New Zealand Climate Change Research Institute
Te Pūtahi Hurihanga Taiao

# Vulnerability and adaptation to increased flood risk with climate change—Hutt Valley summary

Judy Lawrence Simon Tegg
Andy Reisinger Dorothee Quade

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The New Zealand Climate Change Research Institute
Victoria University of Wellington

The New Zealand Climate Change Research Institute
School of Geography, Environment and Earth Sciences
Victoria University of Wellington
PO Box 600
Wellington
New Zealand

Contact: Liz Thomas
Phone: (04) 463 5507
Email: liz.thomas@vuw.ac.nz

Judy Lawrence, New Zealand Climate Change Research Institute, VUW; PSConsulting Ltd
Simon Tegg, New Zealand Climate Change Research Institute, VUW
Andy Reisinger, New Zealand Agricultural Greenhouse Gas Research Centre; New Zealand Climate Change Research Institute, VUW
Dorothee Quade, New Zealand Climate Change Research Institute, VUW

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# List of acronyms

| | |
|---|---|
| HRFPMP | Hutt River Flood Plain Management Plan |
| LIDAR | Light detection and ranging |
| LTP | Long-term plan |
| NES | National environmental standards |
| NIWA | National Institute of Water and Atmospheric Research |
| NPS | National policy statement |
| NZCCRI / CCRI | New Zealand Climate Change Research Institute |
| VUW | Victoria University of Wellington |

# Executive summary

## Research purpose

This report sets out the findings of the Hutt Valley case study on flooding, which is one of three case studies that form Objective 2 of the collaborative, interdisciplinary research project on Community Vulnerability, Resilience and Adaptation to the impacts of climate change. The project is led by Victoria University and funded by Foundation for Research, Science and Technology (FRST)[1].

The Hutt Valley case study concerns the impact of flooding in urban areas, and is based on research in the Hutt Valley in the lower North Island of New Zealand. The purpose of the research is to gain a better understanding of:

- how a possible increase in heavy rainfall, and the associated increase in flood risk arising from climate change, could affect different parts of the community
- how councils and their communities can respond to these increasing risks and reduce their vulnerability within considerable uncertainty about the exact magnitude of future changes in flood risk and socio-economic development.

The research is structured around four research questions.

## Research questions

1. How will climate change affect the frequency and severity of flooding of the Hutt River over the next century?
2. What are the impacts of a range of different flood events on the Hutt Valley community?
3. What socio-economic factors influence the community's ability to adapt to flood risk; and to cope with, and recover from, flooding?
4. What social and institutional barriers constrain adaptation and what opportunities are present for improving adaptive capacity?

[1] FRST was merged in February 2011 with the Ministry of Research, Science and Technology (MoRST) to form the Ministry of Science and Innovation (MSI), which is responsible for the policy and investment functions of both those agencies.

## Research methods

The research focuses on the part of the Hutt Valley south of the Taita Gorge and comprises three interlinked studies.

### Study 1: Modelling biophysical changes and impacts

Biophysical changes were assessed with downscaled climate modelling and Hutt River catchment runoff and inundation modelling. The researchers used the downscaled results of 12 climate models under four emissions scenarios to establish a range of potential changes in rainfall over the Hutt River catchment and changes in the frequency of flood flows. Subsequent inundation modelling of flood flows established the potential extent, depth, and velocity of floodwaters for a 1500–3500 cubic metres per second (cumecs) range of flood scenarios (Ballinger et al. 2010).

### Study 2: Investigating socio-economic sensitivities and impacts of flooding

To investigate the socio-economic impacts of flooding on the Hutt Valley, the researchers undertook three lines of enquiry: RiskScape damage-cost modelling (combining the inundation modelling results with a spatial-asset database and known relationships between flood depths and velocity to project the financial costs of flooding), a survey of residents with a focus on the impacts of the 2004 flood, and an investigation into existing datasets and vulnerability literature relevant to the Hutt Valley.

### Study 3: Investigating the social and institutional factors that influence adaptation

Finally, to gain insight into adaptation barriers and opportunities, the researchers undertook a workshop and in depth interviews with council advisers and decision makers across the Wellington region.

## Research findings

**The frequency of Hutt River flooding is likely to significantly increase over the twenty-first century**

The frequency of Hutt River flooding is likely to significantly increase over the twenty-first century. What is currently considered a 1:440-year flood[2] (a Hutt River flow of 2300 cumecs)—could become a roughly 1:50-year event under a high-emissions scenario. Even under a low-emissions scenario, a flood of this magnitude could still become a 1:100-year event. Damage-cost modelling indicates that floods above 2100 cumecs begin to have direct, but relatively minor, damage costs. Above 2300

[2] There are two main ways of expressing flood risk.

**Annual exceedance probability** (AEP) is the percentage chance that a flood of a certain volume will be exceeded in any given year. For example, a 1 percent annual exceedance probability flood is a flood volume that has a 1 percent chance of being exceeded in any one year.

**Average return intervals** (ARI) represent the chance that a flood of a certain volume will occur over a particular time frame, e.g. A 100-year flood is a flood which has 1 chance in 100 (1:100-year flood) of occurring in any one year.

These two expressions are related. A flood that occurs with 2 percent probability in any given year is equivalent to a 50-year flood. Planning for a 50-year flood does not guarantee protection for the next 50 years.

cumecs, flood damages increase sharply and have significant financial impacts on the Hutt community.

**Locally specific factors can influence vulnerability**

The flood-impacts survey returned 190 responses and revealed that the 2004 flood impacts differed by ethnicity and household composition, highlighting how locally specific factors can influence vulnerability. Despite council efforts to improve how they communicate risk, many residents have a low understanding of flood risks.

**New Zealand local government currently relies on structural flood controls**

In New Zealand, local government manages flood risk and generally favour hard structural flood controls (such as stopbanks) over softer measures (such as land-use restrictions). Relying on structural protection can be problematic in contexts when the risk is changing and uncertain, as the potential future risk cannot be determined definitively. Non-structural measures are designed to reduce impacts from high-impact events which will occur at some time in the future. This means that they are less sensitive to changing risk. Both interviewees and, importantly, surveyed residents recognised the importance of non-structural measures for managing risk. However, interviewees highlighted the difficulties of overcoming institutional inertia and the current practice of using largely structural protection in areas of existing development.

**Floods can be an opportunity for institutional learning and changes to current practice**

Regimes for managing flood risk that are dependent on structural measures can continue without review due to long durations between damaging floods, the timeframes over which flood risk is projected to increase, and a mismatch with local government political and planning cycles. Conversely, when floods do occur they can often be an opportunity for institutional learning and changes to current practice (B. Glavovic, W. Saunders, & J. Becker, 2010).

**New Zealand needs a more comprehensive approach to changes in flood risk associated with climate change**

Findings highlight a need for a more comprehensive approach across New Zealand to changes in flood risk associated with climate change. Suggested changes include financial and technical support for better-quality risk assessments across regions, sharing experiences and approaches across councils to build capacity, and better communication of the risks associated with climate change impacts and the options for addressing them.

# 1 Introduction

## 1.1 Research purpose

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4. What social and institutional barriers constrain adaptation and what opportunities are present for improving adaptive capacity?

## 1.2 Research framework

### 1.2.1 Vulnerability

In this study, vulnerability is understood as a function of exposure, sensitivity, and adaptive capacity—a framework that reflects the vulnerability-assessment literature (Cutter, 1996; Metzger, Leemans, & Schröter, 2005; Metzger & Schröter, 2006; Preston, et al., 2008; Preston & Stafford-Smith, 2009; Schröter & ATEAM consortium, 2004; Smit & Wandel, 2006; Turner II, et al., 2003) and as used in the IPCC Fourth Assessment Report 2007, which defines vulnerability as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change' (Intergovernmental Panel on Climate Change, 2007, p. 883). Vulnerability and its components are shown in **Error! Reference source not found.**.

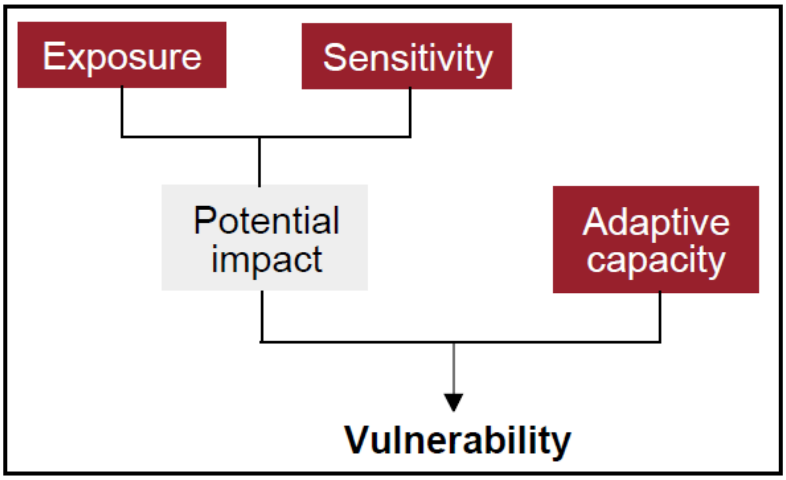


**Figure 1. Vulnerability and its components (Allen Consulting Group, 2005, p. ix)**

### 1.2.2 Exposure

Exposure generally refers to the state and change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables (including their variability and frequency of extremes). The location of people and assets can also be regarded as exposure (Intergovernmental Panel on Climate Change, 2007; Preston & Stafford-Smith, 2009).

### 1.2.3 Sensitivity

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure (Intergovernmental Panel on Climate Change, 2007). A system can be sensitive to direct (physical) impacts (e.g. a given change in rainfall affects the water supply of a city) as well as indirect (socioeconomic) impacts (e.g. age structure of a population influences the degree to which mortality increases during a heatwave).

### 1.2.4 Adaptation

Adaptation is 'the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (Intergovernmental Panel on Climate Change, 2007, p. 869). Adaptation can be autonomous or spontaneous (it is not necessarily a conscious response to observed climate changes and / or their effects), or anticipatory or proactive (anticipating future changes and effects). The phrase 'planned adaptation' is used when adaptation is the result of deliberate policy decisions to respond to climate change (Intergovernmental Panel on Climate Change, 2007).

### 1.2.5 Adaptive capacity

Adaptive capacity describes the ability of a system to adapt to climate change—to moderate potential damages, take opportunities, or cope with adverse impacts (Intergovernmental Panel on Climate Change, 2007; Smit & Pilifosova, 2003).

Adaptive capacity includes

- coping capacity (the ability to accept the impacts and recover back to the system state before the impact, but does not change the system's exposure or sensitivity to reduce future impacts)

- the ability to adapt (the change in a system's exposure or sensitivity to reduce future impacts).

Both coping capacity and ability to adapt can change over time (because of socio-economic and institutional change). However, coping capacity usually implies a return to a state before a temporary shock. The ability to adapt does not assume that an original state should or can be maintained, but that response to climate change leads to lasting changes somewhere within the system (Adger, 2006; Eriksen & Kelly, 2007, p. 506; Turner II, et al., 2003; Yohe & Tol, 2002).

By showing the 'ingredients' of vulnerability, the model shown in Figure 1 represents a static snapshot in time. It does not show interactions between components, nor the steps that can increase or reduce vulnerability over time. Risks and their consequences are unlikely to increase linearly with frequency and severity of extreme events, so a dynamic time component also matters. The adaptive capacity of a household is also, at least in part, determined by the wider community's adaptive capacity. Correspondingly, the community relies somewhat on its regional or district authority to enhance its adaptive capacity (Fankhauser, Smith, & Tol, 1999; Smit & Pilifosova, 2003). Context matters.

### 1.2.6 Resilience

Resilience is defined as the ability of a system to absorb disturbances while retaining the same basic structure, ways of functioning, and self-organisation (Intergovernmental Panel on Climate Change 2007). Successful adaptive capacity—through both autonomous and planned adaptation measures—minimises vulnerability and creates resilient systems. Resilience is similar to coping capacity, but differs in the important respect that coping capacity tends to refer to the ability to recover from specific shocks to a state before this shock, whereas resilience is a more dynamic concept that applies not only to recovery from specific shocks but to the ability to accommodate a broad range of ongoing pressures.

Like vulnerability, it is useful be specific about who is resilient, over what time horizon, to which effect of climate change, about which attribute of concern. The concept of resilience generally implies a commitment to preserve society's basic needs, rights, values, and essential functions in the face of a changing climate and changing socio-economic pressures.

Vulnerability and resilience can combine in the following way. Concrete adaptation measures can reduce vulnerability over time by reducing exposure (e.g. by installing flood defences or retreating from the coastline), reducing sensitivity (e.g. by raising minimum floor levels, or installing air conditioning), or enhancing adaptive capacity (e.g. by increasing people's income levels or social networks). Vulnerability can only be described for a specific point in time, whereas adaptation aims to reduce vulnerability over time and to increase resilience.

Therefore, resilience can be understood as the end-goal of adaptation measures, whereas vulnerability assessments provide time-bound information regarding the most effective options for interventions to reduce vulnerability and increase resilience.

### 1.2.7 Flood-risk management

**The legacy of past decisions affects today's choice of approaches**

When managing flood risk, generally the legacy of past decisions (e.g. location of existing settlements and protection measures) affects today's choice of approaches and these will in turn affect the pathways taken by future generations. The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report noted that, as well as the magnitude of biophysical changes, socio-economic development pathways contribute to a community's vulnerability to climate change (Intergovernmental Panel on Climate Change, 2007).

**The mutual interdependencies of social and technological systems can create development path dependencies that lock in and constrain policy options**

The mutual interdependencies of social and technological systems often create a development path dependency that may eventually lock-in and constrain policy options (Arthur, 1989; David, 1985; Gregory C. Unruh, 2000; G. C. Unruh & Carrillo-Hermosilla, 2006). Present decisions will partly determine future generations' choices and could widen or narrow their options. For example, if the chosen flood-risk approach entails an institutional commitment to capital-intensive, large-scale and long-lived infrastructural development, there is a danger that this will limit future choices, reducing the portfolio of future adaptation options (O'Neill & Barnett, 2010). Thus, the temporal and spatial scales are important when assessing adaptation options. Adaptation may be ineffective or even act to increase vulnerability (maladaptation) (Burton, 1997; Intergovernmental Panel on Climate Change, 2001; Scheraga & Grambsch, 1998; Smit, 1993). Substantial commitment from governments and businesses may be required to break path dependency and to invoke transitions to new approaches to address climate change for the future (Berkhout, 2002).

**Much more attention needs to be given to maintaining reversibility and adaptability in infrastructural development**

In some countries, climate change is already putting pressure on infrastructure sectors and triggering changes in how climate change is considered in technical assessments and public policies (Geels, 2004, p. 914). Substantial, and potentially sudden, changes (including climatic changes and extreme weather events that affect societies' built environments and infrastructure) may create windows of opportunity for new approaches to be considered (Geels, 2004). Such gradual or sudden changes may be used to overcome the lock-in and structural inertia that allowed inferior development paths to persist long after they should have been abandoned (Gregory C. Unruh, 2000; Walker, 2000). The lesson for public policy is that 'much more attention needs to be given to the maintenance of reversibility and adaptability in infrastructural development' (Walker, 2000, p. 833) when addressing the future impacts of climate change in today's decisions.

Applying these insights to flood-risk management may prove challenging in existing hard flood-protection measures if there are sunk costs leading to pathways that lock in vulnerability and exacerbate flood risk. In the worst case, the selected adaptation options may increase, rather than decrease, future vulnerability.

**Adaptive capacity can only be identified through research specific to place and culture**

Adger (2003) demonstrated that adaptive capacity can only be identified through research specific to place and culture. Moser and Ekstrom (2010) highlight the interconnected structural elements that provide the wider context within which adaptation decision making takes place. Recognising these structural elements—the actors, the governance regime in which they operate, and the system exposed to climate change—can help identify barriers to adaptation. These structural elements provide the backdrop for the present New Zealand case study. This case study adds to the growing number of place-based adaptation studies in developed countries, and within the specific institutional arrangements and professional practices that operate in New Zealand.

## 1.3 Case study background

The Hutt River flows in the southern North Island of New Zealand over a course of 54km with a catchment area of 655km$^2$ (Wellington Regional Council, 2001). The Valley is 4.5km at its widest point at Petone Harbour (Adams, Berrill, Davis, & Taber, 2000; Boon, Perrin, Dellow, Dissen, & Lukovic, 2011) and land use changes markedly from the upper to the lower reaches of the river. While regenerating native forests and some exotic plantations cover the upper valley; urbanised areas of residential, industrial, and commercial development dominate the lower floodplain.

More than 150 years of European settlement in this area led to urbanisation with the associated intense modification of the valley floor and hill-slope environment. Controlling flooding has been, and continues to be, essential for developing the Hutt River floodplain (Wellington Regional Council, 1991). Today, about 130,000 people live in the Valley, mostly on its floodplain (Wellington Regional Council, 2001) , protected by one of the largest flood-protection schemes in New Zealand (Greater Wellington Regional Council, 2009).

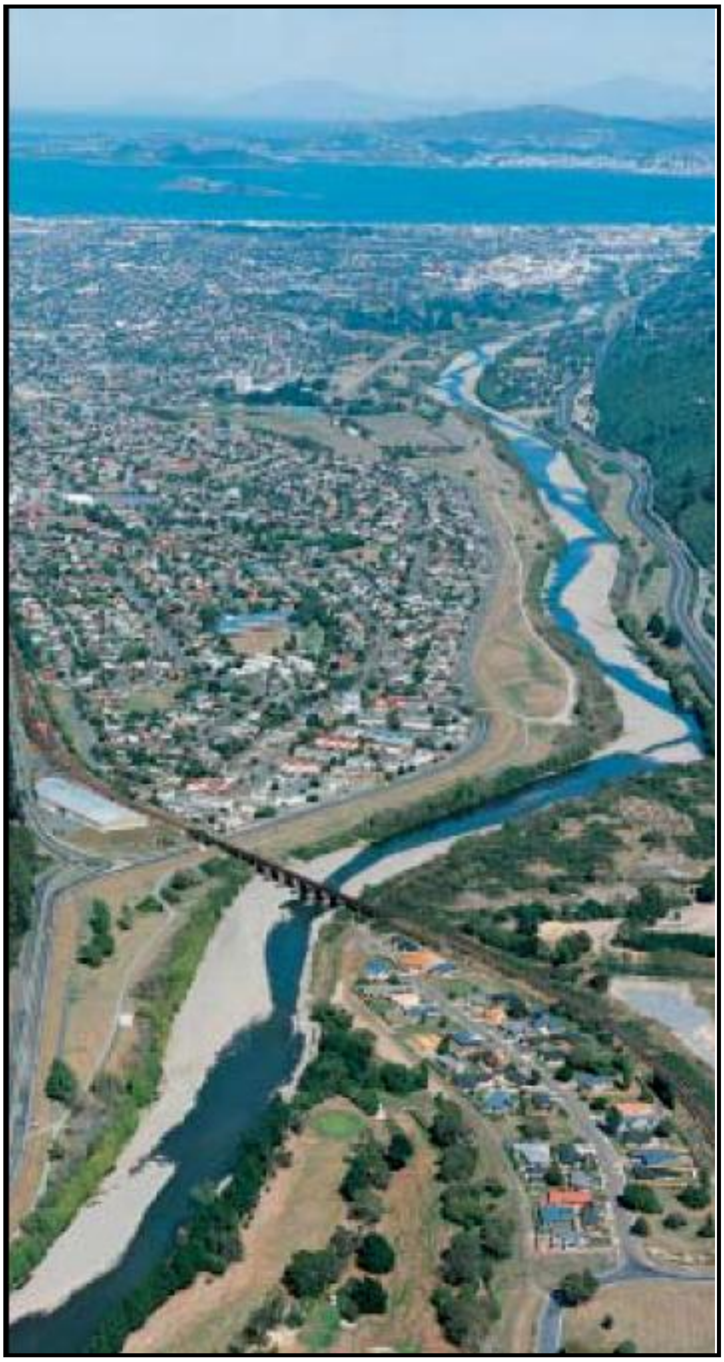

**Figure 2. The Hutt River, Wellington Harbour, and beyond, from Manor Park (WRC, 2001, p. 2, 2)**

### 1.3.1 Institutional context

In New Zealand, flood-risk management is devolved to the local government level represented by a two-tier structure of regional councils and territorial authorities (city and district councils) within their borders. Central government provides technical guidance documents on flood risk and has the statutory ability to create national policy statements (NPS) and set national environmental standards (NES) although there are currently none pertaining to flood risk. Civil defence and emergency management is administered by central government with local roles designated as part of a national emergency management strategy. There is no one statute that sets out the objectives and functions associated with flood-risk management in New Zealand. The key statutes setting out the roles and responsibilities for flood-risk management are the Land Drainage Act 1908, the Soil Conservation and Rivers Control Act 1941, the Resource Management Act 1991 (RMA), the Local Government Act 2002, the Local Government (Rating) Act 2002, the Civil Defence and Emergency Management Act 2002 and the Building Act 2004 (Ministry for the Environment, 2008). These statutes have evolved over time in response to different community and political drivers and operate in parallel, not always well-aligned in practice (Lawrence & Allan, 2009).

Local government has a range of instruments within these statutes that can be used for flood-risk management. For example, long-term plans (LTP)[3] can set out long-term investment targets based on detailed asset-management plans for infrastructure and flood-management plans. Responsibilities under the emergency-management legislation enable councils to develop lifelines plans and to instigate flood warning and evacuation plans. The Hutt area has developed sophisticated digital warning systems for emergency management, which coordinate action across the region. The regional and district plans can instigate rules for land-use activities in areas subject to hazards and can provide information to property owners that identifies hazard exposure and sensitivity. The extent to which the full range of measures in these statutes are used is explored as part of this research

This case study is located within the Greater Wellington Region, which comprises four cities and four district councils. The study focuses on the Hutt City Council area. The Hutt River Floodplain Management Plan (HRFPMP), issued by the Regional Council in 2001, was developed after wide community consultation and is a non-statutory blueprint for the next 40 years with review intervals scheduled every 10 years, or earlier ‘if the flood hazard is significantly altered by flooding, earthquakes or new information’ (Wellington Regional Council, 2001, p. 161). The HRFPMP outlines plans to upgrade the Hutt River stopbank system from a 1900 cumec standard (a 1:100-year flood), to a 2300 cumec standard (an historical 1:440-year flood) over the following 40 years. The 2300 cumec standard is considered to provide a buffer that accounts for future increases in flood frequency associated with climate change at a reasonable cost.

[3] Long-term plans are the key strategic documents for local government in New Zealand.

### 1.3.2 Decision outcomes to date

Having historically experienced recurrent flooding (Wellington Regional Council, 1991), the response so far has been in the form of hard measures; such as building stopbanks, straightening the river channel, and excavating substantial quantities of gravel to improve the river's flood capacity. These combined measures led to progressively building a flood-defence system intended to keep flood waters away from people, rather than keeping people away from flood waters (Wellington Regional Council, 2001). The plan has been progressively updated based on flood experience in the valley over time following flood events. It is regarded as a living document and updates are made only after significant changes in assumptions. The extent to which climate change assumptions have changed is still an open question, largely determined by the available information on changing climate risk. This research is the first time that this question has been explored.

The prevalence of structural measures to alleviate flood risk reflects the legacy of rivers' control legislation in New Zealand and the supporting institutions and funding arrangements[4]. Structural measures are also easier to quantify and cost compared with soft or non-structural measures (behavioural and planning measures) (Agrawala & Fankhauser, 2008). As decision makers are concerned about the economic impacts and costs of their adaptation decisions (Callaway, 2004), they may be inclined to favour structural over non-structural measures. Such an emphasis can result in inappropriate and costly adaptation actions that disregard the vital role of non-structural measures in facilitating adaptation (Agrawala & Fankhauser, 2008). Among the non-structural measures, land-use planning in particular has been identified as having much unused potential for reducing the from natural hazards risk to communities in New Zealand (B. C. Glavovic, W. S. A. Saunders, & J. S. Becker, 2010). However, there are barriers to implementing land-use planning related to the institutional inertia brought about by the historical legacy of existing settlement location, the pressures from those arguing protection of property rights, and the long-term potential inflexibility of existing adaptation approaches.

[4] The Soil Conservation and Rivers' Control Act of 1941 has a heavy emphasis on engineering works and was supported by government subsidies for their construction up until the early 1990s.

# 2 Study 1: Biophysical impacts of climate change

## 2.1 Methodology

To investigate the first two research questions (see page 11), the researchers modelled changes in the frequency of Hutt River floods and the potential impacts of a range of flood events. The analysis methodology used for modelling changes in flood frequency is detailed further in Ballinger, Jackson et al. (2011) 'The potential effects of climate change on flood frequency in the Hutt River'. Inundation modelling is explained fully in Ballinger, Jackson et al. (2010) 'Potential flooding and inundation on the Hutt River'. (These reports are both available on the CCRI website.)

The modelling was undertaken to illustrate a risk-based approach to decision making under climate change. It is not intended to serve specific planning purposes; rather, the study is used to show how decision makers can use such an approach to look at future adaptation options at a strategic level, taking multiple sources of uncertainty into account. A risk framework and the use of multiple downscaled climate models, emissions scenarios, and inundation scenarios are the key elements of this approach. Within a risk framework, researchers assess both the impacts and the probabilities of the full range of potential flood events. In the context of significant uncertainties, such information has much greater potential utility for decision-makers than a single or small number of scenarios that do not consider likelihood or the full range of potential changes and events.

Caveats to the methodology adopted for this study are set out in Appendix 1. In summary, the study lacks specific modelling of stopbank overtopping; uses limited velocity assumptions, and 1-hour design floods[5], to model impacts, which could result in overestimates in particular of flood velocities; and did not consider flood risks associated with the Hutt River above Stokes Valley, stormwater, or minor streams.

Assessing potential changes in flood frequency through to the 2090s required:

- selecting four emissions scenarios and 12 climate models used by the National Institute of Water and Atmospheric Research of New Zealand (NIWA), to establish a range of 48 future climates
- downscaling these climate models to derive rainfall changes in the Hutt river catchment
- running adjusted rainfall data through the TopNet hydrological model, calibrated to the Hutt River (Hoffman 2011).

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[5] Design floods are hypothetical floods used for planning and floodplain management. The 'design flood standard' refers to the flood magnitude that a structural measure has been constructed to withstand. The HRFPMP sets a design flood standard of 2300 cumecs for the majority of stop banks along the urban extent of the Hutt River (Wellington Regional Council, 2001). Design floods are also defined by their probability of occurrence expressed either as annual exceedance probability (AEP; e.g. 2 percent AEP) or annual return interval (ARI; e.g. 1:50-year flood), although these definitions can be problematic in practice (see §4.3 Flood risk communication).

In this instance, the hydrological modelling used 1-hour flood peaks. In reality, flood peaks are typically sustained for less than an hour. This could result in modelling overestimates, particularly of flood velocity.

### 2.1.1 Selecting emissions scenarios and climate models

Incomplete knowledge of the global climate system and an unknown quantity of future greenhouse gas emissions are the two main sources of climate change forecasting uncertainty (Hayward 2008). Global climate models can simulate changes in the historical observed climate reasonably accurately (IPCC 2007), but differences in model construction mean that they give different results when run under the same emissions scenario. In addition, the amount of future GHG emissions is not knowable. Depending on time constraints, resources, and project objectives; some studies use only a single climate model and / or single emissions scenario to project future climate state(s). While this kind of information is of value to researchers wishing to investigate the interactions of particular factors, knowledge of a single or small number of possible future climates may have less utility for decision makers than knowledge of the full range of possible futures expressed in a probabilistic risk framework (Jones 2001).

For this reason, the researchers used results from the 12 global climate models selected by NIWA as having demonstrated sufficient skill in reproducing observed climate patterns in the south-west Pacific region (MfE 2008). The researchers selected three Special Report of Emissions Scenarios (SRES) emissions scenarios (A2, A1B, and B1) and scaled the results for the B1 emissions scenario to 2 degrees global average warming to infer local climate changes based on the B1 pattern) (**Error! eference source not found.**) to reflect the full range of uncertainties for illustrative purposes.

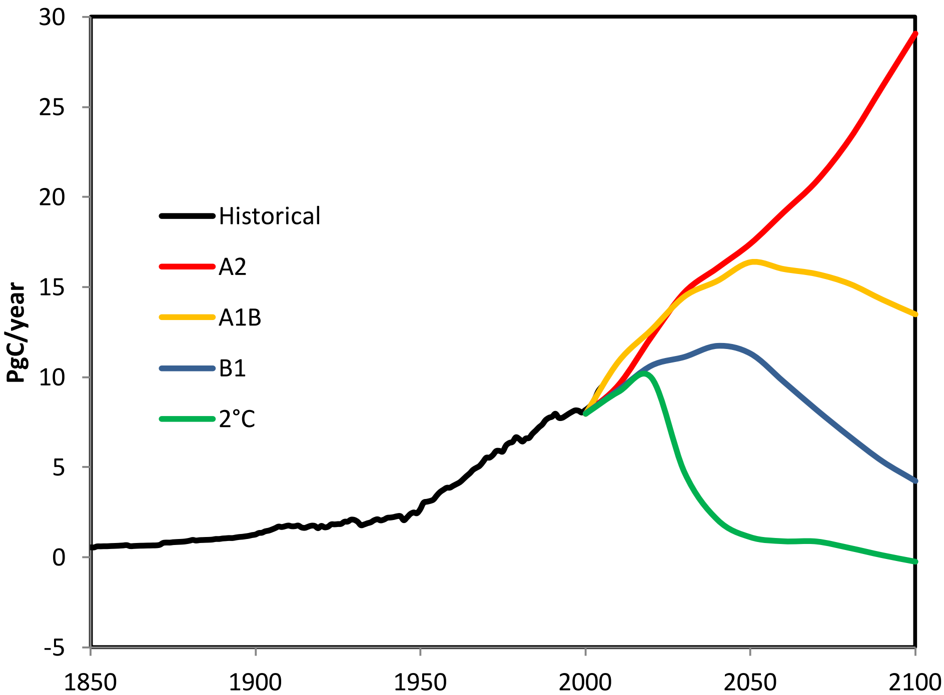


**Figure 3. Global $CO_2$ emissions scenarios. Historical $CO_2$ data from Boden, Marland et al. (2011) and Houghton (2008). The 2°C stabilisation scenario has net negative emissions from 2100 due to large amounts of reforestation and is from Meinshausen (2005)[6]. The three SRES scenarios are from IPCC (2000).**

[6] Meinhausen (2005.) uses a probabilistic framework for analysing emissions scenarios and considers this scenario to have a 75 percent probability of stabilising global mean temperature below 2°C above pre-industrial.

### 2.1.2 Downscaling the models to the Hutt River rainfall distributions

The future climate scenarios were used to perturb historical Hutt Valley rainfall data and generate a range of future rainfall intensity and frequency scenarios consistent with the climate models and the observed local climate. Details on this procedure can be found in MfE (2010, p71) and Ballinger, Jackson et al. (2011, p22).

### 2.1.3 Running adjusted rainfall data through the TopNet hydrological model

The researchers used the hydrological model TopNet, supplied by NIWA and calibrated to the Hutt River catchment (Ibbitt and Woods, pers. comm.). Two TopNet calibrations were attempted with the first calibration becoming the basis for estimating flood frequency changes. A revised TopNet calibration was attempted that gave slightly better representation of observed flows at some key stations, but the derived changes in flood frequency using this revised calibration were almost identical to those derived using the original calibration. Hence, one can conclude that the modelled relative changes in flood volumes and flood frequencies are reasonably robust despite TopNet's limitations in reproducing specific observed flows at some locations.

The TopNet hydrological model simulates river flows based on observed historical rainfall data. This model was run with current climate conditions to ensure that the hydrological model could sufficiently reproduce observed river flows and flood statistics. TopNet was then re-run with the 48 perturbed rainfall scenarios to produce future flood frequencies and intensities under the range of different emissions scenarios and climate models.

Inundation was modelled with two scenarios, one with current stopbank specifications, and one with all stopbanks improved to contain floods of 2300 cumecs, using prescribed 1-hour flood volumes. River flows and associated flood frequencies were calculated from these results and are shown in the next section. For more details, including corrections applied to account for imperfect modelling of historical flood volumes and frequencies, see Ballinger, Jackson et al. (2011).

## 2.2 Flood frequency results

**Flooding is generally projected to become more frequent in the Hutt Valley and degrade the flood-protection standards of existing and planned stopbanks, with a large range of uncertainty**

Based on river flow data from 1972 to 2008, the 100-year flood for this period is estimated to be about 2000 cumecs at the Taita Gorge. While the HRFPMP considers a 1900 cumec flood to represent the 'current' flood risk, this figure has been calculated from 1840–1998 river-flow data (Pearson & McKerchar, 1999) and should more accurately be considered the historical 100-year flood for this period. The 'current' (2011) 100-year flood risk is unknown, but is presumably slightly higher than 2000 cumecs due to ongoing climate change as the following results demonstrate. **Error! eference source not found.** (next page) shows the changes in flood frequencies for two different emissions scenarios. The upper panel shows a highly optimistic scenario where global emissions are reduced rapidly so that the increase in global average temperatures is limited to 2°C relative to pre-industrial levels by 2100. The lower panel shows a scenario where emissions continue to increase throughout the twenty-first century, resulting in global warming of about 4°C by 2100 relative to pre-industrial conditions (A2 scenario in Figure 3). Under these future climate scenarios, the peak volume of the flow of the 100-year flood would increase to between 2300 cumecs (2°C scenario) and

2600 cumecs (A2 scenario) by the end of the twenty-first century as a best estimate across 12 different climate models.

These changes in flood volume can also be expressed as changes in the return period for a given volume flood. Based on the average of the models, for the highest emissions scenario, a 100-year flood would become roughly a 20-year flood by 2100, while the most optimistic emissions scenario would see the 100-year flood to roughly double in frequency to become a 40–50-year flood. Considering the entire range of all 12 models, the potential changes for the optimistic-emissions scenario (based on currently available climate models) could be negligible, but even a 5-fold increase in flood frequencies cannot be ruled out, based on the climate model that simulates the greatest amount of warming and associated increase in heavy rainfall events. For the high-emissions scenario, the minimum change based on current models would be roughly a doubling of flood frequencies.

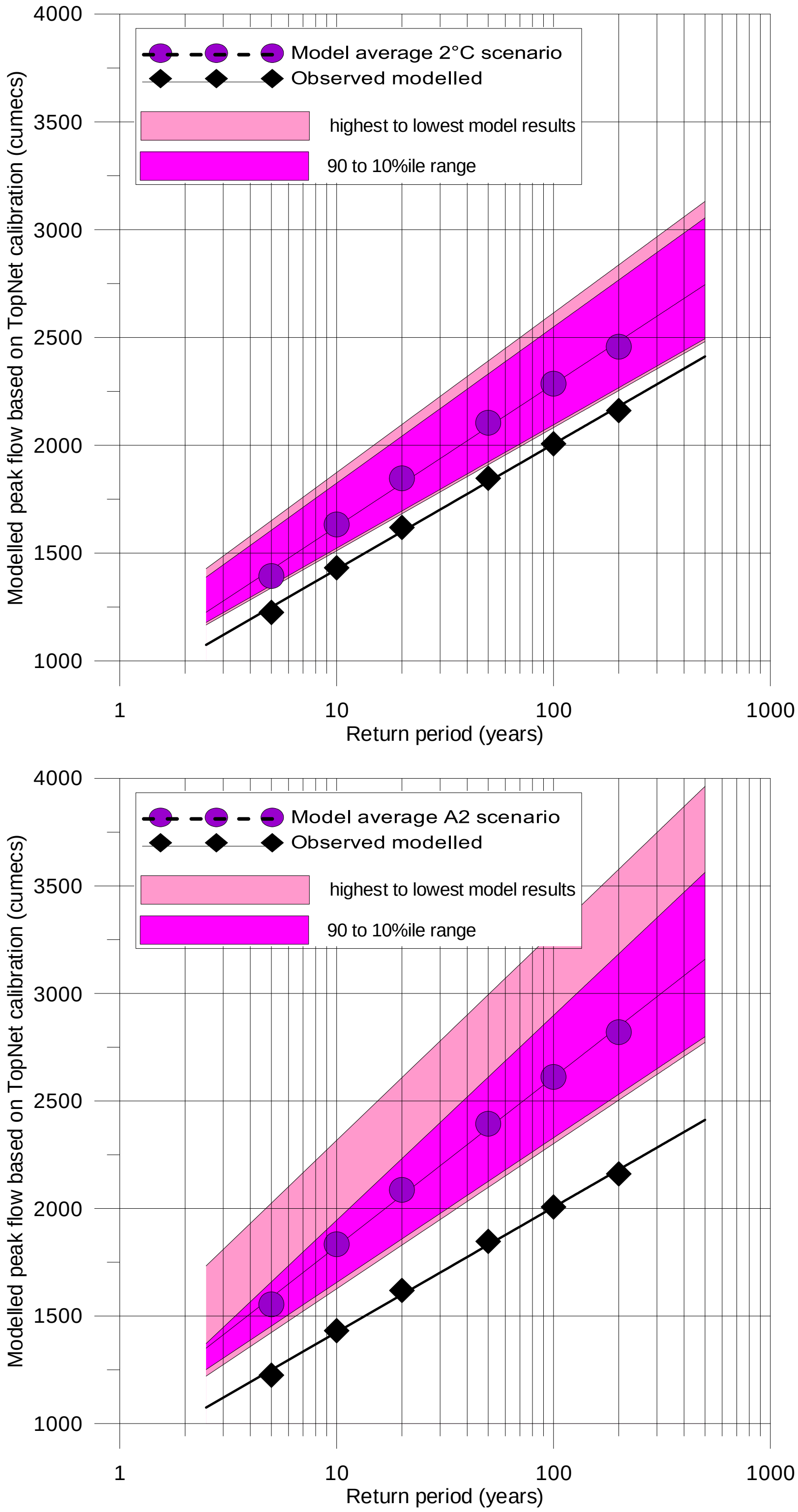


**Figure 4.** **Changes in flood frequencies under different emissions scenarios. The black diamonds and line show present-day flood volumes and their estimated return periods. The purple dots show model average future flood volumes and return periods under two different emissions scenarios (upper panel: rapid global emissions reductions—2°C scenario; lower panel: continued global emissions increases—A2 scenario). The purple band shows the 10 to 90percent range across different climate models, and the light pink band shows the lowest and highest results across all models.**

**Error! Reference source not found.** summarises the raw modelling results by showing a histogram of he range of modelled future flood flow for the 100-year flood under current (1840–1998) and future (2100) conditions for two different emissions scenarios, and for the full range of 12 different climate models. All climate models and emission scenarios indicate an increase in flood frequencies, but the range of possible changes is wide. For the low-emission scenario (upper panel), the volume of the estimated future 100-year flood at the end of the twenty-first century could range from virtually no change up to more than 2600 cumecs. For the high-emissions scenario (lower panel), the potential range of changes runs from 2300 cumecs (currently estimated to be about a 440-year flood) to more than 3000 cumecs. **Error! Reference source not found.** also shows the estimated 1972–2008 100-year flood volume (black), and the mean future 100-year flood volume for the emissions scenario (red).

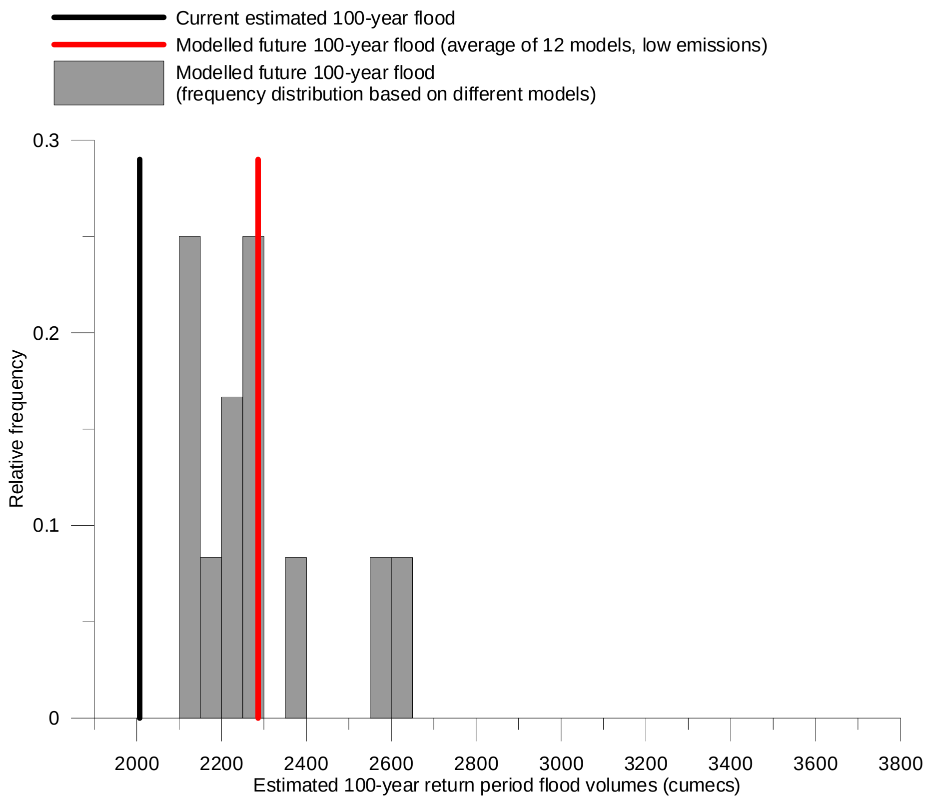


**Figure 5. Histogram of changes in the volume of a 100-year flood under the most optimistic (2°C scenario) for the set of 12 different climate models.**

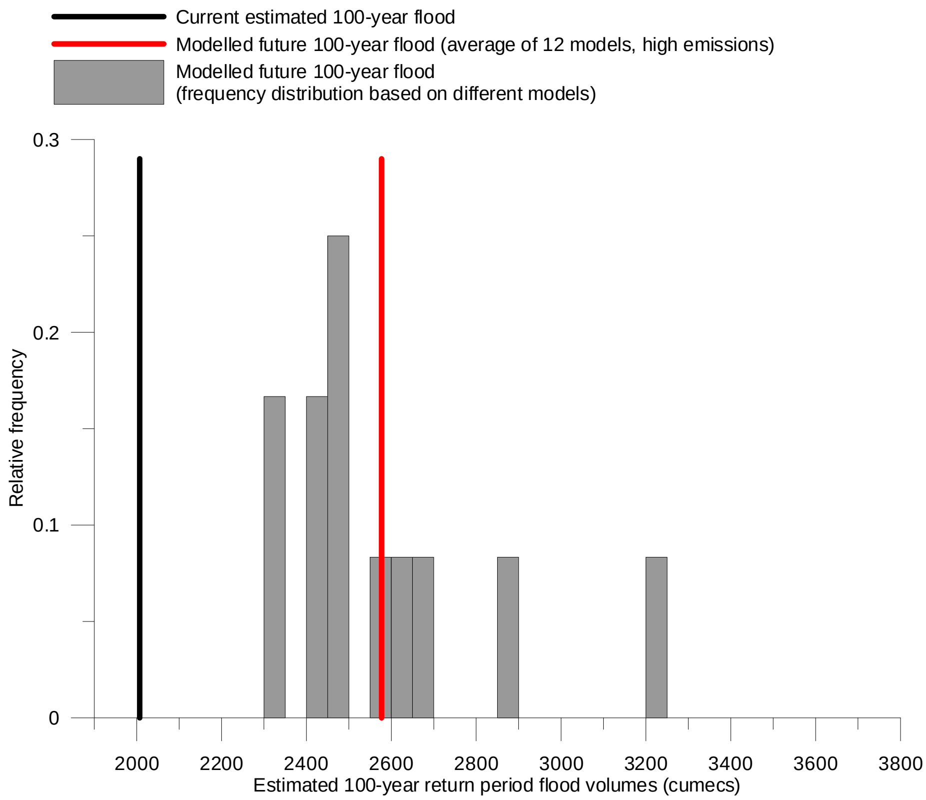


**Figure 6. Histogram of changes in the volume of a 100-year flood under the highest emissions scenario (A2 scenario) for the set of 12 different climate models.**

### Using the 'best-estimate' scenario underestimates the real risk of more extreme events

Relying on a single model average or 'best estimate' figure can be highly misleading, as it covers up the large range of uncertainty in both the emissions scenario and climate model range. Councils need to consider the implications of not only the best estimate of projected climate change but also the potential damages from catastrophic events because they could affect decisions being taken now for assets and people at risk over the longer term. A decision-making process based on risk would need to take the full range of potential future changes into account, rather than relying on a single best estimate, even though such a single 'line in the sand' may be seen to be more robust. Otherwise the extreme events, when most damages occur, would be significantly underestimated. The HRFPMP does not give much regard to the potential for large future changes in flood frequencies. Based on the results presented in this study, floods may have already become more frequent in 30 years time when the plan is due to be completed.

## 2.3 Flooding and inundation on the Hutt River

Once river flow frequencies were projected, the next stage of the research attempted to determine how a range of different river flow volumes would impact the lower Hutt Valley. Ballinger, Jackson et al. (2010) modelled floodwater depths and velocities under two landform scenarios for a range of flood volumes between 1500 and 3500 cumecs (measured at the Taita Gorge gauge), one scenario with current stopbank specifications, and another scenario with all stopbanks improved to contain floods of 2300 cumecs. For flood-volume scenarios with significant stopbank overtopping, the water spilled into the flood plain from the Hutt River will more than fill all available depressions. Therefore, the researchers also modelled the additional effects of inundation and increases in flow velocity from large flood events that significantly exceed stopbank specifications (Ballinger, et al., 2010).

Figures 6 and 7 show modelled inundation under current stopbank specifications for 2300 and 2800 cumec floods respectively. Importantly, the stopbank upgrades set out in the HRFPMP cannot be considered to provide a 1:440-year, or even a 1:100-year, level of protection over the long-term (until 2100), because flood volumes above 2300 cumecs are projected to become significantly more frequent even under low-emissions assumptions (previous section). However, the Hutt Valley floodplain is notably flat and drains to the sea across its lower reaches, meaning that the blue areas at a higher risk from flooding are essentially topographical depressions where floodwater pools. These areas may be some distance from the Hutt River itself, but, in the event of an upstream stopbank overtopping or breaching, can still suffer significant flood damage from floodwater pooling. Such floodplain features limit inundation depth and resulting flood damage in other areas.

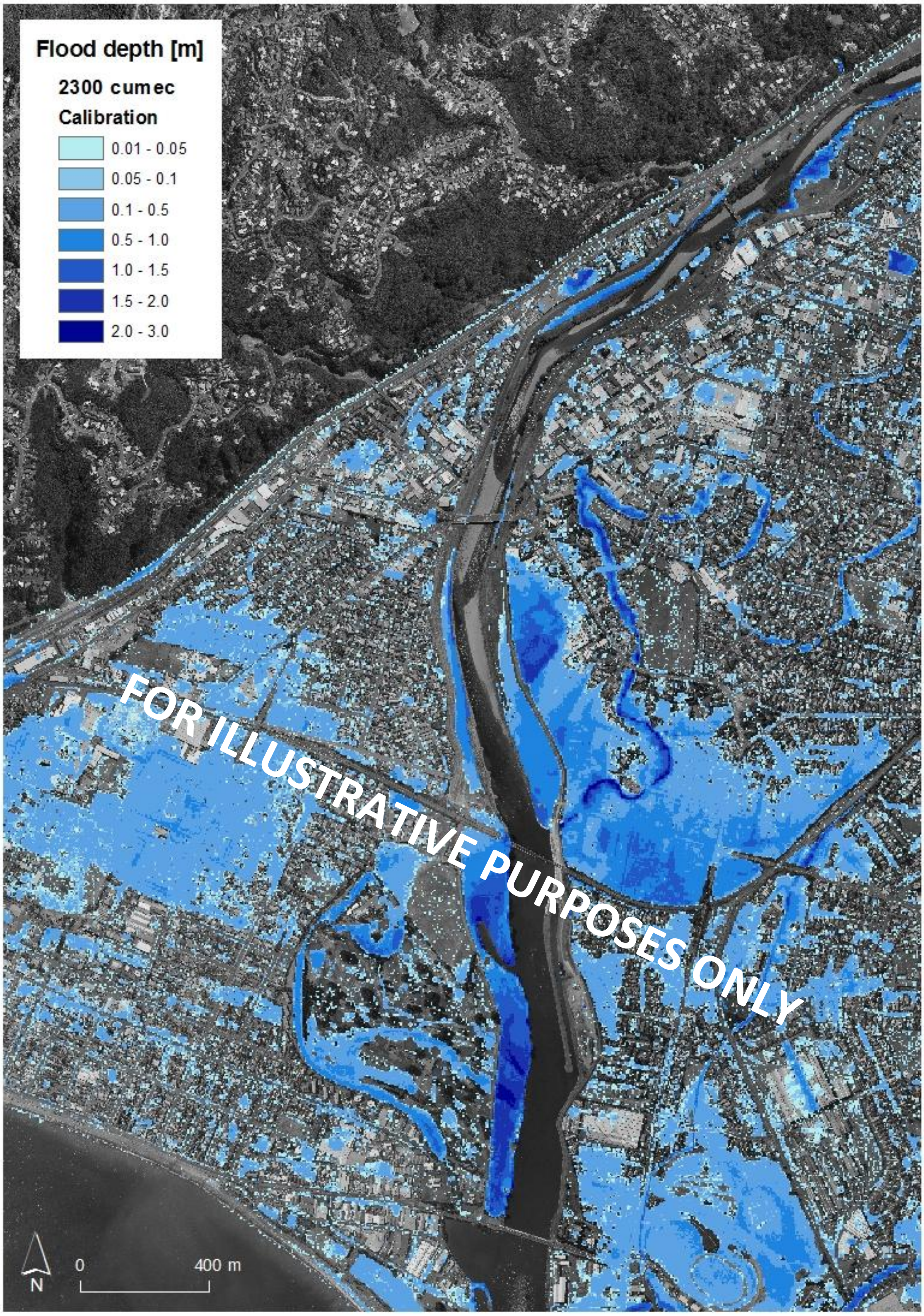


**Figure 7. Inundation of the Hutt Valley from the 2300 cumec flood. Areas flooded where the depth was less than 0.01m are not shown (Ballinger, et al., 2010).**

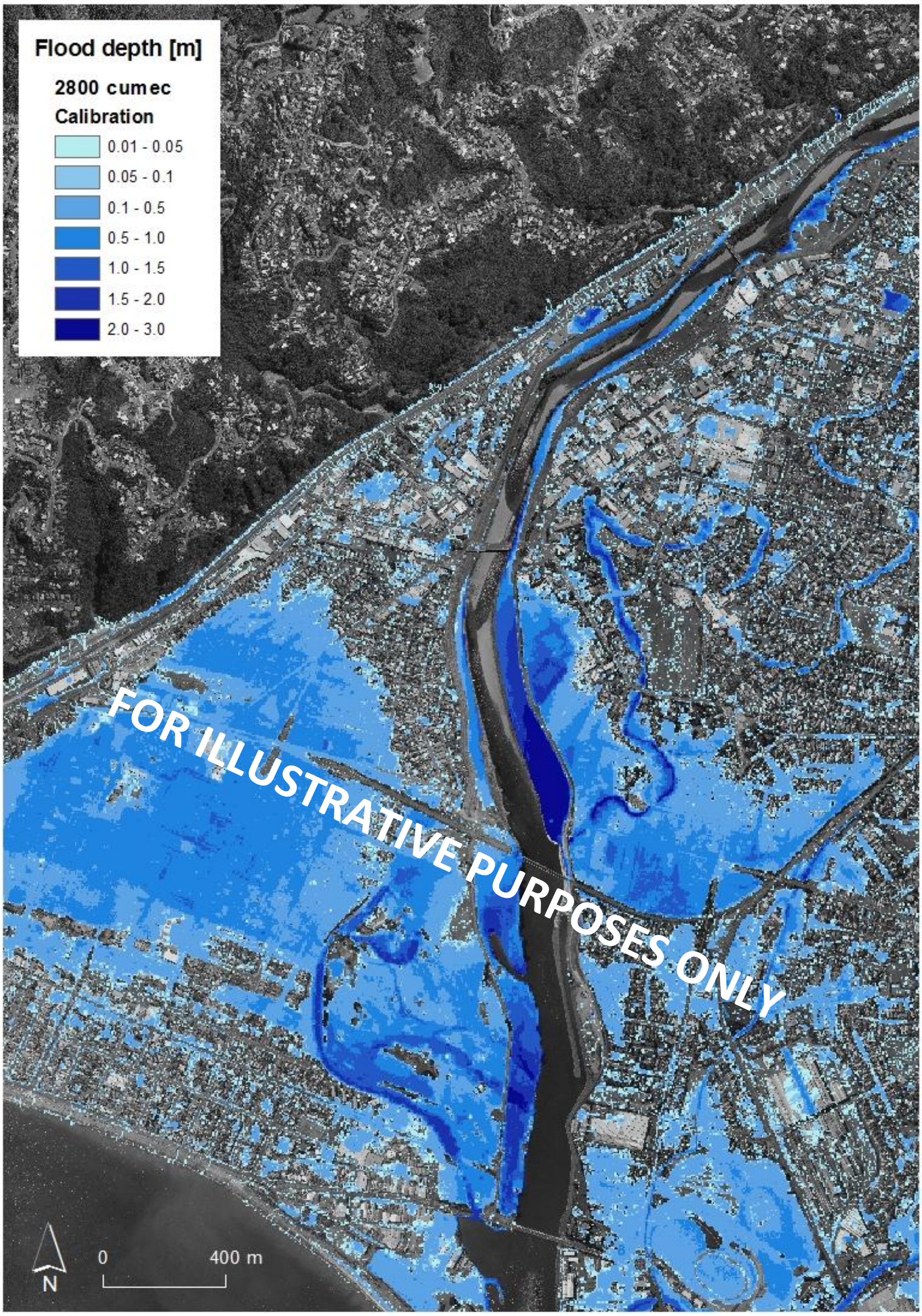


**Figure 8.** **Inundation of the Hutt Valley from the 2800 cumec flood. Areas flooded where the depth was less than 0.01m are not shown (Ballinger, et al., 2010).**

# 3 Study 2: Socio-economic impacts

## 3.1 Methodology

Three methods were used to assess the potential socio-economic impacts of floods:

- a flood-damage model, RiskScape
- an investigation into the socio-economic and demographic composition of the Hutt Valley
- a flood-impacts survey of households, focusing on the recent 2004 flood.

All of these methods used current available data and the researchers did not attempted to project socio-economic changes into the future. Unlike biophysical changes, where using multiple models and emissions scenarios can at least partially manage uncertainties, it was not possible within the scope of this research and the available data to demarcate future socio-economic uncertainty in a similar fashion.

In addition, an understanding of current socio-economic sensitivities may have greater relevance to operational policy-making and its implementation. However, this introduces a degree of inconsistency, as the conceptual model of vulnerability uses a combination of exposure, sensitivity, and adaptive capacity at comparable points in time. The lack of robust quantitative information about future socio-economic development limits the use of the vulnerability model for understanding *future* socio-economic vulnerability. The conceptual approach in this study is generally more relevant to understanding *current* socio-economic vulnerability and possible adaptation pathways that take the present socio-economic conditions as their starting point, rather than a focus on a specific future point in time.

Caveats to the study's methodology are set out in Appendix 1 but are summarised briefly here. The RiskScape damage-cost model uses 1-hour design floods and assumes floods occur in the daytime (which results in greater damage to vehicles in car parks along the river). These assumptions could result in damage overestimates. The flood impacts survey has comparability and representativeness issues for income and between those who had experienced flooding and those who had not, sample-size issues for previous flood experience, missing responses for some questions, and some respondents' knowledge of adaptation options could have influenced their responses. Despite these limitations, the research results can be used to give an indicative illustration of the types of socio-economic impacts in the Hutt Valley.

## 3.2 RiskScape damage model

**Flood impacts increase more sharply beyond 2300 cumecs as increasing flood volumes damage more properties at greater depths**

RiskScape is a flood-damage model developed by GNS Science and NIWA (Schmidt, et al., 2011). RiskScape contains an asset database of all known buildings and their construction type (e.g. type of cladding, floor level, etc.) The researchers ran RiskScape with the inundation model outputs to generate damage-cost estimates based on a given flood depth, velocity, and duration; and the fragility of construction type of affected buildings. RiskScape also generates estimates of damage to vehicles, building contents, clean-up costs, and indirect costs of economic disruption. These damages can then be expressed in aggregate form for the entire modelled area, and also spatially on a meshblock basis. Necessary generalisations mean that aggregate results are more robust than results for individual meshblocks or assets, and estimated damages should only be used for conceptual purposes to understand the range of potential changes possible under various climate change scenarios, rather than predictions of specific damages for specific flood events.

**Error! Reference source not found.** presents the aggregated damage-cost estimates from the iskScape model for the range of flood volumes (1900–3500 cumecs). These estimates are presented only to illustrate how damages can increase sharply beyond certain thresholds (e.g. 2300 cumecs) and specific figures should not be used for technical or planning purposes. While the probability of extreme scenarios may be low, in a risk-based approach planners will need to take the potentially significant impacts of extreme scenarios into account, especially for decisions that have lasting effects such as intensifying infrastructure and development in floodplain areas.

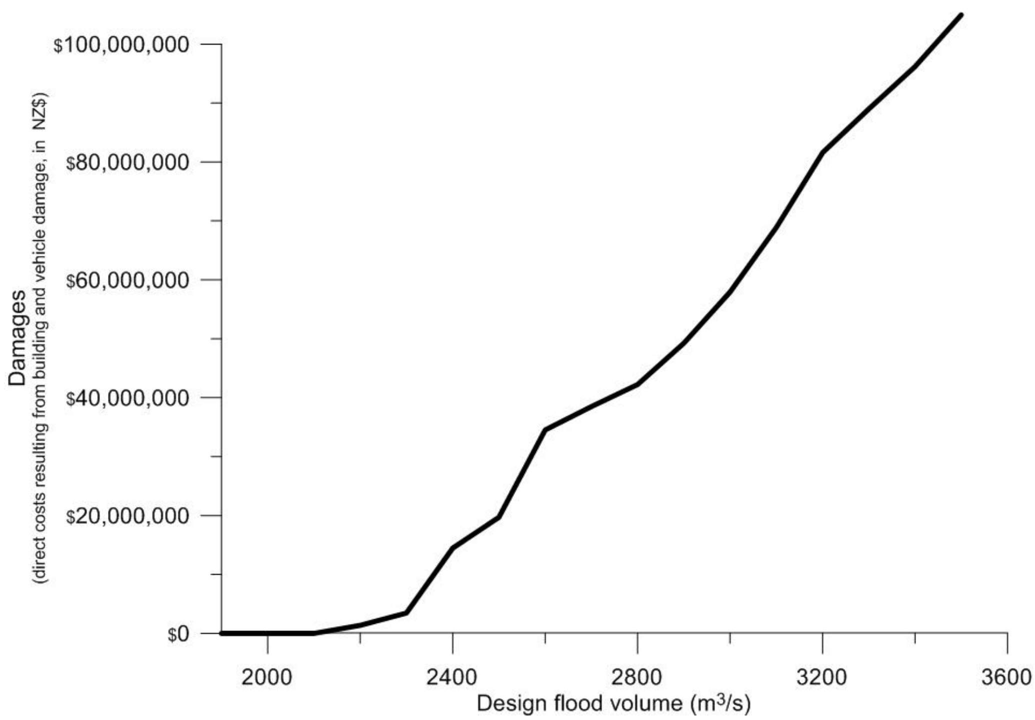


**Figure 9. Aggregated damage cost estimates.**

**Error! Reference source not found.** shows the spatial distribution of damage-cost estimates by eshblocks for the 2300 and 2800 cumec scenarios. In the 2300 scenario, most of the damage is concentrated near the eastern bank between the White Line East area and the Ewen Bridge (yellow circles). Damages reach approximately $500,000 dollars in the Hutt Valley High School meshblock. Petone CBD is flooded (see **Error! Reference source not found.**), but inundation is not deep enough o cause significant direct damage. In the 2800 scenario, an increase in inundation depth intensifies damage on the eastern bank and expands the damaged areas to include large parts of Petone CBD (pink circles).

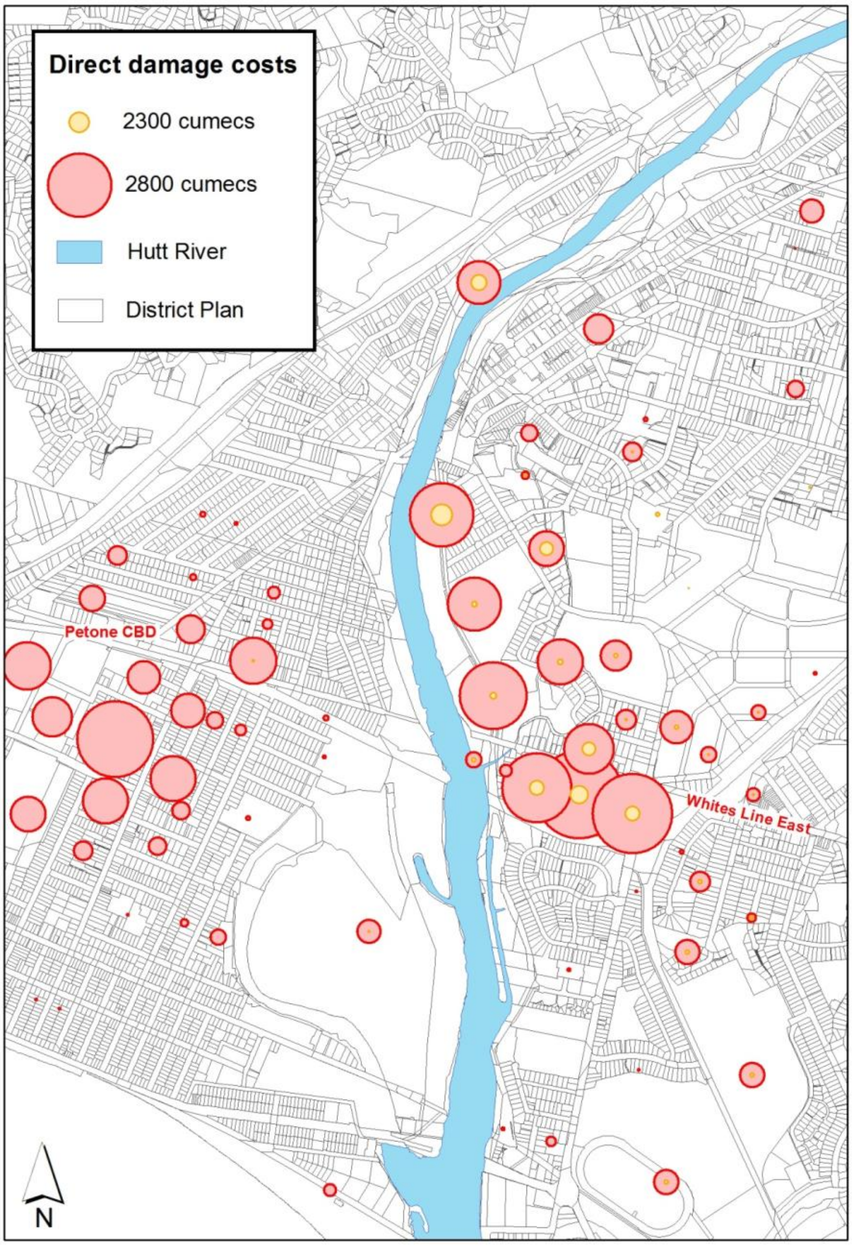


**Figure 10. Spatial distribution of direct-damage costs of 2300 and 2800 cumec floods. Circles are centred over meshblocks and proportionate to RiskScape cost estimates for that meshblock. The largest circles are approximately $3 million dollars.**

## 3.3 Social vulnerability

**Flood impacts can have a disproportional impact on different societal groups**

Flood impacts can have a disproportionate impact on some households or individuals depending on socio-economic or demographic vulnerability. For example, disabled and elderly people may have difficulty evacuating. New immigrants may have no previous experience with floods, limiting their perception of risks, emergency preparation, and possible responses. The researchers examined the spatial distribution of potentially relevant socio-economic factors such as the proportion of elderly, children, and median-income households in the Hutt Valley floodplain.

Socio-economic factors can influence a community's capacity to anticipate risk and adapt to increased flood risk; and to cope with, and recover from, floods when they occur (Adger & Vincent, 2005; Fekete, 2009; Posey, 2009). While a relationship between socio-economic factors and flood vulnerability is well established in principle, it is much more difficult to establish a quantitative relationship between a given factor (e.g. the proportion of the population with a disability) and a proportionate increase in vulnerability in a particular location (Hinkel, 2011). Specific measures of adaptive capacity are difficult to determine from socio-economic data, since adaptive capacity is more often associated with qualitative institutional arrangements rather than socio-economic characteristics (Pahl-Wostl, 2009). Nevertheless, some flood-impact studies have found that a number of socio-economic and demographic factors are correlated with an increased likelihood of evacuation, injury, and mortality (Fekete, 2009) and with proxy measures of adaptive capacity (Posey, 2009).

The four most noted vulnerability factors in the literature can be associated with coping capacity rather than adaptive capacity: elderly population, low income, overcrowding, and living in rental accommodation (Khan 2011). Physically frail elderly may have difficulty evacuating unassisted. The latter three factors are associated with less emergency preparation and poorer-quality housing. Flood survey results did not indicate significant relationships between these factors and impacts from the 2004 flood (discussed below). However, this does not mean that these and other factors are unimportant to future floods of potentially larger magnitude (Khan, 2010).

**Error! Reference source not found.** depicts the age structure and population density of the study rea and provides a visual guide to the ratio between those who may require physical assistance to evacuate and able-bodied adults. Groups of five people above 65 years or older are depicted as red dots, 15–64 years of age as green dots, and 0–14 years as orange dots. Note the concentration of elderly people near the Waititi Crescent area in the middle of the map and of both the elderly and children in the Connolly Street area in the north-eastern corner. Both areas are close to the Hutt River and have retirement homes (as well as an early childcare centre on Connolly Street). Such information is perhaps more useful to emergency-response planning, but as an area's socio-economic and demographic characteristics can persist over the medium-term it is likely to have broader relevance to flood risk reduction measures (Khan 2010).

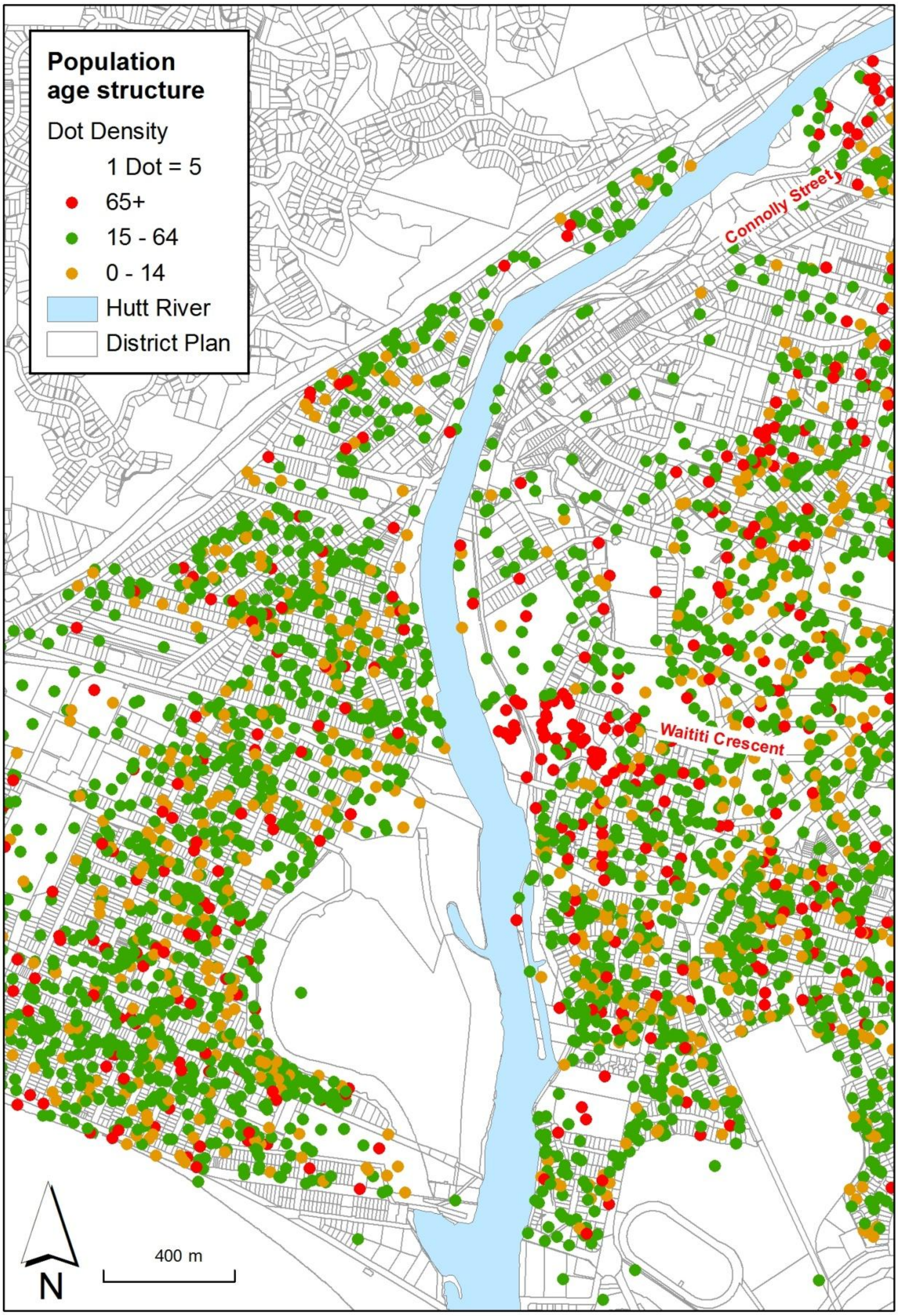


**Figure 11. Hutt Valley age structure and population density. One dot equals five people. Data are from the 2006 census (StatsNZ 2006).**

## 3.4 Flood-impacts survey

A July 2010 postal survey of households investigated whether the 2004 Hutt Valley floods (or any other floods experienced since then) have had any long-lasting effects on individuals or the community, how residents have responded to flood risk, and how views on how future flood risk associated with climate change should be managed. Nine hundred and ninety-six questionnaires were sent out and 189 returned (19 percent return rate). 28.3 percent of respondents (52 people) had experienced flooding in the Hutt Valley or elsewhere and 71.7 percent had not (132 people).

**Figure 1: Flooded houses on Riverside Drive in the 2004 flood (Civil Defense NZ, 2011).**

### Past experience of floods affects residents' behaviour and willingness for flood protection

Flood impacts from the2004 flood were associated with flooding of the Waiwhetu stream[7] (Figure 11). The flood-impacts survey found weak relationships between impacts of the 2004 flood and respondent ethnicity and household composition. Māori and Pacific Islanders were proportionally more likely to have experienced a flood than other ethnicities. Ten out of 17 Māori (59 percent), five out of seven Pacific Islanders (71 percent), and four out of seven responding single-parent households (57 percent) were affected by floods, compared to 55 out of 190 (29 percent) households in the entire sample, although in these cases the sample size is not large enough to draw strong conclusions. Nine households suffered permanent damage or lost items. Twelve households reported that their insurance premiums had increased since the 2004 flood. Thirteen households

[7] The Hutt river flow peaked at 1067 cumecs at Taita Gorge on the Hutt River—a 1:5-year flood, based on the historical climate.

considered themselves financially worse off since the flood (only three of whom reported increased premiums), mainly because they had to rebuild or replace items and / or because council rates went up after the flood event to cover increased flood-mitigation expenses. One respondent was still suffering from a past flooding experience and recorded an ongoing injury of psychological nature (undiagnosed depression). Flood-affected residents were somewhat more likely to take preparatory measures. While statistical significance is reached, the practical significance of these differences is rather low. That is, there is a significant but not strong association as only a small to moderate amount of the variance in preparedness can be explained by flooding experience (see details in Quade and Lawrence 2011, available on the CCRI website). Affected residents were more likely to seek out flood hazard information, communicate with their local council about how to reduce flood risk in their area, raise the floor levels of their houses, and keep ditches and drains clear of debris.

**Flood impacts can include difficult-to-quantify psychological aspects such as depression and ongoing anxiety**

Subsequent interviews with flood-affected-residents revealed ongoing anxiety in some individuals whenever it rains heavily. Affected residents had, in some instances, gone to considerable lengths to protect properties—such as purchasing sandbags, planting trees, and reducing impervious surfaces. There was also evidence that the ownership patterns in flood-prone areas had changed since the flood. Some permanent residents had moved out, changing the area to predominantly rental accommodation. Renters have less incentive to take property-protecting measures and this potentially counteracts the behaviour changes made by the flood-affected residents who remained. Residents’ perceptions of flood-risk management and communication are discussed in section 4.2 below.

# 4 Study 3: Adaptation barriers and opportunities

The researchers wished to determine the extent to which the current regulatory framework, as well as decision-making practice, is able to address current flood risk and future increases in flood risk associated with climate change in the Hutt Valley; and to identify the barriers and opportunities for improving institutional adaptive capacity. The researchers conducted individual interviews and hosted a workshop with local-government advisers. Participants came from a range of councils in the Wellington region: Greater Wellington Regional Council, Hutt City Council, Wellington City Council, and Kapiti Coast District Council. The workshop included managers, staff, and consultants from rivers control, planning, asset management, hazards management, civil defence, and strategy roles within these councils. Findings were also complemented by the flood-impacts survey of households and respondents' perceptions of future risk from climate change impacts, actions taken as a result of flooding, and perceptions of institutional responsibility for risk management.

## 4.1 Local-government workshop and interviews

**Leadership on risk issues often emerges only after significantly damaging events. Future flood events will present opportunities to review current practices, learn from mistakes, and institute more adaptive and resilient practices.**

### 4.1.1 Overview

In general, adaptation approaches varied across councils. Some were making significant strategic headway having mapped inundation and developed strategies to address climate change impacts, (e.g. building design, and retreat from sea-level rise). However, current approaches for managing flood risk (including for stormwater management) do not satisfactorily address current levels of flood risk. Participants reported tensions between district, regional, and central government responsibilities. For example, councils commented that a NPS on flood risk that took climate change into account, and / or other statutory support would strengthen decision-making at a local level by providing a consistent direction that could stand up to pressures when they are challenged in the courts by those wishing to develop land. District councils also wanted clearer rules in the regional planning documents to strengthen their own rule making; while regional councils saw rule making that affects residents as largely a district council responsibility.

Structural protection in the form of stopbanks and pumping is the dominant adaptation response used in the Hutt Valley and involves a combination of community input, a focus on costs, and support by emergency management to address residual risk as it occurs. Non-structural measures are weakly developed.

**Current planning does not account for increased frequency and intensity of future floods**

More importantly, the current approach to flood-risk planning does not take projected increased frequency and intensity of floods into account. This is in the context that a flood greater than 2300 cumecs is more likely than not to occur before 2100 under a low-emissions scenario, and virtually certain to occur under a high-emissions scenario.

The Hutt Valley is a narrow, well-developed floodplain. This does not give local government much scope for adaptation through land-use restrictions such as limiting infill development where it could increase future flood damages, phasing out activities in flood-prone areas, designing flood levels with climate change effects on flooding taken into account, or relocating some buildings.

Historically, extreme events have driven change in regimes managing flood risk. The floods of 1976 and 2004 triggered shifts in the Hutt's flood-risk management to a more comprehensive catchment approach. Such responses to flood events may also provide a window of opportunity for considering a wider range of adaptation options for vulnerable communities and to have these reflected in regional and district plans, asset management plans, and emergency management in an integrated way.

### 4.1.2 Council adaptation decisions

One district council is currently upgrading stormwater capacity from 1:5-year to a 1:20–1:50-year standard over an at least 20-year period—well behind what will be required even to keep up with current flood risk.

The current stopbank standard of 2300 cumecs, as set by the HRFPMP for the central Lower Hutt area, is described as a 1:440-year level of flood protection. Some council respondents thought that the 1:440-year flood standard left the protected developed area 'risk free' based on development and population scenarios at the time of the revised flood plan but without considering climate change impacts over the life of the scheme. Residual risks in these areas were considered to be an emergency-management issue, rather than planning issues. A 1:440-year flood standard was locally considered to be an advanced level of protection, but does not compare so well internationally. For example, the Netherlands has a series of standards up to 1:10,000 years (Jonkman, Brinkhuis-Jak, & Kok, 2004).

The HRFPMP triggered a Hutt City Council district plan change which prohibits buildings in which people are likely to congregate (clubrooms etc.) within the 1:100-year flood extent, and requires proposed buildings with a gross floor area ≥20m$^2$ in these areas to have floor levels above 1:100-year flood level (Hutt City Council, 2006). However, it was confirmed that climate change had not yet been factored into these provisions and that structural works were still relied upon to mitigate risk and emergency management to deal with residual risk during and after a flood event.

### 4.1.3 Where alternatives have been considered

**A number of practices can improve adaptive capacity. Pooling resources, improving access to LIDAR, using aerial photos of past floods, and the LTP process are examples of opportunities for improved assessment and communication of climate change and flood risks.**

Participants noted how the LTP process has provided a regular opportunity for increasing their understanding of climate change and its impacts and their awareness of the future consequences of not addressing climate change risks now. Council advisers reported that using aerial photographs of past floods was an effective and visceral way of communicating flood risk, particularly to new residents with no experience of flooding. Council advisers also recommended improving councils' access to LIDAR[8].

Councils can provide a strategic framework—such as a sustainability approach—to inform understanding of long-term issues and the nature of dynamic change in climate. However, this requires strong leadership over time, as demonstrated by the Kapiti Coast District Council where at least 10 years of community conversations on sustainable futures has enabled managed retreat from coastal hazards to be at least discussed with the community.

To accelerate the consideration of climate change, councils could reframe climate change risks by integrating the risks across council functions. This could be done by using approaches such as integrated catchment management planning, asset management plans, and by taking consistent approaches that consider long-term dynamic climate changes in benefit-cost assessments, scenarios, and extremes. However, there is an in-built bias in the benefit-cost approach as lower-value areas have lower benefit to cost ratios. This indicates that vulnerability assessments to complement benefit-cost assessments are needed.

### 4.1.4 Barriers to decision making

**The uncertainty of climate change projections collides with councils' expressed need for 'robust' or definitive planning guidance**

Another tension that emerged was between an expressed need for more definitive information to inform (and defend) flood protection design standards and the inherently uncertain nature of long-term climate projections. This tension may require changes in the handling of future, uncertain, dynamic risk manifest in increased flood frequency, through the analytical frameworks used, and the nature of rules developed to address such risk through the governance system. These rules could use triggers based on time, event, or damage level to review and apply a range of new adaptation measures. These measures could include further restrictions on building and other land uses, retreat from harm's way, and restrictions on land-use activities in the upper catchment.

[8] LIDAR (Light Detection and Ranging) is a highly accurate method of mapping topographic features using airborne laser scanning. It is an optical remote-sensing technology and has a wide-range of applications as diverse as archaeology, geology, seismology, forestry, meteorology, and atmospheric physics. LIDAR instruments can operate from the ground, from aircraft, or from space (satellite based) (Campbell, 2007; Cracknell & Hayes, 2008; Weitkamp, 2005).

**A lack of integration and strategic oversight within and between the different levels of government can act as a barrier to adaptation**

Participants noted several barriers to improved adaptation decision making; a lack of decision-relevant information on risk and adaptation options, resource constraints, a lack of central government leadership on climate change risks, the siloed organisational structure of larger councils, and the under-resourcing of smaller councils. To date, it has been difficult for councils to integrate climate change considerations into council decision making, largely because of the uncertainty in the information and strong local pressures for development to intensify and expand into new areas. In this context, applying non-structural planning measures that restrict land-use activities and their intensification on the floodplain have been slow to develop. Information on the impacts of climate change, if it exists at all, does not usually come in formats relevant to operational-level decisions for local government. Often impacts information needs to be downscaled and expressed in long timescales.

The consequence of these difficulties has been a perception that the HRFPMP is more than adequate to protect the community from whatever the climate deals up. Long term, this means that considering changing risk may be quite difficult to discuss across the community and the costs of future damage will be borne by future generations and be more costly than if attention was given to future risks now.

## 4.2 Hutt City residents' perspectives of flood-risk management from the flood-impacts survey

In general, survey respondents perceived the Hutt City Council and regional councils, along with the Earthquake Commission (EQC), as having high levels of preparedness for managing a damaging flood, relative to their own communities or households. Flood-affected residents ranked their own and central government preparedness slightly higher and the local councils' and service providers' preparedness slightly lower than unaffected residents. Respondents preferred measures to mitigate the risk of floods to be managed and paid for collectively at the regional and local levels rather than privately through insurance companies or individual households. Respondents would like to see developments of flood-prone areas restricted, or at least a requirement for raised floor levels in new houses, although some indicated that it was a personal responsibility to avoid the flood hazard in the first place by not building in high-risk areas. However, the personal-responsibility view relies on effective public understanding of flood risk and an effective flood risk communication strategy (discussed below).

### 4.2.1 Preferred levels of flood risk and planning time horizons

Most respondents were not willing to accept more than a minimal (<0.5 percent annual) probability of flooding in residential areas in any given year and preferred all houses to be protected to the same level of risk. About one third would like to see protection levels to be differentiated by suburb and 10 percent thought that flood protection should be up to each individual household. Forty percent of respondents considered a planning time horizon of 50 years sufficient, while 29 percent deemed a 100-year horizon more appropriate, and 11 percent favoured more than 100 years. No significant differences were found between flood-affected and unaffected groups regarding acceptable levels of flood risk and preferred planning time horizons in flood-risk management.

### 4.2.2 Knowledge of flood-risk exposure

More than half of the respondents had not seen a flood-hazard map for their community. More than a third had, while 9 percent were unsure. Some respondents noted that flood-hazard maps and information on the flood risk of particular properties were difficult to access and not routinely supplied by councils.

More than half of participants did not know the level of risk they were exposed to. About a quarter and a fifth of participants had 'some idea' or 'reasonable knowledge' of their risk exposure respectively. Past flooding experience contributed to increased knowledge about one's flood risk. However, whether that knowledge is meaningful to people and translates into action may be questionable, as shown by the following quote:

'1:10yr level flood according to HCC [Hutt City Council] & GWRC [Greater Wellington Regional Council] 2010. I don't know what exactly this means for my property and neither does HCC.'

This quote illustrates that providing factual information is necessary, but not sufficient in circumstances where the ultimate aim is to enhance people's ability to gauge the implications of floods of various sizes and adjust their behaviour accordingly. It also raises the issue of whether the information provided about flood risk is in a form that is meaningful to communities. There is also evidence to suggest that using annual percentage or annual return interval (i.e. 1 in 100 year) flood probability formats is fundamentally flawed for risk communication, as these formats predispose people to cognitive biases and subsequent discounting of risk (discussed below) (Tegg & Lawrence, in preparation-a).

### 4.2.3 Preferred flood risk mitigation measures

**The majority of survey respondents preferred land-use planning approaches over structural measures**

Flood-affected and unaffected respondents ranked their preferred flood-risk mitigation measures in a largely similar order. Improvements to the stormwater network were the most salient issue and both groups were unequivocal that alleviating this problem would contribute a great deal to reducing flood risks. This was followed by restrictions on new buildings and renovations in high-risk areas; various structural measures, emergency response options, and modify and shift existing buildings away from high-risk areas. The lowest ranked mitigation measure was 'inaction on flood risk and its increase due to climate change'. While flood-affected and unaffected groups showed little differences in their relative preferences for the suggested measures for mitigating flood risk, there were some significant differences in the strength of preference attached to the measures. Flood-affected respondents had higher preference levels for restricting new buildings or renovations in high-risk areas, modifying or shifting existing buildings away from high-risk areas, deepening river channels, and improving the stormwater network than respondents who had not been affected by flooding.

### 4.2.4 Preferred management responsibilities

**The majority of survey respondents preferred flood risk to be managed and paid for at collective local and regional levels.**

Both flood-affected and unaffected groups ranked the suggested institutions in the same order, assigning regional and city councils the highest responsibility, followed by central government, individual households, and community groups. The ranking is indicative of a pattern from the collective to the individual level. Only after public institutions (various levels of government) were mentioned, was the private level (individual households and community groups) considered.

The flood-affected group expressed statistically significantly higher preferences for regional and city councils to have responsibility compared with the unaffected group for both present and future flood-risk management. The flood-affected also showed stronger preferences for central government and community groups to take on greater responsibility in the future compared to present levels.

## 4.3 Flood-risk communication

**There are potentially fundamental problems with the way flood maps and average return interval floods are used in practice**

Both council respondents and surveyed residents had difficulties in understanding the magnitude of potential risks, suggesting that there are fundamental issues with current risk-communication media. Flood-risk professionals have criticised the annual exceedance probability and average return interval concepts and derivative maps for many years (Pielke, 1999; US Department of the Army, 1992). One criticism is that design floods are calculated from historical data, which could be a highly misleading practice for future planning in areas where climate change will affect flood frequencies (Milly, et al., 2008). Another criticism is that the design flood concepts are frequently misinterpreted. However, a lack of practical alternatives that account for both of these issues may be constraining the improvement of flood-risk communication.

The experience of some flood-risk professionals suggests that using cumulative probabilities over longer time periods (i.e. an equivalent 26percent chance over 30 years, the typical span of a mortgage) to communicate risks is more effective (Ericksen, 2005), but by itself implies a level of preciseness about which the public may be justifiably suspicious (Bell, 2004). Psychological research into the framing effects of different probability formats confirms that subjects tend to discount the risk of hazards when probabilities are expressed with a small relative numerator over short timeframes (such as in the case of a '1:100-year flood' or 1 percent annual flood') compared to an equivalent probability with a larger relative numerator over a longer timeframe (such as a 26 percent chance over 30 years) (Reyna, 2004; Stone, Yates, & Parker, 1994; Tegg & Lawrence, in preparation-a).

Drawing on these insights and the risk-analysis methodology of Jones (2001), the New Zealand Climate Change Research Institute has developed an alternative method for analysing and mapping flood that avoids these framing effects. This method incorporates climate change modelling and presents flood-risk information in a way that may be more meaningful to the public. Resulting flood maps depict the broad likelihood of above-floor-level inundation in the floodplain for a particular emissions scenario over long time periods. Figure 2 provides a preliminary example of this type of map. Figure 12 depicts the likelihood of flooding over 0.6 metres (a typical floor height) between 2011 and 2100.

Maps of this type may be useful for decision makers tasked with evaluating the risk-reduction benefits of different adaptation options and for communicating to the public. These issues, and more detailed discussion of the method, is presented in Tegg and Lawrence (in preparation-b (a)) and Tegg and Lawrence (in preparation-b (b)) (these reports will be available on the CCRI website).

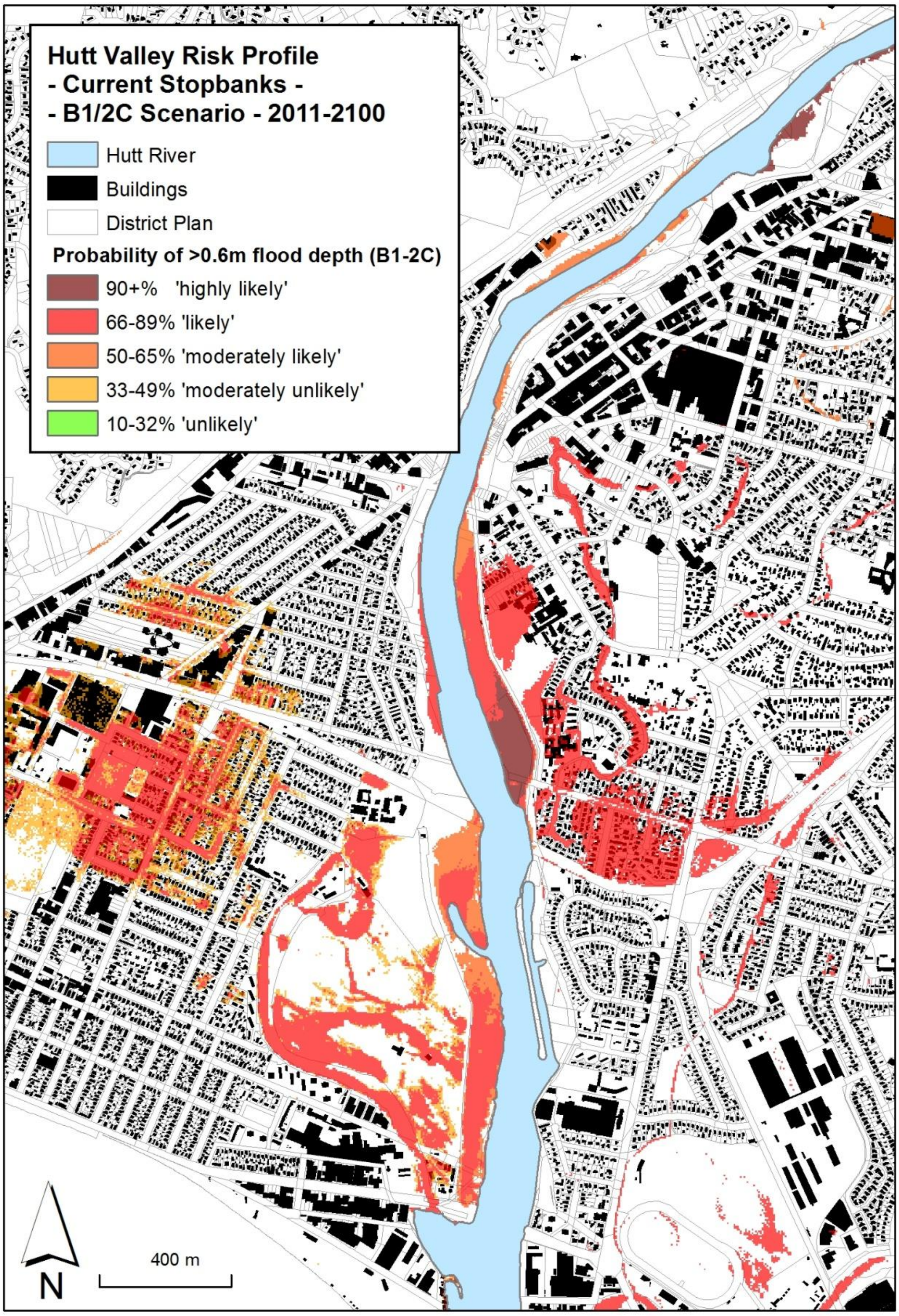


**Figure 12. Figure 2: The probability that zones in the Hutt Valley will be inundated above 0.6m, assuming current stopbank specifications and low emissions (2°C GMT stabilisation / B1 scenario). The above map is based on preliminary results and does not include flooding associated with smaller tributaries and stormwater drainage. It is illustrative only and should not be used for planning purposes (Tegg & Lawrence, in preparation-b (b)).**

# 5 Conclusion

This case study presents findings that can inform local government perceptions of:

- the largely structural protection offered by current strategies managing flood risk
- the adequacy of current structural-protection standards.

As a result of climate change, flood frequency and intensity are projected to increase over the remainder of the century in the Hutt Valley and degrade the flood-protection standards of existing and planned stopbanks. These changes highlight the need for a review of available risk-reduction measures and their implementation, and the importance of national policy guidance integrated with flood protection and planning policies and rules at the three levels of government. **Error! Reference ource not found.** summarises the study's key findings and relates them to the research questions.

The reported reassessments of flood-risk management in the Hutt Valley following major flood events suggest that there may be windows of opportunity to review current flood-risk management and develop new approaches to reduce long-term and changing risk.

A stronger connection between central and local government would provide stronger leadership and a clear strategic framework. This would enable ongoing community conversations to support a broader and more integrated approach to general hazard risks and climate change adaptation. These factors appear to be necessary conditions for changing the way that future flood risks associated with climate impacts are addressed, and hold potential for greater sharing of learning across councils to quickly spread new approaches elsewhere in the region.

The case study identified how residual risks, especially at the extremes, could affect property and people in the Hutt Valley. If planning for risk mitigation is based on 'best estimates', it is likely to significantly underestimate the potential damages in the future. The significance of this for decisions taken today has been highlighted, especially for long-lived assets and settlements.

Socio-economic factors have implications for both spatial land-use planning, emergency management, and for the egress of more vulnerable groups from flood-affected areas. Importantly, those who have experienced risks have a heightened awareness of future flood risk. Some respondents expressed ongoing frustration at delays in the implementation of the Waiwhetu stream mitigation measures, due their perceived lack of political voice.

Councils have prioritised flood-risk management across the region. The Hutt Valley community generally looks to councils to keep them safe. Survey respondents in the Hutt have a low tolerance for flooding generally and are prepared to take individual actions in the face of changing flood risk, but ultimately want councils to act responsibly and to spread the costs across the whole community in an equitable manner.

The general understanding of flood-risk levels was low in the Hutt Valley and few people had seen flood hazard maps. This raises issues of the best form of communication with communities about flood risk and how it will increase over time. Respondents wanted councils to take greater responsibility to inform communities about anticipated flood risks, with stronger guidance and direction through a central government NPS. This NPS would ensure a consistent approach across

New Zealand and would act as the backstop that councils need to support their planning action in event of legal challenge.

Several barriers related to information about flood risk were raised by respondents. There is inconsistency in information bases and in some cases simply a lack of data. Each council is attempting to address similar issues from its own resources, which are insufficient to get an adequate assessment done across the region. It was suggested that councils pool funding to get better cost efficiencies in collecting information about flood risk and that this could speed up the assessment of climate change risks, e.g. future damage assessments would be more robust with better access to LIDAR[9]. Cross-council resource pooling, with some assistance from central government on a needs basis, was seen as a way of addressing these resourcing issues.

The predominant focus on the costs of flood-management investments, rather than benefits (i.e. avoided damage) was another highlighted barrier to addressing long-term flood risk changes associated with climate change. Some of the smaller councils lacked the resources to conduct analyses and benefit-cost assessments that take account of the uncertainty of future impacts.

Council advisors also considered it crucial that councillors have confidence in the robustness of the information on which they base their decisions, and that this confidence was often lacking. In part, this may be due to the nature of climate change information. There is a lack of information on climate change effects on flood risk, a lack of knowledge and experience with alternative options, and a lack of experience with stakeholder and community-based evaluation of such options.

These barriers highlight the need for a more comprehensive approach to changes in flood risk across New Zealand associated with climate change. Suggested requirements included financial and technical support for better-quality risk assessments across regions, sharing experiences and approaches across councils to build capacity, better communication of the risks associated with climate change impacts and the options for addressing them, and further statutory support from central government through instruments at its disposal e.g. NPS and NES.

[9] Light Detection and Ranging—a highly accurate method of mapping topographic features using airborne laser scanning.

| Research questions |
|---|
| How will climate change affect the frequency and severity of flooding over the next century? |
| What are the impacts of a range of different flood events on the Hutt Valley community? |
| What socio-economic factors influence the community's ability to adapt to flood risk; and to cope with, and recover from, flooding? |
| What social and institutional barriers constrain adaptation and what opportunities are present for improving adaptive capacity? |

| Key findings and themes | | | | |
|---|---|---|---|---|
| Flooding is generally projected to become more frequent in the Hutt Valley and degrade the flood-protection standards of existing and planned stopbanks, with a large range of uncertainty. §2.2 | | | | |
| The uncertainty of climate change projections collides with councils' expressed need for 'robust' or definitive planning guidance. Using the 'best-estimate' scenario underestimates the real risk of more extreme events. §2.2; §4.1 | | | | |
| Flood impacts increase more sharply beyond 2300 cumecs as increasing flood volumes damage more properties at greater depths §0 | | | | |
| Flood impacts can have a disproportional impact on different societal groups.§3.3; §3.4 | | | | |
| Past experience of floods affects residents' behaviour and willingness for flood protection. §3.4 | | | | |
| Current planning does not account for increased frequency and intensity of future floods. §4.1 | | | | |
| When councils do not communicate the nature of the flood risk this can reinforce maladaptive responses, especially when those people with the means and experience to cope with flooding move away and are replaced by new arrivals. §3.4; §4.2 | | | | |
| Flood impacts can include difficult-to-quantify psychological aspects such as depression and ongoing anxiety. §3.4 | | | | |
| There are potentially fundamental problems with the way flood maps and average return interval floods are used in practice. §4.3 | | | | |

| | | | | |
|---|---|---|---|---|
| The majority of survey respondents preferred flood risk to be managed and paid for at collective local and regional levels, and preferred land use planning approaches over structural measures. §4.2 | | | | |
| A lack of integration and strategic oversight within and between the different levels of government can act as a barrier to adaptation. §4.1 | | | | |
| Leadership (or lack thereof) at both the central and local government levels can strongly influence the integration of climate change and long-term risk issues into council planning. §4.1 | | | | |
| Leadership on risk issues often emerges only after significantly damaging events. Future flood events will present opportunities to review current practices, learn from mistakes, and institute more adaptive and resilient practices. §4.1 | | | | |
| A number of practices can improve adaptive capacity. Pooling resources, improving access to LIDAR, using aerial photos of past floods, and the LTP process are examples of opportunities for improved assessment and communication of climate change and flood risks. §4.1 | | | | |

**Table 1. Key findings from the Hutt Valley case study**

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# 7 Appendix 1 Methodological caveats

## 7.1 Flood frequency and inundation modelling

**This modelling was undertaken to illustrate a risk-based approach to decision making under climate change—it is not intended to serve specific planning purposes**

There is no current information on the relationship between flood volume and the actual amount of water that would be spilled over various stopbanks once their design level has been exceeded. We assumed that for smaller floods only some of the excess water would spill over the stopbanks, whereas for very large floods all excess water spills over stopbanks. More detailed observations and modelling of stage-discharge relationships would be necessary to produce more robust results.

Our modelling approach is robust in determining the area that could be flooded under a given design flood event and the static depth of inundation. Our approach is limited when it comes to determining flood velocities especially for very large floods, and the resulting changes in local depths associated with currents that form along flow paths. Therefore, both the flood velocities and inundation depths—and the estimated damages—for floods in excess of 2300 cumecs should be treated with caution.

We only modelled the consequences of stopbank breaches and resulting flooding from the Hutt River. We did not attempt to model flooding of minor streams, e.g. the Waiwhetu stream; nor did we attempt to model in detail flooding of the stormwater system, or the interaction of flood waters from the Hutt River with the stormwater system. To fully understand flood risk in the Hutt Valley, all those points would need to be considered and would require research that is outside the scope of this study.

Due to limited high-resolution topographical coverage, we did not model inundation upstream of the entrance of the Stokes stream into the Hutt River, or any downstream inundation that could be due to breaches of stopbanks upstream of this point.

We considered the effects of sea-level rise only in a static fashion, that is, with rising sea level representing an increasing boundary level for the floodplain. We did not model dynamic impacts such as implications for the flow at the Hutt River mouth, or structural implications such as rising water tables.

## 7.2 RiskScape damage-cost model

We used 1-hour design floods to model impacts. In reality, flood peaks are not sustained for 1 hour but typically less, which could result in overestimates in particular of flood velocities.

Floods were assumed to occur during the daytime when car parks are in use. The cost estimates of damage to vehicles in areas with large car parks are sensitive to this assumption.

## 7.3 Socio-economic factors

Natural disaster case studies make it clear that socio-economic factors play a significant role in a community's vulnerability and recovery. However, while this role is well established it is difficult to derive and apply general principles from case studies for quantitative modelling purposes. The relative importance of a particular factor or the importance of socio-economic versus biophysical factors will vary depending on context.

## 7.4 Flood impacts survey

### 7.4.1 Comparability

There was limited comparability of survey data with census data for income. Census and survey used the same income brackets, but census asked for *personal* income while survey asked for *total household* income. As a result, survey mean, median, and mode income are all at the high end of the income bracket range. An additional number of higher-income brackets would have been needed to gather more detailed data.

### 7.4.2 Representativeness and generalisation

A larger sample (or higher response rate) of people who experienced flooding in the past would have provided a robust basis from which to draw more generalisable conclusions. Less than a third of the sample was affected by flooding. Hence, comparative analyses between flood-affected and unaffected people may be limited in their potential to fully assess the interplay between socio-economic attributes and vulnerability to flooding. Phenomena observed in the sample may be due to a sampling error, arising from the fact that only part of the population was surveyed. Additionally, self-selection may have biased the composition of the sample. For example, the age distribution of respondents may reflect a self-selection bias towards those who have relatively more time available to answer the questionnaire.

### 7.4.3 Sample size

When trying to test various subgroups for specific variables, some of the groups were too small to conduct meaningful statistical analyses. For example, there was only one person with long-term health impacts due to previous flooding and too few people who lived in single-parent families AND were affected by flooding.

### 7.4.4 Statistical techniques used

Some socio-economic data was gathered in categorical rather than continuous form (e.g. age, income). This limits the range of statistical techniques available for data analysis. For example, mean, median, and mode may be less meaningful and informative when they refer to a range of values rather than pinpointing a specific value. Some statistical techniques could not be used because the sample population did not consist of the minimum required number to perform the particular test.

### 7.4.5 Missing responses

There is a relatively large number of missing responses for some questions. This suggests that the response rate could have been increased by matching the wording of the specified response options better with the wording of the question.

### 7.4.6 Knowledge of individual respondents

Areas of expertise or general knowledge differ between individuals. For example, when asked to indicate preferences for various flood-risk mitigation measures, some respondents may have been knowledgeable about the pros and cons of these measures, whereas for others evaluating such options may have rather been guesswork.

# 8 Appendix 2 Workshop and interview questionnaire

1. Do participants view the current approach to flood risk management as adequate for the current climate?

    a. Are there any remaining key vulnerabilities under the current climate that the Hutt Valley Flood Management Plan will not address in its current form?

    b. What were the key factors that determined the balance between investment in flood-risk reduction and the benefits of this risk reduction in the current plan?

2. To what extent can the current approach to flood-risk management be up-scaled as and when information from this and further research becomes available about increases in flood risk as a consequence of climate change?

    c. Over what time frames?

    d. What are the technical, economic, social, and environmental implications and potential limits to up-scaling the current flood-risk management approach?

    e. Could such up-scaling maintain the balance between investment in flood-risk reduction and the benefits of this risk reduction as in the current plan?

3. What do you think are the thresholds that could require a fundamental change in the current approach to flood-risk management? How can they be defined?

    a. At what point in time would a fundamental change in approach have to be decided to be effective?

    b. What would the actual trigger points for such decisions likely be?

4. How do flood-risk management decisions in the near term affect the ability of communities to manage a possible increase in flood risk in future?

    a. Given the uncertainty in flood-risk projections, and the near-term cost of increasing flood protection, communities may wish to withhold additional actions to reduce flood risk until the range of uncertainties has narrowed (including decisions not to increase protection now, or not to limit further development in areas at future risk).

5. What frameworks, tools, and regulatory options are currently used by councils to manage uncertainty in flood-risk estimates for the present and future?

6. Can those frameworks deal adequately with the range of potential future changes under climate change and balance near-term and long-term benefits, costs, and risks?

7. To what extent are different parts of a community differently vulnerable to flood risk? To what extent are such differential vulnerabilities taken into account in flood risk management?

    a. Are differential vulnerabilities likely to increase or decrease in future?

    b. Are the tools and regulatory environment in which councils operate able to deal with those differences to ensure sustainable outcomes across different parts of affected communities?

8. Who would benefit most, and who would be most negatively affected, by different approaches to manage the range of potential future increases in flood risk?

9. What are the opportunities and barriers that councils have to implement long-term flood risk management that considers climate change?

    a. What part does uncertainty play?

# 9 Appendix 3 Household survey questionnaire

## QUESTIONNAIRE ON FLOOD AND STORM IMPACTS ON HOUSEHOLDS in LOWER HUTT

**This survey should take about 30 minutes to complete**
**All answers will be kept confidential**

The main purpose of this survey is to learn more about whether and how past floods have a long term impact on residents and their views about flood risk reduction.

To help with this, please tell us if you:

- ☐ 1 Lived at this address during the February 2004 floods and were affected.
- ☐ 2 Lived at this address during the February 2004 floods but were NOT affected
- ☐ 3 Did not live at this address during the February 2004 floods, but have been affected by flooding during other occasions (here or elsewhere)
- ☐ 4 Did not live at this address during the February 2004 floods, and have not been affected by flooding during other occasions (here or elsewhere)

Even if you have never been affected by a flood, here or elsewhere, we still would like you to answer all questions in this survey

If you have filled in the previous survey in 2004, it would be helpful (but not absolutely necessary) if the same person could also complete this survey.

### SECTION A: Overall impacts

This section asks about flood events that have occurred in Lower Hutt from February 2004 onwards, and the impacts those events have (or haven't) had on you.

**1. Has anyone in your household suffered an on-going injury or illness due to past flood events?**

- ☐ 1 No
- ☐ 2 Yes - If yes, please describe in detail, including which flood:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**2. Are any parts of your property still affected by impacts from past floods? (Tick all where structural damage remains, or a permanent loss of function occurred)**

- ☐ 1 No recent flood affected this property directly
- ☐ 2 Recent floods affected this property but there are no on-going damages
- ☐ 3 Section (land)
- ☐ 4 Out-buildings
- ☐ 5 Garage
- ☐ 6 House
- ☐ 7 Other – please give details:

______________________________________________________________________

______________________________________________________________________

**3. Please list any individual possessions that suffered permanent damage or loss, and give the reasons for this (e.g. because insurance did not pay for it and you were unable to afford a replacement, or because they were items of special value (such as photographs, documents etc)**

1 Item: ______________________________________________

Reason for permanent damage: ________________________________

2 Item: ______________________________________________

Reason for permanent damage: ________________________________

3 Item: ______________________________________________

Reason for permanent damage: ________________________________

4 Item: ______________________________________________

Reason for permanent damage: ________________________________

(add more items on separate sheet of paper if necessary)

**4. Which was the biggest past flood event that you are aware of that directly affected your property? (Please give details.)**

- ☐ 1 Approximate date: ________________________
- ☐ 2 I do not know of any events that have affected my property

SECTION B: Insurance and costs

**5. With regard to insurance, which of the following statements are correct in your case? Please answer this question regardless of whether you may have answered this already in previous surveys.**

| | Does not apply | Yes | No |
|---|---|---|---|
| My insurance didn't cover the losses I expected it to | ☐1 | ☐2 | ☐3 |
| EQC[1] has settled my claim in a fair way | ☐1 | ☐2 | ☐3 |
| My insurance company has settled my claim in a fair way | ☐1 | ☐2 | ☐3 |
| My insurance premium has gone up since the event because of increased flood risk | ☐1 | ☐2 | ☐3 |
| My insurance excess has gone up since the event because of increased flood risk | ☐1 | ☐2 | ☐3 |
| I have found it difficult to get insurance cover since the event | ☐1 | ☐2 | ☐3 |
| I can't afford insurance cover now | ☐1 | ☐2 | ☐3 |

[1] EQC: Earthquake Commission

**6. Is your household financially worse off <u>today</u> than it would have been without the February 2004 or other past floods? Please consider only the consequences of and council or community responses to past <u>flood events</u>, not other changes such as the global economic recession.**

☐ 1 No

☐ 2 Yes - If yes, please give details:

________________________________________________________________

________________________________________________________________

________________________________________________________________

SECTION C: Community effects of flood events and flood risk management measures

**7. Have past flood events had any on-going positive or negative effects on your community (e.g. social networks, parks and reserves, amenities)?**

☐ 1 No effects I can think of

☐ 2 Don't know

☐ 3 Positive – please give details

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

☐ 4 Negative – please give details

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**8. Have flood risk management measures (such as works to strengthen stopbanks) had any on-going positive or negative effects on your community (e.g. social networks, parks and reserves, amenities)?**

☐ 1 No effects I can think of

☐ 2 Don't know

☐ 3 Positive – please give details

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

☐ 4 Negative – please give details

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

SECTION D: Knowledge about flood risk and concrete actions to reduce flood risk

**9. Do you know what level of flood risk your property is exposed to? (Tick only one)**

☐ 1 Yes

☐ 2 Only a little

☐ 3 No

If "yes" or "only a little", please tell us the level of risk (as far as you know) where you obtained the information from:

________________________________________________________________

________________________________________________________________

**10. Have you seen any flood hazard maps for your community? (Tick only one)**

☐ 1 Yes

☐ 2 Not sure

☐ 3 No

**11. If you have seen flood hazard maps, how useful do you think they are to inform residents about their flood risk? (Tick only one)**

☐ 1 Very useful

☐ 2 Somewhat useful

☐ 3 Not useful

Details: __________________________________________________________

________________________________________________________________

**12. Since the February 2004 flood, have you: (Tick one in each line)**

| | No | A little | A lot |
|---|---|---|---|
| Sought information on flood risk to your community | ☐ 1 | ☐ 2 | ☐ 3 |
| Sought information on what to do to prepare for a possible flood | ☐ 1 | ☐ 2 | ☐ 3 |
| Become involved with a local community group related to flooding | ☐ 1 | ☐ 2 | ☐ 3 |
| Communicated with the council about how to reduce flood risk in your area | ☐ 1 | ☐ 2 | ☐ 3 |
| Participated in meetings related to flooding and flood risk management measures | ☐ 1 | ☐ 2 | ☐ 3 |

**13. Since the February 2004 flood, has your household undertaken any of these measures, and if so how much has been spent? (Fill in all that apply in each line)**

| | | If yes, approximately how much has been spent? |
|---|---|---|
| Increased your level of insurance | Yes / No | $ ________ on additional insurance per year |
| Raised the floor level of your house | Yes / No | $ |
| Kept ditches and drains around the property clean | Yes / No | $ |
| Protected your septic tank | Yes / No / Does not apply | $ |
| Avoided keeping irreplaceable items or goods of sentimental value on the ground floor of your home? | Yes / No / My house has only one floor | comments |
| Talked to a council about flood risk management measures | Yes / No | about ______ hours |
| Made a plan about what you will do if a flood is threatening (e.g. lift items off ground, evacuation, check drains) | Yes / No | comments |
| Collected emergency survival items or compiled a preparedness kit | Yes / No | comments |

**14. Please list any other actions you have undertaken as a result of previous floods:**

___

___

___

___

SECTION E: Roles and responsibilities to manage flood risk

**15. What chance of flooding above floor level do you find acceptable for an average residential property in any given year? (Tick only one)**

☐ 1 In any given year, there should be a less than a 0.5percent chance of flooding

☐ 2 In any given year, there should be a less than 1percent chance of flooding

☐ 3 In any given year, there should be a less than 2percent chance of flooding

☐ 4 In any given year, there should be a less than 5percent chance of flooding

☐ 5 Don't know

Other: 5 ___________________________________________________________

**16. Over the course of the next 50 years, how often do you feel it would be acceptable for the average residential property to be flooded above floor level? (Tick only one)**

☐ 1 Never

☐ 2 Once

☐ 3 Twice

☐ 4 Three times

☐ 5 Don't know

Other: 6 ___________________________________________________________

**17. Do you feel that all houses should be protected to the same level of risk? (Tick all that you support)**

☐ 1 Yes

☐ 2 No, it should be up to each individual household

☐ 3 No, the most valuable properties should be protected more

☐ 4 No, those with low incomes should be protected more

☐ 5 No, those with high incomes should be protected more

☐ 6 No, some suburbs should be protected more than others

Additional comments:

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

**18. Do you feel that current flood risk should be reduced by: (Tick one in each line)**

| | Least | ← (Scale) | → | | Most |
|---|---|---|---|---|---|
| Raising stopbanks | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Deepening river channels | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Improving the stormwater network | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Shifting houses away from high-risk areas | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Increasing buffers like natural areas and ponds | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Give earlier warnings and improve evacuation plans for floods | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Modify buildings (e.g. raise floor levels and utility services) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Restrict new buildings or renovations in areas with high flood risk | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Nothing needs to be done - I'm happy with the flood risk level in my community | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

Other:

______________________________________________________________________

______________________________________________________________________

**19. Please indicate on the scale whose responsibility you believe it is to manage the risk from floods. (Tick one in each line)**

| | Not at all | ← | (Scale) → | A great deal | |
|---|---|---|---|---|---|
| Central Government | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Regional Council | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Hutt City Council | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Community groups | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Individual households | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Nobody; if a flood wants to come then it will come | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

**20. How big are the following barriers to flood risk management measures: (Tick one in each line)**

| | No barrier | ← (Scale) → | | | Major barrier |
|---|---|---|---|---|---|
| Cost are too high | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Skills are required to prepare | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Information is required to prepare | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Other priorities to think about instead | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Need for co-operation with others | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Floods don't happen often enough to make preparation a high priority | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| I don't trust information about flood risk | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| I agree flood risk is a problem but the way it's dealt with is wrong | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

**Suggestions for reducing barriers to managing flood risk:**

______________________________________________________________

______________________________________________________________

**21. Who do you feel should pay for measures to reduce flood risk? (Tick one in each line)**

| | pay least | ← (Scale) → | | | pay most |
|---|---|---|---|---|---|
| People who own affected properties (property owners) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| People living in affected properties (tenants) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Costs should be apportioned based on the value of the property affected | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Costs should be apportioned based on the income of those owning the property | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Costs should be apportioned based on the income of those living in the property | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| The local community as a whole | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| The district as a whole | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| The region as a whole | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| The country as a whole | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Insurance companies | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

**22. How prepared do you believe the following groups are for future floods affecting your community? (Tick one in each line)**

| | Very prepared | Somewhat prepared | Not very prepared | Not at all prepared | Don't know |
|---|---|---|---|---|---|
| Your household | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Your community | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Central government Ministries (such as Ministries of Civil Defence and Emergency Management, the Environment, Health, or Social Development) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Regional Council, including regional Civil Defence | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Hutt City Council, including district Civil Defence | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Service providers (such as roads, electricity, telephone companies, water suppliers, garbage collectors, energy supplies, sewage treatment companies) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Earthquake Commission (EQC) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Commercial insurance companies | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

SECTION F: Dealing with future changes in flood risk

Climate change is generally expected to increase the occurrence of heavy rainfall, which could result in more frequent river floods and flood damages unless additional measures are taken to reduce the impacts of floods. Sea level rise will further increase flood risk in low-lying areas. Please answer the next 3 questions with this likely future increase in flood risk in mind.

**23. By which measures do you think any <u>increase in future flood risk</u> should be dealt with? (Tick one in each line)**

| | **Least** | ← | *(Scale)* | → | **Most** |
|---|---|---|---|---|---|
| Raising stopbanks | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Deepening river channels | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Improving the stormwater network | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Shifting houses away from high-risk areas | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Increasing buffers like natural areas and ponds | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Give earlier warnings and improve evacuation plans for floods | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Modify buildings (e.g. raise floor levels and utility services) | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Restrict new buildings or renovations in areas with high flood risk | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Nothing needs to be done; I don't believe that flood risk will increase sufficiently to present any cause for concern | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

**24. How far into the future should one look when planning for future changes in flood risk in residential areas?**

- ☐ 1 10 years
- ☐ 2 50 years
- ☐ 3 100 years
- ☐ 4 more than 100 years
- ☐ 5 Unsure

**25. Please indicate on the scale whose responsibility you believe it is to reduce any <u>increase in future flood risk</u>. (Tick one in each line)**

| | **Not at all** | ← | *(Scale)* | → | **A great deal** |
|---|---|---|---|---|---|
| Central Government | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Regional Council | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Hutt City Council | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Community groups | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Individual households | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |
| Nobody; I don't believe that flood risk will increase | ☐1 | ☐2 | ☐3 | ☐4 | ☐5 |

SECTION G: Community participation, trust and leadership

**26. Thinking about how you normally deal with any problem in your *life*, please describe the extent to which you agree or disagree with each of the following statements: (Tick one in each line)**

| | **Strongly agree** | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** |
|---|---|---|---|---|---|
| I try to come up with a strategy about what to do | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I make a plan of action | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I think hard about what steps to take | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I think about how I might best handle the problem | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |

**27. Please describe the extent to which you agree or disagree with each of the following statements: (Tick one in each line)**

| | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Floods are too destructive to bother preparing for | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| A serious flood is unlikely to occur during my lifetime | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| Preparing for floods is inconvenient | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| It is difficult to prepare for floods | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |

**28. Please describe the extent to which you agree or disagree with each of the following statements: (Tick one in each line)**

| | **Strongly agree** | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** |
|---|---|---|---|---|---|
| Preparing for floods will significantly reduce damage to my home should a floods occur | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| Preparing for floods will improve my everyday living conditions | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| Preparing for floods will improve the value of my house/property | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| Preparing for floods will improve my ability to deal with disruptions to family/community life following a flood | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |

**29. Thinking about how you participate in life in your community, please describe how often you undertake each of the following: (Tick one in each line)**

| | Often | Sometimes | Rarely | Never |
|---|---|---|---|---|
| I have worked with others on something to improve community life | ☐4 | ☐3 | ☐2 | ☐1 |
| I participate in local activities or events (e.g., festivals, fetes, fairs) | ☐4 | ☐3 | ☐2 | ☐1 |
| I have contributed money, food or clothing to local causes, charities, or to others in my community | ☐4 | ☐3 | ☐2 | ☐1 |
| I have attended a public meeting on a community issue | ☐4 | ☐3 | ☐2 | ☐1 |
| I have been involved in volunteer activities intended to benefit my community (e.g., fundraising, clean-up days, local groups, Scouts/Brownies). | ☐4 | ☐3 | ☐2 | ☐1 |

**30. Given your general feelings about living in your wider *community*, please describe the extent to which you agree or disagree with each statement. (Tick one in each line)**

| | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| I trust my Local Council to respond to meet the needs of its residents | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I trust the community leaders in my community | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I trust scientists and engineers to give me a fair idea of the actual risk of flooding | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I trust the media (newspapers, TV, radio) to report fairly | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I trust my Local Council to do what is right for the people they represent. | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |
| I have confidence in the law to protect and maintain order in my community | ☐5 | ☐4 | ☐3 | ☐2 | ☐1 |

SECTION H: Demographic and household information

Note: The information you provide us will be kept confidential. We will only look at correlations between demographic information and people's views on flood risk issues. Information about individual households will not be released to anybody outside this research project.

**31. What is your gender? (Tick only one)**

☐1 Male ☐2 Female

**32. Into which age bracket do you fall? (Tick only one)**

| | | |
|---|---|---|
| ☐1 18-19 yrs | ☐2 20-24 yrs | ☐3 25-29 yrs |
| ☐4 30-34 yrs | ☐5 35-39 yrs | ☐6 40-44 yrs |
| ☐7 45-49 yrs | ☐8 50-54 yrs | ☐9 55-59 yrs |
| ☐10 60-64 yrs | ☐11 65-69 yrs | ☐12 70-74 yrs |
| ☐13 75-79 yrs | ☐14 80-84 yrs | ☐15 85 years + |

**33. Which ethnic group do you belong to? (Tick the box or boxes that apply to you)**

| | |
|---|---|
| ☐1 New Zealand European | ☐2 Māori |
| ☐3 Samoan | ☐4 Cook Island Maori |
| ☐5 Tongan | ☐6 Niuean |
| ☐7 Chinese | ☐8 Indian |

☐9 Other (e.g., Dutch, Japanese) (Please specify):

## 34. What is your main occupation? (Tick only one)

☐1 Employed: What is your job?

☐2 Unemployed

☐3 Retired

☐4 House person

☐5 Student: What are you studying?

☐6 Other (Please specify):

## 35. What is your highest educational qualification? (Tick only one)

☐1 No school qualifications

☐2 Secondary school qualifications

☐3 Trade certificate or professional certificate or diploma

☐4 University undergraduate degree (e.g., diploma or bachelor's degree)

☐5 University postgraduate degree (e.g., Master's, Ph.D.)

☐6 Other **(Please specify):** ____________________________________________

**36. How long have you lived in your current house? __________ year/s**

**37. Which of the following best describes your household now? (Tick only one)**

☐1 A couple without children

☐2 One person household

☐3 Two parent family with one dependent child or more

☐4 One parent family with one dependent child or more

☐5 Non family household (e.g. flatting)

☐6 Other. Please state:

How many people currently live in your household in total? ______________________

How many bedrooms does your household have? _____________________________

**38. How well does your household speak English? (Tick only one)**

☐1 English is the native language of the entire household

☐2 English is the native language of some members of the household

☐3 English is a second language but fluent for all household members

☐4 English is a second language and fluent for some household members

☐5 English is a second language that we are still learning to speak

**39. Do you, or someone in your house, own or rent the home you live in? (Tick only one)**

☐1 Own or buying, to live in it

☐2 Own or buying, but only for use as a holiday home

☐3 Rent, to live in it

☐4 Rent as a holiday home

☐5 Other (Please specify):

**40. What was your household's total income (before tax) for the 2007 financial year (April 1 2007-March 2008)? (Tick only one)**

| | |
|---|---|
| ☐1 Loss | ☐2 Zero Income |
| ☐3 $1 – $5,000 | ☐4 $5,001 – $10,000 |
| ☐5 $10,001 – $15,000 | ☐6 $15,001 – $20,000 |
| ☐7 $20,001 – $25,000 | ☐8 $25,001 – $30,000 |
| ☐9 $30,001 – $35,000 | ☐10 $35,001 – $40,000 |
| ☐11 $40,001 – $50,000 | ☐12 $50,001 – $70,000 |

☐13 $70,001 – $100, 000 ☐14 $100,001 or more

**41. Does anybody in your household live on a sickness benefit or have a special medical need? (Tick only one)**

☐1 No

☐2 Yes

**42. Does your household have internet access? (Tick only one)**

☐1 No

☐2 Yes

**43. Does your household have access to a telephone? (Tick only one)**

☐1 No

☐2 Yes

**44. Does your household regularly read newspapers? (Tick only one)**

☐1 No

☐2 Yes

**45. Does your household regularly listen to the radio? (Tick only one)**

☐1 No

☐2 Yes

**46. Does your household have a car? (Tick only one)**

☐1 No

☐2 Yes, one

☐3 Yes, more than one