergency management within New Zealand local government

5.1 Overview of this chapter

This manuscript continues from Chapter 4, drawing from the original focus group sessions, as well as follow-up interviews with natural hazard risk practitioners in Aotearoa New Zealand local government, contributing to the scarcity of research on the perception and use of natural hazard risk modelling tools, specifically RiskScape. It is a think piece that explores how risk modelling is perceived and used by different natural hazard practitioners within local government, focussing on functions for strategic policy making, land-use planning, and emergency management. The research finds differences in how risk modelling is perceived and used by each function and goes on to provide opinions on why this is the case. It concludes with recommendations for developing end-user perceptions of risk modelling and better enabling its use for natural hazard risk management.

Table 5-1 positions this manuscript in relation to the other manuscripts within this thesis and the research questions that it has aimed to answer.

Chapter 4 – 1st Manuscript	*Chapter 5 – 2nd Manuscript*	*Chapter 6 – 3rd Manuscript*	*Chapter 7 – 4th Manuscript*
Explores how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk in Aotearoa New Zealand local government.	Think piece exploring how risk modelling is perceived and used by the policy making, land-use planning, and emergency management functions within Aotearoa New Zealand local government.	Explores the thoughts and opinions of natural hazard risk practitioners regarding tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development	Explores the complex system of challenges for the application of natural hazard risk management within local government as a whole and how the science-policy-practice interface can interrupt the complex system's overall dynamic.
RQ1. How is natural hazard risk modelled information perceived and acted upon by local government?			
RQ2. How is risk modelling informed by natural hazard management?			
	RQ3. How are natural hazard management policies and procedures informed by risk modelling?		
RQ4. What are the risk communication barriers and enablers that limit or contribute to efficacy for natural hazard risk management in local government?			
		RQ5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?	

Table 5-1: Positionality of the second manuscript to the thesis

5.2 Manuscript preparation and publication

I prepared this manuscript for the proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM), which I attended in Wellington in 2018. I was the primary author with my supervisors, Dr Saunders, Dr Doyle, and Professor Johnston. The manuscript is a think piece presenting personal thoughts and opinions for how risk modelling is valued in New Zealand local government, based on analysis of interviews with local government practitioners. I collected the data through follow-up interviews with participants from the initial focus group sessions that contributed to Manuscript 1. The data was analysed with the support of my supervisors, who also guided me in the structuring and editing of the manuscript. The final manuscript was accepted for the proceedings of ISCRAM Asia Pacific 2018: Innovating for Resilience – 1st International Conference on Information Systems for Crisis Response and Management Asia Pacific.

5.3 Abstract

While the development of risk modelling has focussed on improving model accuracy and modeller expertise, less consideration has been given to understanding how risk models are perceived and used by the end user. In this think piece, we explore how risk modelling is perceived and used by three different end-user functions for natural hazard risk management in New Zealand local government – policy making, land-use planning, and emergency management. We find that risk modelling is:

- valued and used by strategic policy makers,
- less valued within operational land-use consent planning and not as widely used, and
- valued within operational emergency management but not as widely used.

We offer our thoughts as to why this is the case with reference to focus groups and qualitative interviews held with local government natural hazard risk end-users across the Bay of Plenty, Gisborne, Hawke's Bay, Wellington, Nelson, Tasman, and Canterbury regions of New Zealand. We conclude with recommendations for how risk modelling can be further developed to increase community resilience.

5.4 Introduction

Researchers and practitioners are increasingly using risk modelling to scope the consequences for natural hazard scenarios where there is uncertainty over vulnerability and exposure (UNISDR, 2015; Donovan & Oppenheimer, 2015; Eiser et al., 2012). However, while research has focussed on developing better risk models, less consideration has been given to end-user perceptions and use of risk modelling for natural hazard management (Komendantova et al., 2014; Reiter et al., 2017).

Natural hazard management in New Zealand is achieved through the devolution of central government legislation down to local government for application. Three key pieces of legislation coordinate how natural hazard management is applied:

1. The Local Government Act 2002 (LGA) – provides for local government to meet the natural hazard management needs of communities through local infrastructure, local public services, and performance of regulatory functions;
2. The Resource Management Act 1991 (RMA) – land-use consent planning assures avoidance or mitigation of natural hazards with respect to the use, development, or protection of land;
3. The Civil Defence Emergency Management Act 2002 (CDEMA) – emergency management supports the sustainable management of hazards in a way that contributes to the social, economic, cultural and environmental well-being and safety of the public and also to the protection of property.

Each piece of legislation and its associated policies and processes are applied through separate local government functions. While it is intended that these functions work seamlessly together, it is shown that over time integration remains limited, resulting in different perceptions, and reduced effectiveness for natural hazard management (Becker & Johnston, 2000; Ericksen et al., 2004; Glavovic et al., 2010; LGNZ, 2014; Saunders et al., 2014; Saunders et al., 2015; Basher, 2016; Kilvington & Saunders, 2016; Crawford et al., 2018; Lawrence, 2018).

This think piece explores the differences between how end users perceive and use risk modelling for natural hazard management across the functions of strategic policy making under the LGA, operational land-use consent planning under the RMA, and operational emergency management under the CDEMA. It refers to data captured from focus groups sessions and qualitative interviews held with end users from the Bay of Plenty, Gisborne, Hawke's Bay, Wellington, Nelson, Tasman, and Canterbury regions of New Zealand. We discuss the differences in how end users perceive and use natural hazard risk modelling and conclude with recommendations for how natural hazard risk modelling can be further developed.

Through a better understanding of how each natural hazard end-user function perceives and uses risk modelling, we can improve the usability of risk modelling, increase its application, and therefore build community resilience to natural hazards.

5.5 Methods

In the social sciences, risk perception is subjective, involving people's feelings, beliefs, attitudes and judgements (Barnes, 2001). As such, qualitative approaches were used because they "explore the views, experiences, beliefs and/or motivations of individuals on specific matters" (Gill et al., 2008, p. 292). Two qualitative approaches were used to better understand end-user perceptions towards the risk modelling and its use – focus groups and qualitative interviews.

Focus groups sessions were held with the Bay of Plenty, Hawke's Bay, Wellington, Nelson, Tasman and Canterbury regional or unitary authorities. This method was used because the "explicit use of group interaction produces data and insights that would be less accessible without the interaction found in the group" (Flick, 2006, p. 197). The sessions ranged in size from six to fifteen participants covering functions for strategic policy making, land-use consent planning, and emergency management, and also for engineering, hazard analyst, and GIS technician roles. Participants were encouraged to discuss their perceptions of the use of risk modelling via a semi-structured approach framed by guiding questions as set out in Table 5-2.

Understanding information management:

- How is this group linked with other departments and wider natural hazards risk management within the council?
- How do you communicate risk and hazard information and make decisions across the council?
- What information do you use?
- Where does it come from?
- Do you create or provide your own information?
- How would you like to receive or share risk and hazard information?

Discussion based on examples:

- Do you have any examples of risk-informed decision making or response?
- What went well in terms of information requirements?
- What information was missing or what were the information gaps?

Table 5-2: Focus Group Session Guide

Qualitative interviews were held in Wellington, Hawke's Bay, and Gisborne. Twenty-three participants were individually interviewed covering functions for strategic policy making, land-use consent planning, and emergency management, as well as other roles for environmental science, building control, asset management, engineering, and hazard modelling. As with the focus group sessions, an interview guide was developed to help steer the course of the interviews as set out in Table 5-3.

Thoughts, feelings, and experiences on how natural hazard risk management policy works in that council: • Its level of importance. • How often policy is developed. • How policy is applied. • Links across council for natural hazard risk management. • The local governance environment/mandate for policy development. • Risk-based policy. Views on the use of risk modelling software: • Whether it changes the way participants perceive natural hazard risk? • Whether it better communicates the risk, why, and why not? • Whether it is better at creating efficacy for developing more risk informed policy and procedure? • What participants think are the barriers for the communication, perception, and efficacy for natural hazard risk? • What participants think are the enablers for the communication, perception, and efficacy for natural hazard risk?

Table 5-3: Qualitative Interview Guide

Both the focus group sessions and qualitative interviews lasted between 1–2 hours with data captured through dictaphone recordings and then transcribed. Transcriptions were thematically analysed as it “provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data” (Braun & Clarke, 2006, p. 5). The themes identified emerged through iteratively analysing the transcripts via an inductive, ‘bottom-up’ process (Patton, 2015). The NVivo software package was used to assist with the analysis, categorisation, and organisation of the data into main themes with contributing sub-themes.

5.6 Results

The themes identified from the transcriptions are examined across the strategic policy making, land-use consent planning, and emergency management functions in turn.

5.6.1 Strategic policy making

When discussing how natural hazard risk management was achieved within their council, strategic policy makers were clear about how it was a holistic approach, incorporating different council roles and external influences:

> *You have the engineers and the building consents guys and the planners and they are all collectively are fully aware of the hazards, so as an organisation I think we are pretty good with it. We are constantly, collectively working on contingency plans.*

> *It doesn't always have to look like rules and regulations in a regional plan… you don't have to go anywhere near and RMA planning instruments in reality.*

> *Policy is, in my view, not just about local authority. It is about other industry sectors: very much insurance has a role, or lenders have a role to play in this, and they are having more and more of a role in this.*

While strategic policy makers were unanimous in supporting natural hazard risk management, they were also pragmatic about its relationship with economic development:

> *I guess it's how you meaningfully respond to the threat of natural hazards and what you can do which doesn't prevent people from living and undertaking their daily life and keeping the economy moving and cities growing.*

In line with their holistic, pragmatic view of natural hazard risk, strategic policy makers showed a good understanding of risk management concepts:

> *At the end of the day, what is a reasonable probability that you are willing to accept as a community for risk? [Some policies] would be too onerous to try and work your planning framework around, so there needs to be a bit of risk tolerance in every decision that you make.*

Considering this, strategic policy makers presented mixed perceptions of natural hazard risk modelling and its use. They appreciated its value for providing science-informed results:

> *Looking at what the risks are and establishing priorities… So we have used [risk modelling] as part of that with the fragility curves and working out what the assets are at risk.*
>
> *If we get a handle on the scale of what is at risk, it is always valuable for policy development.*
>
> *I wanted to have something to support me if I'm in a hearing in Environment Court or in a consent (Resource Consent) to show that these areas were at risk.*

However, the uncertainties and assumptions inherent within risk modelling meant that they had limited confidence in modelled results:

> *[Risk modelling] might be entirely valid as a tool to inform your high level strategic special planning but not be able to inform a land use regulatory Environment Court appeal kind of decision-making forum… It comes back to your policy advisors having an awareness of the potential but also the limitations of any of these risk models and also an awareness of the data availability.*

Overall, strategic policy makers appreciated risk modelling as a communication tool that informed policy making:

> *Modelling produces a visual, spatial map output and if there is one thing I know from many years of talking to the community and councils and people is that they can relate to any visual-graphic representation of something people can see. So they're hugely powerful tools for communicating risk and impact and disaster risk reduction.*
>
> *I'm a firm believer that any model is there to support decision making not to make decisions. Only humans can do that in full judgement of the information available. So as a communications tool risk modelling is still quite valid.*

5.6.2 Land-use planning

While land-use consent planners acknowledged the use of other legislation for achieving natural hazard risk management, a common thread for discussions was on using the RMA and associated plans to deliver regulation:

> *My colleagues think the RMA is the Bible and is the key means of delivering on land use planning decisions.*

> *There are two different types of planner; I like to think that we are heading more towards the outcome focussed planner but, to be honest, I think we have gone more towards the book version [where] 'the book' [the District Plan] gives us the answers.*

Considering the land-use consent planning focus on using existing rules and regulations, and due to stretched resources, there has not been the drive or capacity to learn different approaches for natural hazard risk management:

> *That's the problem – sophisticated spreadsheets and sophisticated modelling have never been a strong point in planning.*

> *People are stretched with their workloads and probably find it difficult to develop a new area.*

In conjunction with this, participants reported that risk modelling for less frequent natural hazard events was not synonymous with the policy timeframes used within land-use consent planning:

> *As far as planning is concerned … they're dealing with the here and now, they're dealing with people who come in with development proposals, they're looking at a District Plan which maybe has a ten-year life.*

As such, while there is an appreciation of risk modelling as a tool, it has not been readily adopted within land-use consent planning:

> *I can see that being a really useful tool… there's a social component to it.*

Some of them know about [risk modelling], but I think it just hasn't hit the point where people see it as a valuable tool as far as how they make decisions.

Maybe the software approach is just too much effort, with too little flexibility, to be of value on the day.

5.6.3 Emergency management

An interesting theme that emerged from discussions was how the emergency management function interacted with other parts of the council. While natural hazard risk management is a primary focus for emergency management, it is a less important focus for land-use consent planning and strategic policy making:

Hazards will be in the mix as part of that upcoming plan review exercise, but we have bigger fish to fry.

Even though hazards and [emergency management] are important … when events aren't occurring it just drops down on the importance list.

In addition, emergency management is commonly perceived as only an emergency response function, making it less relevant to other natural hazard risk management functions across the council:

[Emergency management] tends to operate much more on the response and recovery side and try as you might there's not actually a lot of crossover between and dialogue between the emergency management and the planning policy people.

I still think that the Council think of us as the people that work responding to an emergency. [They] don't actually think about the value that can be added from other areas.

Considering this challenging environment, emergency management has had to rely on influential personalities to better enable integration with other natural hazard functions:

She's playing the long game, she's been around for a while doing it, and because of the set of circumstances, she's able now to influence across a wide breadth within the Council, and show the value of [emergency management] to them.

Emergency managers showed a good understanding of risk as part of achieving their function for natural hazard risk management:

So that's where [emergency management] comes in, so you can't actually say "well what is the risk of developing that land there?", unless you understand that if that event happens, what is the impact and the response? We have to evacuate that, we have to house people, we have to this, we have to do that, we have to do planning and that takes resources and time.

It's looking at it and saying "well these are the risks, this is what would need to happen for response" and therefore we could 'tutu' (muck around) with the design to make response easier and therefore carry on. Or go well, the chances are pretty low, therefore the risk is acceptable. Yes, there is a risk but it is acceptable.

Given their understanding of risk management, emergency managers saw value in risk modelling:

It would be very powerful for [emergency] planning, through knowing what the potential impacts would be, in other words, what is the end game? If something happens, what's it going to look like? Then we can go back to the start and say this is our future recovery planning that we are going to have to think about.

Emergency managers also found risk modelling valuable for:

- communication to the public and decision makers
- real-time event response
- exercise development
- contingency planning
- generic plans, such as land-use and civil defence plans, and

- policy development, such as Regional Policy Statements.

However, while emergency managers agree that risk modelling was a valuable tool for natural hazard risk management, on the whole, it isn't used. Emergency managers reported that this is because contributing data is not available and because risk models are not suitable for their specific needs:

> *In terms of CDEM, we need information that is as up to date as possible. We can use it as a response tool as long as the data is available.*

> *I know that … the [emergency management] people weren't too keen on it. Maybe because that is just too hard to use in an event.*

As such, emergency managers have looked to use their own community knowledge as well as other tools for assessing and communicating risk:

> *The Hazards Portal, you know, that's great, great, and [emergency management] is leading that, which is great.*

> *I can virtually do that myself on GIS by plotting all of our lifelines across it, all the residential areas, daytime populations are all going to be in the CBD around this area so we're going to get pretty good loss of daytime in this area. You know these residential areas at night, okay, these are the inundation maps we've got and they're not great but they're better than nothing.*

5.7 Discussion

The themes set out in the results section present a complex and differing environment for the perception and use of risk modelling across the strategic policy making, operational land-use consent planning, and operational emergency management functions for natural hazard risk management. We find that risk modelling is:

- valued and used by strategic policy makers;
- less valued within operational land-use consent planning and not as widely used; and
- valued within operational emergency management but not as widely used.

While the data that informs this discussion represents a significant portion of New Zealand local government (seven of the seventeen regional and unitary authorities), it is not representative of all of New Zealand local government. Perceptions and uses for risk modelling may be different in areas that were not part of the study.

We offer our thoughts on the differences in perception and use of risk modelling of our case study area in turn.

5.7.1 Strategic policy making

Strategic policy making is central to achieving the strategic local government objectives for the social and economic development of their communities. While councils see natural hazard risk management as important (BOPRC, 2018; CRC, 2018; GDC, 2015; GWRC, 2015; HBRC, 2012), it is only a part of the strategic policy making function. Other foci for local government strategic policy making include management of infrastructure, environment, social issues, and economic development. Strategic policy makers take a wider, holistic view to achieve natural hazard risk management outcomes. It is their role to see the 'big picture' and think 'outside the box', straddling all council functions and combining different legislations, policies, plans, tools, and processes. Strategic policy makers also look to public-private partnerships to develop strategy that meets the current and future needs of our communities as per the Local Government Act (LGA) (New Zealand Government, 2002b).

Due to its importance, strategic policy making can easily connect to and integrate with other council functions in order to achieve objectives. It is also more easily able to influence decision makers to financially support the use of methods and tools to achieve those objectives. Furthermore, strategic policy making's position of straddling all council functions, along with private sector business management, has enabled them to develop a more holistic understanding of risk management. For example, ongoing management of ageing and vulnerable infrastructure has resulted in more developed risk-based local government policy focussed on asset management than for any other council function. Strategic policy makers are then able to transfer this knowledge to other areas like natural hazard risk management.

This understanding of risk, the readiness to use different methods and tools, along with its influence within the organisation, has meant that strategic policy makers are using risk modelling the most out of the three end-user functions. Examples of its use for natural hazard strategy development include for a cost-benefit analysis of residential development within Lower Hutt, impacts assessment as part of the Hawke Bay Coastal Strategy (T&T, 2016a), and mitigation strategies for Gisborne District Council (GNS, 2016).

Yet even though strategic policy makers use natural hazard risk modelling the most, they show the least confidence in its outputs. This correlation makes sense. With greater exposure to the uncertainties and assumptions contained within risk modelling comes a greater appreciation of its limitations. We also think that strategic policy makers' more developed understanding of risk better informs them of how much tolerance they have for risk modelling uncertainties and the assurance that risk modelling provides.

Nevertheless, while strategic policy makers are consistent in saying that risk models are too uncertain for rezoning-type applications, they are valued for cost-benefit analysis and communicating risk for high-level policy making.

5.7.2 Land-use planning

Similar to strategic policy making, land-use consent planning is central to achieving the strategic local government objectives for sustainable development. District plan provisions (under the Resource Management Act (RMA)), applied through land-use consent planners, are a useful and wide-ranging legislative instrument. As with strategic policy making, natural hazard risk management is only part of the land-use consent planning function. Planners regulate a number of other community activities including development, industry, transport, water, noise, heritage, hazardous substances, and air quality. Due to the similarities between the two functions, land-use consent planners have a more established relationship with strategic policy makers than with emergency managers.

Land-use consent planning is operationally focussed. It looks to regulate community activities through regional and district plan resource consents, monitoring, and enforcement. While it is not a strategic function like policy making, it is still viewed as important for how councils achieve their objectives. As such, the land-use consent planning function is a well-established, embedded, process-orientated and valued participant in council strategy development.

We suggest that the strength of the RMA is both a benefit and a detriment for how land-use consent planners achieve natural hazard risk management. It is a benefit because it is able to enforce community compliance and therefore more easily achieve natural hazard risk management outcomes. However, it is a detriment because the robust and prescriptive legislation means that many land-use consent planners choose to use established processes rather than exploring new methods and tools to achieve outcomes. In addition to this, the ten-year cycle for district plans is considered by some to be too long for flexible responses for natural hazard risk management, and the three-year political cycle is too short for consideration of risks emerging over longer timeframes (Lawrence et al., 2015). While innovative new risk-based approaches for natural hazard management are being developed (BOP, 2014; CCC, 2017), the results indicate that land-use consent planners are less inclined to 'think outside of the box' to better achieve natural hazard risk management outcomes.

It is interesting to note that the subject of risk management did not enter into many of the discussions with land-use consent planners. This may be because land-use consent planners are less familiar with the subject compared to the strategic policy making and emergency management functions. While efforts for land-use consent planners to think about risk within the RMA have been ongoing (Saunders & Beban, 2012), appreciation for risk management has been slow to develop. This could have been because risk management has not been a focus of the RMA; however, now that section 6 of the RMA has been amended to include 'the management of significant risks from natural hazards' as a matter of national importance (New Zealand Government, 1991, section 6), there is the potential for comprehensive risk-based planning to be implemented.

As such, results show that whilst the land-use consent planning function is able to use risk modelling for natural hazard risk management, it has not generally been adopted. However, land-use consent planners are beginning to see its value, and with the recent changes to how the RMA manages natural hazards risk, there is greater opportunity for it to be used more.

5.7.3 Emergency management

The results suggest that emergency management is not perceived as being as important as strategic policy making or land-use consent planning as it is commonly viewed as only an emergency response function. This perception is supported in the literature (Lawrence et al., 2015; Lee, 2010; LGNZ, 2014; Saunders et al., 2015) and also by emergency managers themselves. Many report how they have historically been employed by response-focussed organisations, such as the army or the police, and as such tend to put more effort into response. While emergency management also operates across reduction, readiness, and recovery to achieve natural hazard risk management, these other activities have less visibility across the council than response. Strategic policy makers have some interaction with emergency managers as part of policy development; however, in many cases, the only interaction land-use consent planners have with emergency management is during emergency response-focussed exercises.

In addition to this, we suggest that the Civil Defence Emergency Management Act (CDEMA), under which emergency managers operate, does not have the same standing for council strategy and management as the LGA or the RMA. Where the LGA and the RMA are central to community development and have wide-ranging responsibilities requiring community compliance with policy initiatives, the CDEMA is not perceived as being as central for community development and has no penalties for non-compliance (New Zealand Government, 2002a; DPMC, 2017). This creates a challenging environment for how emergency management achieves its natural hazard risk management function as they are less integrated with council strategy than policy making or land-use consent planning. While recent events, such as the Canterbury Earthquakes, have helped increase council awareness of emergency management's broader role, the emergency managers interviewed commonly reported being misperceived as only being there for emergency response.

Given the misperceptions of emergency management's role, along with having less integration within the council organisation, emergency management is obliged to be a dynamic function that develops relationships and thinks 'outside of the box' in order to gain influence and achieve its natural hazard risk management function.

As such, emergency management cannot rest on the strength of legislation and established processes as land-use consent planning has and is similar to strategic policy making where it looks to use different legislations, policies, plans, tools, and processes, working across the public and private sectors. Also similar to strategic policy makers, emergency managers show a more developed understanding of risk. We think this is more to do with the risk-based approach that emergency management takes to natural hazard risk management (MCDEM, 2018) than from inclusion into council long-term strategy management.

Given their understanding of risk, emergency managers value risk modelling as a tool. While they can see its value across a number of functions, emergency managers are quicker to see the value of risk modelling as a response tool than as a risk-reduction tool. This could be because of emergency management's tendency to focus on response, but also because emergency managers own the emergency response role, where they would need to collaborate with policy and consent planners to achieve risk reduction.

Even though emergency management is a dynamic function that looks to use different tools to achieve their natural hazard risk management function, on the whole they do not use risk modelling. Emergency managers value risk modelling, but the challenges associated with being a less integrated and misperceived function mean they are not as enabled to use it. Historically, risk modelling was not used due to the limited capability of risk modelling software to fit emergency management requirements. However, as risk modelling has developed, the issue rests more with risk data not being available for emergency management's use, and challenges for emergency management to generate their own data.

5.8 Recommendations and Conclusion

This think piece gives our views on end-user perceptions of natural hazard risk modelling across the strategic policy making, land-use consent planning, and emergency management functions for natural hazard risk management within New Zealand local government. We paint a thought-provoking picture of how risk modelling is perceived and used. Risk modelling sits within a complex, interrelated environment where perceptions of importance, levels of integration, understanding of risk, and willingness to use different methods and tools combine in various ways to influence its use.

As such, we make the following recommendations to develop end-user perceptions of risk modelling and better enable its use for natural hazard risk management:

- Structured collaboration for natural hazard risk management – By structuring for greater collaboration across the strategic policy making, land-use consent planning and emergency management functions, a shared understanding of roles and responsibilities can be developed. As such, issues relating to misconceptions of roles can be broken down, enabling greater integration across the functions, shared perceptions of risk modelling, and improved risk model application (Doyle & Paton, 2017).

- Participatory co-development of risk modelling – Involving strategic policy makers, land-use consent planners, and emergency managers to work together, co-developing risk models through a bottom-up, participatory approach. This will enhance understanding of the capability of risk models, develop confidence in the information that they provide, and build the value of risk modelling across the council for natural hazard risk management (Newman et al., 2017).
- Regular risk management workshops – Natural hazard risks are constantly changing depending on shifts in community vulnerability and exposure. Regular workshops to review the risks and what measures can be employed to reduce them can build an understanding of risk management for decision support, promote its use across the end-user functions, and add value for natural hazard management (Saunders & Beban, 2012).
- Data development – Combine resources to enable greater capacity and capability for natural hazard risk data collection, management, and use. Natural hazard risk modelling end-users can collaborate on standardised controls for data collection, quality, and format so that it is open, shared, usable, and used.

In conclusion, this think piece focusses on the less researched area of how end users perceive and use risk models. We explore how risk modelling is perceived and used by three different end-user functions for natural hazard risk management in New Zealand local government finding that risk modelling is valued and used by strategic policy makers, less valued within land-use consent planning and not as widely used, and valued within emergency planning but not as widely used. Through a better understanding of how each natural hazard end-user function perceives and uses risk modelling, we have made recommendations for how end users can work together to develop their perceptions and use of risk modelling. With improved end-user perception and use of risk modelling, it can be applied more widely, better support decision making for natural hazard risk management, and therefore build community resilience to natural hazards.

6 [3rd manuscript] The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government

6.1 Overview of this chapter

This manuscript shifts the focus away from the challenges of applying risk modelling in Aotearoa New Zealand local government and explores risk perception as a cause for these challenges. It focusses on risk perception for tsunami risk because tsunami is Aotearoa New Zealand's most significant natural hazard risk but is also the least likely. It explores how low-likelihood influences the development of tsunami risk management policy, the barriers and enablers that limit or contribute to this, and briefly how risk modelling (RiskScape) can help communicate risk to influence risk perceptions. The research reinforces the literature, finding that low likelihood presents a significant challenge for the development of tsunami risk management policy in Aotearoa New Zealand. The result is a paucity of tsunami risk management policy. The manuscript goes on to explore cognitive biases as a cause for this and makes recommendations to overcome the low-likelihood challenge for tsunami risk management policy. The research recognises that these challenges arise from more fundamental issues relating to how natural hazard risks are governed in Aotearoa New Zealand. These issues are complex, interrelated, and entrenched within local government, and result in the limited success of natural hazard risk management approaches.

Table 6-1 positions this manuscript in relation to the other manuscripts within this thesis and the research questions that it has aimed to answer.

<table>
<tr><th>Chapter 4 –
1st Manuscript</th><th>Chapter 5 –
2nd Manuscript</th><th>Chapter 6 –
3rd Manuscript</th><th>Chapter 7 –
4th Manuscript</th></tr>
<tr><td>Explores how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk in Aotearoa New Zealand local government.</td><td>Think piece exploring how risk modelling is perceived and used by the policy making, land-use planning, and emergency management functions within Aotearoa New Zealand local government.</td><td>Explores the thoughts and opinions of natural hazard risk practitioners regarding tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development.</td><td rowspan="4">Explores the complex system of challenges for the application of natural hazard risk management within local government as a whole and how the science-policy-practice interface can interrupt the complex system’s overall dynamic.</td></tr>
<tr><td colspan="3">RQ1. How is natural hazard risk modelled information perceived and acted upon by local government?</td></tr>
<tr><td colspan="3">RQ2. How is risk modelling informed by natural hazard management?</td></tr>
<tr><td></td><td colspan="2">RQ3. How are natural hazard management policies and procedures informed by risk modelling?</td></tr>
<tr><td colspan="4">RQ4. What are the risk communication barriers and enablers that limit or contribute to efficacy for natural hazard risk management in local government?</td></tr>
<tr><td></td><td></td><td colspan="2">RQ5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?</td></tr>
</table>

Table 6-1: Positionality of the third manuscript to the thesis

6.2 Manuscript preparation and publication

I prepared this manuscript as the primary author with my supervisors, Dr Saunders, Dr Hudson-Doyle, Dr Leonard, and Professor Johnston, as co-authors. I conducted the data collection, analysis, and drafted the initial manuscript. The co-authors provided guidance on the systematic review analysis, gave insights into patterns in the data collected, and offered feedback on the content and structure of the manuscript. I prepared the final manuscript for submission to the journal. The manuscript, published in 2019 by the Australasian Journal of Disaster and Trauma Studies, was accepted with minor revisions by the journal (Crawford et al., 2019).

6.3 Abstract

The Hikurangi Subduction Interface, located 50 to 100 kilometres off the east coast of New Zealand's North Island, has the potential to generate the most destructive tsunami New Zealand is likely to encounter over a 1000-year timeframe. Yet, while such a severe risk hangs over the area, the number and detail of tsunami risk management policies do not match this risk. This article presents research on the influence of low likelihood on perceptions for developing destructive tsunami risk management policy. It explores the thoughts and opinions of natural hazard risk practitioners in regard to tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development. Results highlight risk perceptions associated with the low likelihood of a destructive tsunami, including such an event being perceived as "not happening here" and the development of tsunami risk management policy perceived as sitting in the "too hard basket". We discuss how these risk perceptions could be influenced by cognitive biases due to their seemingly illogical nature and how risk modelling can be used as a communication tool to help overcome these perception challenges. We conclude with some recommendations for how we could better match tsunami risk management policy with tsunami risk through further developing local government provisions for risk management, the influence of cognitive biases, risk modelling, and policy flexibility.

6.4 Introduction

> *A tsunami caused by an earthquake on the Hikurangi plate interface is thought to be a plausible candidate for the most destructive tsunami New Zealand is likely to encounter over a 1000-year time frame – capable of severe damage to urban areas on the east coast. (Power, Wallace, & Reyners, 2008, p. 6).*

The Hikurangi Subduction Interface is capable of producing an all-of-interface megathrust earthquake ranging in magnitude from M7.5–9.0 (Power, 2013). Figure 6-1 sets out the location of the Hikurangi Subduction Interface off the east coast of New Zealand's North Island, presenting how a tsunami generated within the interface could affect 200–300 kilometres of the nearby coast, potentially impacting on the Gisborne, Hawke's Bay, and Wellington regions, along with a small amount of the Manawatu region (excluded from this study). Table 6-2 provides the modelled median tsunami wave heights and direct losses, derived using the 'RiskScape' model (King & Bell, 2005; King & Bell, 2009), that each of these regions could expect from a M9.0 rupture along the length of the Hikurangi Subduction Interface.

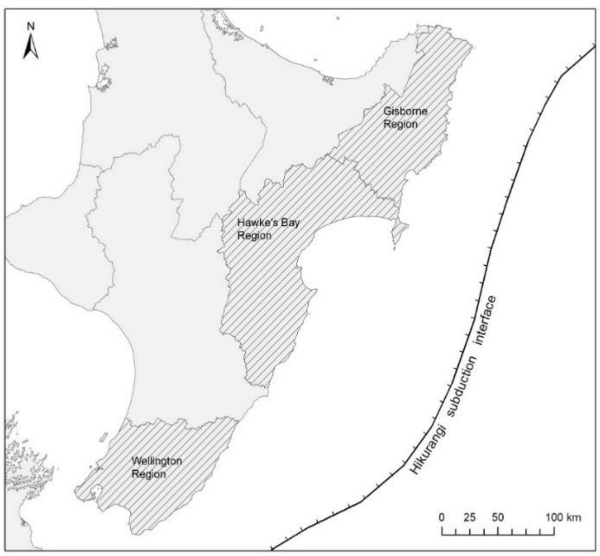

Figure 6-1: The Hikurangi Subduction Interface and the Gisborne, Hawke's Bay, and Wellington regions

Location	Wave height (m)	Deaths	Injuries	Economic loss ($M)
Wellington	7.4	2198	1792	5,556
Hawke's Bay	8.4	4895	3752	5,211
Gisborne	8.0	982	829	1,734

Table 6-2: Modelled median wave height and direct losses from M9.0 rupture on the Hikurangi Subduction Interface (Gill et al., 2015; Horspool et al., 2015)

With such severe consequences impacting these regions, it is understandable that tsunami have been identified as potentially New Zealand's most severe natural hazard (Department of the Prime Minister and Cabinet, 2007). However, considering the comparatively high risk from tsunami, New Zealand spends relatively little on mitigation. This is evidenced in Table 6-3, which presents public spending on tsunami risk management compared to other risks.

Event	Government spending 2008/9, $m	Average annual individual fatality risk/100,000	Spending per unit of risk $m
Assaults	$122	1.3	$93.85
Workplace accidents	$85	4.1	$20.73
Vehicle accidents	$854	9.2	$92.83
Tsunami	$2.55	2.8	$0.910

Table 6-3: Public spending on tsunami risk management compared to other risks (Gill et al., 2015, p. 4)

Our capacity to withstand and recover from the impacts of destructive tsunami is achieved through a combination of scientific research to build our understanding of the hazard and local government policy which enables the risk to be assessed, communicated, and managed within our communities. However, natural hazard risk management in New Zealand local government is challenged by a complex legislative environment, lack of data, misconceptions and biases, limited resources, and the differing requirements of numerous actors (Crawford et al., 2018; Glavovic, Saunders, & Becker, 2010; Kilvington & Saunders, 2016; Saunders, Grace, & Beban, 2014). While the devastating impacts of recent tsunami in the Indian Ocean (2004), Samoa

(2009), Japan (2011), and Indonesia (2018) have raised awareness and spurred tsunami policy development (Johnston et al., 2014; King, 2015), local government have been slow to integrate such lessons into natural hazard risk management policy (Basher, 2016; Lawrence, 2018; Local Government New Zealand, 2014).

This research aims to understand how tsunami risk management policy and procedure relates to tsunami risk in the Gisborne, Hawke's Bay, and Wellington. It explores practitioners' perceptions of low-likelihood, destructive tsunami; their views on tsunami risk management policy; and the use of risk modelling as a communication tool for tsunami risk management. The rest of the introduction describes the complex legislative structure for how tsunami risk management is achieved in New Zealand and introduces risk modelling as a communication tool for tsunami risk management. The method section explains the mixed method approach of qualitative interviews and document analysis used to gain a deeper understanding of practitioners' views on tsunami risk management policy distribution and how tsunami policy is corroborated by practitioners' perceptions of tsunami risk. The findings presented in the results section highlight a paucity of tsunami risk management policy across the study area and sets out three key themes that emerged from analysis of the qualitative interviews: disassociation from tsunami risk, reduced motivation for developing policy, and risk modelling challenges. Following these results, we discuss how cognitive biases associated with low likelihoods influence tsunami risk perceptions and challenge motivation for tsunami policy development. We propose that risk modelling is a valuable tool that can help address this challenge. In the discussion section we also provide recommendations for how risk modelling can work in combination with risk management, cognitive debiasing techniques, and long-term planning to overcome the low-likelihood challenge for tsunami risk management policy development in New Zealand local government. However, we argue that before this is achieved, fundamental challenges for how natural hazard risk is governed need to be addressed.

6.5 Natural hazard risk management, tsunami risk management, and risk modelling in New Zealand

6.5.1 Natural hazard risk management

We view risk as "uncertainty about and severity of the consequences of an activity with respect to something that humans value" (Aven, Renn, & Rosa, 2011, p. 1074). Risk is managed through arrangements for designing, implementing, monitoring, reviewing, and continually improving activities for its control (International Organization for Standardization, 2009). When applied to natural hazard management in New Zealand, risk management sits within a complex, interrelated system of devolved legislation (Local Government New Zealand, 2014). Figure 6-2 sets out the relationship across New Zealand legislation for the management of natural hazards.

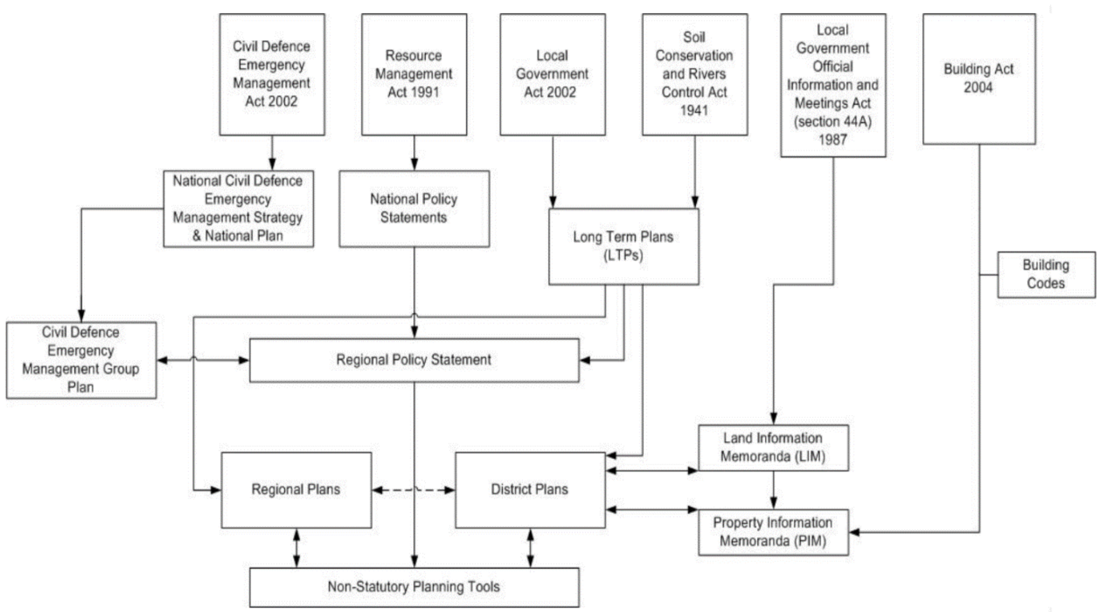

Figure 6-2: Relationships between legislation for the management of natural hazards (The RMA Quality Planning Resource; n.d.)

Within this breadth of legislation, four key statutes provide a framework of responsibilities for how natural hazard risk management is applied:

1. The Local Government Act (LGA) – A local authority must manage risks to infrastructure from natural hazards (section 101B(3)(e); New Zealand Government, 2002b).

2. The Resource Management Act (RMA) – A local authority shall manage risks for the use, development, and protection of resources (section 6(h); New Zealand Government, 1991).
3. The Civil Defence Emergency Management Act (CDEMA) – A local authority shall encourage and enable communities to achieve acceptable levels of risk (section 3(b); New Zealand Government, 2002a).
4. The Building Act (BA) – A local authority must manage consent for construction or alteration of buildings subject to natural hazards (section 71; New Zealand Government, 2004).

While intending to work seamlessly together, each piece of legislation is applied through separate local government functions which often have limited integration and effectiveness for natural hazard management. This is reflected in Saunders, Grace, Beban, and Johnston's (2015) review of local government natural hazards management, where they note that collaborations across different natural hazard practitioner roles are not commonly encouraged for sharing information, good practice, and understanding of roles.

6.5.2 Tsunami risk management

Tsunami risk management sits within this challenging policy environment. While it would ideally be a joint responsibility across the local government land-use planning, emergency management, and building control functions, it has historically sat within emergency management for application (Johnston et al., 2008; Johnston et al., 2014; King, 2015; Saunders, Prasetya, & Leonard, 2011; Webb, 2005). Webb (2005) explains that while all tsunami risk can be managed through land-use planning arrangements, "due to a public desire to use coastal areas and the relatively long return period of damaging tsunami, regulations and land use planning are in reality unlikely to provide effective mitigation for the entire risk" (Webb, 2005, p. 64). As such, the residual risk is managed through a readiness and response approach of public education, warning, and evacuation measures, which are commonly regarded as emergency management functions.

However, over time the growing recognition of risk reduction for natural hazard management has called for greater involvement of land-use planning and building control (Beban &

Saunders, 2013; Glavovic et al., 2010; Saunders, W., Forsyth, J., Johnston, D., & Becker, J., 2007; Saunders et al., 2011; Saunders & Beban, 2012; Saunders et al., 2015). This is reflected through specific reference to tsunami risk management in Policy 25 of the New Zealand Coastal Policy Statement (Department of Conservation, 2010), and also with the recent amendments to section 6 of the Resource Management Act (New Zealand Government, 1991), where the management of "significant risks" from natural hazards is now a matter of national importance.

6.5.3 Natural hazard risk modelling: RiskScape

One avenue for assessing and communicating natural hazard risk is through the use of risk modelling. Quantitative risk modelling combines deterministic or probabilistic hazard models, with data detailing the type and location of assets that are exposed to the hazard, along with models that assess the vulnerability of that asset to the hazard. The result is an assessment of consequence, most often depicted as economic loss, but can also be depicted through infrastructure or societal impacts dependent on the risk management objectives. Risk modelling then acts as an assessment and communication tool that presents the risk information in a way that assists decision makers and communities to better understand their risk and make more informed risk management decisions (Global Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2014b; Global Facility for Disaster Reduction and Recovery, 2014c; Pondard & Daly, 2011).

The risk modelling software used in this research is *RiskScape*[4]. RiskScape has been developed through scientific collaboration between NIWA and GNS Science[5] to meet the demand for a natural hazard impact and loss modelling tool for New Zealand conditions (King & Bell, 2009). RiskScape allows its users to assess tsunami-related risk through existing scenarios saved within the application, or users can upload their own hazard scenario. Users then apply the hazard scenario to an asset database dependent on the asset for which they are assessing risk. The RiskScape asset database holds data on buildings but also includes data for electricity cables, roads, and reticulated water services. The hazard and asset data are then combined with a

[4] https://www.riskscape.org.nz/

[5] The National Institute of Water and Atmosphere (NIWA) and the Institute of Geological and Nuclear Science (GNS Science) are New Zealand Crown Research Institutes charged with promoting the transfer and dissemination of research, science, and technology.

fragility function which calculates the probability or severity of damage for the asset given the intensity of the specific hazard. The output is an estimated loss or consequence as illustrated in Figure 6-3.

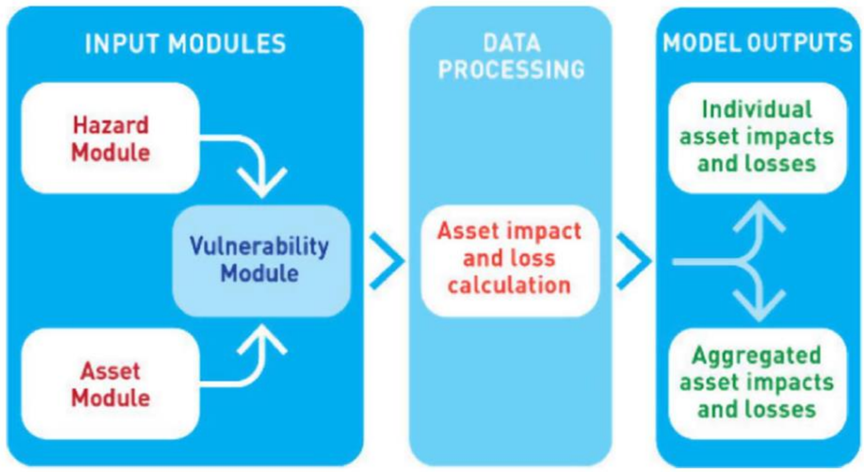

Figure 6-3: RiskScape modelling framework for how natural hazard and asset modules are combined with a vulnerability module to produce quantitative risk information. Source: RiskScape Model Framework (n.d.)

The results from RiskScape modelling are presented in spreadsheet or map form, as shown in Figure 6-4, and can be aggregated. The results can also be exported into geographic information system (GIS) applications for further application and integration with other risk assessment and decision-making or planning tools.

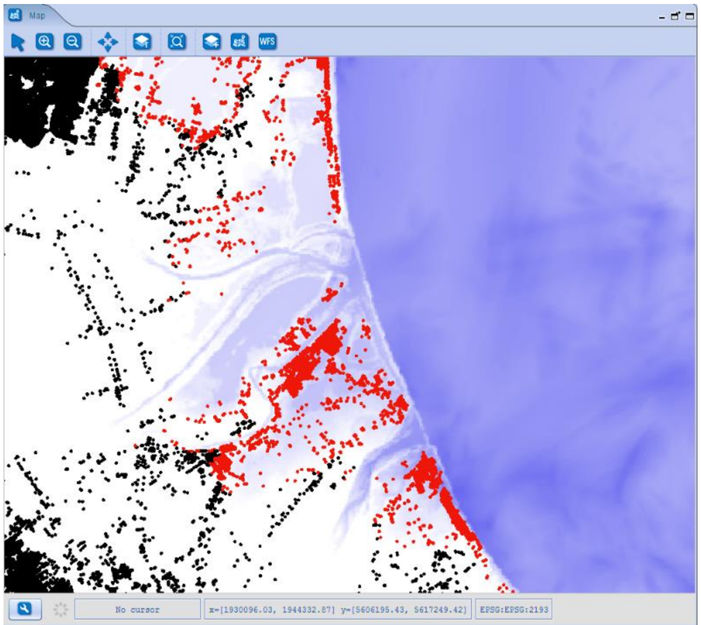

Figure 6-4: RiskScape modelling results shown in map form. The map shows a scenario of individual building exposure to tsunami inundation in Napier City following a Magnitude 8.9 earthquake generated in the Hikurangi Subduction Interface. The blue colours (located amongst the dots) represent the extent of tsunami inundation, the red dots represent buildings that have been impacted by tsunami inundation, and the black dots represent buildings that have not been impacted. Source: Ryan Paulik, NIWA, 2018.

6.6 Methods

Risk perception is subjective, involving people's feelings, beliefs, attitudes, and judgements about the harm and loss associated with the consequences of an event (Aven et al., 2011; Barnes, 2001; Mileti & O'Brien, 1992; Slovic, 1987). However, it is also framed by culture and society (Doyle, McClure, Paton, & Johnston, 2014), with our risk perceptions contextualised and informed by local values and norms and dependent on disciplinary frameworks (World Social Science Fellows on Risk Interpretation and Action, 2014). As such, this research is based on a social constructionist epistemology, where our meaning of 'reality' is informed by creating models of the social world and sharing these models through communication (Young & Collin, 2004). The research follows a qualitative methodology, used because it examines the 'why' and ‘how’ of decision making, seeking to understand the depth and variety of people’s feelings and perspectives, rather than quantities and distributions as studied through a quantitative methodology (Creswell, 2007).

Two methods were used in this research. Document analysis was used to gain an overview of the extent of tsunami risk-based policy, which was then corroborated with qualitative interviews. Qualitative interviews were used to gain a better understanding of subjective views towards tsunami risk management policy and of risk modelling as a communication tool. Each method is described in the following sections.

6.6.1 Document analysis

Document analysis is a systematic procedure for reviewing or evaluating documents. When used qualitatively, this method requires data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). Document analysis has been used in this research to gain an overview of the distributions or patterns of local government tsunami risk management policy to corroborate the findings from the qualitative interviews. It does not seek to analyse the strength or significance of the policy.

New Zealand national legislation, local strategy, and planning policy documents were analysed for their provisions relating to natural hazards, risk management, and tsunami. The documents selected were required to be operational at the time of analysis and refer to natural hazard risk management within the Wellington, Hawke’s Bay, or Gisborne regions. It is recognised that national tsunami warning arrangements are relatively well advanced, but wider risk management documentation is either still needed or in development.

Fifty-eight national and local policy documents were identified via a combination of internet searches and documents provided by participants. Examples include the New Zealand Coastal Policy Statement (Department of Conservation, 2010), the Hawke’s Bay Regional Council – Long Term Plan 2012–2022 (Hawke’s Bay Regional Council, 2012), and the City of Lower Hutt District Plan (Hutt City, 2016). A full list of the documents is given in Appendix E.

The documents were analysed using deductive analysis in accordance with pre-determined criteria (Stemler, 2001). Previous analyses of New Zealand local government natural hazard policy were considered in determining criteria (Becker & Johnston, 2000; Glavovic et al., 2010;

Kilvington & Saunders, 2016; Lawrence & Haasnoot, 2017; Saunders & Beban, 2012), with the criteria for this study primarily based on Saunders et al.'s (2015) evaluation of the use of land-use and emergency management policy documents for natural hazards in New Zealand local government. In their study, a plan was considered to be best practice based on eight indicators including hazard identification, the inclusion of hazard specific rules, and the use of risk management language (e.g. consequence and likelihood). This study adapted Saunders et al.'s (2015) best practice indicators to explore four objectives – the distribution pattern for natural hazards policies in general, the distribution pattern for tsunami policies specifically, the distribution pattern for risk-based policies in general, and the distribution pattern for tsunami risk-based policies specifically. Table 6-4 sets out these four objectives along with the pre-determined criteria which inform each of them.

Criteria	Objectives
The document analysed: • has a section on natural hazards • has a definition for natural hazard • includes natural hazard policies	Explores patterns generally associated with natural hazard management policies.
• lists tsunami as a natural hazard • refers to tsunami as potentially affecting that district/region • includes tsunami policies • refers to tsunami inundation maps	Explores patterns specifically focussing on tsunami hazard management policies.
• has a definition of risk • sets out a risk-based management model • includes risk-based policies • links to risk management policies in other documents	Explores patterns generally associated with risk-based policies.
• refers to tsunami risk – e.g. likelihood and consequences of certain magnitude events • includes tsunami risk-based policies	Explores patterns specifically focussing on tsunami risk-based policies.

Table 6-4: Document analysis criteria with objectives

Limitations for this method are that relevant policy documents or references within the documents may have been missed from the analysis. Considering 58 documents were analysed covering central government legislation and local government strategy and planning policy, we are confident that our data reached the point of 'saturation' (Patton, 2015), and that any missed documents or references have not significantly altered the patterns identified from the analysis.

6.6.2 Qualitative interviews

Exchange of dialogue, fluidly structured, and covering certain issues are common features of the qualitative interview, where meanings and understandings are co-produced through interaction (Edwards & Holland, 2013). Interview participants were identified and invited by a gatekeeper within each region who was able to transfer external information to colleagues within their organisation (Macdonald & Williams, 1993). The gatekeepers were all council staff who worked with the participants of this research. The gatekeepers were known to the lead author of this article, who had worked with them in previous, related research (Crawford et al., 2018a; Crawford et al., 2018b).

Twenty-three participants were interviewed across the Gisborne, Hawke's Bay, and Wellington regions, whose roles included the following functions:

- policy making
- environmental science
- land-use planning
- building control
- emergency management
- asset management
- engineering, and
- hazard modelling.

The qualitative interview guide used in the interviews is presented in Table 6-5 below. The guide provides a semi-structured approach to the interview, to ensure that the same general areas of information are collected from each interviewee. "This provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in getting information from the interviewee" (McNamara, 2009).

Objective 1 Encourage participants to express their thoughts, feelings, and experiences on natural hazard risk management policy in NZ local government, especially what they think are the **barriers** for its development, and what the **enablers** are. Start by asking how natural hazard policy works in that council. Capture discussion on: • Its level of importance. • How often policy is developed. • How policy is applied. • The local governance environment/mandate for policy development. • RMA amendments to include risk focus. • Risk-based policy. • Tsunami risk management. • Links across council for tsunami risk management. **Objective 2** Review participant's views on the use of risk modelling software (RiskScape), compared to without the use of risk modelling. Try to elicit thoughts and feelings on whether they think risk modelling can better communicate tsunami risk to influence decision-maker perceptions and the willingness to engage in improved policy and procedure. Capture discussion on: • Whether risk modelling changes the way participants perceive this risk? • Whether risk modelling better communicates the risk, why, and why not? • Whether participants think risk modelling is better at creating motivation for developing more risk informed policy and procedure? • What participants think are the **barriers** for the communication, perception, and motivation for this risk? • What participants think are the **enablers** for the communication, perception, and motivation for this risk?

Table 6-5: Qualitative Interview Guide

Each interview lasted between one and one and a half hours with data captured through recordings which were transcribed and thematically analysed; thematic analysis "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006, p. 5). Themes were identified using an inductive *bottom-up* approach, where the themes emerge from the data itself (Patton, 2015). The NVivo software package (Bazeley & Jackson, 2013) was used to assist with the analysis, categorisation, and organisation of the data into main themes with contributing subthemes.

Limitations for this method are that participants may feel uncomfortable revealing certain information, or the interviews may not capture the intended data. These were respectively managed via participants being assured that all data collected was anonymous and pooled across locations in the study area, and through the guidance of the Qualitative Interview Guide to capture the intended data.

It is important to acknowledge the lead author's own positionality, having worked in risk and local government emergency management, and how this background has influenced his interpretation of the interview data (Landström et al., 2011; Whitman, Pain & Milledge, 2015). When conducting the interviews, the lead author automatically adopted the position of 'participant as observer' (Bryman, 2008) where he interacted with the participants and expressed his own views from experiences working in local government natural hazard risk management, while participants were also aware of his status as a researcher.

6.7 Results

The results section is separated into two parts reflecting the two different research methods used. The first section gives results for the policy document analysis, highlighting a paucity in local government risk-based tsunami policy. The second section (including its subsections) gives results from the qualitative interview analysis, identifying three emergent themes: "disassociation and inability to internalise tsunami risk", "reduced motivation for developing destructive tsunami policy", and "risk modelling is valued but challenging".

6.7.1 Document analysis

Fifty-eight central and local government policy documents across the Wellington, Hawke's Bay, and Gisborne regions were analysed for their policies relating to natural hazard, tsunami, and tsunami risk management. Our findings have been grouped in accordance with the four objectives of the document analysis as presented in Table 6-6 – natural hazard policy distribution, tsunami policy distribution, risk-based policy distribution, and tsunami risk-based policy distribution. Table 4 presents an overview of the distribution of natural hazard policy and risk-based policy across the documents, both in general and specifically.

Objectives & Criteria		Central Government (13 documents)	Local Government	
			Regional/Unitary Council (17 documents)	District Council (28 documents)
Natural hazard management policies	Has a section on natural hazards	1	12	2
	Has a definition for natural hazard	5	10	5
	Includes natural hazard policies	9	13	14
Tsunami hazard management policies	Lists tsunami as a natural hazard	5	14	16
	Refers to tsunami as potentially affecting that district/region	0	15	17
	Includes tsunami policies	2	5	2
	Refers to tsunami inundation maps	0	2	0
Risk-based policies	Has a definition of risk	2	6	1
	Sets out a risk-based management model	2	8	4
	Includes risk-based policies	9	12	17
	Links to risk management policies in other documents	3	3	2
Tsunami risk-based policies	Refers to tsunami risk – e.g. likelihood and consequences of certain magnitude events	0	1	0
	Includes tsunami risk-based policies	1	1	1

Table 6-6: Distribution for natural hazard, tsunami, and risk-based policy across central and local government policy documents

Table 6-6 shows that natural hazard management is important for local government. This was stated by participants in the interviews and is reflected by the wide distribution of policy referring to general natural hazard management across long-term strategic plans, environmental policy statements, resource management plans, emergency management plans, and plans with specific focus areas such as coastal hazard management. The majority of resource management and emergency management plans for regional councils contain natural hazard-focussed sections, where long-term strategic plans tend not to specifically focus on natural hazards but refer to their general management throughout the document. While the documents contain policy specific to certain natural hazards, the majority of policies within and across the different document types take an *all-hazards* approach, where policies are designed to manage a generic range of hazards. Of the specific hazard policies, the majority focus on more frequent, experienced, and escalating hazards such as flooding, erosion, and sea level rise. These findings are similar to those presented by Saunders et al. (2015).

At the central government legislative level, tsunami is listed as a hazard or emergency in the Resource Management Act (New Zealand Government, 1991), the Civil Defence Emergency Management Act (New Zealand Government, 2002a), the Local Government Act (New Zealand Government, 2002b), the New Zealand Coastal Policy Statement (Department of Conservation, 2010), and the National Tsunami Advisory and Warning Supporting Plan (Ministry of Civil Defence and Emergency Management, 2017). Interestingly, and somewhat problematically, is how tsunami is not listed as a natural hazard within the Building Act (New Zealand Government, 2004), which instead refers to the less specific description of *inundation*. At the local government level, tsunami is recognised as a hazard across the majority of the policy documents analysed. While many of the documents state that tsunami could significantly impact their region, many rate other hazards such as earthquake or flooding as posing a greater risk. Of the 45 local government policy documents analysed, only seven documents contain policy addressing tsunami management. Of those seven documents, the majority of policy is general, for example "contingency plans shall be implemented for emergency events such as… tsunami" (Wairoa District Council, 2015, p. 48).

The only central government documents that define risk are the Civil Defence Emergency Management Act (New Zealand Government, 2002a) and the National Civil Defence Emergency Management Strategy (DIA, 2008), defining it as the likelihood and consequences of a hazard.

This scarcity of risk definition is reflected in local government documents, with only a few defining natural hazard risk as a combination of likelihood and consequence of a certain magnitude hazard. Of these documents, the majority are emergency management plans and coastal hazard strategies. When referring to risk, most local government policy documents are high-level and all-hazard, calling for the identification, assessment, communication, avoidance, and reduction of risks in general. While the documents contain policy requiring the management of risks, there is a paucity of policy setting out frameworks for how this is achieved. Of the documents that do contain risk management frameworks, the majority focus on frameworks for asset management, followed by water quality, hazardous substances, and contaminated site management. Only three of these documents refer to natural hazard risk management; these are contained in either emergency management or coastal hazard management plans.

Of the 58 national and local policy documents that were analysed, three contain specific tsunami risk-based policy. The New Zealand Coastal Policy Statement (Department of Conservation, 2010) does so at the central government level, with the Tairawhiti Civil Defence Emergency Management Group Plan 2016–2021 (Gisborne District Council, 2016) at the regional council level (as a unitary authority[6]) and the City of Lower Hutt District Plan (Hutt City, 2016) at the district council level. Whilst some further documents contain risk-based policies specific to coastal hazards, they are generic and do not specifically relate to tsunami risk management.

6.7.2 Qualitative Interview Analysis

6.7.2.1 Disassociation and inability to internalise tsunami risk

Interview participants commonly used return periods to describe tsunami likelihood, ranging from 500 to 3000 years. They stated that these numbers were unrealistic, or not something they would probably see in their lifetime. In general, participants conveyed that the likelihood of destructive tsunami was so remote that its risk was hard to understand:

[6] A unitary authority is a territorial authority that has the responsibilities, duties, and powers of a regional council.

It’s not been in my lifetime, why would I worry about it? Therefore, when you start getting shown maps it’s like the whole area’s new and it’s like...It’s not real. (Participant).

While participants logically understood that a destructive tsunami could impact at any time and that the consequences would be severe, they had difficulty internalising what the consequences would mean for them. Instead, participants chose to disassociate themselves from the risk, preferring to assure themselves that a destructive tsunami was very rare and that a tsunami “won’t happen here”:

I think ever since the Indonesian event in 2004, and then that big follow up by what happened in Japan in 2011, there's a real fear and perception out there that if we get a decent tsunami it’s going to create devastation, huge devastation, but at the same time there is this, just this general thing “oh well but what is the chance of that happening, it won't happen here” sort of thing. (Participant).

Common across participant discussions was how important the coastal area was for their community to use and enjoy. Many participants lived in coastal areas and stated that, despite awareness of tsunami risk, living on the coast was preferable to living outside of a tsunami inundation area:

I live at Westshore, a big tsunami zone and I’m not going to move. I like living on the coast. It’s worth my while, I think, to have that enjoyment as a trade-off for the risk that I think about. (Participant).

As such, even though the consequences of destructive tsunami are severe, participants stated that the “un-realness” of the likelihood and consequences in combination with people’s affinity for living on the coast meant that they are prepared to accept the risk, believing that destructive tsunami will not happen to them:

People are willing to take a bit more risk around those areas and just accept the fact that there is tsunami, or these one-off major events, which have a return period of I think, two and a half thousand years, which is the largest modelled *one. So most people go "well two and a half thousand years, I'll take my chances". (Participant).*

6.7.2.2 Reduced motivation for developing destructive tsunami policy

Participants stated that currently there was not the same degree of focus within policy frameworks to cover the extremely rare events such as destructive tsunami, which are spaced out over hundreds or thousands of years. In-line with this short-term policy focus, participants found it easier to talk about risk management measures in place for more frequent, experienced hazards such as noise pollution, flooding, and erosion. Participants conveyed that these hazards were more pertinent issues that policy makers, decision makers, and the community could see every day, happening in front of their eyes. As such, policy for managing these more frequent hazards was well understood and received greater acceptance within the community. Participants stated that while tsunami was a coastal hazard, it was easier to separate tsunami from coastal hazard policy development and deal with more immediate concerns:

> *It's pretty easy to deal with some short-term stuff, you know, don't build on that hillside because it's in a slip zone, but tsunami is… you know… you're talking about hundreds and hundreds of years, so how do you identify what the risk is, how do you identify the policy response? (Participant).*

Participants also stated that the cost of implementing tsunami risk management policy would outweigh its benefits, especially when viewed in conjunction with shorter-term planning timeframes for natural hazard management. They believed that while highly concentrated populations, such as Japan, may have the means to reduce tsunami risk by relocating their built assets or through building large protective structures, New Zealand did not have the population concentration or economic means to make that option realistic. Furthermore, participants referred to where tsunami protection walls were overtopped in the Great East Japan Earthquake and Tsunami of 2011, stating that even if there were means to build protective structures, this did not guarantee community protection. They thought that considering the "extremely unlikely" event of a large, destructive tsunami, they would deal with the consequences if they occurred, rather than pay for protective structures which could fail anyway.

Similar to their views on the cost-benefit of applying policy for tsunami protection, participants stated that a precautionary policy approach for destructive tsunami risk management would effectively prohibit community development and economic benefit. Given that community and economic development is central to the objectives of local government (New Zealand Government, 2002b), prohibiting development to manage tsunami risk "just doesn't stack up". This is especially relevant given that the major cities in the Gisborne, Hawke's Bay, and Wellington regions are already located within tsunami inundation areas. Participants stated that policy which limited development of existing buildings in tsunami inundation areas was an issue that would potentially affect too much land and too many assets (built and human). Given the low likelihood of destructive tsunami, participants were uncertain as to how policy could be developed when the benefit from applying the policy was greater than the cost. Participants stated that there were more options for applying policies to manage development in *greenfield* areas where no existing building had taken place; however, they doubted whether policies that restricted greenfield development could be applied without property developer, community and jurisdictive resistance:

> *The uncertainty of tsunami risk sits in the really hard basket when you're looking at established development areas, obviously when you're planning new ones you can take those things into account, but if you're looking at managing existing areas it is really difficult. (Participant).*

> *It just doesn't stack up and I doubt whether we will, as an organisation, head to the Environment Court[7] to try and fight for those provisions and I don't think the Environment Court would be very receptive. (Participant).*

Because of the low likelihood of destructive tsunami and the uncertainties that they entail, policy development to manage tsunami risk is perceived as being in the "too hard basket". As such, planning and policy initiatives to reduce tsunami risk are less explored. One option for better communicating low-likelihood, destructive tsunami risk is through the use of risk

[7] The Environment Court of New Zealand works to solve issues relating to the Resource Management Act 1991. The court largely deals with appeals about the contents of regional and district plans and appeals arising out of applications for resource consents.

modelling. However, as pointed out in the following section, risk modelling comes with its own challenges when applied within local government.

6.7.2.3 Risk modelling is valued but challenging

While some participants were not as familiar with the use of tsunami risk modelling as others, they all agreed that risk modelling was beneficial, especially as it can produce a visual representation of the risk with which people can more easily identify. Some participants referred to the colloquialism that "a picture is worth a thousand words". They added that the ability of risk modelling to spatially distribute natural hazard risks on maps made it a valuable communication tool for community awareness campaigns, for media use, and for increasing decision makers' risk awareness.

Participants also valued the ability of risk modelling to provide loss estimates for planning purposes. They stated that the ability of modelling to tabulate comparisons of loss, depending on differences in exposure and vulnerability of assets, made it useful for *section 32* analyses (New Zealand Government, 1991, section 32), where benefits and costs, and considerations of alternatives, are required to be considered for the development of policies. They also referred to the value of risk modelling for emergency management, where modelled estimates of consequences can be used to inform readiness arrangements and pre-event recovery planning.

Almost all participants believed, especially in the case of low-likelihood hazards such as destructive tsunami, that modelled outputs which clearly and succinctly set out aggregated economic and infrastructural losses were beneficial for communicating risk and influencing decision makers' risk perceptions. However, participants expressed uncertainty as to whether risk modelling would actually change how decision makers would act. Some participants told of previous experiences where decision makers had rejected risk modelling outputs. These participants stated that officially, decision makers did not want to act because they were unsure of the quality of the modelled results; whereas unofficially, decision makers may not have wanted to act on the modelled results because of political reasons:

> *I don't think anyone politically wants to say "yeah, the legacy I left in my tenure was to make sure that there were protection and policies in place to hamper the growth of a city because it exists in a tsunami zone..." (Participant).*

In line with this, participants held reservations over the assumptions and uncertainties inherent within risk modelling. They expressed that risk modelling needed more transparency, rather than being a "black box", so that users could see how data was manipulated within the model and have more confidence in what it was telling them. They expressed that the assumptions of the models and lack of transparency were the first things that get contested by decision makers and the judicial system (Environment Court) when risk modelling had been used in the past to defend policy proposals.

Further concerns that participants had regarding risk modelling was that input data, in a usable format and quality, was very scarce; that data generation was very costly; and that their councils did not have the spare capacity or capability to support in-house risk modelling. Consequently, risk modelling had not yet been able to provide the specific level of information needed to inform detailed land-use and urban planning:

> *The thing with planning is that it requires pretty detailed information in order to justify putting in those policy constraints at the end of the day. You have to absolutely have it backed up 100 percent because you will be fighting it through councils, politicians themselves are not going to approve something unless it's fully sound. (Participant).*

As such, while participants saw risk modelling as beneficial, they were clear to state that it could only ever be a support tool for decision making. Many referred to risk modelling as a communication tool, capable of conveying information in a way that influences risk awareness and perception, to help start decision maker discussions for policy development:

> *That's probably a nice turn of phrase "as a communication tool" because I'm a firm believer that any model is there to support decision making not to make decisions. Only humans can do that in full judgement of the information available. So as a communications tool risk modelling is still quite valid. (Participant).*

6.8 Discussion

> *[Natural hazard preparedness] involves understanding how people construe the relationship between themselves, the hazard and the protective measures available to them and assisting their protective decision making within this socio-ecological context.* (McIvor, Paton, & Johnston, 2017, p. 45)

The results from the policy document analysis show that while natural hazard management is important for local government, there is a paucity of risk-based policy for tsunami management. Factors contributing to this are that the majority of policy takes a generic all-hazards approach; that existing policy tends to focus on more frequent, experienced, and escalating hazards; that the majority of tsunami-specific policy is unclear and non-prescriptive; and that risk-based policy is high-level and lacks reference to frameworks for how risk management would be achieved. As such, of the 58 national and local policy documents that were analysed, only three contain specific tsunami risk-based policy.

This paucity of tsunami risk management policy reinforces similar findings on the need for more specific hazard policy in New Zealand local government (Becker & Johnston, 2000; Glavovic et al., 2010; Local Government New Zealand, 2014; Saunders et al., 2014). The tendency to refrain from developing hazard-specific risk policy in favour of an all-hazards approach could be attributed to policy makers trying not to miss hazards out, as well as resource issues pushing them to achieve the greatest policy coverage with limited budgets. However, given the qualitative interview results where participants logically understand tsunami risk but choose to disassociate from it, we propose that the paucity in specific risk-based tsunami policy could also be attributed to cognitive biases.

Cognitive biases are a human condition where heuristics can sometimes cause us to behave in contrary or seemingly illogical ways. Over 100 cognitive biases have been recognised (Ehrlinger, Readinger, & Kim, 2016), with many acting in contradictory ways to others. While the following discussion focusses on how cognitive biases can influence people to under-perceive risk, other types of cognitive bias can influence people to over-perceive risk (Notebaert, Clarke, & MacLeod, 2016).

While the results show that participants logically understand that an unlikely, destructive tsunami can occur at any time and that the consequences will be severe, their difficulty in internalising the consequences from such an event shows a disassociation from the risk; that "tsunami won't happen to us". Research has established a number of reasons for this. People tend to have a poor understanding of low likelihoods (Doyle & Potter, 2015; Shoemaker, 1980; Slovic, Fischoff, & Lichtenstein, 1982). Slovic, Fischoff, and Lichtenstein (1982) found that people are insensitive to differences in very low probabilities and that below a certain threshold, low probabilities are perceived as the same and tend to zero. Shoemaker (1980) stated that people either ignore low probabilities or are unable to make rational decisions involving low probabilities. Henrich, McClure, and Crozier (2015) reported that people have difficulty perceiving low-likelihood disaster risk, especially when it is framed as a recurrence interval (e.g. 1/ 1000 years). McClure, Allen, and Walkey (2001), Khan, Crozier, and Kennedy (2012), and Baytiyeh and Naja (2016) stated that people are less likely to prepare for disasters due the belief that disasters are too destructive to prepare for successfully. Fraser et al. (2016), Mileti & O'Brien (1992), and Solberg, Rossetto, & Joffe (2010) referred to how warning fatigue and normalisation bias can drive people to underestimate the risk of natural hazards.

Cognitive biases which can influence practitioners to disassociate themselves from tsunami risk include:

- The Ostrich Effect – a tendency to disbelieve or ignore something that has a negative emotional effect, even if there is evidence to the contrary;
- The Optimism Bias – a tendency to underestimate the likelihood that negative consequences will occur from future threats;
- The Confirmation Bias – a tendency to search for, interpret, favour, and recall information in a way that confirms one's own pre-existing beliefs or hypothesis; and
- The Amnesia Bias – a tendency to forget too quickly the lessons of past disasters.

The results show that because of the low likelihood of destructive tsunami and the uncertainties they entail, practitioners perceive that developing policy to manage tsunami risk sits in the "too hard basket", which results in a paucity of tsunami risk management policy.

Cognitive biases which can influence practitioners' motivations towards developing policy include:

- The Myopia Bias – a tendency to focus on overly short future time horizons when appraising costs and the potential benefits of protective investments;
- The Availability Heuristic – a tendency to act on threats which have previously been experienced, or are easy to imagine;
- The Inertia Bias – a tendency to maintain the status quo or adopt a default option when there is uncertainty about the potential benefits of investing in alternative protective measures; and
- The Bandwagon Effect or Groupthink – a tendency for people to do something primarily because other people are doing it, regardless of their own beliefs which they may ignore or override.

The types of cognitive biases that influence policy development for low-likelihood, destructive tsunami are difficult to overcome. This is because these biases tend to be resistant to logic, deconstruction, or the use of training tools (Montibeller & von Winterfeldt, 2015; Weinstein & Klein, 1995). *Debiasing* measures that can improve decision-maker risk perceptions include (Montibeller & von Winterfeldt, 2015; Parkhurst, 2017; United States Government, 2009):

- Clear, easily digestible communication of the risk;
- Identification of the consequences associated with the risk;
- Provision of alternative scenarios and counter-examples; and
- Use of diverse expert information.

We propose that risk modelling can reduce the impact of these types of cognitive bias and therefore support the development of tsunami risk-based policy. The model used in the interviews (RiskScape) visually presents information in map form, which participants found easy to understand and with which to identify. The framework for the RiskScape model has been developed using robust science (Schmidt et al., 2011), is populated with diverse expert information for hazard and fragility models (Bell, Paulik, & Wadwha, 2015; Cousins, 2015;

Kwok, 2016; Uma, 2009), and is capable of presenting modelled consequences in map form and as numerical tables.

The results highlight how participants thought “a picture is worth a thousand words”, implying that the risk model visually communicated risk in a way that they found more informative and easily digestible than other traditional methods. Furthermore, even though they had not personally experienced the low-likelihood tsunami scenario depicted in the risk model, they stated that after seeing the results, they were better inclined to act on the information presented. Participants also thought that the aggregated economic and infrastructural consequences presented in the numerical tables were beneficial for influencing decision makers’ risk perceptions. As such, participants agreed that the ability of RiskScape to communicate consequences visually and numerically could help reduce misperceptions associated with a tendency to forget the lessons from similar disasters or underinvest in risk reduction measures. Participants also valued the ability of RiskScape to provide alternative scenarios. While this enables them to perform cost-benefit analyses for different risk reduction measures, it also provides more certainty around investing in those measures, thus enabling decision makers to move past biases associated with maintaining the status quo.

However, even though participants see risk modelling as beneficial for communicating past cognitive biases and risk perceptions for low-likelihood tsunami, this has not yet been achieved. Concerns relating to data availability, quality and cost, the capacity and capability to use risk models, and trust in modelled results mean that modelling is not widely used in New Zealand local government (Crawford et al., 2018). Also of concern are participants’ views that while decision makers may correctly perceive the risks communicated through risk modelling, they may not act upon them for political reasons.

6.9 Recommendations

This research reveals a number of challenges for low-likelihood, destructive tsunami risk management:

- A paucity of tsunami risk-based policy;
- Cognitive biases influencing tsunami risk perception;

- Challenges for how easily risk modelling can be used within local government; and
- Concerns about decision-maker motivation to enable tsunami risk management policy development.

As such, we recommend the following solutions to further develop a pathway forward for how local government could better match tsunami risk management policy with low-likelihood, destructive tsunami risk:

1. Further resource national risk management initiatives, for example, the Local Government Risk Agency[8], to better enable the development and application of natural hazard risk management frameworks within local government. This could be achieved through structured collaboration and training across the different local government functions responsible for natural hazard risk management (Crawford et al., 2018; Saunders et al., 2014). One option is regular risk management workshops to assess risks and what can be done to reduce them. The result is a shared understanding of each other's risk management roles (Doyle & Paton, 2018), greater integration across functions, and an improved ability to develop specific risk-based policy for destructive tsunami, rather than an all-hazard policy approach.
2. Include debiasing techniques as part of natural hazard risk management workshops so that practitioners and decision makers are better informed about how innate cognitive biases influence their perceptions that destructive tsunami "won't happen here". While increased awareness of cognitive biases may not change risk perceptions, it provides greater context when considering how acceptable the risk information is, allowing practitioners and decision makers to make more informed decisions.
3. Co-develop risk modelling through a bottom-up, participatory approach to enhance the usefulness and usability of the models (Newman et al., 2017). This approach would enable local government users to influence model development so that models can process a wider range of data formats (therefore increasing data availability), have a more intuitive user interface, and have increased quality of information output (Global

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[8] Local Government New Zealand (LGNZ) has proposed a Local Government Risk Agency that pools and coordinates local government resources to lower the risk and cost of disaster. https://www.lgnz.co.nz/our-work/local-government-risk-agency/

Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2016). This would tie in with initiatives to increase local government understanding of risk management so that practitioners and decision makers have a better understanding of the capability and value of risk models and greater confidence in modelled information.

4. Review the flexibility of natural hazard policy instruments to enable policy for low-likelihood hazards that have intervals over thousands of years, thus providing a way forward for long, long-term planning instruments (Lawrence et al., 2015). These long, long-term planning instruments could operate outside of shorter-term planning cycles and apply policy across 100–500 years, incrementally reducing community exposure and vulnerability to natural hazards over generations. A long, long-term plan would separate low-likelihood, destructive tsunami risk management from the more immediate political, financial and community development issues, which currently influence decision makers to perceive it as sitting in the "too-hard-basket".

Furthermore, we propose that these challenges arise from more fundamental issues relating to how natural hazard risks are governed in New Zealand and other countries. When discussing this with practitioners in the interviews, they referred to:

- a complex natural hazard management legislative environment;
- limited national-level clear, structured guidance;
- lack of any mandate within local government to lead cross-council natural hazard management functions;
- misperception or lack of integration across natural hazard management functions;
- the scarcity of available natural hazard data and information;
- a disconnect between science and policy;
- mismatched policy and planning timeframes across land-use planning, emergency management, building codes, and local government responsibilities;
- the differing requirements of decision makers across different practitioners' functions, politicians, and between practitioners and politicians;

- a shortage of resources impacting on capacity and capability.

These issues are complex, interrelated, and entrenched within local government. Participants reported that these issues result in long timeframes for natural hazard policy development, a paucity in risk-based policy, and a reduced ability to apply natural hazard management solutions such as risk modelling (Crawford et al., 2018). Considering this, we recommend the ongoing review of the interrelationship across natural hazard provisions in New Zealand to further explore governance approaches which can more effectively enable the application of natural hazard risk management solutions.

6.10 Conclusion

While the regions of Wellington, Hawke's Bay, and Gisborne are at risk of experiencing the most destructive tsunami that New Zealand is likely to encounter over a 1000-year timeframe, this risk is not currently matched by tsunami risk management policy. An analysis of 58 central and local government policy documents for those regions reveals only three that contain specific tsunami risk-based policy. We propose that this paucity in policy is influenced by cognitive biases which can cause people to disassociate themselves from low-likelihood tsunami risk and reduce motivation for developing risk-based policy. We argue that risk modelling (RiskScape) can help overcome these cognitive biases and aid policy development. While participants see value in risk modelling as a tool to communicate tsunami risk in a way that is more digestible and useful, they are uncertain of how easily it could be used and how acceptable its information is for decision makers. As such, we recommend participatory risk modelling to work in combination with risk management training, cognitive debiasing techniques, and long, long-term planning to overcome the challenge of low-likelihood tsunami risk perception. The complexity of New Zealand's natural hazard governance system remains an issue. However, with a deeper understanding of how New Zealand's natural hazard governance system impacts on the development and application of natural hazard policy, we can better apply solutions and enable our communities to become safer, sustainable, and more resilient.

7 [4th manuscript] Systems thinking for interrupting the cycle of challenges for risk-based natural hazard management in Aotearoa New Zealand Local Government.

7.1 Overview of this chapter

This manuscript picks up from the end of the third manuscript to explore the challenges for the development of natural hazard risk management policy within local government in Aotearoa New Zealand. It views these challenges as a complex system, consisting of feedback loops which inhibit the effective resolution of the challenges. It is proposed that these challenges remain unresolved because they are elements within a complex system. This complex system is explored using a systems-thinking approach and identifies the science-policy-practice interface as an intervention point which can interrupt the complex system's overall dynamic. The manuscript concludes with recommendations for further research into the use of systems thinking for exploring these challenges, as well as how collaboration across the science-policy-practice interface can be improved to apply natural hazard risk management more effectively within local government.

Table 7-1 positions this manuscript in relation to the other manuscripts within this thesis and the research questions that it has aimed to answer.

<table>
<tr><th>Chapter 4 – 1st Manuscript</th><th>Chapter 5 – 2nd Manuscript</th><th>Chapter 6 – 3rd Manuscript</th><th>Chapter 7 – 4th Manuscript</th></tr>
<tr><td>Explores how risk modelling tools, such as RiskScape, can be used to manage natural hazard risk in Aotearoa New Zealand local government.</td><td>Think piece exploring how risk modelling is perceived and used by the policy making, land-use planning, and emergency management functions within Aotearoa New Zealand local government.</td><td>Explores the thoughts and opinions of natural hazard risk practitioners regarding tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development.</td><td rowspan="5">Explores the complex system of challenges for the development of natural hazard risk management policy within local government as a whole and how the science-policy-practice interface can interrupt the complex system's overall dynamic.</td></tr>
<tr><td colspan="3">RQ1. How is natural hazard risk modelled information perceived and acted upon by local government?</td></tr>
<tr><td colspan="3">RQ2. How is risk modelling informed by natural hazard management?</td></tr>
<tr><td></td><td colspan="2">RQ3. How are natural hazard management policies and procedures informed by risk modelling?</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="4">RQ4. What are the risk communication barriers and enablers that limit or contribute to efficacy for natural hazard risk management in local government?</td></tr>
<tr><td></td><td></td><td colspan="2">RQ5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?</td></tr>
</table>

Table 7-1: Positionality of the fourth manuscript to the thesis

7.2 Manuscript preparation and publication

I prepared this manuscript as the primary author with my supervisors, Dr Saunders, Dr Hudson-Doyle, and Professor Johnston, as co-authors. I conducted the data collection, analysis, and drafted the initial manuscript. The co-authors provided guidance on the systematic review analysis, gave insights into patterns in the data collected, and offered feedback on the content and structure of the manuscript. The manuscript was submitted to the International Journal of Disaster Risk Reduction in September 2022.

7.3 Abstract

Local government in Aotearoa New Zealand struggles to effectively apply risk-based natural hazard management. Interviews held with local government practitioners in 2016 and 2017 reveal three main challenges for this: 1) Insufficient central government funding; 2) Lack of central government guidance and mandate; and 3) Limited local government risk awareness. A fourth cross-cutting theme also exists under each of these: Lack of quality data. A review of the literature indicates that while these challenges have been clearly identified over time, in many cases the recommended solutions cannot be applied or are not fully effective, and the challenges persist. We propose that many of these challenges persist because they are elements within a complex system, containing feedback cycles which limit policy development and application of risk management tools and procedures. Using a systems-thinking approach, we identify greater local government use of integrated research as an intervention, which can interrupt the complex system's feedback cycles. We conclude with recommendations for further research into the use of systems thinking for exploring these challenges, and action for how collaborative, integrative research can be improved to more effectively span the science-policy-practice interface and apply natural hazard risk management within local government.

7.4 Introduction

Aotearoa New Zealand is a small island nation that has been ranked as high-risk for almost every natural hazard except for extreme heat and water scarcity (Voerman, 2020). Events including earthquake, volcanic activity, tsunami, flooding, storm, and landslide occur with sufficient intensity that substantial damage and loss of life results (King & Bell, 2006). Financial losses from the impact of natural hazards continue to grow (Insurance Council of New Zealand, 2014; New Zealand Institute of Economic Research, 2020) due to increased natural hazard frequency, intensity, and the growing exposure and vulnerability of persons and assets (UNISDR, 2015; UNDRR, 2020). In their 2018 report, Lloyd's (2018) placed Aotearoa New Zealand as the second most vulnerable economy in the world for annual expected disaster related losses as a percentage of Gross Domestic Product (GDP). Considering the nation's vulnerability to, and losses from natural hazards, it is increasingly important for Aotearoa New Zealand to proactively develop and apply natural hazard risk management policies, tools, and procedures. These measures act to reduce the financial and social vulnerability to hazards before they occur, as well as mitigate costs and losses for responding to, and recovering from them, when they occur.

However, local government has struggled to effectively develop measures to reduce risks. This is reflected by Crawford et al. (2019), who found that of 58 central and local government natural hazard policy documents analysed, the majority of policy referring to natural hazard risk management was ambiguous, high-level and 'all-hazard'. Furthermore, there was a paucity of policy that set out frameworks for how natural hazard risks were identified, assessed, communicated, avoided, and reduced. Crawford et al. (2019) went on to state that of the local government policy documents that contained risk management frameworks, most applied to functions outside of natural hazard risk management, for example asset management, water quality, hazardous substances, and contaminated site management.

This research explores the reason for this paucity in local government natural hazard risk-based policy and resultant application of natural hazard risk management tools and procedures. Semi-structured interviews were held between September 2016 and June 2017 with local government practitioners in functions relating to natural hazard management, including policy making, land use consent planning, emergency management, environmental science, building control, asset management, engineering, and hazard modelling. Participants were asked for their thoughts, feelings and experiences for how natural hazard risk management policy works in their council, revealing a number of interconnected challenges for developing policy and applying natural hazard risk management tools and procedures.

In Section 2 we define the qualitative methods used to gather participant's thoughts, feelings, and experiences regarding natural hazard risk management policy in their councils. The results, presented in Section 3, reveal three main challenges for the application of natural hazard risk management: 1) Insufficient central government funding; 2) Lack of central government guidance and mandate; and 3) Limited local government risk awareness. A fourth cross-cutting theme also exists under each of these: Lack of quality data. These challenges are not new, and the results section refers to associated literature for each challenge, identifying how they have been recognised over time yet, in many cases, remain unresolved. In Section 4, we propose that these challenges remain unresolved because they are elements within a complex system of natural hazard governance within local government in Aotearoa New Zealand containing feedback cycles. These feedback cycles limit the application and effectiveness of solutions delivered via policy, tools, and procedures. Using a systems thinking approach we explore this complex system and identify greater local government use of integrated research as an intervention point, which can interrupt the complex system's feedback cycles. We review the use of integrated research for collaborating across the science-policy-practice interface with local government on natural hazard risk management; itself a complex system of interrelated elements that limit its effective application. Finally, in Section 5, we conclude with recommendations for further use of systems thinking to review and improve the development of risk-based local government natural hazard measures, as well as the effective application of a formally structured, collaborative integrative research approach for bridging the science-policy-practice interface.

7.5 Methods

The research employs qualitative methods to "explore the views, experiences, beliefs and/or motivations of individuals" (Gill et al., 2008. p. 292) because risk perception is subjective, involving people's feelings, beliefs, attitudes, and judgements (Barnes, 2001). Qualitative interviews were used in this research as they are "a conversation with a purpose" (Smith & Smith, 2018, p. 72) and are one of the most powerful tools for gaining an understanding of human beings and exploring topics in depth (Fontana & Frey, 2000). Qualitative interviews were adopted over other qualitative methods (e.g., document analysis, observations, and focus groups) because they engage directly with participants and stimulate discussion on different and more sensitive topics than other methods (i.e., focus groups) (Powell & Single, 1996; Kaplowitz, 2001).

Types of qualitative interviews range from being structured and controlled, increasing in flexibility towards being unstructured and fluid. This research adopted the semi-structured interview as it provides more focus than an unstructured interview but still enables latitude in interview questioning for the researcher to follow up on the participants' responses (McNamara, 2009; Mueller & Segal, 2014). This was deemed appropriate for exploring potentially sensitive discussions where participants identified challenges for the effective development of policy and application of natural hazard risk management tools and procedures. The Massey University Ethical Code of Conduct was followed, and this research received a low risk ethics approval.

Participants were purposively identified and invited by a 'gatekeeper' in each region who was able to transfer external information to colleagues within their organisation (Macdonald & Williams, 1993). The participants were all local government practitioners whose work related to natural hazard management. The gatekeepers were all local government staff who worked with the participants of this research. The gatekeepers were known to the lead author of this article, and had worked with him in previous, related research (Crawford et al., 2018a; Crawford et al., 2018b; Crawford et al. 2019).

Table 7-2 shows that twenty-three participants consented to be individually interviewed in 2016 and 2017, in five local government councils across the Wellington, Hawke's Bay, and Gisborne regions of Aotearoa New Zealand (mapped out in Figure 7-1) all of which are exposed to significant natural hazard risks. The interviews lasted between 1–2 hours, within which participants were asked to relate their thoughts, feelings and experiences on how natural hazard risk management policy works in their council, following a semi-structured interview guide (Table 2).

Council Visited	**Date visited**	**Participant numbers**
Wellington Regional Council	17th of May 2017 16th of June 2017	4
Hawke's Bay Regional Council	22nd – 23rd of September 2016	5
Napier City Council	22nd of September 2016 26th of June 2017	3
Hastings District Council	27th of June 2017	3
Gisborne District Council	26th – 27th of September 2016 28th – 29th of May 2017	8

Table 7-2: Councils and participant numbers for semi-structured interviews

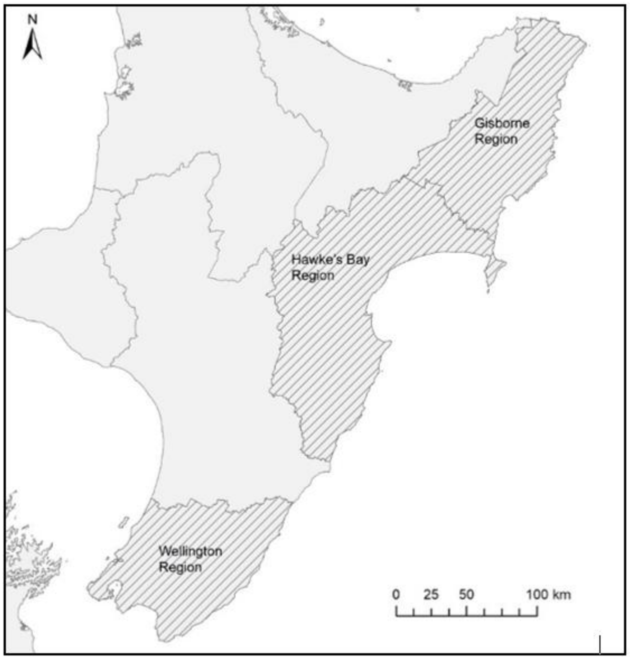

Figure 7-1: Map locating the Wellington, Hawke's Bay and Gisborne local government regions

Thoughts, feelings and experiences on how natural hazard risk management policy works in their council: • Its level of importance • How often policy is developed • How policy is applied • Links across council for natural hazard risk management • The local governance environment/mandate for policy development • Risk-based policy

Table 7-3: Semi-structured interview guide

The recorded and transcribed interviews were thematically analysed using NVivo[9] software. This analysis approach "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006, p. 5). As shown in the semi-structured interview guide (see Table 7-3), participants were not specifically

[9] https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

asked to identify challenges for how natural hazard risk management policy works in their council. An inductive, ‘bottom up’ approach (Patton, 2015) was adopted to code the transcripts. These codes were organised, structured, and re-structured, and reflexively interpreted through the lens of the researcher to generate a set of themes that represent shared patterns of meaning across the interviews (Braun and Clarke, 2006).

7.5.1 Limitations and Risks

The data that informs this research was gathered between September 2016 and June 2017. Intervening events, such as the increasing impact of climate change related events, the Whakaari / White Island eruption in 2019, and the Covid-19 pandemic beginning in 2020, would have influenced risk perceptions and impacted on actions within local government. Policy guidance and development, especially in the climate change space (MCDEM, 2018; MfE, 2017; MfE, 2019; MfE, 2022; WCC, 2020), has also occurred. Therefore, while many of the findings in this research still apply, some participant’s views on local government natural hazard risk management policy will have progressed.

Semi-structured interviews run the risk that participants are not able to attend interview sessions, have a limited understanding of the topics covered, and are not comfortable answering the researcher’s questions. There is also the risk that the researcher is unable to build rapport with participants and/or is unable to actively listen to the participants’ responses and engage in the interview (Mueller & Segal, 2014; Kakilla, 2021).

These risks were managed by having two series of interviews, which allowed practitioners to participate who were unable to attend the initial interview sessions. Participants were purposively identified by gatekeepers, ensuring they were natural hazard practitioners and had a good understanding of their council’s natural hazard policy and procedures. To provide privacy for the discussion, interviews were one-to-one, conducted in a private space and participants were assured that that data gathered would be aggregated across a number of councils and functions so that the thoughts, feelings, and experiences referred to in the research could not be traced to specific individuals. The primary author introduced his background having worked in local government natural hazard risk management, which built rapport with participants.

7.6 Results with literature review

Analysis of the qualitative interviews reveal interconnected challenges for the development of risk-based policy and application of natural hazard risk management. Three main challenges emerged from the analysis: 1) Insufficient central government funding; 2) Lack of central government guidance and mandate; and 3) Limited local government risk awareness. A fourth cross-cutting theme also exists under each of these: Lack of quality data. These challenges have been recognised in the literature on local government natural hazard management over time. While this literature has recommended solutions for these challenges, more recent literature published after the interviews were undertaken has highlighted that in many cases the challenges persist.

7.6.1 Insufficient national funding

Participants commonly called for more central government financial assistance for natural hazard research, data collection, communication, and policy development:

> *I think the real difference is money. If you want to move communities away from hazards, somebody has to pay for it. So, the real deal is for central government to front up with some cash. It all takes money to do something, so the 'do nothing' option is an easy policy response, but it is not a very good political response.*

However, as stated by Hamilton (2013), Aotearoa New Zealand had (and still has) a relatively small economy, had difficulty in recognising a return on investment from natural hazard management, and perceived natural hazard policy as restricting opportunities for social and economic development in hazard risk prone areas. This has resulted in limited availability of central government funding for local government natural hazard risk management.

Given limited central government funding, it is the responsibility of local government to fund natural hazard risk management. However, as identified in the literature over time, local government funding for natural hazard risk management has been limited by the size and wealth of the rate payer base to provide adequate local government funding, as well as available funds being appropriated to other local government activities that are perceived as more urgent/important (Lawrence & Manning, 2012; Manning et al., 2015; MCDEM, 2019; MfE, 2020). Responses from different participants that reflect this theme included:

Something is better than nothing I guess, it's just the question about how we actually fund it in the short term. Its fine for the big councils, they have a nice big ratepayer base, they can justify spending on these things, but we are fairly small one and have trouble funding it. But we still have to do it.

For this Council water [supply] is the number one priority and most of the efforts of the planners and the resource management staff are focussed in those areas, so even though natural hazards and emergency management are important, when events aren't occurring it just drops down on the importance list.

Interconnected with lack of funding is lack of capacity and capability in local government for natural hazard risk management (NZPC, 2019). Participants stated that lack of funding limited their ability to gather quality data and information, develop new skills and recruit skilled resource to use that information for natural hazard management. Responses from different participants included:

Internal resource for the council is always an issue. People are stretched with their workloads and probably find it difficult to develop in a new area.

We have talked about outsourcing to help us with things, but we haven't gone there because while we've got money for our natural hazards policy work, it's not enough to get everything done well. For getting specialist expertise in-house, one problem is that we can't pay them enough to attract them.

Lack of capacity and capability for local government has been recognised as a challenge in the literature over time. Glavovic, Saunders & Becker (2010) identified limited local government capability for land-use planning, emergency management, and risk awareness for natural hazards. Sinclair et al. (2012) stated that the ad hoc approach to emergency management training and evaluation provided no guarantee that emergency response capability was being increased. LGNZ (2014) noted that many smaller local government authorities resourced the emergency management function at well below one full-time-equivalent (FTE), which limited capability to reduce natural hazard risk, and that there was limited human and intellectual risk management capability. Manning et al., (2015) highlighted that there was little local government climate change capacity and expertise. Toka Tū Ake EQC (2019) noted that skilled resources are lacking in natural hazards science modelling, and some models and modelling capability are not optimised. NZCP (2019) recognised that councils are struggling to deal with some big pressures including climate change, and recommended changes in funding and financing. MCDEM (2019) stated that gaps remain in local government emergency response capability and capacity and in the powers of those authorities to act.

Furthermore, the interconnection between insufficient funding and lack of local government capacity and capability was highlighted in a more recent review of the Resource Management Act, titled 'New Directions for Resource Management in New Zealand' (MfE, 2020). The report stated that the new resource management system would critically depend on the capacity and capability of all those involved in it, and that failure to provide sufficient resources to build capability had been one of the more important reasons for past failures.

7.6.2 Lack of central government guidance and mandate

Another common challenge emerging from the qualitative interviews was participants calling for more clear and concise central government guidance and support for them to progress the application of natural hazard risk policy and procedures.

> *If [central government] want to be proactive in terms of trying to make New Zealand more resilient to specific types of natural hazard, then it needs to be a bit more front-footed in terms of a solutions.*

Participants stated that strong central government direction was needed because the policy changes involved would result in unwanted, disruptive change to how people live, which was too contentious to direct at the local government level. They also acknowledged that while central government direction was needed, it would come at political cost. Different participant responses included:

> *It really has to be a national directive. I can't really think of any way around it at the moment. The removal of property rights would be so significant, and you could just imagine the legal challenges that [local government] would get.*

> *Are [central government] going to be the ones that say their legacy is that they crippled people living at the coast, you know, from growing their environment, and there's lots more like that?*

As such, participants noted a reluctance, or indecision from central government to set policy direction, preferring to devolve it to local government.

I am on the National [Tsunami] Working Group and I really wanted [central government] to put in who was going to make that decision but they won't. They said that was a decision for each individual council to decide where that delegation is going to lay.

Furthermore, participants stated that inaction from central government around setting clear guidance had restrained local government from giving effect to natural hazard risk management measures.

The big issue I reckon, in terms of the impediments, is changes going on at a national level. You know, constant rhetoric we're getting from MfE [Ministry for the Environment] around "we're looking at changes here, we're looking at changes there", and then the fact that the planners think that if these changes are coming there's no point in actually putting effort in, because it's such a long game in terms of getting these changes made, so it's better to hold fire at the moment.

The challenges arising from lack of central government guidance have been identified in previous research. Glavovic, Saunders and Becker (2010) called for nationally consistent practical steps to improve the safety and sustainability of at-risk communities. Kilvington and Saunders (2013) identified that guidance for managing natural hazards through land-use planning appeared independent and not located in a conceptual hierarchy, such as a national to local scale. Kilvington and Saunders (2016) highlighted that there was (and still is) no national policy statement (NPS) or national environmental standard (NES), which would provide central government guidance relating to sustainable natural hazard management.

Since the time of these interviews, central government guidance has progressed. In 2017, the management of significant risks from natural hazards was added as 'a matter of national importance' in section 6(h) into the Resource Management Act (RMA) (New Zealand Government, 1991). Climate change guidance has also been published (MfE, 2017; MfE, 2019; MfE 2021; MfE 2022), planning and engineering guidance was published for land prone to liquefaction (MBIE, 2017), and emergency risk management guidance (including emergencies resulting from natural hazards) was provided within planning guidelines for Civil Defence Emergency Management (CDEM) in 2018 (MCDEM, 2018).

While this guidance has provided greater direction, participants at that time were sceptical about how it would make a difference. For example, in relation to section 6(h) into the RMA (which was only proposed at the time of the interviews), one participant stated:

> *Just by inserting an extra couple of lines into section 6 [of the RMA] doesn't miraculously mean that we will all start thinking about hazards. We've been thinking about natural hazards for years and years and years. Whether that makes any material difference, I don't know. But certainly, from where I sit the section 6 addition shouldn't really be that much of a game changer if you're doing good practice already.*

Indeed, despite the inclusion of section 6(h) into the RMA, as well as the proliferation of climate change guidance, more recent literature has identified that the management of significant risks from natural hazards remains a "gap in national direction" (MfE, 2020, p. 197).

Participants were also weary that if clearer central government guidance was provided, it could restrict the flexibility needed for natural hazard risk management policies and procedures to fit within different environments.

> *Part of me is terrified of the prospect [of a natural hazards NPS] because experience with other forms of national direction has meant that it's just going to push stuff down to local government to try and manage. It's either very vague and not specific or very directive and it might hamstring innovation and creativity at the local level. Not to say that we don't need national direction, there's certainly a nice sweet spot somewhere. It's a matter of discovering that sweet spot for central government led initiatives.*

Interconnected with the lack of clear and concise central government guidance, participants described a lack of mandate for coordinated natural hazard management resulting in inconsistent perceptions within councils for different natural hazard risk management functions. When interviewed, policy makers were adamant that their natural hazard management took a holistic approach, incorporating different council functions and external resources. However, interviews with land-use resource planners revealed that they mostly focused on only the regulatory functions defined by the RMA (New Zealand Government, 1991), rather than holistic, outcome orientated management. Furthermore, interviews with emergency managers highlighted that in many cases their function was marginalised from coordinated natural hazard risk management, with it being perceived as solely focussing on managing emergency response and recovery. Responses from different participants on this theme included:

> *You have the engineers and the building consents guys, and the planners and they are all collectively are fully aware of the hazards, so as an organisation I think we are pretty good with it. We are constantly, collectively working on contingency plans.*

> *As far as [resource] planning is concerned … they're dealing with the here and now, they're dealing with people who come in with development proposals, they're looking at a District Plan, which maybe has a ten-year life.*

> *[Emergency management] tends to operate much more on the response and recovery side and try as you might there's not actually a lot of crossover and dialogue between the emergency management and the planning policy people.*

Lack of mandate and the resultant misperceptions for natural hazard risk management functions has been identified in the literature over time. LGNZ (2014) identified that within councils, land-use planning and CDEM planning operated in a more 'silo-ed' manner. Lawrence et al. (2015), and Crowley and Crawford (2016) highlighted how CDEM was perceived as a less connected function for natural hazard planning compared to policy making and land use planning. This working environment reflects Saunders et al. (2015), who noted that collaborations across different natural hazard practitioner roles had not been commonly encouraged for sharing information, good practice, and understanding of roles.

Participants agreed that coordinated natural hazard risk management across local government authorities would be useful for shared understanding of natural hazard risks and achieving mutually beneficial outcomes with limited budgets. However, lack of mandate meant that coordinated efforts were inconsistent across regions, were reliant upon established relationships, and were often only achieved when there was a 'champion' available to take the lead when they had spare time to do it. Different participant responses included:

> *I don't see a discussion going on around region wide coordinated policy for hazard management other than for the coastal strategy that we are doing now.*

> *We have set up a cross council committee to have an overview, as in across our council – our works, engineering, building, strategic planning/policy people, and civil defence so that we can at least get a clear idea of what's happening. We haven't met yet, only because I've been busy doing other things.*

Inconsistent coordination of natural hazard risk management across local government authorities has also been identified in previous literature. As far back as 2012, Saunders and Beban (2012) identified that "there is a lack of consistency in how the natural hazards and associated risk are addressed. One council may have strict planning requirements pertaining to a natural hazard, whereas the neighbouring council has a lesser requirement that allows for development that increases the risk" (Saunders & Beban, 2012, p. 18).

7.6.3 Limited local government risk awareness

Participants consistently stated that while their Council was aware of natural hazards and took their management seriously, they were less aware of natural hazard *risk*. They acknowledged that lack of consistent, quality data resulted in limited awareness for the likelihood of certain magnitude hazard events, and the consequences of their impact. This limited the potential for policy-makers to develop risk-based policy, and for decision-makers, i.e., local politicians, to support/approve it. Different participant response included:

> *The quality of information or availability of information underpins the types of decision making that you can or can't make, and therefore the tools you can or can't deploy. So, if you've got pretty crude data sets, well the chances are you're not going to have sophisticated policy.*

> *The thing with planning is that it requires pretty detailed information in order to justify putting in those policy constraints at the end of the day. You have to absolutely have it backed up 100% because you will be fighting it through councils, politicians themselves are not going to approve something unless it's fully sound.*

Lack of quality data in local government has been identified in the literature over time. Bremer and Glavovic (2013) proposed that a reason for this was that most local government regions do not have the capacity to monitor a large number of natural hazard indicators. They went on to state that the scientific data that could supplement local government information was poorly disseminated, was often in an unusable form, had been lost through poor information management, or was held by private organisations and research institutes. Saunders, Beban, and Coomer (2014) identified the prohibitive cost of obtaining natural hazard risk information, along with the limited information quality and reliability, particularly for low-probability, high-consequence natural hazards. MWH (2016) referred to the high variability in the nature, comprehensiveness, and consistency of information on different natural hazards held by councils. MCDEM (2019) stated that challenges remain in increasing the availability of information and assessments to the people and planners across all levels of government. The UNDRR (2020) recognised that easily accessible disaster information could lead to more comprehensive, detailed, and tangible risk and vulnerability assessments at the regional and local level. However, they go on to state that this would require increased capacity and capability (technical and human resources) for implementation. Most recently, Harrison et al. (2021) noted that the personal interests of key staff within organisations appear to either inhibit or enable data collection and creation, and that "it just depends on who's here and who's leading the team" (Harrison et al., 2021, p. 17).

Participants stated that lack of natural hazard risk data also resulted in misperception of the significance of the risk for practitioners and decision-makers, which has also been identified in the literature over time. Saunders and Beban (2012) stated that high-consequence, low-likelihood events were difficult for practitioners and decision makers to manage, due to a lack of understanding and awareness of their consequences. Doyle et al. (2014) identified that practitioners underestimated the chance of an event likelihood 'today' compared to 'tomorrow', due to interpretive bias which skewed their perceptions on the likelihood of occurrence. Similarly, White and Haughton (2017) refer to the 'tyranny of the present' for risk awareness, where governance arrangements are bound by policy makers' biases towards developing policy based on what is certain and known about the present compared to the future.

This is reflected in participants responses, which highlighted that frequently experienced but lower risk hazards were given greater attention and policy-making support than less frequent, higher risk hazards.

> *The focus is generally on subsidence and a reactive style resilience work where we know there's an issue, you can see it visually, and so we'll go and treat that. As opposed to a tsunami that might come in 20 years' time or whatever and if it came it would wipe out a bridge but because that bridge is fine now, we're not going to do anything to protect it. And I think that's where we are very weak, not just in tsunami but all the natural hazards. We're not looking long-term and assessing the true risk.*

Furthermore, participants recognised that the short incumbency of local government politicians (3 years) along with the short local government planning timeframes (10 years), resulted in challenges for governing less frequent, high consequence hazards, even though they presented greater risk.

Individuals and the public have so many other priorities in the here and now, even politicians when they worry about the next three years. So, the likelihood and the intervals between one tsunami and the next are over the horizon for many.

A district plan is for only 10 years. It's not a particularly long life so if you try to put regulation around a two and a half thousand year event it's hard for communities to be able to wrap their head around planning for that length of time even though it could happen tomorrow. The only people that can come into that space is central government taking a real major lead in it and saying, "the risk is too high, we do need to do something!".

The lack of long-term risk awareness and resultant lack of political efficacy to manage it has also been identified in the literature, where Lawrence et al. (2015) stated that political willingness to act on climate change risk was perceived as "it isn't a problem, or at least not in my term of office" (Lawrence et al., 2015, p. 313).

Given the lack of natural hazard risk data, interconnected with limited local government risk awareness, participants highlighted that it was difficult to develop and gain policy-maker and decision-maker support for tools and procedures used for better managing natural hazard risk. For example, risk modelling was viewed by participants as useful for assessing and communicating natural hazard risks for policy development and decision-making, however it was not commonly used. Different participant responses included:

I think risk modelling is hugely powerful for two reasons: One is for policy-makers and decision-makers to use to develop policy instruments to identify those risk areas and help mitigate some of that risk. It would also be very powerful for CDEM planning, through knowing what the potential impacts would be.

More and more of these models are becoming fairly sophisticated, complex things, and those things in themselves present challenges around transparency. Are they just magical black boxes that spit out something? What does that something actually mean and how was that arrived at, with loads and loads of assumptions or very little? That then leads you to either the policy analyst or the decision maker *having a bit less faith or confidence in the model and what it's telling them.*

7.6.4 The persistence of challenges

The challenges identified in this research are based on data gathered in 2016 and 2017. It is acknowledged that the impact of natural hazard events, the application of central government guidance and the development of policy during the intervening years may have changed practitioner's thoughts and opinions on challenges for local government natural hazard risk management. However, more recent literature indicates that these challenges persist, for example the impact of limited funding on development of local government capacity and capability (NZPC, 2019; MfE, 2020), gaps in central government guidance (MfE, 2020), and lack of available natural hazard data (UNDRR, 2020; Harrison et al., 2021).

The more recent identification of these challenges within the literature adds weight to the discussion, in Section 4, that these challenges persist because of fundamental issues relating to the system for how natural hazard risks are governed in New Zealand. This was recognised by Crawford et al. (2019), who noted that long timeframes for natural hazard policy development, a paucity in risk-based natural hazard policy and frameworks, and a reduced ability to apply (or have success with) natural hazard management solutions was a result of challenges that were complex, interrelated, and entrenched within local government.

7.7 Discussion

The challenges for natural hazard risk management identified in the Results Section persist despite recommendations made in previous research for how they can be resolved. Examples of solutions recommended in the literature over time include:

- The application of natural hazard risk modelling as a risk communication tool (Crowley and Crawford, 2016; Crawford et al., 2018a; Crawford et al., 2018b; King and Bell, 2006; Saunders et al., 2015);
- Local government adoption and application of the ISO 31000 standard and approach for risk management (Beban & Saunders, 2013; Saunders & Beban, 2013; Saunders, Beban, & Kilvington, 2013; Tonkin & Taylor, 2016; Kilvington and Saunders, 2015; Kilvington and Saunders, 2019; MCDEM, 2018; UNDRR, 2020);

- The provision of scientific guidance for local government natural hazard planning and response (Kilvington and Saunders, 2013; Kilvington and Saunders, 2016; Thompson et al., 2015; Woods et al, 2017);
- Development of a centralised natural hazard information database (Basher, 2016; Glavovic, Saunders, and Becker, 2010; Hamilton, 2013; ICNZ, 2014; Lee, 2010; LGNZ, 2014; MfE, 2020; UNDRR, 2020; MfE; 2022);
- The application of dynamic adaptive pathways for managing natural hazard risk (Lawrence, Bell and Stroombergen, 2019; Lawrence and Haasnoot, 2017);
- Communicating uncertainty for decision making on natural hazard risk management (Doyle et al., 2011; Doyle et al., 2014; Doyle et al., 2018; Doyle et al., 2019);
- Gaining community engagement with natural hazard risk management (Kilvington and Saunders, 2015; Kilvington and Saunders, 2019); and
- A framework to help local government decision-makers better understand and approach disaster risk decision evaluation (Brown et al., 2017).

However, in many cases the application and effectiveness of solutions has been limited. Two examples of are:

- The use of the 'RiskScape' risk modelling software and adoption of the ISO 31000 risk management international standard and approach. Despite RiskScape being introduced in 2006 (King & Bell, 2006) to more effectively assess and communicate natural hazard risk for local government policy development and decision making, 14 years later RiskScape had only been used by 10% of surveyed local government practitioners, where the majority (69%) reported that they would need further access to data before they could operate it (Thomas et al., 2020).
- In 2013, the ISO 31000 standard and approach (ISO, n.d.) was recommended for natural hazard risk management under the RMA (Beban & Saunders, 2013; Saunders & Beban, 2013; Saunders, Beban, & Kilvington, 2013). While the ISO 31000 approach has been endorsed by central government and has been adopted in some local government authorities (Kilvington & Saunders, 2015; 2019), many local government authorities have

continued to use alternative and inconsistent risk management approaches depending on various capacities, resources, and risk perceptions (UNDRR, 2020).

We propose that the limited application and effectiveness of solutions delivered via policy, tools and procedures, which results in the persistence of challenges for local government, is because they are elements within a 'complex system' of natural hazard governance. A 'system' is a set of interacting elements that form an integrated whole intended to perform a function (Skyttner, 1996). A 'complex system' is when the relationships between its interacting elements are non-linear or cyclic, creating dynamic processes which have no endpoint and do not perform as intended (Ladyman & Wiesner, 2013; Young, 2017).

As highlighted in the results section, the cycle of challenges for local government begins with insufficient central government funding for natural hazard risk management. Insufficient funding then limits the development of central government guidance and the capacity and capability of local government to apply that guidance, gather more data, and grow awareness of natural hazard risks. Limited local government risk awareness then impacts on decision-makers' willingness to prioritise funding for natural hazard risk management over other local government activities, and practitioners' ability to develop risk-based policy and apply risk-based tools and procedures. Lack of local government risk awareness, along with limited use of risk-based measures then cycles back to limit the provision of funding and guidance at the central and local government levels, as well as the ability for local government to gather data, develop capacity and capability … and the cycle persists.

An approach for exploring a complex system is through 'systems thinking'. Systems thinking is a way for people to understand systems where traditional, siloed, reductionist approaches for dealing with complexity have failed to produce apparent or effective solutions (Aronson, 1996; Siri et al, 2016). While systems thinking is based on an ambiguous collection of interdisciplinary conceptual frameworks (Shaked & Schechter, 2017), its fundamental feature is that it takes a holistic view of a system while identifying the interrelated, non-linear properties and behaviours of the system (Jaradat, Keating & Bradley, 2017; Lee & Green, 2015).

While the systems thinking approach has been applied for natural hazard management overseas (Fawcett & Fawcett, 2013; Mavhura, 2017; Rehman et al., 2019; Sword-Daniels, 2014; Zhuo & Han, 2016), its application for exploring the challenges for local government natural hazard risk management in Aotearoa New Zealand is limited to PhD research on integrated natural hazard planning frameworks (Mamula-Seadon, 2007). As such, this research contributes a preliminary example of the potential for systems thinking to holistically view the complexity of Aotearoa New Zealand's natural hazard risk management system within an already sparse area of research.

The benefits from using a systems thinking approach are that the elements of the system can be mapped out using 'causal loop diagrams'. A causal loop diagram is a cycle that has no endpoint, where an initial element within a complex system influences other elements, which eventually feeds back to influence the initial element (Boardman and Sauser, 2008). Causal loop diagrams enable people to compare and share mental models for the connections and feedback relations between elements within a system and identify the overall system dynamic (Haraldsson, 2004; Toole, 2005). This system dynamic can be 'the same', where similar elements act to build upon each other and strengthen the system dynamic, or 'opposite', where different elements oppose each other and weaken the system dynamic. Most importantly, causal loop diagrams enable people to identify intervention points, which can then be used to interrupt the system's overall dynamic (BeLue et al, 2012).

A causal loop diagram of the interrelated challenges identified in this research is mapped out in Figure 7-2.

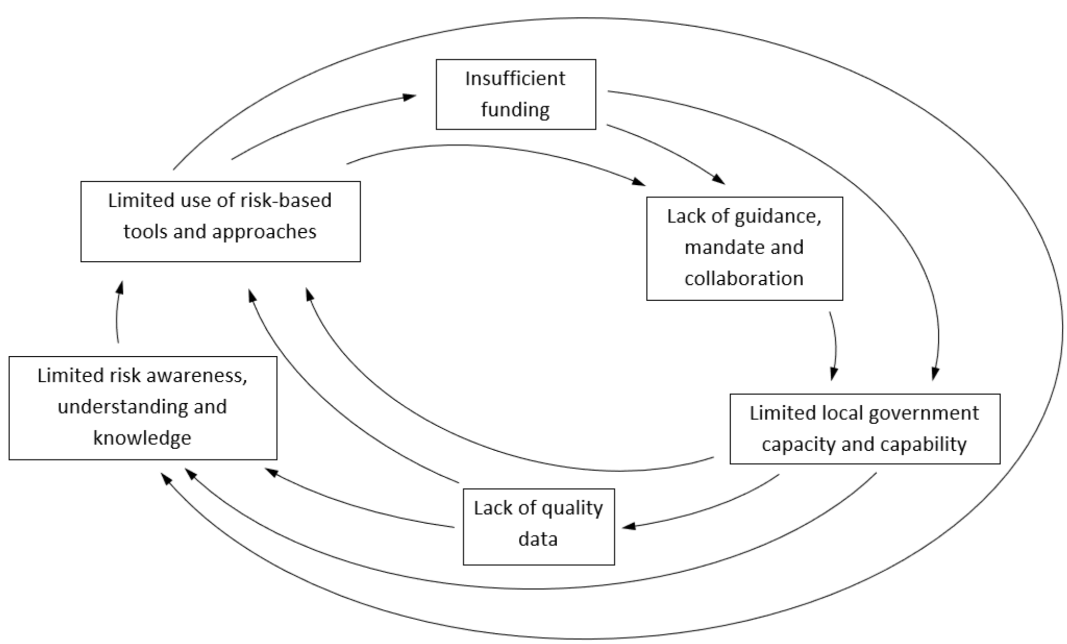

Figure 7-2: Cyclic feedback loop mapping out the interrelated challenges for natural hazard policy, tools and procedures in local government in Aotearoa New Zealand.

The causal loop diagram in Figure 1 shows that the elements within the complex system of challenges for natural hazard policy, tools and procedures in local government are 'the same', where similar elements (challenges) act upon each other. This results in a system where challenges persist or are strengthened, and the success of solutions is limited. As such, an intervention point is needed to interrupt the system's persistent or strengthening dynamic.

Figure 1 highlights that the 'Limited local government capacity and capability' element within the system is interconnected with many other elements. As such, an intervention at this point has significant potential to influence other elements and weaken the system dynamic. We propose that this intervention can be achieved through greater local government involvement in, and use of, 'integrative research'. Van Kerkhoff (2014) defines integrative research as operating within the context of complexity, with a specific aim to contribute to action, implementation and practical change. It acts to bridge barriers that separate traditional modes of inquiry. It is trans-disciplinary, trans-sectoral, integrates across geographical scales, and integrates across styles of knowledge creation (National Research Council, 1999). A fundamental characteristic of integrative research is that it uses collaborative, participatory approaches to co-develop knowledge that can bridge the science-policy-practice interface (Barton et al., 2020; Wyborn et al., 2017).

Frameworks for integrative natural hazard research in Aotearoa New Zealand already exist. Examples include the 'Natural Hazards Research Platform' (2009 – 2019) and the 'Resilience to Nature's Challenges National Science Challenge' (2013 – present). They are (or were) a consortium of research organisations and agencies including Crown Research Institutes, State Owned Entities, universities, private research consultancies, central and local government, industry, and other stakeholders with the objective "to build shared understanding of natural hazards and risks, and to develop practical risk reduction solutions" (Woods et al., 2017, p. 330). Importantly, these integrative natural hazard research frameworks have sat independently of local government. They have not been subject to the local government's challenges of insufficient central government funding or lack of central government guidance and mandate which have resulted in lack of local government capacity and capability. As such, they have brought a new level of research networking capacity to collaboratively bridge the science-policy-practice interface resulting in high quality outputs which have fed directly into natural hazard policy and practice decisions (Beavan et al., 2017).

Despite Beaven et al.'s (2017) positive comments, integrated research frameworks have not been a 'silver bullet' for bridging the science-policy-practice interface for local government natural hazard risk management. The balance and facilitation of participant member organisations is crucial for the success of integrative research and action, which has been identified as a weakness in past integrative frameworks. Beaven et al. (2017) found that the Natural Hazards Research Platform was weighted more towards science and its pre-identified areas for research than towards the policy domain. This can result in 'outsider driven research' (Le De, Gaillard & Friesen, 2015), where externally identified research requisites can be imposed on stakeholders, who have not identified them, or perceived them as important compared to other priorities, resulting in limited engagement from policy makers.

This tension has limited the effectiveness of integrated research to bridge the science-policy-practice interface and interrupt the complex system of challenges for local government application of natural hazard risk management in Aotearoa New Zealand. Challenges associated with this tension include:

- Limited capacity and capability within local government to seek out scientific information and appropriately translate it to a policy question (Bremer & Glavovic; 2013; Gluckman, 2013)
- Scientific research traditionally follows a pre-determined agenda to address research objectives. This can limit the flexibility of approach and reduce potential for sustainable solutions (Le De, Gaillard & Friesen, 2015).
- Uncertainty and doubt attached to scientific information is not well regarded by policy and decision makers, who want either incontestable evidence or appropriately communicated uncertainty, for robust decision making (Doyle et al., 2019; Gaillard & Mercer, 2012; Kilvington & Saunders, 2016; Lawrence & Manning, 2012).
- Different timelines between scientific research and local government policy development make it difficult to ensure natural hazard risk management provisions reflect the latest research findings (Kilvington & Saunders, 2016) and for scientific information to be legitimised through verification and peer-review (Beaven et al., 2017).

- Scientific information can be 'politicised', where its value is accepted only if it adds credibility to the visions already held by local government policy and decision makers (Kilvington & Saunders, 2016).

The importance of a formalised structure has been highlighted for managing these challenges (Thompson et al., 2017; Wyborn et al., 2019). A formalised structure for integrative research frameworks would enable improved collaboration across the science-policy-practice interface through:

- diverse representation from all relevant stakeholders (Thompson et al., 2017), especially policy analysts (Cvitanovic et al., 2018), where engagement is purposefully and strategically codesigned to meet project aims and objectives (Wyborn et al., 2019).
- early reflection and understanding of the different cultural and institutional perspectives between participating groups and the collective expectations and attitudes towards research, which are revisited longitudinally (Crawford et al., 2018b; Kilvington & Saunders, 2016; Thompson et al., 2017; Wyborn et al., 2019).
- skillful and iterative facilitation for bridging barriers between disciplines and organisations (Thompson et al., 2017), with consideration of power dynamics between individuals (Wyborn et al., 2019), for developing and maintaining trust (Cvitanovic et al., 2018).
- clarity between all parties involved regarding scale, timelines, processes, responsibilities and accountabilities, and the criteria for which decisions are made and for outcomes to be measured and achieved, with consideration of the (limited) resources and time that is available (Cvitanovic et al., 2018, Le De, Gaillard & Friesen, 2015; Thompson et al., 2017; Wyborn et al., 2019). The use of scenario planning tools or similar approaches to building shared understanding can help develop this clarity (Keough & Shanahan, 2008; Renn, 2014).
- Strong leadership or 'knowledge brokerage' (Meyer, 2010) in achieving project aims and objectives within a broad and adaptive organisational strategy, which is flexible and allows for unanticipated demands on funding, time and resource (Thompson et al., 2017), as well as adaptation to policy and societal processes (Cvitanovic et al., 2018).

As such, a formalised structure for integrative research frameworks provides guidance for collaborative research to be clear, reflective and effective, and acknowledges local government capacity and capability in how this is achieved.

Despite this, efforts to collaborate with local government across the science-policy-practice interface in Aotearoa New Zealand have largely been achieved on a ‘what seems to work’ basis (Kilvington & Saunders, 2016), rather than a formalised structure. Indeed, Barton et al. (2020) reflect that a formalised structure would have been beneficial in increasing the pace of cocreation and reducing the widespread confusion concerning the knowledge that was required, available, and achievable within integrative research frameworks. However, this “would have required a substantial departure from the precedent set by the science-policy-practice collaborative style that had developed in the preceding five years” (Barton et al., 2020. Reflections Section).

7.8 Recommendations and Conclusion

Local government struggles to effectively coordinate and apply natural hazard risk management. This research identifies three main themes (challenges) that contribute to this: 1) Insufficient national funding; 2) Lack of national guidance and mandate, and 3); Limited risk awareness. A fourth cross-cutting theme also exists under each of these: Lack of quality data. A review of the literature indicates that while these challenges have been clearly identified over time and solutions have been provided, the challenges persist. We propose that these challenges persist because they are elements in a complex system which limits the application and success of solutions. By viewing this complex system of challenges and solutions using cyclic feedback loops, the whole system can be better understood, and interventions can be identified that can interrupt the system’s dynamic.

However, the use of systems thinking for natural hazard risk management is a sparse area or research in Aotearoa New Zealand. Even though the complexities of policies and procedure for natural hazard risk management have been acknowledged over time, only Mamula-Seadon (2007) has previously broached this subject. As such, further research is needed for how systems thinking can be applied.

In a cursory attempt at this, this research has identified integrative natural hazard research frameworks as a medium for developing local government capacity and capability to interrupt the complex system of challenges and solutions for natural hazard risk management. Integrative research frameworks already exist, however their engagement with local government across the science-policy-practice interface has achieved limited success so far. As such, we recommend that integrative research frameworks adopt systems thinking for a clearer, more wholistic view of how they approach both the complexity of natural hazard risk management system in general, as well as complexities for engaging across the science-policy-practice interface.

Furthermore, the importance of a formalised structure has been highlighted for increasing the pace of cocreation and reducing the widespread confusion concerning the knowledge that was required, available, and achievable. However, collaboration has historically been achieved on a 'what seems to work' basis. To address this, we recommend further research is given to the development and application of a formalised structure for collaboration across the science-policy-practice interface in Aotearoa New Zealand. In addition, we recommend that the formalised structure is mandated by integrative research frameworks, including Resilience to Nature's Challenges, and is reviewed over time to ensure it is effective in building shared understanding of natural hazards and risks and developing practical risk reduction solutions. This is particularly important with regard to future funding frameworks that may emerge from the 'Te Ara Paerangi Future Pathways' review of Aotearoa New Zealand's research and science investment system (MBIE, n.d.).

Through review of the challenges facing local government application of natural hazard risk management and research of different approaches for improving how this can be improved, Aotearoa New Zealand is better placed to manage natural hazard risks before they occur and is better able to reduce the losses associated with responding to, and recovering from, them once they occur.

8 Conclusion

8.1 Introduction

This chapter begins with a synopsis of the introduction in Chapter 1 and literature review in Chapter 2 and a summary of the research taken and the results. The chapter then discusses the implications of the research for how risk informs natural hazard management for local government in Aotearoa New Zealand, specifically focusing on the interface between risk modelling for tsunami inundation and local government policies and procedures. Finally, opportunities for future research are presented.

8.2 Background and context

Considering the increased frequency of natural hazard related disasters and their associated losses, it is important that we understand the risk of natural hazards so we can better prepare for them before they occur, rather than just respond to them once they occur. The economic benefits of proactively acting to reduce natural hazard risk before a disaster occurs are clear. Natural hazard risk reduction outweighs the costs of reacting to them by about four times in terms of avoided and reduced losses (Mechler, 2016). These are just economic losses, more intangible or indirect losses, such as impact on community mental health or lost education, can also be reduced through proactive risk management.

However, natural hazard risk cannot just be objectively assessed and quantified as a function of likelihood and consequence. It is also evaluated dependent on how humans subjectively qualify natural hazards within a social setting, incorporating considerations such as doubt, dread, catastrophic potential, controllability, equity, and risk to future generations. This impacts on perceptions of risk where it can be misunderstood or underestimated, resulting in a false sense of security and inaction or underinvestment in risk reduction activities.

Destructive tsunami risk management is an example of this. It remains an underrated hazard mainly due to the perception that the infrequency of tsunamis does not present significant risk compared to other natural hazards (Bryant, 2014). However, tsunami is a significant natural hazard. Between 1998 and 2017, tsunamis caused 251,770 deaths (mostly attributed to the Indian Ocean Tsunami) with costs of US$280 billion (UNISDR, 2018).

Governance for natural hazard risks has progressed over the last 30 years. It has moved away from being solely developed and administered by central government and is now accountable upwards to international frameworks such as the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015b), outwards across multiple central government organisations, and downwards towards local government and community organisations.

Effective governance of natural hazards requires decision makers and practitioners to overcome misperceptions of risk. This is especially relevant for low-likelihood hazards, such as destructive tsunami. Decision makers and practitioners need to be risk aware; manage natural hazard risk via consistent, structured approaches; and ensure natural hazard risk management is connected across government and community actors.

This requires effective risk communication. One approach for assessing and communicating natural hazard risk is through risk modelling. Researchers, decision makers, and practitioners are increasingly using risk modelling to scope the consequences for hazards scenarios that they know they are exposed to but have little to no historical information about. This is particularly true for low-frequency, high-magnitude events such as destructive tsunami (UNISDR, 2015; Donovan & Oppenheimer, 2015; Eiser et al., 2012). However, the use of risk modelling is compromised by unavailability of hazard data, as well as the existence of modelling uncertainties that are often poorly communicated (Doyle et al., 2019). Furthermore, there is limited understanding for how modelled information is received and valued by stakeholders (Komendantova et al., 2014), and how models can be improved to better inform their natural hazard risk preparedness measures. Currently there is no clear recommended approach to address how modelling uncertainty is communicated to stakeholders (Doyle et al., 2019).

Given this background, this research has focussed on how risk informs natural hazard management in local government in Aotearoa New Zealand. It has specifically focussed on the risk of tsunami generated in the Hikurangi Subduction Margin off the east coast of the North Island of Aotearoa New Zealand as it is the country’s most significant natural hazard risk. It has also focussed on the use of the RiskScape risk modelling tool for communicating this risk for local government decision makers and practitioners to enable the development of policies and procedures that reflect the significance of the risk.

Governance for natural hazard risk management in Aotearoa New Zealand is set across a plethora of legislation consisting of high-level, disconnected and widely interpretative policy guidance (LGNZ, 2014). This legislation is devolved to local government for application, which are left to individually manage natural hazard risk with varying degrees of success (Basher, 2016; Crowley & Crawford, 2018a; EQC, 2019; Kilvington & Saunders, 2019).

Consequently, the application of natural hazard risk management in local government is beset with a number of challenges. This research has grouped them into four broad themes:

1. lack of guidance, mandate, and collaboration;
2. limited risk awareness, understanding, and knowledge;
3. lack of funding, capacity, and capability; and
4. unavailability of quality data and information.

Underlying each of these themes are a further two fundamental challenges for natural hazard risk governance: 1) the disconnect of science to policy to practice, and 2) the complexity system of challenges for natural hazard risk management.

Within this context, this research has sought to contribute to the body of knowledge through better understanding how the RiskScape risk modelling tool has influenced the development of local government policy and procedure for tsunami generated by an all-of-boundary earthquake in the Hikurangi Subduction Margin.

8.3 Summary of research undertaken

Three key areas were researched:

- The use of RiskScape, a risk modelling tool for communicating natural hazard risk, where the end-user experience for risk modelling is not well understood and is scarcely covered in the literature.

- Perceptions of and motivation to manage destructive tsunami risk. While tsunami is Aotearoa New Zealand's most significant natural hazard risk, local government policies and procedures to manage tsunami risk are scarce and not well defined.
- Governance for natural hazard risk management. The policy environment for natural hazard risk management in Aotearoa New Zealand local government is beset with challenges impacting on how risk management is applied. While the literature has identified these challenges, gaps in understanding remain for how these challenges can be overcome.

To address these areas, the research questions were:

1. How is natural hazard risk modelling information perceived and acted upon by local government?
2. How is risk modelling informed by natural hazard management?
3. How are natural hazard management policies and procedures informed by risk modelling?
4. What are the risk communication barriers and enablers that limit or contribute to efficacy for natural hazard risk management in local government?
5. What link do these limiting (or contributing) factors have with natural hazard management policy and procedures, and how can those policies and procedures be developed to enhance enablers and overcome barriers?

These research questions were answered over the four manuscripts presented in this thesis with the findings set out in the following sections.

8.3.1 How natural hazard risk modelled information is perceived and acted upon by local government

The first manuscript (*Risk Modelling as a tool to support natural hazard risk management in New Zealand local government*; Crawford et al., 2018a) identified that there was definite interest and engagement in the use of risk modelling for communicating natural hazard risk information within local government. Modelled natural hazard risk information was seen as beneficial for:

- Communication to the public and decision makers
- Real-time event response
- Exercise development
- Contingency planning
- Generic plans, such as land-use and civil defence plans
- Policy development, such as Regional Policy Statements.

However, the first manuscript found a reluctance from the councils to invest in risk modelling for communicating natural hazard risk due to a number of challenges. These were: 1) uncertainty associated with the modelling process; 2) the lack of capability of risk modelling for communicating impacts from multi-hazard events or cascading consequences; 3) unavailability of quality data for risk modelling; 4) an unsupportive legislative environment for enabling natural hazard risk modelling and risk communication; and 5) lack of 'knowledge brokers' and/or 'gate keepers' for linking science with policy and enabling appropriate information translation.

The second manuscript (*End-user perceptions of natural hazard risk modelling across policy making, land-use planning, and emergency management within New Zealand local government*; Crawford et al., 2018b) found that risk modelling was valued and used differently across three different local government functions that are essential for natural hazard risk management. Strategic policy makers valued and used natural risk information and used modelled risk information for providing science-informed results. However, the uncertainties and assumptions inherent within risk modelling meant that, in general, they were reluctant to develop policy based on modelled results because they had limited confidence in them. Land-use planners commonly expressed a lack in drive or capacity to learn different approaches outside of existing rules and regulations (i.e. the Resource Management Act and district plans) for natural hazard risk management. While they expressed an appreciation of risk modelling for communicating natural hazard risk, it had not been readily adopted within land-use consent planning. Emergency managers had a good understanding of natural hazard risk management, valued the use of natural hazard risk information, and agreed that risk modelling was a valuable tool for natural hazard risk management. However, in general, it wasn't used because contributing data was not available and because risk models were not suitable for their specific needs for real-time information, multi-hazard events, and cascading consequences.

The third manuscript (*The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government*; Crawford et al., 2019) acknowledged that modelled natural hazard risk information was valued by local government but challenging to use. Risk modelling was valued because its ability to spatially distribute natural hazard risks on maps made it a valuable communication tool for community awareness campaigns, for media use, and for increasing decision makers' risk awareness. It was also valued because its ability to tabulate comparisons of loss, depending on differences in exposure and vulnerability of assets, made it useful for consideration of benefits and costs, and considerations of alternatives required for the development of policies. However, participants expressed uncertainty as to whether modelled risk information would actually change how decision makers would act. These participants stated that officially, decision makers did not want to act because they were unsure of the quality of the modelled results; whereas unofficially, decision makers may not have wanted to act on the modelled results because, while the results may have been correct, they were politically unacceptable.

8.3.2 How risk modelling is informed by natural hazard management

The first manuscript (*Risk Modelling as a tool to support natural hazard risk management in New Zealand local government*; Crawford et al., 2018a) identified that, in most cases, the CDEM Groups described themselves as 'gatherers' rather than 'generators' of risk information, and therefore reliant on a range of external information sources from other parts of the council as well as from outside agencies. As a result, all the CDEM Groups reported similar challenges arising from a lack of data. Participants also reported a lack of knowledge of what data their council held, adding that even if they knew of its existence, it was often in a format that could not be used outside of its original context.

In light of the challenges in accessing and using natural hazard risk data, some CDEM Groups had seen the need to become proactive instigators for developing natural hazard risk data and are organising forums in isolation in an attempt to share information. In summary, while proactive measures towards managing natural hazard risk were developing across a number of the CDEM Groups visited, results showed a challenging environment for CDEM's use of risk modelling as a tool to better understand and manage natural hazard risk. This was not only because of confusion over CDEM's role and its limited influence for decision making, but also because of lack of data availability and suitability. As such, results showed that there appeared to be no standard approach to generating or sourcing risk data and there was no simple pathway for its communication.

The second manuscript (*End-user perceptions of natural hazard risk modelling across policy making, land-use planning, and emergency management within New Zealand local government*; Crawford et al., 2018b) acknowledged differing levels of capability across three different natural hazard risk management functions within local government for informing and using risk modelling:

1. Strategic policy makers were able to more easily influence decision makers to financially support the data collection and training needed to use risk modelling.
2. Land-use consent planners were also able to support data collection for use in risk modelling. However, the appreciation for their role in natural hazard risk management, and therefore the use of risk modelling, has been slow to develop.
3. On the whole, emergency managers were found to be less integrated within council than the other functions, which has limited their ability to gather or access risk data for use in risk modelling.

The third manuscript (*The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government*; Crawford et al., 2019) found that more frequent hazards, with better availability of data, informed the use of risk modelling more than for less frequent, but higher-risk hazards, such as destructive tsunami. Furthermore, risk perceptions for low-likelihood hazards and the difficulty for participants in internalising the consequences from such events shows a disassociation from the risk and therefore less desire to use risk modelling to better understand it.

8.3.3 How natural hazard management policies and procedures are informed by risk modelling

The second manuscript (*End-user perceptions of natural hazard risk modelling across policy making, land-use planning, and emergency management within New Zealand local government*; Crawford et al., 2018b) found that, overall, policy makers appreciated risk modelling as a communication tool that informed policy making; however, the uncertainties and assumptions inherent within risk modelling meant that they had limited confidence in modelled results. Participants also reported that risk modelling for less frequent natural hazard events, such as destructive tsunami, was not synonymous with the policy timeframes used within land-use consent planning and had therefore not been readily adopted. Furthermore, data unavailability for use in risk modelling meant that modelled results were not suitable for specific needs and other tools, such as GIS, were used for assessing and communicating risk.

The third manuscript (*The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government*; Crawford et al., 2019) identified that natural hazard risk management policy development was focussed more on modelled risk information for frequent, experienced and escalating hazards, such as flooding and erosion, than for the low-likelihood hazard of destructive tsunami. As such, the research found limited action taken by government relating to risk information for low-likelihood, destructive tsunami. Of the fifty-eight central and local government policy documents analysed, only three contained specific tsunami risk-based policy. The research found two main reasons for this. The first was that practitioners perceived the likelihood of destructive tsunami to be so remote that its risk was hard to understand, and the consequences were difficult to internalise given people's affinity for living on the coast. The second was that practitioners perceived the cost of implementing tsunami risk management policy would outweigh its benefits. They stated that Aotearoa New Zealand did not have the population or economic means to move built up areas (cities) away from the coast, and that a precautionary policy approach for destructive tsunami risk management would effectively prohibit community development and economic benefit.

8.3.4 What the risk communication barriers and enablers are that limit or contribute to efficacy for risk management in local government

The first manuscript (*Risk Modelling as a tool to support natural hazard risk management in New Zealand local government*; Crawford et al., 2018a) identified misperceptions for the value of CDEM for contributing to natural hazard risk management, uncertainty resulting from the legislative environment, and limited use of knowledge brokers and gate keepers for translating and sharing natural hazard risk information. While risk modelling was seen as a useful tool for communicating natural hazard risk, issues relating to how data was collected, managed, and shared limited its use. Primary amongst these issues was availability of data, the cost of gathering and/or managing it, and the uncertainty of modelled information.

The second manuscript (*End-user perceptions of natural hazard risk modelling across policy making, land-use planning, and emergency management within New Zealand local government*; Crawford et al., 2018b) found that while risk modelling was seen as a useful tool for communicating natural hazard risk, risk modelling sat within a complex, interrelated policy environment, which impacted on local government natural hazard risk management functions. Perceptions of importance for different natural hazard risk management functions limited integration across those functions, especially for risk communication made through emergency management. Limited understanding of risk and the value of risk management restricted the use of modelling for communicating risk, especially within the highly regulated land-use consents planning function. Unavailability of quality data and limited trust in risk modelling outputs limited its use for risk communication, especially for strategic policy making.

The third manuscript (*The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government*; Crawford et al., 2019) identified that despite risk awareness, less likely hazards, such as destructive tsunami, impacted on how the risk was perceived. Even though participants acknowledged that the consequences from a destructive tsunami would be severe, the low-likelihood and severe consequences were difficult for them to internalise and did not seem real, resulting in a dissociation from the risk where destructive tsunami would not happen to them. This indicated that, despite risk awareness and/or understanding, cognitive biases influenced how risk information was received, especially where the risk information called for a precautionary policy approach that would effectively prohibit people's affinity for living on the coast, was uneconomical and/or did not enable community development. While risk modelling could be used to effectively communicate natural hazard risk to better enable policy development, the information being communicated may not be personally or politically acceptable by practitioners and decision makers. Consequently, this research found that there was less motivation amongst local government practitioners to use risk modelling to better understand and communicate low-likelihood hazards such as destructive tsunami.

The fourth manuscript (*A cycle of challenges for natural hazard risk management for local government in Aotearoa New Zealand – and how it could be interrupted*; Crawford et al. – awaiting publication) found that challenges identified over time for local government application of natural hazard risk management remain unresolved. Three main challenges were identified: insufficient national funding, lack of guidance and mandate, and limited risk awareness. A fourth cross-cutting challenge also exists under each of these – lack of quality data. Insufficient national funding limited local government's capacity and capability to gather quality data and information and recruit skilled resource to use that information for communicating natural hazard risk. Lack of guidance and mandate had limited the establishment of intra and inter-council collaboration and communication of natural hazard risk information and data. Limited risk awareness, as a consequence of limited data, caused misperceptions of the significance of the risk where greater policy-making support was given to frequent, experienced but lower-risk hazards than for less frequent, higher-risk hazards.

8.3.5 The link these limiting (or contributing) factors have with natural hazard management policy and procedures, and how those policies and procedures can be developed to enhance enablers and overcome barriers

The third manuscript (*The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government*; Crawford et al., 2019) identified that risk-based policy favours more frequent, experienced but lower-risk hazards than for low-likelihood but higher-risk hazards such as destructive tsunami. As such, the significance of natural hazard risks was not balanced by the development of policy and procedures for their management. The manuscript recommends that misperceptions of natural hazard risks, along with the unbalanced development of natural hazard risk management policy and procedure, could be solved through:

- Further resourcing of national risk management initiatives, which enable risk management training and workshops, greater integration of risk management across council functions enabling a shared understanding of the risks and an improved ability to develop specific risk-based policy.
- Inclusion of debiasing techniques as part of natural hazard risk management workshops, providing greater context when considering how acceptable the risk information is, allowing practitioners and decision makers to make more informed decisions.
- Co-development of risk modelling so they are easier for end users to apply within local government, for practitioners and decision makers have a better understanding of the capability and value of risk models, and have greater confidence in modelled information.
- Longer-term natural hazard policy instruments to enable policy for low-likelihood hazards that have intervals over thousands of years. This would separate low-likelihood, destructive tsunami risk management from the more immediate political, financial and community development issues, which currently influence decision makers to perceive it as too hard or unacceptable.

The fourth manuscript (*A cycle of challenges for natural hazard risk management for local government in Aotearoa New Zealand – and how it could be interrupted*; Crawford et al. (awaiting publication) found that the challenges that underly the development of policy are a complex system, consisting of feedback loops, which inhibit the effective resolution of the challenges. The manuscript proposes that these challenges are explored using a systems-thinking approach, which can identify intervention points that interrupt the complex system's overall dynamic. It identifies the science-policy-practice interface as an intervention point and recommends the development of a formalised structure, mandated by national integrative research frameworks, for better enabling natural hazard risk communication across the science-policy-practice interface (including through the use of risk modelling), which then enables the development of appropriate natural hazard risk management policy and procedure.

8.4 Research limitations and opportunities for further research

Natural hazard risk management is important. This is acknowledged within local government in Aotearoa New Zealand; however, its system for natural hazard risk management presents complex, interrelated challenges for natural hazard risks awareness, how they are understood, and how they are managed. These challenges have then limited how risk modelling is perceived, valued, and applied for communicating natural hazard risk management. Consequently, risk modelling has not been readily adopted by local government in Aotearoa New Zealand for the development of risk-based policy and procedure.

The manuscripts in this paper identified the challenges that have caused the limited use of risk modelling in local government and have provided recommendations (solutions) for how those challenges can be overcome. However, these recommendations are reliant on a framework for natural hazard risk management that enables them to be applied. The final manuscript proposed the use of a systems-thinking approach for holistically viewing the interrelations and resultant dynamics of the challenges within this framework. This approach helps identify intervention points across the challenges, which act to change the systems dynamics and potentially enable recommendations (solutions) to more effectively be applied. However, the use of a systems-thinking approach is novel within local government natural hazard risk management in Aotearoa New Zealand. Further research is needed to better understand how these challenges interact, how a systems-thinking approach can be applied, and whether a systems-thinking approach is beneficial for identifying and solving complexities related to these challenges.

This research focussed on practitioners' thoughts and opinions of risk modelling and natural hazard risk management policy and procedure. However, the use of risk modelling, the information it provides, and the resultant development of natural hazard risk management policy and procedure is reliant on the support of decision makers, i.e. local politicians. This research has touched on decision makers' risk awareness and understanding, as well as how acceptable risk information is for them. However, the thoughts and opinions that provided these insights were from practitioners, not from the decision makers themselves. Furthermore, the body of literature reviewed for this research found scarce coverage of decision makers' thoughts and opinions on local government natural hazard risk management. As such, the findings in this research need corroboration through further research to better understand decision makers' perceptions and awareness of natural hazard risk; understanding of risk management; value given to modelled risk information; and their resultant motivation to support the development of natural hazard risk management policy and procedure.

This research spanned the science-policy-practice interface between the RiskScape risk modelling tool and its application within local government. However, tensions across the interface due to outsider-driven scientific research and limited engagement from local government policy makers have historically limited collaboration between scientific research the development of local government policy and procedure. Increased facilitation through national frameworks for integrating scientific research with policy (such as Resilience to Nature's Challenges) have further enabled collaboration; however, there is no formalised structure for how this is applied. Further research is needed for the development of a formalised structure for how scientific research collaborates with local government policy makers to increase the pace of collaboration and reduce confusion concerning the knowledge that is required, available, and achievable across the science-policy-practice interface. Furthermore, research is needed for how a formalised structure could be given mandate through national research frameworks, and how effective it is in building shared understanding and collaboration between scientists and practitioners for developing practical risk reduction solutions.

It must be acknowledged that the data for this research was collected in focus groups in 2016, follow-up interviews in 2016 and 2017, and document analysis in 2018. This information was gathered in a rapidly-evolving policy environment. Therefore, while many of the findings in this research still apply, the practitioners' views and the capability of local government for risk modelling and natural hazard risk management will have progressed.

Finally, the research presented in this thesis has limitations but also highlights areas for future research. The four manuscripts and the overall doctoral project will move the academic discussion forward on the topics of how risk modelling informs tsunami hazard management policies and procedures.

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Appendices

Appendix A: Human ethics application

Massey University

Te Kunenga ki Pūrehuroa

NOTIFICATION OF LOW RISK RESEARCH/EVALUATION

INVOLVING HUMAN PARTICIPANTS

Staff researchers and supervisors are fully responsible for ensuring that the information in this form meets the requirements and guidelines for submission of a Low Risk Notification

SECTION A:

1. **Project Title** RiskScape Civil Defence Emergency Management (CDEM) Engagement Project

   Projected start date for <u>data collection</u> 15 October 2015 **Projected end date** 15 October 2018

   (Low risk notifications must not be submitted if recruitment and/or data collection has already begun.)

2. **Applicant Details** *(Select one box only and complete details)*

- **ACADEMIC STAFF NOTIFICATION**

Full Name of Staff Applicant/s

School/Department/Institute

Region *(mark one only)* **Albany** [ ] **Palmerston North** [ ] **Wellington** [ ]

Telephone **Email Address**

STUDENT NOTIFICATION

Full Name of Student Applicant Miles Crawford

Postal Address [redacted]

Telephone [redacted] **Email Address** m.crawford1@massey.ac.nz

Employer

Full Name of Supervisor(s) David Johnston; Emma Hudson-Doyle; Graham Leonard; Wendy Saunders

School/Department/Institute School of Psychology – Joint Centre for Disaster Research

Region *(mark one only)* **Albany** [ ] **Palmerston North** [ ] **Wellington** [x]

Telephone x 63704 **Email Address** E.E.Hudson-Doyle@massey.ac.nz

GENERAL STAFF NOTIFICATION

Full Name of Applicant ....

Section ....

Region *(mark one only)* **Albany** ☐ • **Palmerston North** ☐ **Wellington** ☐

Telephone .... **Email Address** ....

Full Name of Line Manager ....

Section ....

Telephone .... **Email Address** ....

3 Type of Project *(provide detail as appropriate)*

Staff Research/Evaluation:		Student Research: PhD Research		If other, please specify:
Academic Staff		Name of Qualification		
General Staff		Credit Value of Research		
Evaluation		(e.g. 30, 60, 90, 120, 240, 360)		

4. Describe the process that has been used to discuss and analyse the ethical issues present in this project.
(Please refer to the Low Risk Guidelines on the Massey University Human Ethics Committee website)

The student (Miles) reviewed the *Code of Ethical Conduct for Research, Teaching and Evaluations Involving Human Participants*, and discussed with his supervisors and social scientists Dr Sally Potter (GNS Science) and Dr Kate Crowley (NIWA) on potential risks to research participants and their affiliated organisations, the student, and Massey University. The student also reviewed the screening questionnaire with his supervisors to ensure that his project will cause no harm to research participants, etc., as well as discussed with his supervisors to ensure the project research methods are feasible and sound in reaching the project objectives.

5. Summary of Project

1. The purpose of the research

The project will determine the risk information levels of Civil Defence Emergency Management (CDEM) and how risk modelling can be used for CDEM decision-making and risk assessment. The project is a joint research venture between GNS Science (Dr Sally Potter & Nick Horspool), NIWA (Dr Kate Crowley and Ryan Paulik), and Massey University (Miles Crawford). Miles Crawford, a PhD candidate at Massey University, will provide significant input and direction as part of his PhD studies, particularly for the Wellington, Hawke's Bay and Gisborne regions. This ethics application pertains to the entirety of the project, including Miles' research.

2. The methods you will use.

The project will gather data from Emergency Managers via a mixed method of focus groups and follow up interviews. Prospective participants will be provided with information about the project, their rights and tasks, along with an invitation to participate in the focus groups, in line with ethics procedures. Any further information will be provided to participants upon request. The focus group proceedings will be audio recorded and transcribed. Results will be shared (triangulated) with all participants and stakeholders to validate the data collected. Based on the findings, recommendations will be made on how risk modelling can be improved to meet the needs of the CDEM sector. Participants can withdraw from participation in the research at any time.

Please submit this Low Risk Notification (<u>with the completed Screening Questionnaire</u>) as follows:

1. For staff based at either the Palmerston North or Wellington campus; and students whose Chief Supervisor is based at either the Palmerston North or Wellington campus:

External Mailing Address	**Internal Mailing Address**
Ethics Administrator	Ethics Administrator
Research Ethics Office	Research Ethics Office
Massey University	Courtyard Complex, PN221
Private Bag 11222	Turitea
Palmerston North 4442	**Palmerston North**

2. For staff based at the Albany campus and students whose Chief Supervisor is based at the Albany campus:

External Mailing Address	**Internal Mailing Address**
Ethics Administrator	Ethics Administrator
Research Ethics Office	Research Ethics Office
Massey University	Room 3.001B, Level 3
Private Bag 102904	Quadrangle A Building
North Shore City 0745	**Albany Campus**

SECTION B: DECLARATION (*Complete appropriate box)*

ACADEMIC STAFF RESEARCH
Declaration for Academic Staff Applicant

I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. My Head of Department/School/Institute knows that I am undertaking this research. I confirm that this submission meets the requirements set out in the Guidelines for Low Risk Notifications and that the information contained in this notification is to the very best of my knowledge accurate and not misleading.

Staff Applicant's Signature .... Date: ....

STUDENT RESEARCH
Declaration for Student Applicant
I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and discussed the ethical analysis with my Supervisor. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. I confirm that this submission meets the requirements set out in the Guidelines for Low Risk Notifications and that the information contained in this notification is to the very best of n[illegible]e and not misleading.

Student Applicant's Signature .... Date: 1/10/2015

Declaration for Supervisor
I have assisted the student in the ethical analysis of this project. As supervisor of this research I will ensure that the research is carried out according to the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. I confirm that this submission meets the requirements set out in the Guidelines for Low Risk Notifications.

Supervisor's Signature .... Date: 1/10/2015

Print Name Emma Hudson-Doyle

GENERAL STAFF RESEARCH/EVALUATIONS
Declaration for General Staff Applicant
I have read the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and discussed the ethical analysis with my Supervisor. I understand my obligations and the rights of the participants. I agree to undertake the research as set out in the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. I confirm that this submission meets the requirements set out in the Guidelines for Low Risk Notifications and that the information contained in this notification is to the very best of my knowledge accurate and not misleading.

General Staff Applicant's Signature .... Date: ....

Declaration for Line Manager

I declare that to the best of my knowledge, this notification complies with the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants and that I have approved its content and agreed that it can be submitted.

Line Manager's Signature .... Date: ....

Print Name ....

Appendix B: Human ethics approval letter

MASSEY UNIVERSITY
ALBANY

7 October 2015

Miles Crawford
[redacted]

Dear Miles

Re: RiskScape Civil Defence Emergency Management (CDEM) Engagement Project

Thank you for your Low Risk Notification which was received on 7 October 2015.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director (Research Ethics), telephone 06 356 9099, extn 86015, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

Brian T Finch (Dr)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Assoc. Professor David Johnston, Dr Emma Hudson-Doyle, Dr Graham Leonard and Dr Wendy Saunders
School of Psychology- Joint Centre for Disaster research
Wellington Campus

Massey University Human Ethics Committee
Accredited by the Health Research Council

Appendix C: Phase 1 information sheet

RiskScape - Civil Defence Emergency Management Engagement Project

INFORMATION SHEET

Introduction
GNS Science, NIWA and Massey University are conducting a study on how risk modelling tools such as RiskScape can be used for CDEM decision-making and risk assessment. The purpose of the research is to:

- Identify the risk information needs of CDEM for risk assessments, risk modelling and mapping, and related activities (e.g., what kind of impact information and at what scale)
- Identify risk based information pathways to and from CDEM including ownership of data and application
- Identify the data and methods CDEM are currently using to determine risk and impacts or losses from natural hazards (e.g., risk matrix, RiskScape; GIS)
- Determine if and how RiskScape can inform or provide alternative risk and impacts or loss modelling methods currently used by CDEM
- Identify how RiskScape could effectively be used by CDEM in their roles and activities.
- Identify how CDEM would like to use and visualise risk information
- Understand the participant's experience with using RiskScape and other tools used for risk assessment – strengths and weaknesses/challenges
- Establish new functions or make changes for future versions of RiskScape, to enable CDEM to use it more easily and efficiently.

The findings from the project will be used to better understand how the CDEM sector uses risk modelling for emergency management purposes, and to recommend how RiskScape can be improved as a national and international software tool. Key findings will be collated and analysed, and a summary report of results will be communicated to all participants.

Participant Recruitment and Involvement
This research will be conducted via a mixed method of focus groups and follow up interviews to be conducted with CDEM practitioners at times, dates and venues previously agreed with CDEM group managers. Focus group sessions will be small (made up of 6-10 people) and will take approximately two and a half hours. Light refreshments will be provided during the focus group sessions. Participants must be 18 years of age or over. Participants can choose how they would like to be identified in the research findings, or can remain anonymous with discussions at the focus group reported anonymously and results generalised.

Project Procedures

Group discussions will be undertaken in person, and before discussions start, all participants will be informed again about the research, and about their rights as participants. Participants will be asked to sign a consent form if they have not already done so. Discussions will be taped and notes taken, with the participants' consent. If requested, individuals will be sent the group notes to check and confirm their accuracy. Themes will be identified from the tapes and notes and only general findings will be reported. Consent sheets and pre-interview information will be stored separate from group transcriptions to ensure participants' anonymity. Project results will be made available to participants in a variety of formats. All data will be collected, used and stored in compliance with the Massey University Code of Ethical Conduct.

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time before the results are sent for publication;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- ask for the audio tape to be turned off at any time during the group discussion;
- be given access to a summary of the project findings when it is concluded.

Project Team

For further information about the project, please contact:

Dr Sally Potter, GNS Science, P.O. Box 30386, Avalon, Lower Hutt
Ph: 04 570 4858, S.Potter@gns.cri.nz

Dr Kate Crowley, NIWA, 301 Evans Bay Parade, Greta Point, Wellington
Ph: 04 386 0833, Kate.Crowley@niwa.co.nz

Miles Crawford, Joint Centre for Disaster Research, Massey University, PO Box 756, Wellington
Ph: 04 979 3704, m.crawford1@massey.ac.nz

Project Evaluation

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), Massey University, telephone 06 350 5249, email humanethics@massey.ac.nz

Appendix D: Phase 2 information sheet

Joint Centre for Disaster Research, Massey University/GNS Science, PO Box 756, Wellington 6140

Communicating Natural Hazard Risk Interviews

INFORMATION SHEET

Introduction

The purpose of this research is to interview local government practitioners involved with natural hazard risk management about their views and experiences on models for communicating natural hazard risk. The interviews will be undertaken by Miles Crawford, as part of his PhD research on disaster risk management completed through the Joint Centre for Disaster Research.

The aims of the interviews are to:

1. Review local government natural hazard risk management policy and procedure for where participants see the barriers are for its use and development, as well as what enablers there are.
2. Introduce risk modelling (using RiskScape risk modelling software) to evoke thoughts and feelings on what participants think of the tsunami risk and whether they think risk modelling can better communicate tsunami risk to influence decision maker perceptions, and willingness to engage in improved policy and procedure.

The findings from the research will be used to better understand how risk informs natural hazard management, and will be used in conjunction with other research projects to recommend a way forward for local government natural hazard risk management policy and procedure.

Participant Recruitment and Involvement

This research will be conducted via semi-structured, qualitative interviews conducted with participants in the Wellington, Hawkes bay and Gisborne regions at times, dates and venues previously agreed with local government liaisons for each region. The purpose and benefits of participating in the research will be introduced with each liaison before the interviews via email and telephone conversations, encouraging them to include participants across wider hazard management roles within the council. The interviews will be one-to-one, and will take approximately one and a half hours. Participants must be 18 years of age or over and can choose how they would like to be identified in the research findings, or can remain anonymous.

Project Procedures

Before each interview participants will be given a brief introduction on the interview's purpose, provided with a further information sheet, reminded of their participant rights, and asked to sign a participant consent form. Data will be captured through dictaphone recordings and analysed thematically, based on content analysis. Themes derived from the analysis will be shared with all participants soon after the interviews; ensuring the research and approach remains current.

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time before the results are sent for publication;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- ask for the audio tape to be turned off at any time during the interviews;
- be given access to a summary of the project findings when it is concluded.

Project Team

For further information about the project, please contact:

- Miles Crawford, Joint Centre for Disaster Research, Massey University, PO Box 756, Wellington, Ph: 04 979 3704, m.crawford1@massey.ac.nz

Project Ethics Evaluation

This research has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director, Research Ethics, telephone 06 356 9099 x 86015, email humanethics@massey.ac.nz

Appendix E: Natural hazard policy documents included in document analysis for Manuscript 3

1	Resource Management Act 1991
2	Building Act 2004
3	Civil Defence Emergency Management Act 2002
4	Local Government Act 2002
5	Environment Act 1986
6	Local Government Official Information and Meetings Act 1987
7	New Zealand Coastal Policy Statement 2010
8	National Civil Defence Emergency Management Plan Order 2015
9	Department of Internal Affairs (2008) National Civil Defence Emergency Management Strategy
10	Building Regulations 1992
11	MCDEM (2016) National Tsunami Advisory and Warning Supporting Plan [SP 01/16]
12	MCDEM (2015) CDEM Group Planning – Director's Guideline for Civil Defence Emergency Management Groups [DGL 09/15]
13	MCDEM. (2019). National Disaster Resilience Strategy – Rautaki ā-Motu Manawaroa Aituā. Wellington: Ministry of Civil Defence & Emergency Management, April 2019. ISBN: 978-0-478-43523-8
14	Hawke's Bay Regional Council (2006) Hawke's Bay Regional Resource Management Plan including the Regional Policy Statement (RPS).
15	Hawke's Bay Emergency Management Group (2016) Group Plan 2014–2019. Hawke's Bay Civil Defence Emergency Management. (Approved 20 June 2014. Updated as at 22 April 2016.)
16	Hawke's Bay Regional Council (2014) Hawke's Bay Regional Coastal Environment Plan.

17	Hawke’s Bay Regional Council, Napier City Council, Hastings District Council (TBC) Clifton to Tangoio Coastal Hazards Strategy 2120
18	Hawke’s Bay Regional Council (2011) Strategic Plan
19	Hawke’s Bay Regional Council (2011) Long Term Plan 2012–2022
20	Gisborne District Council (2013) Gisborne CDEM Group Tsunami Contingency Plan
21	Gisborne District Council (2016) Tairawhiti Civil Defence Emergency Management Group Plan 2016–2021
22	Tairāwhiti Resource Management Plan 2017 – Part B - Regional Policy Statement
23	Tairāwhiti Resource Management Plan 2017 – Region Wide Provisions
24	Gisborne District Council (2015) Tairāwhiti First! 2015–2025 Long Term Plan
25	Gisborne District Council Hazard Risk Profile 2015
26	Wellington Region Emergency Management Group (2013) Wellington Region Civil Defence Emergency Management Group Plan 2013–2018
27	Wellington CDEM Group Distant Source Evacuation Plan
28	Greater Wellington Regional Council (2013) Regional Policy Statement for the Wellington Region
29	Greater Wellington Regional Council (2000) Regional Coastal Plan for the Wellington Region
30	Greater Wellington Regional Council (2004) Wairarapa Coastal Strategy
31	Napier City Council (2015) Napier City Council Long Term Plan 2015–2025
32	Napier City Council (2011) City of Napier District Plan Chapter 62 Natural Hazards
33	Napier City Council (2011) Safer Napier Policy
34	Napier City Council (2016) 2016/17 Annual Plan
35	Central Hawke’s Bay District Council (2015) Long Term Plan 2015–2025
36	Central Hawke’s Bay District Council (2003) Central Hawke’s Bay District Plan
37	Hastings District Council (2015) Proposed Hastings District Plan

38	Hastings District Council (2012) Hastings District Plan
39	Hastings District Council (2000) Hastings Coastal Environment Strategy Technical Paper #4
40	Hastings District Council Hastings Coastal Environment Strategy (in HDC 2015 proposed plan)
41	Hastings District Council (2014) Local Governance Statement
42	Hastings District Council (2013) Waimarama Community Plan
43	Hastings District Council (2015) Long Term Plan 2015–25
44	Hastings District Council (2016) Annual Plan 2016–2017
45	Wairoa District Council (2005) Wairoa District Plan
46	Wairoa District Council (2014) Significance & Engagement Policy
47	Wairoa District Council (2004) Wairoa Coastal Strategy
48	Wairoa District Council (2015) 2015–2025 Long Term Plan (LTP)
49	Wairoa District Council (2016) Wairoa District Council Annual Plan 2017/18
50	Hutt City (2015) Long Term Plan 2015–2025
51	Hutt City (2016) Annual Plan for 2016–2017
52	Hutt City (2016) City of Lower Hutt District Plan
53	Wellington City Council (2017) District Plan
54	Wellington City Council (2015) Long-term Plan 2015–25
55	Wellington City Council (2015) Annual Plan 2016/17
56	Wellington City Council (2016) 100 Resilient Cities Preliminary Resilience Assessment
57	Wellington City Council (2011) Towards 2040: Smart Capital Strategy
58	Wellington City Council (2014) Draft Wellington Urban Growth Plan 2014–2043

Appendix F: Certificate of regulatory compliance

Appendix G: Statement of contribution – Chapter 4

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Miles Crawford
Name/title of Primary Supervisor:	David Johnston
In which chapter is the manuscript /published work:	Chapter 4

Please select one of the following three options:

(●) The manuscript/published work is published or in press

- Please provide the full reference of the Research Output:

Crawford, M. H., Crowley, K., Potter, S. H., Saunders, W. S. A., & Johnston, D. M. (2018). Risk modelling as a tool to support natural hazard risk management in New Zealand local government. International journal of disaster risk reduction, 28, 610-619. http://dx.doi.org/10.1016/j.ijdrr.2018.01.011

( ) The manuscript is currently under review for publication – please indicate:

- The name of the journal:

International journal of disaster risk reduction

- The percentage of the manuscript/published work that was contributed by the candidate: 80.00

- Describe the contribution that the candidate has made to the manuscript/published work:

The candidate conducted the data collection and analysis in conjunction with Dr Kate Crowley and Dr Sally Potter.

The candidate drafted the manuscript, and made subsequent revisions based on supervisor's feedback.

( ) It is intended that the manuscript will be published, but it has not yet been submitted to a journal

Candidate's Signature:	Miles Crawford (Digitally signed by Miles Crawford Date: 2022.01.20 08:30:33 +13'00')
Date:	20-Jan-2022
Primary Supervisor's Signature:	David Johnston (Digitally signed by David Johnston Date: 2022.01.16 16:02:03 +13'00')
Date:	16-Jan-2022

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Appendix H: Statement of contribution – Chapter 5

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Name/title of Primary Supervisor:	David Johnston
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(●) The manuscript/published work is published or in press

- Please provide the full reference of the Research Output:

Crawford, M. H., Saunders, W. S. A., Doyle, E. E., Johnston, D. M. (2018). End-user perceptions and use of natural hazard risk modelling across policy making, land use planning, and emergency management within New Zealand local government. In K. Stock & D. Bunker (Eds.), Proceedings of ISCRAM Asia Pacific 2018: Innovating for Resilience – 1st International Conference on Information

( ) The manuscript is currently under review for publication – please indicate:

- The name of the journal:

In K. Stock & D. Bunker (Eds.), Proceedings of ISCRAM Asia Pacific 2018: Innovating for Resilience – 1st International Conference on Information Systems for Crisis Response and Management Asia Pacific. (pp. 550–560). Wellington.

- The percentage of the manuscript/published work that was contributed by the candidate: 90.00

- Describe the contribution that the candidate has made to the manuscript/published work:

The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on supervisor's feedback

( ) It is intended that the manuscript will be published, but it has not yet been submitted to a journal

Candidate's Signature:	Miles Crawford Digitally signed by Miles Crawford Date: 2022.01.20 08:23:37 +13'00'
Date:	20-Jan-2022
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Appendix I: Statement of contribution – Chapter 6

MASSEY UNIVERSITY
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STATEMENT OF CONTRIBUTION
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Name/title of Primary Supervisor:	David Johnston
In which chapter is the manuscript /published work:	Chapter 6

Please select one of the following three options:

(●) The manuscript/published work is published or in press

- Please provide the full reference of the Research Output:
  Crawford, M. H., Saunders, W. S., Doyle, E. E., Leonard, G. S., & Johnston, D. M. (2019). The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government. Australasian Journal of Disaster and Trauma Studies, 23(1).

( ) The manuscript is currently under review for publication – please indicate:

- The name of the journal:
  Australasian Journal of Disaster and Trauma Studies
- The percentage of the manuscript/published work that was contributed by the candidate: 90.00
- Describe the contribution that the candidate has made to the manuscript/published work:
  The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on supervisor's feedback.

( ) It is intended that the manuscript will be published, but it has not yet been submitted to a journal

Candidate's Signature:	Miles Crawford Digitally signed by Miles Crawford Date: 2022.01.20 08:20:16 +13'00'
Date:	20-Jan-2022
Primary Supervisor's Signature:	David Johnston Digitally signed by David Johnston Date: 2022.01.16 16:04:26 +13'00'
Date:	16-Jan-2022

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Appendix J: Statement of contribution – Chapter 7

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of candidate:	Miles Crawford
Name/title of Primary Supervisor:	David Johnston
In which chapter is the manuscript /published work:	Chapter 7

Please select one of the following three options:

○ The manuscript/published work is published or in press

- Please provide the full reference of the Research Output:

A cycle of challenges for natural hazard risk management for local government in Aotearoa New Zealand - and how it could be interrupted

○ The manuscript is currently under review for publication – please indicate:

- The name of the journal:
- The percentage of the manuscript/published work that was contributed by the candidate: 90.00
- Describe the contribution that the candidate has made to the manuscript/published work:

The candidate conducted the data collection and analysis, drafted the manuscript, and made subsequent revisions based on supervisor's feedback.

◉ It is intended that the manuscript will be published, but it has not yet been submitted to a journal

Candidate's Signature:	Miles Crawford
Date:	20-Jan-2022
Primary Supervisor's Signature:	David Johnston
Date:	16-Jan-2022

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Appendix K: Copyright form and declaration confirming content of digital version of thesis