**Impacts of Climate Change on Urban Infrastructure & the Built Environment**

**A Toolbox**

# Tool 4.1: Climate Change Adaptation – Key Concepts

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# Contents

# 1. Introduction

## 1.1 Background

What are the likely impacts of climate change for my town or city? What adaptation options should we explore? What are the costs and benefits? Many urban councils in New Zealand are asking these very questions and seeking guidance on the best way to find the answers. One approach is to adopt the following stepwise process from Jacob et al., (2000): 1. Review the state of knowledge on current hazards; 2. Extrapolate future hazards; 3. Assess consequences in terms of likely losses and impacts (requires details on assets, fragilities, risk exposure); and 4. Explore coping and adaptation strategies. This stepwise process based approach is central to the design of the "Impacts of Climate Change on Urban Infrastructure and the Built Environment" Toolbox, where Trays 1 – 4 mimic the above steps, and Tray 5 provides some key messages for using the Tools and improving practice.

While stepping through the Toolbox, or picking out specific Tools to help guide individual pieces of assessment work, it is useful to be aware of the larger picture of where climate change adaptation fits in. This involves having an appreciation of the wider context of decision-making in local government, as well as an understanding of some of the key concepts associated with hazard assessment, risk reduction and climate change.

## 1.2 Purpose of Tool

This Tool provides some climate change adaptation key concepts based on a literature review of primarily urban-based climate change studies. The purpose of this summary is to identify the many issues associated with preparing for and adapting to present-day and future weather and climate hazards in urban (and rural, to some extent) settings. The following sections briefly address some of the key concepts of climate change adaptation as well as some of the wider issues that influence decision making.

# 2. Context of Decisions

All good decisions are made by carefully considering the context within which the consequences and interdependencies of the decision reside. Hunter et al. (2010) describe the context of infrastructure related decision-making in local government:

> "Local governments face many challenges in delivering their infrastructure responsibilities, including access to reliable and

relevant data; challenges in translating the big picture to regional and local levels; (the vulnerability of the locale to various hazards); and the need to manage political risks and get councillor ‘buy-in’ and support.”

### 2.1 Multiple stressors

Climate change affects all the above challenges, and in many circumstances intensifies the challenges currently faced by utility operators (Danilenko et al., 2010). Thus, climate change must be regarded as an additional stressor on a system rather than an isolated effect. Adaptation activities to address climate change-related risks should be considered in relation to all the other stressors and dependencies that are specific to a region or population, including specific population and regional vulnerabilities, social and cultural factors, and the state of the built and natural environment (Ebi and Semenza, 2008).

### 2.2 Learning from the past

Historical context is extremely important for decision-making (Glantz et al., 2009), and in particular the knowledge of the impacts of past extreme events (locally, and in other regions and countries) is a key learning tool (Kenny, 2010). Designing and maintaining water and energy infrastructure systems that work well during present-day extreme events is a major step toward adapting for future climate change.

## 3. Needs of Decision Makers

Climate change has added a new layer of complexity to decision making. Historically, infrastructure design was based on past climatic conditions from which estimates of extreme events were derived. In a changing climate, these past conditions are no longer accurate indicators for planning, maintenance and upgrades. New guidelines are needed for municipal infrastructure, to ensure safety and quality of life and to reduce long-term costs (Roberts, 2008). The Australian Greenhouse Office advise:

> “When managing climate variability in the future, organisations cannot simply rely on the assumption that the prevailing climate will be more or less the same as it was over the past 50 or 100 years. We can expect to live and operate in a climate … that progressively will become different from the current climate in many ways” (Australian Greenhouse Office, 2006).

## 3.1 Guidance

Policy-makers require appropriate information, including vulnerability assessments and predictive models to help them prioritize and be guided in the right direction (Baker et al., 2010). Top-down approaches (to understanding climate change impacts and vulnerabilities) can be used to empower bottom-up responses (such as an evaluation of site-specific adaptation options).

Guidance needs to be practical, which requires it being simple enough to understand and yet sufficiently detailed (Demeritt and Langdon, 2004). For example, the current MfE (2008) climate change guidance is regarded by many stormwater practitioners in New Zealand as useful in that it provides a simple tool for adjusting storm rainfalls [see Tool 2.4.2]. However, the use of the guidance needs to be carefully monitored to ensure it is being applied correctly.

## 3.2 Tools

The "Impacts of Climate Change on Urban Infrastructure and the Built Environment" Toolbox was conceptualised as a result of a perceived need from urban councils in New Zealand for help when faced with the questions: "what will climate change mean for us?" and "what can we do about it?" The Toolbox is designed to step practioners through an evaluative process by providing Tools that can be used to define and implement a research programme to answer these questions.

Every town and city in New Zealand is different and each is faced with different challenges, thus no one solution will fit all. However, the evaluative process (represented by the "Trays" in the Toolbox) can be used as a consistent template that can be populated by an applicable set of Tools or other sources of information.

In addition to the use of tools such as those in the Toolbox, Allman et al. (2004) describe other factors that would support climate change adaptation planning, including increased awareness of climate change amongst council members, officers, the public and local businesses; and innovative mechanisms for raising funding, sharing knowledge and developing best practice between authorities.

# 4. Communication

Climate change is a widely discussed topic. There is an overall scientific consensus on the causes of climate change and the likely global-scale impacts, but there is considerable uncertainty as to the impacts at the local scale. The level of scientific complexity needed to explain why such uncertainty exists is sometimes difficult to communicate. Add in some misinformation and people are easily alienated and/or confused (Frumkin et al., 2008).

### 4.1 Participatory design

The key to successful adoption of climate action plans based on sound science and tailored products, is multiple-stage targeted end user participation (Danilenko et al., 2010). Participatory design supports mutual learning and capacity building between end users and developers, and leads to gains in research and development (Driedger et al., 2007).

Community 'buy-in' from an early stage can be propagated outwards to build awareness, encourage policy changes and develop strong public education and outreach (Roberts, 2008). Local-scale adaptation projects designed for 'win-win' solutions (i.e. enhanced flood protection designed to cope with future events has the co-benefit of reducing present-day flood risk) can be used to demonstrate effective climate change adaptation in action. Such case studies should be shared nationally and internationally to motivate and inspire (Hunter et al., 2010).

## 5. Integration / Mainstreaming

A key responsibility of local government in New Zealand is to provide fundamental levels of service (e.g. water supply, transportation routes, and wastewater) and protection from natural hazards (e.g. flooding, coastal inundation, and landslides) to the community. The resources available to assess protection schemes and infrastructure design and performance for meeting this responsibility are in common usage: e.g. risk assessment, hazard management, low impact urban design, community consultation, and others. All of these approaches are central to and should be used for climate change adaptation (Hunter et al., 2010). Roberts (2008) concludes:

> "Climate change issues need to be rooted in local realities that centre on avoiding or limiting impacts from, for instance, heat waves, heavy rainfall and storm surges and sea-level rise, and also the ecological changes and water supply constraints brought about by climate change" (Roberts, 2008).

It is extremely unlikely for any adaptive work to be undertaken based on analyses of climate change impacts alone (Smit and Wandel, 2006). The New Zealand Ministry of the Environment recommends a mainstreaming approach, whereby 'adaptation to climate change is integrated and anchored in policy mechanisms that are already established to respond across the different sectors' (Ministry for the Environment, 2004).

### 5.1 Modifications to existing initiatives

According to Smit and Wandel (2006), adaptation to climate change involves incremental modifications to existing initiatives. Practical climate change adaptation initiatives must be integrated or incorporated into existing policies, programs, or decision-making processes. These will be related to resource management, community development, livelihood enhancements, coastal zone management, sustainable development and risk management (Smit and Wandel, 2006).

### 5.2 Indicators of integration

Successful integration and mainstreaming of climate change adaptation plans can be evaluated using institutional markers similar to the ones outlined below (Roberts, 2008):

- the emergence of an identifiable political/administrative champion(s) for climate change issues;
- the appearance of climate change as a significant issue in mainstream municipal plans;
- the allocation of dedicated resources (human and financial) to climate change issues; and
- the incorporation of climate change considerations into political and administrative decision making.

Research focusing on the implementation processes for and evaluation processes of climate change adaptation is still uncommon (Smit and Wandel, 2006).

## 6. Climate Change Models, Projections and Scenarios

The most up-to-date source of information on climate change projections and likely impacts for New Zealand can be found on the Ministry for the Environment webpage http://www.mfe.govt.nz/publications/climate/ [see Tool 1.7 for more details].

Regional climate change modelling and impacts research is undertaken by several institutes in New Zealand (e.g. NIWA). While research is continuing to refine our understanding of what climate change might mean for New Zealand (see http://www.niwa.co.nz/our-science/climate/research-projects, for example), it is important to realise that projections of the future climate will always be presented as a *range* of possible changes. This is due to the inability of computer models to perfectly reproduce the complexity of the climate-ocean system and to the lack of knowledge of the exact pathway of future greenhouse gas emissions. As a result, climate change information can only be presented as a set of 'what if' scenarios. To date, no objective means have been developed to identify and particular scenario as being more or less likely than others, reflecting the indeterminacy of collective human choices (Reisinger et al., 2010).

In addition to projections of the changes to average conditions, there is substantial ongoing research (e.g. work on a dynamic Regional Climate Model at NIWA) on the changes to the day-to-day and year-to-year variability of the climate. Such work is vital as some of the most important impacts are the expected changes to the rates at which various key aspects of climate change occurs. If the rates change incrementally and societies are aware of those changes, those societies may be able to adjust human activities accordingly (Glantz et al., 2009).

Lastly, one of the key research questions currently being addressed is how to down-scale Global Climate Models (GCMs) from their current level of analytical resolution (i.e. usually a monthly time step at a spatial resolution of several tens of thousands of square kilometres) to a spatial and temporal scale that is useful for utility planning purposes (Bates et al., 2008). Research into down-scaling methodologies as well as into the feasibility and benefits of high resolution dynamic models is a high priority at NIWA.

## 7. Impact Analyses

The principal manifestations of climate change include higher temperatures, altered rainfall patterns, and more frequent or intense extreme events such as heatwaves, drought and storms (Australian Greenhouse Office, 2006). Understanding the likely impacts of these climatic changes is a burgeoning research field. Some impact analyses need no more detail than a broad indication of the direction of change (e.g. as stated above), particularly if the purpose is to provide a generalised qualitative risk assessment. However, other assessments need detailed climate data projections as input into process-based impact models [see Tools 2.1.3, 2.3.3, 2.4.4 and 2.5.3, as examples]. Smit et al. (2000) conclude:

> "Conceptual process models of impact assessment and adaptation optioneering specify sequential relationships and feedbacks, such as climatic (and non-climatic) stimuli, sensitivity and vulnerability of systems, short-term or

> autonomous adaptations, initial impacts, longer-term or strategic adaptations, and net or residual impacts" (Smit et al., 2000).

Adaptation options (e.g. changes to landuse/zoning, infrastructure upgrades, introduction of regulation) should be designed to provide multiple benefits (i.e. 'win-win' solutions), be modular and flexible so that future enhancements can be easily made, and be properly evaluated to determine their effectiveness (Smit et al., 2000).

# 8. Risk / Vulnerability Assessment

Vulnerability and risk assessment involves understanding present-day exposure to hazards as well as the predicted impacts from climate change for different geographic ecosystems, populations, and sectors (Baker et al., 2010). On the basis of vulnerability assessments, local governments and utility owners are better able to analyse the extent to which system components are exposed to climate change against their operation and value, and identify adaptation measures that reduce potential exposure and improve resilience (Danilenko et al., 2010).

Tool 1.3 in this Toolbox provides an introduction to risk assessment based on New Zealand examples. It is a starting point for choosing the most appropriate risk assessment methods to employ, depending on the nature of the climate change issues of concern and the decisions to be made. A related document [Tool 3.1] provides more in-depth information and guidance on quantifying climate risks. While the complexity in risk assessment methods provides a greater challenge for an assessment, it should be noted that the participatory approach allows multiple perspectives to contribute to a richer set of outcomes (Jones, 2010).

## 8.1 Likelihood of exceedence

One way to manage the complexity of vulnerability and risk assessments is by focussing on a given threshold within a broad range of uncertainty to determine its likelihood of being exceeded within a given planning horizon. For example, Wellington City Council is developing a climate change adaption plan incorporating a risk assessment of projected impacts from several sea level rise projections between 0.5 and 2m. Such threshold-based analyses focus attention on impacts and adaptation, rather than on climate change itself (Jones, 2010).

# 9. Economic / Social Costs & Benefits

Jacob et al. (2000) identify two essential questions that utility owners must ask themselves once a hazard risk assessment has been performed and a set of adaptation options has been suggested: 1) For each possible action, what costs or benefits if any will be incurred compared with doing nothing? and 2) Are there cost-effective actions that can be taken to minimise negative effects on the systems or maximise the benefits?

Glantz et al. (2009) agree that recommendations for adaptation should not be presented without comment (at least) on what the consequences might be if they are not addressed – i.e. a cost of inaction.

## 9.1 Discounting future costs and benefits

Most people tend to value present-day events and knowledge more highly than past events and knowledge or possible futures. Economists call this discounting, because, put simply, people have to survive the present in order to participate in the future (Glantz et al., 2009). Choosing an appropriate discount rate can make a sizeable difference in the cost-effectiveness of an adaptation action, especially if the majority of benefits are perceived to be far into the future. Using a high discount rate decreases the assessed benefit of future actions. The Stern Review's (Stern, 2006) discount rate for climate change damages is approximately 1.4%, which is lower than that used in most economic studies on climate change performed up to that time.

## 9.2 Adaptation costs for infrastructure

Many possible adaptations within urban environments involve the implementation of ‘hard’ or infrastructural measures, such as new or upgraded water storage reservoirs, flood protection schemes, and desalination and waste water treatment facilities. Costing studies have tended to focus on these ‘hard’ measures, as they are easier to cost than behavioural and policy measures (Agrawala and Fankhauser, 2008). RiskScape [see Tools 3.2 and 3.3] and the Rapid Cost-Benefit Evaluation Tool [Tool 4.3] include analyses of costs associated with direct and indirect (e.g. due to the displacement of workers) impacts, although it is recognised that indirect costs are much more uncertain.

Investment in adaptation will not avoid all damages to infrastructure from extreme weather events (Parry et al., 2009). However, the costs of this *residual risk* can be offset somewhat by insurance. Insurance can be considered an instrument for incentivising adaptations aimed at reducing climate risks. Yet, because climate impacts are uncertain, insurance companies may overcharge for climate risk or refuse coverage of risks that might otherwise be insurable (Agrawala and Fankhauser, 2008).

Adaptation costs may also increase several-fold if, in addition to measures that directly reduce climate changes, measures to improve baseline “adaptive capacity” are also included within the purview of adaptation (Agrawala and Fankhauser, 2008).

# 10. Adaptation

There are several forms of adaptation described in the literature. These include anticipatory or reactive, planned or autonomous, facilitated or spontaneous (Baker et al., 2010). A common theme though, is the distinction between adaptation as naturally-occurring (reactive and autonomous) or as planned (facilitated). Adger and Vincent (2005) argue that this distinction fails to account for the ‘nested nature of decision making’ and that ‘each individual adaptation action is constrained by antecedent development and regulatory decisions’.

Resilient adaptation, according to Glantz et al. (2009), is a hybrid concept that merges the best of the suggested practices of resilience and adaptation. Resilience can be viewed as the ability to ‘bounce back’ in a timely way from adverse impacts and shocks. Adaptation refers to adjustments by societies as they deal with the impacts of a changing and variable climate.

## 10.1 An iterative process

Kenny (2010) concludes that successful adaptation needs a flexible, balanced approach and effective research to support ongoing practical innovations. Adaptation is not a one-off event or a single step, but rather an iterative process (Warrick, 2000), and developing an initial set of strategic adaptation responses to the potential impacts of climate change is only the beginning of the process (Glantz et al., 2009). Persistent revisiting and concerted staged actions are required (Baker et al., 2010).

A good strategy for incremental adaptation is to apply probabilistic trends of short duration – up to several decades in length – and update with new climate information on an ongoing basis (Jones, 2010).

## 10.2 A portfolio of actions

Projections of climate change related impacts in New Zealand urban settings usually cover a range from little change to significantly enhanced risk. In the light of this uncertainty, the development of a portfolio of actions and the ability to respond quickly to changing circumstances may be more robust than adapting to a 'most likely' outcome (Jones, 2010).

## 11. Capacity to Adapt

Even with a Toolbox of analysis methods and the overarching guiding principles of risk assessment, many urban centres in New Zealand may lack the full capacity to adapt to climate change due to limited financial and staff resources, little or no political backing and/or inflexible institutional structures. In such situations, it is critical to link adaptation to existing or planned actions that have dedicated resources (Moser et al., 2008) and integrate adaptation (if necessary, without even referring to "climate change") into related co-beneficial strategic plans, such as sustainable development.

Evidence from traditional societies suggests that the capacity to adapt also depends on 'experience, knowledge and dependency on weather-sensitive resources' (Adger and Vincent, 2005). This suggests that locations that regularly experience climate-related hazards (e.g. drought in the eastern North Island) have a greater adaptive capacity than more climate benign locations.

## 12. Barriers / Challenges

Whilst there has been considerable work to calculate indices of vulnerability and adaptive capacities, the practical applications and implications are not so readily apparent (Smit and Wandel, 2006). There may be a 'disconnect' between the science and decision-making knowledge domains. Meinke et al. (2006) conclude that:

> "Decision makers usually manage risk holistically, while scientific information is generally derived using reductionist approaches. This can lead to the scientific information lacking relevance, causing a 'relevance gap' between the information necessary to support policy and decision making and that supplied" Meinke et al., 2006).

Building local knowledge and capacity about climate change risks and adaptive responses is important, as is the sharing of this knowledge. The New Zealand Ministry of the Environment has a strong focus on presenting climate change adaptation 'Case Studies', which demonstrate how some councils are assessing and integrating climate change studies into their operations and plans. Without tangible examples, decision makers will continue seeing environmental issues as constraints on development rather than as essential underpinnings of and contributors to development (Roberts, 2008).

## 13. Dealing with Uncertainty

The problem of how to manage inherent uncertainty is core for those involved in enhancing climate change information. Policy-makers must deal with the uncertainty they are presented with, and learn how to effectively communicate it to the general public (Baker et al., 2010). Planning for an uncertain future must take a reasoned and justifiable approach of determining what elements of the system are likely to be impacted, what information will be needed to make adaptations, and what the timing of such adaptations should be (Major and Goldberg, 2000).

The likelihood of an uncertain future climate means that existing best practices should be continually revised and viewed as providing a source of tactical responses (short-term) to a changing environment (Glantz et al., 2009).

### 13.1 No regrets decisions

To help manage the uncertainty stemming from climate change projections of impacts, planners may benefit from 'no-regrets' measures to aid in decision-making (Danilenko et al., 2010).

> "Developing 'no regrets' strategies is an aspect of mainstreaming, and an approach that helps manage dilemmas, uncertainties, lack of precision in forecasting, multiple sources of contestation, and the fact that adaptation capacity is constrained by its weakest component. A 'no regrets' strategy enables climate change to be dealt with in relation to other issues. It ensures that actions taken to address the effects of climate change produce benefits, even if the effects of climate change are not as marked as anticipated. The term 'co-benefits' is used" (Rojas Blanco, 2006).

### 13.2 Small steps

Adaptation as a series of small steps that have co-benefits or, at least, are reversible is an effective method of slowly reducing climate risks. Alternative possibilities can be easily tested based on limited quantitative or even subjective information (Jones, 2010). A range of incremental policy improvements based on early indications of change and the precautionary principle in relation to future change is essential if communities are to protect their well-being in the face of climate change (Howden-Chapman et al., 2010).

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