Ministry for the Environment
Manatū Mō Te Taiao

Preparing for climate change

A guide for local government in New Zealand

adaptation

New Zealand Government

Disclaimer

This guide is a summary of *Climate Change Effects and Impacts Assessment*, a 150-page report prepared for the Ministry for the Environment by scientists, planners and engineers from NIWA, MWH NZ Ltd and Earthwise Consulting Ltd, in consultation with a range of people from local government organisations. Developing projections of future climate change is still subject to significant uncertainty. The authors have used the best available information in preparing the report on which this guide is based, and have interpreted this information exercising all reasonable skill and care. Nevertheless none of the organisations involved in its preparation accept any liability, whether direct, indirect or consequential, arising out of the provision of information in this guide or its source document.

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Source document

The source document on which this report is based is available in full on the Ministry for the Environment website at: www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/index.html.

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Introduction

Preparing for Climate Change is a guide to help local government across New Zealand assess the likely effects of projected climate change during the 21st century and plan appropriate responses where necessary. This second edition of *Preparing for Climate Change* supersedes the first edition published in 2004.

The guide summarises the main elements of a comprehensive technical report *Climate Change Effects and Impacts Assessment* ('the source report'). Its first edition was updated in May 2008 following the release of the Fourth Assessment Report on the science of climate change produced by the Intergovernmental Panel on Climate Change (IPCC) in 2007. The source report is available in full at: www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/index.html.

Some climate changes are occurring now. While greenhouse gas emission reductions both globally and locally can help slow the rate, climate change cannot be prevented entirely. Changes in a number of key climate parameters – such as temperature, rainfall and sea levels – will occur to differing extents in different parts of New Zealand throughout the 21st century and probably beyond.

New Zealand needs to adapt to these changes. Adapting to long-term climate change will also contribute to our resilience to extreme events as well as to natural fluctuations in climate, such as the El Niño / Southern Oscillation (ENSO) phenomenon.

Some of the impacts of climate change such as increased temperature, longer growing seasons and decreased frost risk, may be beneficial for some sectors of agriculture, forestry and horticulture. These benefits may be limited by negative effects such as prolonged drought, increased flood risk, or greater frequency and intensity of storms. Informed and proactive planning now can help maximise benefits and minimise the direct and indirect costs of climate change.

Local government is responsible for a range of functions that may be affected by climate. These include natural hazards and resource management, land-use planning, building control, and the provision of infrastructure such as stormwater drainage and water supply.

Climate-related risks are not new to local government planners, resource managers and emergency and hazard managers. Climate change is not expected to create new hazards, but it may change the frequency and intensity of existing risks and hazards, as well as introduce some long-term shifts in climate patterns across the country.

Local authorities have both social and legal obligations to take climate change effects into account in their decision-making. This guide explains these obligations, including those under the Resource Management Act.

A key message in the guide is that dealing with climate change effects can be broken down into manageable parts and can easily form part of existing council planning and operational processes. Managing climate change effects does not necessarily require new and additional resources. The guide suggests how councils can carry out simple checks to assess whether climate change effects are likely to be significant for a plan, project or activity. If the effects are likely to be significant, more detailed assessments are recommended and guidance is provided as to how councils might undertake these assessments.

Although the guide will help councils identify, scope and respond to climate change in their areas, it does not provide standard solutions for specific situations. Each region, district and community will have its own climate-related vulnerabilities and priorities. The guide does, however, provide some specific tools to help councils identify and respond to climate change impacts including a decision-making framework, case studies and practical checklists.

The guide comprises three distinct parts:

Part One explains the general effects of projected climate change on New Zealand, current climate variability, projected future climate changes both nationally and regionally, and how climate change may change the frequency and intensity of extreme weather events such as floods and storms.

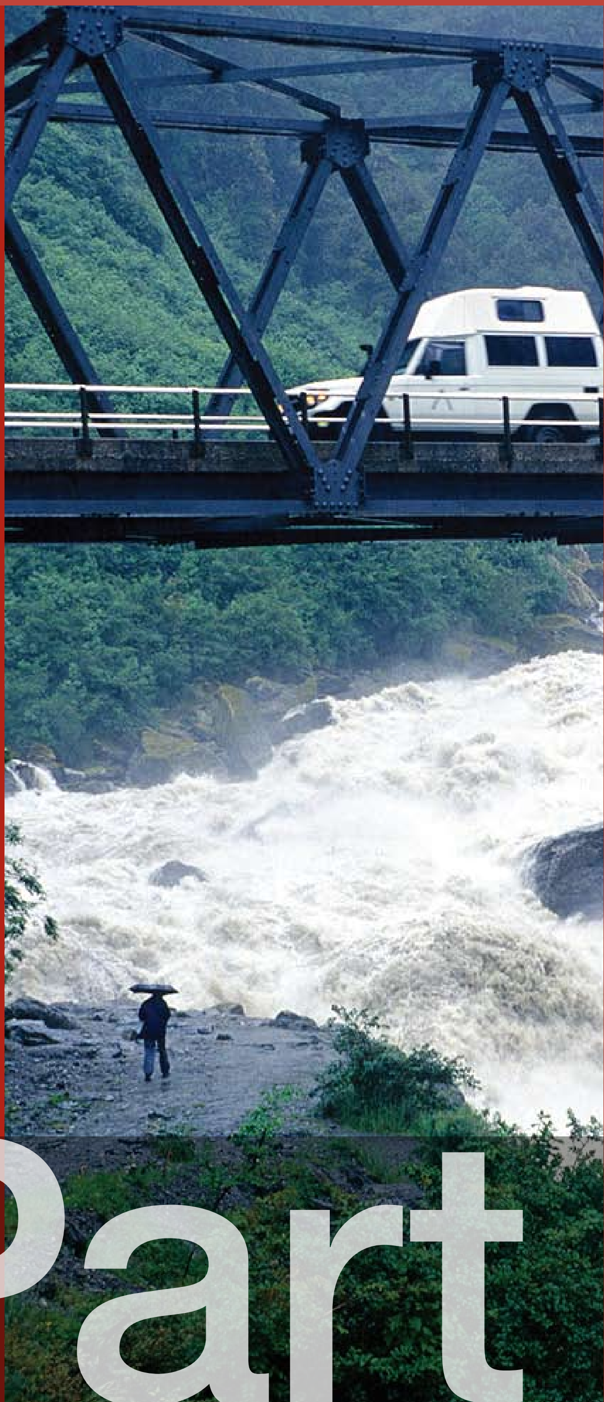
Part Two explains councils' social and legal obligations to take climate change effects into account in their planning and decision-making, the key principles that need to be considered in responding to climate change, and how to assess the impact of climate change on council functions. Checklists are provided to help ensure that climate change is considered in various plans.

Part Three outlines how councils can integrate climate change considerations into council decision-making, and assess both qualitatively and, if necessary, quantitatively what effect climate change could have on specific council functions and services.

Target audiences

Preparing for Climate Change is targeted at those who are involved in local government decision-making, in particular:

- strategic and policy planners
- asset managers charged with planning future asset needs for communities and resolving existing and emerging problems
- engineers charged with designing infrastructure to meet foreseeable risks
- those responsible for natural hazards management, emergency management and 'lifeline' utilities and infrastructure
- staff handling resource consent and building consent applications
- staff responsible for council databases, particularly those providing information on hazards and risks to private landowners and other agencies.



Part One

Current and future climate

This part covers:

- projected climate change effects at national level and, where possible, at a regional level
- possible changes in the intensity of extreme weather events such as floods and storms
- current variability of New Zealand's climate
- significance of climate change versus natural climate variability.

Future climate

Predictions of future climate depend on projections of future concentrations of greenhouse gases and aerosols, as well as on model assessments of how the global climate system will respond to these changing concentrations. Future greenhouse gas concentrations depend on future emissions, which depend in turn on national and international policies, and changes in population, economic growth, technology and energy availability.

The maps in Figures 1–3 show projected patterns for temperature and precipitation derived from models assuming greenhouse gas emissions follow a course described in the source report as 'middle-of-the-road'.

Because natural effects cause the New Zealand climate to vary from year to year (see Figure 4), the changes are specified in terms of the average change for the period 2030–2049 (referred to below as 2040), and for 2080–2099 (similarly referred to as 2090), relative to the climate of 1980–1999 (1990).

The source report on which this guide was based provides full technical detail about how the New Zealand projections were developed.

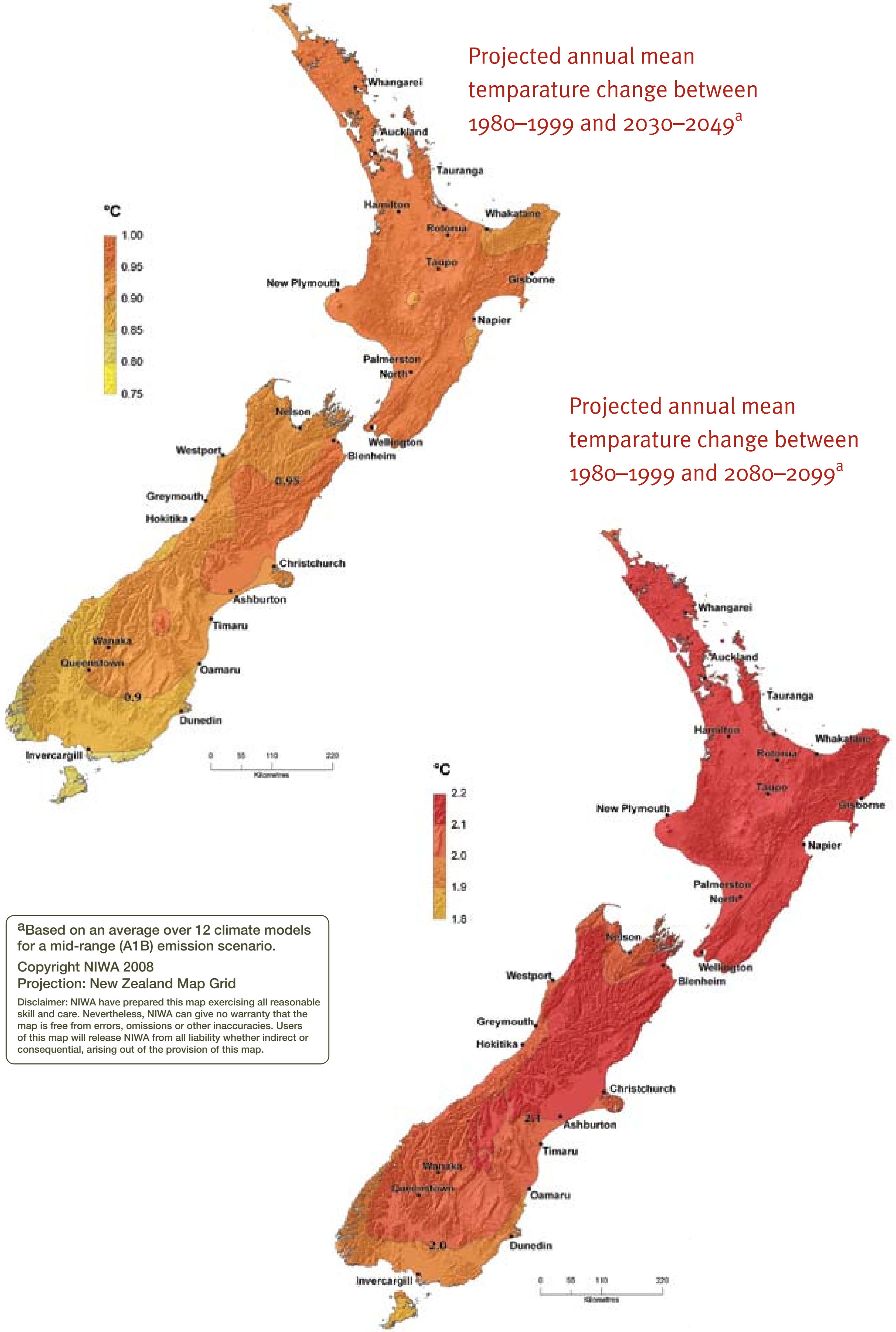
Changes in temperature

The mid-range projections are that New Zealand temperatures will increase by about 1°C by 2040, and 2°C by 2090, relative to 1990. However quite a wide range of future warming is projected for New Zealand when the results of all the models are analysed and all IPCC emissions scenarios are considered: 0.2–2.0°C by 2040 and 0.7–5.1°C by 2090.

Figure 1 shows that the annual-average pattern of warming is projected to be fairly uniform over the country, although slightly greater over the North Island than the South Island. In summer and autumn (not shown), the North Island and northwest of the South Island have the greatest warming, whereas in the winter season the South Island has the greatest warming. Spring has the least warming of all seasons.

Figure 1: Projected mid-range changes in annual mean temperature (in °C) relative to 1990.

The changes shown are an average of the results of 12 climate models for a mid-range IPCC emissions scenario. Note the different temperature scales for 2040 and 2090. These maps are intended to illustrate broad geographical patterns of climate change within New Zealand. They should not be used as definitive predictions of climate change for specific geographical locations. Projections for specific regions are provided in Tables 2 and 3.

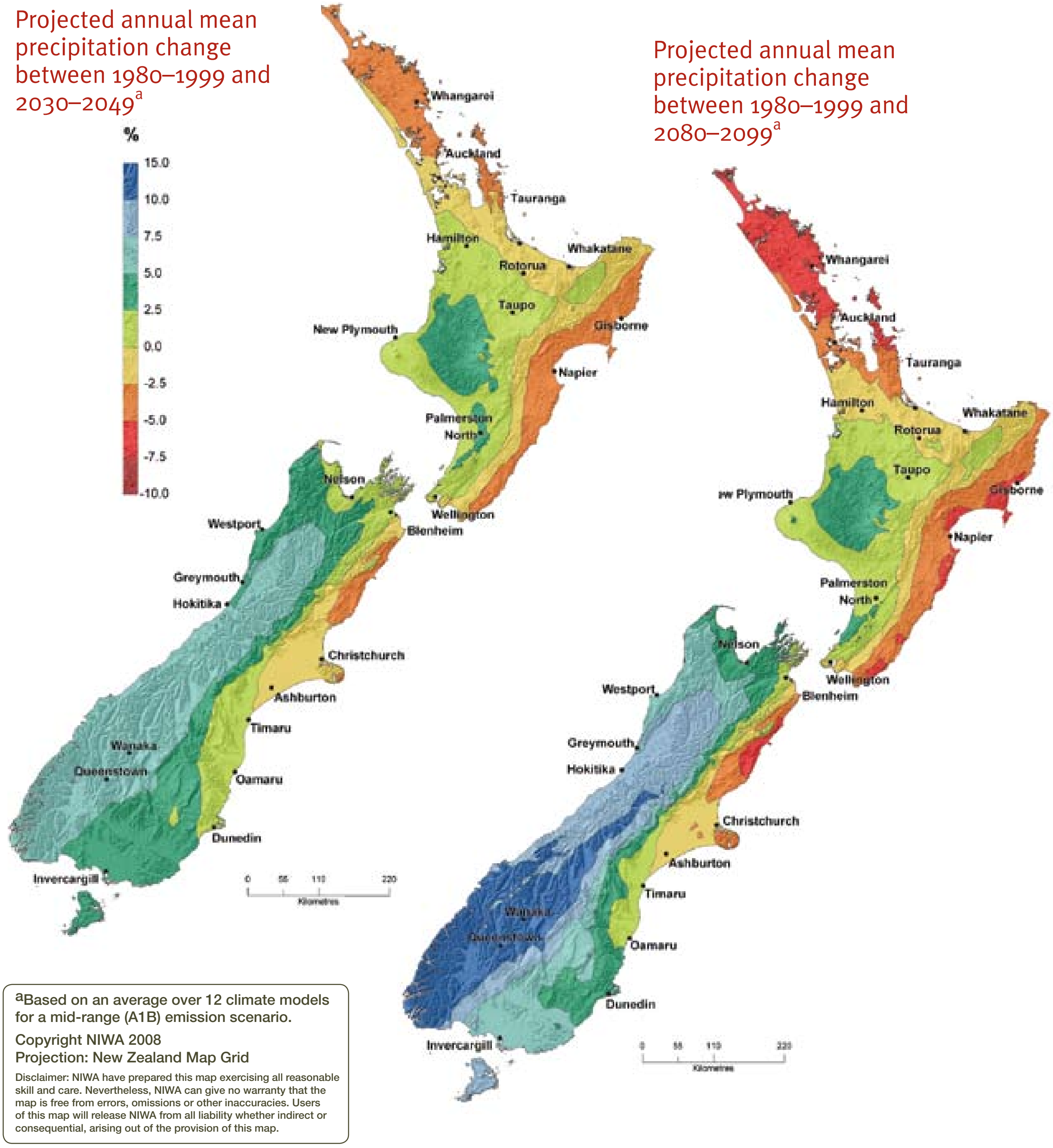


Projected changes in rainfall

Figure 2 shows that the projected mid-range change in the average annual rainfall has a pattern of increases in the west (up to 5 per cent by 2040 and 10 per cent by 2090) and decreases in the east and north (exceeding 5 per cent in places by 2090). This annual pattern of 'wetter in the west and drier in the east' results from the changes in the dominant seasons of winter and spring.

Figure 2: **Projected mid-range changes in annual mean rainfall (in %) relative to 1990.**

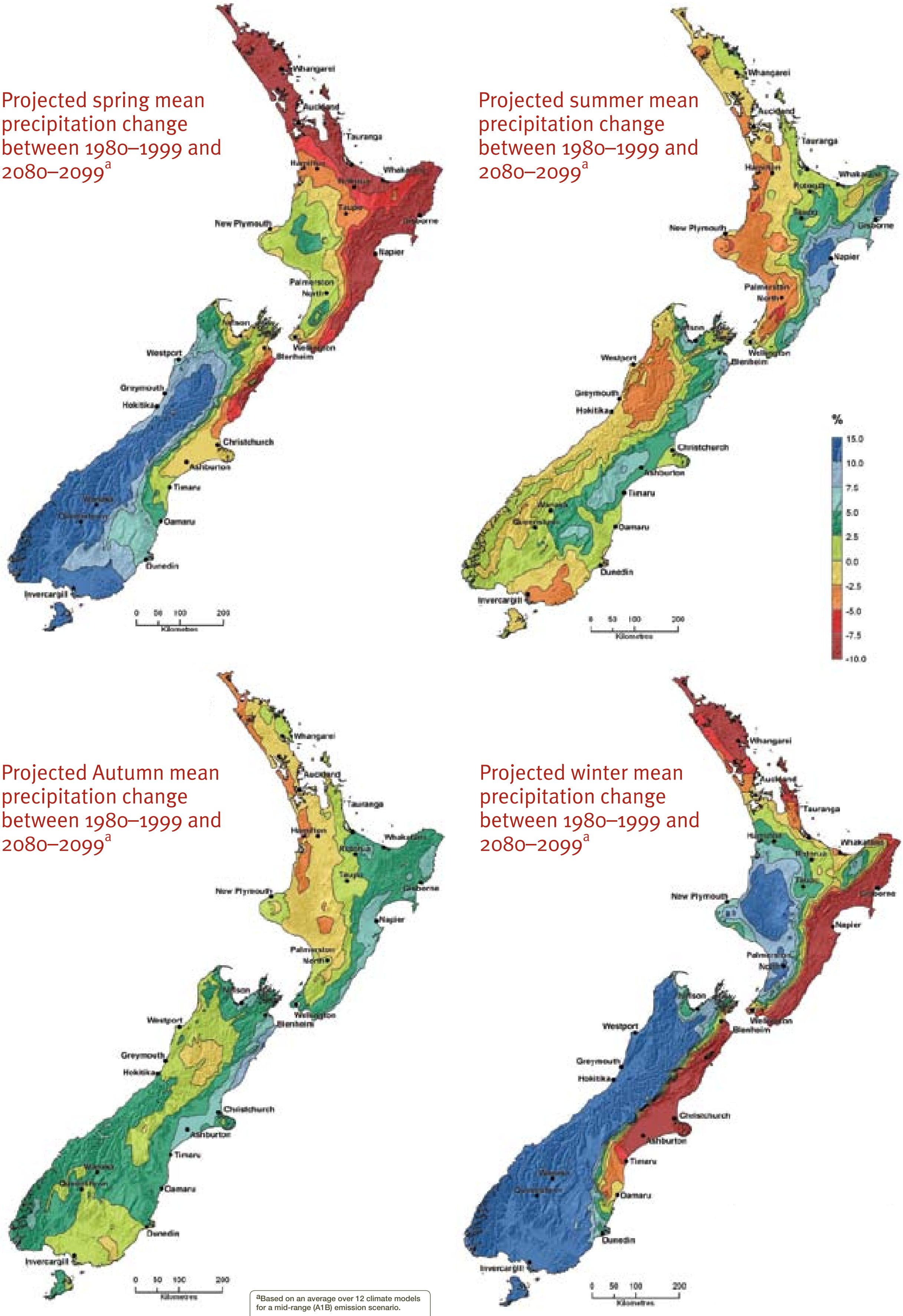
The changes shown are an average of the results of 12 climate models for a mid-range IPCC emissions scenario.



Newly projected changes in seasonal mean rainfall (Figure 3) show a different and more marked seasonality than was evident in earlier projections used in the previous edition of this guide. The latest mid-range model results suggest that increased westerlies in winter and spring will bring more rainfall in the west of both islands and drier conditions in the east and north. Conversely, there will be a decreased frequency of westerly conditions in summer and autumn, with drier conditions in the west of the North Island and possible rainfall increases in Gisborne and Hawke's Bay.

Figure 3: **Projected mid-range changes in seasonal mean rainfall (in %) for 2090 relative to 1990.**

The changes shown are an average of the results of 12 climate models for a mid-range IPCC emissions scenario.



Projected spring mean precipitation change between 1980–1999 and 2080–2099[a]

Projected summer mean precipitation change between 1980–1999 and 2080–2099[a]

Projected Autumn mean precipitation change between 1980–1999 and 2080–2099[a]

Projected winter mean precipitation change between 1980–1999 and 2080–2099[a]

[a]Based on an average over 12 climate models for a mid-range (A1B) emission scenario.

Projection: New Zealand Map Grid

Disclaimer: NIWA have prepared this map exercising all reasonable skill and care. Nevertheless, NIWA can give no warranty that the map is free from errors, omissions or other inaccuracies. Users of this map will release NIWA from all liability whether indirect or consequential, arising out of the provision of this map.

Extreme weather events

Natural variations in our climate will continue to impact on the New Zealand climate in the future and will be superimposed on human-induced, long-term climate change trends. Climate change is expected to shift the *range* of variability and, in some instances, to alter the *patterns* of variability. It will not remove this natural variability. Thus, the effects of climate change may be felt both through changes in long-term averages and in terms of the changed frequency and intensity of extreme events (such as heavy rainfall, storm surges, drought, or very high temperatures). It is this combination of underlying mean climate, appropriate climate change adjustments, and natural variations that will provide the extremes that future New Zealand society faces. A small shift in the average climate can cause significant changes in the occurrence of extremes: generally, it is the extreme events that cause damage.

An increase in the risk of heavy rainfall events could be particularly important for local government planning. However, because increases in rainfall *intensity* do not necessarily imply an increase in annual rainfall *totals*, heavy rainfall events may increase even in areas where the mean rainfall is projected to decrease, because the frequency of storm events may change.

Other climate changes

Changes in temperature and rainfall, along with other climate changes, are likely to lead to more floods as well as more droughts in some parts of the country.

Projections for other climate changes include:

- decreased frost risk
- increased frequency of high temperatures
- increased frequency of extreme daily rainfalls
- higher snow lines and possible reduced snow coverage
- possible increase in strong winds
- an increase in average sea level.

Table 1 qualitatively summarises the main features of the New Zealand climate change projections and contains the best current scientific estimate of the direction and magnitude of change.

Table 1: Main features of New Zealand climate change projections for 2040 and 2090

CLIMATE VARIABLE	DIRECTION OF CHANGE	MAGNITUDE OF CHANGE	SPATIAL AND SEASONAL VARIATION
Mean temperature	Increase (****)	All-scenario average 0.9°C by 2040, 2.1°C by 2090 (**)	Least warming in spring season (*)
Daily temperature extremes (frosts, hot days)	Fewer cold temperatures and frosts (****), more high-temperature episodes (****)	Whole frequency distribution moves right (see 2.2.3 of the source report)	See 2.2.3 of the source report
Mean rainfall	Varies around country, and with season. Increases in annual mean expected for Tasman, West Coast, Otago, Southland and Chatham Islands; decreases in annual mean in Northland, Auckland, Gisborne and Hawke's Bay (**)	Substantial variation around the country and with season (see 2.2.2 of the source report)	Tendency to increase in south and west in the winter and spring (**); tendency to decrease in the western North Island, and increase in Gisborne and Hawke's Bay, in summer and autumn (*)
Extreme rainfall	Heavier and/or more frequent extreme rainfalls (**), especially where mean rainfall increase predicted (***)	No change through to halving of heavy rainfall return period by 2040; no change through to fourfold reduction in return period by 2090 (**)	Increases in heavy rainfall most likely in areas where mean rainfall is projected to increase (***)
Snow	Shortened duration of seasonal snow lying (***), rise in snowline (**), decrease in snowfall events (*)		
Glaciers	Continuing long-term reduction in ice volume and glacier length (***)		Reductions delayed for glaciers exposed to increasing westerlies
Wind (average)	Increase in the annual mean westerly component of windflow across New Zealand (**)	About a 10% increase in annual mean westerly component of flow by 2040 and beyond (*)	By 2090, increased mean westerly in winter (>50%) and spring (20%), and decreased westerly in summer and autumn (20%) (*)
Strong winds	Increase in severe wind risk possible (**)	Up to a 10% increase in the strong winds (>10m/s, top 1 percentile) by 2090 (*)	
Storms	More storminess possible, but little information available for New Zealand (*)		
Sea level	Increase (****)	At least 18–59 cm rise (New Zealand average) between 1990 and 2100 (****)	Refer to Coastal Hazards and Climate Change guidance manual: www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual
Waves	Increased frequency of heavy swells in regions exposed to prevailing westerlies (**)	Refer to Coastal Hazards and Climate Change guidance manual: www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual	
Storm surge	Assume storm tide elevation will rise at the same rate as mean sea-level rise (**)	Refer to Coastal Hazards and Climate Change guidance manual: www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual	
Ocean currents	Various changes plausible, but little research or modelling yet done	See 2.2.9 of the source report	
Ocean temperature	Increase (****)	Similar to increases in mean air temperature	Patterns close to the coast will be affected by winds and upwelling and ocean current changes (**)

Note: The degree of confidence placed by the authors of the source report in the projections is indicated by the number of stars in brackets:

**** Very confident, at least 9 out of 10 chance of being correct. Very confident means that it is considered very unlikely that these estimates will be substantially revised as scientific knowledge progresses.

*** Confident.

** Moderate confidence, which means it is more likely than not to be correct in terms of indicated direction and approximate magnitude of the change.

* Low confidence, but the best estimate possible at present from the most recent information. Such estimates could be revised considerably in the future.

For planning purposes, councils should consider the full range of scenarios provided in the source report on which this guide is based. Changes in the return period of heavy rainfall events may vary between different parts of the country and will also depend on the rainfall duration being considered (see Section 2.2.4 of the source report for more detail).

Projected changes by region

Table 2 and Table 3 on the next two pages show the projected changes for temperature and rainfall for specific locations. The first figure in each table entry gives a mid-range 'working value' for what the change will be and the figures in brackets give the range across the model results within which the change could lie. The first value is in fact the average of the changes estimated by several computer models and for a variety of possible emissions scenarios, while the range gives the maximum and minimum values across these models and scenarios. Refer to the source report for further detail.

Table 2: Projected changes in seasonal and annual mean temperature (in °C) relative to 1990, by regional council area

The first number in each case is a mid-range estimate of what the change will be, the figures in brackets give the model range within which the change could lie.

REGION	DECADE	SUMMER	AUTUMN	WINTER	SPRING	ANNUAL
Northland	2040	1.1 [0.3, 2.7]	1.0 [0.2, 2.9]	0.9 [0.1, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.6]
	2090	2.3 [0.8, 6.6]	2.1 [0.6, 6.0]	2.0 [0.5, 5.5]	1.9 [0.4, 5.5]	2.1 [0.6, 5.9]
Auckland	2040	1.1 [0.3, 2.6]	1.0 [0.2, 2.8]	0.9 [0.2, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.5]
	2090	2.3 [0.8, 6.5]	2.1 [0.6, 5.9]	2.0 [0.5, 5.5]	1.9 [0.4, 5.4]	2.1 [0.6, 5.8]
Waikato	2040	1.1 [0.2, 2.5]	1.0 [0.3, 2.7]	0.9 [0.2, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.4]
	2090	2.3 [0.9, 6.3]	2.2 [0.6, 5.6]	2.1 [0.5, 5.2]	1.8 [0.3, 5.1]	2.1 [0.6, 5.6]
Bay of Plenty	2040	1.0 [0.3, 2.5]	1.0 [0.3, 2.7]	0.9 [0.1, 2.2]	0.8 [0.0, 2.1]	0.9 [0.2, 2.4]
	2090	2.2 [0.8, 6.2]	2.2 [0.6, 5.6]	2.0 [0.5, 5.2]	1.8 [0.3, 5.1]	2.1 [0.6, 5.5]
Taranaki	2040	1.1 [0.2, 2.4]	1.0 [0.2, 2.6]	0.9 [0.1, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.3]
	2090	2.3 [0.9, 6.1]	2.2 [0.6, 5.3]	2.1 [0.5, 5.1]	1.8 [0.3, 4.9]	2.1 [0.6, 5.3]
Manawatu-Wanganui	2040	1.1 [0.2, 2.3]	1.0 [0.2, 2.6]	0.9 [0.2, 2.2]	0.8 [0.0, 1.9]	0.9 [0.2, 2.2]
	2090	2.3 [0.9, 6.0]	2.2 [0.6, 5.3]	2.1 [0.5, 5.0]	1.8 [0.3, 4.9]	2.1 [0.6, 5.3]
Hawke's Bay	2040	1.0 [0.2, 2.5]	1.0 [0.3, 2.6]	0.9 [0.1, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.3]
	2090	2.1 [0.8, 6.0]	2.1 [0.6, 5.3]	2.1 [0.5, 5.1]	1.9 [0.3, 5.1]	2.1 [0.6, 5.4]
Gisborne	2040	1.0 [0.2, 2.6]	1.0 [0.3, 2.7]	0.9 [0.1, 2.2]	0.8 [0.0, 2.1]	0.9 [0.2, 2.4]
	2090	2.2 [0.8, 6.2]	2.2 [0.6, 5.6]	2.0 [0.5, 5.2]	1.9 [0.3, 5.2]	2.1 [0.6, 5.5]
Wellington	2040	1.0 [0.2, 2.2]	1.0 [0.3, 2.5]	0.9 [0.2, 2.1]	0.8 [0.1, 1.9]	0.9 [0.3, 2.2]
	2090	2.2 [0.9, 5.7]	2.1 [0.6, 5.1]	2.1 [0.6, 5.0]	1.8 [0.3, 4.8]	2.1 [0.6, 5.2]
Tasman-Nelson	2040	1.0 [0.2, 2.2]	1.0 [0.2, 2.3]	0.9 [0.2, 2.0]	0.7 [0.1, 1.8]	0.9 [0.2, 2.0]
	2090	2.2 [0.9, 5.6]	2.1 [0.6, 5.1]	2.0 [0.5, 4.9]	1.7 [0.3, 4.6]	2.0 [0.6, 5.0]
Marlborough	2040	1.0 [0.2, 2.1]	1.0 [0.2, 2.4]	0.9 [0.2, 2.0]	0.8 [0.1, 1.8]	0.9 [0.2, 2.1]
	2090	2.1 [0.9, 5.6]	2.1 [0.6, 5.0]	2.1 [0.6, 5.0]	1.8 [0.3, 4.8]	2.0 [0.6, 5.1]
West Coast	2040	1.0 [0.2, 2.4]	1.0 [0.2, 2.1]	0.9 [0.2, 1.8]	0.7 [0.1, 1.7]	0.9 [0.2, 1.8]
	2090	2.2 [0.9, 5.3]	2.1 [0.7, 5.0]	2.1 [0.6, 4.9]	1.7 [0.4, 4.5]	2.0 [0.7, 4.9]
Canterbury	2040	0.9 [0.1, 2.2]	0.9 [0.2, 2.2]	1.0 [0.4, 2.0]	0.8 [0.2, 1.8]	0.9 [0.2, 1.9]
	2090	2.1 [0.8, 5.2]	2.1 [0.7, 4.9]	2.2 [0.8, 5.1]	1.8 [0.4, 4.7]	2.0 [0.7, 5.0]
Otago	2040	0.9 [0.0, 2.4]	0.9 [0.1, 1.9]	1.0 [0.3, 2.1]	0.7 [0.0, 1.8]	0.9 [0.1, 1.9]
	2090	2.0 [0.7, 4.8]	2.0 [0.8, 4.6]	2.2 [0.8, 4.8]	1.7 [0.5, 4.3]	2.0 [0.8, 4.6]
Southland	2040	0.9 [0.0, 2.4]	0.9 [0.1, 1.9]	0.9 [0.2, 2.0]	0.7 [–0.1, 1.7]	0.8 [0.1, 1.9]
	2090	2.0 [0.7, 4.7]	2.0 [0.8, 4.6]	2.1 [0.8, 4.7]	1.6 [0.5, 4.1]	1.9 [0.8, 4.5]
Chatham Islands	2040	0.8 [0.2, 1.9]	0.9 [0.2, 2.0]	0.9 [0.1, 2.3]	0.7 [0.1, 1.8]	0.8 [0.2, 1.9]
	2090	1.9 [0.8, 4.6]	2.1 [0.6, 4.9]	2.0 [0.3, 4.5]	1.8 [0.3, 4.6]	2.0 [0.5, 4.7]

Table 3: Projected changes in seasonal and annual precipitation (in %) relative to 1990 for selected stations within each regional council area. The first number in each case is a mid-range estimate of what the change will be, the figures in brackets give the model range within which the change could lie.

REGION	LOCATION	DECADE	SUMMER	AUTUMN	WINTER	SPRING	ANNUAL
Northland	Kaitaia	2040	1 [–15, 20]	–0 [–14, 16]	–5 [–23, 1]	–6 [–18, 4]	–3 [–13, 5]
		2090	–1 [–26, 21]	–3 [–22, 11]	–8 [–32, 2]	–11 [–33, 8]	–6 [–22, 5]
	Whangarei	2040	1 [–14, 23]	1 [–15, 33]	–9 [–38, –1]	–9 [–25, 3]	–4 [–16, 7]
		2090	0 [–20, 19]	1 [–27, 26]	–12 [–45, –0]	–16 [–45, 1]	–7 [–28, 2]
Auckland	Warkworth	2040	1 [–16, 20]	1 [–13, 22]	–4 [–22, 2]	–6 [–18, 6]	–3 [–13, 5]
		2090	–2 [–31, 20]	–1 [–20, 12]	–4 [–24, 5]	–12 [–33, 6]	–5 [–19, 6]
	Mangere	2040	1 [–17, 20]	1 [–14, 17]	–1 [–10, 5]	–5 [–15, 10]	–1 [–10, 6]
		2090	–1 [–33, 20]	–2 [–21, 12]	–1 [–12, 9]	–9 [–30, 11]	–3 [–13, 9]
Waikato	Ruakura	2040	1 [–18, 19]	2 [–13, 10]	1 [–4, 8]	–2 [–10, 13]	0 [–6, 6]
		2090	–1 [–34, 18]	–1 [–24, 10]	3 [–7, 15]	–4 [–23, 16]	–1 [–11, 11]
	Taupo	2040	3 [–16, 28]	3 [–9, 16]	1 [–4, 7]	–3 [–10, 12]	1 [–5, 8]
		2090	4 [–19, 30]	1 [–16, 9]	3 [–8, 15]	–5 [–23, 13]	1 [–7, 10]
Bay of Plenty	Tauranga	2040	2 [–16, 25]	3 [–12, 25]	–4 [–16, 2]	–5 [–18, 7]	–1 [–10, 8]
		2090	2 [–20, 23]	2 [–15, 16]	–3 [–16, 8]	–9 [–32, 12]	–2 [–12, 5]
Taranaki	New Plymouth	2040	0 [–20, 18]	3 [–8, 13]	2 [–2, 9]	0 [–8, 16]	2 [–3, 9]
		2090	–2 [–38, 15]	1 [–18, 15]	6 [–6, 20]	–1 [–17, 21]	1 [–10, 11]
Manawatu-Wanganui	Wanganui	2040	–1 [–21, 13]	3 [–8, 10]	5 [–3, 15]	1 [–10, 15]	2 [–3, 10]
		2090	–3 [–42, 12]	–1 [–20, 12]	8 [–5, 25]	0 [–16, 23]	1 [–11, 11]
	Taumarunui	2040	0 [–19, 19]	2 [–10, 13]	7 [0, 17]	2 [–12, 19]	3 [0, 13]
		2090	–1 [–36, 18]	–2 [–25, 12]	13 [1, 36]	1 [–16, 26]	3 [–7, 15]
Hawke's Bay	Napier	2040	4 [–33, 38]	5 [–14, 42]	–13 [–34, –1]	–7 [–17, 3]	–3 [–14, 14]
		2090	9 [–46, 52]	5 [–14, 25]	–16 [–45, –1]	–13 [–38, 9]	–4 [–20, 11]
Gisborne	Gisborne	2040	3 [–26, 33]	4 [–18, 46]	–11 [–30, –2]	–9 [–21, 3]	–4 [–15, 14]
		2090	5 [–38, 41]	4 [–25, 27]	–13 [–41, 1]	–16 [–42, 7]	–5 [–22, 8]
Wellington	Masterton	2040	2 [–17, 25]	4 [–8, 32]	–6 [–20, 4]	–1 [–8, 10]	–1 [–7, 9]
		2090	4 [–28, 32]	3 [–7, 13]	–7 [–28, 2]	–4 [–20, 16]	–2 [–15, 7]
	Paraparaumu	2040	0 [–21, 13]	4 [–3, 14]	4 [–1, 13]	2 [–5, 14]	2 [–3, 10]
		2090	–1 [–38, 16]	2 [–12, 14]	9 [0, 26]	2 [–15, 26]	3 [–7, 14]
Tasman-Nelson	Nelson	2040	4 [–14, 27]	5 [–2, 19]	1 [–4, 9]	0 [–8, 9]	2 [–3, 9]
		2090	6 [–13, 30]	5 [–4, 18]	6 [–2, 19]	–1 [–20, 19]	4 [–3, 14]
Marlborough	Blenheim	2040	3 [–16, 25]	4 [–4, 24]	–1 [–10, 7]	–1 [–7, 10]	1 [–5, 9]
		2090	5 [–15, 28]	5 [–5, 16]	1 [–14, 9]	–1 [–18, 20]	2 [–7, 13]
West Coast	Hokitika	2040	0 [–22, 19]	3 [–11, 18]	11 [1, 24]	5 [–1, 18]	5 [–2, 20]
		2090	–1 [–44, 32]	3 [–28, 26]	21 [5, 52]	8 [–11, 46]	8 [–5, 31]
Canterbury	Christchurch	2040	2 [–15, 22]	5 [–10, 30]	–8 [–30, 7]	–1 [–8, 9]	–1 [–10, 9]
		2090	3 [–17, 25]	6 [–6, 20]	–11 [–41, 10]	–2 [–15, 25]	–2 [–14, 16]
	Hanmer	2040	2 [–16, 25]	4 [–5, 19]	–7 [–26, 6]	0 [–6, 12]	–1 [–8, 7]
		2090	4 [–25, 32]	3 [–7, 15]	–10 [–34, 6]	–1 [–13, 29]	–2 [–14, 15]
	Tekapo	2040	1 [–16, 16]	2 [–12, 10]	8 [–1, 19]	6 [–3, 17]	4 [0, 13]
		2090	2 [–30, 31]	0 [–16, 17]	18 [5, 41]	10 [–6, 47]	8 [0, 29]
Otago	Dunedin	2040	1 [–11, 13]	2 [–9, 10]	3 [–10, 13]	2 [–5, 11]	2 [–4, 9]
		2090	0 [–29, 19]	2 [–11, 16]	7 [–16, 24]	6 [–1, 32]	4 [–9, 23]
	Queenstown	2040	1 [–16, 20]	2 [–15, 23]	16 [2, 38]	8 [–3, 21]	7 [1, 22]
		2090	1 [–38, 37]	2 [–32, 20]	29 [7, 76]	15 [–5, 50]	12 [–2, 34]
Southland	Invercargill	2040	–1 [–15, 22]	2 [–17, 22]	10 [2, 30]	7 [–3, 22]	4 [–2, 19]
		2090	–2 [–44, 27]	2 [–31, 19]	18 [1, 51]	13 [0, 47]	7 [–12, 29]
Chatham Islands		2040	–2 [–10, 10]	4 [–7, 29]	4 [–10, 43]	3 [–8, 19]	3 [–5, 23]
		2090	–3 [–20, 16]	4 [–14, 29]	8 [–16, 67]	6 [–14, 45]	4 [–11, 35]

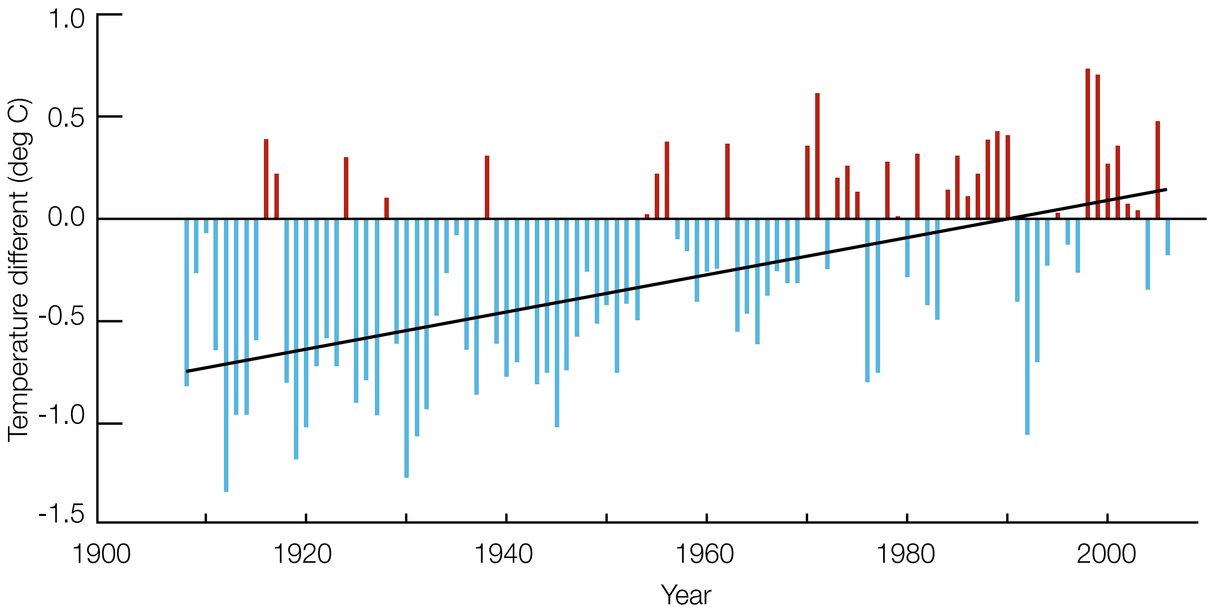
Current climate variability

New Zealand's climate varies naturally from year to year and from decade to decade. Human-induced long-term trends will be superimposed on these natural variations, and it is this combination that will provide the future climate extremes to which New Zealand society will be exposed. Much of the natural variation is apparently random; however there are some cyclical elements as shown for temperature (Figure 4).

Figure 4 shows that, in individual years, annual New Zealand-wide temperatures can deviate from the long-term average by up to 1°C (plus or minus). It also shows that, despite these fluctuations, there has been a long-term increase of about 0.9°C between 1908 and 2006. Similarly, annual rainfall can deviate from its long-term average, by about plus or minus 20 per cent.

Figure 4: **New Zealand average temperature**

Annual mean temperatures are shown by the red (positive) and blue (negative) bars with the long-term trend shown by the solid black rising line (shown as difference in °C from 1980–99 climatology).



Some of the shortest-term temperature fluctuations arise simply because of the natural variability in the weather and its random fluctuations or 'chaos'. Another factor of New Zealand's climate in the recent past is the effect of large volcanic eruptions in the tropics. Typically, they have lead to a cooling of 0.6–0.8°C for a year or more. For example, the impact of the May 1991 Mt Pinatubo eruption is clearly evident in the New Zealand temperature record during 1992 (Figure 4).

Other changes in our climate are associated with large-scale climate patterns over the Southern Hemisphere or the Pacific Ocean. There are a number of key natural processes that operate over timescales of seasons to decades, particularly the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO).

ENSO is a tropical, Pacific-wide oscillation that affects pressure, winds, sea-surface temperature and rainfall. In the El Niño phase, New Zealand usually experiences stronger than normal south-westerly airflow. This generally results in lower seasonal temperatures nationally with drier conditions in the north-east of the country. The La Niña phase is essentially the opposite, usually creating more north-easterly flows, higher temperatures, and wetter conditions in the north and east of the North Island. Atmospheric pressures in the La Niña phase tend to be higher than normal over the South Island which can lead to lower rainfall and, in turn, drought conditions in the north-east of the South Island. Drought can, therefore, occur in New Zealand in both El Niño and La Niña phases. Because the tropical Pacific sea-surface temperature anomalies persist for up to a year, there is substantial predictability in how ENSO oscillations affect New Zealand's climate. The ENSO cycle varies between about three and seven years, with large variability in the intensity of individual oscillations.

The Interdecadal Pacific Oscillation is another, recently identified, source of natural variability in climate. It has cycles that can last over several decades rather than across century timescales. Three phases of the IPO have been identified during the 20th century: a positive phase (1922–44), a negative phase (1946–77), and another positive phase (1978–98).

In a positive phase, sea-surface temperatures around New Zealand tended to be lower, and westerly or south-westerly winds stronger. Temperatures in all regions were lower. In the negative phase, airflows from the east and north-east were observed to increase, as did temperatures in all regions. Conditions became wetter in the north of the North Island, particularly in autumn, and drier in the south-east of the South Island, particularly in summer. The increase in New Zealand temperatures around 1950 (see Figure 4) coincided with the change from positive to negative phase IPO at that time. Sea levels around New Zealand are also affected by the IPO. Particularly large increases in sea level have been associated with IPO transitions from the positive to the negative phase.

It is yet uncertain to what extent the IPO can be accurately used to predict climate phases or patterns in future decades. More frequent natural climate variations, such as the ENSO, are also difficult to predict very far in advance. Hence it is not feasible to project natural variations over the next century. Analysis of the latest sea temperature data suggests that another negative IPO phase may currently prevail – meaning more La Niña (and less El Niño) activity could be expected, compared to the 1978–98 period, together with a period of higher temperatures. Weaker westerlies are also likely, which goes against the observed trend of increasing westerlies.

Significance of climate change versus natural climate variability

Historical records show the national-average temperature can vary by up to about 1°C from year to year, and more than this on a seasonal timescale. Thus, the warmest individual years in the current climate have temperatures lying near the upper end of the projected average (climatological) warming for the 2030s. What currently is an unusually warm year could be the norm in 30–50 years, while an unusually warm year in 30–50 years' time is very likely to be warmer than anything we experience at present.

Projected temperatures for the mid-to-high range of the end of the century are well outside the values experienced by New Zealand in the 20th century. A hot year in 2090 will be more extreme still.

Similar comparisons can be made for rainfall, but with opposite trends expected for different parts of the country. Seasonal anomalies today seem comparable to the projected average ranges for 2030. Areas that currently have water management issues could see present extremes (eg, water shortages) become the norm by the 2030s – depending on the direction of projected rainfall change for their region, and which emissions scenario and model simulation turns out to be the closest to reality. This will be particularly relevant for drought management in eastern New Zealand.

Further details of the estimated changes in both the average and extremes for each major climate parameter are found in Chapter 2 of the source report.

Part Two

Local government and climate change

This guide is a summary of a report prepared for the Ministry for the Environment by external consultants, as noted on page i of this document. To the extent that this summary guide (and in particular Part 2) deals with legal matters, readers should not rely on it as legal advice.

This part covers:

- an explanation of the social and legal obligations of councils to take climate change effects into account in planning and decision-making
- key principles that need to be considered in responding to climate change
- a checklist for considering climate change in plans
- how to assess the impact of climate change on council functions.

Climate-related risk and local government

Climate-related risks are not new to New Zealand local government planners, and resource and hazard managers. By and large, climate change will not create new hazards, but may change the frequency and intensity of existing risks and hazards; it will also introduce some long-term shifts in climate regimes across the country.

Adapting to long-term climate change will also contribute to our resilience to natural fluctuations in climate, such as El Niño (which often leads to dry conditions in northern and eastern parts of New Zealand). Addressing the effects of climate change is most likely to be effective and cost-efficient if it is integrated into local government standard work programmes, rather than planned for in isolation.

Local government is responsible for a range of functions that may be affected by climate change under the Local Government Act 2002, the Resource Management Act 1991 (RMA) and other legislation. Local authorities have both social and legal obligations to take climate change effects into account in their community planning. Long-term planning functions therefore need to embrace expected long-term shifts and changes in climate extremes and patterns, so as to ensure future generations are adequately prepared for future climate conditions.

Key principles for responding to climate change

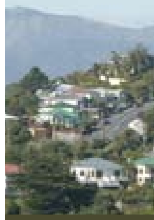
Local government is required to operate under a range of principles that are set out in law or have evolved through good practice and case law. All must be kept in mind when dealing with climate change effects.

The key principles are:

- sustainability
- consideration of the foreseeable needs of future generations
- avoidance, remedy or mitigation of adverse effects
- adoption of a precautionary / cautious approach
- the ethic of stewardship / kaitiakitanga
- consultation and participation
- financial responsibility
- liability.

Sustainability

The concepts of sustainable development are addressed in the Local Government Act 2002 and sustainable management of an area's natural and physical resources in the RMA. Both imply the ongoing ability of communities and people to respond and adapt to change in a way that avoids or limits adverse consequences and enables future generations to provide for their needs, safety and well-being. Since 2004, the RMA has included a requirement that people making decisions in terms of the Act must have particular


regard to the effects of climate change. Over the past decade or more, people have become aware of climate change and its causes and effects, and the causes of climate change have begun to be addressed at an international level. At the same time, local communities have been encouraged to adopt no- or low-regrets responses to climate change.

Such responses fit within the concept of sustainability. They involve applying adaptive, and sometimes limitation responses that will not be regretted, irrespective of the eventual nature and magnitude of climate change effects. Examples are a range of energy-efficiency and conservation practices, forest planting, and avoidance of new development in areas that are already or potentially hazard-prone. However, more recent understanding has developed of the variability of climate change effects, and the possible implications of decisions made in a framework of uncertainty. This has meant a shift to risk-based assessments of climate change effects and responses by local authorities, prior to decisions being made in the interests of long-term sustainability.

Consideration of the foreseeable needs of future generations

Considering the needs of future generations is a fundamental basis of international, national, regional and local responses to climate change. It involves taking into account the interests of future generations, and the direct and indirect costs that they may bear as a result of decisions made today. This means responsible action in the context of balancing the needs of the present with those of the future. The principle applies even where the need for a climate change response is not yet apparent.

Avoidance, remedy or mitigation of adverse effects

Under the RMA, the duty to avoid, remedy or mitigate adverse effects applies to the preparation of plans by local authorities under that Act, every decision made under that Act, and to everyone who carries out an activity or development under that Act. 'Effect' is defined to include temporary or permanent effects, present and future effects, cumulative effects over time, and potential effects of high probability, or of low probability with high potential impact. This means that, through reasonable understanding and analysis of future environmental change, climate change impacts can and should be taken into account when contemplating new activities and developments. This is because climate change can affect the ability of ecosystems and communities to cope with other non-climatic pressures.

Adoption of a precautionary / cautious approach

The concept of a precautionary / cautious approach is implied in the RMA and in the New Zealand Coastal Policy Statement which is prepared under that Act, and is directly stated in the Civil Defence Emergency Management Act 2002. It requires an informed but cautious approach to decisions where full information on effects is not available at the time of decision-making, particularly when there is a high level of uncertainty and where decisions are effectively irreversible.

A precautionary approach is particularly relevant where there are effects of low probability but high potential impact, for example the effects of infrequent but high flood levels in developed flood plain areas. Section 32 of the RMA requires the evaluation of a plan provision to consider the risks of acting or not acting if there is uncertain or inadequate information. This is directly relevant to addressing climate change effects in plans, as well as other situations where a cautious approach may be appropriate.

The ethic of stewardship / kaitiakitanga

The Local Government Act 2002 and the RMA both contain the concepts of stewardship / kaitiakitanga. In the Local Government Act, a local authority should ensure prudent stewardship and the efficient and effective use of its resources in the interests of its district and region. In the RMA, particular regard is to be given to the ethic of stewardship and kaitiakitanga. The principle underpins sound planning decision-making in the interests of the community to avoid or minimise loss of value or quality over time. Its relevance to climate change relates particularly to asset management, land and water care, biosecurity, and biodiversity.

Consultation and participation

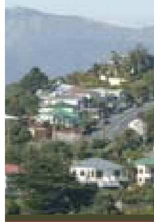
Principles of consultation with communities and affected people are fundamental to local government decision-making. Consultation implies informed input into decision-making processes. For decisions on matters or developments that are relevant to climate change, those being consulted must have sufficient information to understand the likely scenarios and associated risks for their communities. Ensuring adequate information is available within a community for consultation processes to be effective is a responsibility for regional and local government. It will involve the translation of international and national knowledge to local levels, with indications of degree of certainty and uncertainty. Consultation and participation can also be used to raise awareness of risk and appropriate responses – for example, flood risk and how people should respond when a flood occurs in their area.

Financial responsibility

Local government is expected to act within normal codes of financial responsibility on behalf of the community. When undertaking its own activities, particularly asset provision and management, the Local Government Act sets out requirements to identify in detail the reasons for any changes to current provision, and the associated cost. For infrastructure enhancements anticipating future effects of climate change, evaluation of risks as well as the costs of different levels of service will need to be expressed in a transparent manner.

Liability

Local government can be financially liable for decisions that are shown to have been made in the face of information that should have led to a different decision. This is a complex area of law, and councils use a range of techniques to reduce the risk of liability. For example, where single property-based decisions are involved, instruments such as covenants or consent notices attached to titles may be used to identify risks. Larger climate-related issues, such as frequency of flooding of a developed area, are less likely to result in direct liability unless areas become uninhabitable as a result. However, community costs in enhancing or retrofitting infrastructure can become considerable. Questions of equity in relation to wider community interests also arise.



Checklists for considering climate change in plans

The checklists below are designed to assist local authorities to take these principles into account when considering climate change effects in plan development and review.

NAME OF PLAN/DURATION OF PLAN AND	CHECKLIST FOR CONTENTS
LOCAL GOVERNMENT ACT 2002	
Name of plan: Long-term Council Community Plan **Duration:** Ten years, but reviewed every three years or earlier. Can be changed when an annual plan is prepared. **Purpose:** · Describes community outcomes for the district or region. · Provides a long-term focus for local authority decisions. · Provides financial estimates to manage council / community assets.	Are the long-term implications of climate change identified anywhere in relation to community outcomes? Is any statement clear and able to be measured or monitored? If not, is there a comment explaining why not? How is the timeframe of climate change effects handled? Is there adequate explanation of the need to act within the framework of the current plan, although effects may become apparent only during the preparation of future plans? Are adaptive responses to potential climate changes identified in relation to specific assets or activities (water supply, wastewater, stormwater, roading, pest management, parks and reserves management, etc)? Are these responses specific and targeted to the asset? If a change in level of service, or additional capacity, is planned owing to climate change (ie, requirements will be beyond the level of service or capacity based on other considerations), is this explicit and explained? Are other programmes or plans relating to climate change identified (eg, biosecurity, biodiversity) and details and budgets specified? Is a monitoring regime relating to the aspect involving a climate change response identified and are mechanisms, costs and duration foreshadowed? Are the levels of uncertainty involved in the forecasts of climate change explained, and an estimate of the uncertainty provided?
Name of plan: Annual Plan **Duration:** Annual **Purpose:** Supports the Long-term Council Community Plan in integrated decision-making and coordination of the local authority resources; and provides an annual budget and funding impact statement for the local authority.	Are the budget requirements, in relation to climate change responses, identified in the Long-term Council Community Plan, explicitly followed through · for development, maintenance and management of specific assets · in terms of any investigation or research needs for the year · in terms of ongoing monitoring?
Name of plan: Annual Report **Duration:** Annual **Purpose:** Reports on the Annual Plan, measuring activities and expenditure against desired community outcomes and sustainable development.	Are specific Annual Plan provisions relating to climate change reported appropriately, including asset management? If the expected outcome has not been achieved, has this been explained?
RESOURCE MANAGEMENT ACT 1991	
Name of plan: Regional Policy Statement **Duration:** Ten years, but can be reviewed or changed at any time. **Purpose:** Achieves the sustainable and integrated management of natural and physical resources, by providing an overview of a region's resource management issues, policies and methods. Also the strategic integration of land use and infrastructure – eg, coordinating and influencing urban form across multiple districts.	Is climate change and its effects identified as a regional issue requiring a response? Does the Regional Policy Statement explain the national policy context? Does the Regional Policy Statement specify the time horizon for different types of decisions on climate change and its effects? Does the Regional Policy Statement give pointers for the formulation of regional and district plan contents relating to managing the effects of climate change? Does the Regional Policy Statement set out the respective roles and responsibilities of the regional and district councils in managing natural hazards in the region? Does the Regional Policy Statement promote consistency of approach towards climate change by local authorities within the region and across boundaries with neighbouring regions? Does the Regional Policy Statement promote public education as a method of response to climate change and its effects? Does the Regional Policy Statement promote avoidance or limitation of damage and costs from natural hazards, including those exacerbated by climate change, such as: · sea-level rise · increased rainfall intensity · increased incidence of severity or drought · wind events? Does the Regional Policy Statement include provisions for monitoring the effects of climate change, and any relevant statements of environmental outcomes?

NAME OF PLAN/DURATION OF PLAN AND PURPOSE	CHECKLIST FOR CONTENTS
Name of plan: Regional plans **Duration:** Ten years, but can be reviewed or changed at any time. **Purpose:** Achieves the integrated management of natural and physical resources, and assist the regional council in carrying out any of its functions under the RMA, including: managing land for soil erosion and natural hazards; managing water resources and beds of rivers and lakes; and managing the coastal marine area.	Depending on the plan ... Is climate change and its implications identified as an issue? If it is not, is there a valid explanation for why not? Are the approach and policy for climate change consistent with the Regional Policy Statement? Are there one or more objectives relating to climate change, which are adequately explained and integrated with policy and rules? If there are rules or methods that relate to or rely on climate change as a partial or complete justification for their existence (eg, water allocation, flood design clearances, prohibiting building areas), is the provision clearly explained? Are there any decision-making criteria related to taking the implications of climate change into account? Are these explained? Are there provisions for monitoring relevant to climate change effects, and relevant statements of environmental outcomes as a result of the provision(s)? Is there a specific commitment that the council will keep up-to-date with changing understanding of climate change and its implications?
Name of plan: District Plans **Duration:** Ten years, but can be reviewed at any time. **Purpose:** Achieves the integrated management of the effects of use, development and protection of a district's natural and physical resources; and control of land in relation to natural hazards. District plans can also allow councils to control subdivision for the purposes of carrying out functions under the RMA.	Is climate change identified as an issue in the District Plan with adequate explanations? How is the issue expressed in terms of objectives and policies? Is the approach and policy for climate change consistent with the Regional Policy Statement? Have areas of enhanced risk (eg, hazard zones, building lines) due to climate change been identified, with appropriate policy and rules? Do the decision-making criteria relating to natural hazards refer to climate change and its implications?
CIVIL DEFENCE EMERGENCY MANAGEMENT ACT 2002	
Name of plan: Civil Defence Emergency Management Group Plan **Duration:** Five years, but can be reviewed sooner. **Purpose:** Develops an integrated community-based response to the sustainable management of hazards.	Has the risk management analysis taken into account changes due to climate change? Does the recognition of the effects of climate change reflect the current level of uncertainty in the region and adopt a cautious approach as a result? If not, is this explained? Does the plan include a specific commitment to keep up to date with changing understanding of climate change and its implications, including any relevant local monitoring or liaison?
Plans under other legislation, and/or plans that have no specific statutory basis	
Name of plan: For example: Reserve Management Plans, Asset Management Plans, Catchment Management Plans, Landcare and Biosecurity Management Plans **Duration:** Usually no set times. Plans should state their review periods. **Purpose:** A range of purposes. Plans should explain their purpose through stated objectives and policies.	Depending on the plan ... Are there any statements or provisions relating to climate change and managing the effects? If there are, are these appropriately linked to aspects of the plan that have long-term consequences (eg, Reserve Management Plans may appropriately incorporate climate change considerations in relation to species choice for major planting programmes, or recognition of increased drought or flooding in design and subsequent maintenance costs of playing fields; Asset Management Plans may include expectations of changed levels of service needed in the future due to climate change; Landcare Plans may identify aspects such as reduced soil moisture in an area and promote a gradual shift in types of production / management as a response). What monitoring regimes are incorporated?

Assessing the impact of climate change on council functions

A number of council functions, services and activities can be affected by climate change. A key element in responding to climate change will be flexibility and responsiveness in seeking best options to respond to changes over time. Key factors to take into account when assessing whether climate change is likely to have a critical impact on a particular function or activity include: duration, drivers, location, extent and nature of the issues being addressed.

Duration of issue being addressed

Consider the period over which the decision will have effect. Generally, climate change should be considered if the effects of the decision will last 30 years or more, or variability in climate and climate extremes currently presents a problem (for example an inadequate flood defence scheme or stormwater system). Local government decisions have a range of implications in terms of time horizons. For example:

- Approval for a new development area or coastal reclamation is effectively permanent.
- While the former (1991) Building Act was based on an assumed building life of 50 years, the current Building Act (2004) does not include an assumed building life. Many structures are intended to, or do, last a century or more.
- Infrastructure decisions generally assume a 50- to 80-year life, but some can be designed to be built on a staged basis to provide extra capacity in response to climate change over time.
- Decisions on structures in rivers, most coastal structures, and infrastructure that involves regional council consents, have a term of 35 years or less, but in reality their lifetime may be much longer (eg, significant bridges) and they should be recognised as near-permanent.
- Decisions on land care, biodiversity and pest management strategies may be in the context of a three, five or ten-year strategy, but some decisions may have enduring consequences so a long-term view may be appropriate.

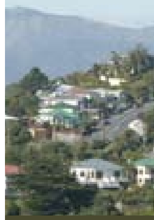
Example 1

The Tasman District's Resource Management Plan 1998 limited the extent of forest planting in the headwaters of specified catchments, to protect aquifer recharge for water supply for the horticulture areas downstream. A range of possible future weather scenarios (but not specifically climate change scenarios) were built into the studies, which led to the plan provisions. Climate change scenarios were omitted in part because of lack of reliable relevant information at the time, but also because it was considered that the relatively short 30-year tree harvesting cycle would allow for modification of provisions over time as climate change information improved.

Presence of a particular 'driver'

Although, it is important for local authorities to acknowledge climate change, and to include it in policy across a range of council functions, these considerations come particularly to the fore when specific decisions are required. For example, any significant investment in infrastructure should always be preceded by a risk assessment that includes climate change implications and a cost-benefit analysis. When climate change is factored in, the resulting asset 'life-cycle' costs should be less than the additional costs from premature retirement of the asset or later unscheduled upgrades. In some situations, the design of new infrastructure may 'lock in' resource requirements in a way that makes later upgrading virtually impossible.

Decisions on subdivisions and developments are driven by applications in the private sector. Councils must make decisions relatively quickly. Such decisions need to be made in the context of climate change effects, possibly exacerbating natural hazards. If a council considers that an application contains inadequate consideration of climate change factors and that such factors are relevant, further information should be sought in preference to making a decision based on inadequate information.



Example 2

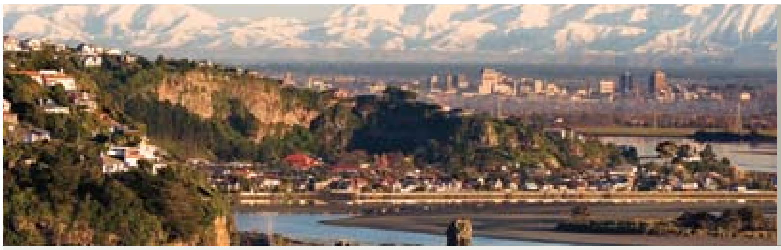
In 1997 North Shore City experienced a significant number of beach pollution events. This was linked to an unusually high number of wet-weather overflow events from its wastewater system.

Community concern led to a detailed analysis of what would be needed to modify the wastewater system so that a performance level of two overflows per year in 2050 could be achieved (taking into account increased population and other factors).

Scenarios were developed from historic rainfall information and predictions of increased frequency of intense rainfall events due to climate change; these scenarios were then applied to designing the modifications, and a risk and cost-benefit analysis undertaken.

The analysis showed that meeting the desired level of service by 2050 in the face of climate change effects would add $100 million to the cost, which had been estimated at $260 million when climate change effects were not considered. The community chose to accept the increased risk of events due to climate change (and therefore reduced level of service in the long term) rather than meet the additional cost of the desired level of service.

However, reviews of the system will incorporate consideration of climate change effects every 3–5 years. ‘Future proofing’ decisions on different components of the system (such as extensions into new development areas) will be made when and where opportunities or needs arise.



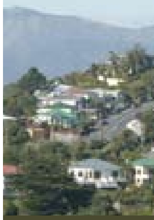
Example 3

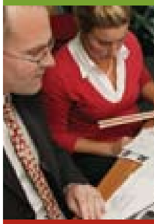
Christchurch City Council examined in 2003 the potential effects of climate change on the Avon catchment and associated coastal areas, and how these risks could be managed. The study focused primarily on an economic analysis of likely damages, and the response options available to local government to manage these. The study discussed possible responses including minimum floor levels for buildings, subdivision restrictions, stopbank improvements, and tidal barrages.

Since this study was undertaken, changes have been made to the City Plan. Aspects of the study’s findings have also been incorporated into the Urban Development Strategy that seeks to reduce the risks to the community from climate change. Options such as set-backs from waterways and raised floor levels of buildings in flood-prone areas have been incorporated.

Location of issue being addressed

Some locations are more vulnerable than others to climate change effects. For example, all proposed developments near the coast should be evaluated in terms of expected sea-level rise over this century, as well as other consequential effects such as increased coastal erosion, salt water intrusion into aquifers, and increased flooding. Development in flood plains also needs to take account of the potential for reduced flood return periods and potentially greater peaks.





Example 4

In the Hutt Valley, the value of development and the social and economic implications of a major flood are so significant that the community has reduced possible flood effects by investing in flood protection rather than by limiting development. The design was made more robust by taking climate change effects into account. There was inadequate information on possible climate change impacts for modelling purposes at the time decisions were made: the community chose a return period of 400 years as the basis for flood protection design, in the knowledge that the level of protection was likely to reduce over time due to climate change impacts. The Hutt Valley 2001 Flood Plain Management Plan provides detailed information on design considerations and levels of protection, taking into account climate change.

Extent of issue being addressed

Decisions that involve, for example, a single building or a small part of an infrastructure asset (unless the latter constrains the rest of the system) are less likely to have fundamental and long-term implications than decisions that affect larger areas. The exception is where a small development sets a precedent, leading to acceptance of subsequent applications.

Nature of issue being addressed

The risk assessment process should identify whether the issue is affected by a single climate parameter or whether it is a complex issue with multiple effects and implications over time. The latter needs to be addressed at a policy level, with decision-making carried through consistently over time. Relatively general information may be adequate to start policy development and information can be refined over time within a generic policy context. For example in planning an urban extension, there may be several options: low-lying coastal areas should be avoided, and if flood plains are being considered, higher and more frequent floods than in the past should be assumed.

Example 5

Transit New Zealand is the Crown Entity responsible for state highways. As such it is required to assess and manage risks to New Zealand's transport network, and ensure its sustainability. Transit New Zealand recognises that it is prudent to consider climate change in the design and planning of all major long-life infrastructures such as bridges, culverts, and causeways that could be affected by climate change impacts within the working life of the structure.

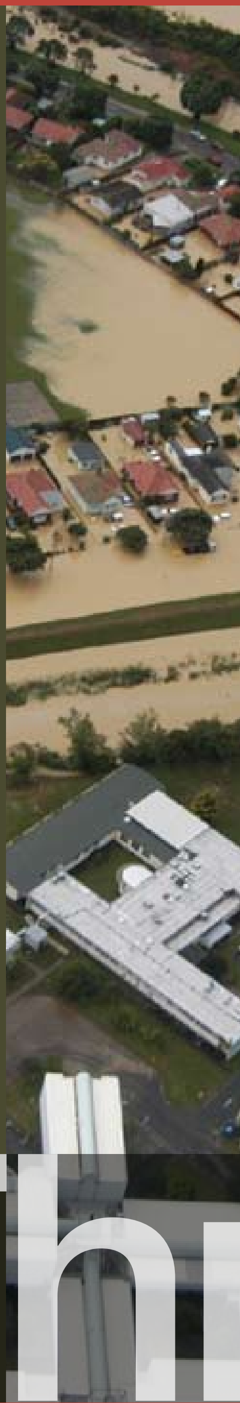
Future-proofing at the design stage makes later retrofits both feasible and cost effective. Some new state highway projects are already considering the impacts of climate change during design and construction. For example, the new section of causeway for Auckland's Upper Harbour Corridor (State Highway 18) was built 0.3 metres higher than the existing causeway, which was then raised to match it. This was in direct response to predicted sea-level rise.

Example 6

Napier City Council has identified sea-level rise due to climate change as a risk to urban sustainability. Since 1996 the council has undertaken several studies of coastal hazards and has imposed coastal hazard areas north of the city, within which future development is strictly limited. Sea-level rise is just one factor being considered in long-term erosion trends in the areas, but is recognised and accounted for in a risk-based planning approach. The city's asset management plans for infrastructure also note possible effects of climate change. Because of the low-lying nature of much of the city area, all systems are pumped and groundwater level changes as well as increased flood frequencies could increase costs. The city regularly reviews plans as climate change information is updated.

Example 7

In May 2005 the Western Bay of Plenty was hit by an intense storm that caused flooding throughout the region. A state of emergency was declared, because stormwater infrastructure, roading, and private properties were substantially damaged by the flooding. While average annual rainfall in the Bay of Plenty is expected to decrease with climate change, extreme rainfall events and flooding such as occurred in May 2005 are projected to increase. This has significant implications for new subdivisions and development in the area. In response, the Tauranga City Council now considers climate change impacts when designing all new or upgraded stormwater infrastructure. The council has also incorporated the factor of increased high-intensity rainfall into its planning for growth and development in the region over the next 50 years.


Part Three

Responding to the effects of climate change

This part covers:

- integrating climate change into council decision-making
- qualitatively assessing the influence of climate change on council functions and services
- undertaking preliminary assessments for the impacts of climate change
- considering heavy rainfall in assessing the effects of climate change
- using a full risk assessment process for climate change effects
- assessing climate change effects using complex scenarios.

Integrating climate change into council decision-making

Climate change is relevant to a wide range of local government functions. It adds to the many uncertainties that councils must consider in all their planning, risk assessment and decision-making. Every council function or service that relies on, or is affected by, climate parameters such as rainfall, sea level or temperature, can be affected by climate change.

Climate change considerations are unlikely to drive or initiate local government action on their own. Rather, through the application of risk management processes in assessing and prioritising possible responses to the effects of climate change, they may modify an outcome. Many councils have already taken steps towards integrating climate change in plans.

The emphasis in this part of the guide is on:

- understanding the scope and variation of climate change
- deciding on priorities for action
- applying risk assessment as a method to determine adaptation responses based on the level of risk.

Climate change risk assessment is best undertaken as part of ongoing council activities, not as a separate issue. It is not necessary to address the impacts of climate change on all functions and services at once. It is a matter of prioritising.

Generally, councils can use a series of steps of increasing complexity to assess whether climate change is relevant to a particular council function, how significant its impact might be, and what the appropriate response might be.

Assessing the influence of climate change on council functions and services has three key stages:

1. The first stage is to qualitatively **identify whether a specific council function or service could be affected by climate change** or, more generally, which council functions are vulnerable to climate variability and, therefore, to climate change.
2. If this process identifies a possible climate change effect, a **preliminary assessment** should be undertaken. This consists of using a range of scenarios for climate change and other drivers to test the likely significance of climate change; and to see whether existing planning and management provisions have a sufficient safety margin to cover any resulting change in risk or resource availability.
3. If it appears that existing provisions do not adequately cover the future change in risk, a **more detailed scientific and technical risk assessment** should be undertaken; this would be followed by an analysis of response options to manage the risk over appropriate timeframes.

While the more detailed risk assessment refers only to the risks associated with climate change, these risks are best assessed together with risks from other hazards and climate variability where possible and not in isolation. The process outlined is not the only one that can be used. If a local authority has an existing risk assessment process, climate change should simply be added in.

The long-term nature of climate change means that the lifetime of a development, service or infrastructure must be considered when assessing risk. The risk may not exist now, but may evolve as a result of climate change. This risk assessment, therefore, recognises the time evolution of risks by introducing a planning horizon and considering the risk at various steps along the way. For a lifetime of 100 years the risk may be evaluated as it is now and as it will be in 25, 50, 75, and 100 years, giving options for responses over time.

There is a complex relationship between coastal hazards and climate change, therefore a detailed risk assessment using independent expertise is usually required when considering activities in coastal areas. A simple screening assessment is not generally appropriate for such a task. For further detail, see the source report *Climate Change Effects and Impacts Assessment* and *Coastal Hazards and Climate Change* (available at www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/index.html and www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual respectively.)

Stage One: Qualitative assessment of the influence of climate change

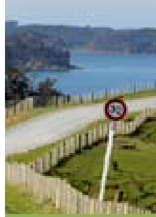
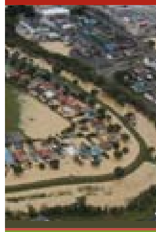
Table 4 and Table 5 overleaf are designed to help council staff understand and qualitatively determine the role of climate, and hence climate change, for a wide range of council functions and services.

Table 4 lists specific council functions, assets and activities and how they could be affected by climate change. Table 5 summarises natural resources that are managed by councils and their sensitivity to climate and climate change.

In using these tables, remember that they are not an exhaustive source of information on the impacts of climate change on all council functions and services. Climate change and its effects should be considered relative to other changes: it will not occur independently of natural climate variability or of future social and economic changes. This guide does not provide guidance on how to make projections of future socio-economic changes – councils will generally have their own resources to estimate future population change and development projections, and the infrastructure requirements to accommodate these.

Table 4: Local government functions and possible climate change outcomes

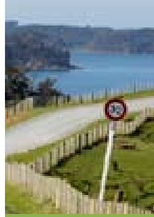
FUNCTION	AFFECTED ASSETS OR ACTIVITIES	KEY CLIMATE INFLUENCES	POSSIBLE EFFECTS	SECTION IN TABLE 4.2 OF THE SOURCE REPORT GIVING TYPE / EXPLANATION OF EFFECTS
Water supply and irrigation	Infrastructure	Reduced rainfall, extreme rainfall events, and increased temperature	Reduced security of supply (depending on water source) Contamination of water supply	See Rivers, Groundwater, Water quality, Water availability, Coastal areas. (Note that there are also rainfall effects in areas dependent on rain water.)
Wastewater	Infrastructure	Increased rainfall	More intense rainfall (extreme events) will cause more inflow and infiltration into the wastewater network Wet weather overflow events will increase in frequency and volume Longer dry spells will increase the likelihood of blockages and related dry-weather overflows	See Drainage
Stormwater	Reticulation Stopbanks	Increased rainfall Sea-level rise	Increased frequency and/or volume of system flooding Increased peak flows in streams and related erosion Groundwater level changes Saltwater intrusion in coastal zones Changing flood plains and greater likelihood of damage to properties and infrastructure	See Rivers, Drainage, Coastal areas
Roading	Road network and associated infrastructure (power, telecommunications, drainage)	Extreme rainfall events, extreme winds, high temperatures	Disruption due to flooding, landslides, fallen trees and lines Direct effects of wind exposure on heavy vehicles Melting of tar	See Drainage, Natural hazards
Urban land use planning / policy development	Management of development in the private sector Expansion of urban areas Infrastructure and communications planning	All	Inappropriate location of urban expansion areas Inadequate or inappropriate infrastructure, costly retrofitting of systems	See particularly Rivers, Groundwater, Drainage, Coastal areas, Natural hazards
Land management	Rural land management	Changes in rainfall, wind, and temperature	Enhanced erosion Changes in type / distribution of pest species Increased fire risk Reduction in water availability for irrigation Changes in appropriate land use Changes in evapo-transpiration	See Water availability, Erosion, Biodiversity, Biosecurity, Natural hazards

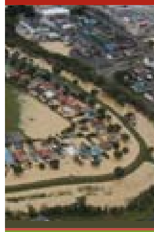




FUNCTION	AFFECTED ASSETS OR ACTIVITIES	KEY CLIMATE INFLUENCES	POSSIBLE EFFECTS	SECTION IN TABLE 4.2 OF THE SOURCE REPORT GIVING TYPE / EXPLANATION OF EFFECTS
Water management	Management of watercourses / lakes / wetlands	Changes in rainfall and temperature	More variation in water volumes possible Reduced water quality Sedimentation and weed growth Changes in type / distribution of pest species	See Rivers, Lakes, Wetlands, Water quality, Drainage, Erosion, Biosecurity
Coastal management	Infrastructure Management of coastal development	Temperature changes leading to sea-level changes Extreme storm events	Coastal erosion and flooding Disruption in roading, communications Loss of private property and community assets Effects on water quality	See Coastal areas, Natural hazards
Civil defence and emergency management	Emergency planning and response, and recovery operations	Extreme events	Greater risks to public safety, and resources needed to manage flood, rural fire, landslip and storm events	See Natural hazards
Biosecurity	Pest management	Temperature and rainfall changes	Changes in range of pest species	See Biosecurity, Biodiversity
Open space and community facilities management	Planning and management of parks, playing fields and urban open spaces	Temperature and rainfall changes Extreme wind and rainfall events	Changes / reduction in water availability Changes in biodiversity Changes in type / distribution of pest species Groundwater changes Saltwater intrusion in coastal zones Need for more shelter in urban spaces	See Groundwater, Drainage, Water availability, Biodiversity, Coastal areas
Transport	Management of public transport Provision of footpaths, cycleways, etc	Changes in temperatures, wind and rainfall	Changed maintenance needs for public transport (road, rail) infrastructure Disruption due to extreme events	See Drainage, Natural hazards
Waste management	Transfer stations and landfills	Changes in rainfall and temperature	Increased surface flooding risk Biosecurity changes Changes in ground water level and leaching	See Biosecurity, Natural hazards
Energy	Transmission lines	Extreme wind, high temperatures	Outages from damaged lines	See Natural hazards

Table 5: Sensitivity of natural resources to present climate and climate change

NATURAL RESOURCE	KEY CLIMATE INFLUENCE	IMPACTS OF CLIMATE CHANGE	PRESENT SENSITIVITY TO CLIMATE
Rivers	Rainfall	River flows likely to, on average, increase in the west and decrease in the east of New Zealand More intense precipitation events would increase flooding (by 2070 this could be from no change, up to a fourfold increase in the frequency of heavy rainfall events) Less water for irrigation in northern and eastern areas Increased problems with water quality	Strong seasonal, interannual and interdecadal fluctuations (see the example in Box 4.1 at the end of section 4.4 of the source report, on peak flows in Bay of Plenty)
Lakes	Temperature and rainfall	Lake levels likely to increase, on average, in western and central parts of New Zealand, and possibly to decrease in some eastern areas Higher temperatures and changes in rainfall, particularly in areas such as the Rotorua Lakes, could result in a range of effects, including: · an increased degree of eutrophication and greater frequency of algal blooms · altering of lake margin habitats, including wetlands, with either increased or decreased rainfall · negative impacts on aquatic macrophytes, particularly native species, if lake levels fall · a decrease in the range of trout with increased water temperatures · increased ranges of pest species (eg, carp), placing even more pressure on aquatic ecosystems	Seasonal and interannual fluctuations
Wetlands	Temperature, rainfall, sea-level rise	Coastal and inland wetlands would be adversely affected by temperature increases, rainfall increases or decreases and sea-level rise	Many already under threat
Groundwater	Rainfall	Little change to groundwater recharge is expected in eastern New Zealand, but increased demand for water is likely Some localised aquifers in northern and eastern regions could experience reduced recharge. For example, small coastal aquifers in Northland would be under threat from reduced rainfall	Seasonal fluctuations; but at present, generally stable over the longer term
Water quality	Temperature and rainfall	Reduced rainfall and increased temperatures could have significant impacts on the quality of surface water resources in northern and eastern New Zealand Lower stream flows or lake levels would increase nutrient loading and lead to increased eutrophication	Most sensitive during summer months and in drier years
Drainage	Rainfall	Increased frequency of intense rainfall events could occur throughout New Zealand, which would lead to increased surface flooding and stormwater flows, and increased frequency of groundwater level changes	Natural year-to-year variation in the location and size of heavy rainfall events
Water availability	Rainfall	Decreases in rainfall, which are most likely in the north and east of New Zealand, coupled with increased demand, would lead to decreased security of water supply	Dry summers, or extended droughts
Erosion	Rainfall and wind	Increased rainfall in the west, and more intense rainfall events throughout New Zealand, could lead to increased soil erosion, including landslides	Intense rainfall events can arise with subtropical lows, and localised low pressure cells





NATURAL RESOURCE	KEY CLIMATE INFLUENCE	IMPACTS OF CLIMATE CHANGE	PRESENT SENSITIVITY TO CLIMATE
Biodiversity	Temperature, rainfall, wind	Increased temperature, reduced rainfall and more frequent drying westerly winds (possible in the east) would lead to changes in distribution and composition of native forest ecosystems throughout New Zealand Fragmented native forests in the north and east of New Zealand will be most vulnerable An increased biosecurity risk, with invasive temperate and subtropical species, would also have negative impacts on native flora and fauna Small increases in temperature will significantly increase the incidence of pest outbreaks in New Zealand, particularly in the North Island and the north of the South Island Both existing and potential new plant and animal pests could become established more widely, even with a slight increase in temperature	Drought can have a severe impact, eg, some native vegetation was adversely affected in Hawke's Bay after the 1997/98 El Niño drought
Coastal areas	Sea-level rise, storm frequency and intensity, wave climate, sediment supply	Effects of sea-level rise and other changes will vary regionally and locally Coastal erosion is likely to be accelerated where it is already occurring and erosion may become a problem over time in coastal areas that are presently either stable or are advancing	Short- and medium-term fluctuations in sea levels (ie, up to about 30 years) are dominated by ENSO and IPO variations
Air	Temperature, rainfall, wind	Increased temperatures in Auckland might increase photochemical smog Fewer cold nights may reduce particulate smog problems in winter in affected towns and cities	
Natural hazards	Temperature, rainfall, wind	The general indications are that New Zealand could experience more climatic extremes in the future. These could include: · more intense rainfall events, and associated flooding, in most parts of the country · more frequent and/or intense droughts in the east · more damaging windstorms · more heat waves · increased fire risk in drier eastern areas	There have been more frequent and intense El Niño events in recent decades, possibly associated with the Interdecadal Pacific Oscillation. The worldwide cost of extreme weather damage has increased owing to a mixture of climatic, economic and social factors

Deciding on the need for quantitative assessment

Having qualitatively determined that climate change could affect a council function or service, a decision has to be made as to whether the impact warrants a quantitative analysis.

Quantitative assessment is most likely to be required:

- whenever infrastructure is upgraded anyway or major developments are undertaken
- if some infrastructure and developments have a lifetime of more than 30 years. Is their design consistent with climate predictions?
- whenever council plans come up for review. If the topic is dependent on, or affected by, climate and the plan regulates long-term actions, it may be affected by climate change.

The following principles are also important in deciding on quantitative assessment:

- Future generations need to be able to respond to risks caused by a changing climate. There is a need to avoid locking the community into a situation of increasing risk which has limited risk management options.
- The risk from climate change varies over time. Analysis and action on climate change should be deferred only if its effects are likely to be negligible compared to other pressures.

Other questions that could be asked include:

- Could an existing problem (eg, recurrent inundation) be exacerbated by climate change?
- What foreseeable problem may be caused or exacerbated by climate change?
- Is the issue complex (eg, deciding on the location of a new suburb as opposed to only one building)?
- Is the location sensitive to climate change (eg, on a flood plain as opposed to a bedrock hilltop)?
- Does a decision imply a permanent long-term change (eg, locating a new suburb as opposed to permitting a campsite)?
- Is much infrastructure involved and are services provided (eg, compare an urban area with a remote rural location)?

Developing quantitative scenarios of the likely effects of climate change

There is much uncertainty about the extent of climate change and about social, economic and environmental change. That makes it necessary to consider a range of possible futures when assessing climate impacts, and whether adaptive responses are needed.

Future scenarios can be developed and combined with expert knowledge and models of the sensitivity of natural or managed systems to climate. This will help determine the likely quantitative effects of climate change on council activities and services.

Scenarios can be developed for preliminary assessments, as outlined over the next few pages, and for more detailed risk assessment studies.

Three broad categories of scenario can be considered:

1. **Social:** Demographic changes are likely to have a significant influence on the demand and supply of local government functions and services, and consequently on natural resources managed by local government.
2. **Economic:** Agricultural, industrial and tourism development all have consequences for local government and the resources they manage. Changes in land use could have significant effects on demand and supply for resources such as water.
3. **Physical / environmental:** Projected future climate change.

Councils will have other sources of information on future scenarios regarding social and economic changes. The information in this guide on future climate change scenarios should ideally be combined with social and economic scenarios in order to paint the most accurate picture possible.

Stage Two: Preliminary assessment of the impact of climate change

A preliminary assessment of the effects of climate change can be carried out at relatively low cost and effort at the design and planning stages of a major project, because it can be integrated into the project development phase. Separate analyses at a later stage are likely to be more costly and less effective, as is action to reduce future risk after the project has been completed.

Table 6 provides guidance on developing scenarios for preliminary assessments and for more detailed risk assessments. It provides suggestions, not firm scientific predictions, for scenario analyses. Especially for strong winds and heavy rainfall, projections are likely to be revised as science and modelling develop further.

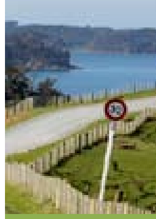
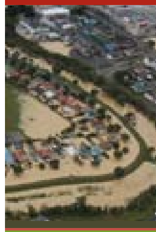




Table 6 should provide planners and engineers with useful initial estimates to test the likely significance of climate change on specific council functions and services. This preliminary assessment may not require independent expertise and can be carried out as part of a larger planning exercise at minimal cost.

For preliminary assessment purposes, the second column in Table 6 outlines how to obtain region-specific values of climate parameters: these are based largely on figures provided in Part One of this guide. The emphasis is on mid-range climate projections. If the preliminary assessment indicates significant climate change impacts or opportunities, a more detailed risk assessment is recommended. That may require a more complex physical or statistical modelling approach: using detailed analyses of current climate statistics in a location, and covering the high and low extremes of predicted climate change over timeframes that are relevant to the particular function or natural resource being addressed. If the preliminary assessment does not suggest significant effects, it is advisable to repeat the exercise using the upper range figures. It may also be useful to examine historical data. This could involve a statistical analysis or use of past events (floods, droughts, hot years etc) with additional changes in the underlying average climate, as indicators of what might happen in future.

Table 6: Values or sources of climate parameters suggested for use in scenario analyses

CLIMATE FACTOR	FOR SCREENING ASSESSMENT SCENARIOS	FOR DETAILED STUDY SCENARIOS
Mean temperature	Mid-range 2040 and 2090 projections (Figure 1; central values from Table 2)	Low, mid and high scenarios from ranges given in Table 2, or approach a science provider for regional numbers
Frost occurrence	For 2090, two top panels of Figure 2.8 in the source report. For 2040 use mid-range CLIMPACTS[1] (or move current seasonal frequency distribution of daily minimum temperature right by seasonal mean change)	Use CLIMPACTS to develop low / medium / high scenario frost changes, and/or approach a science provider for regional numbers
Extreme high temperatures	For 2090 use lower two panels of Figure 2.8 in the source report	Use CLIMPACTS to develop low / medium / high scenario maximum temperatures and/or approach a science provider for location-specific weather generator results
Growing degree days	Use CLIMPACTS for a mid-range scenario	Use CLIMPACTS to develop low / medium / high scenario changes and/or approach a science provider for location-specific projections
Winter chilling		Approach a science provider for weather generator based location-specific projections
Mean rainfall (annual, seasonal)	Mid-range 2040 and 2090 projections (Figure 2 and Figure 3; central values from Table 3)	Low, middle and high scenarios from ranges given in Table 3
Heavy rainfall	Use factors from Table 7 with 5, 10, 50, 100-year average recurrence interval (ARI) values from HIRDS[2] or from local data analyses	Obtain assistance from a science provider with site-specific applications of the gamma function analysis outlined in Appendix 3 of the source report
Flood	Use factors from Table 7 with the rainfalls used to drive the design floods	Approach specialist hydrologist for targeted advice
Water deficit (for irrigation)		Use weather generator in CLIMPACTS for locations of interest, for low / middle / high greenhouse gas scenarios
Snow	Assume snowline rises by 140 m for each 1°C increase in annual average temperature	Requires research and development of linked spatial weather generator / snow budget modelling software for future projections
Strong winds	Increase 99th percentile wind speed by 10% for 2090	Changes in the frequency of strong winds and average recurrence interval of damaging winds are still very uncertain. Consult with a science provider if screening indicates possible problems
Sea level, coastal hazards	Refer to Coastal Hazards and Climate Change guidance manual: www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual	Refer to Coastal Hazards and Climate Change guidance manual: www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual

1 CLIMPACTS is an integrated assessment model for conducting analyses of the sensitivity of New Zealand's managed environments to climate variability and change. See www.climsystems.com/site/home/

2 HIRDS is the High Intensity Rainfall Design System, available from NIWA on CD-Rom.

Consideration of heavy rainfall in assessing the effects of climate change

Heavy rainfall is a key variable in infrastructure planning and design. Table 7 shows recommended percentage adjustments per degree of warming to apply to extreme rainfalls; values are given for various average recurrence intervals (ARIs) and for rainfall durations from less than 10 minutes up to 72 hours. Current extreme rainfall rates for selected locations, durations and ARIs can be obtained from analysis of historical rainfall data sets from particular sites or from the High Intensity Rainfall Design System (HIRDS) CD-Rom (available from NIWA). The projected changes in *annual* mean temperature are listed in the right-hand columns of Table 2 of this guide.

Using these data, at least two screening calculations should be undertaken: one for low and one for high temperature change scenarios. A worked example of the application of this information is provided in Appendix 4 of the source report. In carrying out site-specific analyses, consider the uncertainties in return period estimates for the present climate. In many places rainfall records only cover a past period of a few decades. So, any design rainfall estimates for 50 or 100-year ARIs will contain statistical assumptions and data-based uncertainties.

As mentioned before, increases in rainfall intensity do not necessarily imply an increase in annual rainfall totals, as there are likely to be changes in the frequency of storm events. The use of the range of figures provided below may indicate that climate change could significantly affect a council function or service, and this function or service is of sufficiently large scale or importance to warrant attention. In that case, a full risk assessment using more complex scenarios may need to be undertaken.

Table 7: Factors for use in deriving extreme rainfall information for preliminary assessment scenarios
ARI = Average Recurrence Interval

ARI (YEARS) DURATION	2	5	10	20	30	50	100
< 10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30 minutes	7.2	7.4	7.6	7.8	8.0	8.0	8.0
1 hour	6.7	7.1	7.4	7.7	8.0	8.0	8.0
2 hours	6.2	6.7	7.2	7.6	8.0	8.0	8.0
3 hours	5.9	6.5	7.0	7.5	8.0	8.0	8.0
6 hours	5.3	6.1	6.8	7.4	8.0	8.0	8.0
12 hours	4.8	5.8	6.5	7.3	8.0	8.0	8.0
24 hours	4.3	5.4	6.3	7.2	8.0	8.0	8.0
48 hours	3.8	5.0	6.1	7.1	7.8	8.0	8.0
72 hours	3.5	4.8	5.9	7.0	7.7	8.0	8.0

Notes: This table recommends *percentage* adjustments to apply to extreme rainfall *per degree Celsius of warming*, for a range of average recurrence intervals. The percentage changes are mid-range estimates per degree Celsius and should only be used in a preliminary assessment. The entries in this table for an event of 24 hours' duration are based on results from a regional climate model driven for the A2 IPCC emissions scenario (see Appendix 2 of the source report for more information on IPCC emission scenarios). The entries for 10-minute duration are based on the theoretical increase in the amount of water held in the atmosphere for a 1°C increase in temperature (8 per cent). Entries for other durations are based on logarithmic (in time) interpolation between the 10-minute and 24-hour rates. Caution: Preliminary analysis of NIWA regional climate model results indicates that in some areas increases substantially higher than the upper limit of 8 per cent given in this table are possible.

Stage Three: Detailed risk assessment of climate change effects using complex scenarios

A sound risk assessment process is fundamental to ensuring that climate change is appropriately factored into planning and decision-making processes. The risk assessment process described here is based on the New Zealand Standard for Risk Management, AS/NZS4360, which recommends a scenario-based approach (see sections 4.2.3 and 6.5 of the source report for more detail).

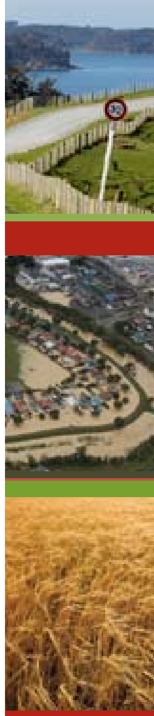
The purpose of risk assessment, in the context of climate change, is to identify risks and hazards caused or exacerbated by climate change and to evaluate their effects and likelihood. This also allows climate change risks and responses to be prioritised with confidence and compared equitably with other risks, resource availability and cost issues.

Because of the uncertainties involved in climate change, a mixture of quantitative and qualitative information should be used. Detailed assessments of the effects of climate change on council functions and services can be approached in any one of three main ways:

- **Modelling:** Computer-generated scenarios of climate change, using either existing models and data, or historical data such as past flood events to determine possible effects in the future.
- **Expert opinion:** Expert advice on plausible scenarios of climate change in a particular region. If, for example, flooding was used in a modelling approach, quantitative analysis could be combined with expert opinion. Lack of data and modelling capability may increase reliance on expert opinion.
- **Monitoring:** The real effects of climate change will only emerge through ongoing monitoring and may be the only way that effects can be quantified over time.

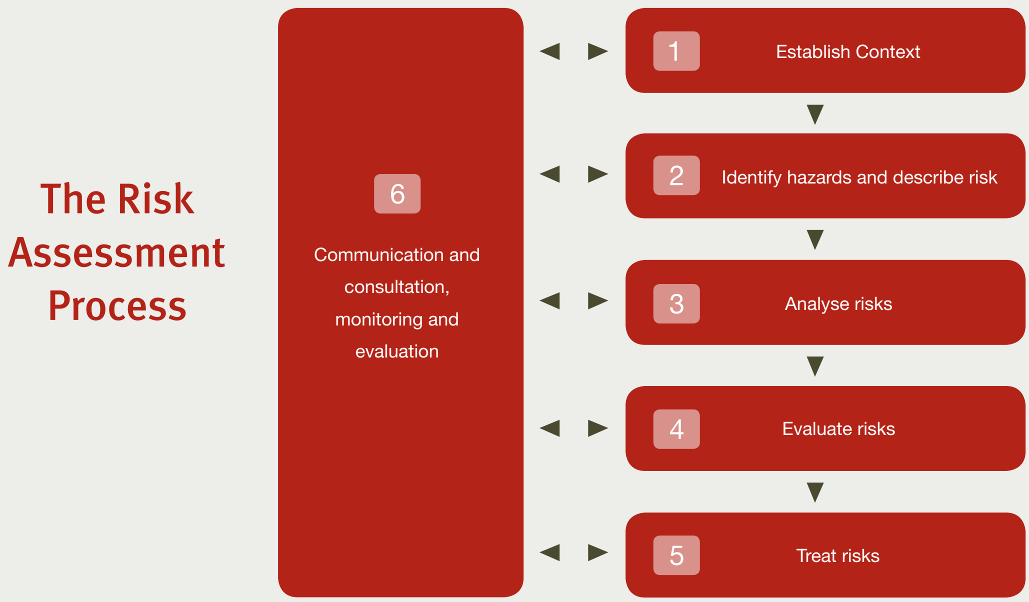
In selecting the approach to take, judgment is required as to which is most applicable to the specific problem or issue. Considerable capability – in terms of expertise, data and quantitative models – already exists for assessing physical impacts. For example, there is a strong capability in New Zealand for predicting river flows but there is generally a much lower capability for quantitative assessment of biological and social / human impacts. In areas such as asset management, where investment in infrastructure is required, quantitative modelling is the recommended principal approach. A combination of approaches, especially monitoring, might be used for addressing biodiversity issues.

Uncertainties or assumptions will be inherent in whichever approach is selected. These need to be taken into account, together with the uncertainties in projections of future climate, when assessing climate change effects.



Six steps to risk assessment

A six-step, scenario-based process for risk assessment is explained in detail in the source report on which this report is based. In summary, these steps are:



1. Establish the context

Define from a strategic, organisational and climate change risk assessment context for what assets, services and functions the local authority has responsibility. Consider which of these may be affected by climate change. Specify what precise service and function is being considered, and what its context is; include community expectations about the level at which this service should be delivered (including comfort levels for delay and/or exceedance, damage from malfunction etc). This context is necessary to decide whether the effect of climate change will be significant.

2. Identify hazards and describe the risks

Develop hazard event scenarios for each locality (land use, natural resource, type of development and council services provided) and/or activity, with specific assumptions about the community context; and use current and historical information to describe the risks.

3. Analyse the risks

Analyse the risks presented by the hazard event scenarios over the lifetime of the development, asset or infrastructure and their degree of likelihood, to separate minor acceptable risks from major risks and to provide data to help evaluate and treat the risk.

4. Evaluate the risks

Use risk analysis findings to categorise for each time step of the asset / service's lifetime (ie, 25, 50, 75, 100 years):

- the risk likelihood (almost certain / likely / probable / likely / rare)
- the level of risk (extreme / high / moderate / low / negligible)
- its consequence (catastrophic / major / moderate / minor / insignificant).

5. Assess appropriate responses based on the risks

Having assessed the implications and risk of climate change, place particular types of climate change risks in context by comparing them to both other types of risks and to each other. Respond as appropriate to priority climate change risks within the context of statutory and other responsibilities, including responsibilities to consult and plan ahead.

6. Communication, consultation, monitoring and evaluation

Ensure there is ongoing:

- communication and consultation with internal and external stakeholders
- monitoring of climate change, the associated risks and the effectiveness of any risk treatment plans, strategies and control measures
- review of risk in light of changing climate change projections in order to ensure risk management plans remain relevant.

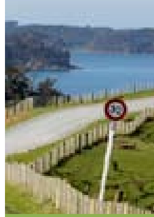
Case studies

Illustrated below are three different scenarios of varying complexity that have been used in climate change risk assessment.

Case Study 1:
Southland water resources

Environment Southland identified three main drivers of change that would affect Southland's freshwater environment in future:

- **Environmental:** The greatest change has been an increase in the average minimum temperature over the past 40 years. The daily temperature range is decreasing faster than elsewhere in New Zealand.
- **Population:** The populations of urban and rural areas have been declining since the late 1970s.
- **Economic:** Agriculture accounts for 82 per cent of the total land area in the region that is not conservation land. Agricultural activities are the largest contributor of nutrients, microbiological and other contaminants to freshwater resources.



Changes in land use can have a major effect on resultant environmental pressures. Over the past decade there has been a rapid expansion of dairy farming and associated industry infrastructure. Tourism is among other economic activities that could increase pressure on freshwater resources.

Thus, if Environment Southland intended studying the possible effects of climate change on Southland's freshwater environment, it would need to consider changes in these key drivers over the next 30 to 100 years. This would require some consideration of alternative scenarios for each driver, as outlined below in Table 8.

Table 8: Examples of possible alternative scenarios for key drivers affecting southland freshwater resources

Scenario	Environment	Population	Economic
1	Low-case scenario of climate change: • slight temperature changes in the order of 0 to 0.5ºC in most seasons • slight increase in summer rainfall, decreases of –20 to –10% in other seasons	Downward trend in population stabilises with low growth over the next 50–100 years	Moderate land use changes with slightly warmer and drier average conditions
2	High-case scenario of climate change: • temperature increases in the order of 3ºC with greater increases in winter than in summer • precipitation increases greater than 20% in all seasons with likely increased proportion that falls as heavy rain	Downward trend in population stabilises with more rapid growth over the next 50–100 years due to more favourable climate (particularly for the agricultural sector such as dairy farming)	Greater intensification of land use with warmer, wetter conditions

Case Study 2:
Water resources changes in three river catchments

In 2001 the Ministry of Agriculture and Forestry commissioned Lincoln Environmental and NIWA to quantify the potential change in agricultural water usage and availability due to climate change, and to assess the implication of these changes on the potential pressures on water sources and water allocation issues.

Changes in three river catchments were studied: Rangitata in South Canterbury, Motueka in Nelson and Tukituki in Hawke's Bay.

Environmental (climate and river flow changes) and economic (land-use changes) scenarios were developed, though the land-use changes were generated principally from the projected climate changes.

The main steps in the development of climate and river flow change scenarios were:

- gathering of historical climate and river flow data for 1971–95 for selected sites in each catchment
- generation of two climate change scenarios for 2050, and site changes (monthly) for precipitation, maximum temperature, minimum temperature, dew point temperature, and wind
- use of a weather generator to synthesise 30 years of daily climate data for 2050 for key sites
- river flow scenarios.

Land-use changes in each of the three catchments were determined by calculation of changes in mean monthly degree-days, combined with local expertise.

Current economic trends for different crops and farming systems were applied, on the basis that they would hold for 2050. The general pattern presented was for more intensive land use. The scenarios of climate, river flow and land-use change were then brought together to quantify possible changes in water demand and supply, using an irrigation scheme simulation model.

Case Study 3:
Stormwater and wastewater effects in North Shore City

A study by North Shore City Council on its wastewater system included examination of the possible effects of climate change on future wet weather overflows.

Existing system performance was translated into expected future performance based on changing rainfall (extreme events) using a statistically established relationship between existing rainfall patterns and existing system performance.

Key aspects of the development of scenarios included:

- the use of 17-year historical rainfall records to determine the existing condition of the receiving environment
- the use of NIWA studies showing likely increases in temperature and rainfall due to climate change
- estimation of storm characteristics in 2050 from the historical records and historical and predicted future rainfall.

The study acknowledged that climate change is well accepted worldwide. However, the effect on North Shore's wastewater system was based on a number of simplified assumptions with inherent uncertainties associated with modelling the effects of climate change. The study recommended that the results, therefore, should be used to assess trends rather than to provide absolute values.

Conclusion

Local authorities are responsible for a range of functions, services and assets that may be affected by climate change. Each community will have its own climate-related vulnerabilities and priorities.

This guide has emphasised the need to assess the potential effects of climate change on council activities and has provided a framework for doing so. A key recommendation is that councils consider climate change effects – and the additional risks and opportunities they may bring – as part of existing planning, risk assessment and operational processes. Generally speaking, councils can also respond to climate change effects via existing processes.

Decisions as to whether a climate change response is necessary should include consideration of legislative frameworks (including hazard management responsibilities, liability and existing use right considerations), community expectations for the present and the future, and the relative costs and risks of delaying action.

A distinguishing feature of climate change-related risks is that the underlying risks themselves change over time. It is important to consider whether future generations will be in a position to adequately address these changing risks if the present generation defers action.

In all cases, it is recommended that councils monitor and record local climate variables in order to better inform risk assessment and associated decision-making in their area.

By responding now to climate change impacts, councils can improve the resilience of their communities to existing natural hazards; in so doing so, they can enhance the prosperity and sustainability of present and future generations.