Climate Change Predictions Policy 2011

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Dunedin City Council – Climate Change Projections (2011)

This document provides updated climate change projections for Dunedin. Table 1 provides a summary of the projections, with further details provided in the following pages.

CLIMATE CHANGE PROJECTIONS SUMMARY

The Council's "Climate Change Predictions Policy" adopted in 2006 was based on projections from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment report published in 2001. More recent projections and information are now available in the IPCC Fourth Assessment Report (IPCC, 2007) and at the regional level by the Ministry for the Environment (MFE, 2008) and the National Institute of Water and Atmospheric Research (NIWA, Reisinger et al, 2010). Recently the Council commissioned a report from the University of Otago (Fitzharris, 2010) to provide an assessment of the Climate Change impacts on Dunedin, to enable effective planning and decision making by the Council in the long term. This recent report forms the basis for these updated projections set out in this document.

Table 1 – Climate change projections for Dunedin (relative to 1990 levels)

Climate Variable	Projected change in Dunedin	
	2040	2090
Mean Temperature Change	+1.1 °C	+2.5 °C
Sea Level Rise	+0.3 m	+0.8 to +1.6 m
Annual Rainfall Change [min, max]	-5 to +5 %	-5 to +15 %
Daily Temperature Extremes	Fewer frosts, increasing very hot days	
Extreme Rainfall	+9%	+20%
Drought	Drought incidence will be largely the same over large areas of the city, slight increase for urban area of Dunedin city and expected to increase for coastal areas north of Waitati	
Waves and storm surge	Storm surge level likely to rise at least in line with sea-level and to be greater when combined with ENSO events and increased storm intensity	
Average wind	Increased annual mean westerly component	
Strong wind	Increased possibility of severe winds	
Snow	Snow level rising with decreased annual mean snowfall	

CLIMATE VARIABLES

A summary of the rationale for each of the climate variables in Table 1 is outlined below. Appendix 1 provides further information of the variables including past observational data.

Mean Temperature Change
The numbers specified in Table 1 have been derived from the upper bound estimates from the *Climate Change Impacts on Dunedin* report (Fitzharris 2010). These projections have come from a report done by NIWA (Reisinger et al 2010), who statistically downscaled IPCC global climate change projections to provide local information for New Zealand regions.

Sea Level Rise
All climate models indicate that sea level rise will accelerate in a warmer world; however there is considerable uncertainty with the timing and rate, due to our incomplete understanding of the processes leading to loss of polar ice sheets (Fitzharris 2010).

IPCC (2007) projections of sea level rise indicate a range of 0.18 – 0.59m by the end of the 21st century, depending on the emission scenario used. However, IPCC estimates were hampered by a lack of understanding of the future rate of loss of polar ice. The Ministry for the Environment (MFE) has recommended that all assessments should consider the consequences of a mean sea-level rise of at least 0.8 metres relative to the 1980–1999 average. However, there is now strong argument emerging that future sea level rise may be considerably higher. Research on Greenland and Antarctic ice sheets that has been published since the IPCC Fourth Assessment Report suggests that ice loss from polar ice sheets could increase total sea level rise by 2090 to between +0.7 to +1.6m, with the recently commissioned *Climate Change Impacts on Dunedin* report (Fitzharris 2010) recommended that Dunedin City should plan for +1.6m sea level rise by 2090. Therefore the Council has decided to plan for a minimum of +0.8m and a maximum of +1.6m sea level rise by 2090 considering the recommendations from both central government and more recently the scientific community. The Council will review these numbers when the IPCC release their Fifth Assessment report in 2014 or earlier if necessary.

It should also be emphasised that further rapid increases in the rate of sea level rise of several metres over century time scales cannot be excluded with progressive melting of Greenland or West Antarctic ice sheets.

Annual Rainfall Change
The numbers specified in Table 1 have been derived from the *Climate Change Impacts on Dunedin* report (Fitzharris 2010). The report also states that there is a tendency for rainfall increases to be greater for inland and southern areas of Dunedin City. North from Waitati, the period about 2040 may be drier than present. Coastal areas will be 5% wetter in spring/winter and 5% drier in summer/autumn. Inland areas will be 5% wetter in all seasons, except for 2090 when spring/winter precipitation increases by 15% above present values. The periodicities in rainfall, which are a feature of the current climate, are likely to continue and therefore groups of years, possibly extending up to a decade in length, will continue to be wetter or drier than usual.

Due to the different climatic zones of Dunedin overlaid with the complexity of other phenomena affecting rainfall such as El Nino, La Nina, the Pacific Decadal Oscillation, the Southern Annular Mode, the Quasi-Biennial Oscillation, solar activity and sea surface temperature, it can be difficult to project a number for the average rainfall change for Dunedin. As the current observations of rainfall in some areas of Dunedin are showing a decreasing trend and other areas a positive trend, it is critical that rainfall is continually monitored for the different climatic zones of Dunedin.

Extreme rainfall events
The intensity of extreme rainfalls is associated with temperature increases and so a consideration of future temperature change is also necessary. As a result of climate change, heavier and/or more frequent extreme rainfalls are expected over New Zealand, especially where the mean rainfall is predicted to increase. The percentage increase in extreme rainfall

depths is expected to be approximately 8% per degree Celsius of temperature increase (MFE 2008).

Storm Surge Events
NIWA provided detailed modelling to the Otago Regional Council, in 2008, and hazard maps on extreme storm surge and wave events for the whole Otago coast. Their results suggested that extreme storm and wave events in the Otago region may in the future temporarily raise sea level by up to 2.63m above present mean level of sea (MLOS). Clearly sea level rises of several tens of centimetres will have significant effects on the predicted sea levels from current storm surge and wave events. They predict that a sea level rise of 0.5m would increase the 100-year return period predictions by 20-30%.

A number of low-lying areas in Dunedin City are at risk of extensive inundation from storm events even in the present climate, especially Long Beach, Purakanui and Karitane. Future climate change and sea level rise will increase that risk, extend it to other coastal communities and threaten to breach the protective dune systems of South Dunedin.

Droughts
Drought magnitude and frequency are expected to increase in a warmer climate as evapotranspiration increases. It has been detailed in the Fitzharris report that current 1-in-20 year drought could occur at lease twice as often in eastern parts of New Zealand under a warming of about $2^{o}C$. If average rainfall increases (which it is projected to for inland and southern areas of Dunedin City) then this will help offset the higher temperatures and prevent a drought from occurring in these areas, but if the projections are not correct then there could be an increase in droughts. Drought is expected to increase for coastal areas north of Waitati.

Fires
The likelihood of fires will increase with hotter, drier conditions. Fire risks will increase for eastern parts of New Zealand (Fitzharris 2010).

Extreme Winds
Unfortunately there is little information currently available for New Zealand on frequency of strong winds under global warming. However, it is suggested that as climate models show an increase in the frequency and strength of the westerly wind belt over this century, the incidence of gales over the area of Dunedin City will be expected to increase.

BACKGROUND TO PROJECTIONS

IPCC Emission Scenarios
Projections of climate change depend heavily upon future human activity and so the IPCC has developed 40 different scenarios, each making different assumptions for future greenhouse gas emissions, land-use and other driving forces such as global population, economic growth, technology, energy availability, and national and international policies. The IPCC scenarios have been grouped into four scenario families, A1, A2, B1, and B2 (Table 2), which emphasise globalised vs. regionalised development on the A,B axis and economic growth vs. environmental stewardship on the 1,2 axis (IPCC, 2000). Three variants of the A1 (globalised, economically oriented) scenario lead to different emissions trajectories: A1FI (intensive dependence on fossil fuels), A1T (alternative technologies largely replace fossil fuels), and A1B (balanced energy supply between fossil fuels and alternatives). Appendix 2 details further these scenarios.

Table 2 – Description of IPCC Emission Scenarios

	More economic focus	More environmental focus
Globalisation	**A1** Rapid economic growth Groups: **A1F1, A1B, A1T**	**B1** Global environmental sustainability
Regionalisation	**A2** Regionally oriented economic development	**B2** Local environmental sustainability

The emissions scenarios span a range of plausible futures and formed the basis of much of the climate projection work done for the IPCC's Third and Fourth Assessments, where they used general circulation model (GCM) experiments to provide future climate change projections. GCMs are numerical models of the planet that simulate physical processes in the ocean, atmosphere, cryosphere and at the surface. The IPCC is unable to indicate whether any one emission scenario is more likely than another. However, the global emissions growth rate since 2000 has been greater than for the most fossil-fuel intensive of the IPCC emissions scenarios, A1F1. Emissions since 2000 were also far above the mean stabilization trajectories for both 450 and 650 ppm $CO_{2,eq}$ (Figure 1).

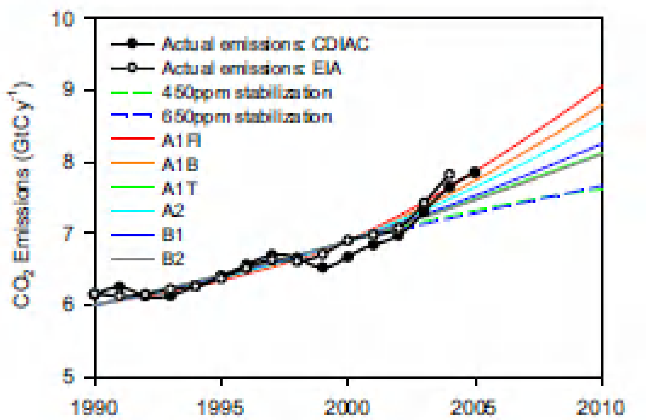

Figure 1 - Observed global CO_2 emissions from the US Department of Energy: Energy Information Administration (EIA) and Carbon Dioxide Information and Analysis Centre (CDIAC) data, compared with IPCC emissions scenarios and stabilization trajectories (Raupach et al 2007).

Therefore reducing greenhouse gas emissions and carbon sequestration (i.e. climate change mitigation work) is as essential as adaptation work and therefore the Council will be developing mitigation goals in line with scientific recommendations and work with other governmental organisations, business and the community to ensure catastrophic Climate Change is avoided.

Climate Change Projections for Dunedin

The climate change projections for Dunedin have primarily been derived from the Fitzharris report, which came from a report done by NIWA (Reisinger et al 2010). NIWA statistically downscaled IPCC global climate change projections to provide local information for New Zealand regions. The other source for the projections has been the Ministry for the Environment (MFE, 2008). They presented information on climate change projections for Otago that also utilised the IPCC emission scenarios. The projections are given for 2040 and 2090 timeframes (relative to 1990 levels), however the effects of global warming and sea level rise will continue after 2090 for centuries even if greenhouse gas concentrations are to be stabilised.

It is not only important that future projections for the Dunedin climate are derived from peer-reviewed science but they must also be compared to historical and current local climate data to provide better accuracy. Appendix 1 presents historical to current data for key climate variables for the urban area of Dunedin (mean temperature change, annual rainfall and sea level rise), from the NIWA Climate database (http://cliflo.niwa.co.nz/), and these have been compared to the projections.

Lastly it is important to take into consideration the complexity of the topography of Dunedin. This topography creates five distinct climate zones, of which their current climate conditions are described in Appendix 3. Historical to current localised climatic information for these distinct zones can be found through the NIWA Climate database. To develop a better understanding of the effects of Climate Change on these five distinct areas of Dunedin, it would be useful to compare local climate monitoring, on a periodic basis, to the projections. As projections available at present cover the Otago region, there may be scope at a later date to work with NIWA to develop better resolution and climate projections for the distinctive climatic zones of Dunedin.

LEGISLATIVE CONTEXT

Key legislation that provides local government with the powers and responsibilities to manage the risks associated with climate change and consider climate change adaptation are:-

- The Resource Management Act 1991 (RMA)
- Local Government Act 2002 (LGA)
- Building Act 2004
- Civil Defence Emergency Management Act 2002 (CDEMA)

Therefore many of the functions of local government relate to, or can be affected, by climate change.

DEFINITIONS

Projections

Projections are used in this policy rather than predictions due to the level of uncertainty involved in determining them. A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised, and are therefore subject to substantial uncertainty. Projection is used instead of prediction in this document because the numbers are based on IPCC emission scenarios which are not predictions but are based on different plausible estimates of future social and economic development (e.g., economic growth, population level) (Solomon et al 2007).

The Climate Change projections for Dunedin detailed in this document will provide the necessary guidance for the Council to fulfil its adaptation objectives.

Climate Change Mitigation and Adaptation

Rational responses to the threat of climate change can be grouped into two sets of actions: mitigation and adaptation. Mitigation involves actions to produce less greenhouse gas pollution and therefore limit the extent of global warming and climate change. Adaptation involves investing in ways to help the community manage the impacts of global warming. Mitigation and adaptation differ in terms of their respective goals as can been seen in Table 3 but are interrelated as mitigation efforts in the long term will ultimately lessen the Climate Change impacts that will need to be adapted to.

Table 3 - Objectives and definitions of climate change mitigation and adaptation

	Objectives	Definitions
Climate change mitigation	• Stabilising greenhouse gas concentrations • Reducing greenhouse gas emissions • Promoting greenhouse gas sinks • Halting dangerous anthropogenic climate change	'Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks' (IPCC, 2007)
Climate change adaptation	• Reducing climate change related harm to natural and human systems • Reducing the vulnerability of natural and human systems to the impacts of climate change	'Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC, 2007)

Sudden versus Slow Impacts

Climatic impacts can also be distinguished by their speed of onset: i.e., those that happen suddenly; and slow-onset impacts that follow a pattern of gradual change (Figure 2). Gaining a better understanding of the specific onset and duration of climatic impacts can help clarify the type of adaptation response necessary, as well as point towards the most adequate planning process. For sudden, short-term events such as storms and flooding, adaptation efforts may need to focus on improved disaster prevention, establishing early warning systems, and effective disaster response which fall into Civil Defence responsibilities. For slow-onset, continuous impacts such as sea-level rise, however, strategic forward planning is critical, and existing planning instruments such as land use planning may need to be altered to take gradual changes in climatic stressors into account. Clarification of the onset of impacts is useful to help focus adaptation goal setting and prioritisation activities.

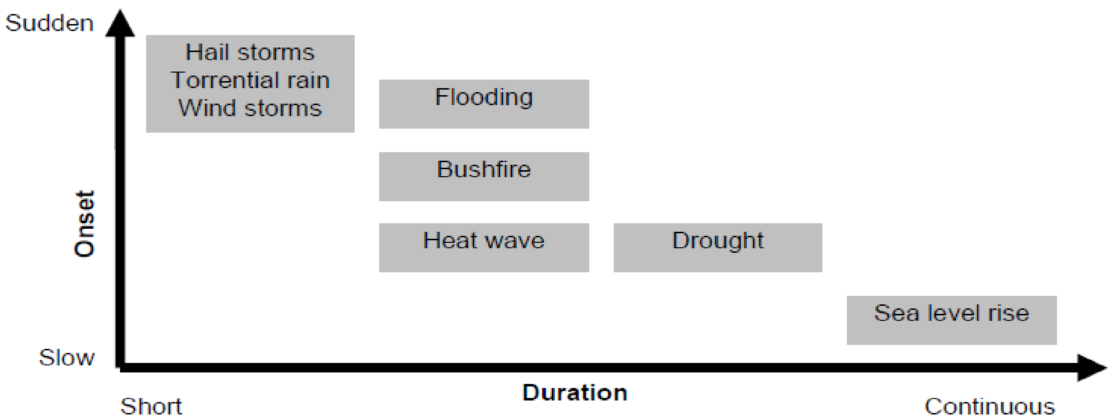

Figure 2 – Typical onset and duration of climatic impacts (Funfgeld and McEvoy 2011)

APPENDICES

Appendix 1 – Climate variables - Historical and current data and MFE projections

Mean Temperature Change (°C)
Current observations and historical data of the temperature in NZ can be seen in Figures 3a and 3b. These figures show a time series of NZ average temperature as observed for 1908 to 2006. Otago Regional Council (2007) appended a future simulation derived from a single climate model for the period 2007 to 2099 for comparison in Figure 3b. As can be seen from Fig 3a and 3b, the temperature in NZ has been rising. Figure 4 is a smaller dataset and is the measured temperature for Dunedin, with predictions for future change based on MFE estimates.

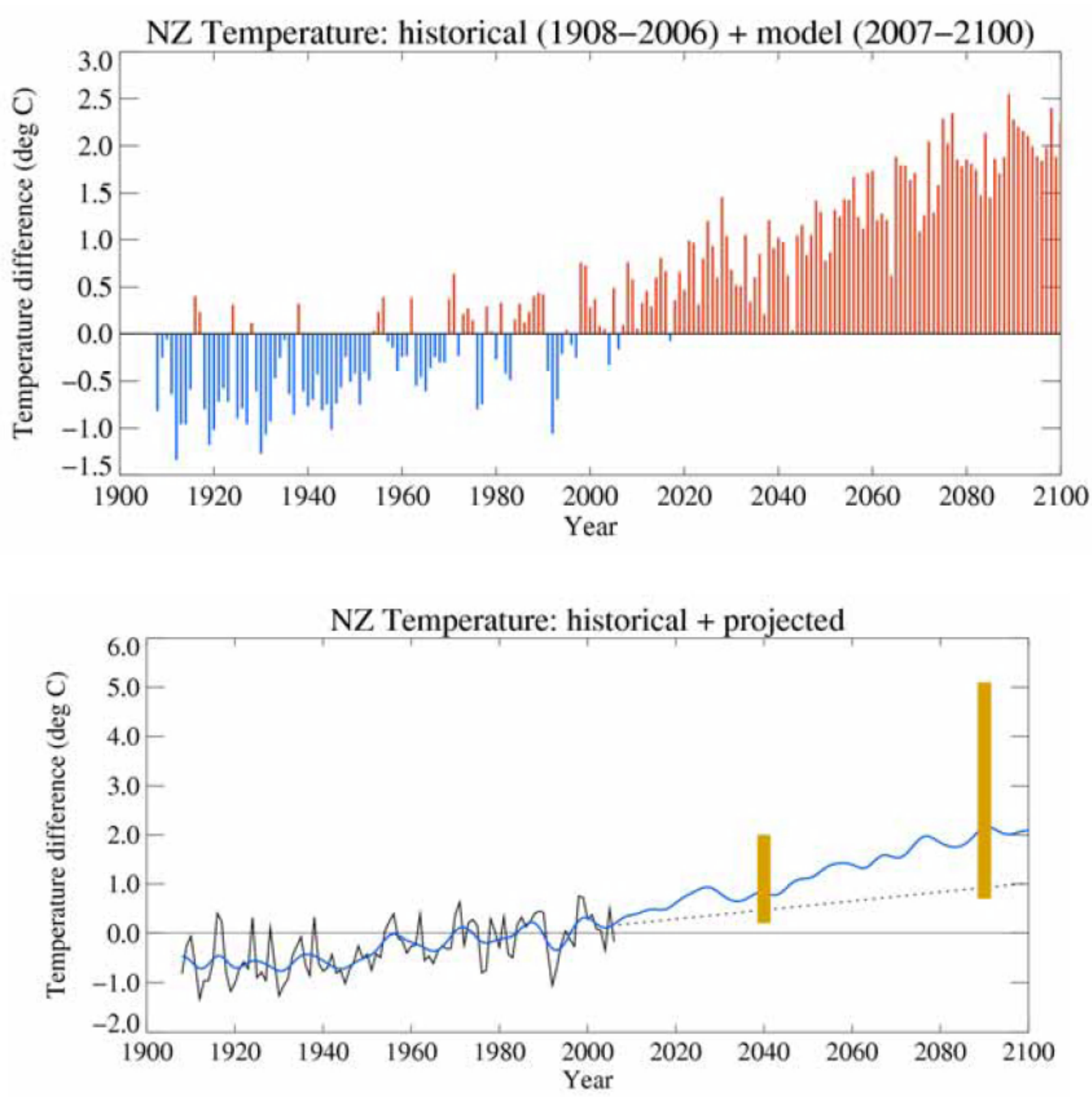

Figure 3a and 3b – New Zealand temperature (in ^{o}C) – historical record and schematic projections illustrating an example of future year-to-year variability. (Source MFE, 2008)

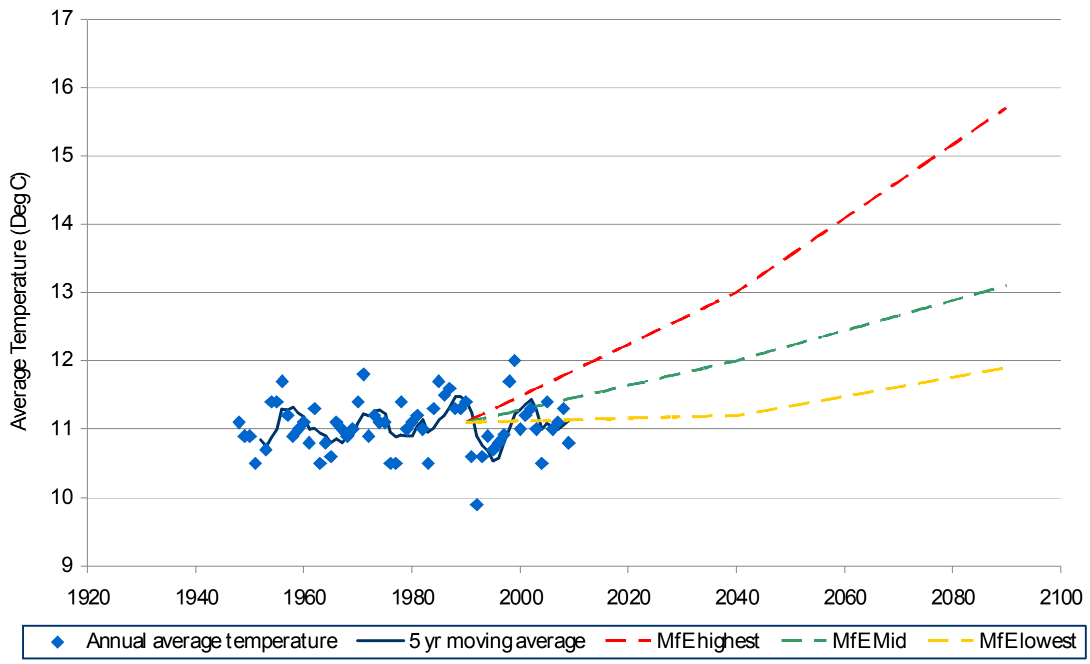

Figure 4 – Observed Dunedin temperature data (ORC)

The Ministry for the Environment (2008) also produced annual mean temperature projections for Otago which came from downscaled projections based on all of the IPCC emission scenarios (Table 4).

Table 4 – Projected changes in seasonal and annual mean temperature (in °C) from 1990 to *2040 and 2090* for Otago relative to 1990. The average change and the lower and upper limits [in brackets] are given (MFE, 2008).

Year	Summer	Autumn	Winter	Spring	Annual
2040	0.9 [0, 2.4]	0.9 [0.1,1.9]	1.0[0.3,2.1]	0.7[0.0,1.8]	0.9[0.1,1.9]
2090	2.0 [0.7,4.8]	2.0 [0.8,4.6]	2.2 [0.8,4.8]	1.7[0.5,4.3]	2.0[0.8,4.6]

Sea Level Rise

Sea-level increased by approximately 120 metres since the end of the last ice age and was relatively stable from about 2-3000 years ago through to about 100 years ago. During the 20th century global average sea level has increased by about 1.7mm/yr. In Dunedin, the tidal gauges have measured the sea level rise to be on average 1.3mm/yr.

During the 21st century sea level is virtually certain (more than 99% probability) to rise (NIWA, 2006). However, the exact amount of sea-level rise by the end of this century cannot be well defined. Sea level rise will continue for centuries even if greenhouse gas concentrations are to be stabilised. The lag between atmospheric and ocean warming, the time required for ice sheets to melt, and the momentum in the climate system, mean that sea levels will continue to rise for several centuries, even after atmospheric greenhouse gas concentrations are limited or stabilised. The timeframe of hundreds of years is relevant to the lifespan of some major pieces of infrastructure and to decisions on the location of major urban areas.

Figures 5 and 6 provide understanding as to how the projections for sea level rise have been changing since the last IPCC Fourth Assessment Report (2007).

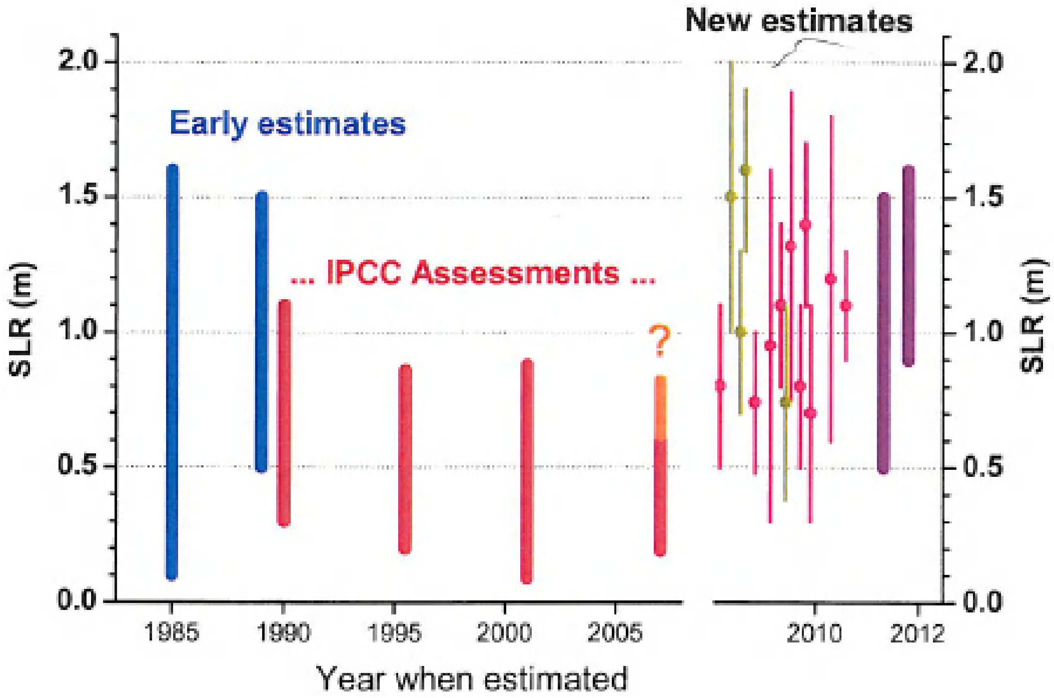

Figure 5 – A summary of scientific estimates for sea level rise by year 2100 that have been made since 1985. The two blue vertical bars are from a US Department of Energy report in 1985 and a major review paper in 1989. The four red bars summarise results from the last four IPCC Assessment reports with the question mark representing the lack of an upper bound mentioned in the Fourth Assessment. The narrow bars on the right show estimates from recent peer-reviewed scientific papers, with dark yellow showing estimates based on the last ice age and pink showing projections from the recent observed trends. The thicker purple bars show the range of 0.5-1.5m given in recent reviews and the range 0.9-1.6m given in a very recent statement from the Arctic Monitoring and Assessment Programme meeting in May 2011.

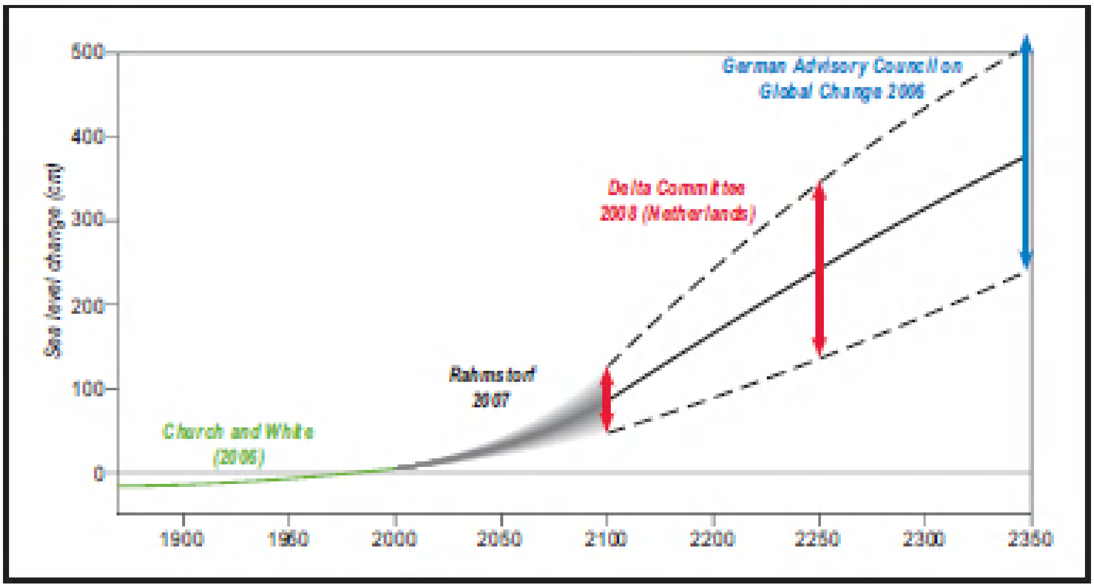

Figure 6 - Recent estimates of future sea-level rise relative to the 1990s. Source: German Advisory Council on Global Change 2009.

Annual Rainfall Change

The actual trend in annual rainfall at Dunedin in recent years (Figure 7) shows that totals have been generally much lower than the predictions shown in Table 4, and are presenting well outside the lower limit of IPCC predictions. A number of wet years would be required to push the 5 year moving average back within the range of IPCC predictions.

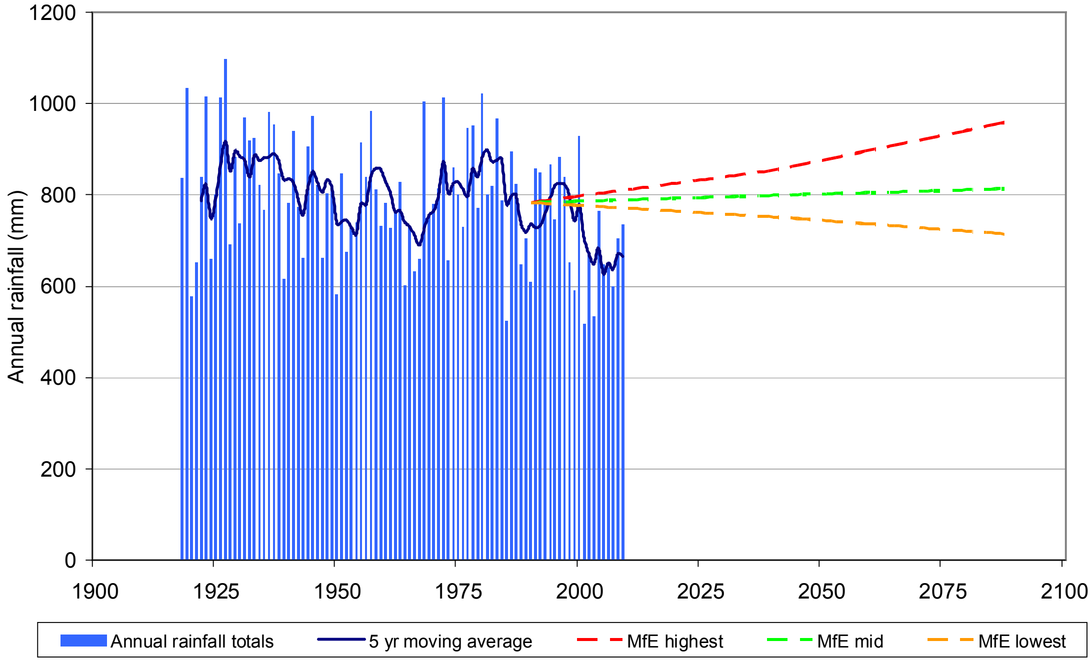

Figure 7 – Observed annual rainfall totals at Dunedin from 1918 to 2008 (blue bars), over-plotted by a 5 yr running average (solid blue line). The dashed red and orange lines indicate the highest and lowest IPCC projections, while the dashed green line shows the most likely projected change out to 2090. (Source, Otago Regional Council, 2008).

The Ministry for the Environment (2008) produced annual rainfall change for Otago (Table 5) which came from downscaled projections based on all of the IPCC emission scenarios.

Table 5 - Projected Annual Rainfall Change (in %) relative to 1990 (source MFE 2008)

Decade	Summer	Autumn	Winter	Spring	Annual
2040	1[-11,13]	2[-9,10]	3[-10,13]	2[-5,11]	2[-4,9]
2090	0[-29,19]	2[-11,16]	7[-16,24]	6[-1,32]	4[-9,23]

As the current observations of rainfall are showing a decrease, which is not in line with the projections, it is important that the Council continue to monitor this key climate variable for all the different climatic zones of Dunedin.

APPENDIX 2 - IPCC Emission Scenarios

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B, where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels. The scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

APPENDIX 3 – Climate Regions of Dunedin City

F1 North Otago Climate (eg around Waikouaiti)
Annual rainfall is low, ranging between 500 mm to 800 mm. There tends to be more in winter than in other seasons. There are less than 100 rain days and severe droughts can occur. Summers are warm, with occasional hot northwesterlies giving temperatures above 30°C. Cool winters with frequent frosts and occasional snow. Prevailing winds are south-westerly and north-easterly.

F2 Hill Climate (eg Maungatuas, Flagstaff, Silver Peaks)
These areas are cooler, cloudier and wetter than F1. Rainfalls average 800 mm to 1500 mm annually. Southwesterlies predominate, with occasional very strong northwesterlies gales. Snow may lie for weeks in winter.

F3 Transitional Central Otago Climate (eg Strath Taieri)
Tending towards a semi-arid, semi-continental climate. Annual rainfall is below 500 mm, with less than 80 rain days. Drought is endemic. Warm and sunny summers and cold frosty winters. Foggy in autumn and early winter.

G1 Eastern Otago Climate (eg Dunedin urban area, Otago Peninsula)
Moderate to warm summers and cool winters. Rainfall is 500 mm to 900 mm and evenly distributed throughout the year, but with a slight winter minimum. Rather cloudy. Winds tend to be from the southwest, or from the northeast along the coast. The Taieri Plain is a variant climate of this region in that it is frostier and sunnier.

M Mountain Climate (eg Rock and Pillar Range)
Climate varies substantially depending on elevation. Annual precipitation is at least 1200 mm. Much of winter precipitation falls as snow and may lie on the ground for many months. Temperatures cool off with elevation at about 0.7°C/100 m.

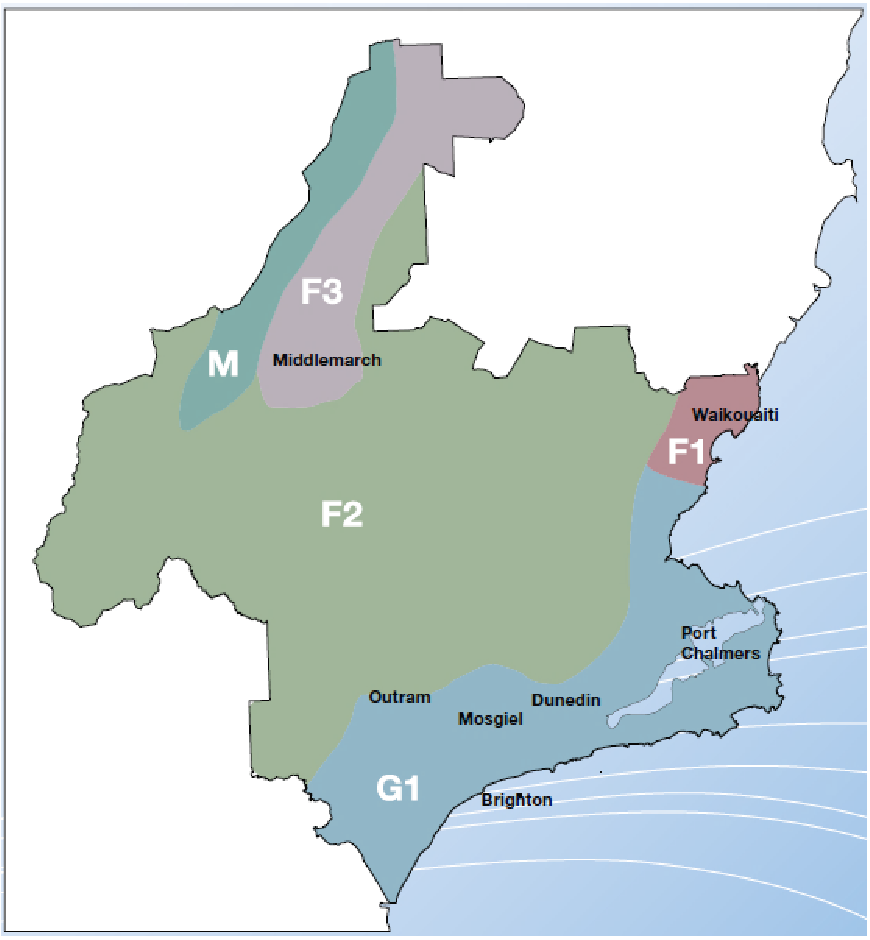

Figure 8 – Climatic regions of Dunedin City (Fitzharris, 2010)

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