Canterbury, its people, its resources

Climate Change

An analysis of the policy considerations for climate change for the Review of the Canterbury Regional Policy Statement

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Table of Contents

List of Figures

Figure 0.1 The purpose of this report

The following figure shows how this climate change report fits into the bigger picture of addressing climate change – regionally, nationally and globally. It is a summary of Section 1 - the introduction to this report which starts on the following page.

CLIMATE CHANGE

CAUSES
emissions of greenhouse gases

↓

New Zealand's central government is responsible for regulation of greenhouse gas emissions.

Reducing emissions requires action from all individuals, companies, science and technology institutions and all levels of government and related organisations.

Although information is included in this **report** about the relationship between emissions and climate change, this report does not deal with the causes of climate change specifically. It is about adapting to climate change rather than reducing greenhouse gas emissions.

EFFECTS
what climate change trends have been recorded to date, and what is projected to happen in the future

↓

This **report** summarises information from international and national studies.

It includes information about what changes to the climate have already occurred, both globally and nationally.

It also includes projections for future climate change – globally, nationally, and specifically for the Canterbury region.

EFFECTS
how do we prepare for future climate change to minimise any adverse effects

↓

This **report** discusses how we can adapt to climate change.

The report looks at how climate change might affect our environment, our society, and the regional economy.

It then includes a specific section which looks at how the review of the Canterbury Regional Policy Statement might need to be changed to take the effects of climate change into account.

The information in this report will help inform all of Environment Canterbury's functions to adapt to climate change.

The information will also be useful to the district councils within Canterbury, and anyone who wants to find out about the potential effects of climate change on our region.

1 Introduction

The purpose of this report is to consider the effects of climate change, and how the review of the Canterbury Regional Policy Statement can respond to them.

It is now generally accepted worldwide that human activities have accelerated climate change, and that further future climate change is unavoidable. Climate change policy issued in October 2006 noted that "the debate on climate change has moved beyond discussion of whether it is happening, to what must be done to reduce emissions and adapt to the inevitable effects of climate change"[i].

Climate change has been caused by the release of greenhouse gases[1] into the atmosphere (further detail about the causes of climate change can be found in Appendix A to this report). Atmospheric concentrations of CO_2 have increased by 35% since 1750, and are currently at concentrations unprecedented over the last 650,000 years. Approximately three-quarters of this is due to the burning of fossil fuel, while the rest is predominantly due to land use change (such as deforestation). Volumes of CO_2 emissions continue to increase – emissions from fossil fuel use during the 1990's averaged at 6.4 GtC[2]/year, which increased to 7.4 GtC/year for the period 2000-2005.[ii]

Figure 1.1 Carbon dioxide levels over the past 350,000 years

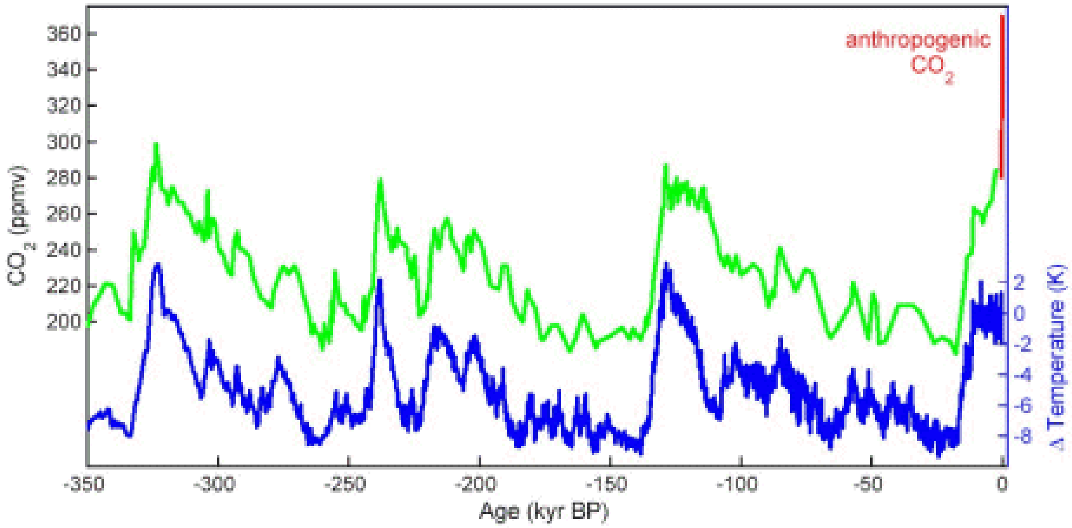


Figure 1.1 Records of CO_2 (green) and temperature (blue) over the past 350,000 years from the Vostok ice core are shown. The recent anthropogenic rise in CO_2 is marked in red. (Source: Rahmstorf, S et al (2004))

[1] The key greenhouse gases that have significantly increased due to human activity since 1750 are: carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O. New Zealand has obligations under the Kyoto Protocol to also report on the release and removal of the following greenhouse gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). This is not a comprehensive list of all greenhouse gases, and does not include indirect greenhouse gases.

[2] Gigaton of carbon

Atmospheric concentrations of methane have increased by 250% since 1750, similarly unprecedented in the last 650,000 years. It is very likely[3] this increase is due to human activity, predominantly agriculture and fossil fuel use. However, annual emissions have declined since the 1990's.[iii]

Nitrous oxide has increased by 18% over the Industrial era. More than a third of the emissions are anthropogenic, primarily due to agriculture. Annual emissions of nitrous oxide have been approximately constant since 1980.[iv]

Figure 1.2 Atmospheric concentrations of methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels.[v]

Figure 1.2 Methane and nitrous oxide levels over the past 10,000 years[vii]

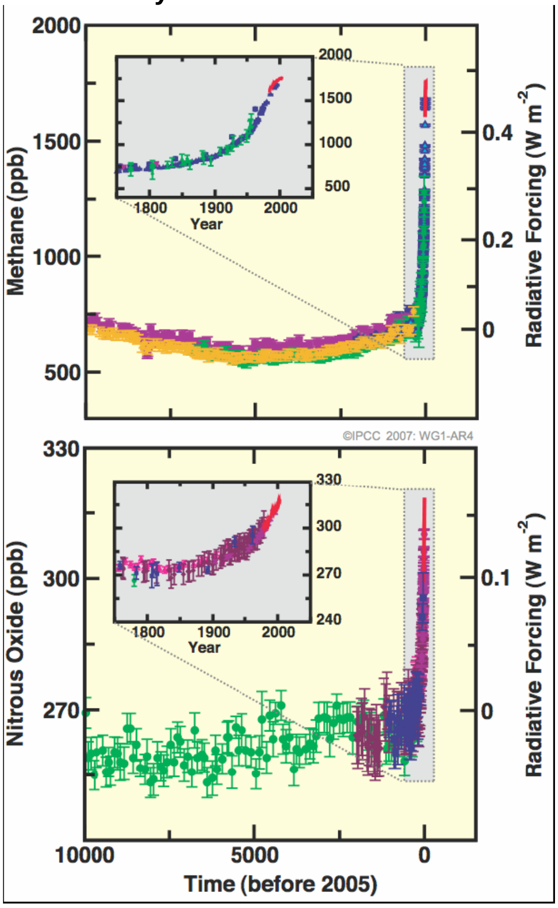
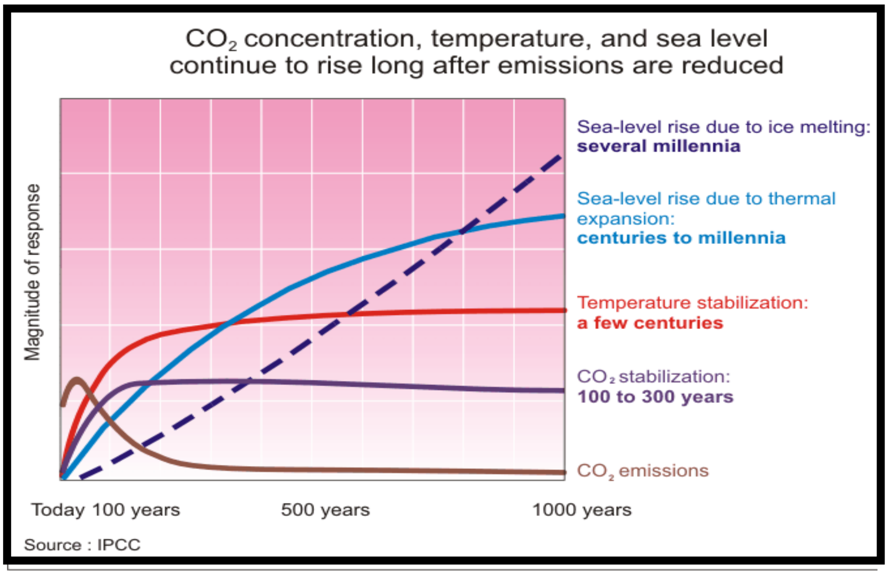


Figure 1.3 Projected carbon dioxide levels and associated climate change[vi]



Regardless of the global response to emissions, the levels of greenhouse gases currently in the atmosphere mean that the climate will continue to change as a result of human activities for the foreseeable future.

Figure 1.3 The graph shows a scenario in which emissions peak around 2050 then fall rapidly. Temperature stabilizes in about 200 years, but sea level continues to rise for over 1,000 years.

[3] Greater than 90% probability

There are two aspects to addressing climate change. Firstly, in order to reduce the impact of humans on the climate as much as is now possible, we must reduce greenhouse gas emissions. New Zealand is part of the international efforts to do this, initially as a signatory to the Kyoto Protocol. As this is a global issue, responsibility for regulatory mechanisms addressing the causes of climate change lies with central government. Amendments to the Resource Management Act 1991 (RMA) in 2004 clarified this[viii].

The second aspect to addressing climate change is to adapt to the now inevitable effects of climate change – humankind is 'committed' to a degree of climate change resulting even from the current elevated greenhouse gas concentrations, which will occur over the coming millennia. Adaptation has the potential to reduce adverse effects of climate change and to enhance beneficial effects, but will incur costs and will not prevent all damages[ix]. Environment Canterbury, in fulfilling its functions under the RMA must *"have particular regard to the effects of climate change"*[4].

The effects of climate change include both effects on our climate (such as temperature increases or flooding), and a wide range of secondary effects (such as damage to strategic infrastructure, institutional upheaval and threats to endangered species). The effects of climate change are set out in Sections 2 to 8 of this report.

Section 2 outlines the historic trends and projected climate changes at a global and national level. Sections 3 and 4 consider historic trends and climate change projections for the Canterbury region.

Associated, or secondary effects on the region are discussed in Sections 5 to 8 of this report. This work examines what changes to the climate might mean for our environment, including both natural and physical resources (Sections 5 and 6), and the social and economic implications (Sections 7 and 8).

The final section of this report considers each of these effects in turn, and what policy response might be considered as part of the review of the Canterbury Regional Policy Statement (CRPS). It is noted that this is an initial 'blue skies' exercise – it does not provide a list of suggested changes to the CRPS, rather it indicates what should be considered further as part of the review of each chapter of the CRPS.

NOTE: Throughout this report, the term "climate change" refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and that is in addition to natural climate variability observed over comparable time periods[x].

[4] Section 7(i) Resource Management Act 1991

2 Global and National Climate Changes

> *There is a key distinction to be made between projected climate change, which will always be hedged in uncertainty, and the overwhelming scientific verdict on past trends. This verdict tells us that climate change induced by human activity is not a theoretical hypothesis, it is in fact a process which is already well underway.*
>
> *It does not tell us precisely how much of the recorded change is anthropogenic, neither does it generate certainty about future trends. In general, the different branches of science construct scenarios, or offer a range of statistical probabilities which reflect a large measure of global consensus.*
>
> *Ken Piddington, Climate Change and Governance Conference 28-29 March 2006*

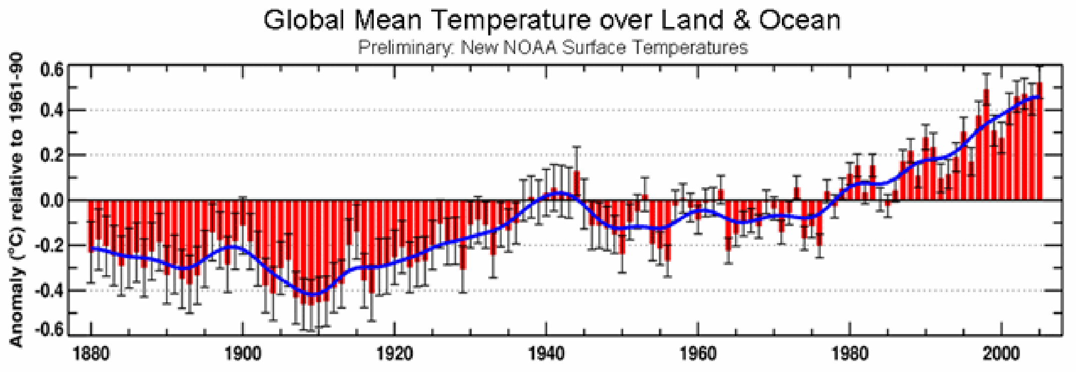
Uncertainty as to the likely changes to our climate, a naturally chaotic and naturally variable phenomenon, is a significant complication when preparing a policy framework for adaptation to the effects of climate change. Some climate change phenomena have more certainty than others, as set out below. Despite this, there is a need to, and a legal obligation to have particular regard to the effects of climate change. This section looks at observed trends in climate change, and projected future changes.

2.1 Observed global trends

Eleven of the last 12 years (1995-2006) rank among the 12 warmest years since recording of global surface temperature began in 1850. An increase in the globally averaged surface temperature by 0.74°C (± 0.2°C) has occurred over the 20th century. The warming trend for the last 50 years is nearly twice that of the past 100 years, at an average warming rate of 0.13°C (± 0.03°C) per decade.[xi]

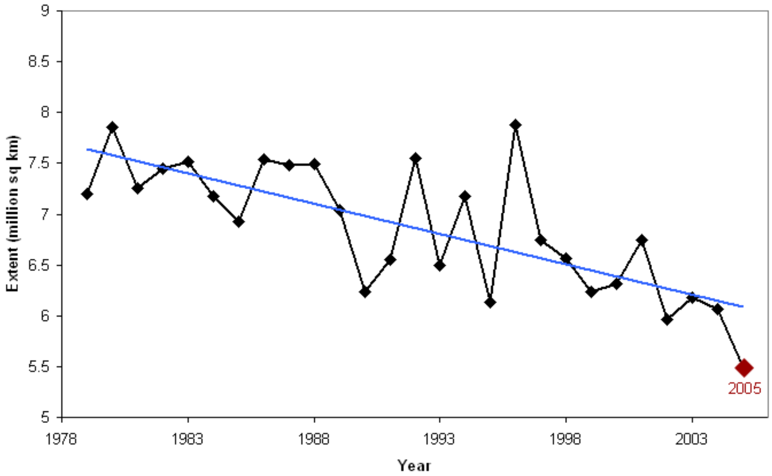
Global average sea-level has risen by an estimated 0.17 m over the 20th century. The rate of sea level rise has increased in recent years. In the period 1961 to 2003 the rate of sea-level rise was about 0.18 m per century, but in the more recent period of 1993 to 2003 this rate has increased to about 0.31 m per century. To date, the world's oceans have absorbed about 80% of the heat in the atmosphere, causing seawater to expand, contributing to sea-level rise. There has also been a global decrease in ice and snow cover, which likewise contributes to sea-level rise.[xii]

Figure 2.1 Global Mean Temperature over Land & Ocean



Source: http://www.climatechangeeducation.org/science/topics.html
from Smith & Reynolds data set

Figure 2.2 Northern Hemisphere Sea Ice Extent



Source: http://www.climatechangeeducation.org/science/topics.html
from NOAA's National Snow and Ice Data Center

2.2 Key phenomena subject to climate change

Observed changes in global climatic phenomena during the 20th century are set out below, including their likelihood[5]: [xiii]

- Warmer and fewer cold days and nights over most land areas (very likely[6] / likely[7])
- Warmer and more frequent hot days and nights over most land areas (very likely / likely (nights))
- Warm spells / heat waves. Frequency increases over most land areas (likely / more likely than not[8]),
- Heavy precipitation events. Frequency increases over most areas

[5] The likelihood shown in brackets relates to two considerations as follows: (likelihood that the trend occurred in the late 20th century, typically post-1960 / likelihood of a human contribution to that trend)

[6] Throughout this report "very likely" means a 90-99% probability

[7] Throughout this report "likely" means a 66-89% probability

[8] Throughout this report "more likely than not" means a 50-65% probability

(likely / more likely than not)

- Areas affected by droughts increases
  (likely in many areas since 1970s / more likely than not)
- Intense tropical cyclone activity increases
  (likely in many areas since 1970s / more likely than not)
- Increased incidence of extreme high sea-level, excluding tsunamis
  (likely / more likely than not)

In addition, the frequency of heavy precipitation events has increased over most land areas, and mid-latitude westerly winds have strengthened in both hemispheres.[xiv]

2.3 Global projections for climate change

Projected changes to the world's climate is dependant on how much greenhouse gases are put into the atmosphere in the future. However, as noted above, even if emissions were stabilised at 2000 levels, we would still be committed to climate change and sea-level rise for more than a millennium because of past and future emissions[9].[xv]

Global average temperatures are projected to increase by an estimated 4.0°C by 2100 (with a range of 2.4°C to 6.4°C) if no steps are taken to reduce greenhouse gas emissions. If CO_2e[10] concentrations are stabilised under 600ppm, global average temperatures are estimated to increase by 1.8°C by 2100 (with a range of 1.1°C to 2.9°C).[xvi]

Warmer and fewer cold days and nights over most land areas is virtually certain[11] to occur this century, as is warmer and more frequent hot days and nights over most land areas. An increased frequency of warm spells / heat waves over most land areas is very likely. An increase in the proportion of total rainfall from heavy falls over most areas is also very likely in the future. Increases in areas affected by drought is likely, as is an increase in intense tropical cyclone activity and incidence of extreme high sea-level (excluding tsunamis). Extra-tropical storms are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns.[xvii]

[9] This is because it takes a long time for the gases to be removed from the atmosphere. Pre-Industrial CO_2e (CO_2 equivalent, taking into account all greenhouse gases) was about 280ppm. It is currently at about 430ppm. Stabilisation of CO_2e at 550ppm would require cuts in emissions to 80% below current annual emissions. Under a 'business-as-usual' approach, 550ppm CO_2e would be reached as early as 2035, with annual atmospheric CO_2e concentrations increasing by about 4.5ppm per year, and with the rate of emissions increasing more and more each year primarily due to population and economic growth.

[10] CO_2 equivalent, taking into account all greenhouse gases

[11] Throughout this report "virtually certain" means a greater than 99% probability

Figure 2.3 Global historic and projected temperature rise[xviii]

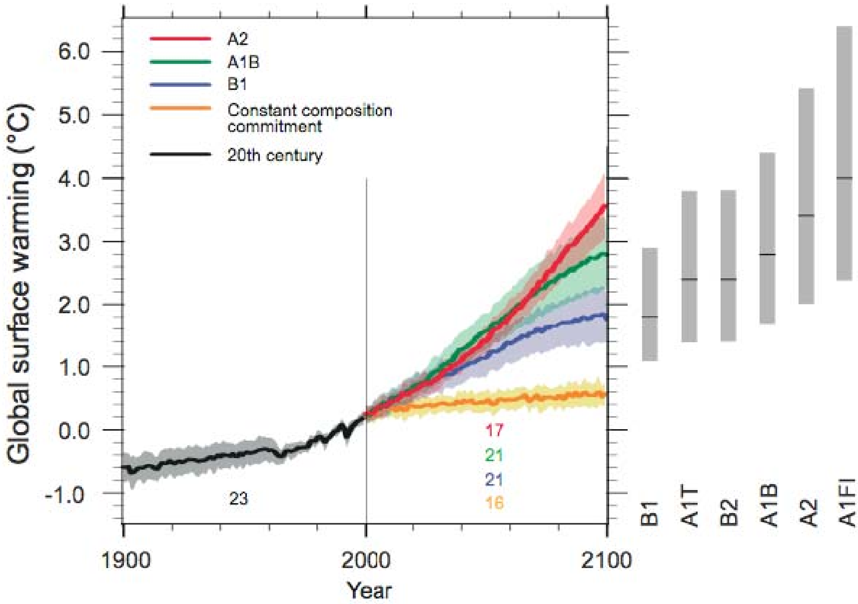


Figure 2.3 Projected increases in average global surface temperature over the 20th century relative to 1980-1999. The blue projection relates to a scenario where atmospheric concentrations of CO_2e are stabilised at 600ppm, the green line shows stabilisation at 850ppm and the red line at 1500ppm. The orange line is based on stabilisation at 2000 levels, about 400ppm (although the actual figure is not given in the IPCC report). The grey bars on the right relate to the best estimate (solid line within each bar) and the likely range assessed for all six of the emissions scenarios (SRES). These correspond to stabilisation of atmospheric CO_2e concentrations from left to right of 600ppm, 700ppm, 800ppm, 850ppm, 1250ppm and 1500ppm.

Sea-level is projected to rise between 0.18 and 0.38 m by 2100, if CO_2e concentrations can be stabilised below 600ppm. However, if CO_2e reach the upper projection of 1500ppm (or business-as-usual) sea-level rise by 2100 would be between 0.26 and 0.59 m. However, these projections do not include rapid dynamical changes in ice flow, which would significantly increase the vulnerability of the ice sheets to warming. Snow cover is projected to continue to contract to the end of the century. Sea-ice is projected to shrink in both the Arctic and Antarctic, with some projections indicating the complete loss of Arctic sea-ice in late summer by the latter part of the century.[xix]

Beyond 2100, sea-level rise from thermal expansion (heating of water) is projected to be 0.3 m to 0.8 m by 2300 based on stabilisation of CO_2e at 850ppm, and this will continue for many centuries. The contraction of the Greenland ice sheet, which would result from sustained global warming, would result in a sea-level rise of about 7m.[xx]

Because much of the CO_2 is absorbed by oceans, this makes them more acidic. The average global surface ocean pH is likely to reduce by between 0.14 and 0.35 units over the 21st century. This adds to the current decrease of 0.1 units since the 1750's.[xxi]

2.4 Observed national trends

There has been a long-term increase in the average temperature of New Zealand of about 0.6°C between 1920 and 2000[xxii]. Sea levels have risen by an average of 16 cm per century since the early to mid 1800s[xxiii]. There has been a 23%-32% loss of glacierised area and an average recession of glacier length of 38% for South Island glaciers over the past century.[xxiv]

Figure 2.4 New Zealand average surface temperature

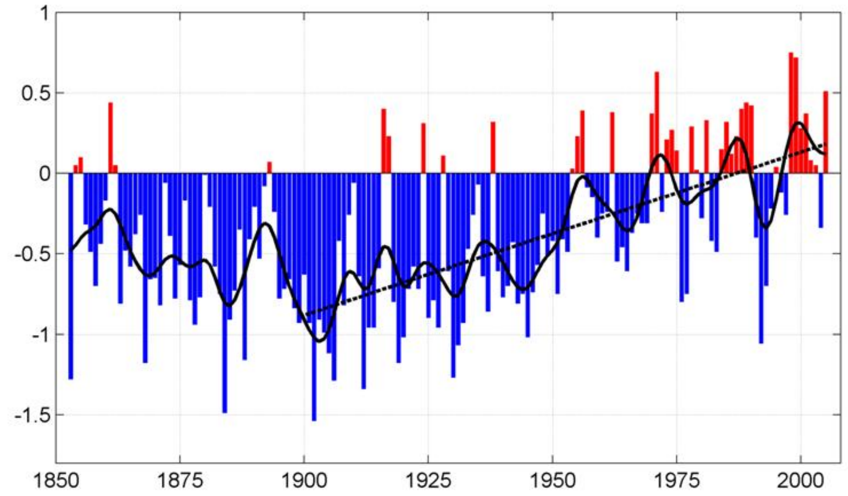


Figure 2.4 Annual anomalies and trends in New Zealand mean surface temperature, compared with 1971-2000 average. The bars represennt annual anomalies, and the smoothed line longer term trends. (Data source: NIWA, 2004, series updated)

2.5 Natural climate change

New Zealand is subject to two identified natural climate variations - the El Niño Southern Oscillation (ENSO) noted above, and the Interdecadal Pacific Oscillation (IPO). 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). It appears that we are now entering a negative phase again.

This natural variability may be altered by climate change as noted above, but can also enhance or suppress the effects of climate change. The positive IPO phase is associated with cooler temperatures, wetter summers in the southeast of the South Island and wetter winters in the north of the South Island. The negative IPO phase is associated with an increase in temperatures across the country[xxv]. Additionally, periods of change between phases (as appears to be currently happening with the change from a positive to a negative phase) is associated with a faster rate of sea-level rise around New Zealand[xxvi].

It may therefore be that the natural variation in climate has masked temperature increases due to anthropogenic climate change, because the positive phase we are just coming out of tends to be cooler. However, the negative IPO phase is also linked to a weaker west-east rainfall gradient across the country. This would weaken the otherwise-projected trend of increased westerly winds as a result of anthropogenic climate change[xxvii] (discussed in more detail in Section 5.3 below).

The interrelationships are very complex, the period of records very short, and higher frequency natural climate variation such as ENSO are not able to be projected very far in advance. Therefore it is not feasible to extrapolate natural variations out to 2100, or include them in shorter-term projections about anthropogenic climate change. However, we still can expect to have significant year to year variability.

2.6 Projected climate change for New Zealand

The average temperature change projected for New Zealand will be less that the global average, as we are buffered by the oceans surrounding us. The following changes arise from the national projections (including levels of confidence in the projections).[xxviii] The regional context, including detail on the degree and timescales of projected change is set out in Section 4 of this report.

- An increase in average temperature (very high) of 0.5-0.7°C by 2030, and 1.5-2.0°C by the 2080s (medium).
- Fewer cold temperatures (very high).
- More high temperature episodes (very high).

- Changes to average rainfall patterns with substantial variation across the country (medium) in keeping with a stronger west-east rainfall gradient.
- Reduced snow cover, shorter seasonal snow lying, snowline rise (medium), glacial retreat[xxix].
- Heavier and/or more frequent extreme rainfall (medium) especially for areas that are projected to have an increase in average rainfall (low).
- Increase in the average westerly windflow across New Zealand (medium)
- Increase in severe wind (low), with little change up to double the frequency of winds over 30 m/s by 2080 (low).
- More storminess (low).

- Sea level rise (very high), with 30-50 cm rise between 1990 and 2100 (high).
- Increase in heavy swells in areas exposed to prevailing westerlies (medium), however the wave climate for Canterbury will continue to be dominated by southerly swells[xxx].

2.7 Extreme and irreversible effects[xxxi]

Smooth, or regular, behaviour of complex systems is an exception rather than a rule. Smooth variations of driving forces can cause abrupt and drastic system responses. The occurrence, magnitude, and timing of these are relatively difficult to predict.

Available records of climate variability reveal sudden fluctuations at all time scales. Large, abrupt climate changes are evident in Greenland ice-core records. Climate is not the only system subject to such irregularity – of equal concern in relation to climate change are ecosystems. Irreversible changes in ecosystems, including extinction events are triggered by disturbances, pests, and shifts in species distributions.

Unfortunately, most of the effects set out above are still focusing on a smooth transition from what is assumed to be an equilibrium climate toward another equilibrium climate (often that a doubling of the atmospheric CO_2 concentration will result in a doubling of effects). This means that most impact assessments still implicitly assume that climate change basically is a "well-behaved" process. This will not necessarily be the case.

The first, and most obvious type of abrupt change would be where the effects of a driver (such as emissions) is not continuous - a critical threshold might be reached, where there is a change to sudden and severe impacts, such as extinction events. Larger changes in mean climate can increase the likelihood of crossing these thresholds.

Even one of the simplest physical thresholds in the climate system—the melting point of ice—could induce such effects. For example, thawing of permafrost regions would be induced by only a few degrees of warming and would severely affect soil and slope stability, with disastrous effects on Arctic infrastructure such as roads. Other examples are bleaching of coral reefs (a temperature threshold) and swamping coastal mangroves (a sea-level rise threshold).

Complexity itself is a second potential cause for abrupt effects in many systems. Complex systems, of course, are composed of many elements that interact in many different ways. Positive feedback loops within those systems can push them into a ‘run-away’ response. One example is the interplay between atmosphere, oceans, cryosphere, and vegetation cover that brought about the rapid transition in the mid-Holocene from a "green" Sahara to a desert, with associated amplification of regional climate change. Another example where a positive feedback loop is in play is the melting of ice sheets. This exposes more darker sea-water, which absorbs rather than deflects the sun’s energy, heating the atmosphere further and therefore melting ice even quicker. This may result in an acceleration of the melting of the ice caps as a result of climate change.

The third category, stochasticity, captures abrupt change triggered by exceptional events such as those discussed elsewhere in this section. In the climate context, these are extreme weather events such as heavy rains. There also is a fourth type that generally arises from a combination of all other categories.

As noted, abrupt climate change is a possibility. By nature climate change is highly unpredictable, and possibly humankind would respond when it is already too late. This underlines the urgency of addressing climate change, and the need to be in a state of preparedness in response to any accelerating trends in weather patterns and sea-level rise.

3 Mean Regional Climate Changes

This section sets out overall projections for changes in *average* climate conditions for the region. It does not include potential changes to the extremes of climactic conditions, in terms of the outer limits of the range of temperatures, rainfall *etc*, which is in Section 4. Neither does this section include the potential increase in effect of climate related natural hazards, either in isolation (*e.g.* cyclones), or in combination (*e.g.* temperature, precipitation and windiness all combine to create drought conditions). Again, these matters are in Section 4.

3.1 Mean Temperature

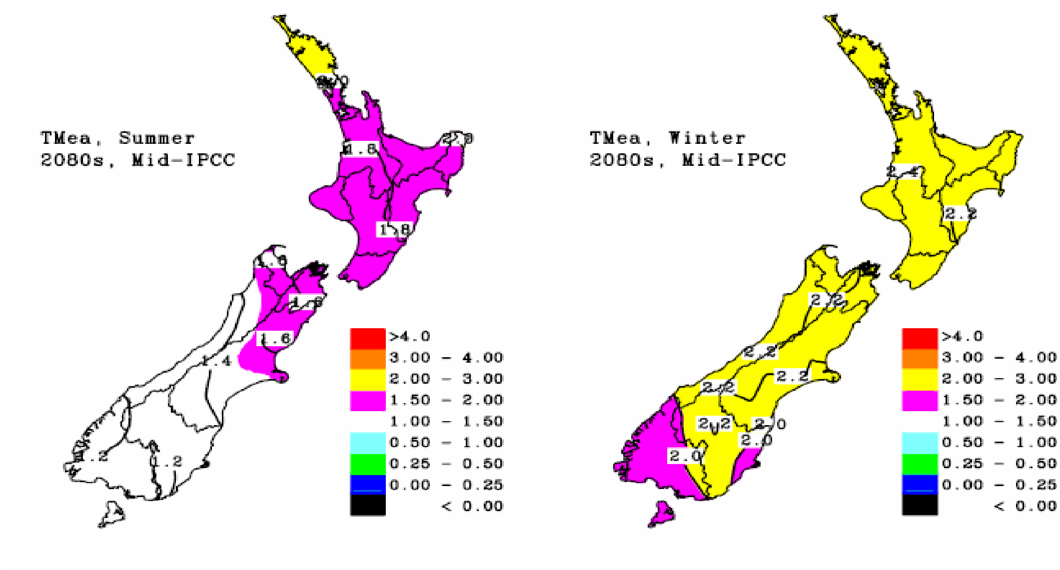
The following table indicates the projected temperature change for the Canterbury region.

Table 3.1 Projected changes in mean temperature (in °C) for Canterburyxxxii

	Summer	Autumn	Winter	Spring	Annual
From 1990 to the 2030s	-0.2 to 1.3	0.1 to 1.1	0.3 to 1.8	0.0 to 1.3	0.2 to 1.4
From 1990 to the 2080s	0.0 to 3.3	0.4 to 3.5	0.8 to 3.9	0.3 to 3.1	0.5 to 3.4

Seasonally, the greatest warming is projected in the winter months. The limited or even slight cooling of the summer months to the 2030s might be due to natural variability, an increase in southerlies, or an increase in westerlies[12][xxxiii].

Figure 3.1 Projected temperature change (in °C) for the 2080s relative to 1990: middle of IPCC 2001 range (MFE, sourcing NIWA projections, 2004)



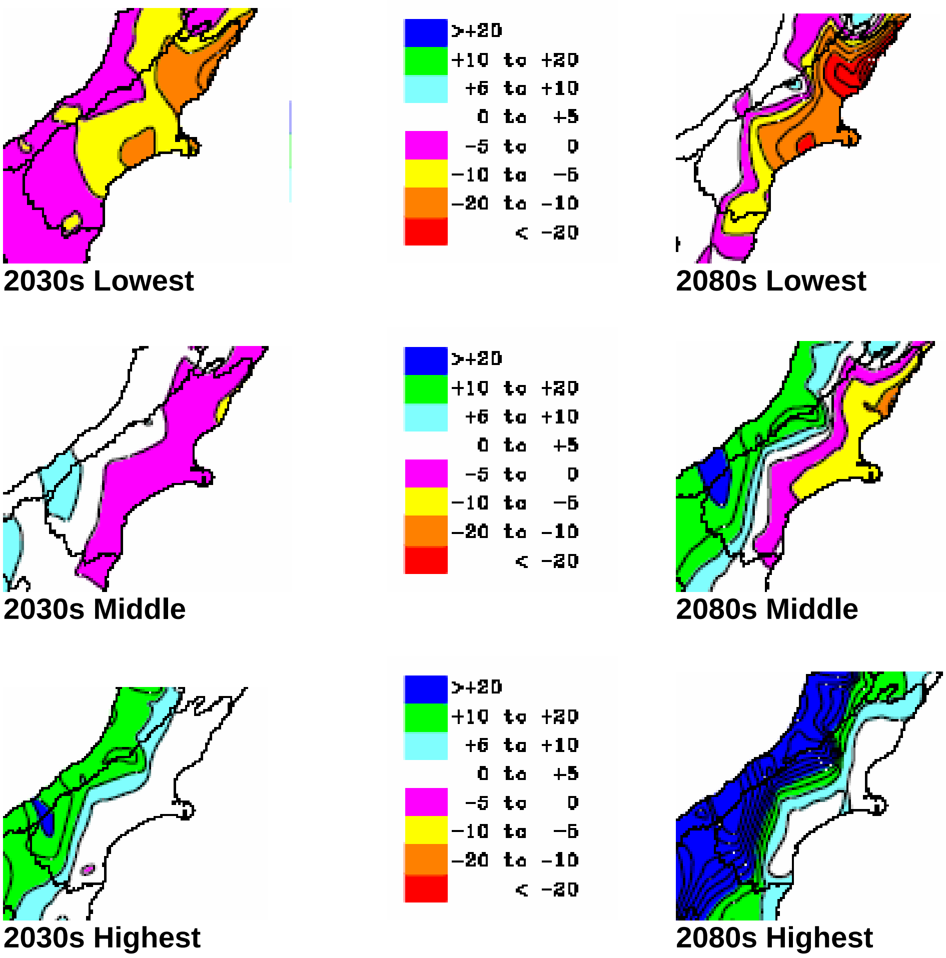
There are slight variations projected across the region, with northern Canterbury projected to increase in temperature slightly more than southern areas of Canterbury, in keeping with national projections.

[12] Whereby stronger westerlies drive the land temperature closer to the upstream sea temperature which is lower than the land temperature in summer.

3.2 Mean Rainfall

The picture for projected changes in regional rainfall is considerably more complex than that of temperature. Some major eastern rivers whose catchments reach back into the Main Divide could maintain or even increase flows, because of projected rainfall increases in these areas. These rivers are the Waitaki, Rangitata, Rakaia, Waimakariri and Hurunui. Although the Waiau and Clarence rivers are mountain-fed, significant increases in precipitation in the northern part of the region are not projected. However, it is noted that a change in phase of the Interdecadal Pacific Oscillation relative to 1978-1998 may mean that these precipitation increases do not eventuate over the next 20 to 30 years[xxxiv].

Figure 3.2 Projected annual precipitation change (in %) relative to 1990

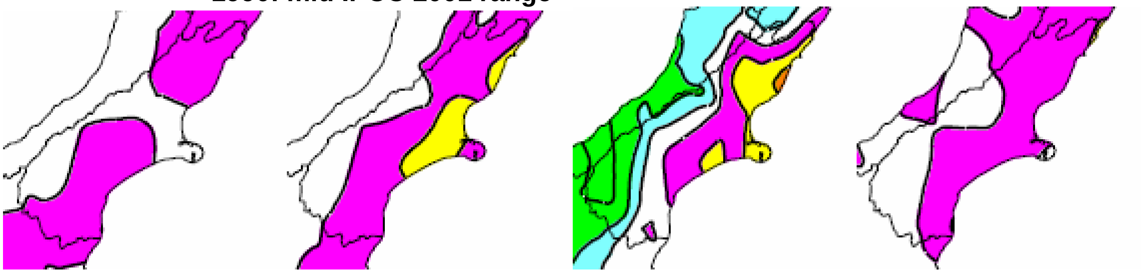


(Ministry for the Environment sourcing NIWA projections, 2004)

Overall, projections indicate that the Canterbury region will experience increasing rainfall in the ranges, and less rainfall on the plains. This has particular significance for groundwater recharge and foothills-fed rivers such as the Waipara, Ashley, Selwyn, Opuha, Opihi, Orari, Pareora, Waihao and Hakataramea, amongst others.

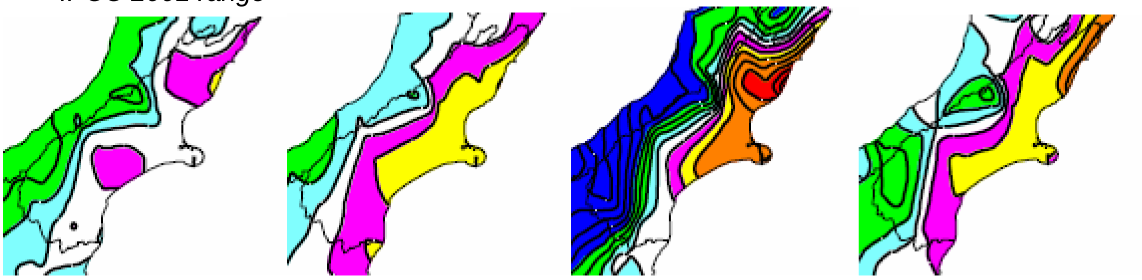
Although the increase in temperatures would be likely to induce a decrease in snow cover, warmer air holds more moisture, and during winter this could be precipitated as snow at high elevations. Therefore, warming does not rule out increased winter snowfall, although the duration of seasonal snow could be shortened and snowlines would rise.[xxxv]

Figure 3.3 Projected seasonal precipitation change (in %) for the 2030s relative to 1990: mid IPCC 2001 range



Summer **Autumn** **Winter** **Spring**

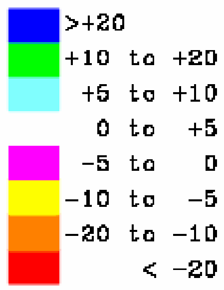
Figure 3.4 Projected seasonal precipitation change (in %) for the 2080s relative to 1990: mid IPCC 2001 range



Summer **Autumn** **Winter** **Spring**

(Ministry for the Environment sourcing NIWA projections, 2004)

Eastern parts of the region are projected to have less annual rainfall overall, particularly in the winter months. Mountain ranges in the north of the region are also projected to have less annual rainfall overall. However, significant increases in precipitation are projected for the Southern Alps, particularly in the winter. North Canterbury is of particular concern, as it is projected to suffer reduced precipitation throughout the year, which is coupled with a lack of alpine-fed rivers in the vicinity to provide more reliable water availability. This is also reflected in the projections for drought noted in Section 4.4 of this report.



As winter rainfall is the largest contributor to groundwater recharge, climate change is likely to induce lower overall recharge and lower groundwater levels[xxxvi].

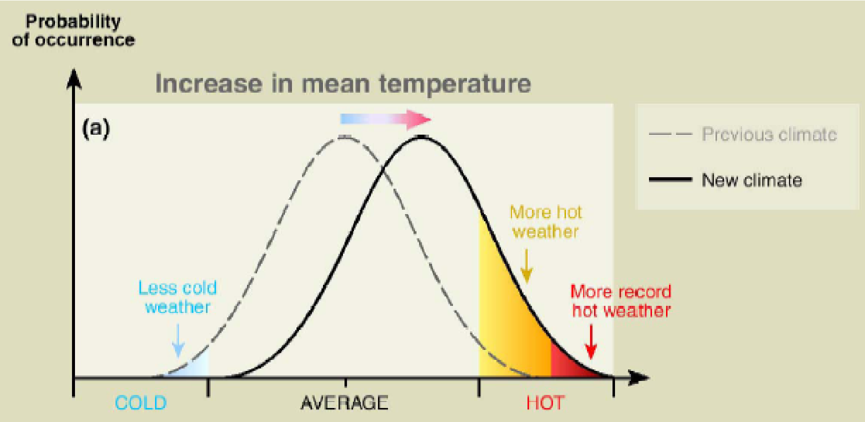
3.3 Sea Level

Sea level change will be consistent with national and global changes, namely a projected rise of between 9 and 88 cm between 1990 and 2100. Sea level rise may accelerate in the future as oceans warm and ice sheets become increasingly unstable. There are also effects related to natural climate variation, as discussed in 2.4 above.

4 Extreme Regional Climate Changes

In reality, the average climate change will be affected most greatly by changes at the extreme end of the range of weather experienced. In the case of temperature, for example, the mean temperature may only shift by a few degrees. However, this shift will be 'produced' by a decreasing number of cold days, and an increasing number of hot days, most likely accompanied by hotter maximum temperatures than have been previously experienced in the area. It is the extreme weather events (such as longer periods of drought) that has the greatest implications for adaptation.[xxxvii]

Figure 4.1 Illustrative diagram of the effect of climate change on mean and extreme temperatures



(Source IPCC Synthesis Report, Watkins *et al* 2001)

4.1 Daily temperature extremes

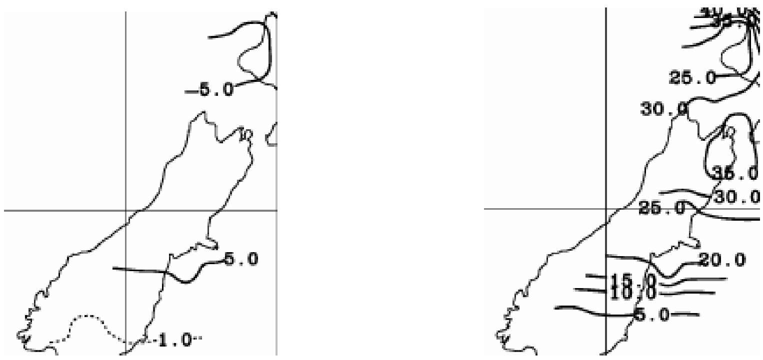
Modelling suggests a significant decrease in the number of frost days experienced in the region, and an increase in the number of hot days, or those days exceeding 25°C.

Figure 4.2 Projected decrease in the number of frost days to 2100xxxviii

Low sensitivity model High sensitivity model

Figure 4.2 Under the low sensitivity scenario, the number of frost days in Canterbury could decrease by between 5 and 10 frost days per year by the end of the century. Under the high sensitivity scenario, there could be 20 to 30 fewer frost days per year in Canterbury. (MfE sourcing Mullan *et al* 2001)

Figure 4.3 Projected increase in the number of hot days (>25°C) to 2100xxxix



Low sensitivity model High sensitivity model

Figure 4.3 As for Figure 4.1, these models are based on two different emissions scenarios. Relatively modest changes are projected by the low sensitivity model, with an increase of between 1 and 5 additional days over 25°C per year for the Canterbury region. However, the more sensitive model suggests increases of between 5 and 30+ hot days per year for the region. (MfE sourcing Mullan *et al* 2001)

The projected reduction in days with a minimum temperature below 0°C is an important change for the region. It appears that the majority of extreme heat events can be anticipated for more northern parts of New Zealand. However, the increase in hot days shown on the high sensitivity model would be a substantial change for the region.

4.2 Extreme Rainfall

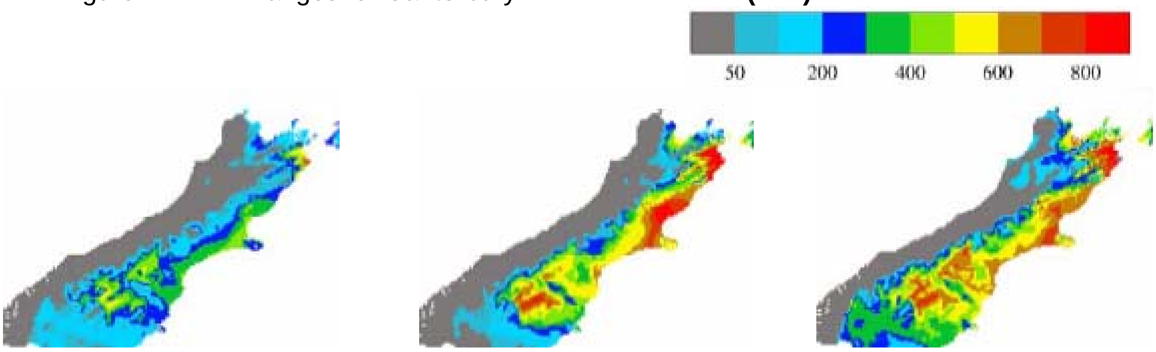
As noted above, a warmer atmosphere can hold more moisture (about 8% for every 1^{o}C increase in temperature). Therefore, there is likely to be increased rainfall depth and intensity associated with climate change[xl]. In addition, the heat that comes from the condensation of this increased moisture will make storms more intense[xli]. However, the likely size of this change is currently uncertain. The likely effect of increases in temperature and westerly wind has been modelled for the Southern Alps[xlii] that suggested increases in both maximum and catchment averaged rainfall. However, the effects vary depending on the duration of the rainfall event being considered.

A working model has been used since 2004 for preliminary assessments that recommends percentage adjustments applied to extreme rainfall for every degree Celsius of warming[xliii].

4.3 Drought[xliv]

Drought is a function of less precipitation, higher temperatures, and increased wind. It is usually measured in ‘potential evapo-transpiration deficit’ or PED. Accumulated PED[13] is the amount of water that would need to be added to a crop over a year to prevent water-related loss of production. Canterbury already experiences annual water deficits of 300-500 mm, and local farmers have adapted to this. The 1 in 20 year drought conditions at Lincoln is a PED of 770 mm, and at Darfield is 465 mm. This means that there is a 5% probability in any one year that this level of water deficit could be experienced at these locations in any one year. The PED ranges across Canterbury are shown in the figure below.

Figure 4.4 PED ranges for Canterbury



Annual Average 72/73-02/03 **El Niño year 97/98** **1 in 20 year drought**

Figure 4.4 The figure on the left shows the average annual PED for the region over the past 31 years. The figure in the middle shows the PED during an extreme drought in an El Niño year. The figure on the right shows the water deficit that currently only occurs during 5% of the years recorded, or a 1 in 20 year return drought event. (Source NIWA, 2005)[xlv]

Modelling of the effect of climate change under two scenarios (25% and 75% of IPCC projections) with two different models has been carried out. This gives a range of potential changes to drought conditions. The modelling looked at both changes in the average water deficit (shown as increases in PED), and the increase in frequency of drought events that currently only occur in 5% of the years. Modelling also looked at how extreme water deficit

[13] For example, a PED of 200 mm over a year could be overcome by applying 200 mm of water at appropriate times by irrigation. The total volume of water needed for this example would be 200 x area in ha x irrigation efficiency factor x 10 (to convert to cumecs).

might get according to projections up to the 2080s. Modelling of this extreme water deficit was for one discrete location in Canterbury, Lincoln.

The modelling indicates that by the 2080s, there will be a significant increase in the average water deficit across Canterbury, with increases of between 2 weeks and over 6 weeks of pasture deficit as an *average* climate condition. The increased water needed for coastal Canterbury to mitigate the effects of climate change is projected to be at least 90 mm (an average increase of about 3 weeks in length of pasture deficit) up to double that, with an increase of over 150 mm common throughout coastal north and mid Canterbury. For context, the current average PED at Lincoln of 469 mm is projected to increase to between 532 mm and 629 mm (2 to 6 weeks of restricted pasture growth).

Figure 4.5 Changes in the annual average PED for Canterbury

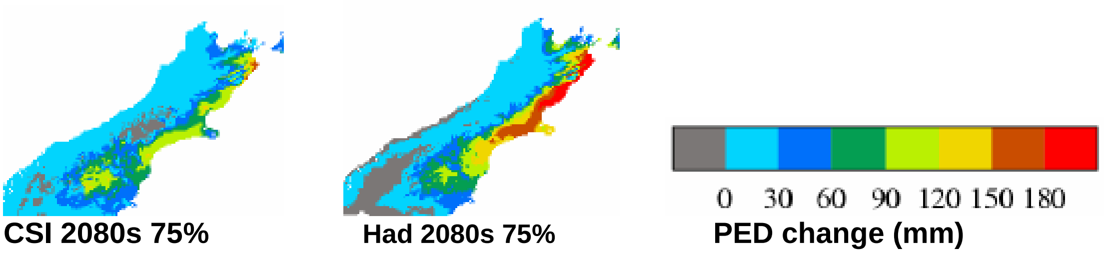


Figure 4.5 The two figures above gives projections of the change in PED to the 2080s, using two different models. Both models are based on the 75% IPCC scenario. These figures can be read together with the left-hand figure in Figure 4.4 above which shows the current situation. Therefore, an area such as Lincoln that currently has an average annual PED of about 400 mm is projected to have an average annual PED of about 490 mm to 550 mm (adding between 90 and 150 mm to the existing average. (Source NIWA, 2005)[xlvi]

The modelled increase in overall PED in Canterbury ranges from 90 mm to 180 mm, reflecting 3 to 6 weeks of pasture deficit. This will lengthen an irrigation season that is currently at least 21 weeks long. The consequent additional surface and groundwater demand in the face of decreased recharge constitutes a significant risk to the agricultural sector.

Turning to the frequency of drought events, modelling projects that even under the most benign modelled effects, drought events will be more common by the 2030s for almost all of Canterbury (see figures 4.6 and 4.7 below).

By the 2030s, current drought events that are so severe that they only occur in 1 out of 20 years are projected to occur more frequently: the most benign modelling suggests between 1 in 15 years (pale blue in Figures 4.6 and 4.7 on the following page) and 1 in 10 years (yellow in Figures 4.6 and 4.7).

Under the most extreme scenario, these severe droughts could occur more than four times as often, an average of once every 5 years, in some parts of the region (areas shown as brown on the following page).

By the 2080s, these severe droughts are projected to occur more often over larger parts of the region. Under the most extreme model, current 20 year droughts will affect much of coastal Canterbury in 1 out of every 5 years. The most extreme projected change is in the northern part of Canterbury, approximately between Kaikoura, Cheviot and Culverden, where current 1 in 20 year events could become as common as twice in every 5 years.

Figure 4.6 Return period of current 1 in 20 year drought events by the 2030s

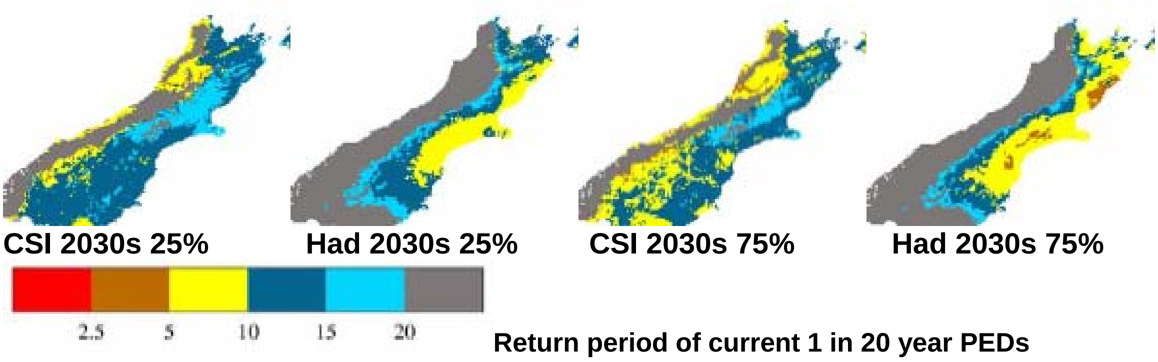


Figure 4.7 Return period of current 1 in 20 year drought events by the 2080s

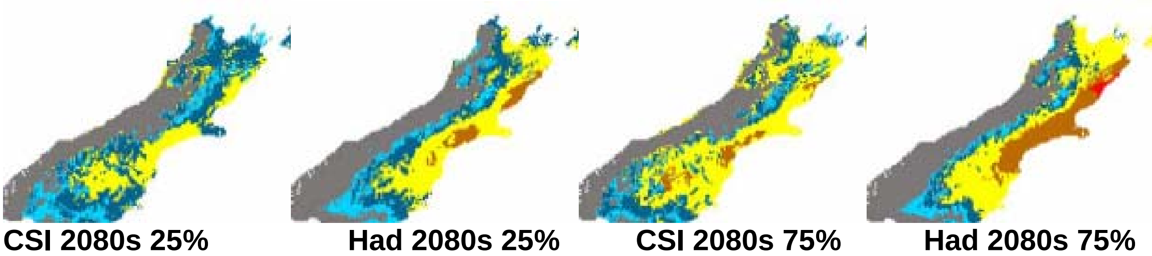
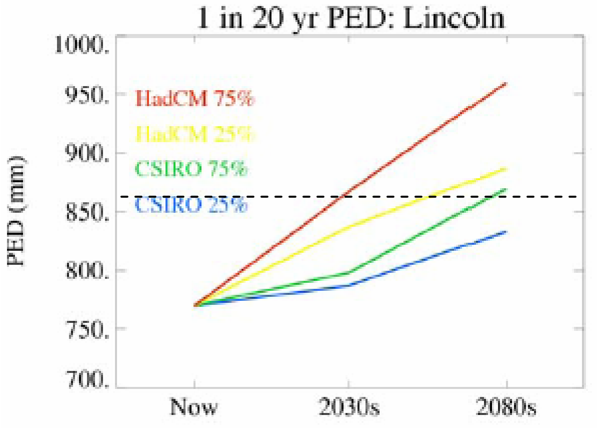


Figure 4.6 The two left-hand figures show the frequency of current 1 in 20 year drought conditions for (25%) up to the 2030s for a 'low-medium' scenario for two different models. The right-hand figures show 'medium-high' scenarios (75%) for the two models up to the 2030s.
Figure 4.7 As for Figure 4.6, but showing the projections up to the 2080s.
(Source NIWA, 2005)[xlvii]

Finally, the extremes of these droughts are also projected to increase for the modelling done for Lincoln. Although projections vary, the severity of drought events that *will* occur every 1 in 20 years significantly increases. For context, the current 1 in 20 year drought event is a water deficit (PED) of 770 mm, and the most severe drought on record was 851 mm in 1988/89.

Figure 4.8 Changes in the PED in drought categorised as a 1 in 20 year event



The dashed line represents the approximate PED of the most severe drought recorded at Lincoln, in 1988/89

As can be seen in Figure 4.8 above, the most extreme drought events that have been recorded could have a return period of 1 in 20 years by the 2080s, and under the most extreme modelling, will be occurring every 1 in 20 years by the 2030s. If the most extreme modelling proves to be correct, drought conditions which are unprecedented in the recent historical record will occur, and with relative frequency (1 in 20 years).

According to these projections, drought represents a major risk to Canterbury. This is in terms of the average amount of water necessary to maintain production, and the frequency and intensity of drought events.

4.4 Storms

There is insufficient information at this stage to draw specific conclusions relating to increasing storm intensity, or increasing frequency of cold fronts. However, storms are likely to be more intense due to the heat released by the additional moisture in the air and because of the increasing temperature gradient between the pole and the equator.[14][xlviii]

4.5 Fires[xlix]

Strong winds, usually combined with high temperatures, low humidity and seasonal drought can combine to create dangerous fire situations. It has been included within this section, however, as it is often a natural phenomena, and is closely linked with climatic phenomena.

Studies and modelling suggest that there is likely to be an increased fire risk. This will include longer fire seasons, increases in fuel drying, easier ignition, and faster fire spread due to wind. Potential increases in thunderstorms and lightning may also play a role.

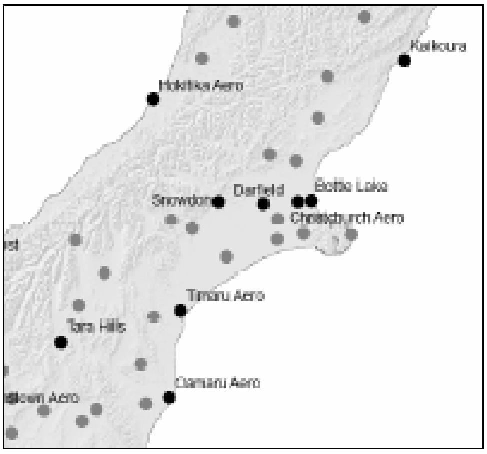
A cumulative measure of fire season severity (CDSR) and an estimate of the increase in the number of days with ‘very high’ or ‘extreme’ fire ratings (VH+E) was used as an indicator of the effects of climate change in the study.

Of the 8 Canterbury stations[15] included in the study, Christchurch Airport showed the greatest increase in risk[16]. Significant increases in fire risk were also seen in the modelling

[14] See also Appendix A for further as to the drivers of climate change.
[15] Oamaru Airport has been included as it lies just on the opposite side of the Waitaki River from Canterbury.
[16] For Christchurch Airport, CDSR values increased by 25-65% and the number of VH+E days increased by over 50%.

for Kaikoura which currently has a low fire risk in relation to other parts of the region. Darfield also showed a significant increase in risk, followed by projected increases in fire risk at Snowdon, Bottle Lake[17] and the Timaru Airport. However, one of the 'high' scenario models indicates that there may be a slight decrease in the number of 'very high' and 'extreme' fire risk days at Tara Hills, near Omarama, most likely a result of an increase in the number of days with heavy rainfall.

Figure 4.9 Research stations used in fire risk study (black dots)



[17] Although the severity rating (CDSR) for Bottle Lake is consistent with Snowdon and Timaru Airport, it has a higher increase in the number of additional days likely to fall into the 'very high' and 'extreme' fire risk categories. This has particular implications because of its proximity to large urban areas.

5 Effects on Natural Resources

As noted above, there is considerable uncertainty about how climate change will manifest itself in day-to-day weather, or even weather patterns over the longer term. Future work will improve our knowledge of climate change, applying the coarse scale climate change projections to localised areas, and taking account of local geographic forms such as Banks Peninsula.

This section, and the following Sections 6, 7 and 8 include all potential effects in an attempt to create a broad-ranging picture of potential effects. Many of these effects are beyond the scope of the Resource Management Act and/or the Regional Policy Statement Review. This is reflected in the matrices found in Appendix E to this report, and the content of Section 9 below. Additionally, probabilities and timescales have not been included in this section, principally because of the resources required to determine these and the length and complexity of any resulting document. However, reference can be made back to Sections 2 and 3 for general indications. For those effects where it is considered the Regional Policy Statement Review can add some value, further work will be necessary to determine the scale, timescale and probability of those effects.

However, climate change is real, and it is already happening. Therefore we should make provision within our policy documents to enable us to adapt to climate change in the future. This will ensure that the region can adapt to future conditions, including taking advantage of any benefits of climate change. It is also necessary to ensure that our actions now do not foreclose future options for coping with climate change.

5.1 Land

5.1.1 Hotter temperatures, increased wind, and the loss of vegetation cover associated with drought conditions would increase top soil loss and may create aridity problems on non-irrigated areas.

5.1.2 An increase in heavy downfall events and flooding would strip soil nutrients and increase landslides, mudslides and erosion.

5.1.3 Land could be lost as a result of coastal erosion as discussed in detail in 5.2 below, and river erosion of 'main divide-fed' rivers as discussed in 5.3 below.

5.2 Coastal and marine areas

5.2.1 Several drivers can affect the supply and subsequent availability or mobility of sediments to the coastline and estuaries – winds, waves, river flow, currents, sea-level rise – all of which may alter under the climate change projections. Open coast beaches in particular are often sensitive to small changes in sediment supply[i]. Coastline that is currently eroding or dynamically 'stable' will retreat landwards if there are no additional sand supplies to keep pace with the sediment demands of the higher mean sea-level and any accompanying changes in wave climate. Bank slumping would also be expected further upstream from river mouths. However, increased flooding as discussed in 4.2 above may supply that sediment.

5.2.2 Base sea-level rise would mean higher tides and storm surges relative to a land datum. Potentially these could also interact with flood events. This would result in increased inundation and overtopping of barriers (dunes, sea-wall *etc*) and greater inundation of salt marshes and coastal wetlands.

5.2.3 Sea-level rise would also result in increasing water depth if sedimentation does not keep pace. This is of particular importance within shallow estuaries as it will change the way waves, tides and storm surges propagate and behave.

5.2.4 Other effects on land that would reduce freshwater quality and/or increase nutrient run-off, would also affect the quality of marine water.

5.2.5 Increases in storminess would increase wave conditions, including storm surges.

5.3 Freshwater

5.3.1 Some major eastern rivers whose catchments reach back into the Main Divide could maintain or even increase flows, because of projected rainfall increases in these areas[18]. However, a change in phase of the Interdecadal Pacific Oscillation relative to 1978-1998 may mean that this does not eventuate over the next 20 to 30 years[li]. Regardless, it is prudent to acknowledge that overall Canterbury will become drier for the foreseeable future[19].

5.3.2 Reduced flows are expected for other rivers, including reduced base flows in the foothills and Banks Peninsula which would have implications for lowland streams. There would be reduced water surplus to streams and groundwater, particularly from eastern forested areas.

5.3.3 Over agricultural land, increased evapo-transpiration resulting from hotter temperatures and drier conditions would reduce water quality in rivers and affect the contamination assimilation capacity of streams. There may be less flow in rivers in late spring/early summer due to reduced snowmelt, although this is not clear due to potential increases in alpine precipitation (as discussed in Section 4.2 above).

5.3.4 Groundwater may suffer from increased saltwater intrusion as sea-levels rise.

5.3.5 Heavy precipitation events have an adverse effect on water quality by increasing nutrient run-off, sedimentation, river erosion and turbidity. They increase the risk of contamination of urban waterways and groundwater by stormwater and other possible sources of contamination from increased flood frequency and intensity. In addition, there is increased risk of overloading sewerage systems. Heavy precipitation events after a period of low recharge comes with an increased risk of nutrient and pathogen contamination of drinking water, particularly non-reticulated water supplies in rural areas.

[18] Rivers that may have an increase in mean flows due to increased precipitation in the Alps are the Waitaki, Rangitata, Rakaia, Waimakariri and Hurunui. Although the Waiau and Clarence rivers are mountain-fed, significant increases in precipitation in the northern part of the region are not projected.

[19] The reasons behind this are set out in Appendix A to this report.

5.4 Organisms – indigenous biodiversity

Habitat and distribution

5.4.1 Climate change, particularly temperature increases and sea-level rise, would alter the geographical distribution of habitats and the distribution of species. Land-based species' distributions would move further south, and higher into the mountains to remain within the same general temperature ranges. Aquatic species would move into cooler headwaters. Marine species' distributions would move south, or deeper into the ocean[20].[lii]

5.4.2 Additionally, where unconstrained, coastal wetlands and intertidal areas would move further inland as a consequence of sea-level rise. Species' distributions in association with river mouths would also shift inland, as saline concentrations encroach further upstream.

5.4.3 The concept of 'moving' species only applies to mobile species, not plants. However, what is meant by species' distribution shift is that those plants in the hotter areas die off, but the species can invade and survive in areas that were previously too cold. This is particularly true for Canterbury where the number of frost days is significantly reduced. Therefore the distribution shifts. However, if this is to happen, it is critical that the species can relocate or invade neighbouring areas, which can only happen if the area is unconstrained.

5.4.4 In reality, human development and structures often constrain species' habitats – for example, remnant bush on the plains are enclosed by productive land and urban development; wetlands and coastal areas are constrained by urban development, hard sea-protection structures such as sea-walls or roads and highways in some areas.

5.4.5 Additionally, there are a number of naturally rare ecosystems and discrete or bounded waterbodies where distribution shift cannot easily occur. The effects of climate change are likely to put considerable stress on these ecosystems.

Ecosystems

5.4.6 Climate change may affect ecosystems in other ways. There may be an increased threat to native species from changed disease vector distribution, such as mosquitoes carrying avian malaria threatening native bird species[liii]. The periodicity of natural ecosystem events *e.g.* beech masting and related irruptions in mice populations, fish schools *etc* may also change.

Aquatic and marine species

5.4.7 A drier Canterbury, and increased water abstraction could disrupt freshwater ecosystems through low flows or drying of streams and rivers.

5.4.8 Sea-level rise would result in decreased light levels in coastal wetlands. Turbidity, both within riverbeds and at sea would also result from an increase in flood events. In addition, waterways and the coast near urban areas are at risk from contamination during flood events, particularly from the inundation of sewerage systems by stormwater. If contamination levels are bad enough, this would adversely affect aquatic and marine species.

[20] When fish in the Gulf of Alaska moved deeper into the ocean in 1993, 120,000 sea-birds starved to death, most likely because they could not dive deeply enough to catch their prey.

5.4.9 Hotter temperatures have particular effects on fish species. As water warms up, the metabolism of fish also speeds up, requiring more food and oxygen to support them. This diverts the fish's energy from growth and reproduction . Additionally, as water warms, the amount of dissolved oxygen within it decreases. This, coupled with the increased metabolic demands, is termed 'oxygen squeeze'[21].[liv]

5.4.10 Temperate lakes also become stratified for longer, there is less mixing of waters in cooler months (and the oxygen and nutrients they carry), and some lakes may even become permanently stratified. This causes crowding in the lower layers, where there is less oxygen, resulting in increased competition for food, and greater susceptibility to disease transmission[lv]. Temperature increases, coupled with increased freshwater from melting glaciers and increased precipitation, can also reduce vertical mixing in oceans.

5.4.11 To date, much of the CO_2 emitted into the atmosphere has been absorbed by the world's oceans. This has caused acidification of the oceans which has the potential to cause weaker shells of marine organisms and effect the auto-regulatory systems such as absorption of oxygen and salt balance[lvi].

Other stresses and vulnerabilities

5.4.12 Any increase in fire could have significant effects on indigenous species, in terms of immediate losses and the loss of large areas of habitat. A significant increase in storminess may also have implications for bird wrecks of our coastal species.

5.4.13 It is finally noted that for species that are already under threat, particularly those that have already lost much of their pre-human habitat, the adverse effects of climate change could tip the balance of survival, or may create a critical situation where intensive interventions are required rather than the species recovering with minimal intervention. In this regard, pest incursions will also play a significant role.

5.5 Organisms – unwanted

5.5.1 Similar to indigenous species, hotter temperatures would allow distribution shift of pest species, resulting in new and increased incursions of pests[22].[lvii] This may also include disease vectors[23].

5.5.2 Increased CO_2 may favour invasive and/or less productive grassland species. There is a potential for increased algal blooms due to ecosystem imbalance, caused for example by elevated CO_2 levels and/or temperature increase *etc*. Additionally, lakes that remain stratified longer, as discussed above, tend to have more blue-green algae, which produce toxins that are harmful to fish, their prey and humans[lviii]. Increases in sea surface temperature may result in increased ciguatera fish poisoning from dinoflagellates.[lix] The changed periodicity of natural ecosystem events *e.g.* beech masting and related irruptions in mice populations, clearly with associated implications for local eruptions of pest species.

[21] Although not indigenous, it is noted that Rainbow trout grow significantly more slowly if their water temperature is increased by just 2°C. Some temperate species such as salmon cannot spawn if winter temperatures do not drop below a certain level. Additionally, many Antarctic fish lack heat shock proteins – molecules that most animals have to repair cellular damage caused by heat.

[22] Recent examples are the frost-tender banana passionfruit, and argentine ants which have unexpectedly survived 2 winters

[23] such as mosquitoes carrying Ross River virus or dengue fever

5.6 Organisms – production (excluding the impact of pests)

Land

5.6.1 There are potential advantages to production from climate change, which the region should adapt to, to take advantage of. Hotter temperatures and fewer frosts would increase agricultural opportunities for fruit and wine production, arable cropping and processed vegetable production. There would be an earlier sowing season and faster growth of horticulture/viticulture species. However, taking advantage of this is dependant on the availability of water. There will be increasing pressure for water resources, and demand for water augmentation schemes. Where water is not available (or farmers cannot afford the infrastructure to secure it) there may be an inability to productively farm some areas of non-irrigated pasture due to the increased frequency of drought, and drier 'average' conditions.

5.6.2 There may also be changes to productivity and nutrient cycling due to increased CO_2 which are beneficial. Research suggests that increased concentrations of atmospheric CO_2 significantly enhances plant growth, due to increased nitrogen fixation by legumes and increased nitrogen efficiency within the plants themselves.[lx] However, there remains some significant debate about this. It seems that biogeochemical feedbacks may reduce the fertilisation effect of elevated CO_2 over time, and that pasture soils under elevated CO_2 appear less able to supply plants with nitrogen and phosphate[lxi]. The positive benefit also depends strongly on the availability of water. The need to counter climate change through avoiding nutrient run-off is also noted. However, addressing this problem would also have benefits for water quality. No-till practices which sequester more CO_2 in the soil than conventional tillage is a mechanism to atmospheric CO_2.[lxii] This practice would have co-benefits for soil erosion and reducing top-soil loss.

5.6.3 Farmers are particularly vulnerable to extreme weather events. Heavy precipitation events such as snow and flooding result in losses of stock, pasture and crops, as well as damage to fences, trees, tracks, access roads and bridges. Strong winds also damage trees, and can result in losses of stock at lambing and calving time.[lxiii]

Water

5.6.4 If concerns about the acidification of oceans and the effect on mollusc and crustacean species prove founded, this would have serious consequences on the seafood industry. Similarly, adverse effects on aquatic and marine species discussed in 5.4 above would have consequences for fisheries. Distribution shift could make some aquaculture areas unviable. Additionally, the increased metabolic rates of fish as discussed above would increase the uptake of toxins such as mercury, cadmium and lead, with associated public health concerns (and detriment to the fishing industry)[lxiv].

5.7 Air

5.7.1 Ironically, in terms of the effects of climate change, the impact on air is likely to be the least affected of all the natural resources, and would in fact be broadly beneficial. International, national, regional and individual actions to address climate change are likely to have incidental benefits to air quality. There may also be a reduction in localised air pollution due to the reduced need for solid fuel burning as a response to warmer wintertime minimum temperatures.

5.8 Resource availability

5.8.1 Increasing demand for water is currently an important issue for Canterbury. This increased demand is likely to become increasingly critical in a future characterised by drier average conditions, and an associated increase in both drought frequency and intensity. It is anticipated that more water will be lost through evapo-transpiration with the result that current agricultural practices will require more water to sustain them.

5.8.2 Managing the combined surface water and groundwater resource is one of the major challenges facing Environment Canterbury, and one where it will be judged, not only by the community at large, but also by major players in the economic development of the region.

5.8.3 The affordability of fossil fuels may change significantly in the future, affecting accessibility and use of this resource. This may result from economic mechanisms to discourage use, and/or to internalise costs arising from Greenhouse gas emissions and associated climate change. There is a relationship between emissions, atmospheric concentrations of Greenhouse gases (GHG), changes to the climate, extreme weather events, and the costs of climate change (although this relationship is unlikely to be linear, particularly at very high GHG concentrations). Therefore, the higher the atmospheric GHG, the greater the cost of climate change is expected to be. If these costs are internalised, this will result in a greater the cost of fossil fuels.[lxv]

5.8.4 Costs associated with greenhouse gas emissions would increase as a result of international efforts to address climate change, and associated national economic instruments to internalise environmental damage and reduce emissions. In this respect, tradeable emission rights, or carbon credits (or whatever other economic instruments are used) are likely to become a ‘resource’ after 2012. However, under the Kyoto Protocol, there will be cost implications for New Zealand in any case[24].

[24] Although the proposed carbon tax was abandoned in December 2005, alternative measures are being sought with the intent of implementing at the end of the first Kyoto commitment period (2012). It is also noted that New Zealand is likely to have to purchase/obtain Kyoto compliant units in order to assist in meeting its obligations for 2008 to 2012 under the Kyoto Protocol. (Reference: *Climate Change Solutions: Whole Government Climate Change Work Programmes* and *Hon. David Parker, Ministerial Presentation 31st August 2006*) As an indication, the most recent estimate of financial liability for a carbon deficit of 41.2 million tonnes is $656 million, although it is noted that this fluctuates depending on deficit estimates, the price of carbon, and exchange rates. (The Press, 12th October 2006)

6 Effects on Physical Resources

6.1.1 There would be reduced energy demands for space heating (overwhelmingly outweighs additional demand for air-conditioning[lxvi]) as a result of warmer temperatures. Additionally, greater rainfall in the upper catchment areas of Canterbury would benefit hydroelectricity lakes, and there may be improved opportunities for wind power generation.

6.1.2 However, extreme weather events can have devastating effects on physical resources, both individual property and strategic infrastructure. Any increase in the frequency, and particularly severity would increase the risk to people, and physical resources. Some examples are: damage to Information and Communications Technology infrastructure from extreme snowfall events or strong wind; greater pressure on stormwater and sewerage systems from heavy precipitation events; threat to low-lying infrastructure and strategic infrastructure in riverbeds; increased erosion and landslides particularly affecting roads; maritime/recreational hazards from increased storminess; threat to recreational facilities and private property from fires.

6.1.3 As well as considering potential damage from natural hazards, adaptation to climate change also includes improving the capacity of strategic infrastructure to cope in natural hazard situations. For example, the capacity of flood control structures, stormwater and sewerage systems, and battery life of mobile telephone transmitters.

6.1.4 Sea-level rise, coupled with high tides, storm events and/or river flooding also increases risk of inundation of both private property and infrastructure such as roads[25] and sewerage treatment facilities.

6.1.5 In the long-term, sea-level rise and coastal erosion would threaten both strategic infrastructure and private property. It would also affect coastal heritage.

7 Societal Effects

7.1.1 There may be positive benefits to society resulting from climate change, including reduced health effects relating to cold weather and air pollution from home heating, and immigration (significant benefits to supplement the existing labour force and address skills shortages, and bring investment).

7.1.2 However, increased extreme weather events would have a detrimental effect on society through injury and loss of life. While some extreme weather events would be an intensifying of natural hazards which we are used to, heatwaves[26] and new disease vectors such as mosquitoes carrying Ross River virus and dengue fever[lxvii] would require a new response.

[25] State Highway 1 near Kaikoura is an obvious example where there is close proximity to the ocean, and the potential for a main route to be cut off, with immediate health and safety risks to the township itself , and compromising traffic flows movement generally.

[26] In the 2003 heatwave, approximately 32,000 additional people died across Europe, considered to be the greatest natural disaster in Europe in recent history. Although this has improved preparedness, initial figures for the current 2006 heatwave in Europe show that this ‘silent killer’ continues to pose a significant threat globally, including developed countries. This could have implications for the region, bearing in mind the increase in days over 25^{o}C set out in Section 4.1 above.

7.1.3 The psychological effects of extreme weather events on a community should also be considered. This is of particular concern for the farming sector who are likely to suffer disproportionately from weather-related events. Of particular concern would be a significant reduction in the return period of drought conditions which may result in year-on-year crop or pasture failure.

7.1.4 Community cohesion may be threatened by increasing competition for scarce water resources. Factors related to climate change may also increase the urban/rural divide. This includes perceptions relating to natural hazards[27], resource use, and the production of food for New Zealand and international markets. Aggressive immigration[28][lxviii], for example from South Pacific and Asian nations, may also threaten community cohesion. This may occur if there is a slowing in economic growth and pressures on New Zealand's resources because of climate change, accompanied by vast numbers of illegal immigrants placing additional stress on societal and economic structures.[lxix]

8 Economic Effects

8.1.1 The Canterbury economy is heavily based on its ability to produce from its land resources[lxx]. Direct agricultural products account for 5% of the GRP but unprocessed and processed agricultural products account for 70% of regional exports. About 22% of the GRP comes from the manufacturing industry, with approximately 50% of this from food products (such as meat or dairy products). Tourism accounts for approximately 5% of the GRP[lxxi]. Exports from Canterbury (Lyttelton and Timaru Ports and Christchurch Airport) account for about 15% of the country's exports. This makes the local economy particularly vulnerable to the effects of climate change.

8.1.2 Many of the adaptation measures proposed make good economic sense – energy efficiency, cleaner production, and reduced health effects from emissions. There may also be significant benefits from increased product diversity made possible by climate change, and reduced health costs associated with warmer weather. There may also be opportunities and co-benefits associated with renewable energy sources and biofuels production (including better utilisation of waste organic materials and reduced reliance on foreign fuel sources, including resilience to 'peak cheap oil').

8.1.3 However, reliance on primary production also makes Canterbury's economy vulnerable to climate change. Particularly severe deterioration of the environment as a result of climate change will have commensurate effects on the local economy, and even affect the national economy if they are persistent and unable to be mitigated over time.

8.1.4 At a national level, the government accepts that while action to reduce greenhouse gas emissions over the long term will have a moderate cost, the predicted costs and

[27] A good example of this was the power outages in June 2006, for some hours in Auckland and some weeks in rural Canterbury.

[28] Environmental researcher Norman Myers predicted that by the year 2050 up to 150 million people could become "environmental refugees" due to rising sea levels. The threat of submergence has forced the Government of Tuvalu to sign an agreement with New Zealand to relocate many of its citizens in the coming decades. The decision was made In November 2005 to evacuate the Papua New Guinean Carteret atolls as soon as possible because sea-level rise was making the islands uninhabitable. According to the Red Cross, the number of people in the Oceania region affected by weather-related disasters has soared by 65 times during the past 30 years.

risks of inaction are considered to be unacceptably high. Likewise, there will be costs associated with adaptation to climate change. At an international level, the Stern Review has indicated that the cost of keeping atmospheric GHG concentrations at around CO_2e 550ppm (the upper limit considered to be feasible and possibly still too high) would be about 1% of global GDP by 2050, with a range of -1% to +3.5%[29].[lxxii] However, the economic cost of business as usual would be an opportunity cost of around 20% in global consumption, now and into the future.[lxxiii] Therefore it appears there will be inevitable costs to the economy arising out of climate change – although what these might be at a regional level has not been discussed.

8.1.5 Costs of adapting to un-mitigated climate change would include costs associated with protection against natural hazards due to increased risk from extreme weather events. In the longer-term this would also include costs associated with sea-level rise. Costs associated with extreme weather events include necessary medical and emergency responses and long-term costs of recovery will also impact on the local economy. Productivity losses may result from social and health effects such as those related to lost productivity during and following natural disaster events, disruption to transport networks, heatwaves and cold-snaps *etc*.

Recent examples of costs of weather-related natural hazard events affecting Canterbury include:

1997-99	Canterbury drought-related losses	$231M
1975	Canterbury storms	$57.27M*
2006	Canterbury snow storm	$42.5M^
1986	North Otago/South Canterbury floods	$37.72M*
2005	Christchurch hail storm	$13M
2000	Canterbury storms	$10.31M*;
1993	Kaikoura flood	$9.52M*
1983	Christchurch storm	$9.51M*
2002	Canterbury hail storm	$3.29M*
1994	South Canterbury floods	$1.85M*

* - adjusted to March 2004, insurance industry payouts only, and not including EQC or flow-on costs
^ - insurance claims

8.1.6 There would also be opportunity losses in relation to the need to avoid natural hazards, such as avoidance of development in flood prone or coastal areas. In addition, opportunity costs may be associated with protection of our natural heritage, particularly where a precautionary approach is adopted to reduce other stresses on vulnerable ecosystems. Other costs of adaptation include depreciation of capital, such as replacement or upgrading of protection works, and accelerated obsolescence such as high carbon technology (power stations, vehicles *etc*).

8.1.7 The economic effects of a carbon constrained global economy for both exports and tourism would have a significant impact on Canterbury due to its reliance on international markets. Effects include potential price-based measures to reduce global emissions and increased oil costs, both of which would make transportation of goods and passengers considerably more costly. There also appears to be a growing awareness of some international consumers about 'food miles', choosing locally made goods instead[30]. Similarly, as other countries make efforts to reduce

[29] The report considers that the risks of the worst impacts of climate change can be substantially reduced if GHGs are stabilised at between 450ppm and 550ppm CO_2e. They are already at 430ppm CO_2e and are rising by 2ppm per year.

[30] It is noted that, while this can be a false economy when all of the inputs are factored in as in the recent case in the United Kingdom relating to New Zealand lamb, it nevertheless may change consumer behaviour.

emissions, continuing increases in New Zealand's emissions is likely to have an economic cost[31].

8.1.8 Globally, insurers have already started increasing premiums as a result of the significant increase in weather-related pay-outs in recent years[lxxiv] and this has impacted on the New Zealand insurance industry. This will increase insurance costs to New Zealanders both in relation to insurance and Earthquake Commission premiums[lxxv].

8.1.9 Climate change will have the greatest impact on developing countries. As part of the international community there are likely to be 'costs' to New Zealand in terms of international aid and famine relief, the provision of infrastructure and technology to enable them to adapt to climate change, and immigration costs.

9 CRPS policy response to the effects of climate change

As required by the RMA, the review of the Canterbury Regional Policy Statement should have particular regard to the effects of climate change, and it is an opportunity to support and provide for the necessary adaptation. There have been considerable changes to the RMA since the adoption of the current RPS, and as noted in the previous section of this report, the current RPS has an inappropriate focus on the causes of climate change, rather than the effects. Of most relevance to this section of the report are the following RMA Section 7 matters, which should be borne in mind when considering the policy response to climate change:-

> *In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development and protection of natural and physical resources, shall have particular regard to —*
> *(i) the effects of climate change,*
> *(ba) the efficiency of the end use of energy,*
> *(j) the benefits to be derived from the use and development of renewable energy*

The following discussion considers the potential effects of climate change as set out in Section 8 above, and indicates where consideration could be given to a policy response within the Canterbury Regional Policy Statement (CRPS). This report does not suggest policy changes, nor does it assess in any detail whether a policy response might be appropriate, within the CRPS or otherwise. It does, however, draw attention to issues that should be taken into consideration as each chapter of the CRPS is reviewed.

A matrix summarising the comparison of Section 8 and the individual CRPS chapters can be found in Appendix E to this report. It is noted that there is not always a direct correspondence between the effects of climate change outlined in Sections 5 to 8 above (and summarised below for each CRPS chapter in this section) and the range of policy considerations set out in this section it is not always an exact match. However, both the effects and the commentary should be considered as part of the review process.

The layout of the sections differs slightly to the current CRPS chapters, but reflects suggested changes in the Section 35 report. However, this should be viewed as a convenience, rather than an indication of the final structure of the revised RPS.

[31] particularly in light of the good environmental reputation New Zealand has retained since international trading began, particularly with European markets, and more recent clean, green and 100% Pure campaigns.

9.1 Soils and landuse (Chapter 7)

Natural Resources
Land
5.1.1 top soil loss
5.1.1 aridity problems on non-irrigated areas
5.1.2 possible nutrient stripping
5.1.2 land destabilisation

Freshwater
5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.2 reduced water surplus to streams and groundwater, particularly from eastern foothills/plains areas
5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt

Organisms – indigenous biodiversity
5.4.1 shift in terrestrial species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.3 / 5.4.4 / 5.4.6 inability of indigenous species to adapt due to fragmented land environments
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.12 loss of wildlife, vegetation and habitat by fire
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Organisms – unwanted
5.5.2 increased CO_2 may favour invasive and/or less productive grassland species

Organisms – production (excluding the impact of pests)
5.6.1 increased agricultural opportunities for fruit and wine production, arable cropping and processed vegetable production
5.6.1 earlier sowing season and faster growth of horticulture/viticulture species, subject to water availability
5.6.1 inability to productively farm some areas on non-irrigated pasture as a norm due to increased frequency of drought
5.6.2 changes to productivity and nutrient cycling
5.6.2 increasing pressure to avoid nutrient run-off

Resource availability
5.8.1 water

Physical Resources
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events

Economy
8.1.1 vulnerabilities arising from reliance on primary production
8.1.2 benefits through increased product diversity, the fertilising effect of increased CO2, improved energy efficiency, cleaner production etc
8.1.5 costs of a more precautionary approach to environmental protection

9.1.1 Policies already exist within the Soils and Land Use chapter addressing soil quality, erosion, and maintaining vegetative cover (including burning), all of which will be of critical importance to mitigate the effects of drought and floods.

9.1.2 This issue of versatile soils[32] is currently subject to some debate[lxxvi]. From a climate change perspective, versatile soils are of increased importance because of their greater productiveness and more efficient use of water resources. While this does not answer the question as to whether versatile soils should remain an issue within the CRPS, or what the appropriate policy response might be, it does add another important dimension to that debate.

9.1.3 Matters related to land-use and nutrients are best addressed in relation to water quality, where the effects of nutrient run-off and contamination are greatest.

9.1.4 The agricultural sector will adapt to make the best use of opportunities afforded by climate change, bringing about changes in the agricultural composition of the region. There may also be renewed interest in silviculture, particularly if this is subject to financial incentives to sequester carbon. There is also likely to be a move towards biofuel from crops and organic by-products to meet government fuel targets. Changes are also likely to arise as this sector adapts to changes in water availability (either positive or negative, depending on the changed local rainfall, local evapo-transpiration, and catchments of local rivers). These changes will impact on soils. However, a policy framework that is effects-based rather than cause based should be able to address these changes, regardless of the production species.

9.2 Landscape and heritage (Chapter 8)

Natural Resources

Freshwater

5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.2 reduced water surplus to streams and groundwater, particularly from eastern forested areas
5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt
5.3.3 reduced water quality from low flows
5.3.5 reduction in water quality due to heavy precipitation events

Organisms – indigenous biodiversity

5.4.1 shift in terrestrial species' distributions
5.4.1 shift in aquatic species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.3 / 5.4.4 / 5.4.6 inability of indigenous species to adapt due to fragmented land environments
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.5 loss of naturally rare ecosystems and discrete or bounded waterbodies
5.4.7 disruption of freshwater ecosystems through low flows or drying of streams and rivers
5.4.9 disruption of marine ecosystems through warming of water
5.4.9 disruption of freshwater ecosystems through warming of water
5.4.10 decreased mixing of water
5.4.12 loss of wildlife, vegetation and habitat by fire
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Organisms – production (excluding the impact of pests)

5.6.1 increased agricultural opportunities for fruit and wine production, arable cropping and processed vegetable production

[32] Class I and Class II in the Land Use Capability Classification System

5.6.1 earlier sowing season and faster growth of horticulture/viticulture species, subject to water availability
5.6.1 increased pressure for water resources, including storage schemes
5.6.1 inability to productively farm some areas on non-irrigated pasture as a norm due to increased frequency of drought

Resource availability
5.8.1 water
5.8.2 fossil fuels

Physical Resources
6.1.5 loss of or threat to heritage sites/structures from sea-level rise and coastal erosion

9.2.1 As with the later biodiversity and pests section, the key adaptations to climate change require -
a) reducing stress on vulnerable species, ecosystems and habitats, and
b) ensuring adequate buffer zones to allow for shift in habitat and distribution.

9.2.2 Assessments for the protection of existing natural and highly indigenous landscapes may need to take climate change into account to ensure their degree of representation is protected, and that distribution shift is allowed where practicable.

9.2.3 Similarly, environmental stresses on ecosystems could be reduced through the provision of adequate buffer zones. Other aspects of habitat and ecosystem protection are discussed in more detail in 10.3 below.

9.2.4 Surface water and groundwater augmentation will likely have an impact on the landscape, whether it is for renewable energy or as part of irrigation schemes (or both). As a principal effect of climate change, consideration should be given as to the appropriate way in which the debate on this issue can be held – either through the preparation of policy documents at various levels, or through the consent process. As an existing resource management issue that is likely to be exacerbated by climate change, consideration should be given to the *landscape and amenity* effects of water augmentation.

9.2.5 Other forms of renewable energy such as wind turbines and structures associated with marine-sourced energy will also impact on landscapes. It may be appropriate at this stage to consider the implications of this infrastructure and consider the degree to which we are willing to compromise existing landscapes in order to provide more renewable energy. Clearly this also needs to be balanced against other considerations such as energy efficiency.

9.2.6 Although the loss of heritage from coastal erosion is a potential adverse effect of sea-level rise, it is considered that the CRPS can add little to policy guidance in this matter. However, it may be appropriate to recognise the importance of protecting heritage (together with strategic infrastructure) to assist future decisions about coastal protection works (signalling a greater benefit than protecting private property, for example). Processes for removing, relocating and recording artefacts would be more appropriately dealt with under the Historic Places Act, and/or under the existing Chapter 6 Policy 4 of the CRPS which applies generally to protection of koiwi tangata (human bones) or taonga (artefacts).

9.3 Biodiversity and pests (Chapter 8, Policy 5 of Chapter 7)

Natural Resources

<u>Land</u>
5.1.3 loss of land area due to coastal erosion

<u>Coastal and marine areas</u>
5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)
5.2.2 greater inundation of salt marshes and coastal wetlands
5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries
5.2.4 reduced water quality

<u>Freshwater</u>
5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.2 reduced water surplus to streams and groundwater, particularly from eastern forested areas
5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt
5.3.3 reduced water quality from low flows
5.3.3 changes in the contamination assimilation capacity of streams
5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation

<u>Organisms – indigenous biodiversity</u>
5.4.1 shift in terrestrial species' distributions
5.4.1 shift in aquatic species' distributions
5.4.1 shift in marine species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.3 / 5.4.4 / 5.4.6 inability of indigenous species to adapt due to fragmented land environments
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.5 loss of naturally rare ecosystems and discrete or bounded waterbodies
5.4.6 threat to native species from changed disease vector distribution
5.4.6 changed periodicity of natural ecosystem events
5.4.7 disruption of freshwater ecosystems through low flows or drying of streams and rivers
5.4.8 disruption of aquatic and marine ecosystems through decreased water quality following heavy precipitation events
5.4.8 decreased light levels in coastal wetlands
5.4.9 disruption of marine ecosystems through warming of water
5.4.9 disruption of freshwater ecosystems through warming of water
5.4.10 decreased mixing of water
5.4.11 acidification of oceans and potential impact on marine species
5.4.12 bird wrecks due to increased storminess
5.4.12 loss of wildlife, vegetation and habitat by fire
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

<u>Organisms – unwanted</u>
5.5.1 alteration species' distributions, new, and increased incursions of pest species
5.5.1 new disease vectors threatening human health
5.5.1 establishment of pest species previously unable to survive cold winters and frosts
5.5.2 increased CO_2 may favour invasive and/or less productive grassland species
5.5.2 changed periodicity of natural ecosystem events *e.g.* beech masting and related irruptions in mice populations
5.5.2 potential for increased algal blooms from elevated CO_2 and/or reduced water mixing due to higher temperatures
5.5.2 increases in sea surface temperature may result in increased ciguatera fish poisoning from dinoflagellates

Economy 8.1.2 benefits through increased product diversity, the fertilising effect of increased CO_2, improved energy efficiency, cleaner production *etc* 8.1.5 costs of a more precautionary approach to environmental protection

9.3.1 As noted in 9.2.1 above, the key adaptations to climate change require-
a) reducing stress on vulnerable species, ecosystems and habitats, and
b) ensuring adequate buffer zones to allow for shift in habitat and distribution.

9.3.2 In relation to biodiversity, this will require reducing existing stresses on indigenous biodiversity to the greatest extent practicable. This will be of critical importance for those species that are already vulnerable or under threat (almost 400 species across the region). Expensive, intensive programmes will still be required for some species (this lies beyond the scope of the CRPS, and is a matter for the Department of Conservation). However, early intervention, habitat protection, and facilitating adaptation of habitats to climate change may help avoid the need for such costly programmes for additional species in the future. Such adaptation measures do fall in part within the remit of an CRPS.

9.3.3 Evidence linking biodiversity loss and climate change will be very difficult to establish in the majority of cases. This is because the effects of climate change will only be one factor in the decline of biodiversity and therefore the effects are difficult to quantify.

9.3.4 A policy framework addressing the effects of climate change should consider the following interventions:
a) controls on subdivision, use and development that may adversely affect that habitat, and
b) including distribution shift *and* any additional stress on indigenous species (or their habitats and ecosystems) within the policy framework to be considered as part of resource consents.
In reaching decisions about any activity that may have an impact on vulnerable or threatened species, habitats[33] or ecosystems, a precautionary approach should be considered to support biodiversity and habitat protection.

9.3.5 Much of the focus on biodiversity is on maintaining and restoring natural habitats and ecosystems to a healthy functioning state, enhancing critically scarce habitats and maintaining and restoring viable populations of all indigenous species and subspecies across their natural range, and maintaining genetic diversity. Given that climate change is likely to result in the loss of some habitat (distribution shift, wetlands, intertidal areas, and drying of waterways), further consideration should be given to how this goal might be achieved, and what role the CRPS might play in achieving this and mitigating these adverse effects of climate change. It should be acknowledged that climate change would mean that these habitats and ecosystems are subject to greater change than in the past due to changes in species populations and geographic location, and this would have an impact on ecosystems as a whole.

9.3.6 There are significant implications in terms of pest management, which should be picked up in the CRPS. However, it is also noted that much pest management work is carried out through the Biosecurity Act, and those plans written under that Act such as the Regional Pest Management Strategy.

[33] In circumstances where less than 20% of the habitat remains, the number of species the remaining area can support declines steeply. This is of particular concern for lowland habitats, where the greatest losses have already occurred.

9.4 Water (Chapter 9)

Natural Resources

Land

5.1.2 possible nutrient stripping
5.1.2 land destabilisation and erosion risk due to harsher climate

Freshwater

5.3.1 some major eastern rivers could maintain or even increase flows
5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.2 reduced water surplus to streams and groundwater, particularly from eastern forested areas
5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt
5.3.3 reduced water quality from low flows
5.3.3 changes in the contamination assimilation capacity of streams
5.3.4 contamination by saltwater intrusion
5.3.5 reduction in water quality due to heavy precipitation events
5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation
5.3.6 reduced water levels (storage), throughflow and natural discharge to springs and lowland streams

Organisms – indigenous biodiversity

5.4.1 shift in aquatic species' distributions
5.4.7 disruption of freshwater ecosystems through low flows or drying of streams and rivers
5.4.8 disruption of aquatic and marine ecosystems through decreased water quality following heavy precipitation events
5.4.9 disruption of freshwater ecosystems through warming of water
5.4.10 decreased mixing of water
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Organisms – unwanted

5.5.1 alteration species' distributions, new, and increased incursions of pest species
5.5.2 potential for increased algal blooms from elevated CO_2 and/or reduced water mixing due to higher temperatures

Organisms – production (excluding the impact of pests)

5.6.1 increased agricultural opportunities for fruit and wine production, arable cropping and processed vegetable production
5.6.1 earlier sowing season and faster growth of horticulture/viticulture species, subject to water availability
5.6.1 increased pressure for water resources, including storage schemes
5.6.1 inability to productively farm some areas on non-irrigated pasture as a norm due to increased frequency of drought

Resource availability

5.8.1 decrease in groundwater storage and availability for existing and potential users
5.8.1 decrease in reliability of supply for existing water users
5.8.1 decrease in availability of water for recreation, aesthetic and other non-consumptive use

Physical Resources

6.1.1 greater rainfall in the upper catchment areas of Canterbury's hydroelectricity lakes
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations

Society and Culture
7.1.4 threat to rural community cohesion and increasing urban/rural divide

Economy
8.1.2 benefits through increased product diversity, the fertilising effect of increased CO_2, improved energy efficiency, cleaner production etc
8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change
8.1.5 costs of a more precautionary approach to environmental protection

Water Quantity – water resources

9.4.1 One of the greatest effects of climate change is likely to be the availability of water. There will be escalating competing pressures from agricultural users, electricity generators (potential increase in demand for hydro-generation as a zero-emission energy source), domestic users (increased water use in hotter weather[lxxvii]), and the need to protect instream values, including against the increased risk of drought and other effects of climate change as discussed in Section 9.3 above. The pressure on water resources will be exacerbated by increased evapo-transpiration, the desire for greater water takes to maximise the production potential of the warmer climate, and the need to counter the increased intensity and frequency of droughts. Although this will become an important issue over much of the eastern part of the region, it will be particularly critical in the northern part of the region such as the Waipara area where decreased rainfall in all seasons, increased evapo-transpiration, and a lack of high-country catchment rivers are all in play.

9.4.2 It is critical that an effective, adaptive, and equitable water resource allocation regime is implemented for the region. Water allocation regimes and the setting of environmental flows should take climate change into account, as should the terms and length of resource consents for water takes. Given the differences in projected precipitation across Canterbury, this should be assessed on a catchment basis. This will have clear environmental and economic effects, and has important implications for social cohesion. Developing water conservation and efficiency strategies is a complementary priority, driven by expected increases in demand.

9.4.3 Canterbury uses by far the greatest amount of its groundwater resources compared to all of the New Zealand regions. The resource in many areas within Canterbury is at the allocation limit. Regional Plans and Water conservation Orders are the key means by which the existing provisions of the CRPS are to be implemented. The policy framework within the proposed Natural Resources Regional Plan (PNRRP) provides for adaptive management of water allocation, both through the rules and differing priority consents and through review of minimum flows, including the restorative streams programme. However, an appropriate response at the CRPS level may be to include the effects of climate change on both the availability of water, and the additional stresses on species and ecosystems, as a matter for consideration as part of any water allocation regime, including both surface and groundwater abstraction. This is particularly true of foothill/plains-fed catchments.

9.4.4 Water storage and/or augmentation will become increasingly important to enable adaptation to expected decreased seasonal water availability. Two policies within the CRPS currently provide guidance on this issue[34], and although they are considered to be effective in establishing the appropriate policy framework through the PNRRP, they are relatively non-specific[lxxviii]. It may be necessary to move towards greater use of more "B" blocks for storage of water during winter, for use in spring and summer. Additional guidance should be considered either at the CRPS or regional plan level. This could follow the Sustainable Water Programme of Action which takes account of the effects of climate change.

[34] CRPS Chapter 9 Policy 2(b) and Policy 5.

9.4.5 Land uses that reduce water availability have been controlled through the PNRRP in water-short catchments. It is noted that within Canterbury there is potential future conflict with increased forestry for carbon sequesteration, however the areas concerned are very limited at this stage. This does highlight, however, the potential conflicts likely to become increasingly difficult as greater pressure is put on water resources – power generation, production, industrial, domestic and stock water supplies, and forestry will all need to be balanced against one another, and as provided by the new RMA Section 30(4). It is noted that urban growth in Amberley and Akaroa is already constrained by the availability of domestic water supplies. A policy framework for the allocation of water to specific activities may be a matter requiring additional guidance within the CRPS.

9.4.6 It is unclear whether the existing policies in the CRPS (through the PNRRP) make adequate provision for the protection of the coastal margin of the aquifer system from salt-water intrusion as a result of sea-level rise[35]. Whilst the issue relates to water quality, the means of resolving it lies with the control of groundwater abstraction to ensure adequate pressure is maintained within groundwater wells and the aquifer itself. Provisions within the PNRRP have been designed to manage such intrusion when related to abstraction, but cannot stop the natural encroachment of saline water.

Water Quantity – flooding

9.4.7 Decisions about flood protection, including their design, should take climate change into account. The CRPS is likely to be an important vehicle for this. Consideration should include both the provision of stop-banks and other flood protection works, and also the location of new development, and the provision of strategic infrastructure.

9.4.8 The capacity of stormwater systems and the design of sewerage infrastructure should also take the likely increased heavy precipitation events into account. The CRPS is currently lacking in guidance about water-related infrastructure (waste water, storm water and domestic water infrastructure). Any new guidance to address this may also be the appropriate mechanism to incorporate climate change projections into the design to reduce the risk of inundation and contamination during flood events.

Water Quality

9.4.9 There appears to be little additional guidance that could be provided to address the effects of climate change on water quality beyond what is already necessary for sustainable natural resource management. Maintaining instream flows and controls on adjoining land-uses and associated run-off (either from industry, agriculture, or other sectors such as transport) should be taken into consideration in any case. On-going research will be necessary into the effect of contaminants on water quality when associated with warmer water, reduced mixing of water, increased CO_2 and lowered O_2 levels *etc*, however any such adverse effects are uncertain at this stage and it would be difficult to provide any specific policy response. However, the need to safeguard the life-supporting capacity of water is likely to require additional and specific responses in the future to address water quality issues which are likely to be exacerbated by climate change (such as contamination from dry periods followed by heavy rainfall).

[35] This relates to abstraction overall, and also abstraction from a specific, localised area. The latter may become a problem if existing wells near the sea are lost as a result of sea-level rise, forcing increased abstraction in areas that are denied adequate recharge, as in the upper parts of the Heathcote Valley, for instance.

9.5 Other water interfaces[36] (Chapters 8 and 10)

Natural Resources
Land
5.1.3 loss of land area due to coastal erosion

Coastal and marine areas
5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)
5.2.2 greater inundation of salt marshes and coastal wetlands
5.2.2 increased inundation and overtopping of barriers
5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries
5.2.4 reduced water quality

Freshwater
5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.2 reduced recharge to streams and groundwater, particularly from eastern forested areas and plains
5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt
5.3.3 reduced water quality from low flows
5.3.3 changes in the contamination assimilation capacity of streams

Organisms – indigenous biodiversity
5.4.1 shift in aquatic species' distributions
5.4.1 shift in marine species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.5 loss of naturally rare ecosystems and discrete or bounded waterbodies
5.4.8 decreased light levels in coastal wetlands
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Organisms – unwanted
5.5.2 potential for increased algal blooms from elevated CO_2 and/or reduced water mixing due to higher temperatures

Organisms – production (excluding the impact of pests)
5.6.1 increased pressure for water resources, including storage schemes
5.6.2 increasing pressure to avoid nutrient run-off

Resource availability
5.8.1reduced water availability in existing wells and less reliable supply in both the surface water and groundwater resource

Physical Resources
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 threat to low-lying infrastructure and strategic infrastructure in riverbeds
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.4 inundation by higher tides and storm surges

Economy
8.1.5 costs of a more precautionary approach to environmental protection

[36] Wetlands, beds of lakes and rivers and their margins

9.5.1 The most important contribution in this area is to reduce pressure on vulnerable habitats and ecosystems and provide buffers to ensure future options for adaptation are not foreclosed. This has particular implications for the development of urban areas to ensure that, wherever possible, areas around wetlands and along the coast remain free of development and associated structures that constrain water bodies. This will allow wetlands and intertidal areas to 'migrate'[37].

9.5.2 The CRPS includes provisions which seek to reduce environmental pressure on wetlands and intertidal habitats. As with other sections above, a precautionary approach that includes the effects of climate change should be adopted when considering activities that affect these areas[38].

9.6 Coastal environment (Chapter 11)

Natural Resources
Land
5.1.3 loss of land area due to coastal erosion

Coastal and marine areas
5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)
5.2.2 greater inundation of salt marshes and coastal wetlands
5.2.2 increased inundation and overtopping of barriers
5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries
5.2.4 reduced water quality

Freshwater
5.3.4 contamination by saltwater intrusion if groundwater levels are allowed to decline, the interface will move inland regardless of management practice

Organisms – indigenous biodiversity
5.4.1 shift in marine species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.8 disruption of aquatic and marine ecosystems through decreased water quality following heavy precipitation events
5.4.8 decreased light levels in coastal wetlands
5.4.9 disruption of marine ecosystems through warming of water
5.4.10 decreased mixing of water
5.4.11 acidification of oceans and potential impact on marine species

Organisms – unwanted
5.5.2 potential for increased algal blooms from elevated CO_2 and/or reduced water mixing due to higher temperatures
5.5.2 increases in sea surface temperature may result in increased ciguatera fish poisoning from dinoflagellates

[37] It may be that sea level rise is so rapid that there is insufficient time for areas to adjust. However, adaptation of the coastline to human structures occurs on relatively rapid timescales.
[38] Similar policy response to landscape and biodiversity in Sections 9.2 and 9.3 above.

<u>Organisms – production (excluding the impact of pests)</u>
5.6.4 adverse impacts on commercial fisheries and aquaculture from ecosystem changes
5.6.4 adverse impacts on commercial fisheries and aquaculture from internal regulation, metabolic and reproductive changes
5.6.4 marine and aquatic distribution shift
5.6.4 increased uptake of toxins by fish and shellfish

<u>Resource availability</u>
5.8.1 water

Physical Resources
6.1.2 increased risk from recreational/maritime hazards
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.4 inundation by higher tides and storm surges
6.1.5 loss of or threat to infrastructure and/or property from sea-level rise and coastal erosion
6.1.5 loss of or threat to heritage sites/structures from sea-level rise and coastal erosion

Economy
8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change
8.1.5 costs of a more precautionary approach to environmental protection

9.6.1 Issues relating to storm surges and inundation in extreme coastal/weather events are addressed within the natural hazards chapter of the CRPS as set out below (Section 10.12 of this report). Matters relating to coastal wetlands are addressed in the wetlands provisions as discussed in Section 10.5 above.

9.6.2 However, additional provisions may be necessary to address changes to the coastline particularly where (if) local studies show there is going to be significant pressure for an up-scaling of protection works[39][lxxix]. It may be appropriate to consider whether the CRPS should include guidance relating to hard beach protection works, or the considerations that might impact on those decisions (such as the protection of strategic infrastructure or heritage as set out in Section 10.2 above).

9.6.3 It is unlikely that the CRPS can contribute greatly to the process of adapting to other effects of climate change such as the acidification of the oceans, warming of coastal waters (particularly shallow waters such as estuaries), pests and micro-organisms, and other stresses and impacts on desirable species such as indigenous and migratory marine species and production species.

[39] For example, the preferred management of the coast around the Avon-Heathcote Estuary/Ihutai mouth relies on monitoring, together with beach re-nourishment if required. If sea-level combined with tides/storms/floods result in regular over-topping of the dunes and/or an inability for the dune system to remain viable, there may be increasing public pressure for hard solutions such as sea-walls, which have their own environmental impacts.

9.7 Urban development (Chapter 12)

Natural Resources
Land
5.1.2 land destabilisation
5.1.3 loss of land area due to coastal erosion

Coastal and marine areas
5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)
5.2.2 increased inundation and overtopping of barriers
5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries
5.2.4 reduced water quality

Freshwater
5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula
5.3.3 reduced water quality from low flows
5.3.4 contamination by saltwater intrusion
5.3.5 reduction in water quality due to heavy precipitation events
5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation
Organisms – indigenous biodiversity
5.4.1 shift in terrestrial species' distributions
5.4.1 shift in aquatic species' distributions
5.4.1 shift in marine species' distributions
5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats
5.4.3 / 5.4.4 / 5.4.6 inability of indigenous species to adapt due to fragmented land environments
5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development
5.4.8 disruption of aquatic and marine ecosystems through decreased water quality following heavy precipitation events
5.4.12 loss of wildlife, vegetation and habitat by fire
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Resource availability
5.8.1 water
5.8.2 fossil fuels
5.8.3 air (to restrict the total carbon emissions making emissions opportunities into a resource - likely to be subject to economic mechanisms such as cap and trade)

Physical Resources
6.1.1 greater rainfall in the upper catchment areas of Canterbury's hydroelectricity lakes
6.1.1 improved opportunities for wind power generation from increased wind
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 threat to low-lying infrastructure and strategic infrastructure in riverbeds
6.1.2 loss of or threat to lives, infrastructure and/or property from fire
6.1.2 damage to ICT infrastructure from extreme snowfall events and high winds
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations
6.1.4 inundation by higher tides and storm surges
6.1.5 loss of or threat to infrastructure and/or property from sea-level rise and coastal erosion
6.1.5 loss of or threat to heritage sites/structures from sea-level rise and coastal erosion

Society and Culture 7.1.1 immigration 7.1.2 loss of life and injury due to extreme weather events 7.1.3 psychological effects of extreme weather events 7.1.4 threat to rural community cohesion and increasing urban/rural divide 7.1.4 aggressive immigration and pressure on societal and economic structures from vast numbers of environmental refugees **Economy** 8.1.2 benefits of improved efficiencies (including energy efficiencies), drier and warmer homes, improved air quality and associated improvements in health 8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change 8.1.4 productivity losses from natural hazards 8.1.4 immediate costs associated with natural hazard events 8.1.5 costs of a more precautionary approach to environmental protection 8.1.6 economic impacts of a carbon (and water) constrained global economy 8.1.6 international awareness of and reaction to climate change 8.1.7 increasing insurance costs to cover increased incidents and intensity of natural disasters

9.7.1 There are three aspects of adapting to the effects of climate change that should be taken into account in relation to urban settlement and associated infrastructure. The first is constraints on the location and layout of built structures to avoid these effects. This would include constraint on development in areas susceptible to flooding or inundation, avoidance of high risk structures such as hazardous substance facilities in areas subject to erosion or subsidence, and consideration of the effects of climate change when locating and designing strategic infrastructure.

9.7.2 The second aspect is to protect resources so we are better able to cope with climate change. This includes providing habitat buffers to allow distribution and habitat shift, and protecting land that is most able to utilise water resources and continue to be productive in times of drought.

9.7.3 The third aspect is providing for a settlement pattern that allows the efficient and cost effective provision of infrastructure[40], the efficient end use of energy[41], and can realise the benefits of renewable energy[42]. An example of an appropriate response would be to integrate settlement and transport infrastructure, including public transport, to reduce the need to travel by private vehicle. Additionally, integrated management of strategic infrastructure could include the provision of a range of services, facilities and employment locally wherever possible. These improved efficiencies will also increase resilience to changes to the availability or cost of carbon-based non-renewable fuels.

9.7.4 Consideration could also be given to social and cultural changes to our urban areas as an effect of climate change. Significant immigration may result in different styles of development, and different needs within the built environment (such as places of worship for those communities). However, this matter may be most appropriately addressed at a district level. Additional matters relating to social cohesion are discussed in relation to water (Section 10.4 above) and other social impacts are beyond the scope of an CRPS (Section 10.14 below).

9.7.5 The response to climate change within the Greater Christchurch area is similar to those matters set out in 10.7 above.

[40] Refer RMA Section 30(1)(gb)
[41] Refer RMA Section 7(ba)
[42] Refer RMA Section 7(j)

9.8 Air (Chapter 13)

Natural Resources
Resource availability
5.8.3 air (to restrict the total carbon emissions making emissions opportunities into a resource - likely to be subject to economic mechanisms such as cap and trade)

Air
5.7.1 improved air quality from actions to reduce Greenhouse gas emissions
5.7.1 improved local air quality due to less domestic heating necessary

Economy
8.1.2 benefits through increased product diversity, the fertilising effect of increased CO2, improved energy efficiency, cleaner production etc
8.1.2 benefits of improved efficiencies (including energy efficiencies), drier and warmer homes, improved air quality and associated improvements in health

9.8.1 Central government has signalled that “all sectors of the economy should play an equitable part in the national response to climate change, reflecting the fact that some sectors will be able to achieve emissions reductions more easily than others”[lxxx]. Therefore the costs for these emissions will be allocated by national mechanisms, and decisions within any given sector to emit greenhouse gases will be informed by those mechanisms.

9.8.2 Controlling discharges of contaminants from the transport sector (currently accounting for the fastest growing sector) was also considered as part of the Section 32 for the Air Quality Chapter of the proposed Natural Resources Regional Plan, and was found not to be enforceable or able to be implemented. It would also be difficult to justify any such controls without relying on the need to reduce greenhouse gas emissions which is explicitly excluded from consideration (albeit that the discharge of contaminants into the air from vehicles have significant other adverse effects).

9.9 Energy (Chapter 14)

Natural Resources
Resource availability
5.8.2 fossil fuels
5.8.3 air (to restrict the total carbon emissions making emissions opportunities into a resource - likely to be subject to economic mechanisms such as cap and trade)

Physical Resources
6.1.1 reduced energy demands for space heating
6.1.1 greater rainfall in the upper catchment areas of Canterbury’s hydroelectricity lakes
6.1.1 improved opportunities for wind power generation from increased wind
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations

Society and Culture
7.1.1 reduced health effects relating to cold weather and home heating

Economy
8.1.2 benefits through increased product diversity, the fertilising effect of increased CO2, improved energy efficiency, cleaner production etc
8.1.2 benefits of improved efficiencies (including energy efficiencies), drier and warmer homes, improved air quality and associated improvements in health

8.1.2 opportunities and co-benefits for renewable energy sources including biofuels production (use of waste organics/less foreign fuel/resilient to peak cheap oil)
8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change
8.1.6 economic impacts of a carbon constrained global economy
8.1.6 international awareness of and reaction to climate change

9.9.1 Changes in the economics of the energy sector, including both technological changes and Government advocacy of renewable energy sources, is likely to bring forward applications for previously unpopular or uneconomic power generators, particularly wind turbines and solar PV systems (and possibly marine-based generation), as well as additional hydro-generation. The CRPS could play an important role in facilitating the development of renewable energy, and giving clear signals to the energy sector about preferred approaches to energy and areas where other values would take priority (such as landscape values, or the use of solar water heating on heritage buildings).

9.10 Transport (Chapter 15)

Natural Resources
Land
5.1.2 land destabilisation
5.1.3 loss of land area due to coastal erosion

Coastal and marine areas
5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)
5.2.2 increased inundation and overtopping of barriers

Organisms – indigenous biodiversity
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Resource availability
5.8.2 fossil fuels
5.8.3 air (to restrict the total carbon emissions making emissions opportunities into a resource - likely to be subject to economic mechanisms such as cap and trade)

Physical Resources
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 threat to low-lying infrastructure and strategic infrastructure in riverbeds
6.1.2 increased risk from recreational/maritime hazards
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations
6.1.4 inundation by higher tides and storm surges
6.1.5 loss of or threat to infrastructure and/or property from sea-level rise and coastal erosion

Economy
8.1.1 vulnerabilities arising from reliance on primary production
8.1.2 opportunities and co-benefits for renewable energy sources including biofuels production (use of waste organics/less foreign fuel/resilient to peak cheap oil)
8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change
8.1.4 productivity losses from natural hazards
8.1.6 economic impacts of a carbon constrained global economy
8.1.6 international awareness of and reaction to climate change

9.10.1 Adaptation to the effects of climate change is discussed in 9.7 above, as one aspect of the strategic infrastructure associated with settlement, and in 9.9 above in relation to discharge of contaminants to air.

9.10.2 Port and rail infrastructure could be given protection to ensure that future options for more sustainable modes of transport are not foreclosed[43] and acknowledging that transport corridors are important to other network utilities as well. However, a significant cause of inefficiency within the freight industry is the poor provisions made for servicing of commercial developments[lxxxi]. In addition to other matters addressed for urban development, the CRPS could include provisions that draw attention to this problem and ensure adequate provisions are included in district plans to improve the efficiency of the transport network.

9.11 Natural hazards (Chapter 16)

Natural Resources
Land
5.1.2 land destabilisation

Freshwater
5.3.5 reduction in water quality due to heavy precipitation events
5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation

Coastal and marine areas
5.2.2 increased inundation and overtopping of barriers
5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries

Organisms – production (excluding the impact of pests)
5.6.3 loss of stock, crops and pasture due to extreme weather events
5.6.3 damage to trees, fences, access roads, bridges, buildings and structures and other farm infrastructure due to extreme weather events

Physical Resources
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 threat to low-lying infrastructure and strategic infrastructure in riverbeds
6.1.2 increased risk from recreational/maritime hazards
6.1.2 loss of or threat to lives, infrastructure and/or property from fire
6.1.2 damage to ICT infrastructure from extreme snowfall events and high winds
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections
6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations
6.1.4 inundation by higher tides and storm surges

Society and Culture
7.1.2 loss of life and injury due to extreme weather events
7.1.2 ‘new’ threats such as heatwaves and new disease vectors
7.1.3 psychological effects of extreme weather events
7.1.3 psychological effects of on-going effects such as crop and pastoral failure
7.1.4 breakdown in social cohesion and particularly the urban/rural divide

[43] In relation to freight, only a small proportion of freight is contestable (could be transported by trucks or rail, for instance) and therefore modal shift is unlikely to be significant in the short term. If transportation costs increase significantly this is most likely to be addressed by changes to industry practices (such as a reduction in ‘just in time’ business models) and changes to products availability where transport costs make certain products unviable.

Economy 8.1.4 productivity losses from natural hazards 8.1.4 immediate costs associated with natural hazard events 8.1.7 increasing insurance costs to cover increased incidents and intensity of natural disasters

9.11.1 The short-comings of this chapter of the CRPS (Chapter 16) are acknowledged[lxxxii]. This includes the need to address the effects of climate change, clearly delineating responsibilities, and addressing risk more directly[lxxxiii].

9.11.2 Responding to the effects of climate change can be broken down into four adaptations: firstly, avoiding adverse effects from natural hazards in the first instance; secondly, responding to natural hazard events when they do occur; thirdly, clarification of the roles and responsibilities for addressing natural hazards; and finally, responding to new information regarding the effects of climate change. These are discussed in detail below.

9.11.3 Avoiding the adverse effects of natural hazards:

a) land destabilisation – developments can be designed to withstand slips, and potentially dangerous installations (such as storage facilities or pipelines for hazardous substances) can avoid location in areas that have a high risk of land instability. Although this relates to climate change effects of soil saturation, it is also relevant to earthquakes which are not affected by climate change. This approach can be found within the proposed Natural Resources Regional Plan.

b) floods – consideration should be given to any areas where development should not be permitted for reasons of potential flooding. There may be merit in the application of consistent flood hazard severity/periodicity across the region (application of controls for 1:100 year events in relation to habitable buildings, for example), and any consideration of these hazard lines should take the likelihood of increased frequency and intensity of flood events into account, particularly in relation to the major rivers that reach back into the Main Divide. This will need to be assessed in relation to the flood protection works that are already in place, and those that are planned.

c) infrastructure – planning for strategic infrastructure of all kinds should take additional stress and vulnerability from extreme weather events into account. This should include both location and construction. In particular, the effects of climate change should be taken into account when designing water-related infrastructure such as domestic supply, treatment, sewerage, and stormwater.

d) storms and sea-level rise are likely to have a significant impact on our coastline. As discussed in Section 9 above, consideration should be given to any policy guidance within the CRPS, or whether this matter should lie solely within the Regional Coastal Environment Plan.

9.11.4 Responding to natural hazards:

a) slips and landslides
b) floods
c) extreme snow fall
d) drought
e) heatwave
f) sea-surge and coastal inundation
g) tornado, hurricane (possibly will never come as far south as Canterbury) or other very high wind event
h) pandemic (altered disease vector distribution)

Consideration should be given as to whether it is necessary or of value to cover each of these potential natural hazards separately within the CRPS, as a high-level policy document.

9.11.5 Roles and responsibilities:
These need to be clarified, and work needs to be done to ensure that appropriate emergency structures are in place to deal with natural hazards as they arise. This need for clarification of roles and responsibilities is acknowledged in the Section 35 report. This work should also include planning for infrastructure that ensures the effects of natural hazards are minimised, such as lifeline utilities planning[lxxxiv]. It is noted that the need for this work does not rest on the effects of climate change, but is necessary in any case.

9.11.6 Keeping up-to-date:
There may need to be a ‘feedback loop’ built into this chapter in particular. Our understanding of the effects of climate change is at a relatively early stage, further complicated by the natural variation and unprojectability of weather. Further refinement of climate models and growth of understanding over the 10 year lifespan of an CRPS should be provided for. Therefore, there should be appropriate monitoring and other mechanisms to ensure this chapter remains up-to-date.

9.12 Human hazards and waste (Chapters 17 and 18)

Natural Resources
Land
5.1.2 land destabilisation

Coastal and marine areas
5.2.2 increased inundation and overtopping of barriers

Freshwater
5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation

Organisms – indigenous biodiversity
5.4.13 loss of habitat and stress to vulnerable species and ecosystems

Organisms – production (excluding the impact of pests)
5.6.4 increased uptake of toxins by fish and shellfish

Resource availability
5.8.3 costs associated with greenhouse gas emissions

Physical Resources
6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events
6.1.2 greater pressure on stormwater and sewerage systems
6.1.3 need for infrastructure design to accommodate climate change projections

Economy
8.1.2 benefits through increased product diversity, the fertilising effect of increased CO2, improved energy efficiency, cleaner production etc
8.1.2 benefits of improved efficiencies (including energy efficiencies), drier and warmer homes, improved air quality and associated improvements in health
8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change
8.1.6 economic impacts of a carbon constrained global economy
8.1.6 international awareness of and reaction to climate change

9.12.1 The CRPS can continue to promote the avoidance of waste at all levels, including cleaner production and reuse of products and materials. This has benefits for reducing regional energy needs for both production and transport.

9.12.2 The CRPS can also endorse rules within the proposed Natural Resources Regional Plan and the Regional Coastal Environment Plan that reduce the risk of unintentional release of contaminants by not locating high risk facilities (such as hazardous substance storage facilities and landfills) in areas where they may be compromised by natural hazards.

9.12.3 Again, the issue of emissions from landfills lies outside the scope of the CRPS, and is addressed through a National Environmental Standard in any case. Recovery of methane for fuel could be considered for support within the CRPS, although, as the case at Burwood indicates, economic incentives are likely to prove more effective and relevant.

Appendix A: What causes the climate changes?

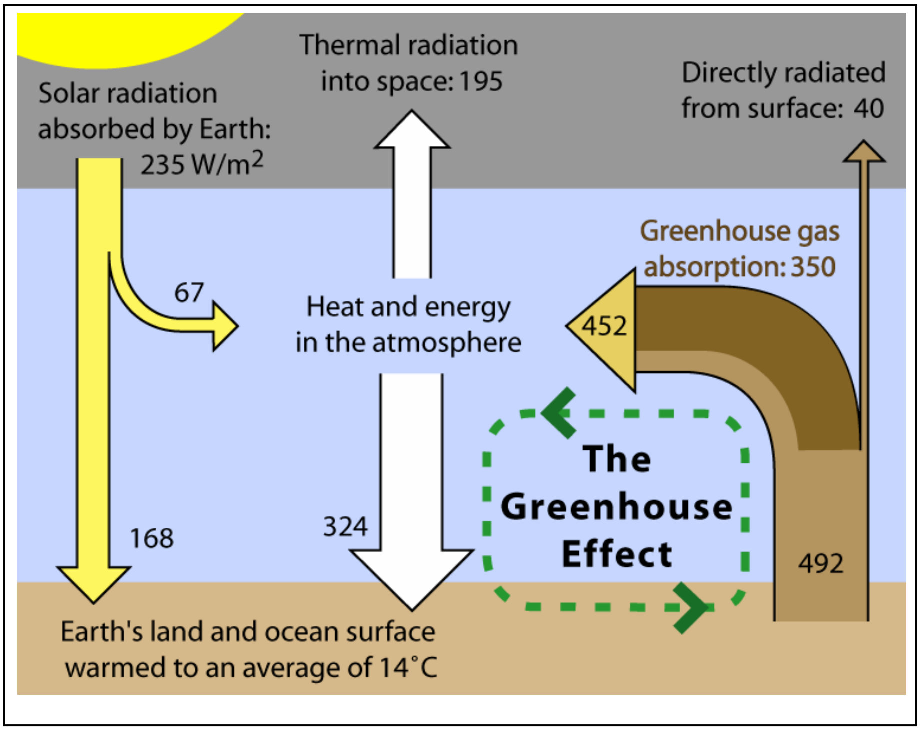
A.1 Global Warming

When sunlight reaches the Earth's surface, some is absorbed and warms the earth.

The energy that bounces back off the Earth is at a much longer wavelength because the Earth is cooler than the sun. Some of this longer wavelength energy is absorbed by greenhouse gases before it can escape back out into space. The absorbtion of this energy also helps to warm the Earth's atmosphere.

Greenhouse gases also *emit* longwave radiation. Some of this is lost out into space, but some is again bounced back to Earth's surface. It is this capturing and bouncing back of the energy that is the "Greenhouse Effect". This is a natural process that warms the planet by up to 30°C.

Figure A.1 The Greenhouse Effect



A schematic representation of the exchanges of energy between outer space, the Earth's atmosphere, and the Earth surface. The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the greenhouse effect. *Source: Wikipedia "Greenhouse Effect"*

However, the significant increase in greenhouse gases in the atmosphere, as a direct result of human activities, is enhancing the Greenhouse Effect resulting in global warming.

A.2 Climate modelling[lxxxv]

The climate system is highly complex with multiple interactions occurring at a range of scales between the ocean, land surface, cryosphere and biosphere. The use of coupled atmospheric-ocean general circulation models (GCM's) are therefore required to assess the way in which climate may change over the next 100 years.

These models have a relatively coarse spatial resolution. At this scale, topography is only coarsely resolved. As topography plays a key role in determining local climate, especially in New Zealand, the large scale atmospheric data output from the GCM's is used to drive mesoscale models, such as those developed by NIWA, which can be run at the much higher resolution (5-50 km) required.

A.3 Reduced precipitation[lxxxvi]

Using this approach, a significant drying is indicated for the Canterbury region in the most recent NIWA study[lxxxvii]. This is because of a reduction in precipitation, and an increase in potential evapo-transpiration.

There are a number of mechanisms, evolving over different spatial and temporal scales, by which these changes are expected to occur over the coming century. In broad terms these include:

a) An increase in the westerly wind strength:
The oceans to the north of New Zealand only mix to a depth of about 50-100 metres, while those to the south mix to a much greater depth, to about 1 kilometre[lxxxviii]. Therefore the southern oceans take a lot longer to warm, as there is more water to be heated. Over the shorter term (50 to 100 years) this results in an increase in the north-south thermal gradient over southern mid-latitudes, and an increase in the westerly wind strength at New Zealand latitudes. In Canterbury, an increase in westerly wind strength is associated with reduced rainfall, and increased evapo-transpiration.

b) A shift of the sub-tropical ridge:
While the strength of the westerly wind is expected to increase, the warming of the earth will also cause the location of the westerly wind maxima, and the sub-tropical anticyclones to shift southward[lxxxix]. Anticyclonic systems are also associated with drier conditions as the subsiding air within the system inhibits the formation of convective cloud and so precipitation, while the higher sunshine hours also increase evapo-transpiration.

c) Local effects due to the changing rate of warming of the land and sea:
The land warms at a faster rate than the ocean, and this is likely to affect the local wind systems of the Canterbury region (such as the sea breeze circulations, and local thermal winds), but no studies have addressed this to date.

It should be emphasised that the way in which these large scale changes impact on the Canterbury region will depend on the way in which they interact with the existing seasonal pattern of climate. However, an increase in either westerly wind strength and/or the occurrence of anticyclone-dominated weather would have the effect of reducing the precipitation over the Canterbury region, making the region drier.

A.4 Sea Level Rise

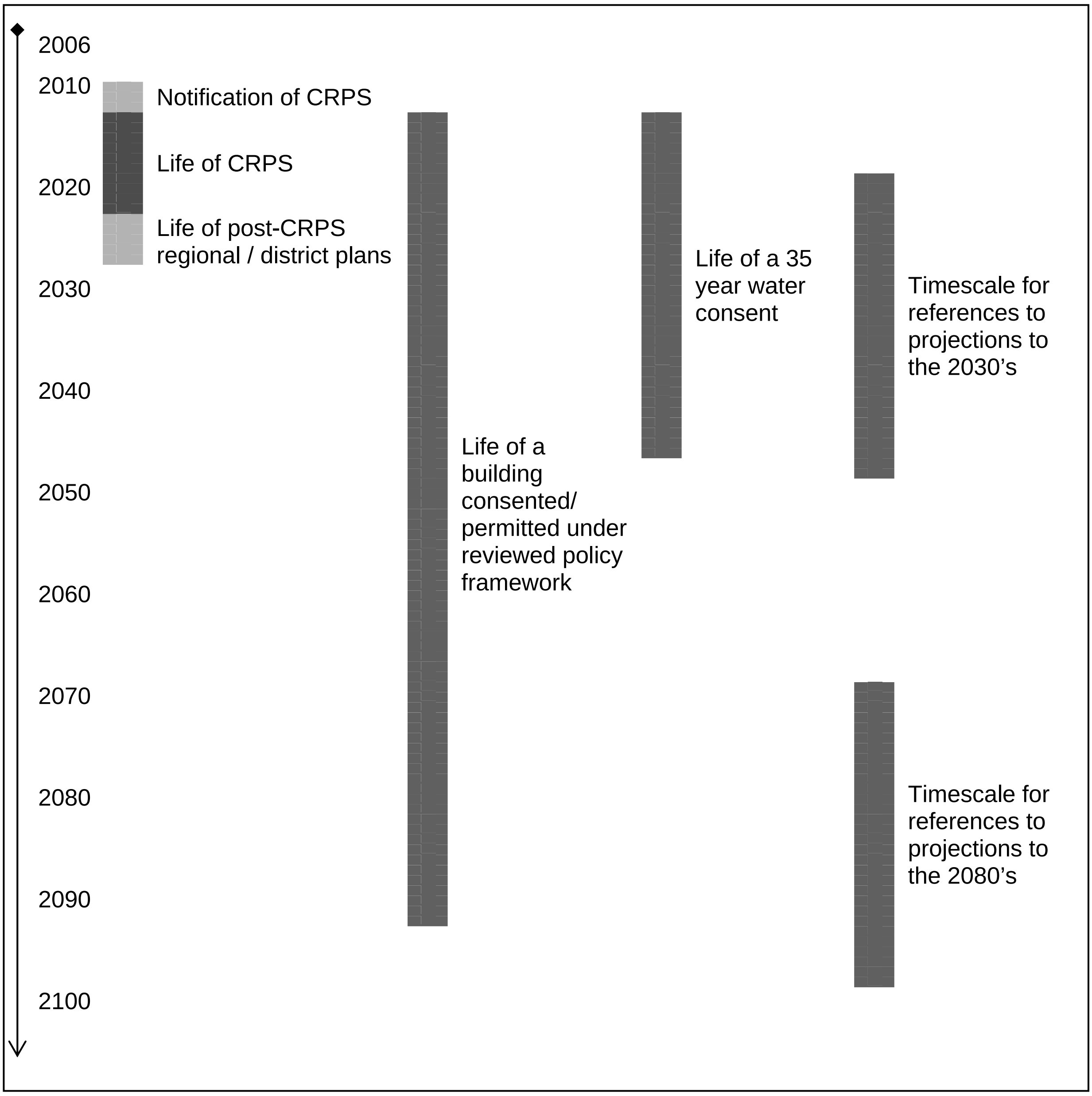
As water heats up, it expands. Additionally, the melting of ice which currently sits on land (such as Greenland ice sheets) also result in global sea-level rise. The current sea-level rise resulting from these is about 1.8mm per year. This *global* sea level rise does not take into account the local conditions which may accentuate or stifle the effect. Therefore the *relative* sea level rise needs to be taken into consideration – or the change in the sea level as it relates to the local coastline.

It seems that parts of New Zealand are slowly emerging as a result of ice melt since the last Ice Age (about 0.4mm to 0.5mm a year). Additionally, tectonic movement also affects the region. Most of the Canterbury coast lies on the Canterbury-Chathams Platform, which has minor subsidence of about 0.1 to 0.2mm/yr. The northern Hurunui and Kaikoura most likely to be affected have an average tectonic uplift of only about 1mm per year[xc]. Therefore, the coastal portion of the Canterbury Plains may expect sea level rise not only due to climate change, but also tectonic activity. Taking all of this into consideration, a relative sea-level rise of 1.7mm per year ±0.4mm is projected for the Canterbury coast. This translates to a 0.73 metre rise in sea-level to 2050, and a 1.58 metre sea-level rise to 2100. This does not account for an acceleration in sea-level rise due to ice melt and/or positive feedback loops increasing atmospheric CO_2e concentrations.

There remains considerable debate about the degree of sea-level rise that might happen. The UK Chief Scientist (Sir David King) believes that without reductions of 60% of emissions by about 2050, the melting of the Greenland ice sheet will become irreversible and sea-levels would rise 7 metres from that alone, although this will not occur in this century, and is subject to a much longer timeframe than is relevant for the CRPS Review considering the effects of climate change[xci].

Appendix B: A note about timescales...

Review of the CRPS must take a long-term view in order to provide for sustainable management to meet the needs of ourselves and future generations. However, the following timeline gives some perspective as to the timing of projected changes to climate discussed throughout this report in relation to a planning policy cycle. An optimistic view has been taken regarding the length of time it will take to make the reviewed CRPS operative, and how quickly changes will be incorporated into district plans. In reality, experience tells us that this will take much longer, making response to climate change within this policy cycle even more critical.



Appendix C: Tables showing projected seasonal precipitation changes for specific locations within region

The following tables provide some more specific information about rainfall (and snow *etc*). Because there is such a range of projected climate changes across the region, this information supplements Figures 3.3 and 3.4 in Section 3 of this report.

Table A.1 Projected changes in precipitation (in %) for Christchurch[xcii]

	Summer	Autumn	Winter	Spring	Annual
From 1990 to the 2030s	-6 to +8	-9 to +1	-12 to +10	-11 to +4	-10 to +1
From 1990 to the 2080s	-12 to +38	-36 to +8	-28 to +9	-21 to 0	-17 to +4

Eastern parts of the region are likely to have less annual rainfall overall, although there is likely to be an increase in precipitation over the summer months.

Table A.2 Projected changes in precipitation (in %) for Hanmer[xciii]

	Summer	Autumn	Winter	Spring	Annual
From 1990 to the 2030s	-16 to +5	-9 to +1	-15 to +11	-11 to +4	-12 to +3
From 1990 to the 2080s	-22 to +32	-17 to +5	-32 to +12	-21 to +3	-21 to +3

Mountain ranges in the north of the region are likely to have less annual rainfall overall, although there is likely to be an increase in precipitation over the summer months.

Table A.3 Projected changes in precipitation (in %) for Tekapo[xciv]

	Summer	Autumn	Winter	Spring	Annual
From 1990 to the 2030s	-9 to +8	-4 to +8	-6 to +35	-10 to +17	-3 to +13
From 1990 to the 2080s	+1 to +46	-10 to +7	-3 to +76	-18 to +34	+2 to +31

Appendix D: Checklist for addressing climate change in Regional Policy Statements

The following checklist can be found in *Climate change effects and impacts assessment: A guidance manual for local government in New Zealand* Appendix 5, Table 1. This appendix looks at how well the current Canterbury Regional Policy Statement 1998 addresses climate change.

1. Is climate change and its effects identified as a regional issue requiring a response?

Climate change is specifically identified as a regional issue in relation to air (Chapter 13, Issue 3) and energy (Chapter 14, Issues 1 and 2). Indirect references are made with regard to settlement and the built environment (Chapter 12 Issue 1), transport (Chapter 15, Issue 2) and waste (Chapter 18, Issue 1).

However, there is a tendency for these issues to relate to the *causes* of climate change, rather than the *effects* of climate change. This is contrary to legislation[44], and has been criticised in Environment Court decisions[45].

2. Does the policy statement explain the national policy context?

The policy statement does not explain the national context, particularly as it pre-dates the Resource Management (Energy and Climate Change) Amendment Act 2004.

3. Does the regional policy statement specify the time horizon for different types of decisions on climate change and its effects?

No.

4. Does the regional policy statement give pointers for the formulation of regional and district plan contents relating to managing the effects of climate changes?

Whilst some methods might be relevant, these currently carry little weight and are very generalised. The exception to this is the references to the Regional Energy Strategy in the energy chapter (Chapter 14, 14.3 method (a)) and the transport chapter (Chapter 15, 15.3 method (f)).

5. Are the respective roles and responsibilities of the regional and district councils in managing natural hazards in the region set out?

The Section 35 analysis of the Regional Policy Statement found the delineation of these roles as set out in the CRPS to be ineffective[xcv].

6. Does the regional policy statement promote consistency of approach towards climate change by local authorities within the region and across boundaries with neighbouring regions?

The 1998 RPS makes no specific provision for addressing the effects of climate change across boundaries. It does establish a policy framework relating to greenhouse gas

[44] The Resource Management Act 1991 establishes the effects of climate change to be an 'Other Matter' for which the council must have 'particular regard' (Section 7(i)), together with 'the efficiency of the end use of energy' (Section 7(ba)) and 'the benefits to be derived from the use and development of renewable energy' (Section 7(j)). Recent court decisions have reinforced the distinction between the causes and the effects of climate change, making it clear that the causes of climate change are only a matter for national government (Refer Greenpeace NZ Inc v Northland RC A094/06 Judge LJ Newhook 11 July 2006 and Todd Energy Ltd v Taranaki RC W101/05 Judge Thompson 7 December 2005)

[45] Refer Christchurch RC v Waimakariri DC C5/2002 Judge Treadwell 25 January 2002

emissions and the use of fossil fuels, although the language of the CRPS is far from mandatory, and therefore fails to provide consistency of approach. One of the methods of the settlement and the built environment chapter is co-operation with district/city councils and the integrated management of natural and physical resources.

7. Does the regional policy statement promote public education as a method of response to climate change and its effects?

It does in relation to greenhouse gas emissions (Chapter 13, 13.3 method (e)), energy use (Chapter 14, 14.3 methods (f) and (g)) and transport (Chapter 15, 15.3 method (d)). However, as with the rest of the CRPS, this focuses on the causes of climate change, rather than the effects.

8. 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?

Although hazard lines are included within the Regional Coastal Environment Plan, they are not provided for within the CRPS, and there is no specific provisions for adapting to sea-level rise within the CRPS.

9. increased rainfall intensity?

There are no specific provisions for increased rainfall intensity, although the effects of climate change have been taken into account when considering resource consent applications, and conditions on those consents.

10. increased incidence of severity or drought?

There is no specific provision for this, and it is currently unclear whether the policy framework for water allocation adequately takes account of the likely variation in water availability in the future. It is expected that the third order process of determining water allocation volumes for groundwater abstraction zones will, or can, take into account climate change by reducing consented abstractions and managing environmental minimum flow rates in waterways, and managing groundwater levels.

11. wind events?

There are no specific provisions for this natural hazard.

12. Does the regional policy statement include any provisions for monitoring effects of climate change, and any relevant statements of environmental outcomes?

The policy statement makes specific provision for the monitoring of sea level rise (Chapter 16, 16.3 method (i)). However, the method is only in relation to monitoring to aid understanding, and does not provide any guidance relating to the outcomes of that monitoring.

Appendix E: Climate change effects and CRPS matrix

			Soils and landuse	Landscape and heritage	Biodiversity and pests	Water	Water interfaces	Coast	Urban development / UDS	Air	Energy	Transport	Natural hazards	Human hazards and waste
NATURAL RESOURCES	Land	5.1.1 top soil loss	✓											
		5.1.1 aridity problems on non-irrigated downland areas	✓											
		5.1.2 possible nutrient stripping	✓			✓								
		5.1.2 land destabilisation	✓			✓			✓			✓	✓	✓
		5.1.3 loss of land area due to coastal erosion			✓		✓	✓	✓			✓		
	Coastal	5.2.1 coastline retreat (potentially mitigated by increased sediment load from increased rainfall in the Alps)			✓		✓	✓	✓			✓		
		5.2.2 greater inundation of salt marshes and coastal wetlands			✓		✓	✓						
		5.2.2 increased inundation and overtopping of barriers					✓	✓	✓			✓	✓	✓
		5.2.3 changes to wave, tide and storm surge propagation and behaviour in shallow estuaries			✓		✓	✓	✓				✓	
		5.2.4 reduced water quality			✓		✓	✓	✓					
	Freshwater	5.3.1 some major eastern rivers could maintain or even increase flows				✓								
		5.3.2 reduced flows for non-alpine rivers, in foothills and Banks Peninsula	✓	✓	✓	✓	✓		✓					
		5.3.2 reduced recharge to streams and groundwater, particularly from eastern forested areas/plains areas	✓	✓	✓	✓	✓							
		5.3.2 less water in rivers in late spring/early summer due to reduced snowmelt	✓	✓	✓	✓	✓							
		5.3.3 reduced water quality from low flows		✓	✓	✓	✓		✓					
		5.3.3 changes in the contamination assimilation capacity of streams			✓	✓	✓							
		5.3.4 contamination by saltwater intrusion				✓		✓	✓					
		5.3.5 reduction in water quality due to heavy precipitation events		✓		✓			✓				✓	
		5.3.5 overloading of urban and domestic infrastructure and other possible sources of contamination from heavy precipitation			✓	✓			✓				✓	✓
	Resource availability	5.8.1 water	✓	✓		✓	✓	✓	✓					
		5.8.2 fossil fuels		✓					✓		✓	✓		
		5.8.3 air (to restrict the total carbon emissions making emissions opportunities into a resource - likely to be subject to economic mechanisms such as cap and trade)							✓	✓	✓	✓		✓
	Air	5.7.1 improved air quality from actions to reduce Greenhouse gas emissions								✓				
		5.7.1 improved local air quality due to less domestic heating necessary								✓				
	Organisms – unwanted	5.5.1 alteration species' distributions, new, and increased incursions of pest species			✓	✓								
		5.5.1 new disease vectors threatening human health			✓									
		5.5.1 establishment of pest species previously unable to survive cold winters and frosts			✓									
		5.5.2 increased CO_2 may favour invasive and/or less productive grassland species	✓		✓									
		5.5.2 changed periodicy of natural ecosystem events *e.g.* beech masting and related irruptions in mice populations			✓									
		5.5.2 potential for increased algal blooms from elevated CO_2 and/or reduced water mixing due to higher temperatures			✓	✓	✓	✓						
		5.5.2 increases in sea surface temperature may result in increased ciguatera fish poisoning from dinoflagellates			✓			✓						

			Soils and landuse	Landscape and heritage	Biodiversity and pests	Water	Water interfaces	Coast	Urban development /	Air	Energy	Transport	Natural hazards	Human hazards / waste
NATURAL RESOURCES, continued	Organisms – indigenous biodiversity	5.4.1 shift in terrestrial species' distributions	✓	✓	✓				✓					
		5.4.1 shift in aquatic species' distributions		✓	✓	✓	✓		✓					
		5.4.1 shift in marine species' distributions			✓		✓	✓	✓					
		5.4.2 / 5.4.4 shift in location of wetland and intertidal habitats	✓	✓	✓		✓	✓	✓					
		5.4.3 / 5.4.4 / 5.4.6 inability of indigenous species to adapt due to fragmented land environments	✓	✓	✓				✓					
		5.4.4 inability of constrained wetlands and intertidal habitats to shift due to human development	✓	✓	✓		✓	✓	✓					
		5.4.5 loss of naturally rare ecosystems and discrete or bounded waterbodies		✓	✓		✓							
		5.4.6 threat to native species from changed disease vector distribution			✓									
		5.4.6 changed periodicy of natural ecosystem events			✓									
		5.4.7 disruption of freshwater ecosystems through low flows or drying of streams and rivers		✓	✓	✓								
		5.4.8 disruption of aquatic and marine ecosystems through decreased water quality following heavy precipitation events			✓	✓		✓	✓					
		5.4.8 decreased light levels in coastal wetlands			✓		✓	✓						
		5.4.9 disruption of marine ecosystems through warming of water		✓	✓			✓						
		5.4.9 disruption of freshwater ecosystems through warming of water		✓	✓	✓								
		5.4.10 decreased mixing of water		✓	✓	✓		✓						
		5.4.11 acidification of oceans and potential impact on marine species			✓			✓						
		5.4.12 bird wrecks due to increased storminess			✓									
		5.4.12 loss of wildlife, vegetation and habitat by fire	✓	✓	✓				✓					
		5.4.13 loss of habitat and stress to vulnerable species and ecosystems	✓	✓	✓	✓	✓	✓	✓			✓		✓
	Organisms – production	5.6.1 increased agricultural opportunities for fruit and wine production, arable cropping and processed vegetable production	✓	✓		✓								
		5.6.1 earlier sowing season and faster growth of horticulture/viticulture species, subject to water availability	✓	✓		✓								
		5.6.1 increased pressure for water resources, including storage schemes		✓		✓	✓							
		5.6.1 inability to productively farm some areas on non-irrigated pasture as a norm due to increased frequency of drought	✓	✓		✓								
		5.6.2 changes to productivity and nutrient cycling	✓											
		5.6.2 increasing pressure to avoid nutrient run-off	✓				✓							
		5.6.3 loss of stock, crops, and pasture due to extreme weather events											✓	
		5.6.3 damage to trees, fences, access roads, bridges, buildings and structures and other farm infrastructure due to extreme weather events											✓	
		5.6.4 adverse impacts on commercial fisheries and aquaculture from ecosystem changes						✓						
		5.6.4 adverse impacts on commercial fisheries and aquaculture from internal regulation, metabolic and reproductive changes						✓						
		5.6.4 marine and aquatic distribution shift						✓						
		5.6.4 increased uptake of toxins by fish and shellfish						✓						✓

		Soils and landuse	Landscape and heritage	Biodiversity and pests	Water	Water interfaces	Coast	Urban Devt / UDS	Air	Energy	Transport	Natural hazards	Human hazards and
PHYSICAL RESOURCES	6.1.1 lower energy demands for heating									✓			
	6.1.1 greater rainfall in the upper catchment areas of Canterbury's hydroelectricity lakes				✓			✓		✓			
	6.1.1 improved opportunities for wind power generation from increased wind							✓		✓			
	6.1.2 loss of or threat to lives, infrastructure and/or property from extreme weather events	✓				✓	✓	✓			✓	✓	✓
	6.1.2 threat to low-lying infrastructure and strategic infrastructure in riverbeds					✓		✓			✓	✓	
	6.1.2 increased risk from recreational/maritime hazards						✓				✓	✓	
	6.1.2 loss of or threat to lives, infrastructure and/or property from fire							✓				✓	
	6.1.2 damage to ICT infrastructure from extreme snowfall events and high winds							✓				✓	
	6.1.2 greater pressure on stormwater and sewerage systems				✓	✓	✓	✓				✓	✓
	6.1.3 need for infrastructure design to accommodate climate change projections				✓	✓	✓	✓		✓	✓	✓	✓
	6.1.3 need for improved capacity of strategic infrastructure to cope better in emergency situations				✓			✓		✓	✓	✓	
	6.1.4 inundation by higher tides and storm surges					✓	✓	✓			✓	✓	
	6.1.5 loss of or threat to infrastructure and/or property from sea-level rise and coastal erosion						✓	✓			✓		
	6.1.5 loss of or threat to heritage sites/structures from sea-level rise and coastal erosion		✓				✓	✓					
SOCIETY AND CULTURE	7.1.1 reduced health effects relating to cold weather and home heating									✓			
	7.1.1 immigration							✓					
	7.1.2 loss of life and injury due to extreme weather events							✓				✓	
	7.1.2 'new' threats such as heatwaves and new disease vectors											✓	
	7.1.3 psychological effects of extreme weather events							✓				✓	
	7.1.3 psychological effects of on-going effects such as crop and pastoral failure											✓	
	7.1.4 breakdown in social cohesion and particularly the urban/rural divide	✓			✓			✓				✓	
	7.1.4 aggressive immigration and pressure on societal and economic structures from vast numbers of environmental refugees							✓					
ECONOMY	8.1.1 vulnerabilities arising from reliance on primary production	✓									✓		
	8.1.2 benefits - product diversity, the fertilising effect of increased CO2, improved energy efficiency, cleaner production etc	✓		✓	✓				✓	✓			✓
	8.1.2 benefits- improved efficiencies, drier and warmer homes, improved air quality and associated improvements in health							✓	✓	✓			✓
	8.1.2 co-benefits for renewable energy including biofuels (use of waste organics/less foreign fuel/resilient to peak cheap oil)									✓	✓		
	8.1.3 and 8.1.4 costs of emission reduction and adaptation to the effects of climate change				✓		✓	✓		✓	✓		✓
	8.1.4 productivity losses from natural hazards							✓			✓	✓	
	8.1.4 immediate costs associated with natural hazard events							✓				✓	
	8.1.5 costs of a more precautionary approach to environmental protection	✓		✓	✓	✓	✓	✓					
	8.1.6 economic impacts of a carbon constrained global economy							✓		✓	✓		✓
	8.1.6 international awareness of and reaction to climate change							✓		✓	✓		✓
	8.1.7 increasing insurance costs to cover increased incidents and intensity of natural disasters							✓				✓	

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Appendix G: Endnotes to the Report

The following endnotes relate to specific references throughout the report. Only the title of the relevant document has been referenced in the endnotes. For the full reference, refer to Appendix F: Sources and References.

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