New Zealand Climate Change Research Institute
Te Pūtahi Hurihanga Taiao

Perspectives on flood-risk management and climate change—implications for local government decision making

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Contents

List of figures and tables

List of acronyms

AR4	Fourth Assessment Report
GWRC	Greater Wellington Regional Council
HCC	Hutt City Council
HRFPMP	Hutt River Flood Plain Management Plan
IPCC	Intergovernmental Panel on Climate Change
LIDAR	Light Detection and Ranging
LTP	Long-Term Plan under the Local Government Act 2002
NPS	National Policy Statement under the Resource Management Act 1991

Executive summary

Research purpose

This paper explores the barriers and constraints to adaptation in a context where there is pre-existing settlement and infrastructure, geographical constraints, and existing investment in a major flood-control scheme. The paper then addresses possible ways the barriers and constraints could be overcome.

The primary research from which this report draws sought to identify the vulnerability of an urban community (Hutt City, below Taita Gorge in the Hutt Valley) to the effects of a possible increase in heavy rainfall arising from climate change, the associated increase in flood risk, and how councils and their communities can respond to those increasing risks and reduce their vulnerability.

Research questions

1. What are the barriers and constraints to adaptation, in particular potential types of maladaptation, using the framework suggested by Barnett and O'Neill (2010) and O'Neill and Barnett (2010), and the adaptation restrictions and barriers identified by de Bruin and Dellink (2011)? (Section 3)
2. How might local government decision makers overcome the barriers and constraints to adaptation identified in the household survey[1], which are relevant for managing future flood risk: institutional barriers; risk communication; and the role of institutions, individuals, and communities in preparing for floods? (Section 4)

Research methods

This research draws on literature and on three sources of empirical data:

- A survey of households that had experienced and not experienced flooding, relating to past flood experience and management of current and future flood risk exacerbated by climate change.
- A workshop with local government practitioners to understand how a possible increase in heavy rainfall and associated increase in flood risk could affect different parts of a community and how councils and communities can respond to increasing flood risks and reduce vulnerability.
- Follow-up in-depth interviews to the workshop with a sample of local government practitioners in the Wellington region.

[1] See NZCCRI-2011-06

Research findings

There is potential for maladaptation

The analysis identified a potential for maladaptation should flood-risk management and planning disregard:

- the differing vulnerabilities across the Hutt Valley population
- the incentives and motivations for individuals to prepare their households for future floods
- the potential for present decisions to limit future choices.

In addition, the implementation of available adaptation options may be constrained by limits on available funding, or the fraction of damages avoided by adaptation could be suboptimal if there is an imbalance in the extent to which damage potential and upfront costs are considered. The optimal timing for undertaking adaptation measures may face barriers related to the long lead times required for planning for some measures, as well as from inertia in the decision-making system, locking in existing community assets through inflexible adaptation options with higher future costs.

Residents and local government practitioners preferred local government to be responsible for managing flood risk

Both residents and local government practitioners considered regional and district councils to have the main responsibility for flood-risk management. Residents preferred local government to meet its obligations primarily by improving the stormwater network and by placing land-use planning restrictions on new buildings, renovations, or infill developments in high-risk areas and areas with high long-term residual risk. Residents indicated that measures should include raising floor levels, providing financial assistance for flood-risk management, and better emergency and general flood-risk information, and that inaction on these issues was unacceptable.

Overcoming barriers to adaptation requires open debate, leadership, and adaptive management

Workshop participants identified that overcoming constraints and barriers to adaptive management would require:

- simple and clear information that enabled discussion of a range of adaptation options within a long-term strategic framework
- the leadership of forward-thinking individuals.

Experience in the Wellington region suggests that extreme climate events may push open policy windows of opportunity and enable change to happen.

Central government statutory direction is important

Local government practitioners identified the need for central government statutory direction through a National Policy Statement(NPS) and guidance on a consistent approach across New Zealand as to how councils can address climate change risks and their effects at the local level. This is important for cost effectiveness by reducing challenges in the courts or their failure when they are challenged.

Using a wide range of measures to manage flood risk provides flexibility to deal with uncertainty and changing risks

Using the full range of measures to manage flood risk, including non-structural and planning measures such as land-use planning, is suggested as providing the flexibility required to deal with uncertainty about specific local effects of climate change, as well as with changing risks in the future. Close collaboration between district and regional levels of government is critical for integrated flood and stormwater management. Respondents identified the potential for learning across territories, sharing experiences, and economies of scale in investment in service provision.

Respondents saw that tailoring risk communication to the audience and updating this as new information came to hand was necessary:

- to enable communities to fully understand the residual risks associated with the current predominantly structural approach to managing flood risk
- to enable residents to appreciate the importance of preparing their households for future floods.

A risk-based approach that considered the impact of climate extremes would enable councils to reduce underestimates of risk and locked-in investment patterns and increase flexibility in risk-management approaches. Such an approach would have to include elements of adaptive management, using:

- triggers and indicators (like an event of a certain size or frequency)
- progressively restrictive hazard lines complemented with funding for retreat of existing buildings inland or to higher ground
- planning measures that identify raised floor levels, removable buildings, places to relocate to, and a source of funding for vulnerable communities.

1 Introduction

1.1 Background

Global climate change is unequivocally happening with inevitable impacts, such as sea-level rise, requiring adaptation by societies around the world (Intergovernmental Panel on Climate Change 2007a). However, climate change impacts are locally specific, warranting the attention of not only global but national and local decision makers. Crafting comprehensive adaptation responses that integrate the particular local environmental and socio-economic conditions in a forward-looking and strategic way, is a challenge facing local government decision makers in New Zealand.

Projected climate change impacts in the west of New Zealand's lower North Island over the coming decades are increases in mean annual rainfall (as an average change in precipitation over 12 climate models) as well as in the frequency and severity of extreme rainfall events (Intergovernmental Panel on Climate Change 2007b; Ministry for the Environment 2008). These climatic changes are expected to exacerbate the existing flood risk for residents of low-lying areas along rivers and streams, such as communities in the Hutt Valley. Flood-risk management in New Zealand is devolved to local government, which creates particular challenges in the context of climate change. Dealing with increasing risk requires greater local technical and financial resources and challenges the often short-term local planning time horizons.

1.2 Research purpose

This report explores the barriers and constraints to adaptation in a context where there is pre-existing settlement and infrastructure, geographical constraints, and existing investment in a major flood-control scheme. The report then addresses possible ways the barriers and constraints could be overcome.

The primary research from which this report draws sought to identify the vulnerability of an urban community (Hutt City, below Taita Gorge) to the effects of a possible increase in heavy rainfall arising from climate change, the associated increase in flood risk, and how councils and their communities can respond to those increasing risks and reduce their vulnerability.

1.3 Research questions

1. What are the barriers and constraints to adaptation, in particular potential types of maladaptation, using the framework suggested by Barnett and O'Neill (2010) and O'Neill and Barnett (2010), and the adaptation restrictions and barriers identified by de Bruin and Dellink (2011)? (Section 3)
2. How might local government decision makers overcome the barriers and constraints to adaptation identified in the household survey[2], which are relevant for managing future flood risk: institutional barriers; risk communication; and the role of institutions, individuals, and communities in preparing for floods? (Section 4)

[2] See NZCCRI-2011-06

1.4 Research contexts

The Hutt Valley case study adds to the growing number of place-based adaptation research studies in developed countries and in New Zealand.

1.4.1 Geographical context

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 (B. M. 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 1: The Hutt River, Wellington Harbour and beyond, from Manor Park, Lower Hutt (Wellington Regional Council, 2001, p. 2)

1.4.2 Flooding context

The design standard used determines the level of flood protection

The existing design[3] standards of protection and future changes in flood frequencies associated with climate change will influence flood-risk assessment and decisions on adaptation options. In the Hutt Valley, a 440-year[4] / 2300 cumecs[5] design standard was chosen in the 2001 Hutt River Flood Plain Management Plan (HRFPMP) as the basis for flood protection works for most of the Lower Hutt Valley. This flood volume is indicated in Figure 2 along with the current 100-year flood (approximately 2000 cumecs) estimate based on river flow data from 1972 to 2008 (Lawrence et al. 2011).

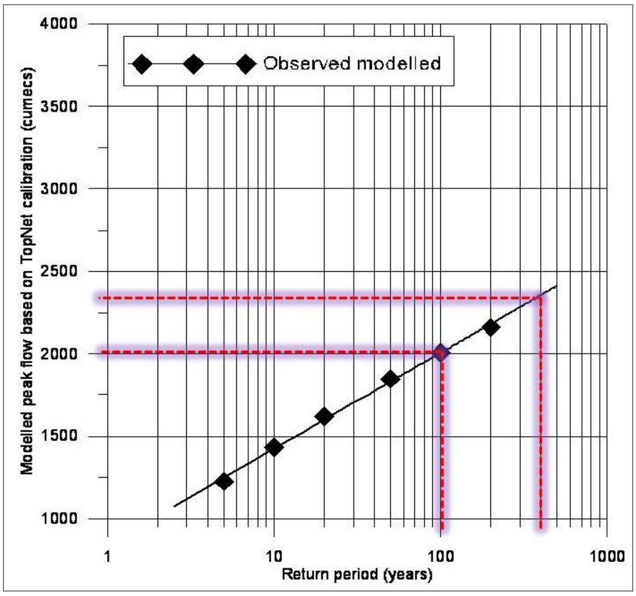

Figure 2: Current 100-year and 440-year floods based on river flow data from 1972 to 2008; Hutt River measured at Taita Gorge (Lawrence et al., 2010)

Future changes in flood frequencies for two different emissions scenarios are shown in Figure 3. Based on projected increases in the frequency of high-volume floods, the 440-year design standard will degrade to a 100-year design standard by the end of the century, assuming a low-emissions trajectory that limits global average warming to 2°C above pre-industrial levels by 2100. For this

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[3] Design floods are observed or synthetic floods used for planning and floodplain management. A design flood is the flood that most structural measures are constructed to withstand. The design flood for the Hutt River is 2300 cumecs (Wellington Regional Council 2001).

[4] 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.

[5] A flow rate of cubic metres per second.

rather optimistic scenario, the potential changes could range from negligible to a five-fold increase in flood frequencies. This means that what is currently a 100-year flood would become a 40-year flood by the end of the twenty-first century as best estimate.

For the high-emissions scenario, the minimum change in flood frequency based on current models would be roughly a doubling (what is currently a 100-year flood would become a 50-year flood by 2100) and in the worst case a 20-fold increase (the 100-year flood becoming a 5-year flood by 2100).

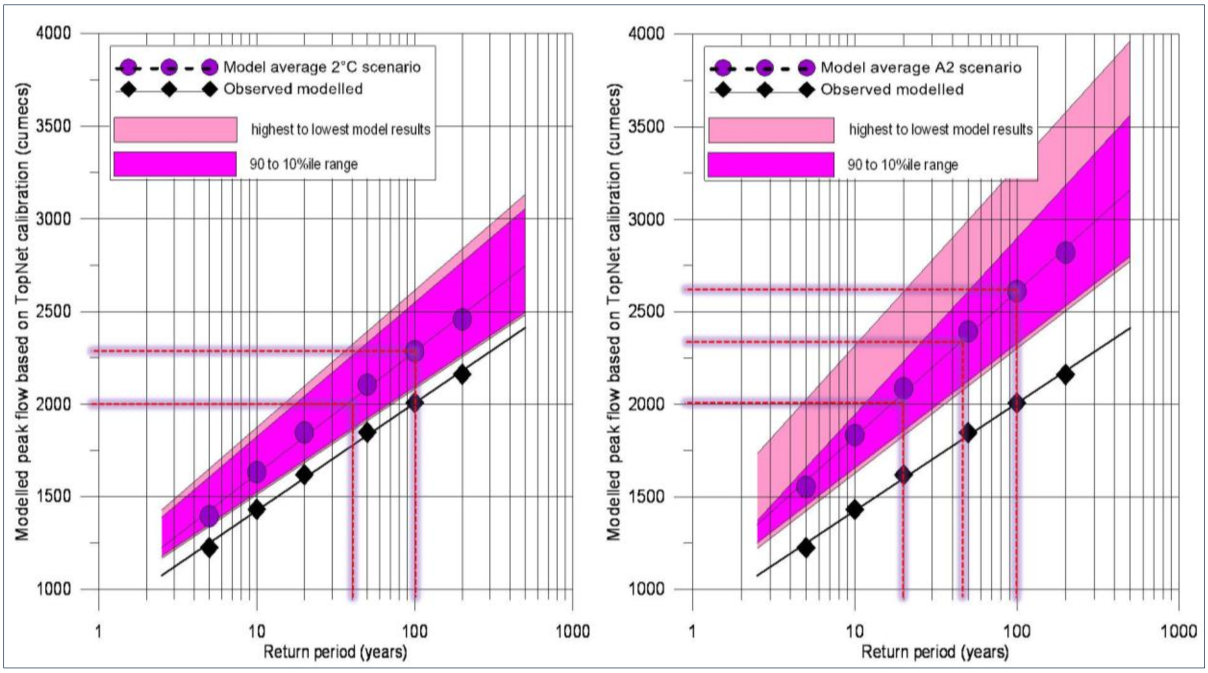

Figure 3: Changes in flood frequencies under different emissions scenarios. The black dots and line show present-day flood volumes and their estimated return intervals. The purple dots show best estimate future flood volumes and return intervals under two different emissions scenarios (left: rapid global emissions reductions; right: continued global emissions increases). The purple band shows the 10–90 percent range across different climate models, and the light pink band shows the lowest and highest results across all models.

All emissions scenarios and climate models show an increase in the frequency of Hutt River floods but the range of possible changes is wide

Looking at the range of flood flows for the 100-year flood under current and future conditions for two different emissions scenarios and for the full range of 12 climate models shows an increase in flood frequencies under all climate models and emissions scenarios, but the range of possible changes is wide. Relying on a single 'best-estimate' figure will be highly misleading as it covers up the large range of uncertainty in both the emissions scenarios and range of climate models. This could have significant implications, especially for the effect of extremes on long-lived assets and settlements over time. As frequency and severity of extreme events increases so does the resulting damage. However, the relationship is unlikely to be linear.

A risk-based approach means giving greater weight to upper-range climate predictions

A risk-based approach is characterised by giving a relatively greater weight to upper-range climate scenarios as their resulting damage is potentially much higher than that of average or 'best-estimate' climate change scenarios. Accordingly, a risk-based approach in local government planning would take into account high-impact, low-probability, and possibly surprise events and climate scenarios. These events and scenarios are commonly left out of planning decision making, largely because a single number is often perceived as more robust by decision makers (Reisinger 2009; Reisinger et al. 2010).Present flood-risk management in the Hutt Valley applies varying protection levels to different areas, based on the probability of them being flooded and the value of the physical assets at risk[6]. The 440-year design standard (flood volume of 2300 cumecs) would equate to only a 100-year design standard by the end of the twenty-first century even if global efforts to reduce greenhouse gas emissions are highly successful, and to an even lower design standard if global efforts remain more lacklustre. This raises questions about what information determined the flood design level, and to what degree differential vulnerabilities[7] were taken into account.

1.4.3 Institutional context

In New Zealand, flood-risk management is devolved to local government, which comprises a two-tier structure of regional councils and the territorial authorities (city and district councils) within their borders. Some councils are unitary—they have both regional and district council functions. The Hutt Valley is located within the greater Wellington region, which comprises four city councils and four district councils. This study focuses on the Hutt City Council (HCC) area.

Several statutes set out the roles and responsibilities for flood-risk management in New Zealand: 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, 2008c). These statutes have evolved over time in response to different drivers partly creating a set of parallel considerations, not always well-aligned in practice (J Lawrence & Allan, 2009).

Local government can manage flood risk using instruments like long-term plans and land-use rules

Local government has a range of instruments within these statutes that can be used for flood-risk management. For example, Long-Term Plans (LTP)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. Regional and district plans can instigate rules for land-use activities in areas subject to hazards and make information that identifies hazard exposure and sensitivity available to property owners. The extent to which these instruments are used across New Zealand varies from council to council. In the context of existing settlements like the Hutt Valley, not all are routinely used.

The HVFPMP, issued by the Greater Wellington Regional Council (GWRC) in 2001, 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).

[6] Risk is commonly defined as ‘probability x consequence’ (Schneider et al., 2007). While the HRFPMP uses a risk-management framework, in reality this appears to be limited to one option—that of structural protection.

[7] Vulnerability differs between social groups based on their access to various forms of capital (social, biophysical, economic, etc.), resulting in different capacities to respond to extreme events and gradual climate change (Morrow, 1999; Turner et al. 2003; Yohe & Tol, 2002).

The flood-risk response to date has addressed historically recurrent flooding (Wellington Regional Council, 1991), in the form of structural measures, such as building stopbanks, straightening the river channel, and excavating substantial quantities of gravel to improve the river's flood capacity. In combination, these measures have led to progressively building a flood-defence system intended to keep flood waters away from people, rather than keeping people away from flood waters.

Central government can provide technical guidance, set national standards, and create national policy statements

Central government provides technical guidance documents on flood risk and has the statutory ability to promulgate national policy statements and set standards, 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.

Section 2 outlines the methods used for the empirical data gathering and data analysis that this paper draws on. Section 3 discusses the empirical findings in the light of analytical frameworks suggested in the literature. Section 4 concludes this paper by highlighting the key implications for local authority decision making.

2 Methods

This paper draws on literature and on three sources of empirical data:

- A survey of households that had experienced and not experienced flooding, relating to past flood experience and management of current and future flood risk exacerbated by climate change.
- A workshop with local government practitioners.
- Follow-up in-depth interviews to the workshop with a sample of local government practitioners in the Wellington region.

2.1 Household survey

A household survey was undertaken to determine:

- whether residents were still negatively affected from past flood events, and if so, whether they showed statistically significant socio-economic characteristics
- whether respondents' past flooding experience and socio-economic attributes affected their preferences for, and perceptions of, flood-risk management measures and the current and future roles and responsibilities for floods affected by climate change.

Residents' views were elicited by way of a postal questionnaire of 996 households that yielded a 19.8 percent return rate (190 households). The sample included 55 flood-affected households (28.9 percent), nine of which (4.7 percent of total sample) had previously had floodwaters inside their houses. The results are broadly indicative only,since several factors influenced data integrity, including sample size / response rate issues, only one third of respondents had experienced flooding, and some survey design issues. Statistical analysis was performed using SPSS and Excel. Qualitative survey data was grouped and summarised using thematic coding as developed by Flick (2009).

2.2 Local government workshop and interviews

A full-day workshop was held with 18 participants from local government (GWRC and HCC) across the range of professional disciplines and council functions, including strategy, planning, flood-engineering design, stormwater design, hazard management, and civil defence; and at different levels within councils, including managers and advisers. Several technical experts participated from their individual practitioner perspectives, from research institutes, the university, and an engineering consultancy. The purpose of the workshop was to understand how a possible increase in heavy rainfall and associated increase in flood risk could affect different parts of a community and how councils and communities can respond to increasing flood risks and reduce vulnerability.

Before the workshop, participants received information on the flood-risk modelling methodology used and its preliminary results, as well as initial findings from the analysis of the household survey. The workshop began with a presentation of the frameworks used for understanding vulnerability and a risk-based approach to uncertainty.

The five topics discussed were:

1. The adequacy of the current approach to flood-risk management for the current climate
2. Its capacity to be up-scaled to deal with increased flood risk as a consequence of climate change
3. The thresholds that could trigger a fundamental change in the current approach, and how they could be defined
4. The impact of near-term decisions on long-term management of changing flood risk in the future
5. Identifying barriers and opportunities for adaptation in a way that accounts for dynamic change in climate over time

Three note-takers recorded workshop discussions and cross-checked and condensed the notes before sending them to participants for comments on accuracy and clarification. The workshop was followed up by 10 individual face-to-face interviews to explore the questions in more detail.

3 Framework for vulnerability and adaptation to climate change impacts in the Hutt Valley

3.1 Research framework

3.1.1 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, Kasperson, et al., 2003) and as used in the IPCC's Fourth Assessment Report (AR4) 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, 2007b, p. 883). Vulnerability and its components are shown in Figure 4. By showing the 'ingredients' of vulnerability, this model represents a static snapshot in time. It does not show interactions between components, nor the steps that can increase or reduce vulnerability over time.

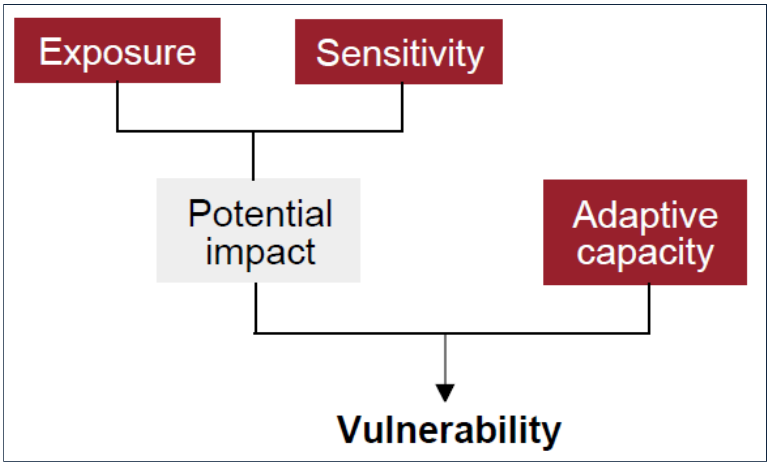

Figure 4: Vulnerability and its components (Allen Consulting Group, 2005, p. ix)

3.1.2 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, 2007b; Preston & Stafford-Smith, 2009).

3.1.3 Sensitivity

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure (Intergovernmental Panel on Climate Change, 2007b). 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).

3.1.4 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, 2007b, 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, 2007b).

Adaptation is a dynamic process over time (despite Figure 4, which depicts vulnerability as a static concept)—a process of continuous social and institutional learning, adjustment, and transformation (Fünfgeld & McEvoy, 2011, p. 6). In a flood context, Kundzewicz (2002) diagnoses past and likely future increases in both exposure and adaptive capacity. Kundzewicz however cautions that exposure is growing faster than adaptive capacity, thus increasing vulnerability. Also, increased exposure due to human activities (e.g. eliminating natural flood storage such as wetlands and natural vegetation and due to settlement, and locating infrastructure increasingly in floodplains) (Kundzewicz, 2002) can create a distinct ‘self-made’ aspect to vulnerability.

3.1.5 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, 2007b; 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, Kasperson, et al., 2003; Yohe & Tol, 2002).

3.1.6 Resilience

Resilience is the ability of a system to absorb disturbances while retaining the same basic structure, ways of functioning, and self-organisation (IPCC 2007). 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 flood risk area), reducing sensitivity (e.g. by raising minimum floor levels), or enhancing adaptive capacity (e.g. by increasing people's income levels or social networks). Therefore, vulnerability can only be described for a specific point in time, whereas adaptation aims to reduce vulnerability over time and to increase resilience.

3.2 Madaptation

3.2.1 Factors leading to maladaption

Over-reliance on structural measures

A risk-based approach was chosen to manage flood risk in the Hutt Valley, including structural and non-structural measures (also called hard and soft measures). However, in reality the risk-management approach used appears to rely predominantly on a suite of engineering (structural) solutions with the use of non-structural measures being only weakly developed. While structural works are important for providing protection up to a certain flood volume, non-structural measures usefully complement this approach by dealing with residual risk. Non-structural planning measures can empower communities to take ownership of the issue and contribute to sustainable and resilient communities (Glavovic, 2010; Kundzewicz, 1999, 2002). Over-reliance on the use of structural versus non-structural measures may set communities on a 'maladaptive' path from a sustainability perspective (Eriksen et al., 2011).

Misjudgement of temporal and spatial scales

Temporal and spatial scales are important in judging the success of adaptation (Adger, Arnell, & Tompkins, 2005). Given the complexities of global change, an overly simplistic view of maladaptation may lead to misjudging actions as maladaptive, when they in fact reflect traditional customary practice, or rational and routine responses that sustain rural livelihoods (Agrawal & Perrin, 2009). Thus, decision makers face the non-trivial task of assessing a range of adaptation options taking into account various timeframes and spatial scales.

A legacy of maladaptive past decisions

The location of existing settlements and protection measures represent the legacy of past decisions. The legacy can affect today's choices of flood protection approaches, which will in turn determine future generations' choices and could widen or narrow their 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). For example, if the flood-risk approach chosen entails an institutional commitment to a capital-intensive, large-scale, and long-lived infrastructural development trajectory, there is the danger that this may limit future choices, reducing future adaptation options (O'Neill & Barnett, 2010). Temporal and spatial scales are important when assessing adaptation options. Adaptation may be unsuccessful (not work) or even act to increase vulnerability (maladaptation) (Burton, 1997; Intergovernmental Panel on Climate Change, 2001; Scheraga & Grambsch, 1998; Smit, 1993). In such cases, usually following a major flood event, substantial commitment from governments and businesses is required to break the path and to invoke transitions (Berkhout, 2002).

Climate change is already putting pressure on infrastructure sectors and triggering changes in the way technical analyses and public policy are developed. (Geels, 2004, p. 914). Further, 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 technologies and approaches to be considered (Geels, 2004). Such gradual or sudden changes may be used to overcome the lock-in and the structural inertia that allowed inferior technologies and 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).

Sunk costs of structural measures

Operationalising these insights in a flood-risk management context may prove challenging given the sunk costs in existing structural flood-protection measures. In the worst case, the selected adaptation options may increase, rather than decrease, vulnerability meaning that maladaptation has occurred.

The 'framing' of adaptation has implications for the adaptation options chosen, the (institutional) responsibilities assigned, the actual on-the-ground implementation and resulting impacts. Therefore,

> '*Ideally, policy developers and decision-makers should pause and query why a type of approach or method will be applied to any particular adaptation project and ascertain the relevance of the underlying concepts for the purposes of the activity'* (Fünfgeld & McEvoy, 2011, p. 6).'

3.2.2 Three dimensions of maladaptation explored in the Hutt Valley context

Drawing on Barnett and O'Neill (2010) and O'Neill and Barnett (2010), three dimensions of maladaptation were explored in the Hutt Valley context—options that, relative to their alternatives, disproportionately burden the most vulnerable, reduce incentives to adapt, and set paths that limit future choices. Each type is discussed below in the light of empirical findings from the survey, workshop, and interviews conducted for this case study.

Adaptation that disproportionately burdens the most vulnerable

Adaptation options that disproportionately burden the most vulnerable can be described as maladaptive. Some respondents to the household survey in the Hutt Valley perceived that funds had been diverted from previously identified support for elevating the floor levels of residential buildings following the last damaging flood in 2004, to flood-protection works that primarily alleviated flood risk to downstream industrial areas[8]. This view was expressed as an absence of coherent planning to avoid or reduce future flood risk. It was noted that 6 years after the 2004 floods, no flood-risk reduction plan was operational[9]:

> '*No work has been done to assist residential area, only the industrial area. Still at risk at least as much as before as stop bank subsides and channel becomes shallower. Still waiting for the flood plain management plan to be developed and 6 years have gone by!'*

In addition, funding options for flood responses that are through general rates may disproportionately burden poorer households who may pay a higher share of their income on property rates and have less disposable income to undertake adaptation, such as moving to a lower-

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[8] This occurred when an opportunity arose to include improvements in downstream flood capacity as part of a government funded project to remove toxic waste from the Waiwhetu Stream, thus delaying the investment upstream where low-income and vulnerable households were located.

[9] Planning work on the Waiwhetu catchment flood plan has now started.

risk area, raising the floor level of their house, or increasing the level of or taking out property insurance. A range of funding options will have different effects on various groups in the community.

Adaptation that reduces incentives to adapt

Adaptation measures can also be maladaptive if they encourage unnecessary dependences between actors, stimulate rent-seeking behaviour, or penalise early actors. In this case study, survey respondents invested in plantings, reduced impervious surfaces, purchased sandbags, put in more drains, or regularly checked drains. Such proactive actions may be discouraged if others (continue to) free-ride on such efforts.

> *'We have done stormwater and nova-piped both edges of section which carry away both neighbours' illegal plumbing (or lack thereof) and excess rain water.'*

Simple and inexpensive policy instruments such as rebates and public education may encourage more residents to take responsibility for action and create powerful new norms in the community (Barnett & O'Neill, 2010). There is a risk that structural measures can undermine community action by instilling a false sense of confidence in flood-protection works as indicated by data from the household survey, workshop, and interviews. Structural measures can transfer responsibility for responses to (local) government and stifle adaptation norms as people rely on structural protection and see no need to adapt their own behaviour (Lyle, 2001; Terpstra & Gutteling, 2008; Van Stokkom & Witter, 2008) (e.g. not preparing for floods or continuing to build houses right behind stopbanks because they feel 'safe').

Some practitioners at the workshop and in the interviews did express the view that a 1:440-design standard was perceived as 'safe', and infill development was continuing under the current council district plan. This is consistent with the literature and may suggest that there is poor understanding of potential climate change impacts arising from possible extreme events. However, some respondents acknowledged that upper-catchment development on greenfield sites would require planning controls to minimise increased flood flows.

Adaptation that creates pathways that limit future choices

The IPCC's AR4 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, 2007b).

There is the danger of setting paths that limit future choices when capital and institutions become committed to trajectories that are difficult to change in the future. Particularly, relying on large infrastructure that proved successful in the past in preventing damage from flooding may decrease future flexibility to respond to unforeseen changes in climatic, environmental, social, and economic conditions (Barnett & O'Neill, 2010).

When deciding which flood-risk management measures or trajectory to choose, decision makers may wish to ask questions such as 'which elements of the flood-protection system installed in the past are being criticised?' or 'which past decisions are seen as regrettable today?' A survey respondent commented *'I feel that houses should not have been permitted by Hutt City Council to be built in flood-prone areas',* while another respondent reflected *'perhaps some flood-prone areas should have no housing?!',* and a third remarked *'District Plan management should not allow infill housing in areas of risk'*. Changes in value judgements over time about certain choices can make past choices appear regrettable or that nothing is lost because of the benefits that have accrued in the interim. This again highlights the difficulty that decision makers face in judging the success of adaptation options across time and space and under changing socio-economic conditions (Adger, et al., 2005).

Additionally, intensified development behind structural-protection works may trigger a cycle of 'serial engineering'. Once development has occurred behind stopbanks, there is usually the demand to maintain and / or increase protection over time (Burby & French, 1981; Gordon & Little, 2009; Lyle, 2001; A. Reisinger, Lawrence, Hart, & Chapman, 2012; Stevens, Song, & Berke, 2010; Tobin, 1995). The pattern in the Hutt Valley has been similar, with any conversation about other options constrained by perceptions of high perceived protection levels from stopbanks. Interviews and workshop findings indicated that HCC was now considering a wider portfolio of options (e.g. raising floor levels in building requirements and excluding areas at risk from flooding from areas identified for infill development in a district plan change).

However, little attention has been given to date to whether current practice is sufficient to address increased flood risk under a range of climate scenarios. Therefore, workshop participants described residual risk as the preserve of civil defence. The notion that increased risk with climate change might reduce civil defence capacity over time, or that such extreme events could become more frequent and increase damages, seemed a new idea to some of the participants, especially district planners and those designing structural protection works.

4 Barriers and constraints to adaptation

Various barriers and constraints affecting decision-making processes and resulting levels of adaptation have been identified in the literature. Some of these barriers and constraints are discussed in the following sections, in the light of the Hutt Valley case study findings.

4.1 Cost constraints on the level of adaptation

Funding is often a constraint on decision makers when addressing adaptation to future risk (de Bruin & Dellink, 2011; Swart et al., 2009).

4.1.1 Reversibility

Some adaptation measures may be irreversible

Firstly, some of the adaptation measures may be irreversible, or a roll back may not be feasible. This irreversibility decreases the ex ante incentives to invest in adaptation when the severity of future climate impacts and consequent damage levels are uncertain (Callaway, 2004; de Bruin & Dellink, 2011). This uncertainty appears to have a stronger influence on decision makers than incentives associated with the avoided consequences of future unspecified impacts. This has occurred in New Zealand in a flooding context and for coastal settlements, evidenced by climate change having featured only relatively recently in Environment Court decisions (Ministry for the Environment, 2008b), despite a statutory requirement for decision makers to address such future impacts associated with hazard risk and climate change[10]. This was identified by interview respondents in their comments about how uncertainty influenced council decision making, especially when climate change impacts were involved.

4.1.2 Competition

Adaptation competes with other investments

Secondly, adaptation competes with other perhaps more immediately needed investments (Crabbé & Robin, 2006; Measham et al., 2011). Committing public expenditure to building up an adaptation capital stock implies the reallocation of scarce resources (Callaway, 2004; de Bruin & Dellink, 2011). A survey respondent commented:

> *'They've diverted funds from other council/regional council/government funded amenities.'*

4.1.3 Myopia

Short-term planning may lead decision makers to disregard long-term consequences

Thirdly, a combination of myopia, relatively short electoral cycles (3 years for both central and local government in New Zealand), and pressure from politically influential interest groups may lead decision makers to disregard long-term consequences of both climate change and current decisions

[10] The RMA requires that 'all persons exercising functions and powers under it … shall have particular regard the effects of climate change' (s 7(i) (New Zealand Parliament, 2010) and the Resource Management (Energy and Climate Change) Amendment Act 2004 specifically requires 'local authorities to plan for the effects of climate change' (s 3b (i)) (New Zealand Parliament, 2004).

(to adapt or not; and if so, how, when, and to what level) (Næss, Bang, Eriksen, & Vevatne, 2005). It is challenging to dedicate substantial financial resources to adaptation investments the benefits of which may not become apparent until the mid or late twenty-first century (de Bruin & Dellink, 2011). Some workshop participants indicated that, in their experience, resources were allocated to short-term and immediate demands.

The lack of investment in adaptation was highlighted at the workshop and in the follow-up interviews. Participants noted high variability among local councils in their capacity to manage flood risk, due in part to variations across New Zealand in funding bases and available human resources.

Residents will resist paying for adaptation measures if they do not perceive direct benefits

Some survey respondents, largely those not flooded previously, expressed dissatisfaction about increased property rates since the 2004 flood to pay for protection measures. This suggests that further increases in rates to finance flood-protection measures may be met with community resistance, particularly if residents perceive no direct benefit from upgraded protection. For example, one survey respondent was critical of the financial contribution (several thousand dollars) that their household had to make to pay for stormwater upgrades in their area, despite not having been flooded.

4.2 Restrictions on the level of adaptation

4.2.1 Damage potential versus upfront costs

Closely linked to limits on available funding is the extent to which the level of adaptation chosen considers both a calculation of damage potential and upfront costs. The fraction of damages avoided by adaptation could be suboptimal (de Bruin & Dellink, 2011) depending on this balance. A number of reasons for this have been proposed in the literature and the following sections assess their applicability in the Hutt Valley.

There is a lack of relevant knowledge / relevant knowledge is not used in decision-making processes

There may be a lack of relevant knowledge. Considering the range of possible climate futures and determining the optimal level of adaptation from the outset appears to be an impossible task. Even if knowledge about the optimal level and measures of adaptation were available, it may not find its way into public decision-making processes—if the people concerned either do not know about it or lack an understanding of what is required (Fankhauser, Smith, & Tol, 1999; Preston, et al., 2008). The interviews and council statutory plans indicate that the full range of flood-risk management tools have not been used in the Hutt Valley. Stopbanks, raised floor levels, and flood warning are the primary tools used. Planning rules and retreat policies have not been used in a strategic way to date, nor is there a long-term plan to address changing risk associated with climate change, other than 10-yearly reviews of the flood-protection scheme. Climate scientists are now more confident about the direction and magnitude of changes and modelling capabilities are improving, although uncertainty ranges are still large and the significance for decision making is often not highlighted.

Within the current institutional and legal framework for flood-risk management in New Zealand, integrating both available and new information into decision making proves challenging for five main reasons.

There is a wide range of projected changes in flood risk due to climate change

Firstly, projections of future flood risk under climate change indicate a wide range of possible changes. In addition, uncertainties are by definition an inherent characteristic of climate projections (Intergovernmental Panel on Climate Change, 2007a, pp. 943, 953), and climate 'surprises' cannot be ruled out[11].

Central government direction on how to use climate information to make planning decisions is needed

Secondly, respondents identified a need for stronger central government direction on the status of climate information as a basis for planning decisions. Many respondents noted the distinction between guidance and statutory requirements. Statutory requirements provide a robust foundation for the decision-making process, enabling councils to withstand challenges in court when property owners pressure for consents in flood-prone areas. In their desire not to be challenged in the courts, decision makers see specific numbers, rather than a range, as a sign of robustness and certainty that can stand up in an evidence-based planning system. As a result, adaptation is delayed, 'best estimates' are used in a way that hides the potential risks and consequences associated with climate change extremes and sometimes buffers are identified but these will eventually be eroded over time. Planning practitioners at the workshop and at the interviews described this practice and a review of Environment Court decisions demonstrates this too (Ministry for the Environment, 2008b).

Even some council advisers understood an increase in protection level of the Hutt River to mean that new development and existing development was 'considered safe behind stopbanks'. There was a strong perception that by raising stop banks they were dealing with foreseeable risk, which to some degree they are but for a short time period. The notion of greater residual risk to manage and reduce protection levels associated with increased flood frequency and intensity over time with climate change was not well understood.

There was a low level of understanding of what the science was saying; rather councils relied on numbers in the Ministry for the Environment flood design and sea-level rise guidance documents (Ministry for the Environment, 2008d, 2009, 2010a) to 'fix' protection levels and hazard lines. This is despite the flexibility afforded in that guidance material, albeit at the lower end of the projected frequency and anticipated changes. This guidance is based on the IPCC's AR4, which noted that dynamic processes related to ice flow could increase the vulnerability of the polar ice sheets to warming and consequently increase sea-level rise. While such processes had been observed, they were not included in the IPCC AR4 models, and could result in sea-level rise substantially larger than IPCC model-based projections. Thus recent research cautions that the IPCC projections may well be an underestimate of the impact of melting ice sheets in polar regions (Vermeer & Rahmstorf, 2009).

Temporary measures can become locked in and dampen the urgency for long-term measures

Thirdly, it has been suggested that adaptation may be restricted due to future risk being suppressed psychologically and people not perceiving a sense of urgency to act. Overall, the survey findings

[11] For example, observations of atmospheric CO_2 concentrations, global mean surface temperature, and sea-level rise exceed IPCC AR4 modelling projections (Rahmstorf et al., 2007). New findings suggest accelerated ice-sheet loss in Greenland and Antarctica (Rignot et al., 2011) as well as sharply increased rates of ice loss from Canadian glaciers (Gardner et al., 2011) and the discovery of new ice sheet dynamics in the Antarctic (Bell et al., 2011).

suggested that respondents were not very knowledgeable about flood risk[12] and / or prepared[13]. Yet, the nature of many qualitative comments suggested that respondents identified flood risk as an important and ongoing issue. HCC's community consultation found that ratepayers and residents regarded flood and stormwater protection as the highest-priority issue[14]. However, largely fixed or static responses have been implemented, such as increasing the protection level of the Hutt River scheme and identifying houses that could be raised above flood levels. However, these will in all likelihood eventually be overtopped in extreme events and can be considered temporary adaptations that potentially lock in risk. Some of those interviewed thought that these measures were insufficient, because they created a false and temporary sense of security dampening the need to take a more comprehensive and long-term approach to adapt to climate change impacts. The impacts of Hurricane Katrina in New Orleans have demonstrated the potential damage and lock-in effects of similar approaches in the USA (Burby, 2006; Gordon & Little, 2009).

More immediate threats can limit adaptation by decreasing adaptive capacity

Fourthly, other and potentially more immediate threats may be present (e.g. pollution, conflict, and disease), which could limit adaptation by increasing vulnerability and decreasing the adaptive capacity of both ecosystems and people. In the Hutt Valley, some qualitative comments showed a perception that other priorities, like cleaning up Waiwhetu stream toxic waste, had delayed raising floor levels in an area of long-term flood risk. Instead, the channel was widened and deepened to remove toxic wastes from the stream, since funding was available for that.[15]

Short-term thinking can prevent proactive action

Finally, a myopic perspective may prevent proactive action if decision makers do not sense the need for a long-term strategic approach (de Bruin & Dellink, 2011). In the Hutt Valley, decision makers took action to improve protection following a number of damaging flood events in 1976[16] and in 2004[17]. Workshop and interview respondents highlighted that these events initiated a more comprehensive whole-catchment approach to flood risk that was linked to a programme to

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[12] More than half who answered the question did not know the level of risk that they were exposed to (54.6 percent). About a quarter (23.8 percent) had some idea about their risk exposure while a fifth (21.2 percent) indicated they were informed about the level of flood risk that their property was exposed to.

[13] When asked to indicate how prepared survey respondents thought various institutions were (EQC, central government, regional and city council, service providers, insurance companies, own households, and community), those with flooding experience assigned relatively higher levels of preparedness to their own households (ranked sixth instead of eighth) than those without flooding experience (ranked eighth out of eight). It is remarkable that both subgroups ranked their own households as the least and third-least prepared groups. Other findings relating to householders' preparedness are presented in Section 5.3.

[14] Hutt City Council Draft Community Plan Submissions Analysis, June 2007.

[15] As reported by several interviewees.

[16] For 1976, two flood events were recorded: the first one at 614 cumecs and the second one at 747 cumecs (as calculated by a regression from the Birchville flows). The first flood incident would be slightly larger than the 2-year flood of 677 cumecs, while the second flood incident would be between a 2-year flood and a 5-year flood of 973 cumecs (GWRC, 2011). However, the major flooding was caused by the Korokoro Stream and not by the Hutt River.

[17] During the February 2004 flood, a maximum flow of 1,067.564 cumecs was recorded for 16/02/2004 (measured at Taita Gorge), which is almost the size of a 5-year flood of 1,089 cumecs (GWRC, 2011).

implement stormwater upgrades in 'hotspot' areas. However, the approach adopted did not fully include a long-term look at changing residual risk and the way planning provisions in the statutory plans could complement the hard structural approach taken. Some other councils in the Wellington region are taking a different approach. For example, Kapiti Coast District Council uses a long-term vision of sustainability that has informed its development and infrastructure planning in a more integrated way over time. A possible factor here has been long-term and consistent leadership from forward-looking councillors and individual staff supporting a sustainability vision and applying the latest knowledge to the issues, and undertaking community conversations on the issues at stake over a 10-year period.

4.3 Barriers to the timing of adaptation

4.3.1 System inertia

Understanding that climate change is a problem and adaptation is needed is essential to break down barriers driving inertia

Inertia can delay adaptation action. Understanding that climate change is a problem and that adaptation is needed to address likely changes is an essential ingredient for breaking down the barriers that drive inertia. The survey responses and council community consultation suggested that flood risk and how it was approached is of concern to residents. For example, delay and inaction were not seen as an option. Managing flood risk on an ongoing basis and maintaining continuous engagement with the issue were assigned a high level of importance. Doing nothing about flood risk was dismissed as unacceptable for the current situation (ranked lowest among all options provided), and this view was held significantly stronger for future flood-risk management[18]). That is, the household survey respondents clearly identified increases in future flood risk as a problem and commented that to think flood risk would not increase in the future would be 'silly'. Similarly, council participants understood that climate change would exacerbate current risks and that adaptation was necessary. However, some respondents saw existing measures as providing protection for the foreseeable future, while others expressed greater urgency, especially for long-lived assets and infrastructure.

Simple and up-to-date information is needed to break down inertia

Inertia in the system was identified at several levels of government. In the Hutt Valley, up-to-date and simple information from sources with integrity was seen as helpful to break down this inertia. Council respondents agreed.

4.3.2 Threats of litigation and short-term planning

Developers put council under pressure to allow development in flood-prone areas

The threat of litigation was seen as a real issue for councils' abilities to restrict further development in hazard-prone areas. The short-term benefits that accrue to developers have become a major pressure on councils in this area. Perceived uncertainty in information can means that councils postpone addressing climate change until better information becomes available. However, there will

[18] p=0.008; r=0.2, i.e. small to medium effect size

always be uncertainties about climate change risk and this is not well understood. Finally, some adaptation measures may take a long time to plan and implement, especially if they are associated with large-scale infrastructure developments that have long lifetimes. For example, in the Hutt Valley (and quite common across most local authorities in New Zealand), stormwater upgrades are programmed over long timeframes. There is a deficit in adaptation to current climate conditions, even without considering future climate risks. For example, for one local authority stormwater system capacity upgrade, work is funded at ~1 percent of the stormwater network each year to raise the standard from a 1:5-year standard to a 1:20 to 1:50-year standard—well behind what will be required even to keep up with current flood risk. This becomes a strategic issue as flood frequency and intensity increase. A system that is sensitive to considering near-term cost rather than future benefit will most likely continue to be unprepared for high costs arising from extreme events.

4.4 Barriers to flexible adaptation options

Locking in existing community assets through inflexible adaptation options is at the heart of adaptation inertia. How such inertia could be removed was explored in this case study. Regular, updated, simple, and clear information on risk along with a range of adaptation options presented for discussion with communities, were identified as a key factors by the workshop and interview respondents. The success of adaptive management that creates greater flexibility was considered dependent on these two factors, along with leadership to make it all happen within a long-term strategic framework. In sum: adjustment will be gradual, rather than radical, unless the three ingredients act together.

4.4.1 Triggers for change: Extreme events and windows of opportunity

The potential for 'surprises' and recent research showing that the IPCC AR4 estimates of change are likely to be conservative, especially regarding sea-level rise, raises the need to consider how these changes affect the way local government approaches climate change adaptation.

Local government practitioners did not understand extreme or abrupt climate change

The notion that there could be extreme levels and increased rates of climate change, making adaptation more than incremental, was outside the understanding of most of the local government practitioners. However, they did indicate that to date, extreme events had triggered effort to upgrade protection and avoid the worst effects of current and near-future flood risk through a more comprehensive approach. Thinking about a shift in action that creates greater flexibility for the future was evident in work being undertaken by Wellington City Council and GWRC. This work is at a very preliminary strategic stage using visual tools of hazard risk and identifying adaptation options for discussion with communities.

The Christchurch earthquake has increased understanding that insurance for extreme events may be unavailable or reduced in the future

The prospect of insurance not being available in the future as reinsurance losses rise has only entered the public discourse since the 22 February 2011 Christchurch earthquake. This effect has also been considered by Fankhauser and colleagues (1999, p. 73) who note that 'insurance premiums may rise, or insurance may be withdrawn […], also reducing returns. As a result, climate-change-sensitive projects will become more difficult to finance. This in itself is, of course, an adaptive measure and (provided financial markets are well informed) helps to reduce society's exposure to climate change risks.'

In summary, the trigger for a change in approach to how climate change related flood impacts are addressed currently relies on large storm events (after the event), potentially with the insurance industry resetting the risk parameters (Botzen & Van Den Bergh, 2009; H. Kunreuther, 2008; H. C. Kunreuther & Michel-Kerjan, 2007). However, it is unlikely this will be sufficient to address changes in flood frequency for assets which have long lifetimes, like existing settlements and infrastructure.

With high-stakes decision making, where probabilities are unknown or low but impacts potentially large 'naïve decision-makers fall prey to a wide range of potentially harmful biases, such as failing to recognize a high-stakes problem, ignoring the information about probabilities that does exist, and responding to complexity by accepting the status quo' (H. Kunreuther et al., 2002, p. 259).

5 Implications for local government adaptation

This section addresses how local government could overcome the barriers and constraints to adaptation by considering:

- who should do something about flood risk
- what should be done about flood risk
- what and how risk can be communicated
- how to reduce barriers to residential preparedness and adaptive management.

5.1 Who should do something about flood risk?

Flood-risk management was viewed as a collective and public responsibility but input from individuals is also important

5.1.1 Local government

The Hutt Valley case study indicated that responsibility for addressing current and future flood risk was unequivocally assigned to local government[19]: *'that's what we pay them for'*. Responsibility for land-use planning was seen as an important instrument in flood-risk management. Central government was also identified as having an important role to play in guiding local government action:

> '*Central Government may need to direct ... HCC and GWRC to take necessary measures to reduce risks.'*

Therefore, flood-risk management was viewed as a collective and public responsibility rather than an individual or private responsibility.

5.1.2 Individual households

However, some survey respondents favoured private property owners paying or at least for being prepared and not placing themselves in flood-prone areas. There was an expectation that funding for measures to manage flood risk should come out of the public purse and that a uniform protection level should be provided across the Hutt Valley.

Similar results were found in the Netherlands, where historically flood-risk management was the sole responsibility of government, resulting in the absence of a public debate on the responsibility of individual households to prepare themselves (Terpstra & Gutteling, 2008). A recent shift in government's approach there from protection (i.e. maintaining a low probability of flooding through structural protection measures) to risk management[20] triggered public debate. Research has shown

[19] GWRC was ranked first followed by HCC by all subgroups and for both present and future flood-risk management. Total sample: for managing current flood risk the mean rank was 4.5 for GWRC and 4.4 for HCC (on a scale from 1 'least responsible' to 5 'most responsible'); for future management preferences the mean rank was 4.6 for GWRC and 5.5 for HCC.

[20] Flood-risk management takes a range of possible climate futures, including the potential for extreme events and surprises, into account when planning adaptation responses rather than relying on a single 'best estimate'

that while about three quarter of householders still consider government to have the main responsibility for damage mitigation, about half of respondents considered the government and their own households equally responsible for disaster preparedness. This suggests that a substantial part of the public may be receptive to communication about disaster preparedness (Terpstra & Gutteling, 2008).

5.1.3 Central government

Local authority decision makers and practitioners clearly acknowledged the role of local authorities in managing flood risk. However, they also highlighted that their ability to give effect to their responsibilities would benefit from stronger direction by central government through a NPS on flooding and other natural hazards. Being able to ground flood-risk management measures on a robust statutory basis—as opposed to the current guidance—was identified as improving councils' ability to make increased use of non-structural planning measures.

Extreme events can provide 'windows of opportunity' for institutional and strategic change. This can include reviewing existing practices, rethinking where communities are located, and can enable transitions out of harm's way through regional and district planning measures. Thus, past experience suggests that future flood events could present opportunities to review current practices, learn from mistakes, and institute more adaptive and resilient practices that will be more flexible as risks change over time.

5.2 What should be done about increased flood risk?

5.2.1 Survey respondents' perspectives

Respondents preferred stormwater-network improvements and land-use restrictions

The case study indicated that improvements to the stormwater network followed by land-use planning restrictions on new buildings, renovations, or infill developments in high-risk areas were assigned the highest priority by respondents. Overall respondents felt that a greater range of flood risk management measures should be used, including raising floor levels and no further infill development in flood-prone areas and in areas where the residual risk would be high over the long term. Better flood information and assurances that all people matter (including those of lower socioeconomic status) were also highlighted as issues warranting council's attention. Inaction was rated as unacceptable[21]. At the same time, a small number of survey respondents commented that the legacy of past decisions could be contributing to community vulnerability:

> '*Council initially should not give licence to build in flood prone areas.'*

This suggests that residential communities in the Hutt Valley may be receptive to communication about increased use of land-use planning tools by councils for addressing increased risks over time.

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for planning decisions. It acknowledges that structural measures by themselves cannot protect against all possible future floods and acknowledges the vital role of non-structural measures for addressing residual risk.

[21] This option was ranked lowest of all options provided. Only 4.3 percent (Q18) and 3.3 percent (Q23) indicated the highest level of support for inaction. Wording of the answer options caused some confusion, resulting in this variable having a high proportion of missing responses (25.8 percent for Q18 and 20 percent for Q23). See Appendix 1 NZCCRI-2011-06 for the full list of survey questions.

Land-use planning addresses residual risk but opportunity costs must be considered

Land-use planning can be a valuable complement to structural measures as it addresses residual risk arising from overtopping or breach of stopbanks in extreme events or stormwater flooding in low-lying areas. However, restrictions on development come with opportunity costs where the alternative land use foregone is of high value—for example, industrial, commercial or residential development. These could represent high costs, since high-value uses build up over many years. However, timing the retreat of high-risk housing in stages over a number of years with community consultation and support may be an option worth considering to avoid damages associated with increasing frequency and severity of flooding from climate change. On the other hand, if flood-risk areas behind stopbanks (i.e. areas affected by residual risk) were to be further developed, the potential damage cost in case of extreme flooding may far outweigh the economic benefits derived from infill development.

5.3 Communicating risk information and preparedness

Relevant findings from the case study that inform potential areas for council provision of information include:

- the high number of Hutt Valley households (54 percent) that do not know the level of risk that they are exposed to
- the difficulty expressed in accessing flood-risk information
- that the majority of respondents (80–96.8 percent) did not take any of the information-seeking actions or communication actions suggested in the survey
- that about half of the respondents (52.8 percent) kept ditches and drains around their property clean and collected emergency survival items or compiled a general preparedness kit (50 percent) not specifically for floods
- that one quarter (25.3 percent) made a plan about what to do in the event of a flood (of those who had a house with more than one floor, 18.2 percent avoided keeping irreplaceable items or items of sentimental value on the ground floor).

Respondents undertook actions that were cheap and easy to do

These actions were all ones that required little time commitment or money to achieve. Those with flooding experience were more likely to have undertaken specific measures, like raising the floor level of their house[22], keeping ditches and drains clean, having talked to council[23], and having made a plan about what to do in the event of a flood. Six people increased their level of insurance following the 2004 floods.

However, most additional actions were largely emergency-preparedness measures, such as storing valuable or essential items above floor level or having an emergency kit or a plan of action in case of imminent flooding, rather than actions that would avoid future flood losses.

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[22] Note that two cells (50 percent) did not fulfil the minimum expected cell count of the chi-square test. Thus, the p-value (0.04) may be unreliable.

[23] Note that 1 cell (25 percent) did not fulfil the minimum expected cell count of the chi-square test. Thus, the p-value (0.049) may be unreliable.

Cognitive dissonance and the optimism bias can prevent people taking action

People may not prepare, despite knowing that it would be beneficial to do so. Such inconsistency, or cognitive dissonance as it is described in social psychology (Festinger, 1957), is not unusual. People may consider preparation unnecessary based on the assumption that '… a probabilistic harm in the future will not come to fruition at all, or will not be particularly bad if it does' (Sunstein, 2007, p. 531), reflecting an optimism bias. People aim to restore consistency by changing either their commitment (chosen course of action) or their perception of the meaning, importance, or validity of the information received, whichever element is relatively less resistant to change (R. L. A. Adams, 1973). It has been suggested that people perceptually distort the meaning of environmental information, thereby acting as risk manipulators rather than as risk takers (R. L. A. Adams, 1973). Thus, people may justify rejecting the need for flood preparation by reverting to the notion that a serious flood is unlikely to occur during their lifetime. For the household survey sample, no such relationship could be shown. However, this does not provide any information on whether or not cognitive dissonance applies, as the statistical tests applied assessed relationships not causality (Pallant, 2007).

Another reason for low levels of household preparedness may be that people shift responsibility from the self to others, namely (local) government (Ballantyne, Paton, Johnston, Kozuch, & Daly, 2000; Lyle, 2001; Paton, 2003).

5.4 How to reduce barriers to residential preparedness and adaptive management

This section identifies the way the barriers described in Section 4 could be addressed.

5.4.1 Funding measures

Survey respondents perceived costs to be the highest out of eight suggested barriers to managing flood risks—the flood-affected even more so than the not affected group (small to medium effect size)—suggesting that financial constraints may need to be overcome to implement what are perceived as effective flood-protection measures. Not all households will have the financial means to undertake flood-proofing measures such as structurally modifying buildings (e.g. raising the floor level of the house).

Councils will need to address how they might fund such measures when ability to pay at the household level is low. For example, funding could be identified over a 10-year timeframe through the LTP process, which involves wide community consultation. On the other hand, councils also face financial constraints (Pini, Wild River, & McKenzie, 2007). Such constraints to improved adaptation decision making were also found in Australia (Measham, et al., 2011) and other countries. Other constraints widely acknowledged in the literature related to a lack of information on vulnerability (Crabbé & Robin, 2006; Mukheibir & Ziervogel, 2007), on climate (Dessai, Lu, & Risbey, 2005), and on relevant scales and timeframes for taking action (Amundsen, Berglund, & Westskog, 2010).

5.4.2 Cooperation with others

Survey respondents ranked the need for cooperation with others as the second-highest, indicating that facilitating community cooperation may be a further target area for councils, or in fact a dual target: communication and cooperation (a) between councils and the community and (b) within the community itself (between community leaders and members).

5.4.3 Education

Use comparisons between past and future floods and tap into people's experiences

Survey respondents saw educating and providing information to enhance people's awareness of flood risk and its likely increase in the future as key measures to reduce barriers. Respondents suggested using comparisons between future and past flood volumes and tapping into people's knowledge where they have already experienced floods of similar volumes. The literature shows that disaster experience leads to vivid memories enabling better recollection of events that can inform subsequent action (Kulig, Edge, Reimer, Townshend, & Lightfoot, 2009; Lee, 1999; Neisser, 1996; Norris & Kaniasty, 1992; Weinstein, 1989), less uncertainty about the nature of events and response, and high personal involvement leading to people more likely to undertake future action (Weinstein, 1989).

Provide information on actions that protect people's livelihoods

Providing information on actions designed to protect people's livelihoods (e.g. protecting economic integrity or enhancing drainage in low-lying streets) can give a sense of empowerment and increase willingness to prepare (Seeger, Sellnow, & Ulmer, 2003; Spence, Lachlan, & Griffin, 2007) because it focuses on reducing vulnerability rather than emphasising the unpredictability of the hazard (Paton & Johnston, 2001). Thus, communication could focus on on-the-ground measures that residents could take individually, such as regularly checking the drains around their property to make sure they are being kept clear of debris and rubbish. Educating residents about their flood risk could also provide a more transparent rationale for planning restrictions on land use, thus potentially garnering enhanced community support for such measures because residents can 'see where planning is coming from'.

Be explicit about the detail underlying decisions

Communities value information on what is being done, how, by when, and which criteria were used for prioritising actions. This is currently underway with the development of the Waiwhetu Stream Flood Plain Management Plan (Greater Wellington Regional Council, 2010, 2011c). The existing HVFPMP, published in 2001, was developed for a 40-year time frame. Reviews are reported to be occurring at 11 or 12-year intervals despite the HRFMP specifying 10-year intervals (Wellington Regional Council 2001). There may be a need for shorter cycles as climate science is advancing with greater confidence in the projections and direction of change as well as indicating more dynamic change (Bell, et al., 2011; Gardner, et al., 2011; Rignot, et al., 2011; Shakhova et al., 2010) and happening sooner (Rahmstorf, et al., 2007; Vermeer & Rahmstorf, 2009).

Emphasise benefits in terms of future damages and costs avoided

When decisions involve significant investments such as those on flood-risk management, councils will want to have very robust information before financial resources are budgeted and property rights affected. The barrier for progressive action by councils associated with the perception of costs of flood-management investment may be overcome, to some extent, by framing the issue as benefits to be gained through reduced costs in the future as an insurance against high future damage costs. Framing climate risks in a way that identifies the potential for high future consequences would be consistent with the recent science. This could overcome the tendency for the present generation having limited incentive to pay for adaptation measures now.

5.4.4 Institutional cooperation

Improve coordination within and between councils

Survey respondents saw institutional cooperation on issues that require coordination within and between councils as essential for ensuring integrated management, (e.g. for stormwater systems: rivers, ponds, stopbanks, erosion control, storm drains etc.). One respondent commented:

> '*Empower one authority (Regional Council?) to manage all aspects of stormwater system, i.e. rivers, ponds, stopbanks, erosion control, storm drains etc.'*

The need for better institutional cooperation, clarification of responsibilities, and coordinated actions and resources was also identified. Larger councils in New Zealand are grappling with a siloed organisational structure, while smaller councils lack the resources to comprehensively address data-collection issues, climate information needs, and assessments of risk-response options.

It was noted that the agreements between GWRC and the territorial authorities within its boundaries were a significant step forward in disentangling and clarifying local government responsibilities across different elements of flood-risk management. The agreements were negotiated after the 1976 flood event when a policy window provided opportunity for change.

5.4.5 Stronger central government coordination

Replace central government statutory guidance with statutory requirements

The problem of institutional limitations has also been reported in Australia (Wild River, 2006) and Canada (Ivey, Smithers, de Loë, & Kreutzwiser, 2004), where municipalities act as delegated agents of a higher power, which limits their leeway in decision making. Similar results were found in the US, where flood-hazard practitioners felt that the uniformity in federal guidelines and methods unduly limited their room for manoeuvre, preventing the use of methods that would better fit local conditions (Downton, Morss, Wilhelmi, Gruntfest, & Higgins, 2005). In New Zealand on the other hand, local decision makers frequently call for stronger central government direction, which currently takes the form of *guidelines* for flood risk management and the integration of climate change information (Ministry for the Environment, 2010a, 2010b). Participants noted that if these took the form of *statutory requirements* instead, local authorities could fend off development pressure much more confidently as their decisions would be more likely to withstand challenges in court.

Make flood-hazard information available to property owners

Although required to, councils are reluctant to make flood-hazard information available in the face of property owner pressure and potential legal challenges as to its efficacy and effect on property values. Delineation of risk areas on flood-hazard maps often becomes a political issue with complex power dynamics because it causes commotion among residents who are concerned about increasing insurance premiums and decreasing property values as a result of stigmatising at-risk properties Internationally, the evidence on impacts of flooding and risk-area designation is mixed (Lamond, Proverbs, & Antwi, 2008). Theoretical contributions to housing market economics suggest that myopia and amnesia may lead to a full recovery or even exceedance of pre-flood of property values, depending on the frequency and magnitude of flooding (Pryce, Chen, & Galster, 2011).

Similar problems arise with flood-hazard maps, where demarking risk zones may be contested. This has been found in Canada (Lyle 2001), for example. However, research in New Zealand does not find consistently substantial and persistent reductions in property values upon disclosure of flood-hazard areas through flood-hazard-zone maps (Montz, 1993).

Local decision makers referred to their experience publishing flood-hazard maps for the Hutt Valley, which caused disquiet amongst residents and developers and was reported to have led to some individuals using their influence to have their property excluded from the hazard zone. Thus, experience has shown how policies can become politicised (see also Næss, et al., 2005) and the subject of debate where long-term interests in community safety clash with short-term development and political interests, and where the public good of flood protection stands against private property rights, including the right to develop one's property.

However, local government has a responsibility to provide information of hazard risk when it is known. Some councils indicated that they were more likely to make such information available if they had the solid backing of a NPS and robust (certain) projections of future flood risk. Robust projections are constrained by cost and a NPS has not been forthcoming to date.

Without leadership on climate change and long-term risk management, it has been difficult for councils to integrate climate change considerations into their decision making and to resist political pressures to weaken the application of non-structural planning measures that restrict land-use activities and their intensification on the floodplain. In some cases, instead of bearing the political costs associated with making hard decisions about long-term risk, decisions have been put off and passed to subsequent councils and to the community generally who, along with affected landowners, will bear the impacts and the costs of mitigation when future flooding occurs.

5.4.6 Long-term thinking

Survey participants also stressed the need for institutional cooperation that takes a long-term and holistic view of existing and potential future risk factors and is supported by political will, sufficient funding, and appropriate prioritising tasks.

> *'The biggest barrier is lack of political will by HCC. Central Government may need to direct … HCC and GWRC to take necessary measures to reduce risks. Needs to take account of current risk factors and future ones relating to climate change and deforestation and further urbanisation.'*

5.4.7 Reduced imbalances in council resourcing

Interview and workshop participants identified a number of practices that could help overcome imbalances in council resourcing and that could improve adaptive capacity generally. Pooling resources, improving access to Light Detection and Ranging (LIDAR)[24], 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. Sharing learning and better integrating risk responses within and across councils were identified as measures offering improvements for flood-risk management in the Hutt Valley. Shared learning may also speed up intra-regional and inter-regional diffusion of new successful approaches.

In sum, it can be said that Hutt Valley residents consider flood risk a matter of high and ongoing importance. They attach the main responsibility for planning, implementation, and funding of flood-risk management to the public / collective level, headed by local government, and guided by central government statutory direction. Stormwater management and land-use planning were perceived as the critical issues determining the Hutt Valley community's resilience and vulnerability, as it is shaped by present flood risk and its projected increase in the future due to climate change. Using local experience and information comparing experienced damages with likely future damages could provide a transparent rationale for planning restrictions on land use and enable residents to better understand the basis of local planning decisions.

[24] LIDAR is a highly accurate method of mapping topographic features through the use of 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; Taylor & Francis, Weitkamp, 2005).

6 Conclusion

This analysis of the empirical findings for local government decision making has highlighted a number of issues that will assist councils when considering the changing nature of climate risk and consequent damages over time.

6.1.1 A risk-based approach

A risk-based approach that considers the impact of climate extremes will enable councils to reduce underestimates of risk and locked-in investment patterns and increase flexibility in risk-management approaches. Such an approach would have to include elements of adaptive management using triggers and indicators like an event of a certain size and progressively retreating hazard lines. It would also need to be complemented with funding and planning measures that identify raised floor levels, removable buildings, and places to relocate to.

Risk-based approaches are currently being used in a small number of areas in New Zealand (e.g. Hawke's Bay region, Tasman district, and Canterbury region). However, to date none have explicitly considered vulnerability from a social perspective and do not consider the need to enhance adaptive capacity of communities through targeted education of property owners, the design of more flexible planning instruments that can be adjusted over time without incurring high costs, or helping increase household preparedness. Such approaches could ultimately help shift public understanding towards acknowledging residual risk and the need to address it in a more flexible way.

Work is continuing on a risk approach that might increase flexibility for flood-risk management associated with climate change. Such flexibility has the potential to help reduce sensitivity; for example, through targeted support (funding) for the most socio-economically vulnerable households. The close collaboration between district and regional government on integrated flood and stormwater management appears critical, since respondents saw flooding in an integrated way and saw potential for learning across territories, experiences, and economies of scale in investments in service provision.

6.1.2 Institutional cooperation

Similarly, decision makers themselves identified the agreements between GWRC and the territorial authorities within its boundaries as a significant step for disentangling local government responsibilities across different elements of flood-risk management. The agreements were negotiated after the 1976 flood event when a policy window provided opportunity for change.

6.1.3 Central government statutory guidance

Central government statutory guidance was highlighted as a necessary condition to avoid duplicating effort across New Zealand and to strengthen the resolve of local councils in dealing with development pressures when more restrictive land-use planning was being proposed.

6.1.4 Tailored risk communication

To enable communities to fully understand the residual risks associated with current structural approaches to managing flood risk, respondents perceived the importance of tailoring risk communication to the audience and the need to have a way of updating risk communications as new information comes to hand.

6.1.5 Non-structural planning mechanisms

Respondents also highlighted the importance of non-structural measures, in particular land-use planning, as tools for a long-term strategic approach to the increasing risks from climate change.

Non-structural measures:

- can provide the flexibility required to deal with uncertainty about the specific local effects of climate change and changing risks in the future
- are reversible
- are generally publicly accepted
- do not contribute to further environmental degradation (Kundzewicz, 2002).

  '*Since a flood protection system guaranteeing absolute safety is an illusion, a change of paradigm is needed'* (Kundzewicz, 2002, p. 11).

6.1.6 Simple, clear information from trusted sources

However, the most critical issues that arose repeatedly in this case study were the need for simple and clear information from reputable sources that decision makers can trust about the efficacy of climate change risks and their local effects, and greater national direction through a national policy statement and guidance as to how councils can address them cost-effectively with community buy-in and reduce the risk of failure when challenged in the courts.

The common practice of using 'best estimates' for planning purposes, will underestimate risk at the extremes (where most damage occurs), and discount the dynamic and uncertain nature of climate risks. This fundamentally challenges current planning practice that relies on a single number, a narrow range of possible futures, and relatively high degrees of certainty and predictability. While councils are familiar with risk management and the handling of uncertainties in other contexts (e.g. earthquakes, engineering projects), climate change poses new challenges related to conflicted dialogue, short political cycles, and present-day priorities taking precedence over things that are perceived to be in the future. Moving from 'best estimates' to a risk-management approach requires both a 'head change' on part of the local decision makers and a change in the legal status of the direction provided by central government.

Household preparedness cannot prevent all or most of the economic impact of a major flood. Emergency management does not have the capacity to continue indefinitely addressing residual risk as protection levels are lowered by ongoing changing flood risk with climate change. Inadequate land-use and building-construction practices are more important determinants of the severity of hazard impacts (Lindell & Prater, 2002). However, given that the storm damage in the lower North Island of 15 and 16 February 2004 resulted in claims of $112m (in original terms) or $124.58m (in

31/12/2007 adjusted terms) (Insurance Council of New Zealand, 2009), even a 1 percent reduction in losses would save an appreciable amount.

The RMA’s requirement for sustainable management under which local government operates in New Zealand foreshadows consideration of intergenerational issues; public safety; as well as avoiding, remedying, or mitigating adverse effects of activities on the environment, and the avoiding or mitigating natural hazards. These together encompass criteria that have been proposed to assess the sustainability of flood protection: reversibility, fairness, risk, consensus (Simonovic, 1998), efficiency, and synergism (Kundzewicz, 2002).

7 References

Adams, B. M., Berrill, J. B., Davis, R. O., & Taber, J. J. (2000). *Modeling site effects in the Lower Hutt Valley, New Zeland.* Paper presented at the 12th World Conference on Earthquake Engineering, Auckland, New Zealand.

Adams, R. L. A. (1973). Uncertainty in nature, cognitive dissonance, and the perceptual distortion of environmental information: weather forecasts and New England beach trip decisions. *Economic Geography, 49*(4), 287-297.

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268-281.

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change Part A, 15*(2), 77-86.

Agrawal, A., & Perrin, N. (2009). Climate adaptation, local institutions and rural livelihoods. In N. W. Adger, I. Lorenzoni & K. L. O'Brien (Eds.), *Adapting to climate change: thresholds, values, governance*. Cambridge: Cambridge University Press.

Allen Consulting Group. (2005). *Climate change risk and vulnerability: Promoting an efficient adaptation response in Australia. Final report. Report to the Australian Greenhouse Office*. Melbourne: Allen Consulting Group.

Amundsen, H., Berglund, F., & Westskog, H. (2010). Overcoming barriers to climate change adaptation - a question of multilevel governance? *Environment and Planning C: Government and Policy, 28*(2), 276-289.

Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal, 99*(394), 116-131.

Ballantyne, M., Paton, D., Johnston, D., Kozuch, M., & Daly, M. (2000). *Information on volcanic and earthquake hazards: the impact on awareness and preparation. Institute of Geological and Nuclear Sciences Limited Science Report No. 2000/2*. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences.

Barnett, J., & O'Neill, S. (2010). Maladaptation. *Global Environmental Change, 20*(2), 211-213.

Bell, R. E., Ferraccioli, F., Creyts, T. T., Braaten, D., Corr, H., Das, I., et al. (2011). Widespread persistent thickening of the East Antarctic Ice Sheet by freezing from the base. *Science, 331*(6024), 1592-1595.

Berkhout, F. (2002). Technological regimes, path dependency and the environment. *Global Environmental Change, 12*(1), 1-4.

Boon, D., Perrin, N. D., Dellow, G. D., Dissen, R. V., & Lukovic, B. (2011, 14-16 April). *NZS1170.5:2004 Site Subsoil Classification of Lower Hutt.* Paper presented at the Ninth Pacific Conference on Earthquake Engineering: Building an Earthquake-Resilient Society, Auckland, New Zealand.

Botzen, W. J. W., & Van Den Bergh, J. C. J. M. (2009). Managing natural disaster risks in a changing climate.(research article)(Report). *Environmental Hazards, 8*(3), 209(217).

Burby, R. J. (2006). Hurricane Katrina and the paradoxes of government disaster policy: bringing about wise governmental decisions for hazardous areas. *The ANNALS of the American Academy of Political and Social Science, 604*(1), 171-191.

Burby, R. J., & French, S. P. (1981). Coping with floods: the land use management paradox. *Journal of the American Planning Association, 47*(3), 289-300.

Burton, I. (1997). Vulnerability and adaptive response in the context of climate and climate change. *Climatic Change, 36*(1), 185-196.

Callaway, J. M. (2004). Adaptation benefits and costs: are they important in the global policy picture and how can we estimate them? *Global Environmental Change Part A, 14*(3), 273-282.

Campbell, J. B. (2007). *Introduction to remote sensing*. New York: Guildford Press.

Crabbé, P., & Robin, M. (2006). Institutional Adaptation of Water Resource Infrastructures to Climate Change in Eastern Ontario. *Climatic Change, 78*(1), 103-133.

Cracknell, A. P., & Hayes, L. (2008). *Introduction to remote sensing* (2nd ed.). London: Taylor & Francis.

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography, 20*(4), 529-539.

David, P. A. (1985). Clio and the Economics of QWERTY. *The American Economic Review, 75*(2), 332-337.

de Bruin, K. C., & Dellink, R. B. (2011). How harmful are restrictions on adapting to climate change? *Global Environmental Change, 21*(1), 34-45.

Dessai, S., Lu, X., & Risbey, J. S. (2005). On the role of climate scenarios for adaptation planning. [doi: 10.1016/j.gloenvcha.2004.12.004]. *Global Environmental Change Part A, 15*(2), 87-97.

Downton, M. W., Morss, R. E., Wilhelmi, O. V., Gruntfest, E., & Higgins, M. L. (2005). Interactions between scientific uncertainty and flood management decisions: Two case studies in Colorado. *Global Environmental Change Part B: Environmental Hazards, 6*(3), 134-146.

Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D. A., Molefe, J. I., Nhemachena, C., et al. (2011). When not every response to climate change is a good one: identifying principles for sustainable adaptation.(Report). *Climate and Development, 3*(1), 7(14).

Eriksen, S., & Kelly, P. M. (2007). Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change, 12*(4), 495-524.

Fankhauser, S., Smith, J. B., & Tol, R. S. J. (1999). Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics, 30*(1), 67-78.

Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford, CA: Stanford University Press.

Flick, U. (2009). *An introduction to qualitative research* (4 ed.). London: Sage Publications.

Fünfgeld, H., & McEvoy, D. (2011). *Framing Climate Change Adaptation in Policy and Practice. VCCCAR Project: Framing Adaptation in the Victorian Context. Working Paper 1*. Melbourne, Australia: RMIT University.

Gardner, A. S., Moholdt, G., Wouters, B., Wolken, G. J., Burgess, D. O., Sharp, M. J., et al. (2011). Sharply increased mass loss from glaciers and ice caps in the Canadian Arctic Archipelago. *Nature, advance online publication*.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6-7), 897-920.

Glavovic, B. C. (2010). The Role Of Land-Use Planning In Disaster Risk Reduction: An Introduction To Perspectives From Australasia. *The Australasian Journal of Disaster and Trauma Studies, 2010-1*.

Gordon, P., & Little, R. G. (2009). Rethinking Flood Protection. *Public Works Management & Policy, 14*(1), 37-54.

Greater Wellington Regional Council. (2009, 06/10/2009). About GW & the Region: Our role: Some facts about the region. Retrieved 17 December, 2010, from http://www.gw.govt.nz/Some-facts-about-the-region/

Greater Wellington Regional Council. (2010). Upstream. *Newsletter, 1*(November 2010), 1-4.

Greater Wellington Regional Council. (2011a, 28/02/2011). The Hutt River at Birchville. Retrieved 28 February, 2011, from http://www.gw.govt.nz/hutt-river-at-birchville/show/108

Greater Wellington Regional Council. (2011b, 26/08/2011). Hutt River at Taita Gorge. Retrieved 26 August, 2011, from http://www.gw.govt.nz/hutt-river-at-taita-gorge/show/8?fromDate=01%2F01%2F2001+11%3A01&toDate=25%2F08%2F2011+11%3A01

Greater Wellington Regional Council. (2011c, 01/02/2011). Waiwhetu Stream: Floodplain Management Plan. Retrieved 28 February, 2011, from http://www.gw.govt.nz/FMP-Waiwhetu/

Harvatt, J., Petts, J., & Chilvers, J. (2011). Understanding householder responses to natural hazards: flooding and sea-level rise comparisons. *Journal of Risk Research, 14*(1), 63-83.

Insurance Council of New Zealand. (2009, November 2009). Current issues: Weather losses: The cost of disasters. Retrieved 23 February, 2011, from http://www.icnz.org.nz/current/weather/

Intergovernmental Panel on Climate Change. (2001). *Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change*. Cambridge, United Kingdom, and New York, NY, USA.

Intergovernmental Panel on Climate Change. (2007a). *Climate Change 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007b). *Climate Change 2007: Contribution of Working Group II to the Fourth Assessment Report.* Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change (Ed.). (2007c). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Ivey, J. L., Smithers, J., de Loë, R. C., & Kreutzwiser, R. D. (2004). Community Capacity for Adaptation to Climate-Induced Water Shortages: Linking Institutional Complexity and Local Actors. *Environmental Management, 33*(1), 36-47.

Kulig, J. C., Edge, D., Reimer, W., Townshend, I., & Lightfoot, N. (2009). Levels of Risk: Perspectives from the Lost Creek Fire. *The Australian Journal of Emergency Management, 24*(2), 33-39.

Kundzewicz, Z. W. (1999). Flood protection - sustainability issues. *Hydrological Sciences Journal, Special Issue: Barriers to Sustainable Management of Water Quantity and Quality, 44*(4), 559-571.

Kundzewicz, Z. W. (2002). Non-structural Flood Protection and Sustainability. *Water International, 27*(1), 3-13.

Kunreuther, H. (2008). Reducing losses from catastrophic risks through long-term insurance and mitigation. *Social Research, 75*(3), 905-930.

Kunreuther, H., Meyer, R., Zeckhauser, R., Slovic, P., Schwartz, B., Schade, C., et al. (2002). High Stakes Decision Making: Normative, Descriptive and Prescriptive Considerations. *Marketing Letters, 13*(3), 259-268.

Kunreuther, H. C., & Michel-Kerjan, E. O. (2007). Climate change, insurability of large-scale disasters, and the emerging liability challenge. *University of Pennsylvania Law Review, 155*(6), 1795-1842.

Lamond, J., Proverbs, D., & Antwi, A. (2008). The effect of floods and floodplain designation on value of property: An analysis of past studies (pp. 633-642).

Lawrence, J., & Allan, S. (2009). *A strategic framework and practical options for integrating flood risk management-to reduce flood risk and the effects of climate change. Report prepared for the Ministry for the Environment.* Wellington.

Lawrence, J., Tegg, S., Reisinger, A., & Quade, D. (2011). *Hutt Valley flood vulnerability. Prepared for the Ministry of Science and Innovation*. Wellington: New Zealand Climate Change Research Institute, School of Geography, Environment and Earth Sciences, Victoria University of Wellington.

Lee, O. (1999). Science Knowledge, World Views, and Information Sources in Social and Cultural Contexts: Making Sense After a Natural Disaster. *American Educational Research Journal, 36*(2), 187-219.

Lindell, M. K., & Prater, C. S. (2002). Risk area residents’ perceptions and adoption of seismic hazard adjustments. *Journal of Applied Social Psychology, 32*(11), 2377-2392.

Lyle, T. S. (2001). *Non-structural flood management: Solutions for the Lower Fraser Valley, British Columbia.* Simon Fraser University, Burnaby, British Columbia, Canada.

Measham, T., Preston, B., Smith, T., Brooke, C., Gorddard, R., Withycombe, G., et al. (2011). Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies for Global Change, Online First*, 1-21, doi: 10.1007/s11027-11011-19301-11022.

Metzger, M. J., Leemans, R., & Schröter, D. (2005). A multidisciplinary multi-scale framework for assessing vulnerabilities to global change. *International Journal of Applied Earth Observation and Geoinformation, 7*(4), 253-267.

Metzger, M. J., & Schröter, D. (2006). Towards a spatially explicit and quantitative vulnerability assessment of environmental change in Europe. *Regional Environmental Change, 6*, 201-216.

Ministry for the Environment. (2008a). *Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand (2nd edition)*. Retrieved from http://www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/climate-change-effect-impacts-assessment-may08.pdf.

Ministry for the Environment. (2008b). *Coastal hazards and climate change: A guidance manual for local government in New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2008c). *Meeting the challenges of future flooding in New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2008d). *Preparing for climate change: A guide for local government in New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2009). *Preparing for coastal change: A guide for local government in New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2010a). *Preparing for future flooding: A guide for local government in New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2010b). *Tools for estimating the effects of climate change on flood flow: A guidance manual for Local Government in New Zealand*. Wellington: Ministry for the Environment.

Morrow, B. H. (1999). Identifying and Mapping Community Vulnerability. *Disasters, 23*(1), 1-18.

Mukheibir, P., & Ziervogel, G. (2007). Developing a Municipal Adaptation Plan (MAP) for climate change: the city of Cape Town. *Environment and Urbanization, 19*(1), 143-158.

Næss, L. O., Bang, G., Eriksen, S., & Vevatne, J. (2005). Institutional adaptation to climate change: Flood responses at the municipal level in Norway. *Global Environmental Change Part A, 15*(2), 125-138.

Neisser, U. (1996). Remembering the Earthquake: Direct Experience vs. Hearing the News. *Memory, 4*(4), 337-358.

New Zealand Parliament. (2004). *Resource Management (Energy and Climate Change) Amendment Act 2004*. Wellington: New Zealand Parliament.

New Zealand Parliament. (2010). *Resource Management Act 1991. Reprint as at 16 December 2010*. Wellington: New Zealand Parliament.

Norris, F. H., & Kaniasty, K. (1992). Reliability of delayed self-reports in disaster research. *Journal of Traumatic Stress, 5*(4), 575-588.

O'Neill, S., & Barnett, J. (2010, 29 June - 1 July). *Defining and assessing maladaptation.* Paper presented at the National Climate Change Adaptation Research Facility (NCCARF) Conference: International Climate Change Adaptation Conference: Climate Adaptation Futures: Preparing for the unavoidable impacts of climate change, Gold Coast, Australia.

Pallant, J. (2007). *SPSS survival manual : A step-by-step guide to data analysis using SPSS for Windows (Version 15)* (3 ed.). Maidenhead: Open University Press.

Paton, D. (2003). Disaster preparedness: A social-cognitive perspective. *Disaster Prevention and Management, 12*(3), 210-216.

Paton, D., & Johnston, D. (2001). Disasters and communities: vulnerability, resilience and preparedness. *Disaster Prevention and Management, 10*(4), 270-277.

Pini, B., Wild River, S., & McKenzie, F. M. H. (2007). Factors Inhibiting Local Government Engagement in Environmental Sustainability: case studies from rural Australia. *Australian Geographer, 38*(2), 161-175.

Preston, B. L., Smith, T., Brooke, C., Gorddard, R., Measham, T., Withycombe, G., et al. (2008). *Mapping Climate Change Vulnerability in the Sydney Coastal Councils Region*. Canberra: Prepared for the Sydney Coastal Councils Group by the CSIRO Climate Adaptation Flagship.

Preston, B. L., & Stafford-Smith, M. (2009). *Framing vulnerability and adaptive capacity assessment: Discussion paper*. Aspendale, VIC: CSIRO Climate Adaptation Flagship.

Pryce, G., Chen, Y., & Galster, G. (2011). The Impact of Floods on House Prices: An Imperfect Information Approach with Myopia and Amnesia. *Housing Studies, 26*(2), 259-279.

Rahmstorf, S., Cazenave, A., Church, J. A., Hansen, J. E., Keeling, R. F., Parker, D. E., et al. (2007). Recent climate observations compared to projections. *Science, 316*(5825), 709.

Reisinger, A. (2009). Closing windows and opening flood gates: Recent climate science and implications for climate policy. *Policy Quarterly, 5*(2), 45-51.

Reisinger, A., Lawrence, J., Hart, G., & Chapman, R. (2012). From coping to managed retreat: The role of managed retreat in highly developed coastal regions. In B. Glavovic, R. C. Kay, M. Kelly & A. Travers (Eds.), *Climate change and the coast: Building resilient communities*: Taylor & Francis.

Reisinger, A., Wratt, D., & Mullan, B. (2010, 29 June - 1 July). *Scenarios vs. probabilistic futures: Towards a risk-based understanding of climate change and adaptation priorities.* Paper presented at the National Climate Change Adaptation Research Facility (NCCARF) Conference: International Climate Change Adaptation Conference: Climate Adaptation Futures: Preparing for the unavoidable impacts of climate change, Gold Coast, Australia.

Rignot, E., Velicogna, I., Broeke, M. R. v. d., Monaghan, A., & Lenaerts, J. (2011). Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise. *Geophysical Research Letters, 38*(L05503).

Scheraga, J. D., & Grambsch, A. E. (1998). Risks, opportunities, and adaptation to climate change. *Climate Research, 10*, 85-95.

Schneider, S. H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C. H. D., Oppenheimer, M., et al. (2007). Assessing key vulnerabilities and the risk from climate change. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. v. d. Linden & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 779-810). Cambridge, UK: Cambridge University Press.

Schröter, D., & ATEAM consortium. (2004). *Global change vulnerability: assessing the European human-environment system*. Potsdam, Germany: Potsdam Institute for Climate Impact Research.

Seeger, M. W., Sellnow, T. L., & Ulmer, R. R. (2003). *Communication and organizational crisis*. Westport, CT: Praeger.

Shakhova, N., Semiletov, I., Salyuk, A., Yusupov, V., Kosmach, D., & Gustafsson, Ö. (2010). Extensive Methane Venting to the Atmosphere from Sediments of the East Siberian Arctic Shelf. *Science, 327*(5970), 1246-1250.

Simonovic, S. P. (1998). Sustainability criteria for possible use in reservoir analysis. In K. Takeuchi, M. Hamlin, Z. W. Kundzewicz, D. Rosbjerg & S. P. Simonovic (Eds.), *Sustainable reservoir development and management. IAHS Publication no. 251* (pp. 55-58). Wallingford, UK: International Association of Hydrological Sciences (IAHS) Press.

Smit, B. (1993). *Adaptation to Climatic Variability and Change: Report of the Task Force on Climate Adaptation. Prepared for the Canadian Climate Program, Department of Geography Occasional Paper No. 19*. Guelph, Ontario, Canada: University of Guelph.

Smit, B., & Pilifosova, O. (2003). From adaptation to adaptive capacity and vulnerability reduction. In J. B. Smith, R. J. T. Klein & S. Huq (Eds.), *Climate change, adaptive capacity and development* (pp. 9-28). Loondon: Imperial College Press.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*(3), 282-292.

Spence, P. R., Lachlan, K. A., & Griffin, D. R. (2007). Crisis Communication, Race, and Natural Disasters. *Journal of Black Studies, 37*(4), 539-554.

Stevens, M., Song, Y., & Berke, P. (2010). New Urbanist developments in flood-prone areas: safe development, or safe development paradox? *Natural Hazards, 53*(3), 605-629.

Sunstein, C. R. (2007). On the divergent American reactions to terrorism and climate change. *Columbia Law Review, 107*(2), 503-557.

Swart, R., Biesbroek, R., Binnerup, S., Carter, T. R., Cowan, C., Henrichs, T., et al. (2009). *Europe adapts to climate change: Comparing national adaptation strategies. PEER Report No 1.* Helsinki: Partnership for European Environmental Research.

Terpstra, T., & Gutteling, J. M. (2008). Households' Perceived Responsibilities in Flood Risk Management in The Netherlands. *International Journal of Water Resources Development, 24*(4), 555-565.

Tobin, G. A. (1995). The levee love affair: a stormy relationship? *JAWRA Journal of the American Water Resources Association, 31*(3), 359-367.

Turner II, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., et al. (2003). A Framework for Vulnerability Analysis in Sustainability Science. *Proceedings of the National Academy of Sciences of the United States of America, 100*(14), 8074-8079.

Turner II, B. L., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., et al. (2003). Illustrating the Coupled Human-Environment System for Vulnerability Analysis: Three Case Studies. *Proceedings of the National Academy of Sciences of the United States of America, 100*(14), 8080-8085.

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy, 28*(12), 817-830.

Unruh, G. C., & Carrillo-Hermosilla, J. (2006). Globalizing carbon lock-in. *Energy Policy, 34*(10), 1185-1197.

Van Stokkom, H. T. C., & Witter, J. V. (2008). Implementing integrated flood risk and land-use management strategies in developed deltaic regions, exemplified by The Netherlands. *International Journal of River Basin Management, 6*(4), 331-338.

Vermeer, M., & Rahmstorf, S. (2009). Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences of the United States of America, 106*(51), 21527-21532.

Walker, W. (2000). Entrapment in large technology systems: institutional commitment and power relations. *Research Policy, 29*(7-8), 833-846.

Weinstein, N. D. (1989). Effects of personal experience on self-protective behavior. *Psychological Bulletin, 105*(1), 31-50.

Weitkamp, C. (2005). *Lidar: range-resolved optical remote sensing of the atmosphere* New York: Springer.

Wellington Regional Council. (1991). *The Hutt River: A modern history 1840-1990*. Wellington: Wellington Regional Council.

Wellington Regional Council. (2001). *Hutt River Floodplain Management Plan: For the Hutt River and its Environment*. Wellington: Wellington Regional Council.

Wild River, S. (2006). Australian Local Government Attempts to Deliver Beneficial Environmental Outcomes. *Local Environment, 11*(6), 719-732.

Yohe, G., & Tol, R. S. J. (2002). Indicators for social and economic coping capacity - moving toward a working definition of adaptive capacity. *Global Environmental Change, 12*(1), 25-40.