SUSTAINABLE FUTURES 30|50
WHANGAREI DISTRICT

Whangarei District

Climate Change Constraints Report

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Executive Summary

Climate change has long been perceived as a threat to the environment, but in recent years this threat perception has expanded to include social, cultural, security, and economic concerns. The theory underpinning anthropogenic climate change, put very simplistically, is that increased emissions of so-called greenhouse gases (carbon dioxide, methane and so on) into the atmosphere traps more energy from solar sources which, in turn, can raise global temperatures.

As global temperature rises, it is expected to have an impact on the habitable ranges of flora and fauna, increase natural hazard risk, impact on traditional methods and areas of food production, increase infrastructure costs, and, in short, impact on many other areas of global human life. Higher global temperatures can affect the global biogeochemical cycles by changing various rates of reaction at massive scales. It is also generally recognised that future temperature changes will not necessarily rise in a relatively predictable linear fashion, but instead will consist of tipping points, in which one action causes further reactions across the board that either speed up or slow down the rate of temperature increase.

The projected changes for Northland in terms of temperature range between 1.1° C and 6.4° C by 2100, with the best estimates being between 1.8° C and 4.0° C. Under climate change scenarios, the number of hot days locally could double by 2040 compared with present, and increase by 40 - 50 extra days per annum by 2090 within Whangarei District (Gardiner et al 2008) if the mean annual temperature is 2.3° C above present mean annual temperatures. This would change the frequency of hot days from equivalent of three weeks per annum to almost 10 weeks.

Precipitation projections have more variability across the district, according to the season, with an overall decline in precipitation. In terms of seasonal changes, major decreases are likely in winter and spring precipitation, and very small changes (with possible increases) in summer and autumn precipitation occur around the eastern hills north of Whangarei Harbour, but an overall decline south and west of Whangarei City.

The projections suggest that Northland is likely to have sub-optimal conditions for the production of many of its 'traditional' primary products, with subsequent loss of productivity in some years. Overall, the drying of pastures in spring is expected to be advanced by one month and potential moisture evaporation is likely to increase, with severe droughts (equivalent of present 1 in 20 year events) likely to occur more regularly.

A changing climate will have an impact on infrastructure in Whangarei District, with larger peak flows in stormwater systems, potential water supply problems, effects on wastewater disposal, damage to roading infrastructure, and changes in the coastline all being of importance. Many of the high priority natural hazards found in Northland and Whangarei are driven by extreme weather events such as storms, ex-tropical cyclones and other factors that influence rainfall and wind patterns, and all impact on agriculture, biodiversity, health, vulnerability, and other Council business.

In Future One the biggest concern is likely to be continued major growth in coastal areas, which are exposed to a wide range of hazards, both in existing settlements and dispersed between settlements. There will be increased exposure inside Whangarei City together with its margins, with land instability and flood susceptibility being key issues, especially around the CBD. Marsden Point/Ruakaka is exposed to the more risky hazards in terms of the coast as the extent of the coastal hazard line maps indicate, and there is ongoing risk from flooding.

The main concern in Future Two is whether the proposed twin city at Marsden Point/Ruakaka will result in a high level of exposure to various risks, especially around Ruakaka resulting from climate change. Future Two has the highest potential in terms of reducing transport based and probably industrial-based carbons emissions as a very large proportion of the population is contained in two main centres, meaning that public transport options are very high and new industrial plant is developed that uses more modern technology and meets higher environmental standards.

Of the three futures, Future 3 is likely to reduce exposure to climate change risk the most across the district, as policies to promote consolidation would also aid adaptation and mitigation. However, of note in terms of Future 3 is the possible expansion of Hikurangi and Waipu as development nodes. Given the substantial flood hazard area located in the vicinity of both, and the strong possibility of isolation in the event of flooding, any development in these areas needs to be carefully managed. Future Three has the most capacity for adaptation and mitigation measures, and is considered the most resilient in respect to climate change as it builds up capacity more widely across the district.

1 Introduction

1.1 Background

In December 2009, representatives from most nations gathered in Copenhagen, Denmark, in order to develop an international policy framework for addressing climate change that succeeds the Kyoto Protocol. On the 10th of August 2009, the New Zealand Government announced its initial 2020 carbon emission policy for the purposes of the negotiations in Copenhagen, which will impact on the economy and the environment in Whangarei District. The issue of climate change is an important consideration for long term strategic planning in Northland, especially as the literature singles out Northland as a place likely to see substantial impacts, due to increased coastal settlement, climatic hazard risk changes, as well as its historical dependence on primary production (Hennessy et al 2007). Whangarei District faces quite extensive risks but may well see increased opportunities arsing from climatic changes.

Climate change has long been perceived as a threat to the environment, but in recent years this threat perception has expanded to include social, cultural, security, and economic concerns. In May 2009, the prestigious medical journal "The Lancet" featured a major article which framed climate change as the "biggest global health threat of the 21st century" (Costello et al 2009). Recently, health practitioners in New Zealand made similar claims[1]. As well as health concerns, projected large scale migration resulting from climate instability is expected in many parts of the world, and the New Zealand Government has certainly considered this in relation to Pacific Island peoples (Boston et al 2008). Apart from these possible consequences for social dynamics across the world, there are also concerns over climate change impacts on cultural resources, such as heritage sites or the survival of various plant and animal materials for customary purposes (UNESCO 2009). For example, there are concerns about impacts of sea-level rise on various important historical and cultural sites along the coast such as wahi tapu and urupa.

Whilst the economic impact of future climate changes had been discussed internationally, at least in terms of present day costs, it wasn't until the Stern Report, published by the World Bank in 2007, that economic ramifications of future climate change really started to be discussed. In brief, and at risk of oversimplification, the Stern Report (2007) suggested that future economic costs of its impact (as a proportion of total world GDP) was substantial (between 5 - 20% losses in the future global economy) and that the relative costs of mitigation and adaptation were presently low but would rise over time (originally 1% but later revised to

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[1] Johnson, M. (9th October 2009) Doctors attack climate change stance. New Zealand Herald. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10602173

2% of present global economy). This, in the reports view, meant the world needed to take action now to protect future generations and the global economy. The overall result of this research implied that earlier actions of a large scale would lead to relatively smaller future costs and less economic impact than inaction or small actions.

On a more local scale, major climatic events already have an impact on infrastructure, and any change in either the frequency or magnitude of natural hazard events must be contemplated as a high risk. In recent years, both Far North District Council and Whangarei District Council have cited major costs to roading infrastructure as a result of major storms in 2007. In Hamilton and Wellington, modelling carried out by the New Zealand Centre for Ecological Economics suggest that projected increases in extreme weather events can produce long term additional maintenance costs for roading.

New Zealand guidance on planning for climate change is incorporated into various documents for local government, and the public, prepared by Ministry for the Environment (MFE), Ministry of Agriculture and Forestry (MAF), and other government ministries. The MFE report prepared for local government uses two main timeframes: 2030s and 2080s for modelled changes. Neither timeframes exactly aligns with Whangarei District Council's Sustainable Futures 30/50 timeframes (2041 and 2061 respectively), but they do represent the outer time envelope within which Whangarei District Council's project operates.

These reports represent a tiny proportion of work being carried out at present, with thousands of research papers being written all over the world. The high level of research is reflective of the prominence that climate change will play over the next 50 years. Because of this, the decision was taken to prepare this report as a stand-alone document that addresses all aspects of sustainable wellbeing, whether economy, society, culture, or environment, rather than simply including climate change as a topic within the natural hazards constraints report or other background reports.

This report is broken down into five main sections: Section 1 is a summary of the climate change phenomenon, and tries to explain the science behind it. This also includes some information on expected global impacts which may have a bearing on the development of the district over the next 50 years. It begins by outlining the historical context of climate change internationally, and within New Zealand.

Section 2 is a summary of the expected impacts on Northland, and Whangarei. It begins with a brief overview of the direct and indirect impacts. It also contains information on the future Hazardscape of Whangarei District, in which climate changes may impact on the magnitude and frequency of some hazard events.

Section 3 considers more detailed impacts of climate change on several sectors (or issues) including infrastructure, biodiversity, agriculture, health, and water.

Section 4 is an overview of the legislation and institutions charged with mitigating and adapting to the impact of climate change. The third part examines the response by various agencies at the central, regional, and local level, including a brief overview of legislation, policies and programmes of relevance.

Section 5 contain relevant localised concerns such as potential hotspots within Whangarei, from environmental, social, cultural and economics point of view, as well as discussions on the impact of climate change from a spatial point of view as plausible impacts on the three futures used in these reports.

1.2 Principles of Climate Change

The average temperature of the Earth has risen and fallen over millions of years, with shifting climates having impacts on ecosystems, people and places (Stern 2006, IPCC 2007, Richardson et al 2009). Major naturally occurring climatic effects have generally been the main drivers of change in Earth's past, but over the last 20 years, the possibility of climatic changes resulting from human activity has become of increased concern and debate.

The theory underpinning anthropogenic climate change, put simplistically, is that increased emissions of so-called greenhouse gases (carbon dioxide, methane and so on) into the atmosphere traps more energy from solar sources, which in turn raises the temperature. The next part of the theory is that there is a predictable link between CO_2 concentrations in the atmosphere and average global temperature. If this link is accurate, then measuring and projecting concentrations of greenhouse gas in the atmosphere will give relatively accurate projections on future climates. This relationship between CO_2 concentrations and temperature changes is then used to calculate the impacts on temperature of various rates of global emissions or to argue for potential limits on future emissions.

The theory of anthropocentric climate change is not new, with one of the earliest comments coming from the Swedish scientist Arrhenius in 1896 who suggested that human activity could substantially warm the atmosphere by adding carbon. This comment arose during the beginning and expansion of the Industrial Revolution and the use of coal within factories. It has been estimated that approximately 900 billion tonnes of CO_2 has been released through industrial activity and land-use changes since the beginning of the Industrial Revolution, of which 450 billion tonnes is estimated to remain in the atmosphere (Costello et al 2009). This would mean that the other 450 billion tonnes has been removed from the atmosphere through biogeochemical processes such as absorption within the ocean, uptake in forests and other large scale environmental processes (Richardson et al, 2009).

Reported atmospheric CO_2 concentrations reached 387 parts per million (ppm) in 2008, which is much higher than any other time within the last 650,000 years, during which CO_2 concentrations ranged between 180-300ppm (Richardson et al 2009). The recent CO_2

concentrations are in uncharted territory for humanity in terms of underlying climate. It is this very global and futuristic nature of climate change that makes policy difficult to develop, as convoluted political debates in New Zealand have illustrated.

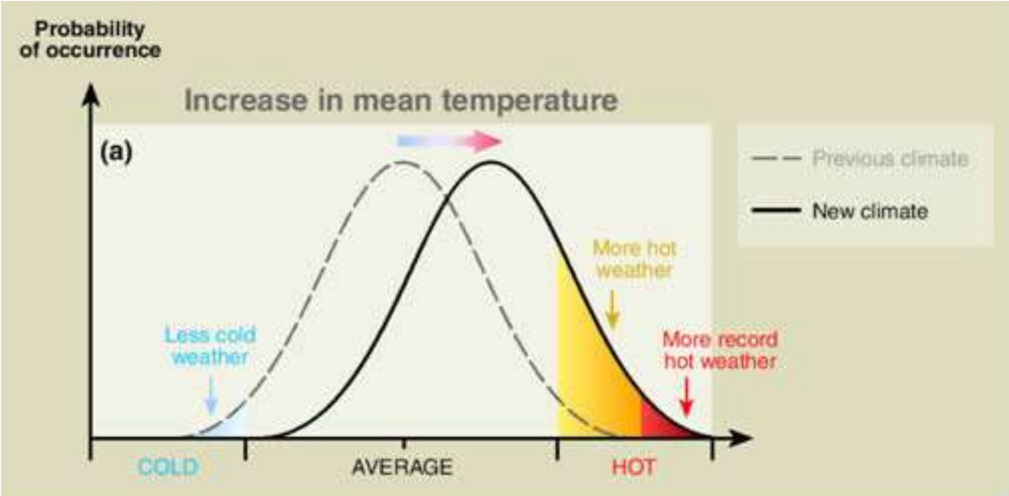


Figure 1: Effect of Climate Change on Average and extreme temperatures. Sourced from MFE 2008 (sourced from figure 4.1-IPCC Synthesis Report, IPCC 2001b). Illustrative only.

It is estimated that the average global temperature has already risen by 0.76° C from pre-industrial times, and the average sea level by 4 cm. Of the last 13 years, 12 have been the highest on record for the last 150 years, with 1998 being the warmest (Costello et al 2009). 1998 was notable for the extreme El Nino worldwide which helped raise temperatures well above global means. This information has caused some criticism of climate change theories as critics have suggested that if climate change was real, then we should expect a linear rate of temperature growth, with each year higher than the previous. However, when correcting for major global weather pattern drivers and their historical impact on global temperature, the trend in mean temperature is rising (IPCC 2007, MFE 2008).

Higher global temperatures can affect the global biogeochemical cycles by changing various rates of reaction at massive scales. There are difficulties to gauging the full impact of these changes of the biogeochemical cycles, as there are many other factors at work that may enhance or limit the impacts of climate change. An example of this is concern over increased acidification of the ocean that occurs as more CO_2 is absorbed that then leads to reactions in which more carbonic acid is produced. Higher levels of carbonic acid lead to acidification which can then impact on the life cycles of most marine life, which can effect productivity of the oceans. However, understanding the impact of acidification is only in early stages of research.

The next element of climate change theory suggests that, as more heat is trapped in the atmosphere, this leads to more energy in the global circulatory system, which in turn means that there would be more energy available to drive large scale weather events. Higher temperature also allows more moisture into the atmosphere (if available locally, such as the moisture above oceans). Climate-related disasters around the world have seen a fourfold increase since the early 1980s such as flooding, fires, and cyclones increasing from 120 to 500 per annum (Hughes & Mercer 2009). There is general expectation that this trend will continue to increase. None of these individual events can be directly attributable to climate change, but overall, the numbers and intensity of these events give clues that something is changing. This, in turn, puts additional pressure on many social systems, especially if they face multiple events.

As global temperature rises, it is expected to have an impact on the habitable ranges of flora and fauna, increase natural hazard risk, impact on traditional methods and areas of food production, increase infrastructure costs, and, in short, impact on many other areas of global human life (IPCC 2007, Foden et al 2008, Richardson et al 2009). The projected change in climate patterns can have a significant impact on the structure of ecological communities and tolerance of flora and fauna to climatic extremes in Whangarei District and elsewhere. Changes in temperature or water conditions may enhance the prospects for weed or parasite species, change pasture production levels and future forage species, decrease the rate of seedling recruitment, and overall decrease future prospects of species adjusted to present climate parameters rather than future ones.

These different broad aspects to climate change theory are important as much of the research community have indicated that a temperature increase of 2°C is the critical threshold before large scale runaway changes occur, along with the capacity for society to cope with these changes. Based on the present temperature trends, it is postulated that in accepting a 2°C change as the guard rail, then only 750 billion tonnes more carbon would be allowed to be emitted into the atmosphere between now and 2050 (Meinshausen et al 2009). Many of the negotiations at Copenhagen will be about how to allocate these carbon emissions across various countries, bearing in mind variable historic contributions from to the problem, levels of energy intensity within an economy, size of individual countries present footprint, all of which needs to be built into some future agreement.

Whilst 1 or 2° C mean temperature increases may not sound like a large change, it can have a very significant influence on the occurrence of 'extreme weather'. For example, Auckland has a mean of 21.3 hot days (above 25° C) and Tauranga has approximately 23.3 hot days. Whangarei would have similar numbers to both these centres. However, under climate change scenarios, the number of hot days could double by 2040 compared with present, and increase by 40 - 50 extra days per annum by 2090 within Whangarei District (Gardiner et al 2008) if the mean annual temperature is 2.3° C above present mean annual temperatures. This would change the frequency of hot days from equivalent of 3 weeks per annum to almost 10 weeks. Higher numbers of hot days can have an impact on issues such as increased energy use for cooling and air-conditioning, flora and flora, agriculture, and many other parameters.

Whilst it is acknowledged that climate change is likely to impact many aspects of life in New Zealand, the following impacts stand out as being key future drivers for this district:

- Water security, with droughts increasing in frequency and intensity, and subsequent potential losses on agricultural production.
- Flooding, with rain events more intense leading to greater storm run-off.
- Extreme weather causing greater erosion of land surfaces, more landslides, redistribution of river sedimentation, and a decrease in the level of protection provided by levees.

1.3 Policy Responses

In terms of climate change policy, there are two general types of response: mitigation and adaptation. To date, most of the work undertaken in New Zealand is related to reducing the overall carbon footprint, or mitigation. Mitigation in climate change refers to those activities which reduce the amount of carbon emissions (either carbon dioxide or other "greenhouse" gases such as methane). These can include energy efficiency gains, changes in transportation patterns, and other activities designed to reduce the emission of greenhouse gases. However the methods of mitigation vary strongly between different sectors of New Zealand and the ability to reduce emissions may be limited in some cases. At the global level, mitigation of carbon emissions is still the main topic of debate, such as implementing the Kyoto Protocol and any future successor aimed at reducing carbon emissions.

Adaptation, on the other hand, relates to actions used to address the consequences of climate change. It is generally accepted that a certain amount of warming is going to happen as a consequence of past emissions, and that this warming will result in further climate change issues for societies to deal with. Therefore, action is still required to reduce the impacts of these new problems, and that governments and agencies will need to promote and encourage adaptive actions. For local government, this often means that adaptation needs to be incorporated into planning, infrastructure and community development. In some respects, this fits into existing planning activities but with more emphasis on planning for issues likely to be enhanced by climate change impacts. Some carbon reducing activities, such as the planting of trees or the conservation of energy, may have benefits for both mitigation and adaptation, dependant on the policy used. It is partially for this reason that climate change policies on both mitigation and adaptation have been likened to developing an insurance policy, with multiple activities undertaken to reduce risk. Figure 2 illustrates the broad theory behind why adaptation is important in the context of planning, especially around coastal settlements.

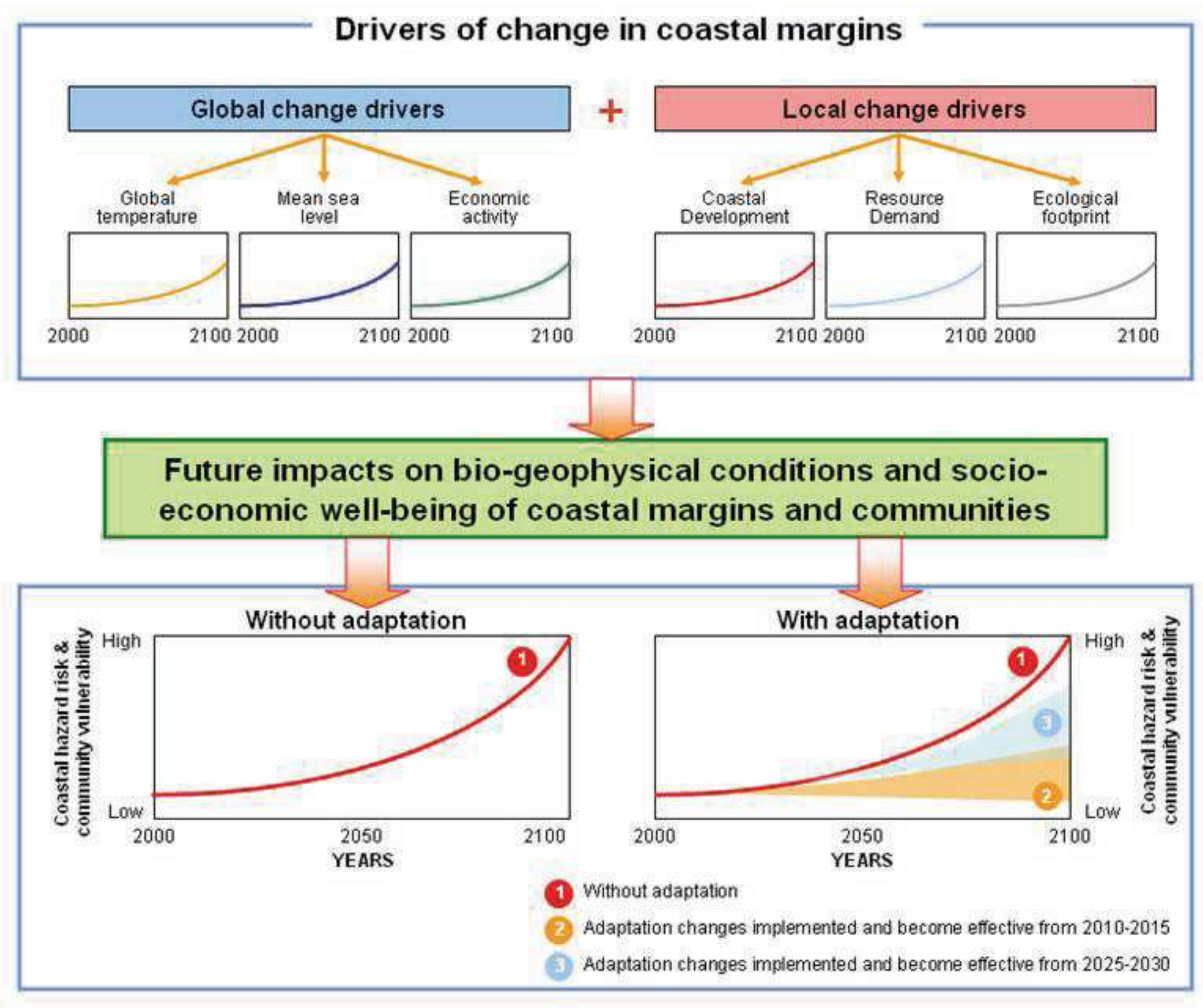


Figure 2: Conceptual Representation of the Drivers of Change in Coastal Margins and the Implications for Coastal Hazard Risk and Vulnerability of Coastal Communities: when no adaptation occurs, and when adaptation is implemented in the near term and mid term. Sourced from MFE (2008:42).

2 Climate Change Projections – International

2.1 Introduction

Climate change has only come to the fore of global politics in the last 20 years, with the Inter-government Panel of Climate Change (IPCC)[2] being established in 1988 as a high-level international advisory body. The IPCC collates a mass of research on emission sources, large-scale modelling, probable impacts, and suggestions for necessary actions to mitigate future impacts. Most large international agencies, whether the Organisation for Economic Co-operation and Development, other agencies within the United Nations, or the World Bank, have also devoted substantial resources to understanding the implications of climate change across the

[2] The IPCC is an agency under the United Nations barrier, whose role is to coordinate the preparation of reports based of quality, peer-reviewed information by scientists worldwide. It does undertake primary research itself.

world, culminating in more accurate environmental projections, modelling, and environmental data.

Over the last 20 years, the IPCC has prepared four major reports, each based upon the most up-to-date peer reviewed science and modelling from their respective periods, and these looked at the physical science, social and economic risks, and appropriate responses. Modelling global impacts is a highly complex exercise, and many models are created and used to prepare and guide each IPCC report. Each model is used to project different temperature scenarios based on different assumptions about the path of emission and the way that the global biophysical systems will respond to changes in $C0_2$ levels. This information is then used, in turn, by various countries to better understand the impacts of climate change for their region. The IPCC's most recent report was published in 2007, and provides a foundation for assessing potential impacts in Australia and New Zealand. Chapter 11 of the Fourth Assessment IPCC Report is specifically concerned with Australia and New Zealand, whereas Chapter 16 is concerned with Small Island States and contains focused information about impacts across the Pacific.

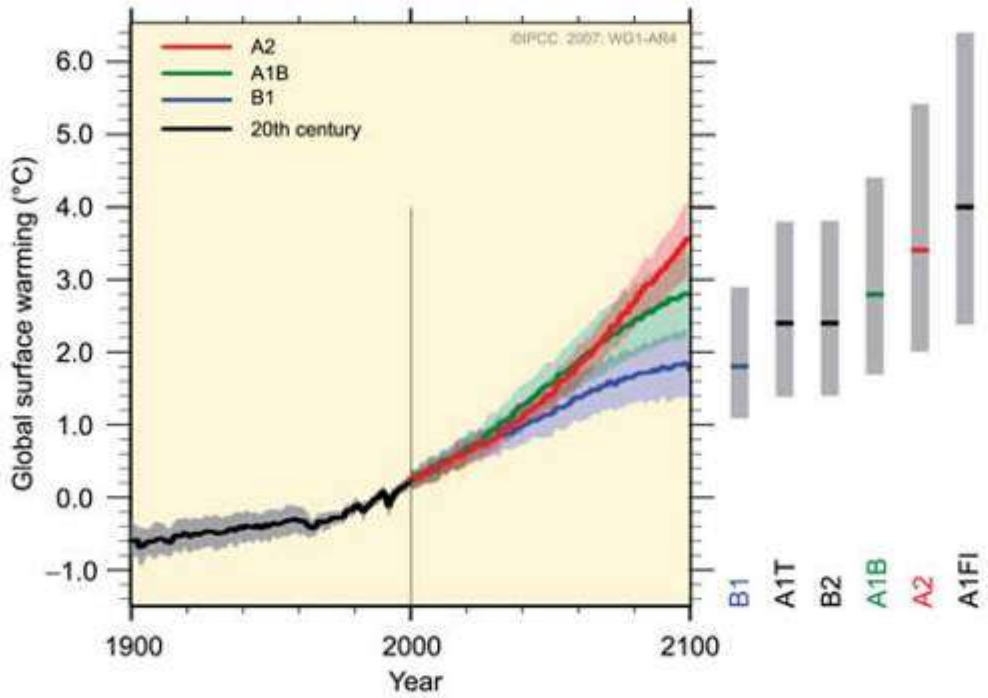


Figure 3: IPCC Multi-model Temperature Projections for Selected Scenarios. The grey bars show the range in global warming for the scenarios. Sourced from MFE 2008 (from IPCC 2007a).

Figure 3 illustrates the projected changes in global temperature, dependant on the different emissions paths (e.g. how much carbon is emitted, and when the peak emissions period occurs). Each emissions path is represented by the vertical lines on the right of the figure.

Figure 4 below illustrates the ways that temperature changes are distributed across the planet. Of note are higher levels of warming near the poles and smaller changes near equatorial areas.

In addition, the level of temperature changes near oceans tend to be smaller than away from maritime influences, as the oceans tend to moderate some of the heat impacts.

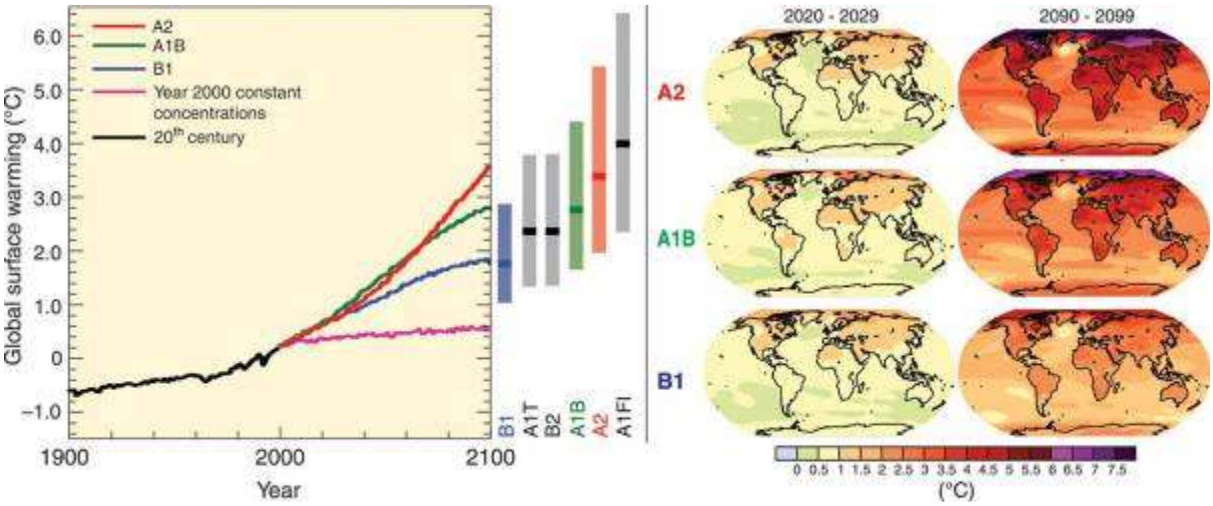


Figure 4: Projected Temperature Distribution across Globe According to Scenario. Sourced from IPCC 2007.

Changing temperatures can also potentially shift prevailing winds and air circulation. These potential large scale changes are then used to assess the impacts on broad precipitation patterns around the world. These broad maps are then downscaled to regions. Over the years, as modelling capacity and research findings have increased, downscaling this information to regions has improved, and finer level modelling is now applied. Figure 5 indicates the broad changes in precipitation around the world.

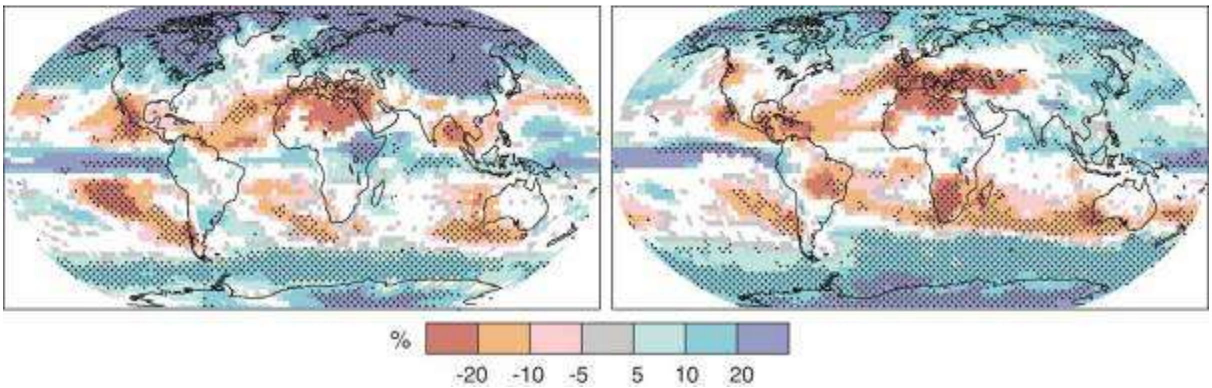


Figure 5: Projected Global Precipitation Changes for 2030 and 2080, sourced from IPCC 2007.

Recent evidence has suggested that the figures adopted by IPCC for its fourth report were conservative, and that the real rate of change is happening faster than these earlier projections. A recent report "Climate Change: Global Risks, Challenges & Decisions Synthesis Report" published in March 2009 (Richardson et al 2009), and other reports of a similar types, were used by the international community for the purposes of negotiation at Copenhagen and these reports imply that the rate of change is faster that those projected in 2007, as the rate of growth in emissions is at the upper level of projections used by the IPCC.

It is also generally recognised that future temperature changes will not necessarily rise in a relatively predictable linear fashion, but instead will consist of tipping points, in which one action causes further reactions across the board that either speed up or slow down the rate of temperature increase (Costello et al 2009). As modelling capacity and accuracy increases, it is hoped that global models will be able to better account for these global tipping points in models. This uncertainty sits behind the calls from the wider research community for an upper limit on the average global temperature change of 2°C. In this view, 2°C is the limit from which climate change becomes dangerous climate change, when the influence of large scale tipping points creates even higher levels of uncertainty than at present. Dangerous, in this sense, refers to a level of change which is difficult to manage, as various tipping points would create major feedbacks in the system. A 2°C maximum temperature increase translates into emissions tonnes targets of approximately 750 billion tonnes (Meinshausen et al 2009). Various major tipping points/events have been identified worldwide and are illustrated in Figure 6.

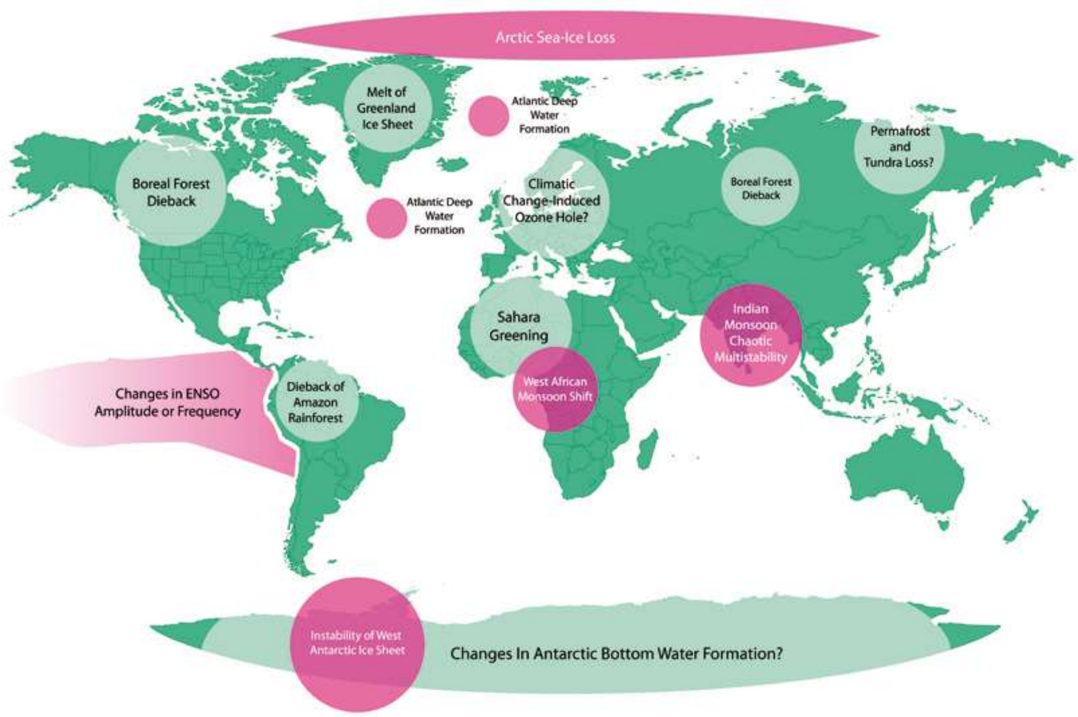


Figure 6: Major Global Climate Change 'Tipping Points'. Sourced from Richardson et al 2009.

These regional systems and processes are substantial drivers of current global climate, and it can be very difficult to predict their impact or downstream effects should their character change. Table 1 notes the potential tipping points for some major global events, as well as illustrating the high level of uncertainty in projections for these types of events, with many of the projected risks either having large ranges of risk, or large ranges of projected magnitude of changes. Table 1 also illustrates the connection between carbon concentrations and the possibility of certain events.

Extreme climate response or impact	**CO_2 peaking at 450 ppm**	**CO_2 peaking at 550 ppm**	**No mitigation**
Temperature outcomes	**1.5 (0.8–2.1) °C**	**2 (1.1–2.7) °C**	**5.1 (3–6.6) °C**
(a) Species at risk of extinction	**7 (3–13)%**	**12 (4–25)%**	**88 (33–98)%**
(b) Likelihood of initiating large-scale melt of the Greenland ice sheet	**10 (1–31)%**	**26 (3–59)%**	**100 (71–100)%**
(c) Area of reefs above critical limits for coral bleaching	**34 (0–68)%**	**65 (0–81)%**	**99 (85–100)%**
Estimated lower threshold exceeded by 2100			
(d) Threshold for initiating accelerated disintegration of the west Antarctic ice sheet	**No**	**No**	**Yes**
(e) Threshold for changes to the variability of the El Niño – Southern Oscillation	**No**	**No**	**Yes**
(f) Threshold where terrestrial sinks could become carbon sources	**Possibly**	**Possibly**	**Yes**

Table 1: Summary of Extreme Climate Responses, High-consequence Outcomes and Ranges for Tipping points for Three Emissions Cases by 2100. Sourced from Garnaut et al 2008 p102.

2.2 Observed and Projected Climate Changes – National

In New Zealand, mean air temperature increased by approximately 1.0°C between 1855 - 2004, with a rise of 0.4°C occurring since 1950 (MFE 2008). In the coasts around New Zealand, local sea surface temperature has risen by 0.7°C since 1871 (MFE 2008). Relative sea-level rise has averaged 1.6 +/-0.2 mm per year since 1900. Between 1971 and 2004 tropical cyclones in the south-western Pacific averaged 9 per annum, with no trend in frequency or magnitude recorded locally. Between 1951 and 1996, the number of cold nights and frost occasions declined by 10-20 nights per year as an average across the country. This recorded decline in frost nights also matches many anecdotal accounts of fewer frost days from Maori (Lyver et al 2009, King et al 2008, 2009). Figure 7 illustrates average national temperature variance from year to year, but also how most years tend to be warmer from 1970 onwards.

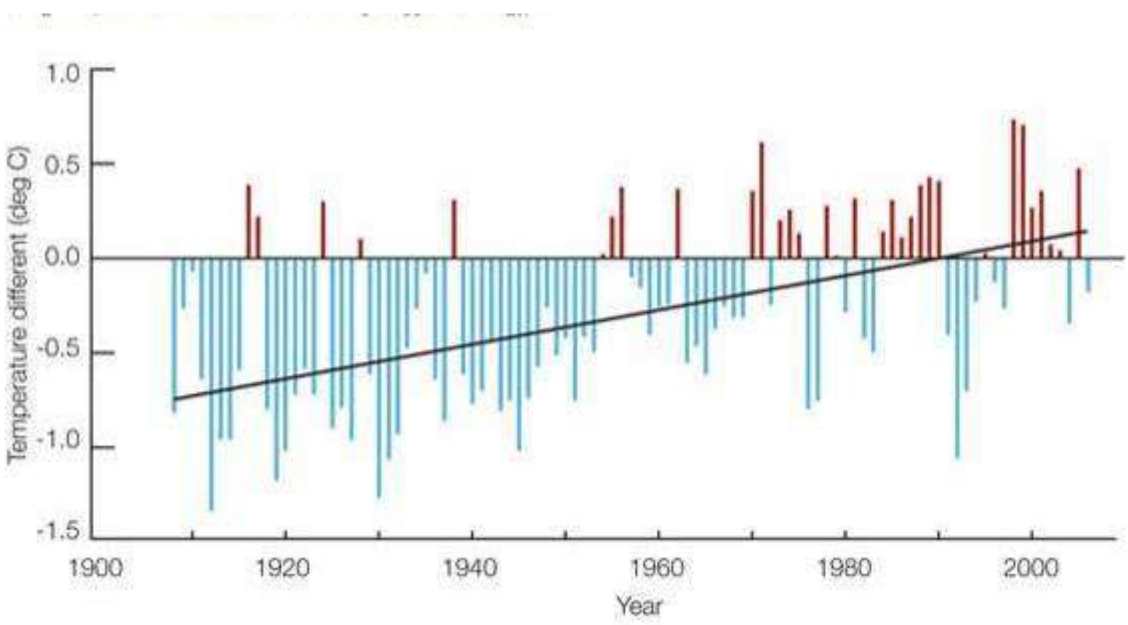


Figure 7: New Zealand average temperature illustrating year to year variability of the national-average temperature. Sourced from MFE 2008.

Overall, the scenarios for climatic changes in New Zealand portray an average range of warming between 0.1-1.4°C by 2030, and a range of 0.2-4.0°C by 2080s, dependant on the scenario used (e.g. emissions path), and it is through these climate projections that local government is expected to develop their planning. These ranges are somewhat smaller than other parts of the globe, due to the moderating effect of the large seas around New Zealand.

Figure 8 illustrates the broad patterns of projected temperature changes across New Zealand. In the first map, much of the North Island (with the exceptions of parts of the East Coast and Hawkes Bay) sees an average increase of 1°C, whilst the South island sees more varity in projected changes. In the second, there is very little variation in the North Island, with most places projected to increase by 2.2°C. The South Island see's much more variety in projected increases by region.

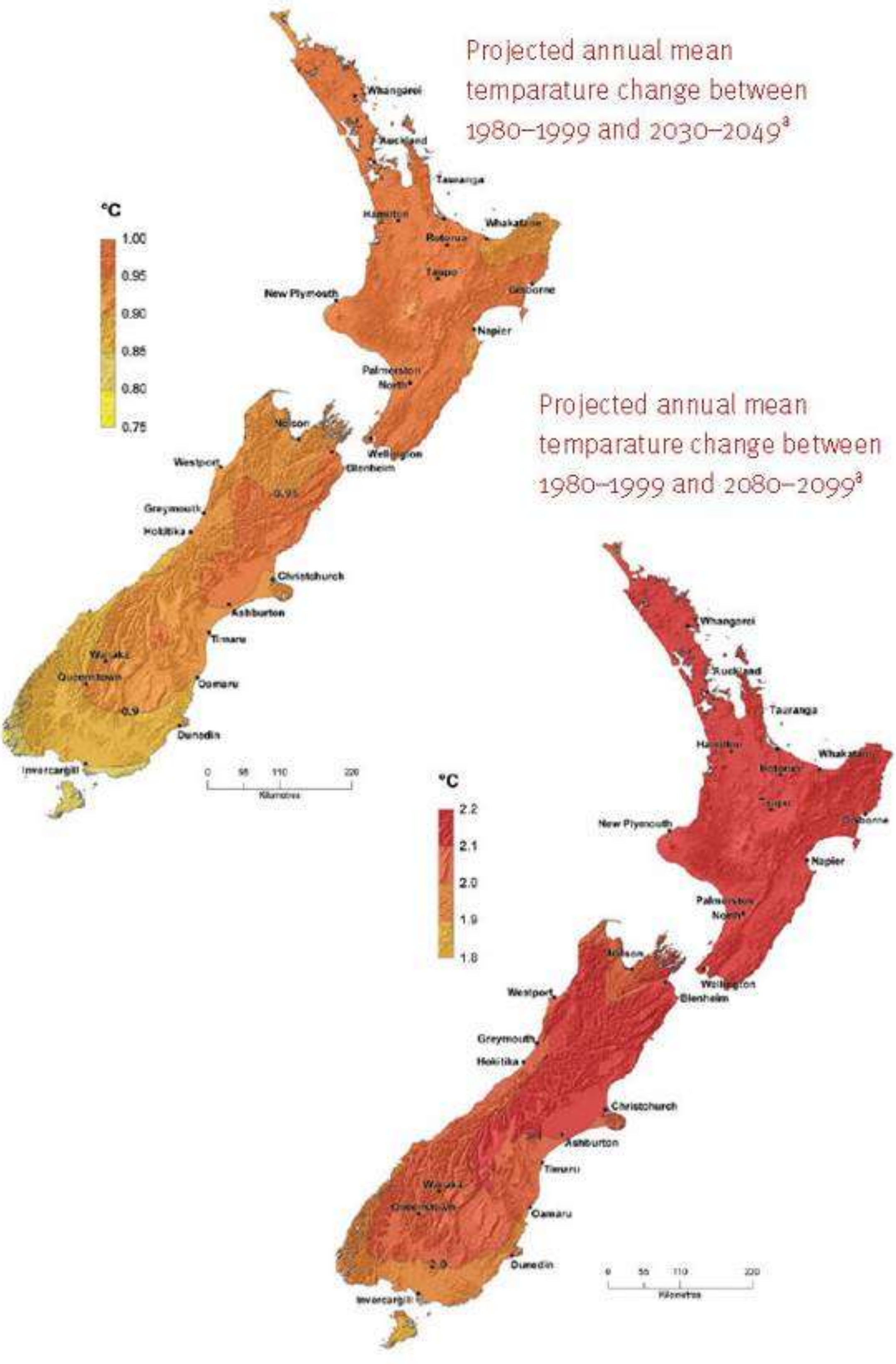


Figure 8: Projected mid-range changes in annual mean temperature (in °C) relative to 1990 across New Zealand. Sourced from MFE 2008.

Figure 9 illustrates the broad level projected changes in precipitation levels across the country, with some parts receiving considerably more precipitation whereas others, such as Northland, and much of the eastern coast of the North Island and the northern South Island receiving less. This broad scale changes also differ by season, and may be a limiting factor for some crops life cycle, depending on their individual needs. The more extreme changes are in winter and spring rainfall patterns, which may effect early parts of the growing season, whilst summer and autumn rainfall patterns are comparatively less affected (and may see a small increase in summer).

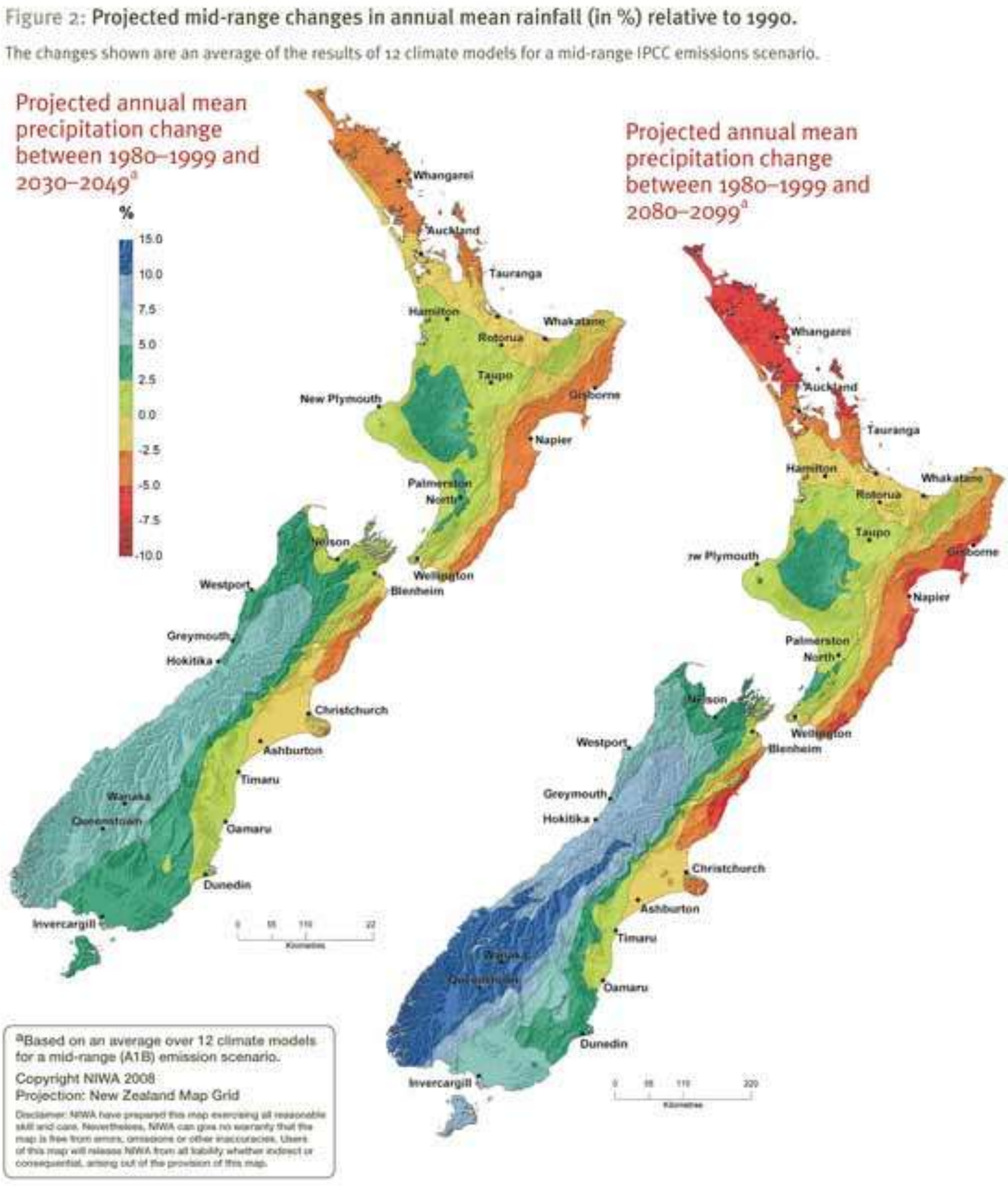


Figure 9: Projected Annual Mean Precipitation Changes Across New Zealand for Two Time Periods. Sourced from MFE 2008, p7.

As Figure 8 and 9 indicate, there is wide variety between regions over future projected precipitation and temperature impacts. Parts of New Zealand may well benefit from changes in climate in terms of optimum growing conditions or changes in water accessibility, especially in southern Otago and Southland (Ecoclimate 2008). However, other parts of New Zealand will see less optimum growing periods. For example, water resources are likely to be stressed in some areas of New Zealand, especially on the eastern coasts of both Islands, around Marlborough, Canterbury, Hawkes' Bay, Bay of Plenty, and Northland. Conversely, on the western coasts, more rainfall is expected (Ecoclimate 2008). However, there is also expected to be strong seasonality in the precipitation ranges, with winter seeing the biggest reductions in average precipitation in the north and east, and the highest increases in rains on the west and south. Once again, these projections are changes to the long average, rather than the year to year variations. In individual years, overall precipitation or temperature may be slightly higher or slightly lower than the long run average.

It is noted that average rainfall has already recorded a decrease in the north-east, mainly due to change linked to the climate system called the Inter-decadal Pacific Oscillation, but this trend is expected to continue due to climatic changes (MFE 2008). Regional reductions in rainfall in eastern New Zealand are highly likely to make agricultural activities more vulnerable to shocks. This projected reduction in precipitation happens at a time when there has been increased water demand in New Zealand, mainly due to agricultural intensification; with the total irrigated area increasing by 55% per decade, which in turn puts further pressure on national water resources (Ecoclimate 2008, Aqualinc 2006).

There is expected to be an increase in average wind-flow speeds, especially as the westerly component of New Zealand wind-flows increases. The MFE (2008) planning document suggests that changes in the westerly wind component of 10% by 2040 and 20% by 2090 in the spring and winter seasons. This increased westerly component leads to increased precipitation over many western and southern parts of New Zealand but less precipitation in the eastern North Island, the north-east of the South Island, and in Northland. In these areas, the winds are expected to have a drying effect. Overall, the drying of pastures in spring is expected to be advanced by one month and potential moisture evaporation is likely to increase in New Zealand, with severe droughts (equivalent of present 1 in 20 year events) are likely to occur more regularly. By the 2030s, these severe droughts increase in frequency between a range of 7 – 15 years by 2030 or, even more significantly, a range of 5 - 10 years by 2080s in regions such as Northland[3].

[3] The range is dependant on the model used, with the larger increases in return period based on the Med-High scenarios. More recent research indicates that the worldwide emission profile is closed to the Med-High than the low-med scenarios. In this case, the equivalent of a 1 in 20 year drought event would be a 1 in 7 year event.

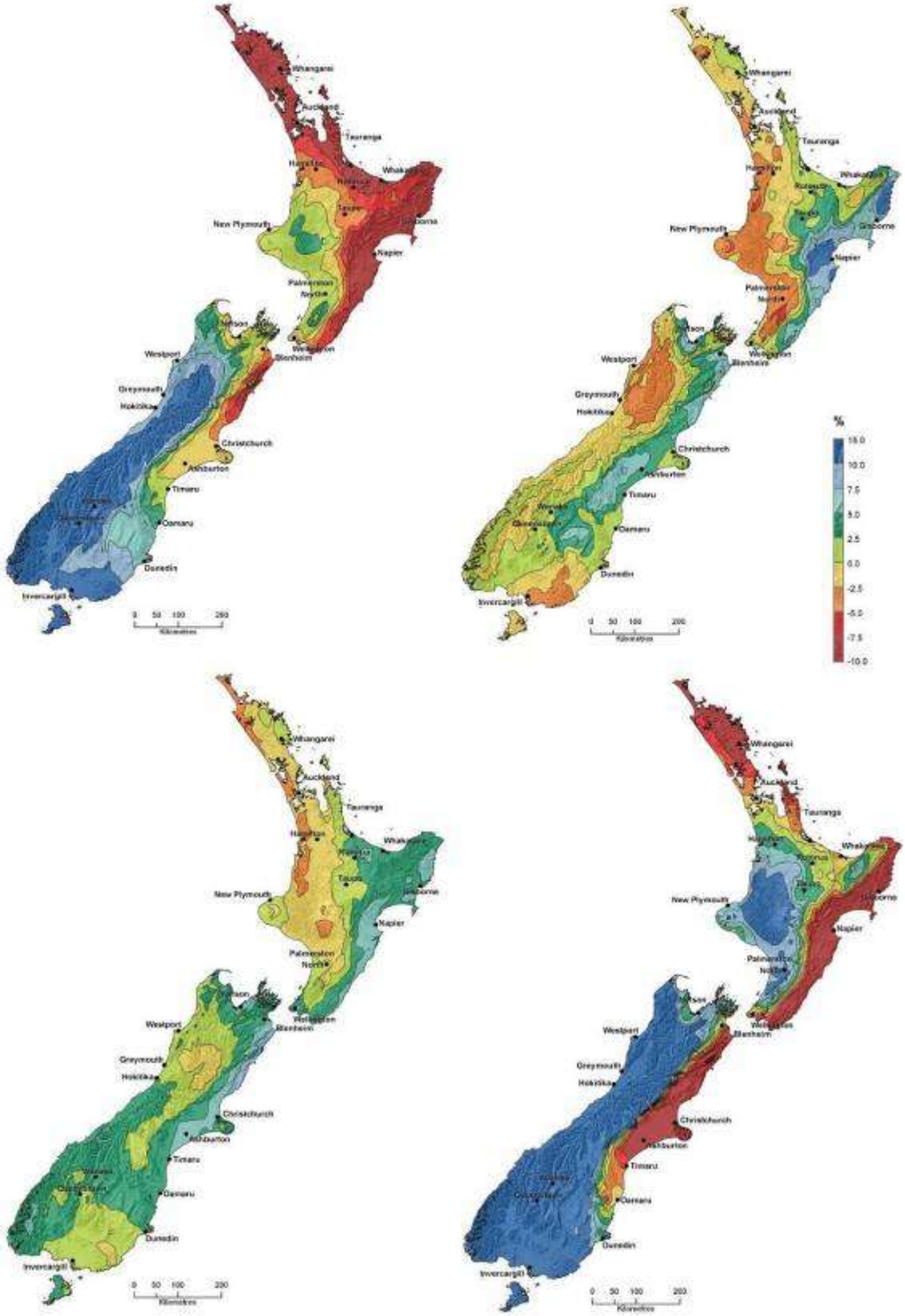


Figure 10: Map Illustrating Projected Precipitation Changes by Season Across New Zealand. Sourced from MFE 2008

The strongest regional driver of climate variability in New Zealand is the El Nino-Southern Oscillation (ENSO), with further impacts from the Inter-decadal Pacific Oscillation mentioned above also having an influence on the magnitude of weather events. El Nino brings stronger and cooler south-westerly airflows; which in turn brings warmer and drier conditions to the north-east area of New Zealand, with the converse occurring during La Niña event (wetter conditions in the north and east of New Zealand). There is also discussion in the climate change literature as to possible change in the frequency and magnitude of El Niño events globally. Overall, there is some expectation that both may increase, with more intense El Niño being the most expected change. In New Zealand and Australia, El Niño tends to bring drier conditions, whereas in other parts of the globe, El Niño brings wetter weather to South America, which is generally regarded as a water rich continent. Changes in the ENSO cycle hold some significance for New Zealand's agriculture industry, and that of our competitors in Australia, and South America. However, projecting changes in ENSO from climate change has a high level of uncertainty associated with it (MFE 2008) and cannot easily be incorporated into planning .

In terms of extreme weather, coastal settlements on both coasts of New Zealand will face increasing vulnerability to tropical cyclones, storm surges and sea-level rise (MFE 2008). In addition to these broad level climate changes, an increased frequency of high-intensity rainfall events or other extreme weather events is expected. Spread of some disease vectors is very likely across the whole country, but areas such as Northland will have climatic conditions favourable to more subtropical and some tropical species[4]. However, with the exception of some eastern areas, New Zealand is noted to have comparatively more resilience than Australia (Hennessy 2007).

[4] It is also noted that prevailing westerly winds have been the source of exotic species in the past, and further increases in prevailing westerlies will increase these opportunities for exotic invertebrate species.

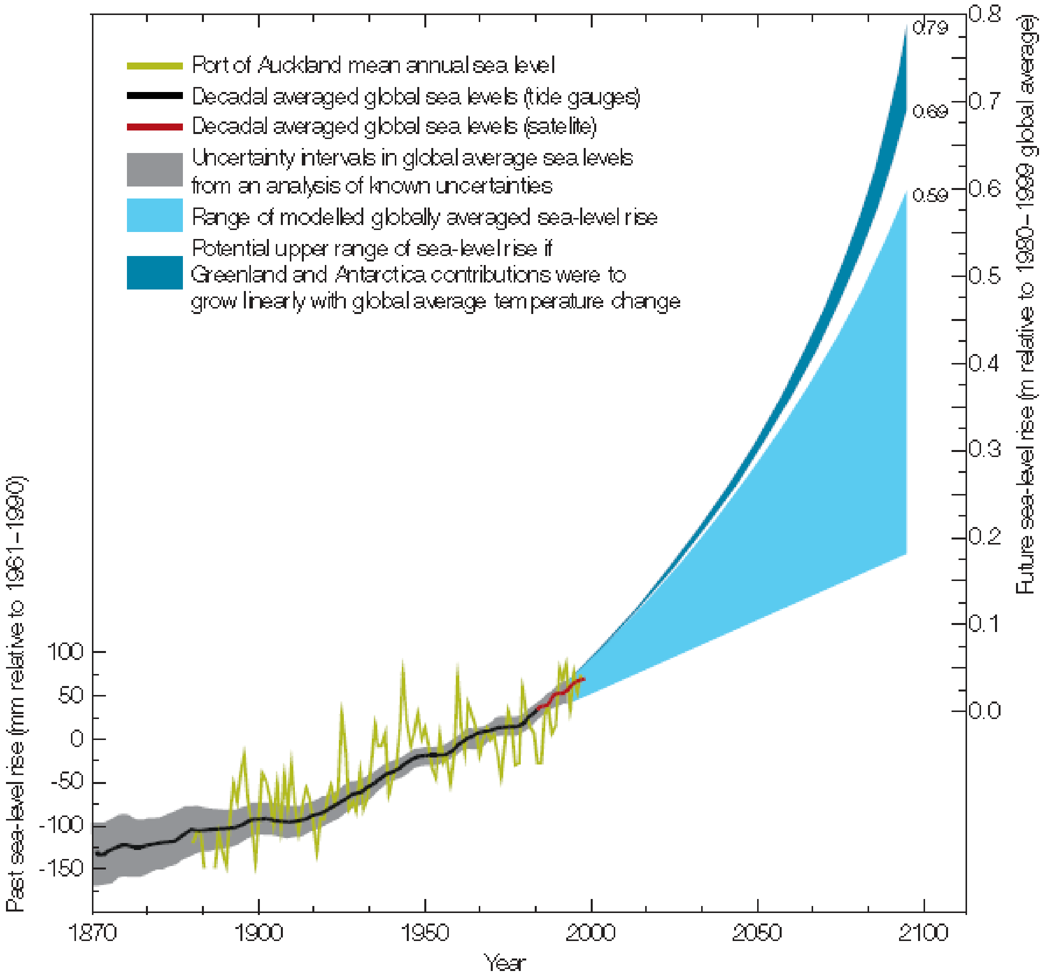


Figure 11: Projected Sea-level Change Model Range for New Zealand. Sourced from MFE 2008.

Figure 11 illustrates projected sea-level rise. These were based on emissions records and predicted projections in 2007. Change of this magnitude is likely to have significant impacts locally, especially as this is the average, with the extremes potentially being higher. The models include predictions on sea-level rise, with estimates of 18-59 cm rise being the current predicted rangeout to 2100 as per the , although there are additional ranges being floated. Since the publication of the 2007 IPCC report, recent research has indicated that rates of emissions were underestimated, and have been rising faster than projected (Richardson et al 2009). This more recent research indicates higher rates of sea level and global temperature rises than those in government documents. The rapidly changing projections hold some concern especially given the Government's intention of producing a National Environmental Standard on Sea-level Rise for planning purposes[5].

[5] (http://www.mfe.govt.nz/laws/standards/future-sea-level-rise/index.html).

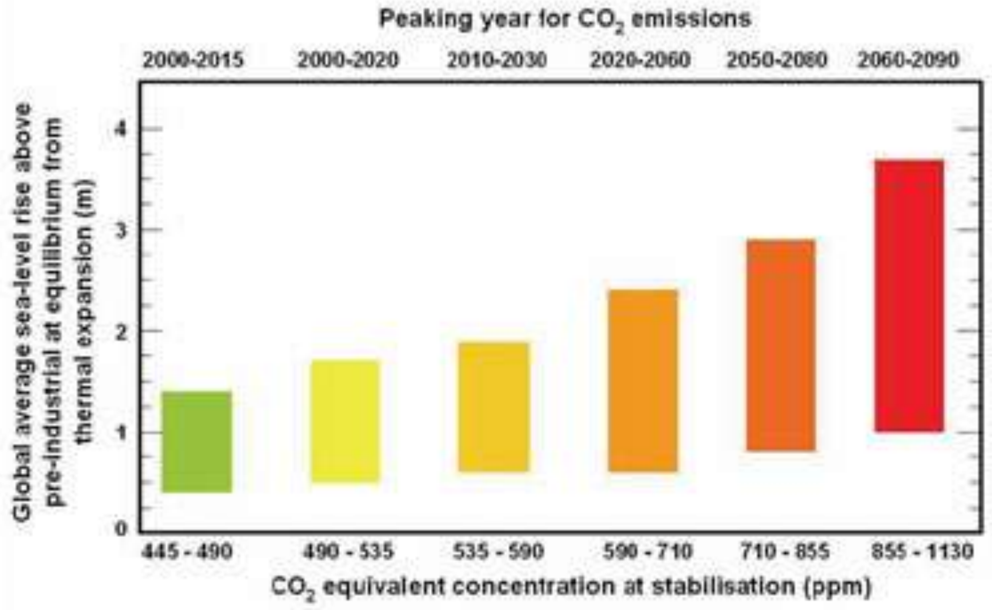


Figure 12: Commitment to Sea-level Rise Beyond 2100. Showing long-term equilibrium global average sea-level rise above pre- industrial levels for a range of different carbon dioxide stabilisation concentrations and assumed time periods for peaking carbon dioxide equivalent emissions. Sourced from MFE 2008.

2.3 Climate Change Projections for Northland

The projections suggest that Northland is likely to have sub-optimal conditions for the production of many of its 'traditional' primary products, with subsequent loss of productivity in some years. Adaptation measures may provide viable alternatives to present methods or inputs, with changes in farming technique, investigations into alternative feed crops, and a re-evaluation of some land uses all being expected to occur over time.

Region	Decade	Summer	Autumn	Winter	Spring	Annual
Northland	2040	1.1 [0.3, 2.7]	1.0 [0.2, 2.9]	0.9 [0.1, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.6]
	2090	2.3 [0.8, 6.6]	2.1 [0.6, 6.0]	2.0 [0.5, 5.5]	1.9 [0.4, 5.5]	2.1 [0.6, 5.9]
Auckland	2040	1.1 [0.3, 2.6]	1.0 [0.2, 2.8]	0.9 [0.2, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.5]
	2090	2.3 [0.8, 6.5]	2.1 [0.6, 5.9]	2.0 [0.5, 5.5]	1.9 [0.4, 5.4]	2.1 [0.6, 5.8]

Table 2: Temperature Increases Projected for Northland. Sourced from MFE 2008

The projected changes for Northland in terms of temperature range between 1.1 C and 6.4 C by 2100, with the best estimates being between 1.8 C and 4.0 C, and are illustrated in Figure 13.

	 **Mean Temperature Changes 2030-2049 (use key on left)**		 **Mean Temperature Changes 2080-2099 (use key on left)**

Figure 13: Expanded Focus Temperature Changes for Whangarei District. Adapted from MFE (2008)

These Figures are simply magnified versions of Figure 12, and are here for the purpose of focussing more directly on the changes within Whangarei District. Once again, it is important to note that these are average numbers and can translate into more extreme weather conditions (e.g. heat waves, cold snaps). Figure 14 illustrate to increase is the numbers of days in which the maximum temperature exceeds 25° C should the mean temperature change by 2°C. At present Whangarei has approximately 3 weeks of hot days, but with 2°C change, this would increase to almost 10 weeks.

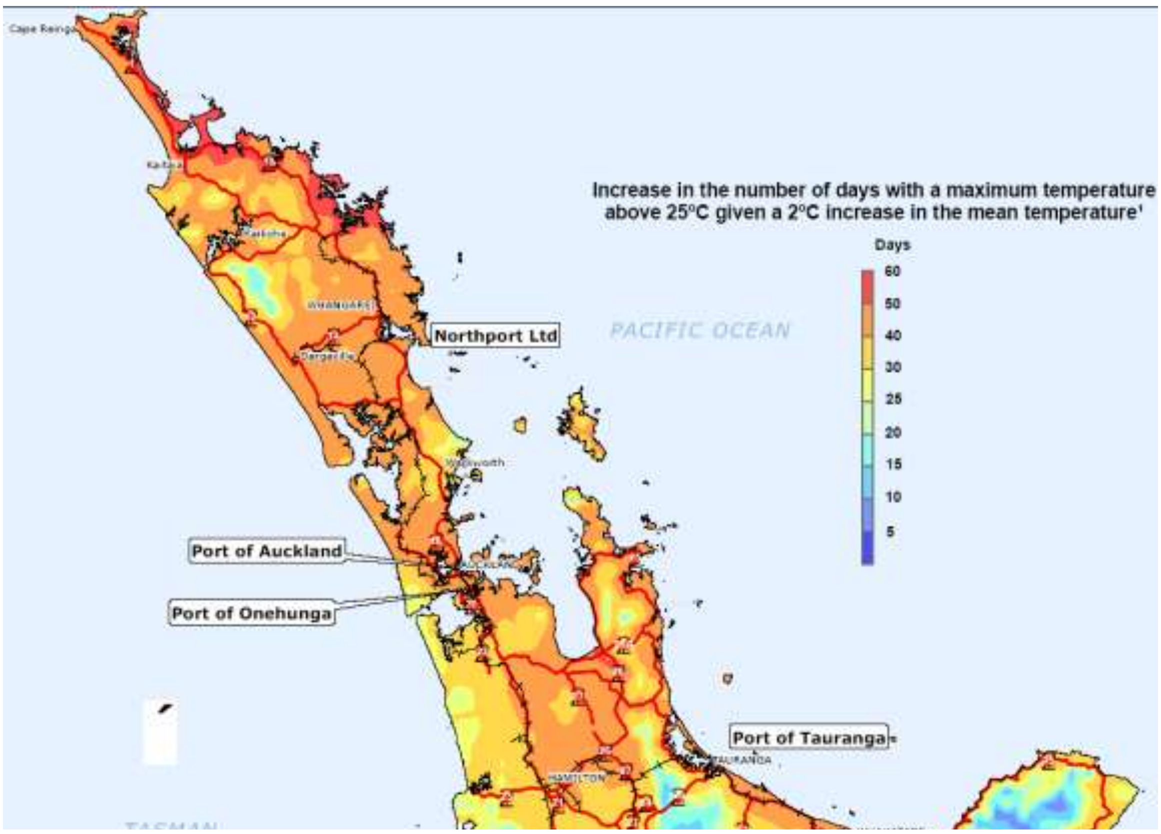


Figure 14: Changes in the Numbers of Days over 25°C per Annum by 2100. Sourced and Adapted from Gardiner et al 2008.

Whilst future changes in temperature are roughly comparable across the whole district and much of the region, the precipitation projections have more variability across the district, according to the season, with an overall decline in precipitation. In terms of seasonal changes, major decreases are likely in winter and spring precipitation, and very small changes (and possible increases) in summer and autumn precipitation occur around the eastern hills north of Whangarei Harbour, but an overall decline south and west of Whangarei City.

Region	Location	Decade	Summer	Autumn	Winter	Spring	Annual
Northland	Kaitaia	2040	1 [−15, 20]	−0 [−14, 16]	−5 [−23, 1]	−6 [−18, 4]	−3 [−13, 5]
		2090	−1 [−26, 21]	−3 [−22, 11]	−8 [−32, 2]	−11 [−33, 8]	−6 [−22, 5]
	Whangarei	2040	1 [−14, 23]	1 [−15, 33]	−9 [−38, −1]	−9 [−25, 3]	−4 [−16, 7]
		2090	0 [−20, 19]	1 [−27, 26]	−12 [−45, −0]	−16 [−45, 1]	−7 [−28, 2]
Auckland	Warkworth	2040	1 [−16, 20]	1 [−13, 22]	−4 [−22, 2]	−6 [−18, 6]	−3 [−13, 5]
		2090	−2 [−31, 20]	−1 [−20, 12]	−4 [−24, 5]	−12 [−33, 6]	−5 [−19, 6]
	Mangere	2040	1 [−17, 20]	1 [−14, 17]	−1 [−10, 5]	−5 [−15, 10]	−1 [−10, 6]
		2090	−1 [−33, 20]	−2 [−21, 12]	−1 [−12, 9]	−9 [−30, 11]	−3 [−13, 9]

Table 3: Projected difference in Precipitation per Season for Northland Locations Source: MFE 2008. Note: all data relative to 1990 levels.

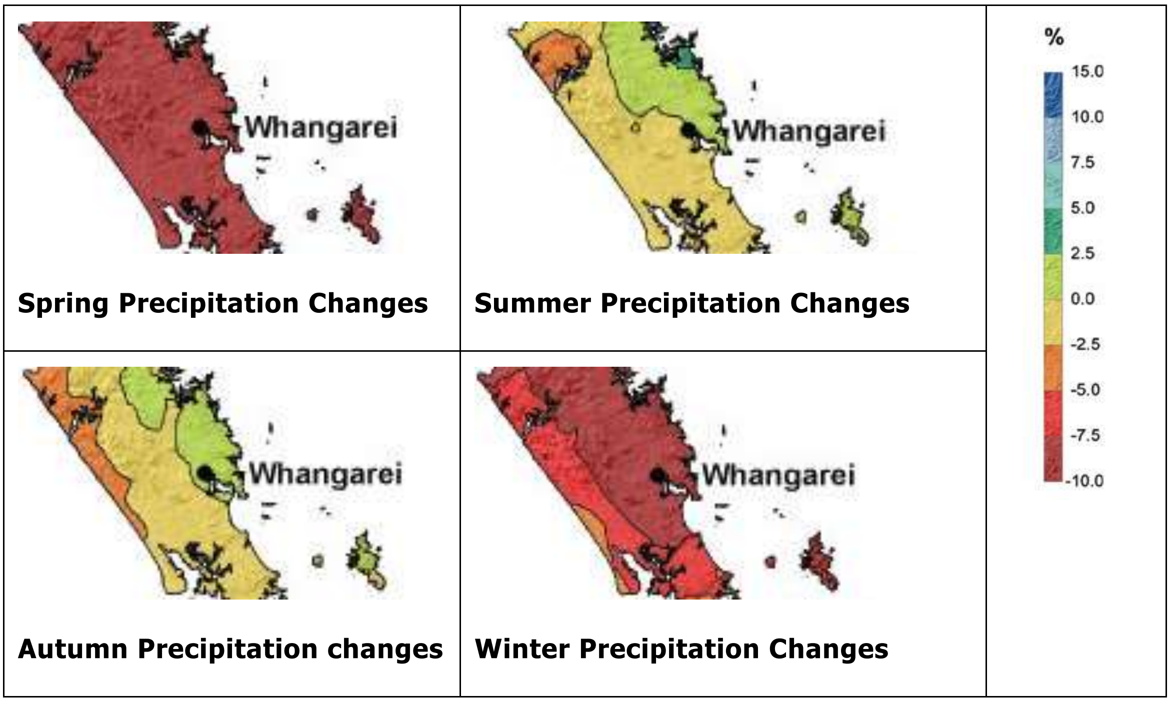
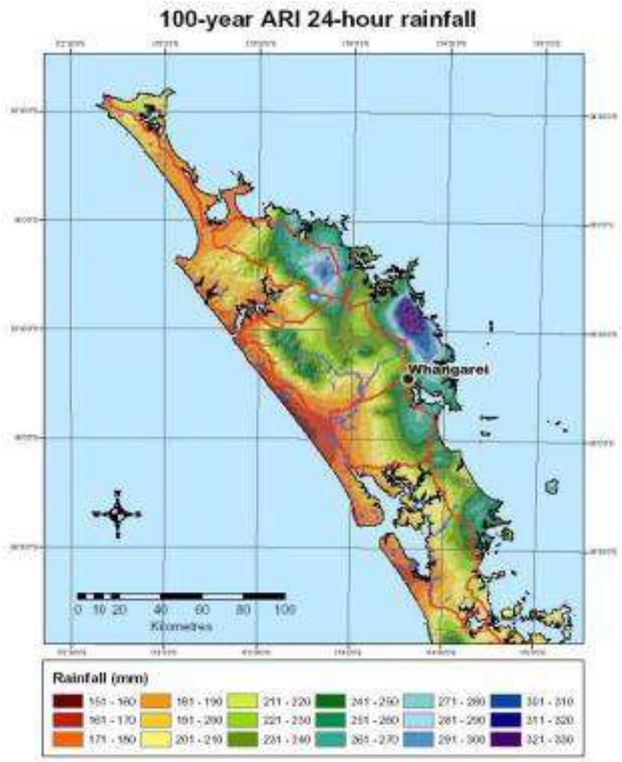
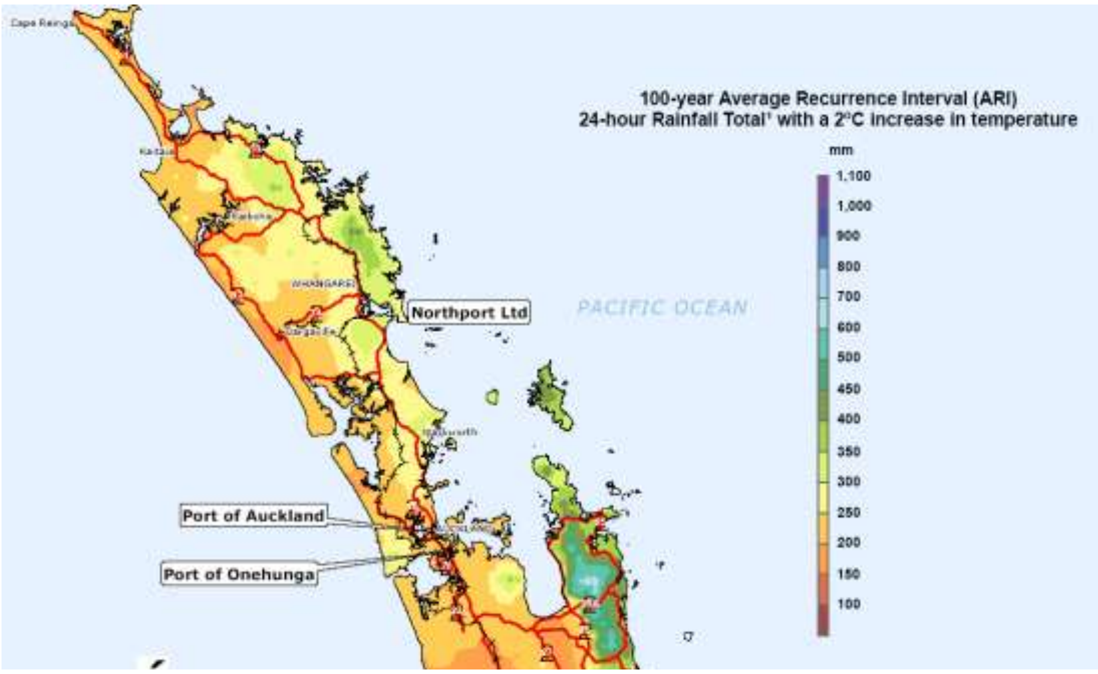


Figure 14: Expanded Focus on Precipitation Around Whangarei District. Adapted figure sourced from MFE 2008.

In addition, there is expected to be an increased likelihood of extreme precipitation events, illustrated in Figure 16.



Present Projected Extreme Rainfall 100 year Annual Return Interval for Northland. Sourced from Gray (2009)



Future Projected Extreme Rainfall 100 year Annual Return Interval for Northland. Sourced and adapted from Gardiner et al 2008.

Figure 15: Projected Extreme Precipitation Frequency Changes Due to Climate Change Impacts. Sourced from Gray (2003) and Gardiner et al (2008).

Note that the two figures are sourced from different reports, Gray (2003) and Gardiner et al (2008). As such, they use slightly different colouration and scales for different intensities of rainfall over a 24 hour period. Despite these colour/scale differences, they illustrate a projected increase in the peak rainfall intensities, with Whangarei City (depending on where in the city) presently ranging between 230-270 mm per 24 hour period, but increasing to a range of between 250 and 350 mm in a 24 hour period, should a 2°C average warming occur. Both maps also show that the eastern hills, especially around Puhipuhi, will see peaks of 330 mm increasing to peaks of up to 450mm per 24 hours, which would have major impacts downstream in the Hikurangi Basin and subsequent flows into the Wairoa/Wairua catchment. It is also interesting to note that projected changes in parts of Whangarei City extreme precipitation risk will rise to more than the present risk levels in Puhiphui, which is the wettest part of Northland.

Whangarei District has approximately 270 kilometres of coast-line, including enclosed waters like harbours and estuaries, and exposed rocky and sandy sections. At present, the Whangarei District Plan indicates coastal hazard lines to guide development along the coast. These coastal hazard lines do include assumptions about climate change impacts. Whangarei District Council is presently checking the validity of these lines around Bream Bay. Several other coastal settlements within the district are low-lying, and small increases in mean sea level could cause inundation in some locations. However, compared with other locations in New Zealand, risks of inundation are not as high (MFE 2008). Despite this, several coastal settlements in the district are low-lying, and small increases in mean sea level could cause inundation.

Whangarei is considered subtropical, but by most measures of 'subtropical" it would probably be at the lower end of the 'subtropical scale' (for an Australian example, Brisbane is considered subtropical). Whilst the climate data out to 2040 indicates a continuation of subtropical conditions for Northland, the modelled projections for 2090 would put Northland into the higher end of subtropical. Researchers often speak about a 'climate envelope' when understanding the range of tolerances for many species, and their viability[6]. These underlying changes in climate parameters may make some forms of subtropical crops more viable, and some present temperate crops less viable across the district. It is difficult to imagine what this will mean for local crops, apart from a crude approximation. Using present temperature averages, seasonal precipitation, and other parameters, Northland's present climate would be similar to areas about 200 kilometres south of Sydney. But future climate changes may change to be more like the climate of communities to 300 km north of Sydney. Such a shift in climate will have an impact on the viability of present crops and pest species type.

[6] However, a species actual presence is also determined by local environmental factors such as soil as well as climate.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY AIR TEMPERATURE (°C)													
Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	19.9	20	19	16.5	14	12.2	11.2	11.7	12.9	14.3	16.4	18.2	15.5
2040	21	21.1	20	17.5	15	13.1	12.1	12.6	13.7	15.1	17.2	19.3	16.4
2090	22.2	22.3	21.1	18.6	16.1	14.2	13.2	13.7	14.8	16.2	18.3	20.5	17.6
MEAN DAILY MAXIMUM AIR TEMPERATURE (°C)													
Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	24.4	24.2	23	20.4	18	16	15.1	15.6	16.8	18.3	20.6	22.6	19.6
2040	25.5	25.3	24	21.4	19	16.9	16	16.5	17.6	19.1	21.4	23.7	20.5
2090	26.7	26.5	26.1	23.5	20.1	18.9	17.1	18.5	19.5	20.2	22.5	24.9	21.7
MEAN DAILY MINIMUM AIR TEMPERATURE (°C)													
Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	15.4	15.7	15	12.6	10.1	8.3	7.2	7.8	9	10.4	12.2	13.7	11.4
2040	16.5	16.8	16	13.6	11.1	9.2	8.1	8.6	9.8	11.2	13	14.6	12.3
2090	18.8	19.1	17.1	14.7	12.2	10.3	9.2	9.8	10.9	12.3	14.1	16	13.5
MEAN NUMBER OF DAYS OF GROUND FROST													
Data are mean monthly values of the number of days with ground frosts for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	0	0	0	0	1	3	4	2	1	0	0	0	11
By 2080 -no frost days													
MEAN RELATIVE HUMIDITY (%)													
Data are mean monthly values of 9am relative humidity for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	80.7	83.6	83.8	86.4	87.4	89	88	84.6	80.2	81.2	77.9	78.5	83.1
MEAN DAILY GLOBAL RADIATION (megajoules/square metre)													
Data are mean monthly values of mean daily global radiation for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	20.8	18.4	15.5	11.3	8.4	7.1	7.4	10.3	13.7	16.9	18.8	20.4	13.8
MEAN MONTHLY RAINFALL (mm)													
Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	90	112	142	129	120	179	151	146	130	116	80	92	1490
2040	90.9	113.1	143.4	130.3		162.9	137.4	132.9	118.3	105.6	72.8	92.9	1430.4
2090	90	112	143.4	103.3	121.2	150.4	126.8	122.6	109.2	97.4	61.2	92	1385.7
MEAN MONTHLY WET-DAYS - with at least 1.0 mm of rain													
Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data													
WHANGAREI	7	8	10	11	11	14	15	14	13	10	9	8	132

Table 4: Present Climate Parameters and Future Climatic Parameters (Sourced and Adapted from NIWA and MFE 2008)

Imagining what these differences in temperatures and precipitation might mean for Whangarei is pretty difficult, especially as Whangarei is already within the warmest region of the country. To help this process of imagination, we searched for a maritime location in Australia with a present annual mean temperature and annual precipitation rates similar to the projected climate of Whangarei in 2090 e.g. around 17.6°C annual mean temperature and about 1380 mm per annum precipitation. We had hoped to find a reasonably large, well-known settlement but few places actually fitted the bill, partially because of the stronger seasonality in New Zealand. In the end, the closest we could find was a small fishing village on the New South Wales Coast. Welcome to Harrington NSW.

Harrington, NSW, is about 330 km north of Sydney, and is a part of Greater Taree Council, with a population of 45000. In terms of latitude, Harrington and Greater Taree would be roughly 440 km north of Whangarei. This is equivalent to places such as Lord Howe Island; the very southernmost islands of the Kermadec Islands; or roughly another 100 km north of Three Kings Islands. However, this is not as far north as Norfolk Island. Like Northland, agriculture and tourism are important local industries, and health service provision is an increasing part of the local community. It is an area facing an aging population, and is also seeing population growth through increased retirees. It is seen as a lifestyle destination where the quality of the natural environment is seen as a major asset. It was known as a "two dollar town" for its low historical wages and has difficulties in attracting high quality staff. Similar to Whangarei, the dairy industry has been the key contributor to the local economy for some time, but there are many concerns over the fragmentation of good quality agricultural land. The local approach to economic development has some similarities to Northland, as the following excerpt from their local council would suggest.

"Value adding of dairy products such as yoghurt and cheeses.

Beef cattle - can be successfully combined with plantation forestry.

Native flower growing - Waratahs, Christmas Bush, Christmas Bells, Proteas[7].

Horticulture - eucalypt plantation seedlings, specialist nursery lines.

Dairy goat production - for raw milk, cheese and yoghurt making.

Winemaking - there are many irrigated farms available with good soil.

Plantation forestry - grow the forests of the future on your own land.

Organic fruit, vegetable and herb production - several certified properties in production.

Free range egg production - a rapidly growing "no-cruelty" industry."

In terms of crops, many of the main local crops are very similar to those found in Northland. The major ones include macadamia, vegetables, blueberries, stone fruit, avocado, passionfruit, pecan nut, and olives. To the north of the area banana and mangoes are grown, but they struggle when competing against tropical fruits sourced from Queensland. As well as these crops, other crops grow very successfully on the North Coast including limes, mandarins, wine grapes, lychees, guava, raspberries, strawberries, clumping bamboo and tea.

In the map bellow, the yellow section indicates Greater Taree Council and Harrington, whilst the grey area is Greater Sydney.

Figure 16: Sourced from Wikipedia, NSW Council Boundaries.

[7] Of interest is that many flowers used in the Sydney Olympics in 2000 were sourced from this area.

3 Climate Change – Sectoral Analysis

The previous sections outlined overall projections for climatic changes internationally, nationally and locally. This chapter, and the following sections, are concerned with the implications that such climatic change will have on key sectors across Whangarei. These sectors include primary production, infrastructure, local government, biodiversity, health and vulnerability.

Given the global significance of climate change, in this chapter up to three different contexts will be examined, as appropriate, these being international, national, and local[8]. This is important as the linkages between the global and local can be very relevant for an area like Whangarei District, which is historically dependant on primary production although in recent year some diversification has occurred (Infometrics, 2009). Having an idea about the wider context is important as these changes will impact on local trends and policy decisions over the next 50 years. For example, at the global level there are many expectations that internationally important agricultural areas will be under pressure from changes in temperature and water cycles. These changes may create shifts in the various countries capacity to supply products or services. However, other shifts in demand for some products may also occur as wider societies avoid some resource intensive goods in preference to less resource intensive goods.

3.1 Primary Production

International Context

The most recent report from the IPCC makes it clear that primary production (agriculture, forestry, fisheries and so on) is likely to be heavily impacted by changes in climate (Hennessy et al 2007, Easterling et al 2007). Two types of impacts on primary production are expected from climatic changes; these being long run changes in overall climatic conditions for production growth, and short-medium term impacts of extreme weather conditions. Chapter 5 of the most recent report (Easterling et al 2007) outlines both the evidence and the implications of changes for water cycles and weather extremes critical to many agricultural and forestry operations. It should be noted that for most species of agricultural or horticultural importance, little is known about the effects of climate change on all crops, with most research focussing on key international or national crops, and some commercially important stimulant crops such as coffee. This research is then used to gauge overall impacts on primary production.

Presently up to 40% of terrestrial land surface is managed for cropland and pasture (Foley et al 2005). Natural forests constitute a further 30% of terrestrial land surface, leaving approximately 30% that consists of mountains, deserts, and urban areas (Hennessy et al 2007).

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[8] Local for the purpose of this section refers to both wider Northland impacts as well as Whangarei District impacts.

Demand for agricultural products is still growing, but the rate of demand growth is decreasing (IPCC, 2007). Conversely, growth in world food production declined from 2.2% per annum to 1.6% per annum. Bearing in mind both these demand and production factors, it is estimated that, globally, production of food requires a 55% increase in crop production by 2030 and approximately 80% by 2050 to meet projected demands for food globally (IPCC 2007). This translates into another 185 million ha of rain-fed crop land (19% increase on present amounts) and 60 million ha of irrigated land (30% increase on present amounts) being utilised[9]. In terms of wider changes to crops, decreases in precipitation are predicted by 90% of modelled climate simulations, leading to concerns over food production in certain areas, especially in places such as Asia and Africa (Richardson et al 2009). For wood products, plantation forests may be supplying 44% of wood consumption by 2020, and 75% of wood consumption by 2050. Global fish production and demand are expected to both increase, but the range of preferred catch species is expected to shift, especially as some of the presently popular fish stocks are already under pressure (Easterling et al 2007).

The land presently managed for cropland and pasture is generally the most attractive locations within which to undertake agriculture, due to more favourable aspects of soil fertility, access, water, topography, and other factors (Easterling et al 2007). Many international production areas are already exposed to multiple stressors such as water resource decline (quantity or quality or both), biodiversity reduction, soil erosion, urbanisation and other stressors, which, in turn, increases their sensitivity to climate change shocks (Easterling et al 2007).

In many places, the use of irrigation and fertilizers can reduce the impacts of local limiting factors relating to water and nutrients, but climate change impacts on irrigation water and other infrastructure needs will lead to calls for increased storage capacity and increased efficiency of water transmission. However, there are also concerns over the high fertilizer requirements of the most popular commercial crops, the dependence on oil for fertilizer production, and a growing concern over the resource availability of raw materials such as phosphates that are used in agriculture (Cordell et al 2009).

Any future expansion of agriculture away from present popular areas will tend to be onto more marginal land (whether fertility or access costs) that absorb more resources for initial set-up and ongoing maintenance, and will generally give smaller returns per ha than more favourable sites. There may also be shifts to food types or production techniques that require minimum resource inputs, whether water, fertilizer, land and so on. As much of future production growth may take place in more marginal lands and waters, this could result in a trade-off between ecosystem services[10] and food production.

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[9] Approximately 3.6 billion ha globally is regarded as being too dry for rain-fed agriculture.

[10] More on ecosystem services is contained within the section on biodiversity.

High temperatures during flowering can reduce grain size, number, and quality for some cereal crops. Yield is often damaged through climate extremes, with winds, storms, hail, unseasonal frosts representing the main culprits, but heat waves can also have an impact on quality. In terms of growing conditions, elevated CO_2 levels will often have a positive impact on plant growth and yield. However, the magnitude of the change differs between different plant species, and will depend on other factors such as photosynthetic path, species, and growth stages, etc. Subsequently some species will respond better to CO_2 changes than others, with fast-growing trees or plants generally responding more strongly than slow growing trees to changes in CO_2. Given this differential impact on plant species, plant community structure will be modified by elevated CO_2, with rapid changes in species composition expected.

Every plant species has different tolerances to water limits, temperatures, light, pest invasion, and soil conditions, etc. Many of the more productive crops (in terms of yield) have been deliberately selected for traits such as improved fruiting or faster growth, but this is often at the expense of other traits such as pest resistance or water deficit tolerance. It is known that crops exhibit threshold responses to their climatic environment, which in turn affects growth, development and yield (Porter and Semenov 2005). There have been recent reports of some farmers in developing countries returning to older seed varieties that continue to produce cereal yields in times of unstable, unsettled weather[11]. Many modern varieties of seed type are specifically designed to produce high yields relative to older seed varieties, but depend on stable weather patterns. Stability doesn't just mean benign weather conditions, but can also refer to consistent climate extremes such as too much or too little water (e.g. drought resistant varieties of seed) that are stable. Whilst older varieties of seed may not produce the same consistently high levels of yield, they can tolerate a wider variety of climates.

CO_2 temperature interactions are recognised as a key factor for future weed species issues, and pest animal outbreaks. Weed species are generally adapted to taking advantage of rapid changes in climate, new resource areas, and perturbations in the local environment. Recent United States and Canadian experiences with outbreaks and damage caused by Mountain Pine Beetle are illustrative of the potential for pest species to cause havoc (Easterling et al 2007). Increased climate extremes may also create optimum conditions for the promotion of plant disease and pest outbreaks, and individual plants stressed by weather extremes may be more susceptible to pest and disease outbreaks. In Australia, there are concerns over cattle tick range expansion, whilst in New Zealand, introduced cattle ticks occur mainly in northern New Zealand but are likely to spread south.

Cereal productions in parts of the world are facing significant challenges, with some large scale production areas facing water shortages and worsening growing conditions. This will put

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[11] http://www.globalnewsblog.com/wp/2009/10/08/environment-back-to-traditional-farming-to-beat-climate-change/

pressure on supply of some crops, and some impacts on social dynamics should crops fail regularly. The IPCC report notes that C3 & C4[12] crops respond differently to CO_2. Overall, for C3 crops, the CO_2 enhanced growth response initially compensates for a moderate increase in temperature, but this declines as temperatures peak (Easterling et al 2007). C4 crops such as maize may see reductions in growth duration which reduces water requirements in the initial stages, but also is projected to decline. This suggests that the main cereal crops will be more severely impacted in the latter part of the 21st century, but, as always, depends on the region concerned.

For pastoral industries, it is known that thermal stresses reduces productivity, conception rates, and can be potentially life-threatening for livestock. Increase in climate variability and droughts may lead to livestock loss or encourage farmers to use stock that having better stress coping potential but at the expense of milk production yield. Higher temperatures are expected to put ceilings on dairy milk yield in some locations worldwide. Higher temperature or benign conditions may also increase insect pest loads of many different livestock species. Extreme events can also incur losses for farmers. Few studies into stock losses resulting from climate extremes have occurred within New Zealand or worldwide, but large scale variation in the climate can pose difficulties for farm management and will require mitigation works. For example, farmers in Whaingaroa Harbour Care project near Raglan noted significant reduced stock losses due to fencing off of livestock from waterways, and given expected increases in heavy precipitation events, such works will continue to be required.

In terms of the forestry industry, modelling studies predict increased global timber production, but on a regional basis there is increased variability in terms of supply. However, despite an increased research focus, little is globally known or modelled in terms of fire, insects, forest health, wood quality, and extreme events on forests.

In terms of global fisheries, fish provides 2.6 billion people with 20% of protein intake (Easterling et al 2007) but 75% of current fish species are fully exploited, overexploited, or depleted (FAO 2004, Worm et al 2009). Aquaculture may mitigate some of these issues, especially for some specific types of species such as shellfish, but for many popular finfish species, the role of aquaculture in fisheries, whilst increasing in some locations, is not expected to change markedly. Like forestry, the wider impact of climate change on worldwide fisheries (marine or freshwater) has seen increased research, but there is still a high level of uncertainty over impacts on oceanic currents, marine or freshwater food chains/webs, and nutrient cycling processes. Nutrient supply to the upper productive layer of the Pacific may be declining, as well as changes in the deposition of wind borne particles. In addition, deep ocean currents often carry high levels of nutrients into less productive warmer waters, and changes in these currents

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[12] C3 & C4 crops refer to photosynthetic path of plant.

can have large impacts on fisheries, as the impacts of El Nino on the Peruvian fishery illustrate (Garcia-Herrera et al 2008), where the fishery regularly collapses from being the largest in the world to almost negligible catches in subsequent years.

Future spread of pathogens within waters is also likely, e.g. the spread of fish and other marine and freshwater life diseases. Some species not presently capable of surviving in present conditions may well find increased temperatures to their liking. Given that Whangarei has large numbers of boats visiting from around the world, the likelihood of an invasion is already very high. What is known is that increased temperature will effect fish growth and metabolic rates. Some research onto rainbow trout (as a species of commercial and recreational importance) has occurred, with the result indicating that, should there be an increase of 2°C, then in winter, some positive effect may be found in high latitude areas, but negative if in summer. In some borderline areas, trout numbers may reduce or disappear altogether[13].

Overall, in terms of food-crop faming, including tree-crops, global projections indicate small losses out to 2030 from shifts in climate, but these become larger losses between 2040 and 2090. The secondary message from the research is that any increase in the frequency or magnitude of climate extremes may lower crop yields beyond the impacts expected from mean temperature changes. Whilst some present mid to high latitudes (colder areas) will benefit for better growing conditions, those locations already considered warm will not benefit much at all.

National Context

New Zealand has a reputation for having the world most innovative farmers, in terms of changing crop types, inputs, and production methods. This may be important as possible changes in the local crop types and productivity becomes increasingly likely. Some fruit species may lose their viability in their present areas of production, and new crops may be introduced to adapt to new climate parameters. This, in turn, will lead to changes in skills needed to harvest the crop; lead to changes in labour needs, and may promote different supply strategies. In addition, changes in flooding, drought, pest invasions, etc will need to be addressed by the primary production community, and taken into account in their future planning.

Similar to the international context, temperatures are expected to increase along with changes in amount/distribution of rainfall over New Zealand. These changes will impact on overall capacity for agricultural production in some regions. The final impact will be dependant on a range of factors including historical responses to natural hazard risks, local flexibility in agricultural practice, and relative dependence on permanent infrastructure, e.g. high intensity methods using confined animal feeding operations that cannot be moved easily.

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[13] However, a decrease in trout numbers in some locations within New Zealand may have positive benefits for native fish (McGlone 2001).

Work is also being carried out by various industry organisations on the potential cost of lost production, barriers to market share, and possible adaptation costs, as they have risk of future lost income. The most visible example of this is the kiwifruit industry, which historically has been dependant on frost as a precursor to budding on kiwifruit plants. Early modelling suggested that kiwifruit may not be viable in Northland, and may only be viable in the Bay of Plenty through the introduction of specialised techniques to improve fertilization and fruit set (Kenny 2005).

The various livestock and dairy industries are also undertaking research to reduce emission from livestock, and greater emphasis on the real carbon intensity of New Zealand production is being undertaken. This last aspect is being undertaken to combat the crude measurement of food miles as an adequate indicator of carbon intensity that has found favour in Europe. Food miles do not adequately account for full the full use of carbon across the whole food production cycle, in the form of energy, feed, and other aspects of production. However, use of carbon footprint labelling is increasing in Europe.

Given temperature and precipitation change projections, increases in drought risk are likely to occur in some parts of New Zealand. Mullan et al (2005) have modelled the likely changes, using the models produced for the IPCC downscaled for regional purposes. Figure 17 illustrates likely types of drought frequency. These models are projections of growing degree days (GDD) and soil moisture deficit that were then used to project future changes in agricultural productivity. Agricultural regions in eastern NZ without alpine-fed rivers are likely to face greater shortages of water in the future. Drying of pasture in spring may begin earlier than at present, as well as early spring growth patterns. Tait el al have shown that year-to-year fluctuation in rainfall, days of soil moisture deficit and GDD can affect the wider New Zealand economy, so these projections do hold some risk to the wider New Zealand economy. Most pasture in New Zealand is dominated by ryegrass and white clover; neither of which are drought tolerant (Zhang et al 2007), and pasture containing more tolerant species may be needed.

The maps in Figure 17 from Mullan et al (2005) indicate a range of projected drought scenarios in which the frequency of an equivalent to a present 1 in 20 drought period increases. 25% in the figure represents a low/medium scenario whilst 75% is a medium/high scenario.

Yellow indicates a possible frequency change to between 1 in 5/1 in 10, whereas brown indicates an extreme of between 1 in 2. 5 and 1 in 5 by 2080. The key finding was that severe droughts (equivalent to a present 1/20 ARI) will occur at least twice as often by 2080s, on a low-medium scenario across New Zealand. In a medium-high scenario, the overall frequency of extreme drought is even higher across New Zealand, at least four times as often.

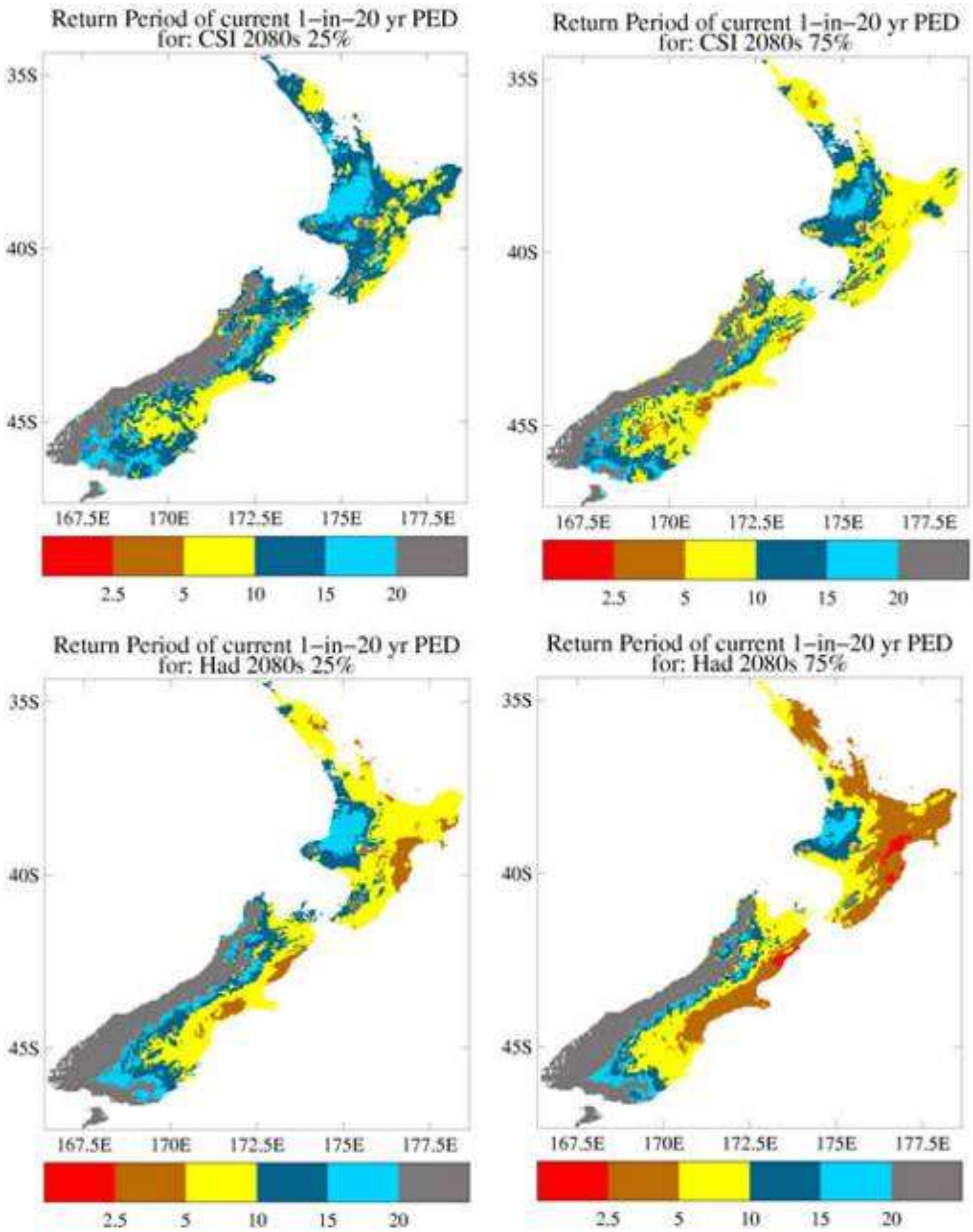

Figure 17: Future return periods (years) of current climate 1-in-20 year PED events, for four scenarios: CSIRO 2080s 25% and 75% scaling (upper panels) and Hadley 2080s 25% and 75% scaling (lower panels). Sourced from Mullan et al 2005, p 50

At present water used for irrigation accounts for 77% of consented water use in New Zealand, and it is noted the area that is irrigated has expanded by 40% per decade since 1990. In 2008, a report by Aqaulinc estimated that water allocation nationally had increased by 50% between 1999 and 2006 (Aqaulinc 2008), although Northland was one region where this wasn't the case, and officially recorded a small decrease in allocation needs.

Research in Australia has indicated that the areas climatically considered to be tropical have already expanded by approximately 300 km southwards (Isaac & Turton 2009). This is having an impact on yields, pest biota, and the viability of some crops, both positive and negative. Whilst temperature change provide new opportunities in terms of new crops, it does decrease opportunities in historic industries and the capital used to develop those industries. Various research projects have occurred around New Zealand that assess potential of crops according to the local biophysical and climate factors such as the *Topoclimate* project used in Otago and Southland, and, more locally, *Crops for the Kaipara* project which looked at a few alternative crops in Northern Kaipara/South Hokianga sub-districts in Northland (Wratt et al 2006). However, little publicly available research appears to have been undertaken across New Zealand as a whole that assesses potential future crops at the broad level in light of new climate parameters.

Local Context

Many of the high priority natural hazards found in Northland and Whangarei are driven by extreme weather events such as storms, ex-tropical cyclones and other factors that influence rainfall and wind patterns, and all impact on agriculture (WDC 2009). A report produced by the Ministry of Agriculture in 2008 outlined the economic cost of extreme weather events in New Zealand, especially around drought and to a lesser extent flooding, and attempted to model future economic costs in terms of climate change. In terms of key agricultural viability parameters, water is expected to be a key limiting factor in future production. Parts of Northland have a natural shortfall of water during the growing seasons. Low level droughts do occur regularly, and occasionally these low level events occur over consecutive growing seasons.

Climate change projections suggest reduced water availability in Northland, especially with no alpine fed rivers are available that can be used to reduce water vulnerability. Repeated low-level drought conditions carrying over consecutive years are expected to occur more regularly, from approximately 30% chance to 40% in the next years. The likelihood of consecutive extreme drought rises from 1% to 5% probability or from a 1 in 100 year Annual Return Interval (ARI) to a 1 in 20 year ARI. The impacts of such a scenario would be extremely damaging to local productivity.

The Ecoclimate (2008) study indicated that projected dairy and sheep/beef production in the driest 'scenario' years in both 2020-2049 and 2070-2099 is projected to be worse that the driest year recorded between 1972-2002, and average year production and worst year production are both projected to decline in Northland. This will have a corresponding effect on agricultural returns, with average projected effects ranging from 81% to 92% of present income levels as an average decline level. In the worst years, declines in dairy income of between 39% and 54% are projected, depending on the scenario used. Sheep and beef activities are not immune to major drought either , with average income declines of 82% to 88% of present income over time, and worst year impacts of 41% to 50% of present income also being projected.

If the scenarios contemplated in Ecoclimate (2008) occur, then the Whangarei District is likely to have a climate-driven need for extending irrigation systems as well as protecting groundwater resources for future use. Approximately 7000 ha of land in Northland are already irrigated, of which a small portion is found in Whangarei District. In Northland, surface water is known to be over allocated, as well as many unknowns over groundwater resources (Aqualinc 2008, p18-20).

Whilst all these figures don't necessarily account for changes in technology, preferred crops, or changes in pasture, they do suggest that climate change is a significant economic risk for Northland. If droughts become more common, the potential need for irrigation goes up significantly, and securing adequate water from upper catchment becomes more necessary. In addition, reducing water losses to evaporation from high temperatures in water distribution networks, natural or built, becomes more critical.

3.2 Infrastructure

National Context

Most infrastructure used for human settlements, whether public or private utilities, is likely to be around for 50 or more years. This long lifespan for larger scale investments means that changes in climate will have the potential to affect the overall efficiency or purpose for which the asset was developed, irrespective of the type. Infrastructure is generally developed to meet identified outcomes for specific costs, and if parameters change, then the infrastructure may be less efficient. Thermal and other building qualities may change in the face of underlying changes in baseline environmental conditions. The concept of future-proofing construction is meant to build in capacity to adjust to changes in public tastes or environmental conditions, and is a good example of adaptation options being developed.

Jollands et al (2005), notes that several European and American studies have indicated climate change projections suggest large scale damage to infrastructure. However, there have been few assessments in New Zealand of projected climate change impacts on infrastructure. Whilst professional organisations such as the Institute of Professional Engineers of New Zealand (IPENZ) and building organisations like BRANZ are advocating the need to incorporate climate change into individual asset preparation and planning, little research has been done on their wider effect within New Zealand. However, broad impacts on functions are outline in table 5.

Function	**Affected assets or activities**	**Key climate influences**	**Possible effects**
Water supply and irrigation	Infrastructure	Reduced rainfall, extreme rainfall events, and increased temperature	Reduced security of supply (depending on water source) Contamination of water supply

Wastewater	Infrastructure	Increased rainfall	More intense rainfall (extreme events) will cause more inflow and infiltration into the wastewater network. Wet weather overflow events will increase in frequency and volume Longer dry spells will increase the likelihood of blockages and related dry weather overflows
Stormwater	Reticulation Stopbanks	Increased rainfall Sea-level rise	Increased frequency and/or volume of system flooding Increased peak flows in streams and related erosion Groundwater level changes Saltwater intrusion in coastal zones Changing flood plains and greater likelihood of damage to properties and infrastructure
Roading	Road network and associated infrastructure (power, telecommunications, drainage)	Extreme rainfall events, extreme winds, high temperatures	Disruption due to flooding, landslides, fallen trees and lines Direct effects of wind exposure on heavy vehicles Melting of tar
Planning/ policy development	Management of development in the private sector Expansion of urban areas Infrastructure and communications planning	All	Inappropriate location of urban expansion areas Inadequate or inappropriate infrastructure, costly retrofitting of systems

Table 5: Broad Scale Impacts of Climate Change on Local Government Functions from MFE Screening Assessment. Sourced from MFE 2008, p51.

Two recent studies, one based around Wellington City and one based in Hamilton City, have endeavoured to model the wider impacts of climate change on various types of infrastructure (Jollands et al 2005). Whilst the environmental context (whether demographic, environmental, or financial) is different to Whangarei, this research gives guidance as to what may be important areas of analysis. The Hamilton case study indicated a potential need to increase water storage capacity for longer lasting water shortage periods. However, of major interest was that road repairs due to extreme weather conditions were raised as the most pressing climate change issue, especially as prolonged periods of rain are generally agreed as the main cause of road repair needs. Energy and peak electricity emerged as the second most pressing issue, especially in the case of higher peak temperatures in summertime. However, in both assessments, demographic changes had more significance than climate change impacts. In areas facing both pressures of population growth and climate change, it is expected that the negative effects would be magnified.

Local Context

A changing climate will have an impact on infrastructure in Whangarei District, with larger peak flows in stormwater systems, potential water supply problems, effects on wastewater disposal damage to roading infrastructure, and changes in the coastline all being of importance. In recent years, the cost of storm damage to roading infrastructure to Whangarei has been high and any changes in storm frequency or intensity is likely to have further impact on the roading network, and the subsequent resources required for repairs. The Whangarei District Council Environmental Engineering standards applies a target of 20% additional capacity for assessing lifetimes and potential for different infrastructure, which is roughly equivalent to accounting for 2.5 degrees of temperature warming.

As well as planning for new infrastructure, climate change impacts can impact on present infrastructure already exposed to natural hazards. Figures 18 and 19 are broad scale map of the locations of key Whangarei District infrastructure mapped against flood susceptibility and coastal hazards, as these are the natural hazards most likely to have an increased impact under climate change projections. Both maps illustrate that some infrastructure, apart from stormwater systems, is already located within flood susceptibility areas; especially around Whangarei City in the central and south areas. Outside of Whangarei city, locations such as Waipu and Ruakaka have key infrastructure located in flood susceptible areas. These maps do not show actual pipelines in these areas, but there are many pipelines located within flood susceptible areas that could be at risk from increases in extreme weather patterns. In terms of coastal hazards, few major built assets are located in the coastal hazards zone although some minor council infrastructure such as signs or parks equipment is present.

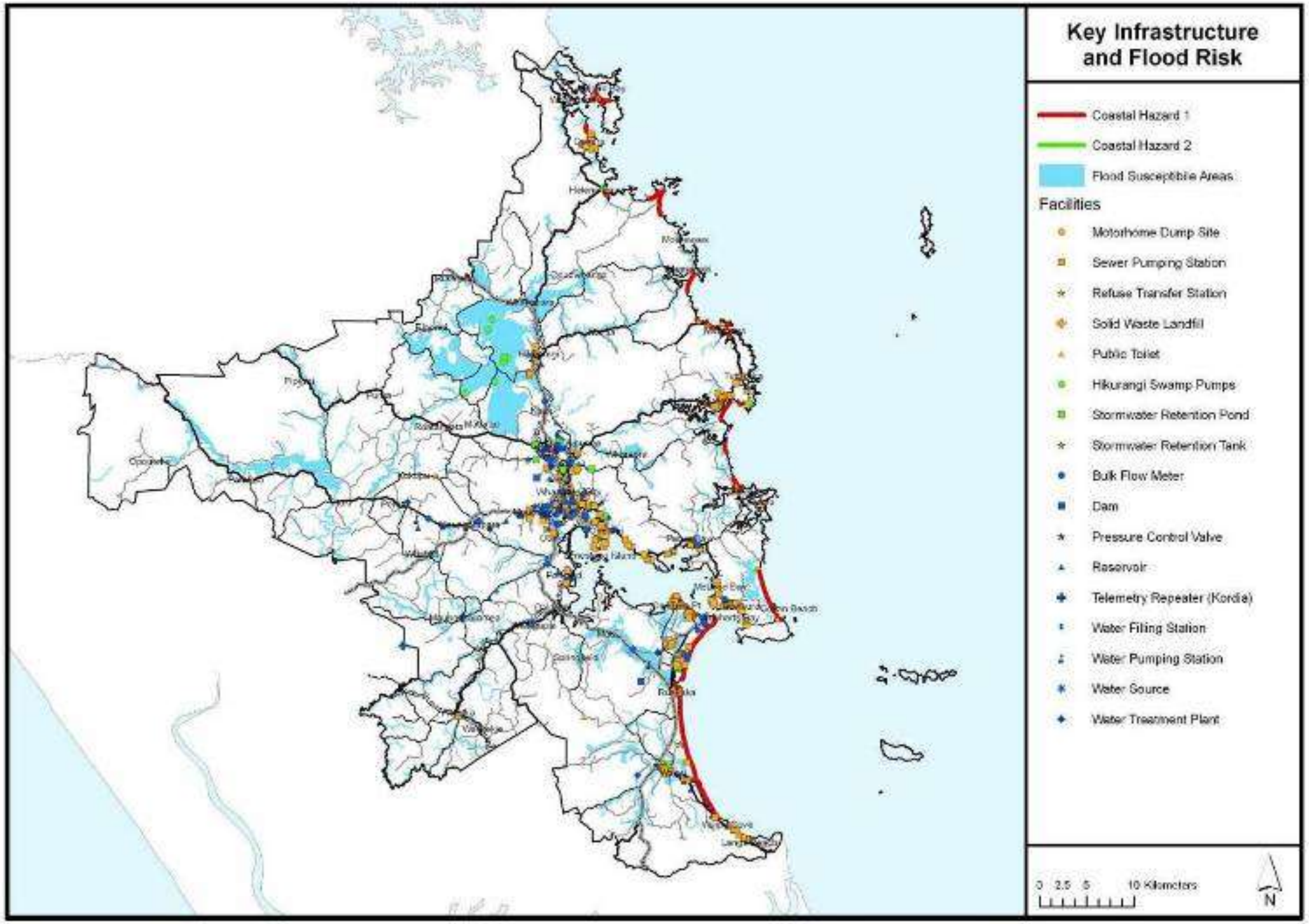

Figure 18: Map of Key infrastructure located across Whangarei District

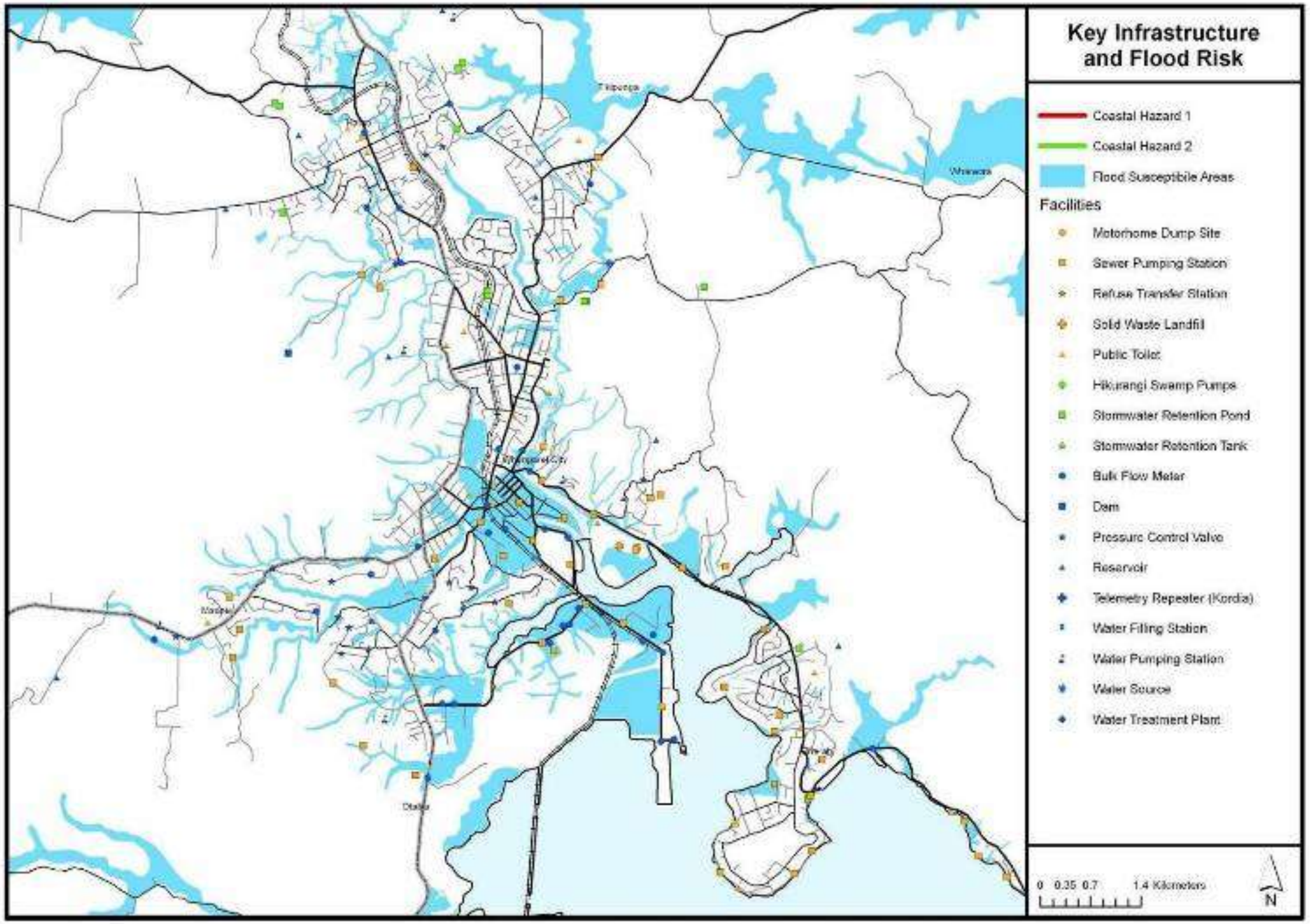

Figure 19: Map of key infrastructure located around Whangarei City

Stormwater

Whangarei District Council has considerable investment in stormwater systems, especially around Whangarei City. There are 11 major Whangarei City stormwater catchments and 17 smaller settlements with stormwater networks. In terms of infrastructure, Whangarei District Council currently has:

Trunk and Local Stormwater Pipes 290 km
Manholes 5,904
Pump stations 7
The pressures of extreme weather on the stormwater system will perhaps be the most obvious impact of climate change on stormwater in Whangarei. More extreme events are likely, resulting in more frequent system flooding, higher peak flows in streams and related erosion activities within the waterbed, groundwater level changes, and potential saltwater intrusion within some catchments. Research by NIWA predicts the present randomness of storms to continue, and what is considered to be an extreme rainfall event at present is expected to occur 2 - 4 times more frequently over time. This is despite the overall decrease in average annual precipitation for the district. These potentially higher peaks in rainfall events will impact on the capacity of the stormwater system to manage water.

Wastewater

Whangarei District Council has 9 wastewater schemes, these being located at Whangarei city, Ruakaka/One Tree Point, Waipu, Ngunguru, Oakura, Hikurangi, Portland, Waiotira, and Tutukaka, all of which serve approximately 23000 connections. These various schemes are built around the following infrastructure:

Trunk and local sewers 536 km
Pump Stations 126
Manholes 8,353
Advanced Tertiary Treatment Plant 3
Septic Tank/Wetlands 1
The effects of extreme weather on the sewerage system are often the subject of debate in New Zealand, and within Whangarei. Problems may arise when there is stormwater inflow and infiltration into a sewerage network, which, if exceeds the capacity of the system, can lead to overflow periods. Conversely, long dry spells can lead to blockages if insufficient water is available for flushing. Weather extremes will therefore influence the efficiency of the infrastructure. The LTCCP 2009-2019 already noted significant capacity issues in existing systems, and there are areas within the district that could benefit from a shift to community based systems away from on-site systems (e.g. septic tanks). Septic tanks in the countryside

area can also be affected by changes, especially rises, in water tables over time. A single failing system can have widespread effects, as the recent Northland Regional Council Recreational Water Quality report indicated in terms of a problem that occurred in Taurikura[14].

The LTCCP noted that a significant percentage of the pipe system was constructed between 1960 and 1980, and these were coming to the end of their useful lives. Renewal and maintenance of these systems allows opportunities for future proofing of this system to meet climate change projections. The LTCCP also noted the effects of overflows, and that work on removing contamination to harbours is a goal of several projects currently underway at Whangarei District Council. Negative impacts on urban treatment plants (which are often low lying) and coastal sewerage treatment plants are also expected. There are pipelines at risk from natural hazard events in many locations around Whangarei City, and in some of the coastal settlements. However this is not dissimilar to the present where pipelines are already located in hazardous areas (e.g. around the Town Basin). The treatment ponds, and downstream water bodies may see increased frequency of algal bloom events.

There will also be cost implications associated with the mitigation of carbon emissions, with methane often being released, in both sewerage treatment plants as well as landfills. However, like landfill gas, there may be some prospects for energy generation as research in Marlborough has shown. Whilst the scale of operations, e.g. the volumes from urban users, at present may not be large compared with larger centres of population, as technology becomes more cost effective, then possibilities to use this source of energy may emerge. Methane emissions from these facilities will enter the Emissions Trading Scheme (ETS) from 1 January 2013, with voluntary reporting from 1 January 2011 and mandatory reporting from 1 January 2012.

Transport

Whangarei District Council currently has the following assets:

Sealed Roads 1,046 km

Unsealed Roads 717 km

Timber Bridges 68

Large Culverts greater than 3.4 sq m 169

Culverts and Drainage structures 18,698

Footpaths 331 km

Footbridges 26

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[14] www.nrc.govt.nz/upload/4013/Rec%20Bathing%20report%202008-09%20(web).pdf - 2009-11-25

As work in both Hamilton and Wellington have shown, costs associated with repairs for road damage are likely to increase in most scenarios of climate change. However, it should be noted that these are both urban councils and Whangarei District's stronger rural character and spatial sizes is likely to mean higher costs that those projected for Hamilton and Wellington. This is further complicated by smaller population density to fund repair works. In addition, many isolated communities within Whangarei District continue to be at risk from being cut-off in a weather related natural hazard event.

Apart from the road damage, disruption to travel patterns and goods freight due to flooding, landslides, fallen trees and lines, tar melt, wind exposure, coastal inundation, bridge failure may be more evident. The New Zealand Transport Agency has also identified risks to the State Highway network in the Northland region, with several areas being prone to landslip risk, and some relatively low lying land being near the state highway network. Flood events in the last few years have illustrated the potential for disruption to this network.

Whilst the roading network is the most critical asset in terms of transport for Whangarei District Council, other forms of transportation are also important, either now or over time. These include air, rail and coastal shipping. Gardiner et al (2009) in their report to the New Zealand Transport Agency noted some important issues for the other transport infrastructure. Potential issues for the rail network include track buckling, location of railway tracks in low lying locations, impacts of additional slips and erosion, and changes in groundwater levels and subsequent design requirements for foundations. For coastal shipping, issues include rising sea levels and present wharf levels, land stability and protection needs for ports, impacts of rising sea levels on water volumes in harbours and flows over harbour entrances, and the effects of changes in river flooding susceptibility that may coincide with high spring tides near river mouths (Gardiner et al 2009).

Water

In terms of its own infrastructure, Whangarei District Council currently has:

Dams 4
River and Spring Intakes 8
Treatment Plants 7
Booster Pump Stations 19
Reservoir Sites 27
Water main (≥50mm) 707km
Metered Connections 24,247
Average Daily Production 25,260 m3/day
Maximum Daily Production 39,190 m3/day

Whilst the other infrastructure types tend to more affected in times of extreme increases in water, water infrastructure may be more affected by dry conditions, at least in terms of supply. Changes in precipitation can impact on the supply of water, especially if key catchments capacities, and modelled recharging rates, were developed under present climate conditions and those conditions change markedly. Dry spells can also affect people not on reticulated supplies and dependant on rainwater, which is the case for many parts of our coastal areas. Other residents are dependant on aquifer recharge to ensure bore water supplies. Should multiple dry spells occur, there will be pressure on council to provide additional reticulated systems across the district. Many coastal settlements north of the Whangarei Harbour do not have reticulated systems and are dependant on rainwater or bore supplies, as are some popular lifestyle areas.

Higher temperature can increase the likelihood of algal events and pathogen increase in rainwater tanks. Changing flow regimes at both peaks and low flows can change water quality, with subsequent need for other costs of cleansing or, in extremes, new supply sources. Abstracting water from streams and groundwater reduces water available for other users and has an impact on the ecosystem. Water consumption in Hamilton estimated increased requirements from 10,000 litres per person per month to 16,000 per person per month, which, when combined with population increases, would lead to increased water storage needs (Ruth et al 2007).

Extreme rainfall events can increase sedimentation rates, increase turbidity and raise costs for providing clean water. Reduced flows in aquifers or waterways due to lack of recharge can result in saltwater intrusion into coastal aquifers. Coastal settlements sometime face shortages during summer months which tend to coincide with peak populations of holiday makers. And like both reticulated stormwater and sewage systems, pipe breakage and leakage can also be a problem. Water is also provided for fire-fighting purposes within the reticulated areas and is available to those with alternate supplies during times of drought via water tankers. Most of the water tankers take their supply from the Whangarei city urban reticulation system. The costs implications of supply via water tanker are not just in terms of the direct costs of water and the transportation costs (which rises markedly depending on distance from water supply point), but could also be measured in terms of costs from additional damage to the roading network from increased water transport use.

Solid Waste

Whilst solid waste infrastructure is smaller in scale than other forms of infrastructure, it faces a different series of risks from climate change, primarily around the maintenance and use of refuse stations and landfills. Physical issues that need to be dealt with include surface flooding onsite, increased biosecurity risks, and changes in local groundwater profile. In addition, the emission of landfill gas is also subject to costs emerging from the Emission Trading Scheme. Whangarei District Council currently has:

1 Resource Recovery Park (Re:Sort) including a designated hazardous waste storage area.
5 big bin transfer stations
5 small bin transfer stations.
There is a landfill being constructed at Puwera, and several closed landfills across the district. Currently, Whangarei District Council presently transfers waste to the Redvale landfill in Auckland, and emissions trading on fuel costs could raise the cost of this activity.

One major potential issue is costs associated with the Climate Change Response (Emissions Trading) Amendment Act (2008), which established the new Emissions Trading Scheme, which is now subject to change. Operators of waste disposal schemes that produce greenhouse gas must account for the emissions that result directly or indirectly from their activities and will be required to enter into the ETS in 2013. This needs to be factored into the solid waste activity. Methane emissions from these facilities will enter the ETS from 1 January 2013, with voluntary reporting from 1 January 2011 and mandatory reporting from 1 January 2012.

Parks

Whangarei District Council currently has the following assets:

Sports parks 82 ha
Walking Trails 36.6km
Children's Playgrounds 36
Skateboard Areas 4
Street Trees 9485
Wharves and Jetties 14
Boat Ramps 21
Managed sites (including road berms) 706
Like the conservation estate, parks and reserves tend be highly affected by climate change, with risks to recreational infrastructure, pest invasion, changes in vegetation, fire risk, biodiversity reduction, and damage from extreme weather events all posing difficulties. Further details of this are found in sections relating to further council functions (3.2) and to biodiversity (3.3).

Damage to public walking tracks following extreme weather events, similar to the storm damage suffered within Whangarei District in recent years, has the potential to increase due to climate change. Conversely, increased drying of vegetation or drought conditions will increase the possibility of closing some tracks due to extreme fire conditions as a precautionary measure. Increased spread of weeds across council lands that may need to be managed for health and safety purposes may lead to additional costs. Extreme heat can also impacts on children playgrounds, reducing longevity of these over time.

3.3 Further Council Issues

Whilst the previous section is concerned with direct impacts on infrastructure, Whangarei District Council holds many responsibilities under the Local Government Act 2002, Resource Management Act 1991, and other pieces of legislation to prepare for climate change. It can be difficult to quantify some of these, but some impacts on council operations may be more subtle in their impact so they are worth listing. In Australia, one council, Blue Mountains City Council near Sydney has differentiated various impacts into primary, secondary, and tertiary impacts, dependant on the perceived directness of the impact on council operations and the wider community (BMCC, 2009). Temperature, precipitation, and extreme weather events were classified as primary drivers of impacts there, and will be similar here. Note that they are not listed in any particular order of risk, uncertainty, or severity.

Primary Impacts

- As extreme weather events increase in intensity, more damage to council property and assets is likely to accrue. These include buildings, roads, pipelines, parks and economic assets. If maintenance costs increase substantially, then other projects may not be able to be implemented.
- Additional cost may be derived from increased insurance premiums for council operations, buildings, and assets.
- Long term damage to local iconic features, such as increasing landslide risk for some natural features in the district, washing out of some popular beaches, and drying out of bush.
- Higher temperatures bringing into play legislation and regulations on public health and occupational hazards, which will impact on outdoor workers functions, whether council staff or employed contractors.
- Vulnerability of single transport routes for some communities. This is an issue already for some communities in the district, and these, and other, communities will continue to be vulnerable to loss of access.
- Loss of public/private gardens due to lack of water in some years, or an overall use of more limited watering days. This happens on occasion in other parts of New Zealand, but has not been experienced thus far in Whangarei District.
- Drying of bush will leading to local changes in biota, and increased risk from fires.

- Impact on vegetation of pre-emptive clearing if some wildfire risks to the wider community are perceived around some settlements. Whilst the New Zealand bush is generally wetter than in Australia, wild fires do exist and have occurred near major settlements in New Zealand, and in Northland. Pre-emptive clearance can pose a dilemma as the removal of vegetation may increase local drying conditions as less water is infiltrated into the soil.
- Should in-stream water level drop markedly, there can be decreased water quality as stream water temperature rises allowing better growing conditions for some algae. In addition, smaller flows accompanied by no shift in inputs will also impact on water quality.
- There can be increased calls to provide water security following any severe drought. Given the relatively stressed nature of some local resources such as groundwater, some requests or consents for more storage capacity may be implemented.
- Most buildings in New Zealand are designed to absorb impacts from seasonal changes in soil wetting/drying due to local water tables (Branz 2007). Changes to soil wetting/drying regimes dues to climate change can impact on foundations of buildings. Near the coast, higher water tables are expected, due to higher sea levels and older buildings may not be designed with this in mind.
- In some areas, more surface flooding can be expected, with consequential damage to foundations and buildings. In others, longer term patterns of drying then sudden wetting can also cause an impact on foundations.
- In addition, changes in water tables will impact on remaining bores in our district. According to the NRC State of the Environment Report (NRC 2007), many bores are utilised within the Whangarei District. In the key "at risk" aquifers of Maunu, Maungakaramea, Three Mile Bush, Matarau, and Glenbervie, 396 bores are registered with Northland Regional Council. Changes in the water table, or changes in the aquifer recharge due to dry spells will put additional pressure on these aquifers. When this is added to the pressures from changes in land development above coastal aquifers and in at-risk rural areas, new methods of water provision may be required. There are others outside these area, as well as additional bore 'hotspots" at Waipu and Ruakaka.
- Soil erosion due to increase in wind speed and pressure, especially in those areas exposed to prevailing westerlies.
- Private water tanks can be affected by changes in climate. Increase water temperatures within watertanks may be suitable for more pathogens, and thus creating higher health risks, and there having consequentially higher costs for treatment.

- Many buildings in New Zealand, and around Whangarei District may not be designed to suit new conditions, which may be a problem given that much of the present housing stock will continue into the new climatic environment. Recent calls for future-proofing dwellings will aid new stock, but older stock may be prohibitively expensive to retro-fit.
- Power outages: The infrastructure industry in New Zealand has been responding to the threat of climate change and its impacts on infrastructure, but increased extreme weather events is likely to have an impact on the security of supply, which in turn can have an impact on the council and public operations, including pumping stations, lights, and so on.
- Increased costs due to emergency housing provided by local government in the event of an emergency event, as well as increased costs of coordinating/responding to natural hazard events for all emergency providers.

Secondary Impacts

- Increases in council operational costs were already noted above, but there will be higher operational costs across the wider community for maintenance of building and structures, leading to downstream effects on ability of some to pay rates.
- There is expected to be increased energy costs within the community, which has been noted in recent debates over the Emissions Trading Scheme, both here in New Zealand and abroad. This can also have an impact on the community's ability to pay rates.
- Heat waves in Europe highlighted the costs relating to health impacts on the elderly from high temperatures or disease epidemiology. The Demographic Report prepared by Whangarei District council indicates a swiftly aging population profile, which increases the significance of this secondary risk.
- As a larger user of energy and a potential source of emissions, there will be costs associated with Whangarei District Council reporting on its emissions, beyond the increased costs associated with actual energy use.
- Changes in the policy environment as legislation at central government shifts the focus onto local government activities. Over time, it is expected that central government endeavours to mitigate and adapt to climate change will increase, especially as increased information becomes available, and as the international policy direction becomes clearer. Recent examples of this include amendments to the Resource Management Act 1991, considerations in various Government Policy Statements, the Emissions-trading bill, international agreements and so on. These changes in legislation may occur fairly rapidly, and will require local government to be nimble on its feet. In addition, there may also be pressure on council planning emerging from national and

international insurers' decisions over the insurability or viability of some areas for future development, especially close to the coast or waterways.

- As more costs/funds are sunk into emissions trading, less funding will be available for other activities such as maintenance activities. However, there are also some opportunities for Whangarei District Council to take this into account over planning for reserves or investments in forestry.

Tertiary Impacts

- Community preferences for dealing with climate change issues are shifting, especially as concerns grow, and local government policies may need to shift to meet community demands, similar to increased concerns over freshwater and coastal water quality.
- Increasingly in Australia, and to a lesser extent New Zealand, there is an onus on local government to consider the impacts of climate change on their communities, and incorporate it within their local strategic planning, and this will increase potential liability issues (England 2008). In Australia, there has been discussion as to how local government may be held legally liable for decisions relating to potential climate change, with financial considerations also being found in the mix. Whilst local governments have measures of protection against liability issues under some legislation, over time there is a risk that these protections will be dependant on confirmed council actions.
- Costs associated with both mitigation and adaptation can affect the local community ability to pay rates. Beyond this, climate change mitigation and adaptation changes may eventually change the tax system in New Zealand, which also affects revenue streams across the whole community. Some policies internationally are to be tax-neutral where green taxes and derivations are not meant to add to the revenue stream of central governments but this is not set in stone.
- There are ongoing concerns about climate change impacts on tourism numbers, which is important given tourism's important contribution to the local economy, and source of employment.
- There will be effects on population settlement locally and nationally. Some areas in New Zealand, and within the region, may experience population decline due to higher hazard risks. For example, wildfire risk in some parts of Australia has already had an impact on settlement patterns there, and increased drying may prompt further changes.
- Potential loses of some environmental amenity in other locations due to increase development pressures in more favourable areas, e.g. those areas at less risk from climatic hazards.

- Related to questions of future demographics and skill shortage globally, some places already experience difficulties in attracting qualified staff, which in turn hampers ability to roll out adaptive measures and respond to climate change in a timely fashion.
- Given uncertainty around climate change impacts, there is also uncertainty about the appropriate time horizons for planning. The appropriate time horizon for natural hazards planning will represent a blend of practicality, feasibility, affordability and any impact on private or public property rights. Planning time horizons of 200 years are increasingly being used in some parts of Australia that will comfortably account for changes in climate change projections. At present, the case law emanating form the Environment Court has not been quite so directive but notes that a 100 year planning horizon as reasonable for coastal planning, depending on the local situation and assessed risks[15].

3.4 Biodiversity

International Context

Research on climate change implications for global biodiversity has expanded massively in recent years. The prevailing climate exerts major influences over the distribution of species (Pearson & Dawson 2003), at various time-scales. Therefore any change to 'normal' climatic conditions will have an influence on local species survival, either increasing or decreasing opportunities, which, in turn, can affect the functioning of a local ecosystem. Most of the literature, whilst recognising some benefits for agricultural species in some locations, tends to see climate change as having an overwhelmingly negative impact on global biodiversity. This negative prognosis is possibly due, in part, to the notion that biodiversity is already in decline in many parts of the world, and climate change is likely to exacerbate this decline. Figure 20 illustrates the broad impacts of climate change on biodiversity.

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[15] **Bay of Plenty Regional Council v Western Bay of Plenty District Council A 27/02**. The Environment Court considered that the Regional Council's approach should be accepted and that it was sound to plan for a 100-year predicted risk period. The District Council argued that only a 50-year risk period should be planned for, but this was rejected, particularly considering the principles in the New Zealand Coastal Policy Statement. It was also argued that the voluntary assumption of risk by private property owners does not abrogate the Council's responsibility of controlling the use of 'at risk' land for the purpose of avoiding or mitigating natural hazards.

Fore World Developments Ltd v Napier City Council W 029/06. In this case, appellants sought to have land zoned residential to enable subdivision, despite coastal erosion concerns. Conclusions on the case included

- A 100-year timeframe is appropriate for considering coastal issues.
- The 'Bruun rule' was accepted as an adequate method for assessing the effects of sea-level rise on coastal retreat.
- A graduated coastal hazard zone was not favoured in this case owing to difficulties of application and enforcement with a relatively small overall width of land.
- Adoption of a precautionary approach, based on weighted consideration of the level of knowledge of the risk, its likelihood of occurrence and the consequences, was accepted.

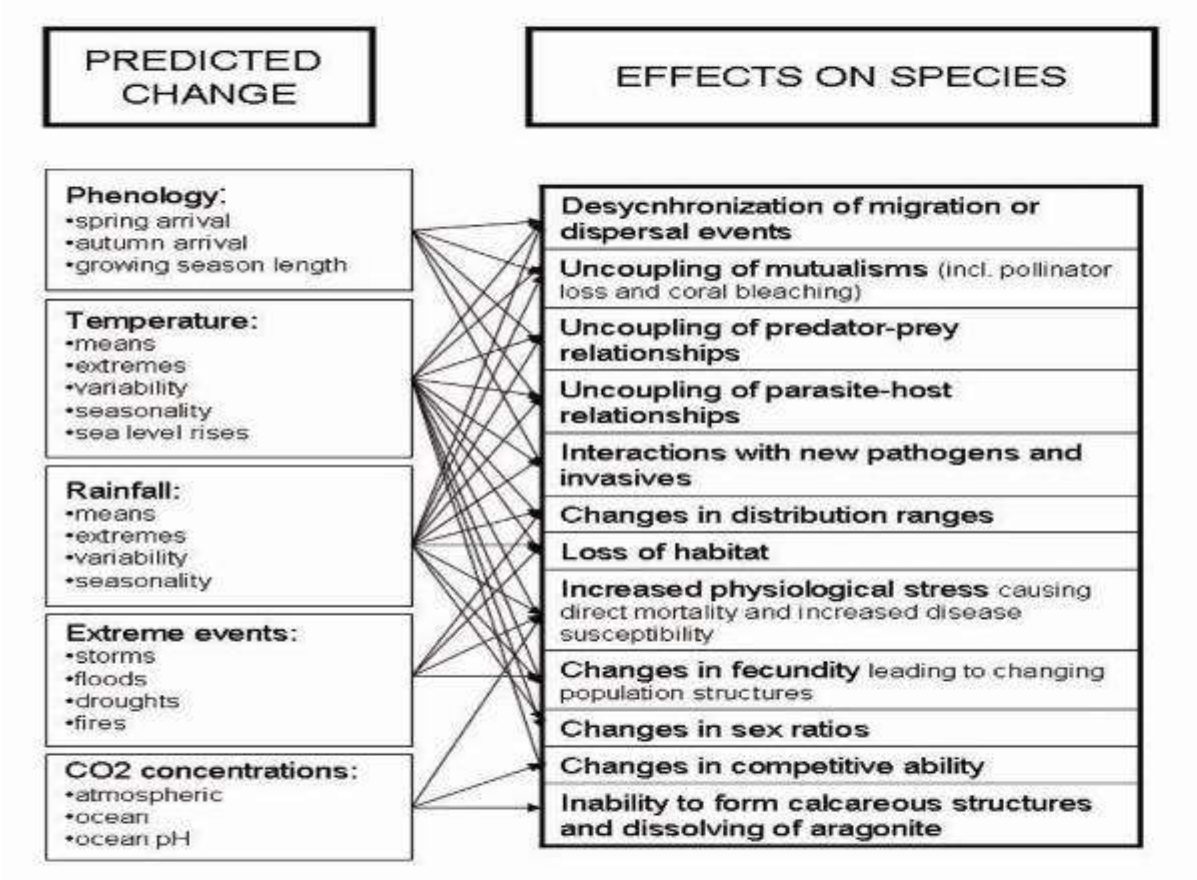

Figure 20: Broad Potential Impacts of Climate Change on Biodiversity. Sourced from IUCN (2008), p75.

This concern over biodiversity loss is relevant as recognition increases of how important fully-functioning and resilient ecosystems are for maintaining quality of life in local communities, irrespective of their wealth. The Millennium Ecosystem Assessment Report (MEA 2005), coordinated by the United Nations Environmental Programme and released in 2005, compiled large volumes of information on the state of ecosystems worldwide. The summation of this information gathering is that most global ecosystems were under pressure already, and that their capacity for production, waste absorbency capacity, and ability to provide goods and services to people were increasingly at risk. Climate change is expected to increase the pressure on these already stressed ecosystems, beside the other major global drivers such as land-use change, increased urbanisation, and pest invasion (Fischlin et al 2007, Gayton 2008). Whilst pressures of pest species, habitat fragmentation, and removal of vegetation are likely to continue being of greater concern in the short to intermediate term in New Zealand, the relative importance of climate change as a significant driver of environmental change will increase over the longer term (Fischlin et al 2007). It should be recognised that each set of pressures on biodiversity will provide feedbacks for exacerbating other pressures, e.g. as an area gets fragmented, it becomes more susceptible to weed infestation. Weeds then impede growing conditions for the remaining indigenous species seedlings, meaning that some species cannot breed as easily, or resist large scale weather events, or cope with changes in climate (Dukes et al 2009).

Climate change impacts on biodiversity can be broken down into three main types: specific impacts on individual species and their physiology and traits; wider impacts on ecosystems resulting from changes in their species (community) composition because individual species do better or worse in new climatic conditions; and the impacts of weather extremes in the survival of some species. All types of impacts are connected and will create feedbacks.

Every living organism has a large suite of characteristics or traits particular to it, and because of these traits they will 'fit' into an ecosystem. Some traits are directly related to the functioning of an individual, e.g. metabolic rate, thermal stress limitations, and growth rates (speed and size). Some traits are more related to the overall population of the species including reproductive rates, age of breeding, numbers of offspring, breeding seasons and time of gestation. Some traits emerge through the interactions of a species with their wider ecosystem, including diet and feeding strategies (generalist or specialist), resources required for body conditioning and survival, predator-prey reactions, disease resistance, nesting strategies, preferred habitat, etc. The presence or survival success of a particular species within an ecosystem is determined by their suite of traits. Climate change has the potential to severely disrupt the operation of these traits for many species. For example, increasing temperatures may lead to changed metabolic requirements for some species, which, in turn, may lead to different feeding strategies or needs.

Some species' traits may be more susceptible to climate change than others. The International Union for the Conservation of Nature (2008) notes five main traits that can enable identification of at-risk species. These traits include:

- Specialised habitat requirements (e.g. polar conditions, or plants that can only be found on specialised soil types, alpine plants);
- Narrow environmental tolerances (e.g. particular acidity levels in soil or water required for maturation, or limited tolerance for temperature extremes);
- Reliance on specific environmental triggers that can be disrupted by climate change (e.g. cues for mating, hibernation, forest required for seed germination);
- Dependence on inter-specific interactions (e.g. pollination of seed dispersal by only one animal) that can be disrupted by climate changes. Diet types can also be a clue for susceptibility, with more potential impacts on specialist feeders of more concern than generalist feeders;
- Poor ability to colonise new areas (through limited mobility or barriers such as mountain ranges. Modified landscapes can also present a barrier to migration), meaning that species cannot migrate to new areas that 'fit' with their traits.

As well as these generalised habitat or species impacts, temperature changes can also increase disease prevalence within a species. There is expected to be increases in the distribution and prevalence of infectious diseases (Lafferty 2009) that affect people, fauna, and flora. Other diseases may emerge in new areas as a response to the new environmental parameters that favour different microbes, such as warmer or wetter climes. Additionally, thermal stress on plants makes them more susceptible to environmental damage, and aids invasion by parasites, pests, and microbes. Drought events can lead to large scale tree die-off in some locations, and leads to longer term shifts in local ecosystems, e.g. from forest to scrub, as different individual species cope better with drought (Adams et al 2009). With higher rates of drought projected, tree die off is likely to be more common.

Climate change will change the overall life history of many plants, including their key periods of flowering, growth, and fruiting. Different traits of individual species may be enhanced to the expense of others of the same species, e.g. more leafy growth at the expense of seeding. This change in plant life history may mean that all-year-round food is not available to support many different species of animal. Changing temperatures is also likely to impact on the hatching times of many invertebrate species. This may have downstream effects on those insectivorous birds that depend on large invertebrate populations at key times, such as feeding chicks. Whilst many species can adjust, given enough time and lack of pressures, the declining state of biodiversity globally may not give enough time for most species to adjust to new climate by changing feeding habits or their reproduction times.

Of major global import is the fate of pollinators under climate change projections. Around the world, early flowering in many plant species compared with their average flowering times is being noted, as is elevation shift in some species dependant on cooler conditions, and mismatches in timing between pollinator needs and flowering periods. It is estimated that between 17-50% of plants will suffer from disruption in the plant-pollination relationship due to changes in climate (Hegland et al 2009), and this is likely to have an impact of the make-up of the global food supply, especially as many food plants that require pollination are fruit and vegetables species. This concern is in addition to to other issues related to pollination such as “colony collapse disorder” leading to massive loss of honey bee colonies in the United States, varroa mite, or problems in the UK bee keeping industry through increasingly wet summers. The role of alternative pollinators such as native bees, hoverflies, and beetles etc for the pollination of popular food crops is now under scrutiny and research.

Whilst much is written about the impacts of climate change, most recommendations to adapt to these changes centre on the maintenance and enhancement of present vegetation over the short-term. A resilient and relatively intact ecosystem is expected to be able to better adapt to climate change impact such as changes in growing conditions favouring weed species, resilience to natural hazard events, etc. There is still debate as to the longer term management of biodiversity and individual species populations and whether there is a need for direct action. Direct action solutions continue to be based on human-augmented colonisation of new areas, similar to the work carried out for many endangered bird species in New Zealand, whilst indirect action revolves around re-connecting important centres of biodiversity in the landscape, via wildlife corridors or riparian areas.

National Context

Similar to the global situation, it is recognised that climate change will exacerbate the impacts of drivers such as habitat fragmentation, biosecurity, and pest control in New Zealand. Whilst habitat destruction in recent years has slowed considerably[16], fragmentation of the remaining patches remains a problem in some regions, especially as patches are open to weed invasion, and may not have high levels of recruitment by indigenous species. Empirical data from New Zealand indicating the impacts of climate warming include earlier egg laying in the welcome swallow (Evans et al 2003), changes in seed production for Nothofagus along elevation gradients, and a westward shift of Chilean jack mackerel.

Compared with many parts of the world, research into the overall impacts of climate change on New Zealand biodiversity have been comparatively low in number. A few generalized reports (e.g. McGlone 2001, Kenny 2006, Green 2006), and occasionally more specific research on individual species such as alpine flowers, tuatara, freshwater invertebrates, and kauri have been undertaken[17]. This is probably due to more pressing concerns over ongoing habitat loss or fragmentation, land-use changes, and invasion by exotic flora and fauna that dominates research in New Zealand. The reviews by McGlone (2001), and Wren, (2006) provide an overview of likely impacts, but more recent reviews are not available.

Indigenous forests of fragmented lowland areas, including Northland, are vulnerable to drying out, and there is expected to be an increase in fire hazard risks (DOC 2009). In terms of fauna, changes in climate will change the resources available for feeding, nest building, and will change predator numbers and the timing of their peak populations. Changes in key resource timings may lead to periods where the primary food source is not available for building breeding condition necessary for reproduction for many bird species. If climate change leads to increases in drought severity and frequency, then more indigenous species will be facing problems from drought. This is not limited to land-based impacts, but is likely to impact on coastal resources as well, especially as there is likely to be shifts in local oceanic temperatures, which, in turn, will change their corresponding food webs. This may lead to changes in local

[16] Although Northland as a whole removed the bulk of habitat in the North Island.

[17] The Department of Conservation has commissioned a report on conservation and biodiversity which is due to be released in 2010.

recreational fishing species, or create new opportunities if some species are better adapted to the new changes in local conditions.

Streams, and their corresponding biota, are highly susceptible to the impacts of climate change, with higher water temperatures, shifting sedimentation patterns, and changes to the invertebrate communities being expected (Winterbourn et al 2008). Some specialist species of biota are expected to suffer reductions in their ranges or may be outcompeted by exotic species. Research has already indicated that drought was a major driver on the replacement of native dune grasses by marram grass, which can cope with drier conditions for longer periods. This finding has implications for longer term dune restoration programmes along northern coastlines.

Changes in the wider ocean and coastal system will influence plankton behaviour and food availability, which will impact on marine bird conditions and fitness and subsequent breeding condition (Mills et al 2008). Poulin and Mouritsen (2008) have modelled changing coastal water temperatures on the numbers of parasite species in the Otago Harbour (and in Denmark). The concern is that coastal amphipod populations may collapse as their parasites grow in number due to benign temperatures. This, in turn, can change the structure of the benthic environment as these amphipods contribute to harbour floor dynamics (Mouritsen et al 2005).

Mangroves will continue to spread southwards and further inland within estuaries, changing seabed structure and local water patterns, especially when combined with large scale nutrient enrichment and sedimentation (Lovelock et al 2007). Distribution of migratory birds may change, including patterns and location of breeding settlements as their food sources change. Many northern harbours are important for international seabird populations that migrate around the world. In New Zealand, climate change impacts pose a threat to some albatross species, including the encroachment of *Dracophyllum* scrub onto their breeding habitat in some southern islands.

A more recent, and subtle concern, is the fate of the tuatara over the longer term. For tuatara hatchlings, sex is often determined by the temperatures occurring during egg hatching, with higher temperatures producing more males, like many reptile species (Mitchell et al 2008). Increases in temperature will lead to more unbalanced populations of male and female offspring. Whilst female tuatara can change their burrow habits, this option is limited to various environmental cues and suitable locations, and may not be sufficient to offset the prevalence of males (Mitchell et al 2009). For longer lived species like tuatara, this represents an additional concern to their longer term viability.

New Zealand, as signatory to the Convention of Biological Diversity, and to United Nations Framework Convention on Climate change, has specific international obligations on both climate change and biodiversity. Historically, New Zealand response to biodiversity issues has centred on using and maintaining the conservation estate. Much of the Conservation Estate is located in elevated areas or locations without high production qualities. It consists of multiple sites with fixed specified boundaries. The problem with this approach is that climate change is projected to change habitat qualities and composition, meaning some reserves may not be able to fulfil the functions that they have in the past, especially as important species access to food resources becomes disrupted. Whilst the boundaries of these reserves were usually formed and determined by the present habitat, they rarely include the full range of habitat requirements of species living within them. This is especially important if modified landscapes present a barrier to the migration of some species looking for new resources for their use. Sometimes issues around barriers to migration can be mitigated by the purchase of additional private land or by means of private covenants. However, adding to the conservation estate can be a long, and controversial, process and there is the danger that the speed of inclusion is not fast enough to prepare new habitat to gazette as useful reserves.

Local Context

Northland is significant in terms of biological diversity in New Zealand. Conversely, it also has the highest number of threatened species across all regions, and much remaining productive lowland forests are heavily fragmented. Most indigenous habitat tends to be located on the steep hills. At present, approximately 14% of Whangarei District is covered by indigenous habitat, of which only 6% is formally protected as Department of Conservation reserves. This level of formal protection is amongst the lowest (as a proportion of area) for a district in New Zealand. Northland has been singled out in the IPCC as an area that faces high levels of climatic change risk in terms of drought, settlements and primary production, and the same implication would hold true in terms of biodiversity.

Extreme weather events such as drought have already been implicated in the decline or disappearance of species historically found in, or close to, Whangarei District, such as weka, pateke, and kiwi. Whilst much of the decline can be attributed to predator and pest invasion and habitat fragmentation, the climate impacts on the quality of food and other resources is important. Moore et al (2006) note that pateke (brown teal), are vulnerable to death by starvation. Whilst pateke take a variety of plants and animals in their diet, and are not susceptible to decline in any one food source, future reductions in overall food availability make them vulnerable to nutritional stress in dry periods. Drought has been implicated in catastrophic decline of two Northland pateke populations.

Drought also played a role in the loss of local weka populations, as invertebrates from the leaf litter are the principal food of weka. During a drought, leaf litter and subsoil dry rapidly, and cracks open, in which invertebrates can take refuge, but are out of range for feeding insectivores. Kereru (Kukapa) is a very important bird species for transporting seed and fruits of many New Zealand plants. In Lyver et al (2009), the authors noted that Tuhoe in the Ureweras, have noted the changes on the fruiting pattern of miro, which in turn impacts on kereru populations as miro is a source of preferred food. Cues for synchronized masting[18] appear to be changing across many species. Whilst this is further south, changes in fruiting patterns in Northland can have a similar effect.

The invertebrate community, above and below ground, on land and in water, is generally regarded as being both highly susceptible to climate changes, but also has the most capacity to change rapidly due to short generation times. However, little is presently known about droughts, or flooding impact on terrestrial invertebrate populations, which is of concern as they are important to wider ecosystems in many ways.

Whangarei District is at risk from a large variety of biological invaders, especially given its favourable climate. It is generally rated as having one of the highest invasion and naturalization rates of any region in New Zealand, both on land and in water (Sullivan et al, 2005). For example, the Northland Regional Pest Strategy notes 21 terrestrial and 17 aquatic species of concern (NRC, 2007). In an assessment prepared by Williams (2008), another 34 at-risk plant species were assessed for their "weediness" and invasibility, and many are potential threats. Wardle (2005) notes that 19 introduced ant species have established in Northland (a high number when compared with 10 indigenous ant species for the whole of New Zealand) including Argentine and Darwin's ant which are regarded as problems across the world. Ward (2009) specifically singles out Kaitaia in particular and Northland as a whole as being suitable for the colonisation of Solenopsis invicta, regarded as the world worst invasive ant. Whilst this suitability doesn't change, or is enhanced due to climate change, the bigger risk is that other areas become more suitable for colonisation, and could lead to further invasion sources into Northland. On a similar basis, fears of biological invasion in other regions from Northland sources may also become a possibility over time, and lead to inter-regional controls over produce sourced from at-risk areas. Although this risk seems a highly unlikely occurrence in New Zealand at present, such controls are regarded as normal in parts of Australia.

Kenny (2005) also mentions that several pest plants currently found in small or non-vigorous colonies in Northland may benefit from changes in climatic conditions, and increase the chances for present species to become pests. A lack of frosts has been cited as enabling the invasion of the tropical grass webworm in the Far North, at the bottom of the Aupori peninsula. This was an invader probably borne on prevailing winds from Australia, and managed to establish in 1999, but their range is limited by present climate conditions. Likewise, Kriticos et al (2007) notes that Oriental fruit flies are already able to colonise Northland but few other locations. and systems are set up to reduce this biosecurity risk. Changes in climate in other regions elsewhere could lead to increased colonisation of pests into Northland from other regions in New Zealand, which may not fit usual biosecurity survellience arrangements.

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[18] Seeding in all the trees of a given species at the same time.

Many areas around the world have similar climate to Northland, and are potential sources of invasive species into Northland. Many insect species are also able to travel of air currents, and some have made their way to New Zealand (Dymock 2006). Increased winds speeds in the climate scenarios suggest that Northland exposure to potential invasive species from this source is likely to increase. Whilst not all successfully establish, the risk is present. Other sources of risk include increased cruise ships, cargo vessels and leisure yachts (Dymock 2006), especially as recreational facilities and Marsden Port continues to expand.

3.5 Health

International Context

Health professionals around the world regard climate change as a substantial risk to global health. This includes risks in both wealthy and poor countries, irrespective of whether they are temperate or tropical. The quality of the local environment has long been a key contributor to healthy communities. The present situation for global health is not good, with estimates of 1,500 million people without access to clean drinking water, and about 800 million people failing to have enough food to eat each night, including 200 million children under the age of five (Costello et al 2009).

Health risks emerging from climate change take on many forms; ranging from the invasion in invertebrate pests capable of spreading disease through to physiological threats resulting from heat waves. Changes in ecosystem functions and their downstream impacts on water quality and quantity that impact on human health, and risks emanating for global food supply inadequacy conspire to make climate change a very large health risk. Costello et al (2009) note six main aspects of climate change impact that will have adverse health outcomes. These include changing patterns of disease and mortality, food security, water and sanitation, shelter and human settlements, extreme events and population migration.

Health impacts of climate change are expected to have a disproportionately high impact on poor urban dwellers, especially where poverty related infectious diseases are exacerbated by changes in climatic conditions (Woodruff et al 2006). Climate change has an effect on the spread of disease by increasing carrier reproduction rates, speeding up their life cycle, and increasing bite frequency, e.g. more mosquitoes, growing faster, and biting more. It is estimated that between 260 million and 320 million more people will be affected by malaria in new areas previously free of transmission by 2080 (Costello et al 2009). By 2080, approximately 6 billion people will be at risk of contacting dengue fever compared to 3.5 billion without climate change impacts (Costello et al 2009). Places such as Jakarta are already dealing with additional dengue fever outbreaks around Jakarta, and the cost of treatment is expected to rise significantly. Dengue fever is already being transmitted in parts of North-eastern Queensland. The potential range for the main mosquito vector in Australia by 2100 could extend as far south as Sydney as more humid conditions prevail along this coast, with a total increase in range of 1800 km southwards (Woodruff et al 2006).

The impact of heat-waves on human societies can be very high, and in Australia mortality in older age groups is expected to increase by 50% to 300% above present levels by 2100 based on the present age structure, but when combined with demographic aging, is likely to be much higher (Woodruff et al 2006). Heatwaves in Europe in 2003 caused up to 70,000 deaths, with urbanised areas more affected than rural ones (Costello et al 2009).

National Context

Recently, some New Zealand health professionals have formed the New Zealand Climate and Health Group, which seeks to bring attention to the impacts of climate change on health in New Zealand (and globally) through lobbying, undertaking "green prescriptions", and other activities relating to both adaptation and mitigation. A recent article in the New Zealand Medical Journal from Metcalfe et al (2009) notes that health professionals must get involved in addressing climate change as it will have profound consequences for health in New Zealand.

At present, New Zealand is relatively free of insects and other arthropods that carry diseases (Derraik & Slaney 2007). The most likely suspect for a potential future disease outbreak is the Ross River Virus. New Zealand currently has relatively low numbers of mosquito species (12 indigenous and 4 exotic), although at least 30 species have been intercepted at the border. The main limiting factor for the establishment of mosquito's species is the climate (Derraik & Slaney 2007). The literature also notes that some mosquito species prefer highly modified environments that, in conjunction with higher temperatures, will allow some species to potentially establish and thrive (Derraik & Slaney 2007). Ongoing development in Northland will continue to modify environments and allow conditions for some exotic mosquito species to thrive.

Local Context

In recent years, Avian and Swine Influenza have received a great deal of publicity, but other types of disease, such as the Ross River Virus, could also become established in Northland, given the benign climate and potential vector species. The outbreak of new diseases is expected to be another area exacerbated by climate change. Infectious diseases of note that are vector-borne (e.g. mosquitoes, mites/ticks etc) include the salt-marsh mosquito (Aedes camptorhynchus) capable of transmitting Ross River Virus and Barmah Forest Virus. Other intercepted threats include mosquito species capable of transmitting dengue fever, Japanese encephalitis, and other viral fevers. It should be noted that yellow fever, malaria, and filariasis are not regarded as high risk (MOH, 2001). Northland is mentioned frequently in regard to potential for the establishment of vector borne diseases (e.g. Mackerath et al, 2007). The socio-economic report produced for Sustainable Futures 30/50 has already noted the prevalence of many diseases in Northland, and in the Whangarei District. Given the poor present health state within Northland, health impacts resulting from climate change is likely to have a disproportionate impact on local health outcomes.

3.6 Vulnerability

International & National Context

When understanding risk, hazard planning needs to recognise the inequalities that exist across society, which in turn means that some communities may be more vulnerable to the impacts of climate change, rather than just focussing of the presence of physical hazards (Tapsell et al 2002, Werrity et al 2007). Vulnerability is not just the physical proximity to a natural hazard, but is also related to the active and less visible resources that a population has to recover or mitigate the effect of a natural hazard. Thus a vulnerable population is a function of factors such as access to resources or power, health status, minority status, gender and so on (Adger 2006). Hazard management planning now needs to consider different ways of identifying more vulnerable communities as well as reducing the impact of natural hazards. By mapping natural hazards likely to be exacerbated by climate change against various socio-economic indicators such as social deprivation or age structure aids the evaluation of vulnerability.

Very little research on the impacts of climate change on the more vulnerable in New Zealand has been undertaken at present. Recent negotiations over the Emissions Trading Scheme that endeavoured to reduce the impact of costs on the poor and vulnerable are a probable starting point for further consideration of the disproportionate impacts of climate change on the marginalised in New Zealand. The general prognosis at the international level is that the presently poor and vulnerable will be disproportionately impacted by climate change (Costello et al 2009). This is because they are often more dependent on their local environment for fuel, food and fibre, and they have a smaller diversity of income sources to protect against shocks. In addition, vulnerable people are often located in more marginal areas, which are more susceptible to natural hazard events, have poorer living conditions, and overall have fewer options available to them in the event of change. Low income areas face increased risk due to inadequate insurance, limited means to improve the thermal comfort of home[19], and less ability to purchase 'green alternatives' due to initial outlay costs. The home insulation programme does mitigate this to a certain extent.

Some elements of vulnerability are not highly visible. Gurran et al (2008), in the context of Australia 'sea-change communities' listed several social characteristics that increase their risk to

[19] It is noted that the present insulation scheme implemented by the New Zealand Government has the potential to alleviate some of this vulnerability by the provision of grants – but in some case the initial outlay may still be relatively substantial for the householder concerned.

climate change. For example, a high turnover of population can increase risk. As new residents move to risky areas, they may not be aware of potential risks or the best methods of response agreed to within the local community. Several coastal communities in Whangarei District have developed Community Response Plans to prepare for natural hazard events such as tsunami. A high turnover and summer peak population within these communities means that much more effort is required to keep residents up to date. Should an event occur, the risk level is going to increase if proportionally fewer people are aware of the emergency plans. In addition, new residents may have weaker local support networks than longer term residents, and have fewer resources available to prepare or respond in the event of a natural hazard event.

Accommodation tenure type can also have an impact; as tenants may not have the means necessary to lessen their vulnerability to risk or depend on actions by their landlord for any improvements that reduce their risk. On the other hand, landlords can have less certainty about the long term viability of present tenant arrangements, and therefore may not wish to invest large sums that may not produce a return in the longer term. In addition, international research has indicated that landlords are less likely than homeowners to rebuild following a natural hazard event, which can lead to greater displacement of communities than otherwise would happen. This displacement, in turn, can place pressure on existing unaffected housing stock, or lead to declines in local population dynamics that takes years to recover. An extreme example of this was Hurricane Katrina in New Orleans, but in New Zealand, flooding events have the potential to spark longer term decreases in population locations such as Matata in the Bay of Plenty. In Australia, some commentators are also predicting a decrease in populations of those areas affected by the 2009 Bushfires.

An older population profile is also an important consideration, as aged people are more vulnerable to health and safety impacts of disease outbreaks, storm events, and heatwaves. Proximity to critical health care may be very important. In addition, aged people may have less mobility than the general population, and could well become isolated quickly. Older people dependent on a fixed income can also be vulnerable. In the Manawatu floods, problems were encountered when evacuating aged care facilities, and a similar situation also happened in the Far North during the events of 2007. Pricing mechanisms to mitigate climate emissions though initiatives such as the Emissions Trading Scheme may have a disproportionate impact on the vulnerable sectors such as the older population on a fixed income or those with lower incomes or lower disposable incomes.

Local Context

Different settlements in Whangarei District have different characteristics associated with them including age, wealth, transportation access, etc. As part of the Sustainable futures 30/50 programme, various reports such as the Demographic Report for the Whangarei District, the Socio-economic Profile for the Whangarei District, and the forthcoming Social Report contain information and statistics that are worth considering in the context of planning for climate change and our settlements. Whilst there are expectations than many of the present natural hazard risk areas may see higher likelihoods of biophysical events happening, it is difficult to ascertain the actual impact on the magnitude or spatial scale of the change.

The following maps illustrate some of the more vulnerable populations around the district, whether through lack of access to resources or age structure. The three types of maps used for this process include: areas with low household income ($30,000 or less) and natural hazards; Deprivation Index[20] and natural hazards; and the final one is mapping populations where the median age is 45 or more (these locations would have a high proportion of older people).

[20] The Deprivation Index is also used by the health profession as part of determining priorities. It is based on data that include such variables as: *Income* - aged 18–64 years receiving a means-tested benefit; *Income* - living in households with equivalised income below an income threshold, *Owned home* - not living in own home; *Support* - aged under 65 years living in a single-parent family, *Employment* - aged 18–64 years and unemployed; *Qualifications* - aged 18–64 years and without any qualifications; *Living space* - living in households below an equivalised bedroom occupancy threshold; *Communication* - with no access to a telephone, *Transport* - with no access to a car.

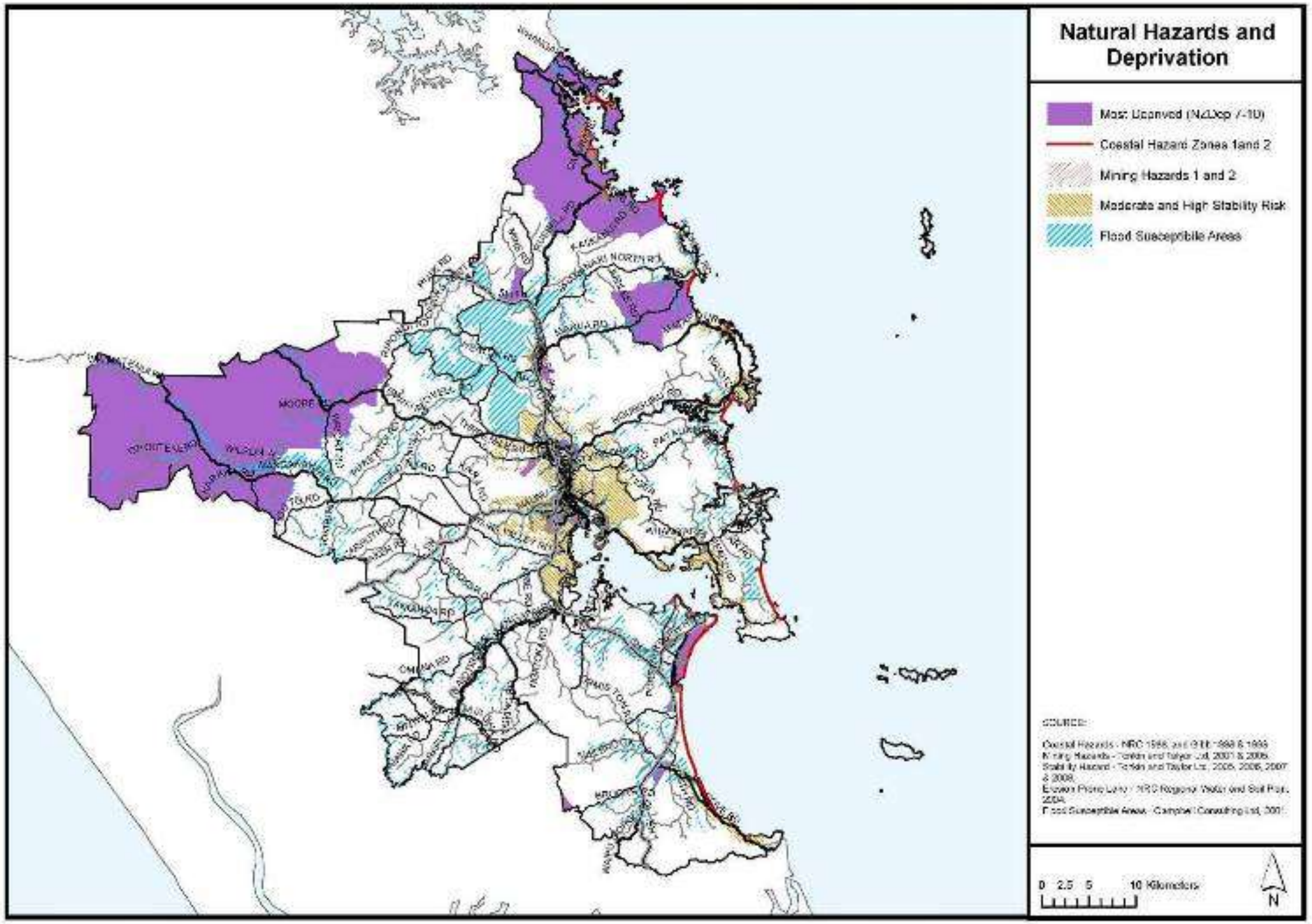


Figure 21 Map of Key Natural Hazards and Deprivation Index - Whangarei District

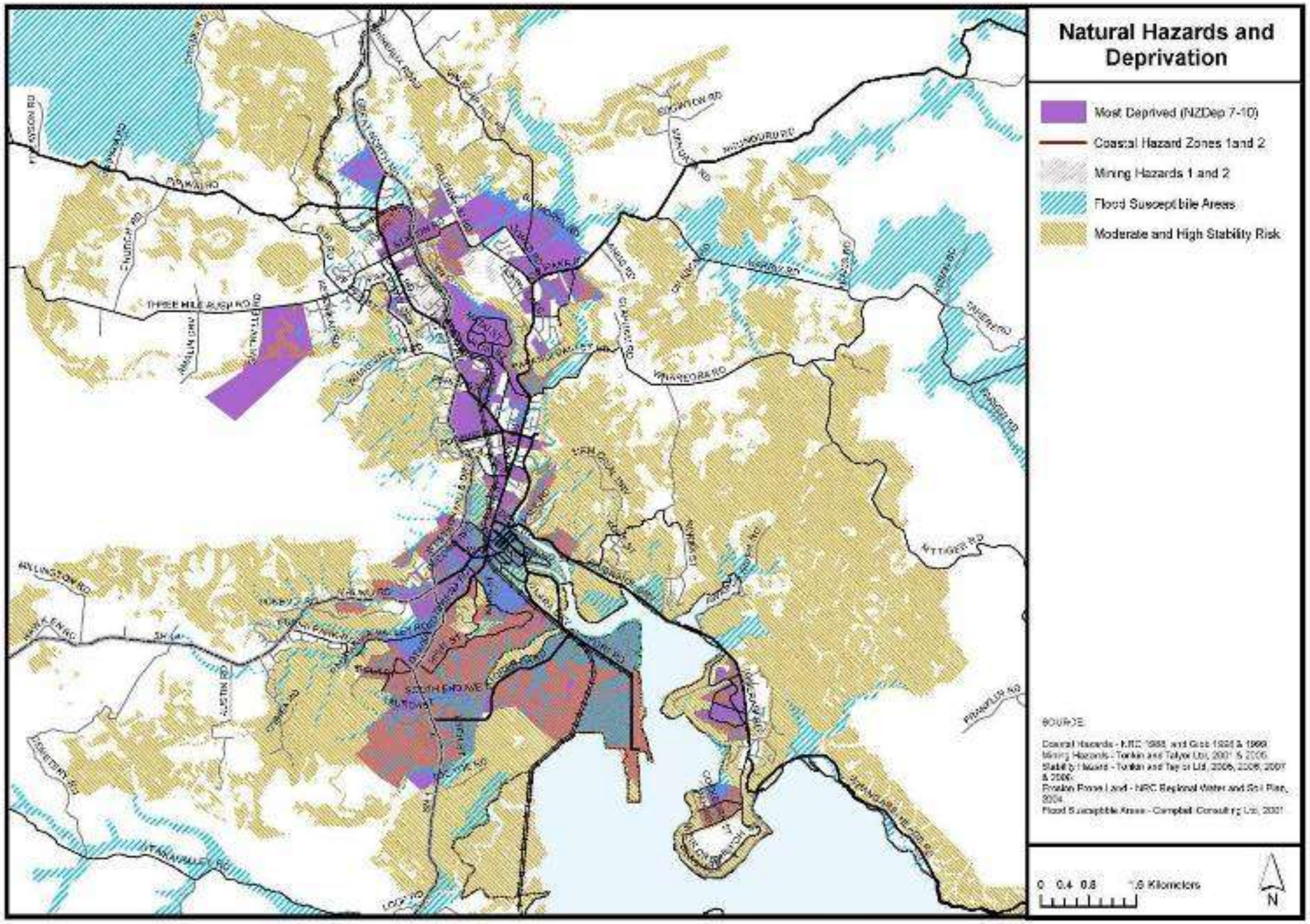


Figure 22: Map of Key Natural Hazards and Deprivation Index - Whangarei City.

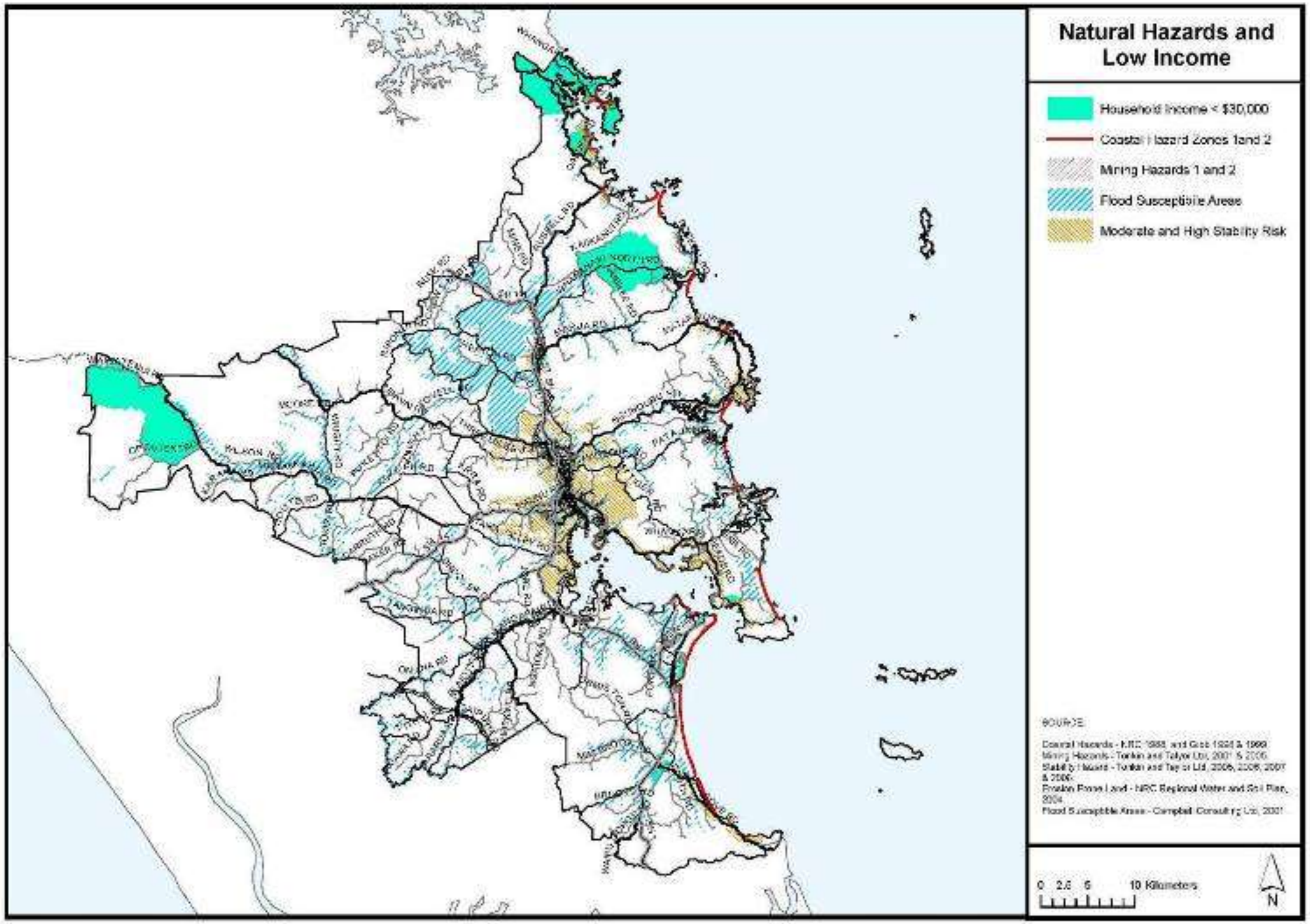


Figure 23 Map of Key Natural Hazards and Low Income Households – Whangarei District

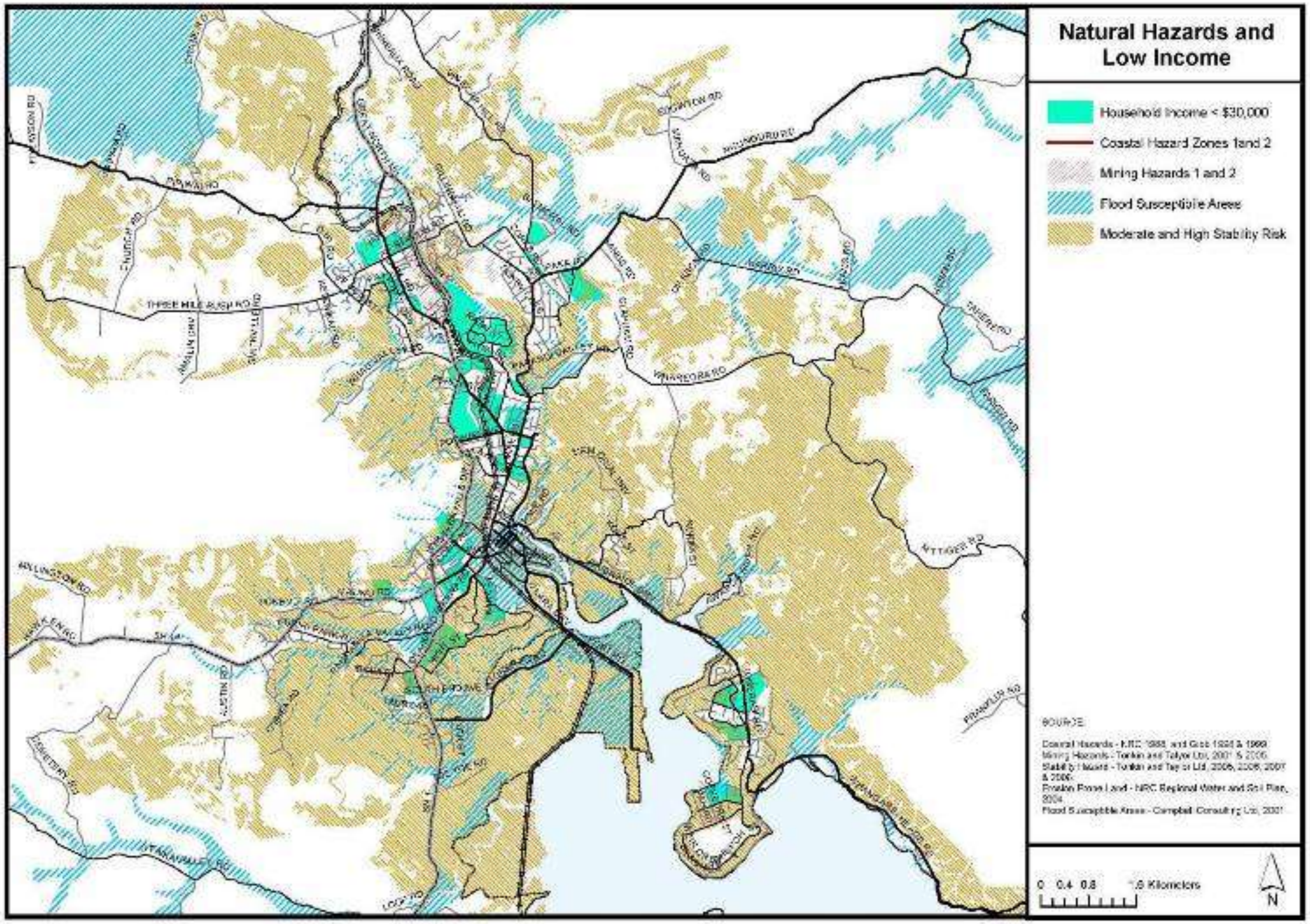


Figure 24: Map of Key Natural Hazards and Low Income Households – Whangarei City

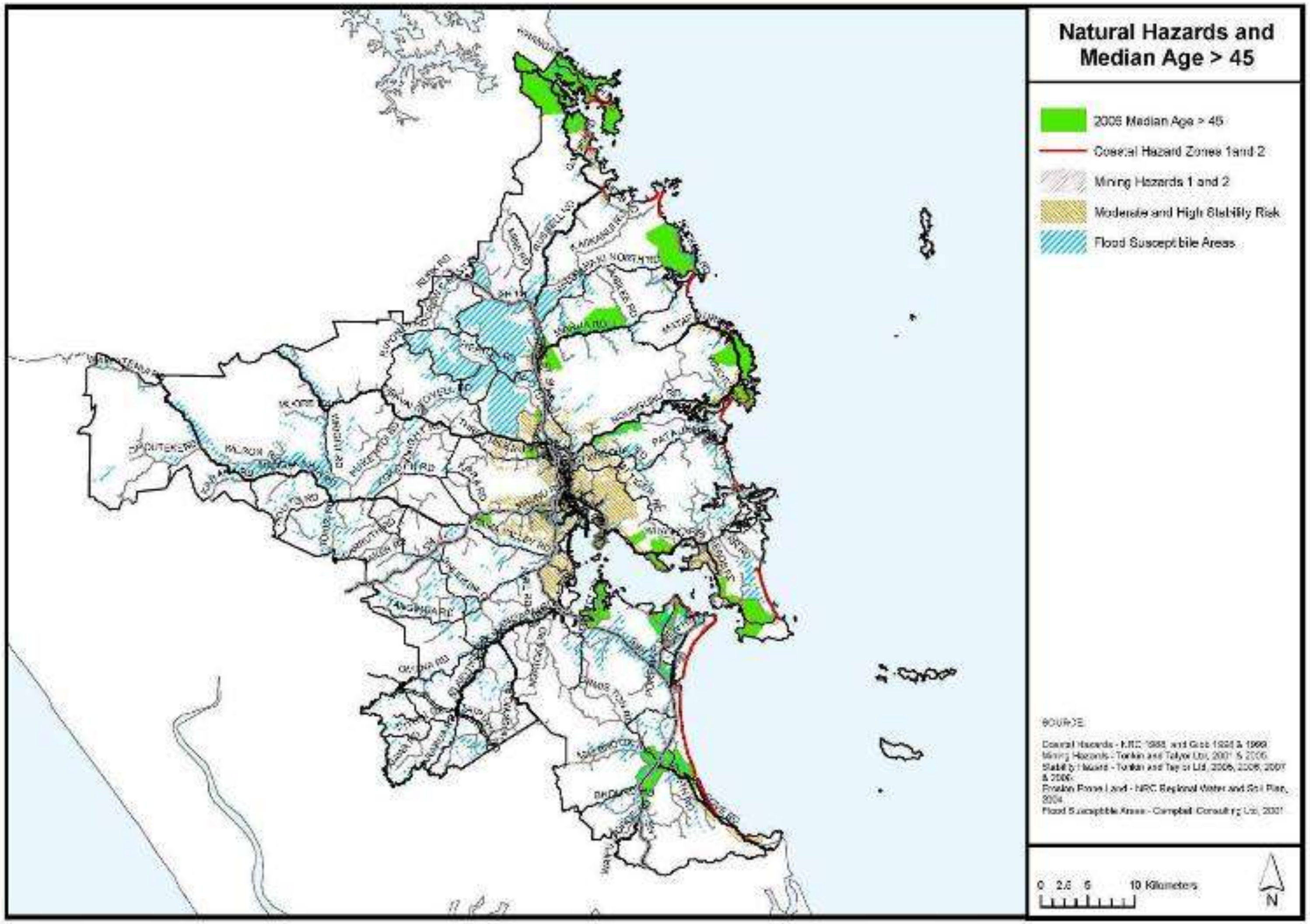


Figure 25: Map of Key Natural Hazards and Locations where Median Age is above 45 – Whangarei District

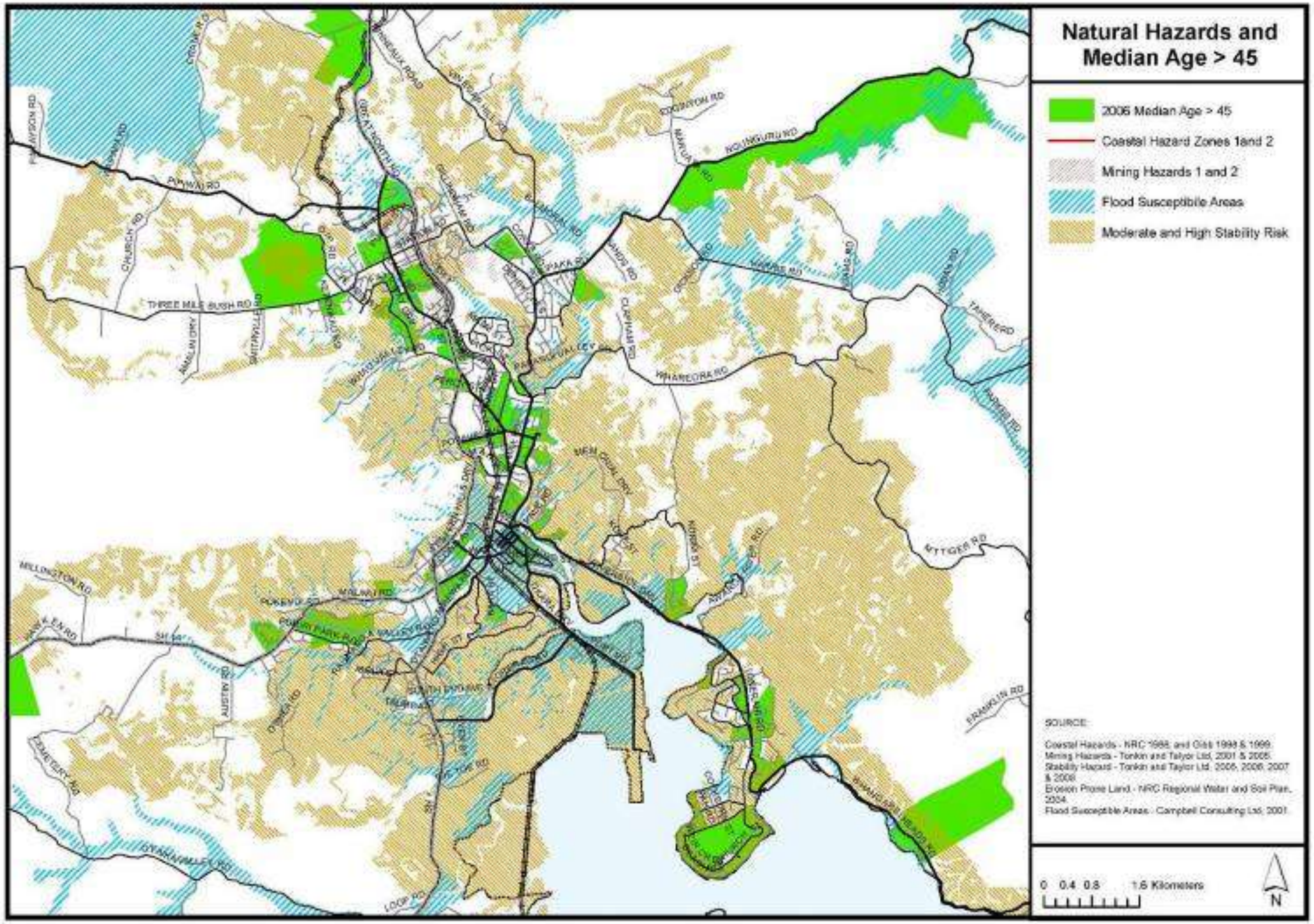


Figure 26: Map of Key Natural Hazards and Locations where Median Age is above 45 – Whangarei City

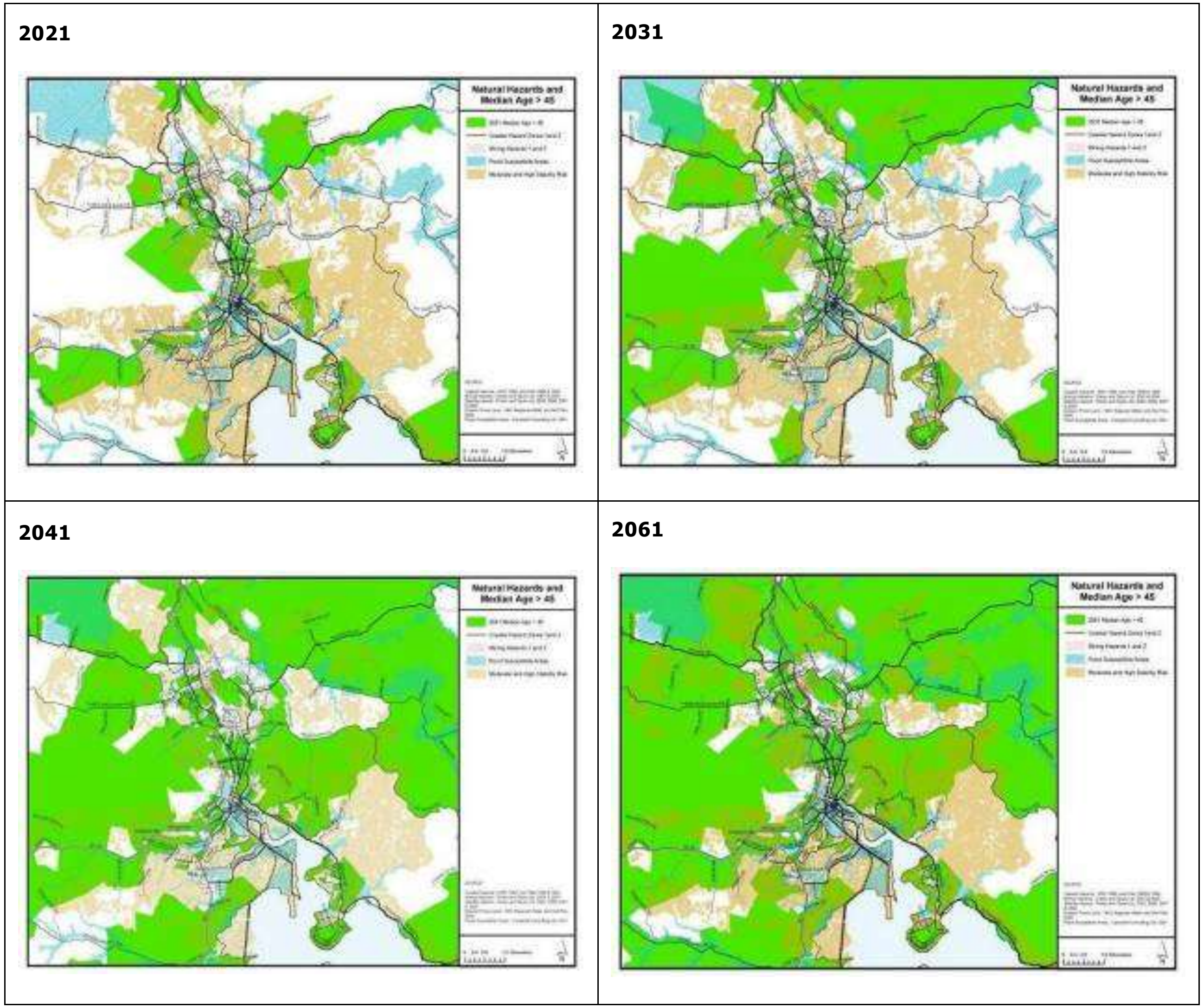


Figure 27: Time Series Contrasting Aging Population and Key Natural Hazards - Whangarei City.

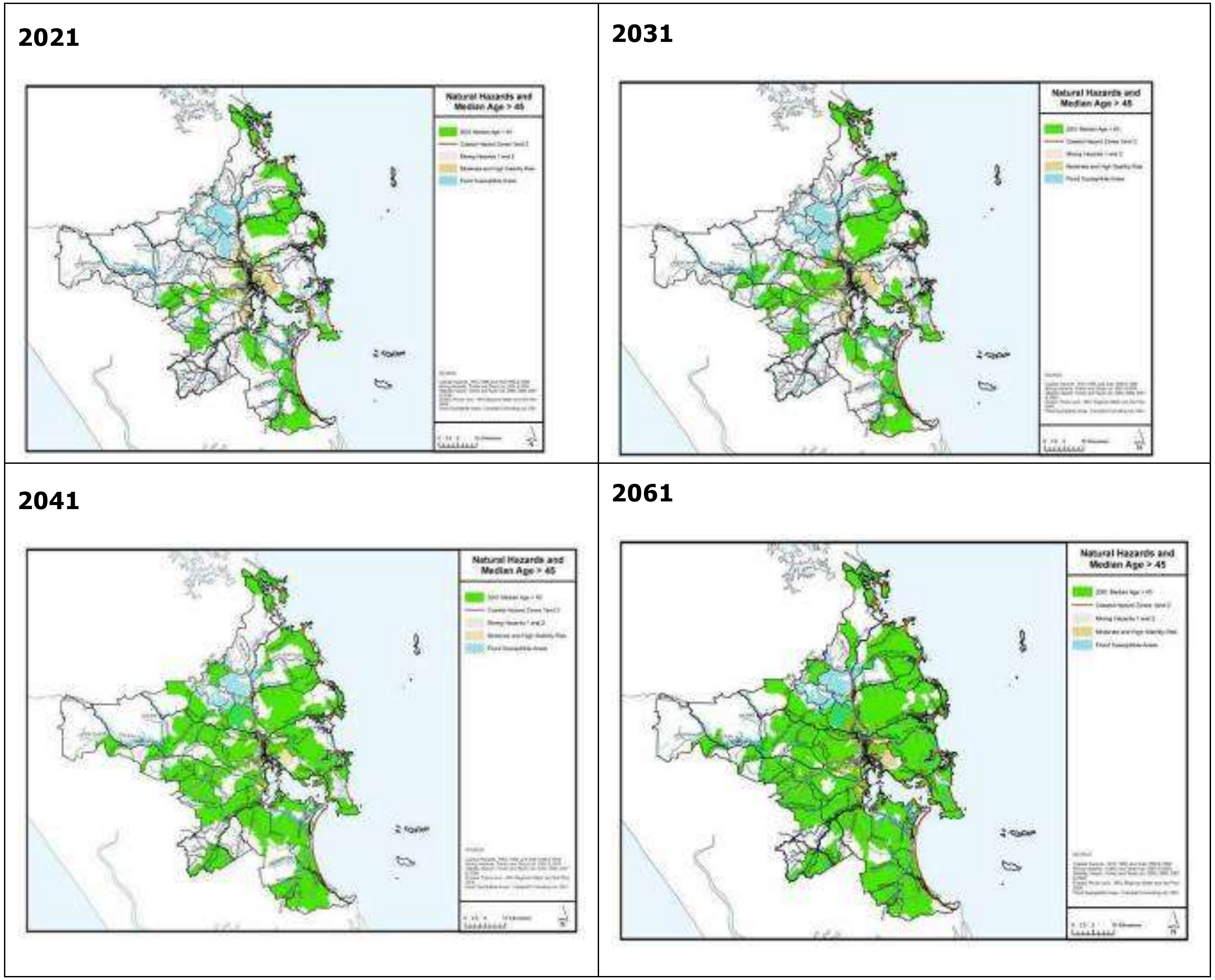


Figure 28: Times Series Contrasting Aging Population and Key Natural Hazards – Whangarei District

Figures 21 illustrates that high levels of deprivation exist in some parts of the district, but few of these areas are located in areas with flood susceptibility. Inside Whangarei City (Figure 22), more areas with a high deprivation index are located in areas with hazard risk of both flood susceptibility or stability risk. A similar situation holds in regards to low household income and natural hazards in Figures 23 & 24, but these are not exactly the same locations as the deprivation index. Figures 25 & 26 maps age data against natural hazards, identifying those locations with a median age of 45 or more as being possible locations of increased vulnerability. Some vulnerable areas identified on these maps are similar to both the deprivation index data and the low household income data, but other locations emerge, such as Waipu. Figures 27 & 28 are projections into the future, which identify, based on current information, those areas within Whangarei District that are projected to have median ages of 45 or more over time. As both series indicate, as the population of Whangarei District becomes progressively aged, more settlements could be considered vulnerable to natural hazards. Eventually, by 2061, most parts of the district have a median age of 45 or more, although the areas that don't have a median age of 45 or more in 2061 are areas that are presently vulnerable. In other words, as Whangarei District becomes increasingly vulnerable to biophysical natural hazard events and extreme weather resulting from climate change, the increasingly aged population will add to that vulnerability, and the ability to respond to issues will reduce.

3.7 Case Study Area - Waipu

Presently, Northland Regional Council (NRC) is undertaking the Priority Rivers Flood Risk Reduction Project, on 27 catchments around Northland, of which seven are located within Whangarei District. As part of this process, NRC are carrying out detailed survey of the catchments, producing flood hazard maps, assessing likely consequences to local communities, and eventually producing flood risk reduction plans. As part of best practice, factors such as climate change influence on precipitation changes are normally included within modelling. Whangarei District recently received a similar type of report on the Waipu River, *Waipu Stormwater Catchment Management Plan (AWT 2009)*. This was presented to the Waipu community in October 2009.

This report was to evaluate present and future flooding issues within the catchment. This catchment (2,200 ha) has seen extensive deforestation, including riparian vegetation, that has lead to the potential for higher peak flows and flood levels, stream erosion and sedimentation in the catchment. Present urban areas, such as Waipu, are located on low-lying land. Higher sea levels and different precipitation patterns are expected to compound this present flooding susceptibility. Waipu itself is situated at the point where the main tributaries of the river system meet. Much of the low-lying area is also poor draining and will retain water for longer periods.

This report contains a variety of maps and diagrams, and also includes some modelling of the impacts of sea level rise and its contribution to inland inundation.

The reports and maps were developed using the methods and parameters outlined in the climate change document 'Climate Change Effects and Impacts Assessment: A Guide for Local Government in New Zealand', and would assume mid range estimates for climate change. This lead to the following precipitation projections

Annnual Return Interval	Mm/ 5 mins	Mm/hr
5 Year ARI Existing	5.9	70.5
5 Year ARI Future	7.3	87.4
100 Year ARI Existing	12.1	145.2
100 Year ARI Future	15.0	180

Table 6 Rainfall Patterns for Waipu Catchment

The projected impacts of these increased extreme rainfall patterns on the flooding profile of the Waipu catchment are illustrated in the following (Figure 26) two flooding maps that compare the present risk versus the future risk.

The final outcome of this research was that with climate change exacerbation, flooding events in Waipu could be very significant, especially around the township. This would be compounded by the vulnerability of the population based on demographics. To reduce this risk, there are some significant costs involved in building new infrastructure, whether hard (as in pipes and drains) or soft. The recommended approach in this report considered riparian restoration to be the most effective of potential mitigation methods that could reduce peak flows. However, decisions on any particular option have not yet been made. The following Figure (26) compares and contrasts the likely impact of a large scale rain events (1/100 Present and a 1/100 Future with climate change projections incorporated) on flooding in the Waipu Catchment. The colour show the intensity in terms of the floodwater depth.

Other larger settlements around the district may see similar increases in their exposure to inundation, if similar patterns in rainfall intensity occur, e.g. increased precipitation extremes, and may require some means of mitigation to reduce risk.

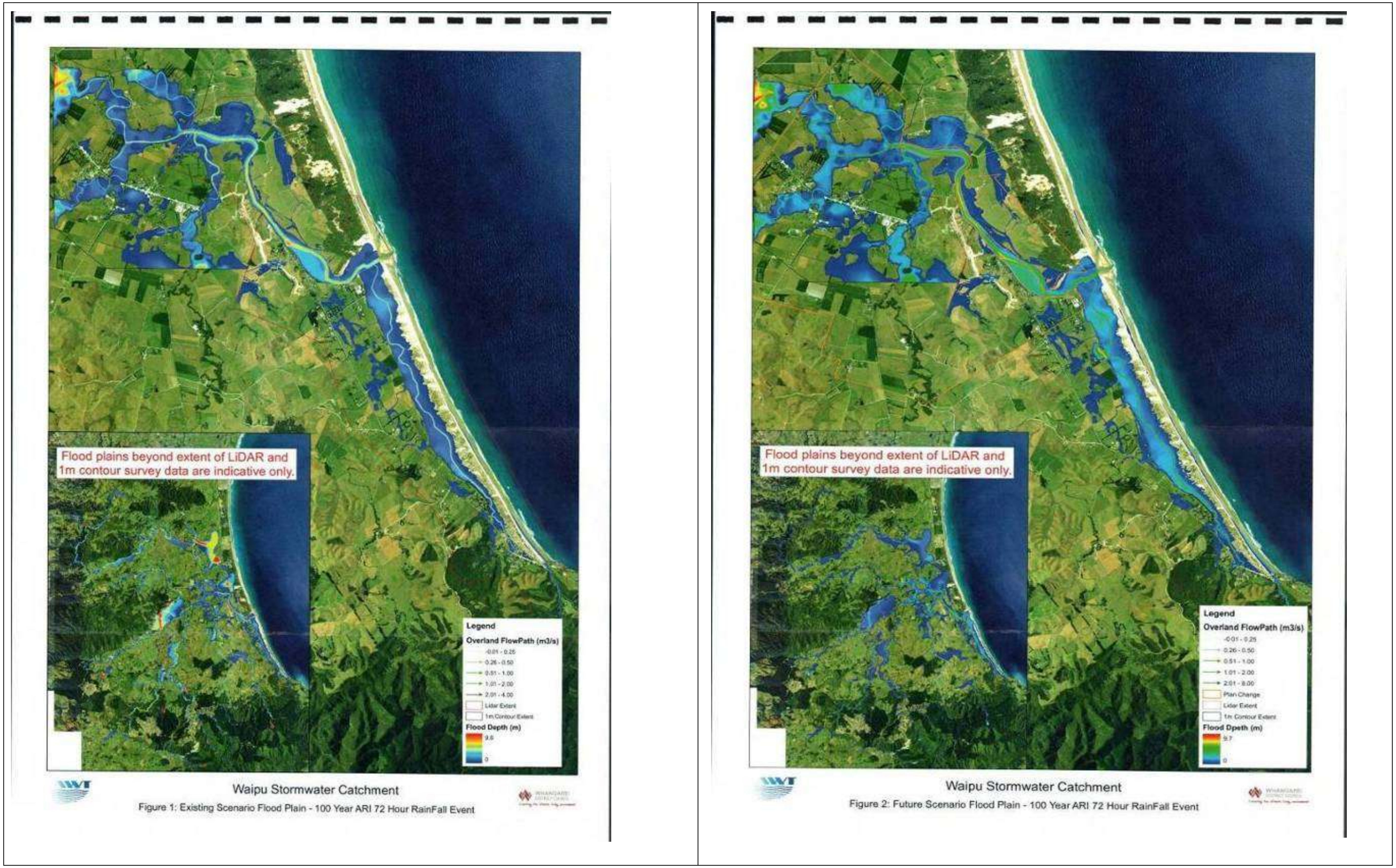
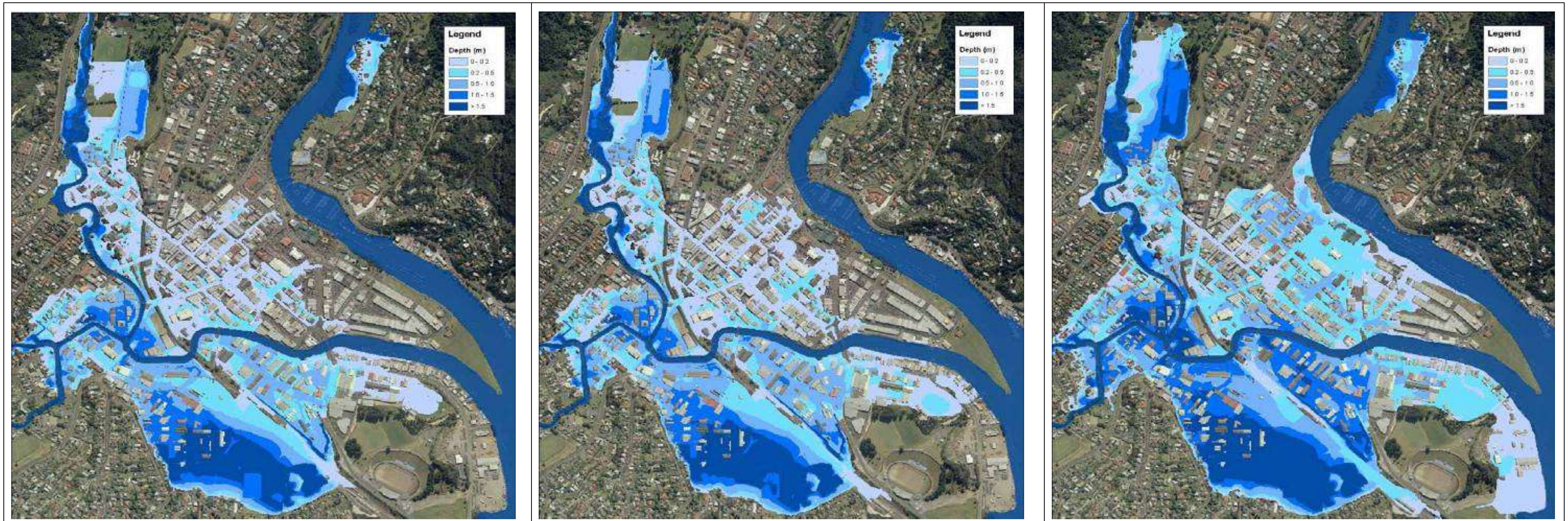


Figure 29 Maps Illustrating Changes in Projected Flood levels for Waipu. Please note that paler blue and dark green are deeper flows. Sourced from AWT (2009)

3.8 Case Study Area – CBD

In 2006, URS completed a flood damage assessment for the Whangarei Central Business District (CBD) as part of developing the Whangarei CBD Floodplain Management Strategy. This research included an assessment of the impacts of climate change on flooding in the CBD. Overall, all climate change scenarios projected high peak flood levels, and greater flooding extents, and that flooding events would occur more frequently. The conclusion, at that time, is that the damages resulting from a 100 Annual Return Interval (ARI) flood event at present would be approximately $69 million. A 100 ARI in the future, where extreme precipitation has been augmented by climate change impacts, would increase projected costs to between $84-150m. This equates to annual damage projections in the CBD in the order of 5.6 million at present, but would equate to annual damage projections in the order of 8-22 million per annum in the future. The first example would affect 600 properties (425 building flooded), rising to 900 (870 buildings flooded) under climate change scenarios. Both estimates will be regarded as too low if floodwater cannot discharge to the sea, due to driving onshore waves that create a 'plug' in the harbour entrance. More details are available in the document (URS 2006) but following figure series of maps (27) sourced from that report illustrate the difference when climate change projections are included in future flooding event scenarios. As the illustrations indicate, incorporating climate change projections into modelling of flooding events makes a significant difference to both the potential flooding depth, but also the area that is likely to flood. This is evident around the eastern parts of the CBD, close to the area currently used for extensive light industry and similar services.



100-year ARI event, existing scenario.

100-year ARI event, under LOW climate change scenario.

100-year ARI event, under HIGH climate change scenario

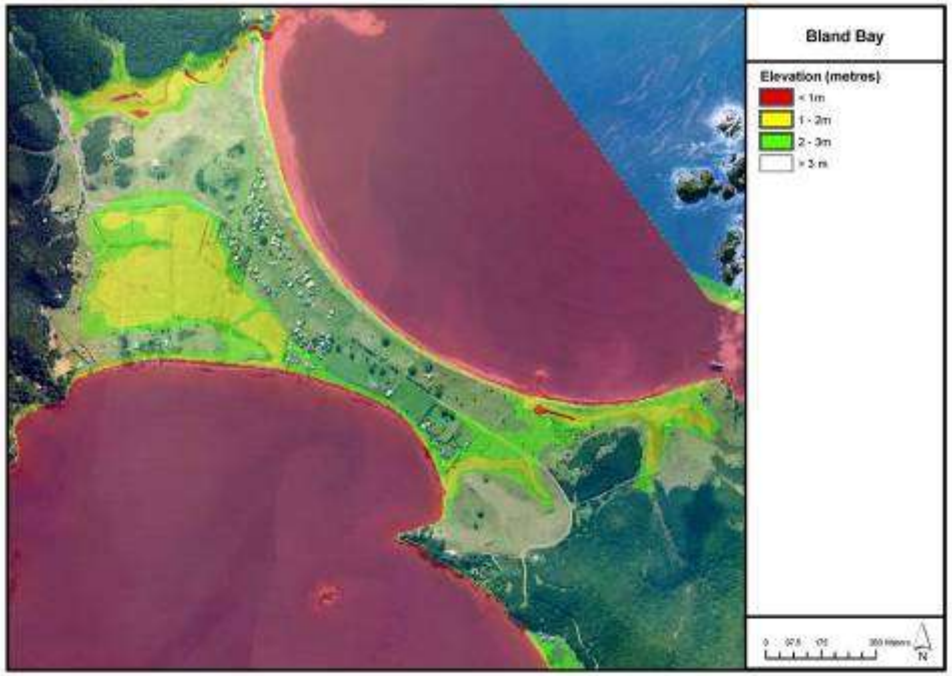
Figure 30 Flood Map Comparisons: Present, Future Low and Future High Scenarios. Sourced from URS 2006

3.9 Case Study Areas – Northern Coasts Elevation above Mean High Water Spring

The three previous case studies are based upon specific research that investigated undertaken the impacts of climate change on key locations in the district: CBD, Waipu, and Bream Bay, including Marsden Point and One Tree Point. Work has gone into the development of coastal hazard lines (for the District Plan) for the entire coast that make allowances for climate change. These lines can be found in the Whangarei District Council District Plan, and also the Natural Hazards Constraints Report for Sustainable Futures 30/50. The coastal hazard lines indicate those areas along the coast that may be subject to inundation from high tides and storm surges or coastal erosion. These were initially prepared using some of the projections from the IPCC report in 1996.

Little specific recent research has been undertaken to investigate potential impacts of climate change on the settlements that occur between Bland Bay and the northern coastline of the Whangarei harbour. The following series of maps are based solely upon the elevation of land above mean high water spring, and do not include calculations for the impact of storm surges, king tides, coastal erosion and so on. As such, they are relatively crude measure of the impacts of climate change on these settlements. Despite this, they are useful when understanding the broad risks and vulnerability associated with some settlement to climate change impacts and potentially tsunami. In general terms, most buildings or dwellings appear to be above 3m in elevation, but in many settlements, some access points can be quite low.

In terms of the following maps, colours overlay has been used to indicate the elevation of areas above mean high water spring. In the case of the red colour overlay, it is the intense red along the boundary between land and sea that is of importance, rather than the bays themselves. In the case of the green overlay, the colour on the map appears lighter than the key. In all maps, if there is no overlay, then the elevation is above 3m.



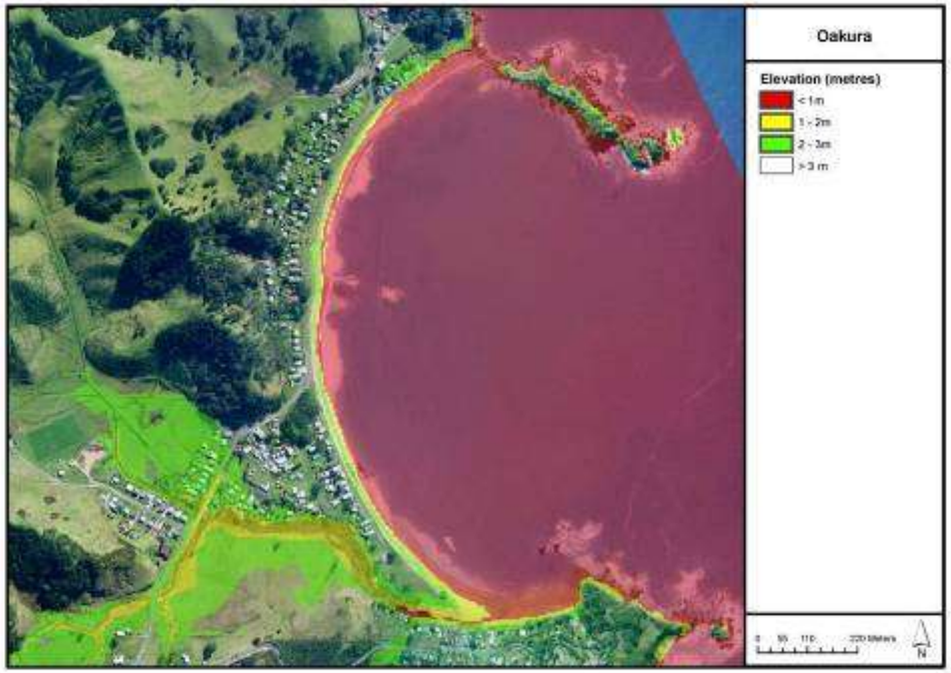


Figure 31 Elevation above MHWS Bland Bay

Low-lying area lie to either side of the main bach settlement at Bland Bay, but most dwellings are located above 3 metres in height. However, the main road into the settlements crosses some low-lying areas, and could be at risk.

Figure 32 Elevation above MHWS Oakura

Like Bland Bay, the bulk of the settlement is located above 3 metres, but the main road into the settlement is located on low-lying land that follows a stream in the south of Oakura. Many dwellings are located between 2 and 3 metres above mean high water spring.

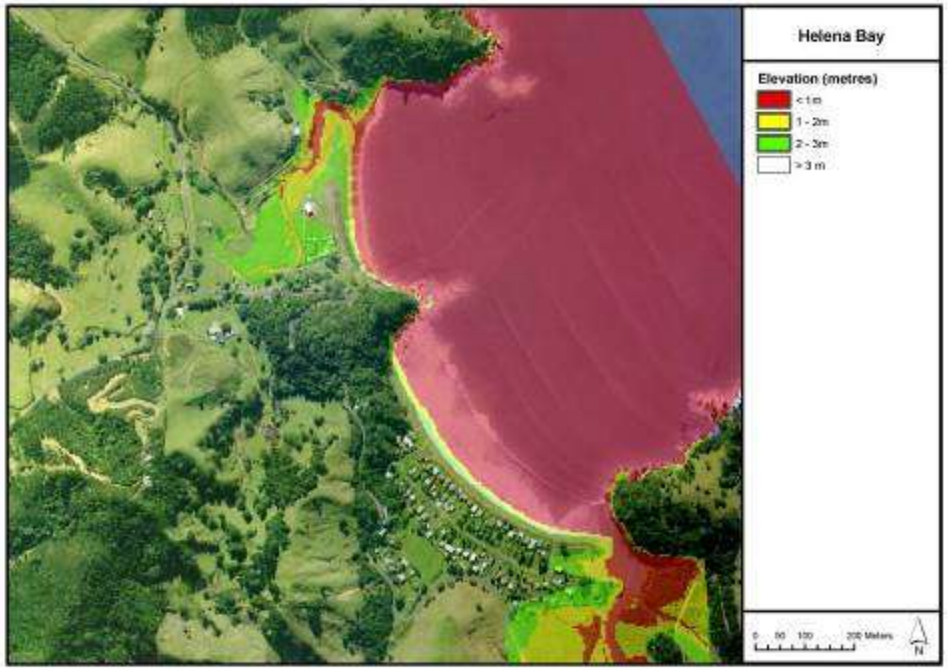


Figure 33 Elevation above MHWS Helena/Teal Bay

Most of the dwellings within Helena and Teal Bays are at least 3 metres above MHWS, although the dwellings in close proximity to the Teal Bay Estuary on the right hand of the picture are between 2 and 3 metres above MHWS.

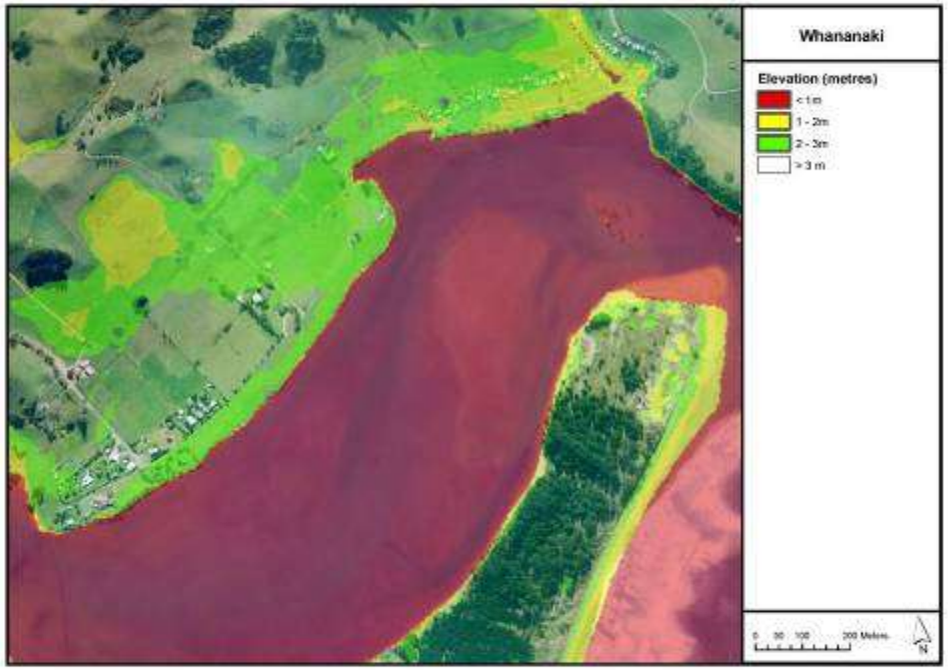
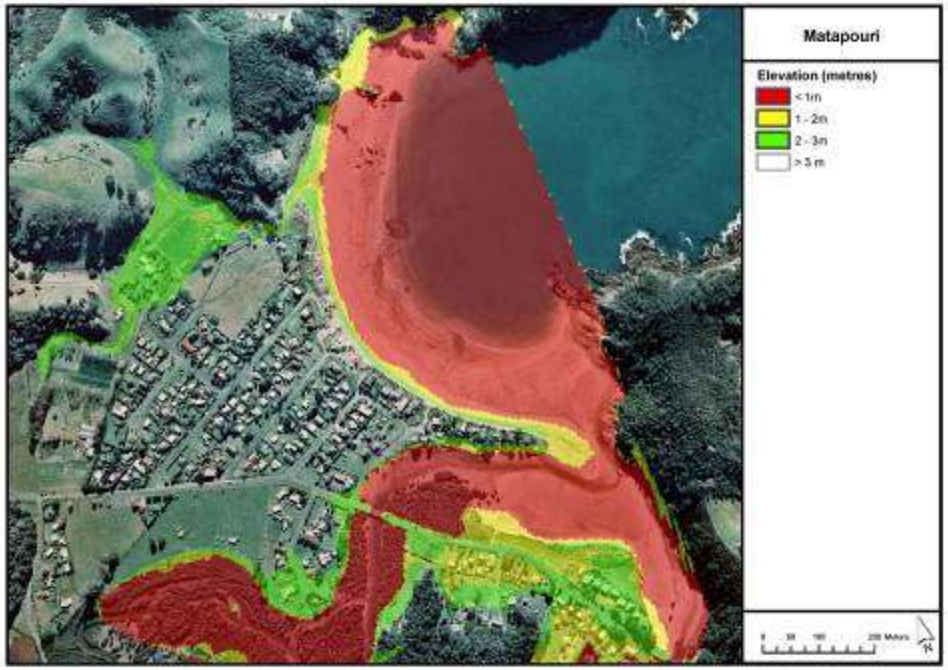


Figure 34 Elevation above MHWS Whananaki

Much of Whananaki North is relatively low-lying, including by the main bach settlement before the rise over to Rockells Bay. Several sections of the road are also low-lying and are vulnerable. Of note is land to north of the road that is lower than the land adjacent to the coast.



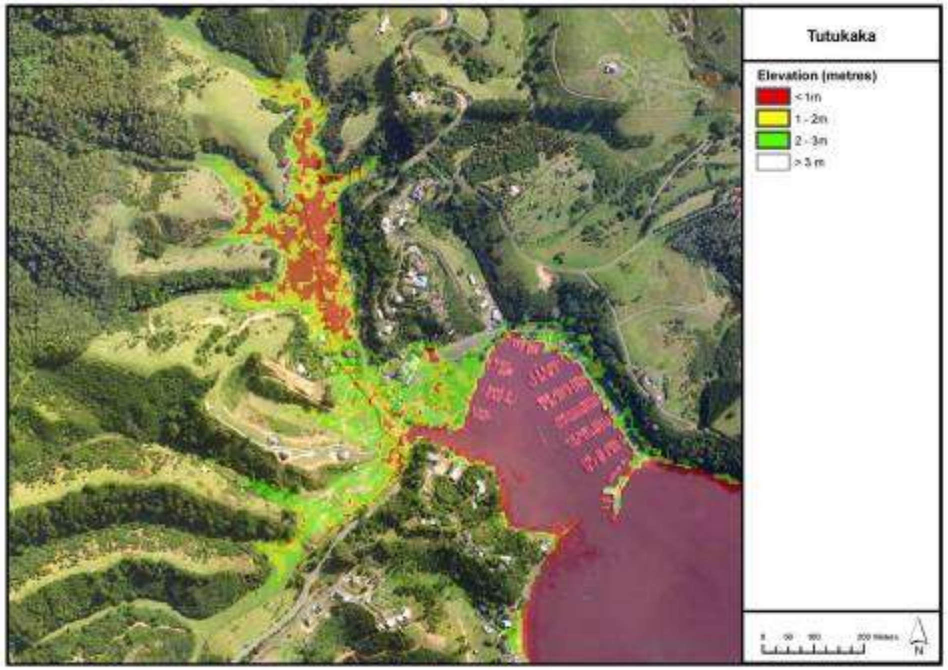


Figure 35 Elevation above MHWS Matapouri

Parts of Matapouri before the bridge are very low-lying (between 1 and 2 metres above MHWS) along with the road section, whereas the bulk of the settlement across the bridge is at least 3 metres above MHWS.

Figure 36 elevation above MHWS Tutukaka

Few residential dwellings are below an elevation of 3 metres above MHWS, but the services (including shops) located near the stream or in the basin are relatively low-lying. In addition, the road runs through an extremely low-lying section that is vulnerable.

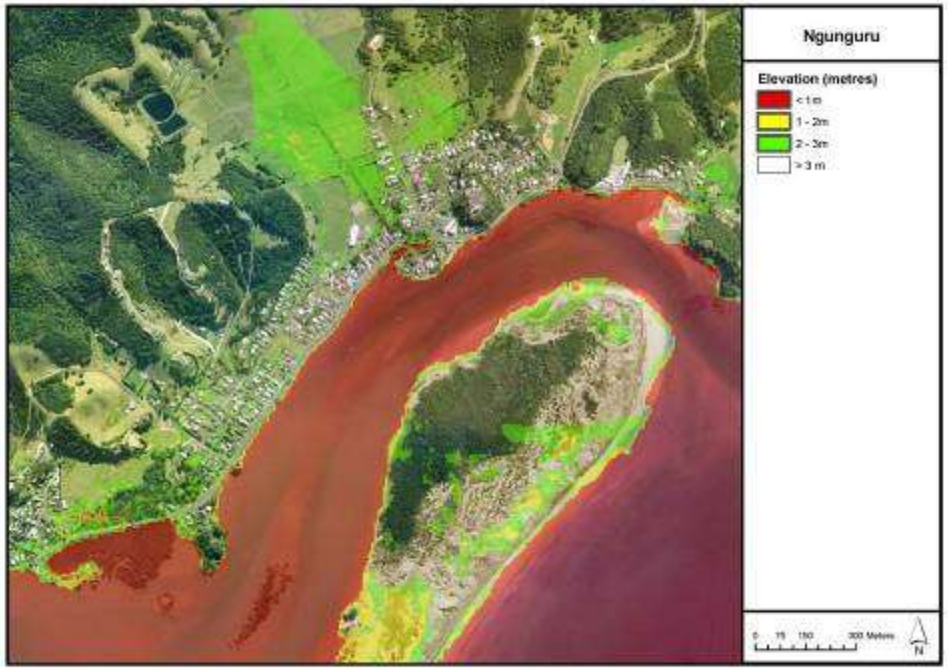


Figure 37 Elevation above MHWS Ngunguru

Most of Ngunguru around the main settlement area is located above 3 metres above MHWS, although a relatively low-lying section is located in the north. However, part of the access into Ngunguru along the causeway would be vulnerable.

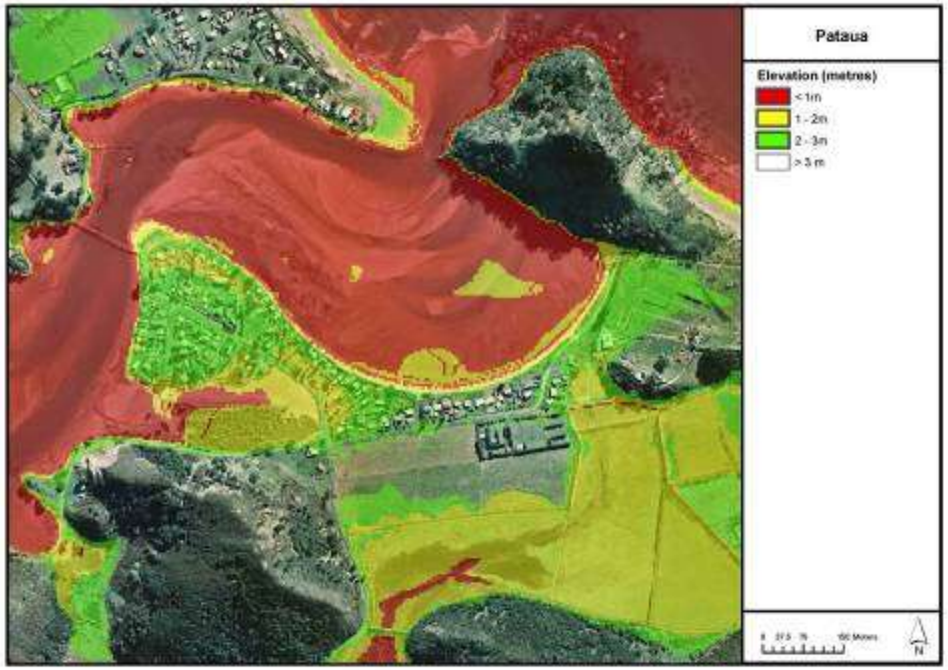


Figure 38 Elevation Above MHWS Pataua

Pataua South has extensive areas of low-lying areas, some of which contain dwellings. Roads to both Pataua North and South pass through extremely low-lying areas and are vulnerable.

4 Climate Change Responses

Addressing the impacts of climate change will require response from government, business and individuals. Government plays a primary role in providing the playing field, as well as the rules of the game. Each governmental sector has a role, whether central, regional or territorial. (Greenaway & Carswell 2009). Over many years, New Zealand policy environment for climate change has been lacking in certainty. Whilst economic incentives and disincentives have always been part of the expected policy environment, at different stage of the process different tools such as carbon taxes and a carbon market have been preferred. All options have costs and benefits associated with them. At present, the use of carbon credits and an Emissions Trading Scheme is the preferred option.

Local government has a range of functions and responsibilities relating to climate change under various pieces of legislation[21]. Regional and district councils have an important role in both mitigation and reduction of carbon emissions, both in New Zealand and around the world. For example, in New Zealand, 34 councils affiliated with the Communities for Climate Protection Programme carried out deliberate actions to reduce carbon emissions by 133000 $CO_{2\text{-}e}$ per annum, and this rate was growing over time as different councils were at different stages of the process (ICLEI 2009). Actions ranged from building audits, lighting upgrades and street lighting management, different approaches to managing water and sewerage, and so on. In addition, there are various central government policies and strategies relating to agriculture, transport, energy, emergency management and tourism development[22] that all note the need to take account of climate change in planning. However, for the purpose of this report, only the key documents, policies, or mechanisms to address climate change are mentioned.

4.1 Emissions Trading Scheme

Emissions trading is regarded as a key means of reducing carbon emissions around the world, and is expected be the major component of future climate change mitigation strategies, with many countries looking to achieve emissions reductions using economic incentives and market forces. New Zealand has opted to utilise the emission trading approach, following earlier investigations into, and the eventually discard of, tax disincentives. The premise of the Emissions Trading Scheme is that private firms have the best knowledge of their operations and where savings can be made. Should price signals be given (through carbon charging), then

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[21] A good reference for the full list of natural hazard provisions in various pieces of legislation can be found in Tonkin and Taylor, (2006). Natural Hazard Management: Research Report. Found on http://www.qualityplanning.org.nz/qp-research/natural-hazards-aug06/natural-hazards-aug06.pdf. This document also has a comprehensive section on risk management.

[22] http://www.nztourismstrategy.com/files/NZTS2015%20final.pdf

firms often know the most cost-effective method of reducing their carbon footprint according to their needs and capacity.

No matter what option the New Zealand Government chooses to take, there is a high risk that the economy will be impacted in some way shape or form. It could be the loss of income through protectionist practices of trading partners; it could be loss of trading partners' discretionary income to purchase relative luxuries such as New Zealand milk and cheese, or it can be local direct costs. New Zealand, whilst having a small net carbon footprint relative to other countries, has the fourth highest carbon emissions per capita (Metcalfe et al 2009).

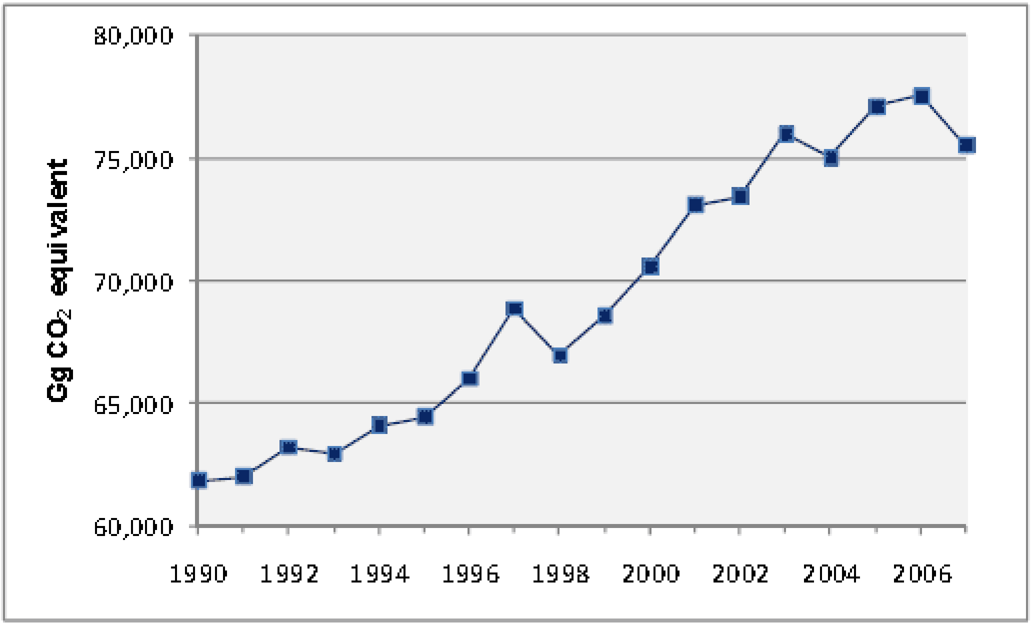

Figure 35: Trends of Carbon Dioxide Equivalent Emissions in New Zealand. (Sourced from MFE 2009a, p16)

As figure 35 illustrates, emissions within New Zealand have been rising since 1990. Figure 36 shows where most of the growth in emissions has occurred in terms of key sectros and figure 37 illustrates the actual amounts of emissions per key sector.

In responding to the Emissions Trading scheme, Whangarei District Council is in a difficult situation. On one hand, it is recognised that the potential costs involved may present an additional burden on residents of our district in terms of additional costs in of energy bills, costs associated with the new landfill in development, and impacts on spatial planning. However, it is recognised that using economic instruments to promote better behaviour can be useful in fermenting a transition to a less carbon intensive future in our communities.

Responding to mitigation policies (such as emissions trading) is the role of central government, but is something that Whangarei District Council needs to be cognizant of, given that we will see increases in costs for our infrastructure development, maintenance, and use, and that of the wider community. Whangarei District would expect that the whole exercise should be revenue-neutral, with any additional revenue garnered from the New Zealand Government as brokers being re-circulated in such a way as to help communities better balance their carbon profile, and incentivise actions associated with adaptation. As an outlying provincial centre, long dependant on primary production and having a relatively poorer socio-economic profile than other parts of New Zealand, Whangarei District and Northland as a whole may find itself disproportionally impacted by the Emission Trading Scheme, depending on the final design.

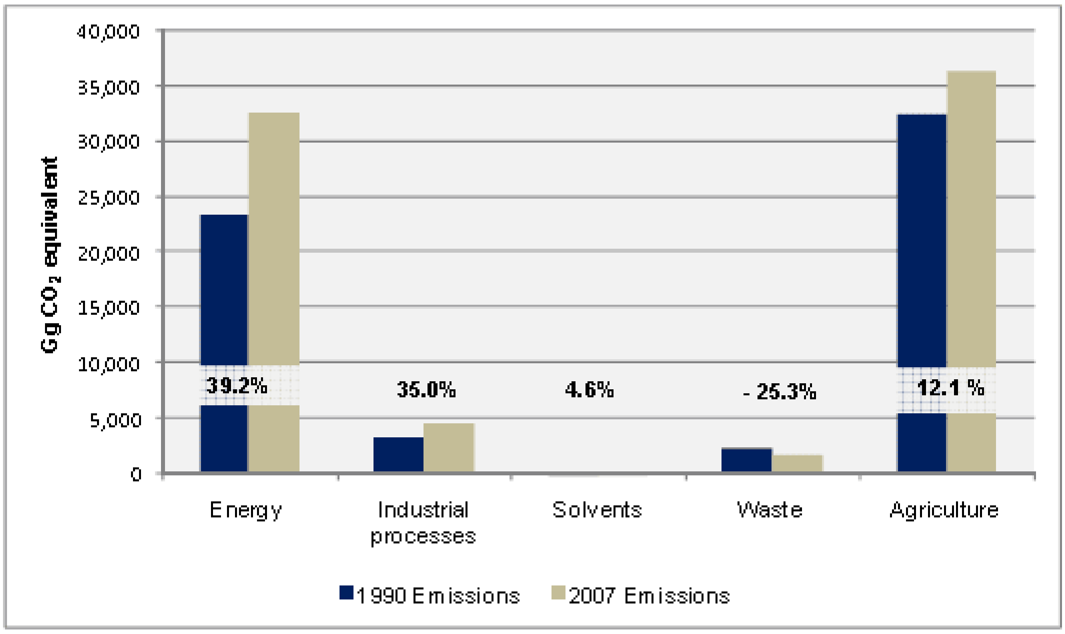

Figure 36: Changes in Emission per Sector over time. (Sourced from MFE 2009a, p22)

However, dependant on the final scheme, Northland may also see relatively disproportionate benefits and opportunities arising from the ETS, given that many of the most cost-efficient means of addressing climate change mitigation are directly concerned with revaluing the importance of marginal landscapes. For example, in a report *"Rural Australia Providing Climate Solutions: A Preliminary Report to the Agricultural Alliance of Climate Change"* , it was recognised that the rural community can benefit very strongly from emissions trading, through the provision of offsets, renewable energy possibilities, localised demand for local products and so on. However, the actual policy setting, in terms of timing, pricing, primary beneficiaries, and enabling mechanisms would influence the net impact. Whilst it is recognised that rural Australia has different drivers and a different structure to that in Whangarei, it does indicate that rural Northland can benefit but will need guidance in achieving this.

As an area quite dependant on a continuing role for primary products, it is also worth further commenting on the notion that agriculture will be incorporated into international emissions policy. The arguments for agriculture's inclusion in New Zealand is based on the high carbon emissions component of the national emissions profile (approximately 48%). We are aware that many are against the inclusion of food-production in any sort of emissions trading, citing food shortages across the globe as being the main argument for non-inclusion.

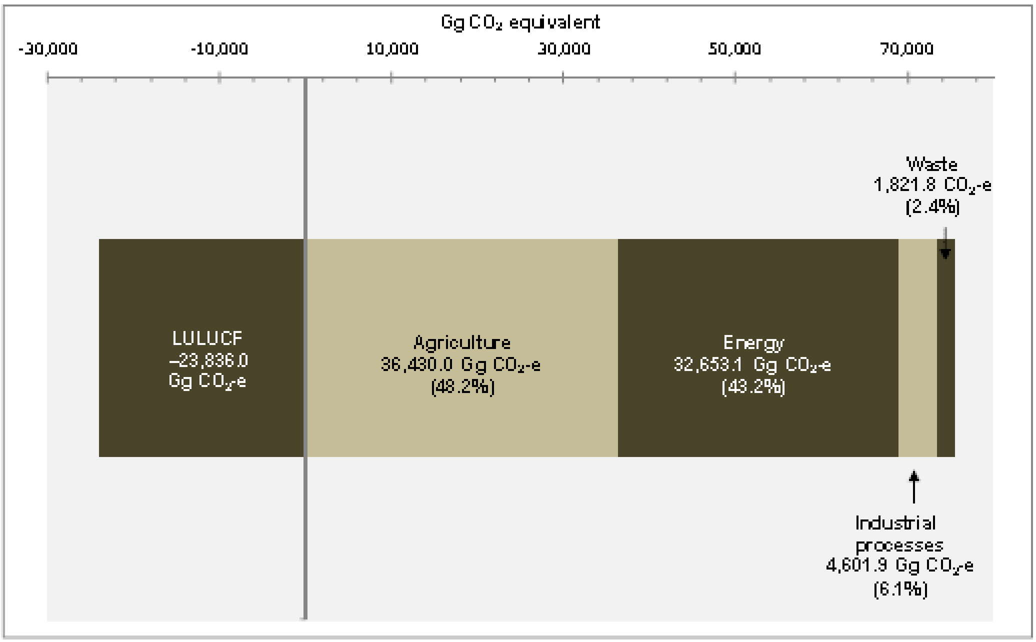

Figure 37: Break down of Key Sectors Emissions. Sourced from MFE 2009a, p.21) (Please note that the LULUCF refers to Land Use, Land Use Change, and Forestry).

It is also noted that the production of similar types of food overseas (such as in the United States) are highly energy intensive enterprises, and New Zealand is more efficient in producing these goods. Given the small population size, and the amount of good land available, some of which is well watered, New Zealand is the right place to produce this type of product, especially compared with areas with less significant resources of per-capita agricultural land, water endowments, and large local population. New Zealand does use high levels of fertilizers (including transportation of raw ingredients from the main sources Saudi Arabia, Canada, Morocco and Qatar[23]), whose production does requires much fossil fuels. Any policy that addresses the production of food is a fine balancing act between these factors.

It is recognised that costs arising from mitigating carbon emissions will impact on the most marginal segments of dairying and other primary industries, where very heavy level of external inputs are presently required and in this regard some parts of Northland would qualify as being marginal. With this in mind, there may need to be significant incentives to enable a transition to less carbon intensive forms of primary production. Incentives to ensure that transformation of primary produce into value added products is a serious option for an area such as Northland.

[23] MFAT Trade and Statistics

Incentives could include targeted adaptation programmes and research that enable primary production to continue, especially in subtropical conditions. It is recognised that the Centre for Agricultural Greenhouse Gas Research announced by Government as one part of the process, but given that Northland will see be seen to be something of a 'canary in the coal mine' in terms of future primary production conditions, there will be value in setting up adaptation programmes in Northland that also addresses transition to low carbon economies.

With the high level of growth in carbon emissions, there is ongoing discussion over the final form of the Emissions Trading Scheme in New Zealand, and it is likely that the final form will change after the completion of this report. However, there is some value in detailing out some of the key points of the scheme, in order to assess the likely costs within Whangarei District. The Emissions Trading Scheme covers the following sectors of the economy: forestry, transport fuels, electricity production, industrial processes, synthetic gases, agriculture, and waste, all of which enter the market at different stages.

Overall, the evidence indicates that the emissions target needs to be robust enough to give us strong bargaining ability in the future, and perhaps get a 'premium price' from the market for New Zealand emissions whose quality chain of evidence can be trusted. However, the policy setting needs to be structured so that most of the costs arsing from emissions are re-circulated as opportunities within the New Zealand economy. This will often mean opportunities in terms of primary production across Northland.

The key points of this are:

Sector	**Voluntary reporting**	**Mandatory reporting**	**Full obligations**
Forestry	-	-	1 January 2008
Transport fuels	-	1 January 2010	1 July 2010
Electricity production	-	1 January 2010	1 July 2010
Industrial processes	-	1 January 2010	1 July 2010
Synthetic gases	1 January 2011	1 January 2012	1 January 2013
Waste	1 January 2011	1 January 2012	1 January 2013

Agriculture	1 January 2011	1 January 2012	1 January 2015

Table 7: Timeframe for Sectors to Enter the Emissions Trading Scheme Sourced from MFE Website[24]

Stationary Energy, industrial processes (SEIP) and liquid fossil fuels (LFF) sectors will enter the NZETS on 1 July 2010. There is a transition phase in which these sectors can utilise a fixed price option for their required units, or a use a $25 per ton fixed price option. There will also be some free allocation for some industries.

Local Context

In order to gauge the impact of the Emissions Trading scheme, at least in terms of costs, it is worth knowing how many tonnes of CO_2 equivalent are emitted within the district. Work has been carried out on this at the national level[25] in several reports, and has been estimated at each territorial authority level at least in terms of energy use. Table 8 illustrates the key carbon profiles related to energy across the various G9 Councils. It should be noted that this figure is based on a single year, and gives an estimate of the profile per area in the year ending March 2007.

G9 Local Authorities	Total CO2 equivalent tonnes	Population (2007 Estimate)	CO_2 per Capita		Households (Census 2006)	CO_2 per Household
Gisborne District	332,226.10	45,900	7.24		15,486	21.45
Hastings District	551,605.83	73,600	7.49		25,155	21.93
Napier City	666,374.02	56,900	11.71		21,450	31.07
New Plymouth District	574,876.06	71,400	8.05		26,508	21.69
Palmerston North City	544,136.79	78,800	6.91		27,513	19.78

[24] http://www.climatechange.govt.nz/emissions-trading-scheme/basics.html

[25] http://www.eeca.govt.nz/energy-end-use-database

Rotorua District	569,495.68	68,000	8.37		23,223	24.52
Tauranga City	791,930.40	108,800	7.28		39,951	19.82
Wanganui District	280,203.02	43,600	6.43		16,872	16.61
Whangarei District	533,453.93	77,500	6.88		27,615	19.32
New Zealand	**36,591,301.55**	**4,228,300**	**8.65**		**1,454,175**	**25.16**
G9 Average	538,255.76	69,388.89	7.82		24,863.67	21.80

Table 8: Estimated CO_2 equivalent Tonnes from Energy Use for G9 Councils in the year ending 2007. Based on www.eeca.govt.nz/energy-end-use-database. Accessed 22/10/09.

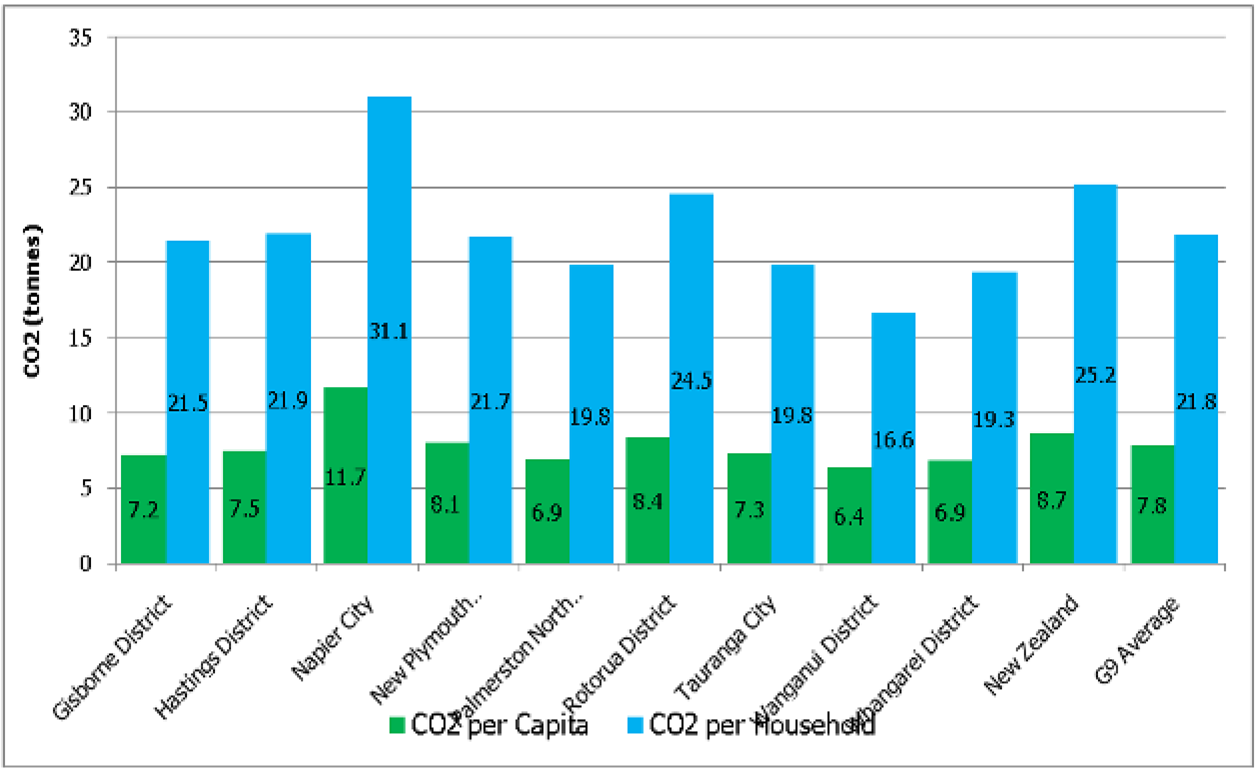

Figure 38 Estimated CO_2 equivalent Emissions per household & capita derived from Energy for G9 Councils. Based on [www.eeca.govt.nz/energy-end-use-database. Accessed 22/10/09](http://www.eeca.govt.nz/energy-end-use-database).

Overall, the level of emissions per capita within Whangarei District, in terms of energy use alone (this figure doesn't count emissions from other sources) was approximately 6.88 tonnes per person per annum. (See Figure 38). On a national basis, this would be one of the smaller carbon emissions tonners per capita (bottom 20% of New Zealand territorial authorities, 13th out of 72), where the national average is 8.65 carbon tonnes per capita.

Of interest also is that transport related energy emissions are approximately 50% of local emissions, which is reasonably high compared with other provincial councils (See Table 9).

Territorial Authority	Transport Proportion
Gisborne District Council	45.60%
Hastings District	45.30%
Napier City	31.30%
Nelson City	39.60%
New Plymouth District	51.10%
Palmerston North City	54.70%
Rotorua District	40.20%
Tauranga City	53.50%
Wanganui District	45.80%
Whangarei District	49.80%

Table 9 Proportion of Transport Related CO2 Emissions for G9. Based and adapted from. http://www.eeca.govt.nz/energy-end-use-database. **Sourced on 22/10/09.**

Agriculture will enter the NZETS on the 1 January 2015. However, agricultural participants will be required to report their emissions from the 1st January 2012. The point of obligation will be initially set at the processor level, but may change to the farm level at a later date if this was the preferred industry option.

Based on the estimate costs used by MFE in the ETS Report to Government, $25 per carbon tonne is roughly equivalent to 2.5 cents/kg for milk solids, 6 cent/kg for sheepmeat, 3 cents/kg for beef, and 6 cents/kg for venison. The Landuse Report, using Statistics New Zealand figures, notes that Whangarei District has approximately 130,000 dairy cattle, 115,000 beef cattle, 2,500 deer, and 100,000 sheep[26]. It is estimated that the average milk solids per cow within the

[26] The New Zealand Dairy Statistics 2008-09 notes approximately 96000 dairy cows but we have used the Statistics numbers in other report and have chosen to continue with that approach.

Whangarei District is 287 kg (LIC 2009). At 2.5 cents per kg (estimated costs by MFE 2009), this would translate to approximately $7.20 per cow leading to a district bill of $NZ 688,000 at a carbon price of $25 per tonne.

On a similar basis for the beef industry, the average steer weight in New Zealand (MeatNZ 2009) is 307 kgs. At 3 cents per kg, this would equate to $9.20 per cattle beast, with a subsequent district liability of $1058000. In terms of sheep, at a sheepmeat weight of 16.7 kg per sheep, this would equate to approximately $1.00 per sheep, and a final district liability of $100,000.

In terms of fertilizer, it is expected that nitrogen fertilizers will increase in cost by $14 per tonne[27]. It is estimated that 7,739 tonnes of urea, and 3,156 other nitrogen based fertilisers were used in the Whangarei District (Statistics New Zealand **2007 Agricultural Census tables**), and this would leave an estimated liability of $272000 for fertiliser costs[28]. This all adds up to significant emission costs for the agriculture industry which is due to enter the ETS in 2015.

4.2 Local Government Act 2002

The purpose of the local government act is to provide the general framework, powers, obligations and responsibilities which local authorities must fulfil.

10 Purpose of local government

The purpose of local government is—

(a) to enable democratic local decision-making and action by, and on behalf of, communities; and

(b) to promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future.

There are some specific sections of the Act that enable Council action on natural hazards which are relative to climate change. These include: Section 14 Principles Relating to Local Authorities, Section 93-96 relating to the preparation of the Long Term Council Community Plan, and Section 163 Removal of Works in Breach of Bylaws. It is expected that climate change is identified as a key strategic planning consideration in Long Term Council Community Plans.

4.3 Resource Management Act 1991

This Act is the primary tool for managing the environment together with natural hazards.

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[27] Urea Fertiliser use in New Zealand has expanded greatly, with only 18000 tonnes across the whole of New Zealand in 1990, 122000 in 1996, and 433000 tonnes in 2007 (MAF 2008).

[28] Although this may be reduced by the use of nitrogen inhibitors, of which 769 ha were treated in Whangarei District

5 Purpose (1) The purpose of this Act is to promote the sustainable management of natural and physical resources.

(2) In this Act, sustainable management means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while—

(a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Several key documents and policies are prepared under the Resource Management Act and include:

National Policy Statements (NPS). These are documents prepared by central government for providing clear guidance to regional and territorial authorities on various environmental and resource management issues. Both regional and territorial authorities need to 'give effect' to the provisions in these documents. The first NPS prepared was the New Zealand Coastal Policy Statement (NZCPS). The NZCPS was the subject of a review in 2006, and the new document is currently being finalised. The draft version has strong provisions in regard to natural hazard management.

Central government has also indicated that a National Policy Statement on Flood Risk Management is a distinct possibility[29]. Whilst draft proposals have been put forward by various organisations, nothing substantial has been put into the public arena.

The Resource Management Act sets out explicit functions for regional councils and district councils in the management of natural hazards:

Section 30 Functions of regional councils under this Act (1) Every regional council shall have the following functions for the purpose of giving effect to this Act in its region:

(c) the control of the use of land for the purpose of—

(iv) the avoidance or mitigation of natural hazards:

Section 31 Functions of territorial authorities under this Act

(1) Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:

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[29] http://www.mfe.govt.nz/issues/land/natural-hazard-mgmt/manage-flood-risk.html

(b) the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of—

(i) the avoidance or mitigation of natural hazards; and

Regional policy statements, regional plans, and district plans are prepared under this legislation and contain provisions relating to natural hazards and climate change. These local policy and plan provisions are contained within Appendices 2 & 3.

The Resource Management (Energy and Climate Change) Amendment Act 2004 development provisions for "all person exercising functions and powers under the principal act to have particular regard to:

The efficiency of the end use of energy
The effects of climate change
The benefits to be derived from the use and development of renewable energy.
Thus local governments are explicitly directed to plan for the effects of climate change, but not to consider the effects of climate change of discharges into air of greenhouse gasses. This means that local government is responsible for adaptation to the impacts of climate change, but mitigation of climate change emissions policy remains at central government. Thus, councils cannot regulate carbon emissions through resource consents. But this does not preclude them from undertaking activities that reduce their emissions. Under the Local Government Act (2002), councils are expected to promote sustainable development, and climate change is a topic that crosses all aspects of wellbeing.

4.4 Northland Regional Council (NRC)

NRC is the main authority addressing climate change in the region and coordinates Northland's CDEM Group under the Civil Defence and Emergency Management Act. It has the function of integrating regional infrastructure as well as erosion control, sedimentation reduction, and the management of water quantity and quality. Managing natural hazards features heavily in the Draft Community Plan 2009-2019, Northland Regional Policy Statement, and various regional plans prepared by NRC. These provisions emphasis the importance of gathering and disseminating information on natural hazard risk; the importance of monitoring; the need for territorial authorities to provide appropriate natural hazard provisions in their respective district plans; the promotion of natural flood control mechanisms such as wetlands; and outlines NRC's responsibilities. It also produces a State of the Environment Report which contains sections on natural hazards and coastal hazards. In addition, its key role in the promotion of sustainable land use across the region is important for both adaptation and mitigation.

4.5 Whangarei District Council

Whangarei District Council has four main responsibilities in regard to climate change: district plan provisions and resource consents, building consents, infrastructure provision, and civil defence responsibilities. The District Plan contains provisions relating to natural hazards and some reference to climate change, and has objectives, policies, and rules relating to flooding in areas zoned as flood susceptible in the District Plan maps as well as policies relating to sea level rise and natural hazards. Infrastructure ranges from the maintenance of the stormwater system, coastal protection activities, through to the management of the Hikurangi Swamp Flood Control Scheme.

Whangarei District Council has also been concerned with mitigating the effects of flooding in the CBD[30], and facilitating the preparation of community response plans in fast developing coastal communities[31]. The Draft Community Plan also recognizes the risks associated with flooding, but has opted to transfer management of flooding to NRC. The rural areas have seen less effort from Whangarei District Council, apart from ongoing debate over the Hikurangi Swamp scheme.

As previous sections have indicated, impacts of climate change cross all aspects of council functions and responsibilities (Day & Chapman 2005).

4.6 Iwi Management Plans

In general terms, natural hazards and climate change are not noted explicitly within any of the Iwi Management Plans lodged with Council (from Ngatiwai, Ngati Hine, and Patuharakeke). However, many of the issues, objectives and policies recorded within these documents make mention of various natural features that will influence the potential management of natural hazards such as flooding. Significantly, each IMP has significant sections on water quality and much of this is centred on rehabilitation as well as integrated approaches to catchment management.

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[30] Links to the CBD flooding documents can be found here: http://www.wdc.govt.nz/customerservice/?lc=reader&m=ts&i=1626

[31] E.g. Marsden Bay Community Response Plan, Whananaki Community Response plan etc. Per comm. Mitchell, A. Emergency Management Officer WDC.

5.0 Comparison of the Three Futures

The Whangarei District Council Growth Strategy outlines three alternative futures for the district over the next 30/50 years. The Three futures are presented to stimulate debate as to the preferred future settlement pattern for the district over the next 50 years. The following is a brief analysis of the most plausible impacts of climate change, dependant on the likely spatial patterns of development in the Whangarei District. Once again, it should be reiterated that this assessment is at a broad level and there are high levels of uncertainty in some respects.

What the three futures do is give a rough estimate of exposure to climate change impacts and whether it is likely to increase or decrease the potential for future settlement, dependant on the preferred future strategy. There is some focus on the potential nodes/themes and their exposure to certain hazards. These include Whangarei City and margins, countryside areas including Hikurangi, Marsden Point/Ruakaka, and coastal settlements.

Future One represents a lightly regulated, market led approach to development and, in general, reflects land development in the district over the past 10-20 years. It is presented as a continuation of this lightly regulated, largely market driven approach to land development and can be seen as a baseline against which to evaluate the other two options, in addition to being an alternative development path in its own right.

Futures Two is an intermediate position between Futures One and Three. It represents a moderately controlled, less consolidated development path based upon a three tier settlement pattern. These tiers consist of: twin cities at Whangarei and Marsden Point/Ruakaka competing with each other for higher level service provision; urban and coastal settlements with some associated urban sprawl and ribbon development; and rural urban development largely at village level with some sporadic development throughout the rural area.

Future Three represents a managed, consolidated development path based upon a structured five tier settlement pattern. This hierarchical arrangement is as follows: Whangarei City as the primary district and regional urban centre with a strong, protected and enduring CBD; a satellite town at Marsden Point/Ruakaka which complements (but does not compete with) Whangarei City; five urban villages within greater Whangarei; one rural (Hikurangi) and two coastal growth nodes at Parua Bay and Waipu; and two rural villages along with eight coastal villages located along the coastline from Waipu Cove in the south to Oakura in the north.

The report identifies that many parts of the district are already susceptible to climate change, especially in term of the more heavily settled parts of the district near the coasts including harbours. Certain areas of the district may be more susceptible to impacts from climate change, whether it is due to a relatively aged population, a low socio-economic status, proximity to hazard, or a heavy dependence on primary production with little off-farm resources.

In general terms, weather related hazards will be exacerbated by climate change. Coastal hazards and flooding can be, and have been, managed by a variety of policy tools including regulation, education and incentives. In some parts of the world, including New Zealand, the process of managed retreat has been an option to avoid coastal hazards. The three alternative futures will be impacted differently by coastal and flooding hazards.

Biological hazards are generally managed through the health system, in the case of human epidemic, rather than local government planning, but the research indicate that these factors will increase under the increasingly warmer temperatures. Different spatial distributions will increase or decrease opportunities for the management of health ooutcomes. Weed and pest popuplations can be affected by climate change and spatial distributions. For example, as most new naturalised weed species are sourced from urban gardens, a more distributed population will facilitate quicker colonisation by weed species. Overall biological hazards have little impact on the future scenarios, except that .

Wildfire, despite some concerns, is seen as a low priority at present, and may not represent a major obstacle to future development around settlements but may be a risk for distributed populations.

Drought is another natural hazard which can have a strong impact on the district. It can be difficult to mitigate in terms of choosing settlement patterns, although the promotion of riparian and other indigenous vegetation in catchments can reduce water evaporation and allow storage for slow release of waters in dry spells if they are not fragmented by settlement. Likewise more distributed populations are more dependant upon on-site water systems, whilst more consolidated settlements allow more opportunity for jount water systems. Should settlement and land-use reduce the availability of water resources then it may be prudent to avoid aquifers and undertake activities to improve catchment storage. The way that climate changes are managed or accommodated will be a distinguishing factor between the three futures, and whether the pattern or intensity of settlement incorporates adaptation methods. Adaptation in this sense refers to actions for the purposes of reducing or removing risk. This could include setting aside areas to help mitigate or avoid the impacts of natural hazards.

In order to produce the three settlement patterns assessment, it is assumed that Future 1 has low management (in terms of policy direction), Future 3 has high management, and Future 2 has medium management. This management criterion relates to the use of regulation, incentives, education and provision of infrastructure to reduce exposure to climate change, and whether the exposure level is increase or decreased in a similar way to natural hazards.

These risks are compared against four general geographical area types and their relative population sizes: Countryside[32], Coastal, Marsden Point/Ruakaka, and City/Urban; and classified as increase/neutral/decrease in exposure, and whether it is expected to be high, medium or low increase.

Geographic Type	Baseline	Future 1 (%)	Future 2 (%)	Future 3 (%)
City & Margins	66%	57%	61%	61%
Coastal areas	8%	13%	10%	14%
Marsden/Ruakaka	4%	3%	19%	11%
Countryside	20%	25%	7%	11%
Total	100%	100%	100%	100%
Urban (5000+)	70%	60%	80%	84%

Table 10: Relative Percentage of Total Population in Geographical Area Type

In table 10, baseline numbers are based on data from the Census 2006. Following this, Future One is based on recent growth rates that are projected into the future, on an area by area basis. Future Two and Future Three represent a combination of information, in which possible growth nodes (especially at Marsden Point/Ruakaka, Waipu, Parua Bay, Hikurangi) are assigned maximum potential numbers to begin with. Then all other areas are attributed values based on the Growth Model 2.7 (WDC, 2008), with any remainder being found in the wider countryside. This method is likely to see an underestimation in the countryside population for Future Two which records 7% of the total population compared with 20% presently.

Please note that settlement figures for Waipu and Parua Bay are contained within the coastal geographical type rather than within the countryside geographical type. Commentary in this report discussing the relative merits of various settlement nodes are in terms of climate change and do not account for other constraints that may be evident.

However, of more importance is the impact of combining settlement patterns with climate change on the key sectors. These include agriculture, infrastructure, biodiversity, health, and vulnerability

[32] Countryside in this case means lifestyle settlement in currently popular areas, along with farming activities.

5.1 Future One: Lightly Regulated, Market Led Development (Business as Usual)

In this Future there is continued market led development resulting in a widely dispersed settlement pattern consisting of two discernable trends:

(1) Urban development dispersed throughout the district with concentrations in Whangarei, Marsden Point/Ruakaka, and other urban, rural and coastal locations and along transport corridors.

(2) Widely dispersed, sporadic rural residential development throughout the district including both countryside and coastal countryside environments.

The countryside area has recently seen significant growth, and if projected into the future, there is expected to be a substantial population dispersed in the countryside (from 20% to 25%). Recent population growth at Marsden Point/Ruakaka has not been very strong, and if projected into the future, this area actually decreases its relative percentage of population (from 4% to 3%). Dispersed settlement in the coastal area is also likely, with 13% of the population living in coastal areas. The relative percentage of population found in Whangarei city decreases in this Future, from 66% to 57%. Of the three futures, this is the least urbanised and most dispersed.

In Future One, exposure to climate change is expected to increase in most geographical settlement types, especially as much of Whangarei District already experiences natural hazard risk and this will be exacerbated. Flood hazard susceptibility and coastal hazards are the main natural hazard risks, with slope instability also playing a significant role. Natural hazards not only impact on where people live, but can impact on their places of work, transport corridors, and their accessibility to all types of services.

Business as usual follows past trends, and given that many new lots have been created in places already susceptible to hazard risk, future development is also likely to occur in the same risky areas if these trends continue. The need for the retrofitting of infrastructure of some catchments and potential removal of properties whose risk increases dramatically may occur in this scenario, especially in locations where house were built without consideration of climate change. This can be a very expensive exercise, depending on the numbers of properties at risk.

One of the key questions in this scenario is the overall impact of expansion of lifestyle blocks across the district. A greater number of lifestyle blocks may result in less land being available for the purposes of primary production, especially in those areas that are of high quality. More lifestyle blocks may actually buffer native habitat, as research has shown, but is likely to have a negative impact on agricultural production. This is important as Whangarei is relatively well watered, but there may well be demands for more irrigation and water storage facilities with future dry spells. The development of such infrastructure may be limited by large scale break up of present farming units into smaller blocks.

Given the sporadic patterns of settlement in Future One, there will be less certainty surrounding infrastructure expenditure need to mitigate natural hazard risks exacerbated by climate change due to fears that any expenditure may not be in the best place for the longer term, and the dispersed nature of settlement may mean higher costs in providing suitable works to reduce risk.

There will be increased exposure inside Whangarei City together with its margins, with land instability and flood susceptibility being key issues, especially around the CBD. In terms of potential hot spots as indicated on the map as development nodes; north of Onerahi, Otaika, and eastern margins of the city all face a variety of risks, especially slope instability. Areas such as Maunu, Tikipunga, and Kamo are comparatively less risky for continuing development. However, many of the services enjoyed by residents of these areas will be at risk. The key issue is the continued and increased flood susceptibility of the central business area, and the ongoing need to mitigate flood hazards in this area. Marsden Point/Ruakaka is exposed to the more risky hazards in terms of the coast as the extent of the coastal hazard line maps indicate, and there is ongoing risk from flooding. Waipu, as specifically noted in the case study, has the capacity to be heavily impacted by climate change.

However, in this "Future" the biggest concern is likely to be continued major growth in coastal areas, which are exposed to a wide range of hazards, both in existing settlements and dispersed between settlements. Most coastal settlement themselves already have some levels of risk, and the areas between these settlements are also at risk from slope instability, flooding in some places, and coastal hazards. Many are low-lying and located close to waterways. Depending on the real rate of sea level rise (especially with scenarios of 0.75 - 1.9 metres towards the end of this century now being projected (Vermeer & Rahmstorf 2009), this impact could be considerable, and costly for residents and council alike. A further issue for the coast is the isolated nature of some settlements, and their dependence upon infrastructure such as roads, which is also at risk from flooding and land instability.

Agriculture	As noted in the Land Use Report, Future One would continue the fragmentation of productive land, and the population would continue to spread over well-watered land close to the city. Whilst lifestyle properties may increase the restoration of indigenous vegetation, these areas will continue to be important and perhaps necessary for the production of food.
Infrastructure	With more scattered settlement pattern, costs associated with maintenance of infrastructure are likely to remain high, and there will be resultant high costs for the maintenance of repair following natural hazard events. Of the three futures, this scenario has the least capacity to build an efficient public transportation network as the population is still scattered. This means that opportunities to reduce transport related carbon emissions is limited, and will probably increase, dependent on transport

	technology changes. There will continue to be a dependence on Whangarei as the main urban centre for employment, meaning that many people will still need to travel to Whangarei City for employment and services needs.
Biodiversity	With continued scattered settlement, fragmentation of remaining habitat, coastal and rural, will continue, meaning that these areas are less resilient to invasion by pest and weed species. Research has noted that weed species numbers are relative to distance from people gardens, and continued expansion into bush areas will exacerbate this problem. However, as noted in the Ecosystem Services Report, lifestyle properties can also promote the restoration of indigenous vegetation, depending on management options.
Health	As the population is both scattered and is aging, it is likely that health resources will be stretched around the district. In addition, similar to the biodiversity comment, it is possible that pest species will invade, and may scatter across the district. It is more difficult to isolate areas in a scattered population should additional pest control effort be necessary to contain new pests.
Vulnerability	Some parts of the district may be more exposed to climate change than others, based upon levels of deprivation, household income or an aging population. The continued push for lifestyle blocks may decrease vulnerability if new settlers are self-sufficient, but compared with rural communities as a whole this level of self sufficiency is likely to be smaller. In addition, continued dispersion in this scenario will mean that marginal landscapes will continue to be popular places to live, and these locations tend to be more exposed to natural hazards that will be exacerbated by climate change, e.g. they are close to water. The self-sufficiency of settlements themselves is small, as they all face increased population aging, but don't necessarily build up enough population size to provide a range of services that could offset the increase in vulnerability.

Table 11: Future One – Key Sectors and Climate Change

In terms of rural residential areas on the fringes of the City, population expansion in this area is expected to increase the risk exposure, due to the increase in dispersed population. Areas including Maungatapere, Maungakaramea, northwest of Kamo, and around Glenbervie are of this nature and do not have a heavy exposure to present natural hazard risks that would be exacerbated by climate change.

However, these areas are found on important aquifers and near waterways, and therefore is expected to substantially impact on water resources and have been noted as being 'at-risk' aquifers by NRC (2004). Given the substantial level of population increase in this Future (close to 21000 people dispersed across the countryside), the impact on water resources is expected to be very high and of concern should groundwater access be required. Of additional concern is how distributed settlement in some upper catchments might affect downstream flow patterns in settlements that already face some flooding. These areas include countryside area near Ruakaka (west of SH1), Glenbervie, and Springs Flat.

In addition, there are still some concerns over infrastructure provision, namely roads that may be at risk though low-lying topography or unstable land, and methods used to respond to major natural hazard events. A dispersed settlement pattern results in longer times for response, wider search and rescue areas per capita and can stretch emergency services to their limit.

6.2 Future Two: Twin City/Urban and Coastal Spread

Future Two represents a moderately controlled, partly consolidated development path based upon a three tier settlement pattern. These tiers consist of:

(1) Twin cities at Whangarei and Marsden Point/Ruakaka

(2) Urban and coastal settlements with some associated urban sprawl and ribbon development,

(3) Rural urban development largely at village level with some sporadic development throughout the rural area.

Under this scenario, the countryside area has seen a substantial decline in its relative population size, from 20 % down to 7% (most likely underestimated), both dispersed and within any larger present rural settlements. Population growth at Marsden Point/Ruakaka has been very high, and the relative population has jumped from 4% to 19% of the population. Settlement in the coastal area has also continued, with an increase in the relative population of 8% to 10% likely. The relative percentage of population found in Whangarei City decreases a little in this Future, at least when compared with the present baseline. However, of the three futures, this is the most concentrated with 80% of the population found in Whangarei and Marsden Point/Ruakaka settlements (See table 10).

Natural hazard risk reduction can be a costly exercise, especially if large scale engineering (soft or hard) is required. In this scenario, settlement is given some direction towards two main areas, which does increase certainty in ensuring that any expenditure in risk reduction is undertaken the right place. Despite this increased certainty, there are still questions as to whether having competing city centres also results in competing infrastructure expenditure used to mitigate natural hazard risks. Both main localities already experience flood risk, and the is likely to be an increased exposure in both under climate change scenarios. However, the infrastructure required for newly established Marsden Point/Ruakaka is likely to be cost-effective compared with retrofitting around Whangarei City.

Future Two is likely to increase some exposure to natural hazard risks around Whangarei City and its margins, especially in terms of both flood susceptibility and slope instability, but given the population projected for other parts of Whangarei District (e.g. Marsden Point/Ruakaka), the increased exposure in Whangarei City is comparatively smaller than either of the other two "Futures". In addition, the development of a twin city at Marsden Point/Ruakaka would take some pressure off critical infrastructure services by having a second centre, but conversely, it may mean fewer resources are available to mitigate the existing flood hazards around the city. Whilst there will be increased exposure to land instability around the urban nodes, and some coastal hazards around Whangarei Harbour, this is relatively smaller than other futures.

Agriculture	This scenario sees more consolidated populations across the district, and has less pressure on versatile soils and aquifers.
Infrastructure	With more consolidation comes an increased ability to maintain key routes following extreme events. In addition, given the key focus on Marsden Point/Ruakaka, which is still in the process of developing, any infrastructure provision can, and should, accommodate climate change projections more easily than retrofitting. In this, despite both locations having exposure to flooding, Ruakaka/Marsden may be cheaper per capita to develop mitigation options for climate change. The more consolidated settlements does open up the option for more public transport, including ferry and bus services, between Whangarei City and Marsden Point/Ruakaka, which does reduce vulnerability in these two settlements. Passenger rail is possible between Whangarei and Marsden/Ruakaka because of large population catchments at each end, and the many links between both settlements. This possibility is greater than Future Three. The increase opportunities for public transport allows for some reduction in transport related carbon emissions.
Biodiversity	Compared with Future One, this scenario has a less distributed population, and there will be less fragmentation of existing habitat areas, although some locations along the coast are still under pressure for settlement. However, with a primary focus on Marsden/Ruakaka, this scenario may see reduced resources to adapt and prepare for climate change impact on biodiversity in other locations. Offsetting this is increased resources for restoration around Marsden Point/Ruakaka.
Health	Compared with Future One, this future will be better prepared for health impacts resulting from climate change, especially if the infrastructure around Marsden Point/Ruakaka is prepared, including major health facilities. However, there may be competition for health resources between Whangarei City and Marsden Point/Ruakaka.
Vulnerability	Compared with Future One, this future is less vulnerable, and does have the potential to ensure that the greater parts of the population have access to a wider range of resources in both main centres. However, those settlements outside of Whangarei and Marsden Point/Ruakaka will remain too small to ensure access to resources that reduce vulnerability, or build local jobs, and are likely to remain quite vulnerable as they cannot be self sufficient.

Table 12: Future Two Key Sectors and Climate Change

The main concern in Future Two is whether the proposed twin city at Marsden Point/Ruakaka will result in a high level of exposure to various risks, especially around Ruakaka resulting from climate change. The Flood hazard risk increase is the highest of the three futures, especially given that a larger population at Marsden Point/Ruakaka means that land use is likely to be intensive, with much of the area used for settlement purposes. Continued growth in the usage of the industrial areas in close proximity to the coast will increase the exposure to coastal hazards of employment areas (although this is likely to occur to a certain degree, irrespective of the "Future" as a similar issue arises in Whangarei City).

In terms of coastal settlement, coastal hazard risk exposure is expected to increase, especially around some of the popular development areas already experiencing sporadic development. Whangarei Heads, Waipu/Langs Cove and the Ngunguru/Tutukaka all have low lying areas where inundation can be exacerbated by climate change. However, overall less dispersed settlement along other parts of the coast will likely offset this increase, and the exposure increase due to climate change is less than Future One.

In terms of further countryside settlement, this "future" is not likely to see a large increase in risk exposure as the dispersed population is expected to decrease as a proportion of the overall population growth. In addition, the areas still expected to be popular are those that don't have substantial risks associated with them. These include Maunu-Maungatapere and northwest of Kamo. This still poses some risk to water resources, but given the population, overall impact on water resources will lead to a decrease in water resources risk.

5.3 Future Three: Satellite Town/Rural and Coastal Villages

Future Three represents a controlled, consolidated development path based upon a structured five tier settlement pattern. This hierarchical arrangement is as follows:

(1) Whangarei City as the primary district and regional urban centre with a strong, protected and enduring CBD.

(2) A satellite town at Marsden Point/Ruakaka which complements (but does not compete with) Whangarei City.

(3) Five urban villages within greater Whangarei urban area.

(4) One rural and two coastal growth nodes.

(5) Two rural villages along with eight coastal villages.

Under this scenario, the countryside area has still seen a large decline in its relative population size, from 20% down to 11% of the total population. However, most of this is contained within rural settlements such as Hikurangi, Maungatapere, and Maungakaramea. Population growth at

Marsden Point/Ruakaka is high, with the population jumping from 4% to 11% of the population. Settlement in the coastal area is also high, with an increase in the relative population percentage of 8% to 14%, which is the highest of the three futures. However, the bulk of this growth is around Parua Bay and Waipu. The relative percentage of population found in Whangarei City decreases somewhat in this Future (from 66% to 61%). Depending on the definition of urban, this is the most urbanised settlement pattern with 84% of the population found in Whangarei, Marsden Point/Ruakaka, Waipu, Hikurangi, and Parua Bay (if we assume that 5,000 and up is an urban population). Otherwise the total for Whangarei City and Marsden Point/Ruakaka is 72% (see table 10)

The increase in population may allow for an increased resource base to fund natural hazard risk reduction activities, and with the population concentrated in particular settlements, expenditure use to decrease risk exposure may be allocated with more certainty. In this future, settlement patterns are given the most direction towards main nodes and there will be more direction away from areas of hazard risk. Despite this increase in certainty, Future 3 still sees the expansion of some development nodes; with an accompanying expansion in risk exposure, and some difficulties should transportation corridors be affected by a natural hazard event.

This future is likely to increase risk exposure around the City and its margins, especially in the urban nodes, compared with the other futures. This is because there would be policies in place to promote development within or close to existing urban boundaries. Future 3 will probably exacerbate the exposure to instability hazards, given that consolidation of existing areas is a preferred means of settlement. This consolidation approach would, however, mean that any resources expended on the mitigation of natural hazard risks is more easily carried out with certainty, and there would be more core funding available for mitigation through expanded numbers of beneficiaries. Marsden Point/Ruakaka still sees some settlement, but compared with Future 2, this settlement is more constrained and likely to be the most compact of the three futures, and policies would be likely to promote strong mitigation to some hazards. However, there will be an increase in risk exposure, particularly to flooding.

Coastal area settlement in this future will have increased risk exposure, but overall, despite having the highest relative percentage of population, it is expected to be less that Future One as the population is less distributed along the coast and consolidated in coastal growth nodes. Overall, this scenario is expected to reduce potential exposure to coastal hazards and flood susceptibility, and may allow for more soft engineering solutions to alleviate some risk in concentrated areas. In addition, it will probably reduce impact on water resources (in terms of aquifers and watersheds). The growth of Waipu and Parua Bay as development nodes still holds some risk, with flood hazards around Waipu, and some moderate slope stability in the vicinity of Parua Bay.

Agriculture	Due to consolidation of settlements and reduced loss of productive land, this scenario would have the least impact on agriculture and any adaptation activities to improve water resources.
Infrastructure	Because of consolidation, costs associated with reducing natural hazard risk is able to be considered with more certainty, and maintenance efforts following events can be targeted smaller number of key infrastructure points. More consolidated settlement does open up the option for more public transport, including ferry and bus services, across the whole of the district, rather than just being limited to Whangarei City. Passenger rail is possible between Whangarei and Marsden Point/Ruakaka, but this possibility is less than Future Two. Overall, this settlement patterns has the highest capacity to reduce carbon emissions, especially as the consolidated settlement patterns allows for more localised employment and service centres across many of the settlements.
Biodiversity	As each of the scenarios has suggests, settlement patterns can be a double-edged sword in terms of biodiversity. On one hand, a reduced dispersed population is less likely to fragment remaining habitat patches due to reduced demand. However, reduced numbers of lifestyle blocks can reduce the level of indigenous vegetation restoration efforts, and local government is likely to need to take a greater role in the promotion of indigenous vegetation restoration efforts. However, more concentrated populations can mean that more funding is available for restoration that is seen as a public good. In addition, more concentrated populations will allow council parks staff to allocate their resources in a more targeted way.
Health	More concentrated development may lead to more health services being distributed across the whole of the district, as many of the village grow to a size where health professional offices may be viable.
Vulnerability	Similar to health outcomes, vulnerability in this scenario is the least of the three futures, as more consolidation means that present settlements can be more self-sufficient in the event of emergency, and may have more capacity to respond to events.

Table 12: Future Three Climate change and Key Sectors

Of the three futures, Future 3 is likely to reduce exposure to climate change in countryside areas the most, as the policies promote consolidation in the present settlement sites. However, of note in terms of Future 3 is the possible expansion of Hikurangi and Waipu as development nodes. Given the substantial flood hazard area located in the vicinity of both, and the strong possibility of isolation in the event of flooding, any development in these areas needs to be carefully managed. In Hikurangi, there is some potential in several areas, including the basin alongside Valley Road, north of the sports grounds and to the east of SH1, and perhaps the lower hills/slopes surrounding Mt Hikurangi that face the main settlement. These are also areas that have less risk associated with old mining zones. Based on present information, several areas in Waipu have potential for future settlement including alongside St Marys Road, South Road, and the area between Cove Road, Nova Scotia Drive and the Waipu River. However, it is noted that further research of the catchment is being undertaken in Waipu, and that further work on the Hikurangi Catchment would be required to ensure the settlement viability as future growth nodes.

6 Conclusion

As indicated in this report, Whangarei District has a high exposure to natural hazard risk and much of this risk is going to be exacerbated by climate change, irrespective of the future settlement pattern. Many of the issues in the Natural Hazards Report are likely to remain relevant into the future. But there are other issues, often temperature related, that cannot be easily captured by simple reference to natural hazards. Climate change will have an impact on the local economy, management of parks and infrastructure, community resources, community capacity, and overall quality of life for the District's residents.

However, different settlement patterns have an impact on the magnitude of the influence of climate change on various issues, with each of the different futures having strengths and weaknesses. For example Future Three has the most capacity for adaptation and mitigation measures, and is considered the most resilient in respect to climate change as it builds up capacity more widely across the district. Alternatively, Future Two has the highest potential in terms of reducing transport based and probably industrial-based carbons emissions as a very large proportion of the population is contained in two main centres, meaning that public transport options are very high and new industrial plant is developed that uses more modern technology and meets higher environmental standards. Thus different settlement patterns and choices about where people live or want to live will have an impact on the capacity of Whangarei District to meet the challenges of climate change over the next 30 to 50 years.

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Appendix 1: Main Features of New Zealand Climate Change Projections for 2040 and 2090. Sourced from MFE 2008, p14

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Mean temperature	Increase (****)	All-scenario average 0.9°C by 2040, 2.1°C by 2090 (**)	Least warming in spring (*)
Daily temperature extremes (frosts, hot days)	Fewer cold temperatures and frosts (****), more high temperature episodes (****)	Whole frequency distribution moves right (see section 2.2.3)	See section 2.2.3
Mean rainfall	Varies around country, and with season. Increases in annual mean expected for Tasman, West Coast, Otago, Southland and Chathams; decreases in annual mean in Northland, Auckland, Gisborne and Hawke's Bay (**)	Substantial variation around the country and with season (see section 2.2.2)	Tendency to increase in south and west in the winter and spring (**). Tendency to decrease in the western North Island, and increase in Gisborne and Hawke's Bay, in summer and autumn (*)
Extreme rainfall	Heavier and/or more frequent extreme rainfalls (**), especially where mean rainfall increase predicted (***)	No change through to halving of heavy rainfall return period by 2040; no change through to fourfold reduction in return period by 2090 (**) [See note 2]	Increases in heavy rainfall most likely in areas where mean rainfall is projected to increase (***)
Snow	Shortened duration of seasonal snow lying (***), rise in snowline (**), decrease in snowfall events (*)		
Glaciers	Continuing long-term reduction in ice volume and glacier length (***)		Reductions delayed for glaciers exposed to increasing westerlies

Wind (average)	Increase in the annual mean westerly component of windflow across New Zealand (**)	About a 10% increase in annual mean westerly component of flow by 2040 and beyond (*)	By 2090, increased mean westerly in winter (> 50%) and spring (20%), and decreased westerly in summer and autumn (20%) (*)
Strong winds	Increase in severe wind risk possible (**)	Up to a 10% increase in strong winds (> 10m/s, top 1 percentile) by 2090 (*)	
Storms	More storminess possible, but little information available for New Zealand (*)		
Sea level	Increase (****)	At least 18–59 cm rise (New Zealand average) between 1990 and 2100 (****) See *Coastal Hazards and Climate Change manual (MfE 2008)*	See *Coastal Hazards and Climate Change manual (MfE 2008)*
Waves	Increased frequency of heavy swells in regions exposed to prevailing westerlies (**)	See *Coastal Hazards and Climate Change manual (MfE 2008)*	
Storm surge	Assume storm tide elevation will rise at the same rate as *mean* sea-level rise (**)	See *Coastal Hazards and Climate Change manual (MfE 2008)*	
Ocean currents	Various changes plausible, but little research or modelling yet done	See section 2.2.9	
Ocean temperature	Increase (****)	Similar to increases in mean air temperature	Patterns close to the coast will be affected by winds and upwelling and ocean current changes (**)