A Climate Risk Report

Climate Change

Risk Assessment:

Nambucca Shire Council

Climate Risk

Climate Change Risk Assessment: Nambucca Shire Council

December 2010

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Australian Government
Department of Climate Change and Energy Efficiency

Funded with the assistance of the Australian Government Department of Climate Change and Energy Efficiency.

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The authors would like to acknowledge the support and valuable input from Grant Nelson and the staff and community of Nambucca Shire Council.

Executive Summary

About this Project

This report forms part of an Australian Government initiative designed to support local government climate change risk assessment and adaptation planning. As well as providing an initial analysis of climate change risks this project provides Council considerable information for future planning of development and operational expenditure. Regionally specific climate change information was developed, including downscaled climate change projections (over 2900 spatial data sets), extreme event analysis, historical re-analysis, climate variability review, and newly developed regionally specific economic modelling. The data generated for this project allows Council to own and manage its own current climate change information (eg for strategic planning, operational budgets, maintenance schedules).

Methods

This climate change risk assessment follows the AS/NZS 4360 standard (as directed by the Australian Government Department of Climate Change for the funding requirements of the Local Adaptation Pathway Program). The project contains a combination of qualitative and quantitative analysis and results from staff and community workshops. Following this project the final step will be undertaken in the Adaptation Plan.

Introduction to Climate Change

The world is warming with considerable evidence showing that it is a result of human activities. Regardless of society's actions temperatures are predicted to rise for the next century and these create risks that need to be managed. In this report we present the range of the hazard estimates from the point of view of risk management, rather than discussion of which scientific results are most likely to be correct.

The warming of the oceans is forecast to increase sea levels in a nominal range of 0.2m and 0.8m (IPCC 2007). However the effects of ice sheet melt are expected to increase the risk range with recent science showing that sea levels are projected to rise between 0.8m and 2.0m by 2100. Data from the Australian Bureau of Meteorology shows the past decade was the hottest on record and that 2009 was the second hottest year since high quality records commenced in 1910.

Climate Drivers

The main 'global' climate drivers which affect extreme weather events in the Mid North Coast region are expected to be El Nino Sothern Oscillation (which usually affects extreme rainfall and flooding, hail and storm frequency) and the longer-term decadal oscillations (Pacific Decadal Oscillation or Interdecadal Pacific Oscillation) that affect the general climate regime and frequency of extreme events. During Interdecadal Pacific Oscillation (IPO) positive events with El Nino dominant (1920-1945 and 1975-2006) there is a low flood risk and high drought risk. During an IPO negative phase, La Ninas are stronger and there is greater chance of flooding and lower risk of drought.

Historical Climate

Nambucca has experienced a gradual increase in mean annual temperatures over the past 100 years with its highest temperature recorded being 41.7°C. Heatwave events are uncommon (occurring every 12 years) with an average of 1-3 days per year over 35°C being recorded. Average yearly rainfall ranges from 1100m – 1500mm with the highest annual recorded rainfall being 3016mm. Over the past decade Nambucca has experienced significant rainfall / flooding events, in 1999, 2001, 2006 and 2009. The existing extreme rainfall return rates range from 1-in-5 year events of 272mm in three days, through to 1-in-100 year events of 536mm in three days.

Projected Climate Change

The projections for Nambucca show increasing average temperatures. Annually the mean monthly maximum temperatures are projected to increase by approximately 6% in 2030; 14% in 2050; and 22% by 2070. For the periods 2030, 2050 and 2070, the average annual maximum temperatures are project to increase by 0.89 °C, 1.77 °C and 2.92 °C respectively. Alarmingly, the projections show average maximum temperatures in December may increase by over 2°C by 2050 and 4 °C by 2070.

Projections for annual precipitation do not depart considerably from recent historical levels (figure 13). However, the ensemble of five GCMs projects a significant change in rainfall by month and season. The models show that by 2030, rainfall is projected to increase during the late spring to autumn (November to May) and decrease during the winter and early spring (June to October). For 2050 and 2070, the pattern is similar although the degree of change is exacerbated. This is especially so in the period of 2070 with a range of up to +22% in summer and up to -22% in the winter.

Recent science anticipates that sea levels may increase by between 0.8m and 2.0m by 2100 (surpassing recent NSW policy guidance) and current 1-100 year storm surges may occur every few years by 2050. Climate models for this project predict Nambucca to experience 63.95cm increase in sea levels by 2100 plus additional contributions from potential ice-sheet dynamic processes (ie melting of ice sheets); with a range of global average estimates being between 80cm and 2.0m, causing current 1-100 year storm surges to occur every few years by 2050.[1].

Summary of Risks

Climate change will present an array of risks for Nambucca Council. Of most concern is the capacity of Council and the community to respond to a confluence of anticipated impacts (climate and non-climate). By 2030 the modelling for this project shows that intense rainfall will be beyond what is currently used as a benchmark for flood studies, heatwaves will occur more often, and council operational costs will increase substantially.

Exacerbating these risks is the challenge of reduced ecosystem services and an ageing population. With 35% of the population

[1] These sea levels could surpass NSW DECCW's Sea Level Rise Policy Statement (released November 23rd 2009) which has benchmarks of 0.4m by 2050 and 0.9m by 2100, The NSW Government has advised councils (DECCW, 2009) that they may no longer be exempted from liability under section 733 of the Local Government Act – 1993 if they fail to follow these benchmarks. This suggests that though prudent risk management may imply the use of higher sea level rise estimates for long lived, high risk facilities (eg SES, medical centres, aged care, long lived infrastructure etc.) Council would be in breach of acting in 'good faith' toward the State Government if were to do so. Therefore, the Council may only be able to provide and require full disclosure of the range of sea level rise risks to land owners and buyers, and require that they consider these in their own decision making. Council may also seek to consider time-frames beyond 2100 where it believes that supporting infrastructure will be required to be viable in such locations beyond the end of the century. .

expected to be over the age of 65 by 2030 there is the potential for decreased rate revenue, a population vulnerable to heatwaves and other extreme weather events, and a depressed economy.

Specific critical issues that Nambucca will need to consider include:

- **Water availability:** The projections show that there will be marked reductions in winter water runoff. This will pose challenges for potable water and water for environmental flows.

- **Critical infrastructure:** Council is responsible for numerous bridges, which are prone to the current and anticipated extreme weather events. If bridges are damaged by extreme weather but have not received adequate maintenance then Council may not receive funding from the State to rebuild. Given the projected increase in rainfall intensity Council should give consideration for a resource injection into bridge upkeep.

- **Flooding thresholds:** All future development will be guided by flood plans. Failure of Council to consider the projected increases in precipitation may result in increased asset exposure for community and council, as well as potential litigation. There are existing settlements (eg Wellington Drive, Gumma, Scotts Head) that may require an immediate review of threats from isolation after extreme weather.

- **Sea level rise / storm surge**: There are many properties and access points that will be exposed to challenges presented by storm surge. Council has a challenging task ahead in maintaining a balance between community expectation for adaptation and resources it has to undertake the task.

- **Carbon pricing:** Council and the community are exposed to increases in energy costs. This may lead to reduced ability of Council to provide services.

- **Urban design and strategic planning:** A scoping assessment of areas identified as future urban has identified potential issues from bushfire, flooding, carbon prices and heatwaves. These are all manageable if considered appropriately during early stages of development. Failure to consider the anticipated low carbon economy may have negative repercussions on the community and deter future investment into the area.

- **Funding options:** The disproportionate demographic means that by 2030 Nambucca will receive only limited increases in full paying rateable properties during a period in which increases in operational costs (from climate change) are anticipated.

- **Economic challenges:** Without adaptation climate change will have a significant impact on the local and regional economy. Council should examine actions to support economic resilience and diversification. Anticipated damage to coastal foreshores and the natural environment are likely to have a negative impact on the area's economy.

- **Environmental degradation**: Although specific impacts on individual species and ecosystems is difficult to ascertain it is likely that climate change will challenge the surrounding natural environment. A confluence of periods of decreased runoff, average warming, extreme temperatures and changing rainfall and urban/agricultural expansion may erode water quality and facilitate expansion of invasive species

Capacity: Council staff are highly skilled, but may be challenged with the potential workload required for dealing with more severe and more frequent climate change related challenges.

Economic Impacts

The cumulative economic impacts for the region including Kempsey, Nambucca and Bellingen have been modelled as $3.2 billion from physical climate change impacts, mainly to tourism and agriculture, assuming no adaptation is undertaken. This will have the effect of reducing Gross Regional Product by 5.5% by 2050, real wages by 2.4% and land values by 2.4%.

The region may be able to address most of the climate change impacts through appropriate and timely adaptation – with sea level rise being a major persistent challenge which may defy cost effective adaptation.

On a positive note, the economic analysis indicates that the region may be a net beneficiary under a transition to a low carbon economy – driven mainly by the ability to offer affordable tourism to east coast cities under a low carbon economy, and the forecast of continued water supplies providing seasonal variations can be managed.

Conclusion

All aspects of the above impacts will place a strain on the financial viability of Council. Council will need to make challenging decisions regarding the cost-benefit of early, mid and late term adaptation options. Increased energy and maintenance costs are virtually certain, placing strains on Council's ability to provide other adaptive measures to support community. Increased maintenance and operational costs will likely run into millions of dollars (and even more if tort-based litigation occurs).

Even if appropriate adaptation commenced immediately, expenses will increase due to climate change, although evidence suggests that these can be reduced substantially with good management.

There are clear cost implications, as resources will have to be found to: A. Upgrade the capital stock and systems to be climate resilient. B. Cover high operational and maintenance costs, C. Cover the increased risk of potential liabilities, D. Undertake further detailed research / analysis.

Failing to recognise and adapt to the climate change threats now will place considerable strain on council resources in the future and create the potential for significant dependence on the NSW and Australian Government for support. Compounding this issue further is evidence from assessment of climate variability and reanalysis work in this report which shows that the region may currently be entering a phase of anticipated severe weather events.

Without due consideration of the climate risks, and of other key risks, such as oil vulnerability, by 2030 the Council and community it represents could see serious challenges that threaten to place considerable financial strain on Council.

The above risks have been further explored in the Climate Change Adaptation Plan due for community consultation.

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Abbreviations and Acronyms

A1FI High IPCC scenario (see Box 1 below)

BOM Bureau of Meteorology

CPRS Carbon Pollution Reduction Scheme

ENSO El Nino Southern Oscillation

EWE Extreme weather events

GCM General Circulation Model

GHG Greenhouse gas

GRP Gross Regional Product

IPCC Intergovernmental Panel on Climate Change

IPO Interdecadal Pacific Oscillation

PDO Pacific Decadal Oscillation

SOI Southern Oscillation Index

The Emissions Scenarios of the Special Report on Emissions Scenarios (SRES)

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

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines. (IPCC Third Assessment Report - Climate Change 2001 - Complete online versions).

The IPCC also have B1 and B2 storylines. For further information see http://grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/029.htm

1 Introduction

Climate change presents an array of challenges for local governments and the communities they represent. The physical evidence and the associated NSW and Australian regulatory responses demonstrate that to ignore this science could expose a myriad of risks for the local community.

The enormity of the challenge to reduce greenhouse gas (GHG) emissions has resulted in many early strategies being focussed on mitigation, rather than adaptation. However, as the anticipated impacts become more evident, recognition is growing among local authorities that action must be taken soon, to first identify and then manage climate change risks. Sound adaptation strategies require a holistic approach, and planning can play a significant role in supporting and implementing adaptation actions.

Weather-related disasters occur at both very local and regional scales, as documented by various observations and indicators from the past. Extreme weather events (EWE), such as the flash floods that surprised Coffs Harbour after torrential rain on 23 November 1996, can cluster in time, as did the intense rain events in Bellingen in February, May and July 2009, or the six major storms that hit the coast near the Queensland border in 1967. Recent work on coastal erosion suggests a dominant 30-40 year cycle entered a new phase at the end of the recent decade; formal publications (Castelle *et al.* 2008) express concern over considerable coastal urban expansion which has made some urban areas less, rather than more, climate-resilient to the expected stormier weather phase.

The Mid North Coast region, which includes the Bellingen, Kempsey and Nambucca shires, shares with other parts of the Eastern Australian coast many characteristics that make it susceptible to major interruptions caused by EWE. These include prolonged and intense rains that can lead to flooding and disruption of normal activities, heat waves and associated bushfires, severe wind storms and hail, and extended periods of drought. The Mid North Coast is in the transition zone between temperate and sub-tropical climates and is thus subject to a more diverse range of climate drivers (determining influences) than further north in, say, the more heavily populated South East Queensland region or the region south of Sydney.

Climate change is more than an environmental issue. In addition to the environmental challenges climate change also has the potential to erode the local economy, strain Council resources and pose challenges to human health and well being. Yet if managed appropriately, action to address climate change should allow the council to build on existing sustainability drivers and work towards resilience to other non-climate issues (such as peak oil and global financial challenges).

1.1 About This Document

This document is a vital step in the process to identify a path towards Council's resilience to climate change. The next stage of the process, the adaptation plan, will be released mid 2010. This research has been funded by the Australian Government as part of the Local Adaptation Pathway Program (LAPP) with in-kind support from Bellingen, Nambucca and Kempsey Shire Councils. The aim of this stage of the project is to undertake a scoping risk assessment to identify potential climate change risks for Bellingen, Nambucca and Kempsey Shires. The assessment explores potential risks specific to each council as well as at a regional level.

This document is separated into two parts. **Part A** presents the project's methodologies; introduces the topic of climate change; introduces the current understanding of climate variability in the region; graphically presents selected projected climate change scenarios for 2030, 2050 and 2070; and outlines types of climate change hazards.

Part B explores the anticipated impacts that the projected climate change impacts may have on the Council operations; the community; the local economy; and the natural environment.

PART A

2 Methodology

This project is an integrated risk assessment that incorporates critical analysis undertaken by Climate Risk Pty Ltd and its sub-consultants. The results of this project include findings from community and staff workshops (using the AS/NZS 4360 methodology); economic analysis (using ACIL Tasman's general equilibrium model and climate change perturbations from Climate Risk Pty Ltd); climate change projections (provided by CLIMSystems using an ensemble of five general circulation models); and scoping environmental and water analysis from the Snowy Mountain Engineering Company (SMEC).

This climate change risk assessment follows the AS/NZS 4360 standard (as directed by the Australian Government Department of Climate Change for the funding requirements of this LAPP project). The risk assessment process for this project followed the Australian Government Guide "Climate Change Impacts & Risk Management: A Guide for Business and Government" (Department of Environment and Heritage 2006). This is report addresses the first four steps. Following this project the final step will be undertaken in the Adaptation Plan. Ultimately the process includes the following steps:

1. Establish the context
2. Identify the risks
3. Analyse the risks
4. Evaluate the Risks
5. Treat the risks

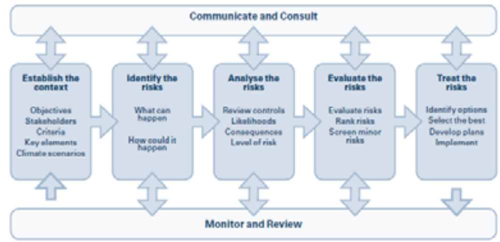


Figure 1. The risk management and adaptation process set out in the AS/NZS 4360 Risk Assessment Standard (Adapted from Australian Government 2006, p.19)

3 Introduction to Climate Change

This chapter briefly introduces the science on climate change and its anticipated international and national impacts.

Chapter Summary: The world is warming with considerable evidence showing that it is a result of human activities. Regardless of society's actions temperatures are predicted to rise for the next century with recent science showing that sea levels are projected to rise between 0.8m and 2.0m by 2100. Data from the Australian Bureau of Meteorology shows the past decade to be the hottest decade, and 2009 the second hottest year, since quality records commenced in 1910.

There is now overwhelming evidence that global average temperatures are increasing as a result of anthropogenic (human-derived) interference of the earth's climatic system (Stern 2006; Pittock 2005; Stefan 2006). The latest data reveal a clear trend of increase in the rate of carbon emissions released across the globe, which is contributing significantly to global warming. Data released by the Global Carbon Project (2008) show that since the year 2000, anthropogenic carbon dioxide (CO_2) emissions have grown at four times the rate of the previous decade, and are exceeding the worst-case scenario projected by the IPCC's long term scenarios.

The Earth's global temperature has warmed significantly over the past one hundred years (IPCC 2007). On average, the world is currently 0.74°C warmer than a century ago (IPCC 2007) (Figure 1). This rate of change has not been uniform across the globe; northern latitudes have warmed much more than other regions. Mounting evidence shows that the increase in the Earth's global temperatures is already affecting terrestrial biological systems, with such changes documented in numerous scientific publications and international reports (IPCC 2007; Rosenzweig *et al.* 2008).

The fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC) Working Group II warns that consequences of climate change, including sea level rise and increased frequency and intensity of weather events, will result in 'adverse effects on human and natural systems' (IPCC 2007, p. 52).

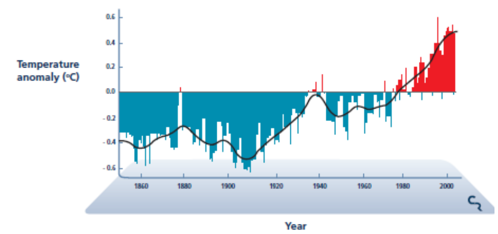


Figure 2. Temperature anomaly from pre-industrial times. This graph highlights a significant increase in average temperature on Earth since the 1900s.

Current international negotiations are attempting to reduce greenhouse gas emissions to significantly below 1990 levels (up to 80% reduction by 2050). However, the latest data suggest GHG emissions are growing faster than ever, mainly as a result of increased wealth, rapid economic growth in China and India, and declining efficiency of the world's natural carbon sinks (Global Climate Project 2008; Canadell *et al.* 2007).

Regardless of existing efforts to curb GHG emissions by countries signatory to the Kyoto Protocol, it is now widely accepted that global world temperatures will continue to rise for the remainder of this century at least. This is due to locked-in impacts, stemming from existing carbon loading in the atmosphere. Latest projections by the IPCC suggest that average global temperatures will increase by approximately 1.8°C to 4.4°C by 2100 (IPCC 2007). However, some scientists, including James Hansen, director of the NASA Goddard Institute for Space Studies, believe these projections are conservative and that global temperatures could rise by up to 6°C by century's end (IPCC, 2007, IEA 2008).

Although these figures may not seem significant, an increase of only 2°C can have serious consequences. As shown by Garnaut (2008, p.139), 1.8°C - 2.3°C warming may cause 10%-17% of the world's species to become extinct, and bring about a 19% - 40% likelihood of irreversible melting of the Greenland Ice Sheet (leading to significant sea level rise). An increase of 1.5°C - 2.5°C is also likely to have negative impacts on ecosystem services (eg water and food supply), and have serious consequences for human and animal health (IPCC 2007, p.26). Some argue that 2°C of average warming would prompt the beginning of 'runaway' climate change. This refers to a process whereby positive feedback mechanisms are triggered (such as the drying of the Amazon Rainforest or melting of permafrost), leading to the higher end of climate change projections being realised (ie a 6°C temperature increase on 1990 levels & 1.4 to 2m of sea level rise by 2100; Hansen *et al.* 2008; Pfeffer et al. 2007).

Strategies to deal with climate change generally consist of two elements: adaptation and mitigation (Pittock 2005, p.7). The IPCC defines adaptation as an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (Metz *et al.* 2001).

3.1 Climate Change in Australia

Australia is vulnerable to a changing climate. The past century has seen Australia experience an average warming of 0.7°C and a significant reduction in coastal precipitation (Preston & Jones 2006). This warming trend is set to continue given predictions that average temperatures in Australia could increase by 0.4°C - 2°C above 1990 levels by 2030, and 1°C - 6°C by 2070 (Preston & Jones 2006).

Data from the Australian Bureau of Meteorology (BOM) show the past decade is the hottest on record (0.9°C above the 1961-1990 average; Fig. 3). The data also indicate that 2009 was the second hottest year since 1910 (BOM 2010).

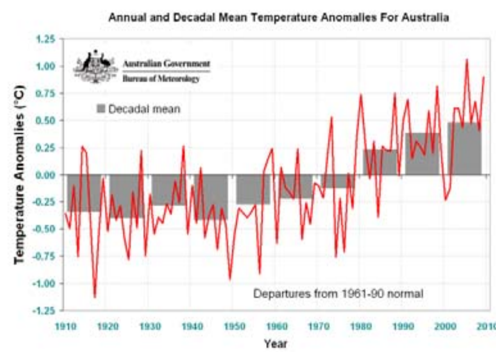


Figure 3. Annual and decadal mean temperature anomalies for Australia, compared with 1961-90 avrg. (BOM 2010).

According to the Australian Government Department of Climate Change, climate change will place considerable strain on Australia's coastal communities, due to threats including sea level rise and increased storm surges, changes to marine and coastal biodiversity, and changes to fisheries (Voice *et al.* 2006, p.2).

4 Current Understanding of Regional Climatic Drivers

This chapter explores climate drivers of the region and highlights current data on climate averages and extremes.

Chapter Summary: The main 'global' climate drivers which affect extreme weather events in the Mid North Coast region are expected to be El Nino Sothern Oscillation (which usually affects extreme rainfall and flooding, hail and storm frequency) and the longer-term decadal oscillations (PDO or IPO) that affect the general climate regime and frequency of extreme events. During IPO positive events with El Nino dominant (1920-1945 and 1975-2006) there is a low flood risk and high drought risk. During an IPO negative phase, La Ninas are stronger and there is greater chance of flooding and lower risk of drought.

4.1 How to judge climate variability in space and time?

It is instructive to divide each region into three subregions (essentially according to terrain and proximity to the coast) to describe climate and extreme weather event characteristics. After the fashion of Blackmore and Goodwin's (2009) assessments for the Hunter region just to the south of the Mid North Coast region, it is justifiable to define the mid-north coast region in terms of coastal, central lowlands and western (highland) zones, as each often experiences rather different climate characteristics, variability and change.

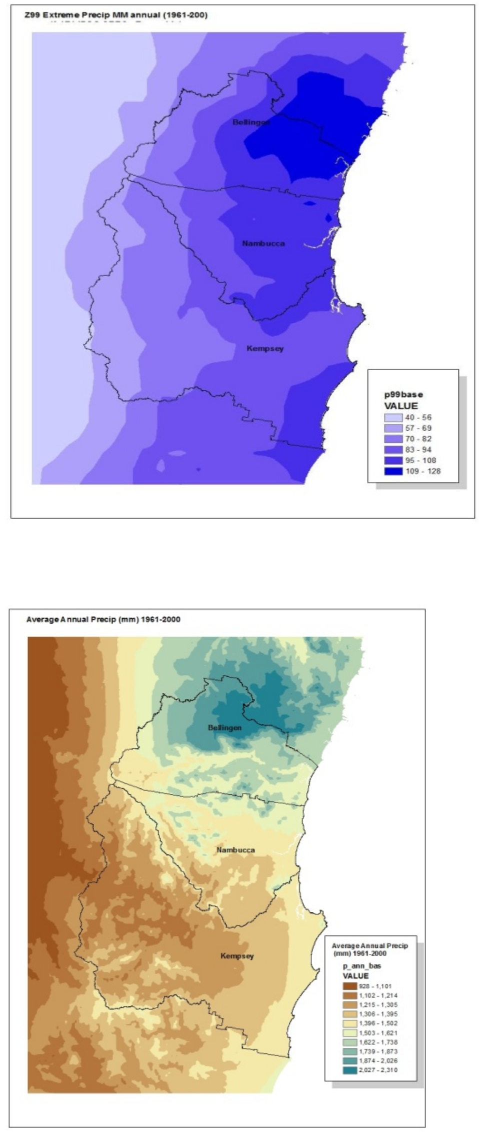


Figure 4. CLIMsystems maps for the standard 1961-2000 period. Extreme precipitation (top image) and average annual precipitation (bottom image).

The CLIMsystems maps above (Fig 4) for the standard 1961-2000 period show a dependence of annual rainfall on topography and proximity to the coast (right-hand map above), but a clustering of extreme conditions (1 in 100 year rainfall as shown in the left-hand image) in the near-coastal strip. The hills from Bellingen to Coffs Harbour are particularly prone to high and intense rainfall.

For temperature, similar considerations apply (Fig 5). The map shows showing the mean daily maximum temperature for the 1961-2000 period emphasises the predictable decrease of temperature with elevation, but these effects may also be affected by the inland westerly, desert winds that inhibit the inland penetration of cooling afternoon sea-breezes.

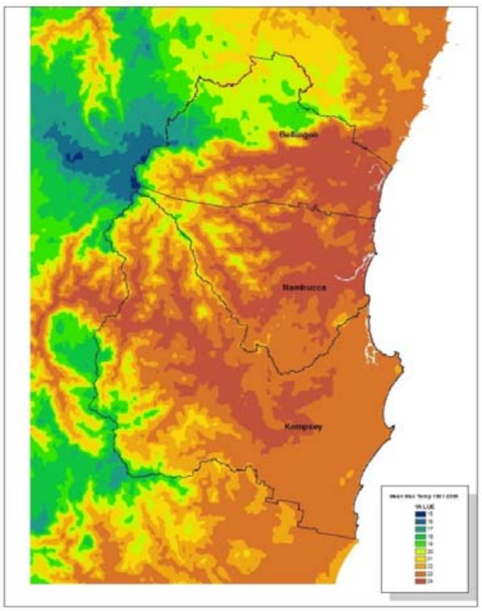


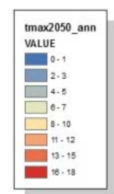
Figure 5. Annual mean maximum temperature, 1961-2000.)

5 Climate Drivers and Oscillations for the Mid North Coast Region

The many drivers of weather and climate events can interact in often quite complex ways, producing variability in meteorological behaviour and patterns in time and space. Island countries such as Australia and Indonesia are influenced by conditions in several surrounding oceans. The influence of one ocean can vary at seasonal timescales and, via longer-term shifts in the banded motion of the atmosphere and oceans, over still longer-term periods. The influences of different oceans on the climate/weather conditions will vary geographically; Queensland is more affected on a seasonal basis by changes in the West Pacific Ocean, Victoria and southern New South Wales by those in the Southern Ocean. For the Mid North Coast of New South Wales, there are likely to be competing influences, with the dominant influence changing over seasons and years.

It is also useful to consider events clustered by month and season since the forcings and resultant weather patterns have fairly well-defined seasonality for this part of Australia (which is in the transition zone between temperate and sub-tropical classifications).

The response to climate change is likely to vary across seasons and geographical space, as well as being conditioned by tl climate cycles that are relevant to t and processes. These climate cycl various names (eg the El Niño-Oscillation, ENSO) and have 'frequencies' (although these clim



mostly occur in quasi-periodicities whereby frequency is meant in an overall statistical sense).

There is increasing recognition of the role these influences have in, for example, determining seasonal rainfall and long-term drought and flood patterns; the debate about whether climate variability or climate change is dominant has moved on, to finding the interacting roles of each for a given region. The influence of climate change on these patterns of behaviour then becomes the key question, but the ability to answer this pushes the very limits of existing ocean-atmosphere climate models.

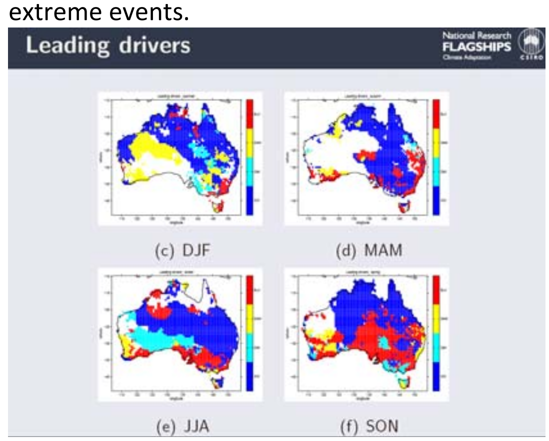
The current understanding of the primary climate drivers for the general New South Wales coastal areas includes the following:

- **Synoptic** weather systems often impeded by blocking high-pressure systems that can encourage the occurrence of several days of extreme conditions (especially heat waves and convective storms). To some degree, this can be described by a set of 'blocking indices' that are calculated from the spatial patterns of upper-level winds over various parts of Australia. It will be shown later that maximum temperatures at various locations in the region for a month are often correlated strongly with one blocking index.
- **Multi-week** systems such as those associated with monsoonal activity and the westward progression of large-scale anomalies in the Madden-Julian Oscillation (MJO) eight-phase system that influences much of Australian rainfall.
- **Seasonal and inter-annual cycles** such as those produced by solar variability, the hemispheric atmospheric and ocean cycles such as the Southern Oscillation (SOI), Southern Annular Mode (SAM), Indian Ocean Dipole (IOD) and more continental cycles such as the position of the Sub-tropical Ridge (STR).
- **Decadal variability** such as the Pacific Decadal Oscillation (PDO) or similar Inter-decadal Pacific Oscillation (IPO), that produces a 30-40 year waxing and waning of correlations of, say, monthly rainfall and SOI/IOD.
- **Climate change influences** such as the general expansion of the sub-tropics (shown in drifts in the position of the STR, for example), the intensification of the hydrological cycle (leading to more intense rainfall events) and the increase in impacts of storm surges (as sea levels rise and storm effects on marine events increase).

The following set of figures (taken from Risbey et al. 2009) illustrates the seasonal and geographic variability of the main drivers for rainfall, and the proportion of the variability (variance) explained by the dominant driver.

The drivers for extreme events, rather than for average climate values, may be quite different. Yet for many climate parameters these drivers are poorly known. The latter part of this report outlines new results obtained for this project through the use of local observations and new weather reconstructions for the region.

Previous research has shown that the main 'global' climate drivers which affect EWE in the Mid North Coast region are expected to be ENSO (which usually affects extreme rainfall and flooding, hail and storm frequency) and the longer-term decadal oscillations (PDO or IPO) that affect the general climate regime and frequency of extreme events.



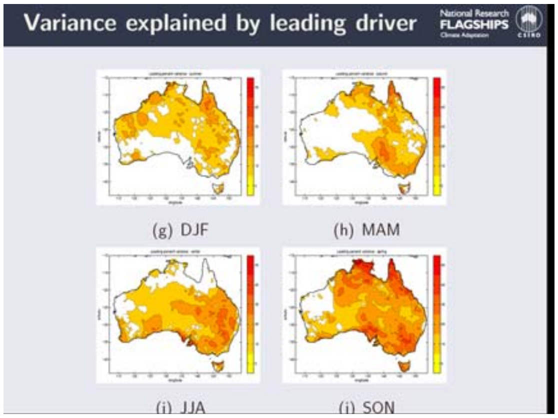


Figure 6. Leading climate drivers for rainfall, and proportion of variability explained by the dominant driver (from Risbey et al. 2009).

For the Mid North Coast, the above set of complex information can be summarised as follows (but more detailed analysis is needed):

Season	Main driver for seasonal rainfall	% variance explained
Summer	SOI	20
Autumn	Blocking	20
Winter	SOI	10
Spring	SAM	10

Table 1: Main drivers of seasonal rainfall for the Mid North Coast.

There is strong evidence for the interaction of the IPO and ENSO in NSW droughts, bushfires and flood events. During IPO positive events with El Nino dominant (1920-1945 and 1975-2006) there is a low flood risk and high drought risk. During an IPO negative phase, La Ninas are stronger and there is greater chance of flooding and lower risk of drought (Frank *et al.* 2008, Kiem *et al.* 2002, Verdon-Kidd and Kiem, 2008).

Recent work at the University of Newcastle and elsewhere has emphasised how flood risk in NSW, as shown below, for example, is not only greater in La Nina years but is modulated by the value of the IPO/PDO (by a factor of 20% or so for most statistics of the average return intervals).

It is unclear at this stage how climate change is affecting the ENSO and PDO mechanisms and the links between these processes and regional extremes. Long-term datasets are needed to elucidate these effects (typically this requires an observation period around six times the length of the dominant cycle – which means data for at least 80-100 years to examine the main drivers for NSW rainfall, for example). For an interpolated dataset recently issued by the Bureau of Meteorology, the long-term cycles are evident in several parameters, such as diurnal (day) temperature range (a 30 year cycle), minimum temperatures (30 year cycle) and the annual rainfall for the region (5 and 30 years cycles).

6 Nambucca – Existing Climate

This chapter explores the historical climate of the area.

Chapter Summary: Nambucca has experienced a gradual increase in mean annual temperatures over the past 100 years with its highest temperature recorded being 41.7°C. Heatwave events are uncommon (occurring every 12 years) with an average of 1-3 days per year over 35°C being recorded. Average yearly rainfall ranges from 1100m – 1500mm with the highest annual recorded rainfall being 3016mm. Over the past decade Nambucca has experienced significant rainfall / flooding events, in 1999, 2001, 2006 and 2009. The existing extreme rainfall return rates range from 1-in-5 year events of 272mm in three days, through to 1-in-100 year events of 536mm in three days.

6.1 Nambucca's Past Climate (1961-2000 Average)

As shown above, average and extreme climate values may vary greatly between different geographic areas, both currently and in forthcoming decades when the complications of anthropogenic climate change will be added to the equation. This chapter presents the mean historical climate for the period of 1961-2000, which defines the base period for all the projected climate change maps and data. Using the data after 1960 as baseline is a convention of World Meteorology Organization (WMO) and IPCC for climate change research.

Although the maps and data below are presented as averages for the duration of the entire 1961-2000 period, there is often clustering of events due to the climate variability described in the previous chapter.

6.1.1 Temperature

NSW experienced its hottest day on record in 2009, a year for which BOM data shows mean temperatures to be 'very much above average' for the Mid North Coast (BOM 2010) (Figure 7).

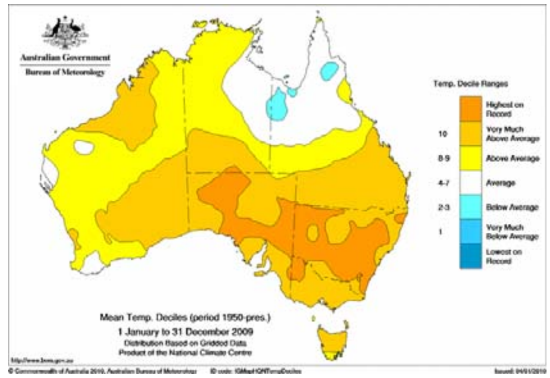


Figure 7. Australian 2009 annual temperature according to mean temperature deciles (1950-present).

There has been a gradual increase in mean annual temperatures over the past 100 years, in line with measurements elsewhere in Australia. The figure below concentrates on the difference (anomaly) between the annual temperature over the region and the 1961-90 average; anomaly values during the past 30 years have been consistently greater, by 0.2-0.7 °C (Figure 8). The historical record for the diurnal temperature range shows quite distinct long-term cycles (of around 35 years).

As Figure 5 demonstrated, the Mid North Coast Region does not average a large number of days exceeding 35°C. For Nambucca specifically, there is an average of 1-3 days such days per year (over 35°C; Figure 9), with the number varying slightly across this region. Heatwave events (five or more consecutive days over 35°C) are not common, occurring at a rate of once every 12.7 years (CLIMSystems 2009).

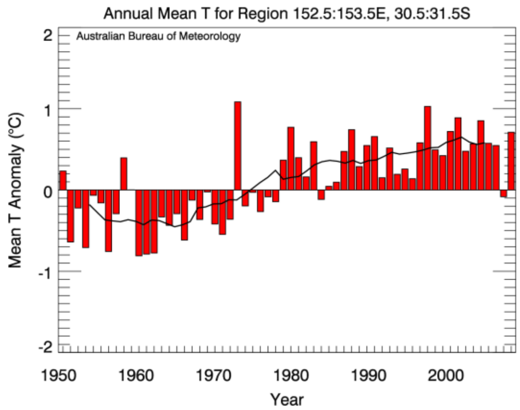


Figure 8. Annual mean temperature anomalies, as compared to the 1961-1990 average (BOM 2010).

As for maximum monthly temperatures temperatures, historical information for the area is very limited. As a resort, use has been made of the Smoky Cape (South West Rocks) site at the southern boundary of the shire ,and the longer-term records at Port Macquarie. The reanalysis results for the region are also likely to be useful.

6.1.2 Rainfall

The map below (Figure 10) shows that much of the shire experienced approximately 1100mm- 1500mm of annual rainfall for the 1961-2000 period. During the past decade Nambucca has experienced significant rainfall / flooding events, in 1999, 2001, 2006 and 2009. During 2009, five natural disasters were declared for the Nambucca Shire due to heavy rainfall in February, March, May, October and November of that year. Urunga (north of Nambucca) recorded the wettest day with 510mm of rainfall on 1 April 2009. According to BOM (2010), rainfall during 2009 was classed as 'very much above average'. A signal of stronger extreme precipitation appears to be making itself evident in the northern part of the shire (Figure 11).

The existing extreme rainfall return rates range from 1-in-5 year events, of 272mm rainfall over three days, through to 1-in-100 year events, of 536mm rainfall over three days (Figure 12).

The historical analysis show that there is reasonable consistency in the rainfall statistics across the sites, with slightly lower values found at the inland highland site (Table 3).

For coastal sites (highlighted in blue), values for highest monthly rainfall ranges from roughly 700-1400 mm. Annually, their mean rainfall is approximately 1450 mm, with the figures for highest recorded annual rainfall being 3200 mm. There are 14 days of rainfall above 25 mm (according to Port Macquarie figures).

For the lowland site (highlighted in green), highest monthly rainfall is roughly 700 mm, mean annual rainfall 1333 mm, and the highest annual rainfall 2450 mm. At the inland highland site (no highlight) the highest monthly rainfall is less than the above sites, at around 661 mm. The mean annual rainfall is 1283 mm, and the highest annual rainfall is about 2300 mm. There are about 12 days of rainfall greater than 25 mm.

For monthly and decadal statistics, and discernment of any rainfall drivers, attention has been restricted to the set of sites shown in the tables below.

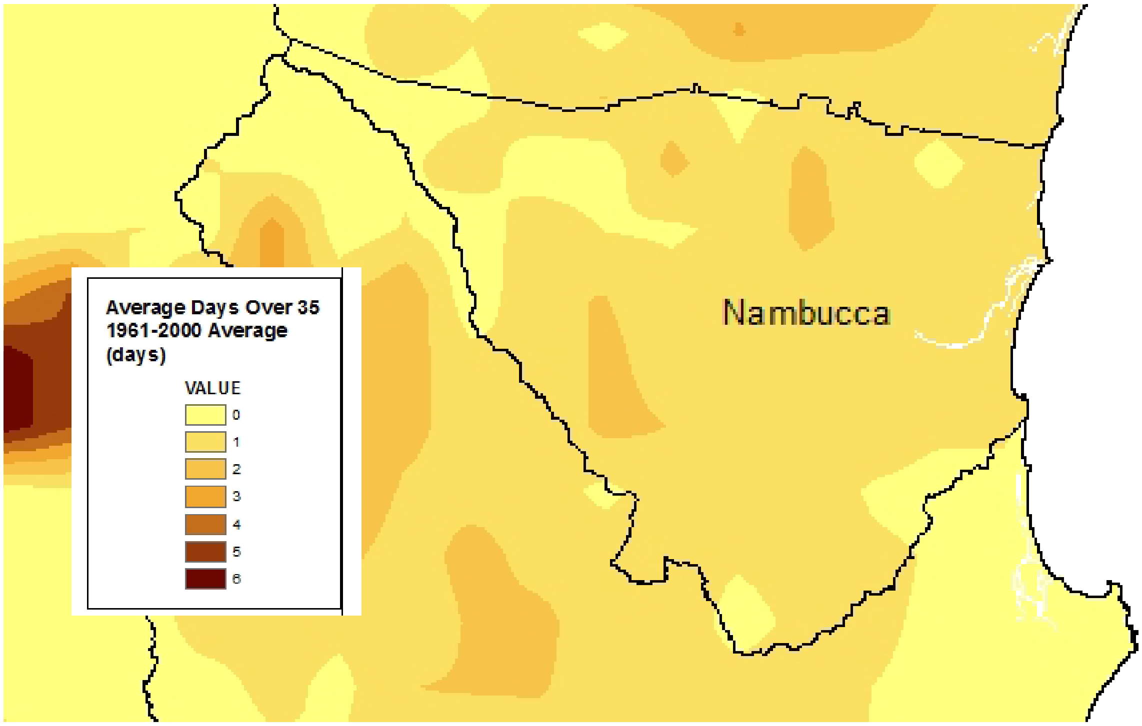


Figure 9. Average number of days per year over 35°C in the Nambucca region, 1961-2000.

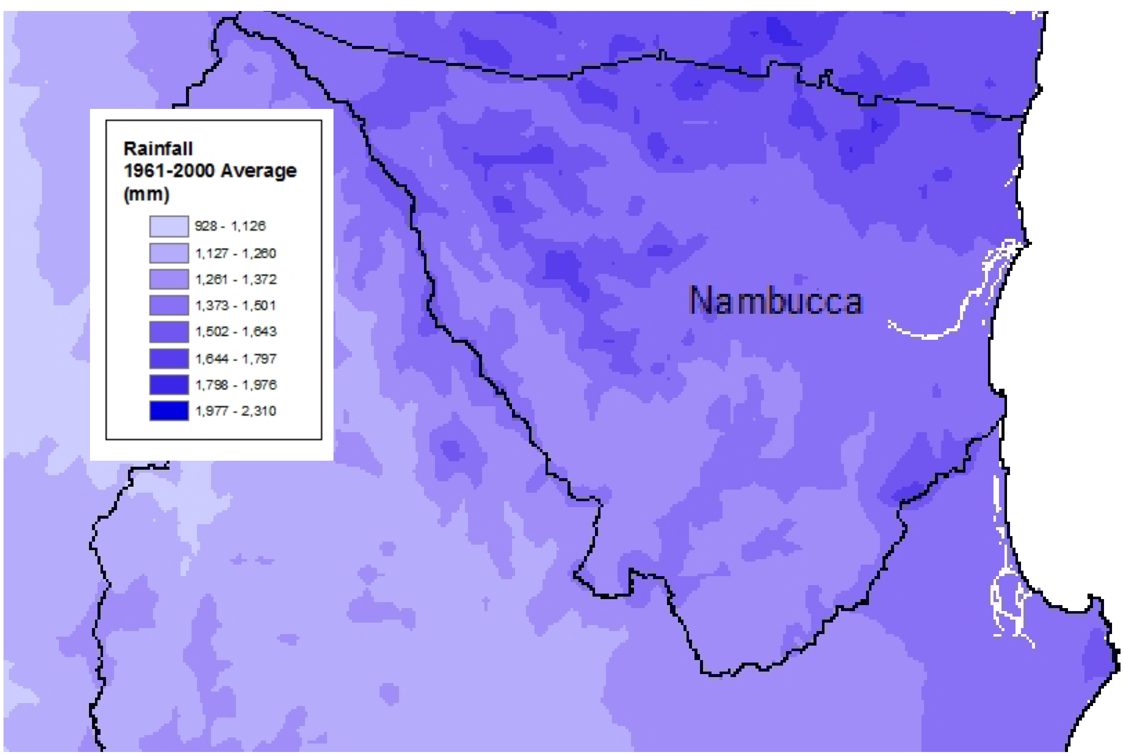


Figure 10. Annual rainfall, averaged over the 1961-2000 period.

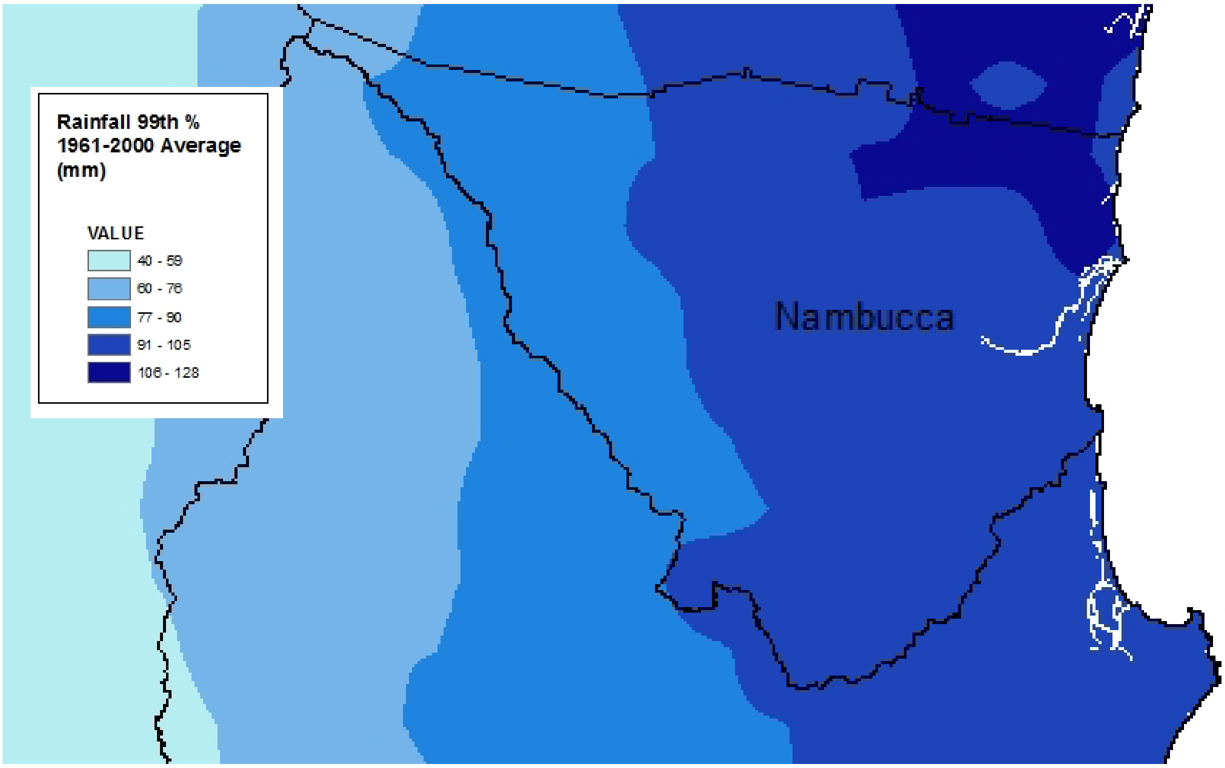


Figure 11. Spatial distribution on extreme rainfall 1961-2000 (mm).

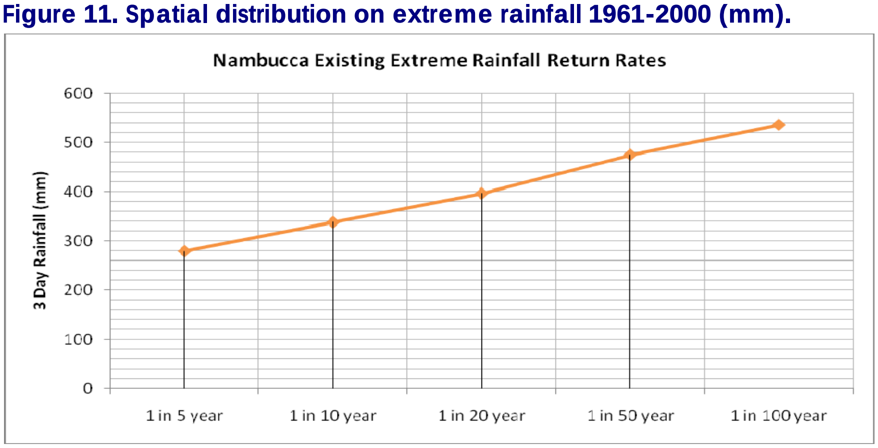


Figure 12. Current return rates of extreme rainfall events for Nambucca.

Site	Period	Elevation	Median Tmax	95% Tmax	Highest Tmax
Smokey Cape	1957-2009	117	38.2	39.3	41.7
Walcha	1965-1975	1050	N/A	N/A	35.6
Port Macquarie	1957-2003	20	33.2	41.0	41.7

Table 2. An indication of regional maximum temperatures based on data from Smokey Cape, Walcha, and Port Macquarie.

Table 3. Rainfall statistics for the mean annual rainfall, the 90th percentile and maximum annual rainfalls, the maximum monthly rainfall and, where available, the mean number of days per year with rainfall over 25mm.

Site	Period	Elevation (m)	Distance to coast (km)	Mean annual	90^{th} % annual	Highest annual	Highest monthly	Mean no days>25mm
Nambucca Heads	1964-2009	5	< 5	1407	2037	3016	704	n.d.
Macksville	1888-2009	33	7	1333	1950	2450	709	n.d.
Walcha	1879-1986	1050	160	1283	1900	2327	661	12.6
Port Macquarie	1840-2009	20	< 5	1535	2111	3204	1388	13.9

Table 4. Maximum monthly rainfall (mm)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
Smokey Cape	527.0	405.4	649.3	702.6	466.5	541.6	597.5	380.6	254.4	536.4	434.8	466.0	702.6
Macksville	423.9	669.0	588.2	537.6	507.9	625.4	552.9	389.1	628.6	332.8	481.4	412.9	669.0
Walcha	286.9	305.7	171.2	170.2	177.2	222.9	194.3	154.1	163.7	168.8	239.6	211.6	305.7
Reanalysis	447.2	435.6	299.9	393.1	225.4	495.0	286.4	150.1	225.1	220.6	299.2	313.2	495.0
Regional mean	385.8	538.7	502.1	444.1	466.1	505.8	457.6	245.7	230.7	388.2	288.3	291.6	538.7

Table 5. Monthly maximum rainfall (mm) by decade

Summary	20s	30s	40s	50s	60s	70s	80s	90s	2000-03	All
Smoky Cape		355.6	597.5	559.7	702.6	536.4	474.6	466.5	351.8	702.6
Macksville	555.8	588.2	552.9	432.6	625.4	669.0	512.6	481.4	234.4	669.0
Walcha	305.7	286.9	239.5	249.7	239.6	280.6	244.4	204.6		305.7
Reanalysis	313.2	245.2	495.0	354.6	252.9	290.5	435.6	318.4	140.3	495.0
Regional mn	538.7	321.7	473.7	428.6	505.8	502.1	416.3	295.0	403.4	538.7

7 Projected Climate Change

This chapter presents the projected climate change for the Nambucca Shire Council and surrounding environs for 2030, 2050 & 2070.

Chapter Summary: The projections for Nambucca show increasing average temperatures. Annually the mean monthly maximum temperatures are projected to increase by approximately 6% in 2030; 14% in 2050; and 22% by 2070. For the periods 2030, 2050 and 2070, the average annual maximum temperatures are project to increase by 0.89 °C, 1.77 °C and 2.92 °C respectively. Importantly, the projections show average maximum temperatures in December may increase by over 2°C by 2050 & 4°C by 2070.

Projections for annual precipitation do not depart considerably from recent historical levels (figure 13). However, the ensemble of five GCMs projects a significant change in rainfall by month and season. By 2030, rainfall is projected to increase during the late spring to autumn (November to May) and decrease during the winter and early spring (June to October). For 2050 and 2070, the pattern is similar although the degree of change is exacerbated. This is especially so for the period of 2070 with a range of up to +22% in summer and up to -22% in the winter.

Recent science anticipates that sea levels may increase by between 0.8m and 2.0m by 2100 (surpassing recent NSW policy guidance) and current 1-100 year storm surges may occur every few years by 2050. Climate models for this project predict Nambucca to experience 63.95cm increase in sea levels plus additional contributions from potential melting of ice sheets.

The projections from CLIMsystems displayed here are based on an ensemble of five general circulation models (GCMs): CSIRO Mk 3.5, ECHO-3G, IPSL CM4, MICROC 3.2 & MRI CGCM

It is important to understand the uncertainties in GCM projections, and acknowledge that not all GCMs present similar results. Please refer to the appendices for more detail on these GCMs and why they were chosen for this report. Examples comparing the outputs between the above ensemble of GCMs and the CSIRO Mk 3.5 model are presented in appendix B.

7.1 Precipitation Changes

Projections for annual precipitation do not depart considerably from recent historical levels (figure 13). However, the ensemble of five GCMs projects a significant change in rainfall by month and season. By 2030, rainfall is projected to increase during the late spring to autumn (November to May) and decrease during the winter and early spring (June to October). For 2050 and 2070, the pattern is similar although the degree of change is exacerbated. This is especially so for 2070 with a range of up to +22% in summer and up to -22% in the winter (Figures 14 and 15).

As for intense rainfall, summer and spring show a significant increase on the 1961-2000 average (as much as 45% in summer by 2070) with minor to moderate increases in the winter and Autumn seasons (Figure 16). There will be a change in the return rate of three-day intense rainfall, that is, such events will occur more frequently. Results based on the ensemble of GCMs (A1FI) show that the level of rainfall experienced in what is an currently 1-in-100 year event (of 536 mm) may occur as a 1-in-50 year event by 2050; and the current 1-in-50 year event (475 mm) may occur as a 1-in-20 year by 2070. Also, in 2070, the 1-in-100 year intense rainfall may be 135mm more than current events (Table 6 and Figure 17).

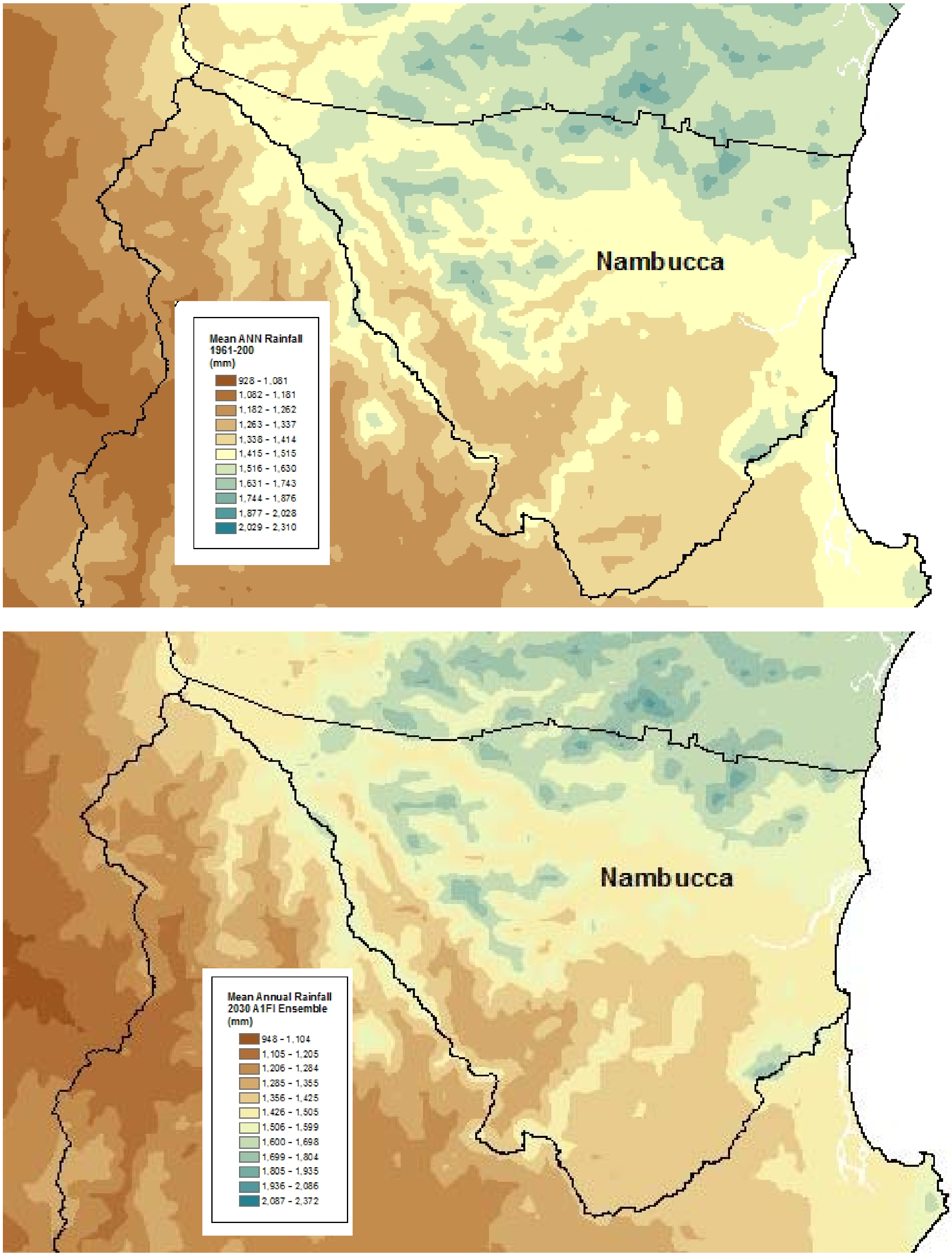


Figure 13. Mean annual rainfall 1961-2000 (top) and 2030 (bottom).

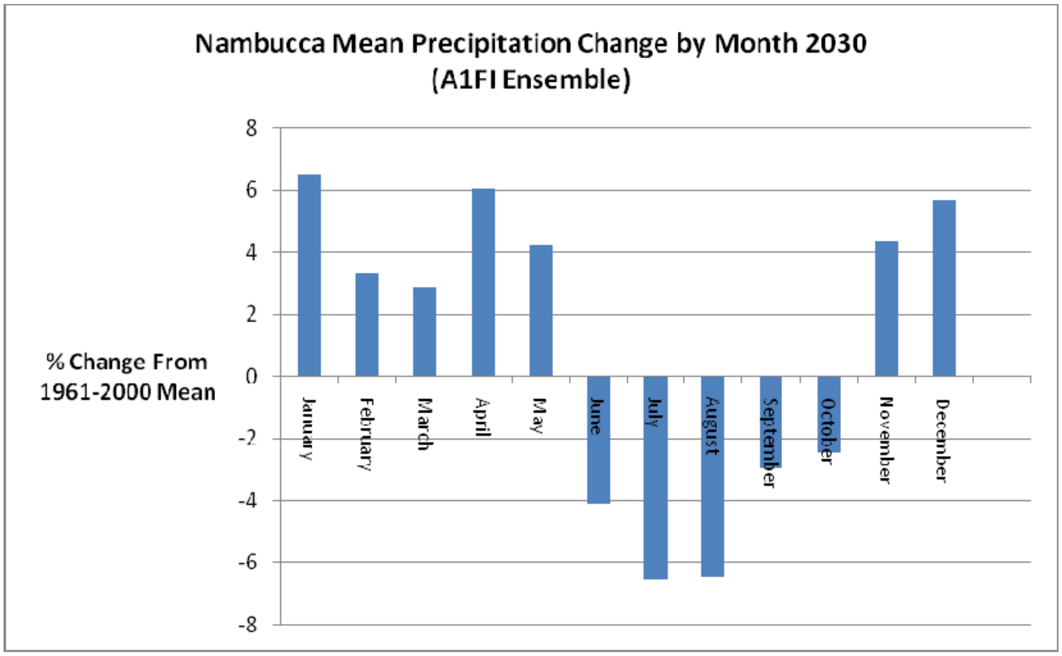


Figure 14. Nambucca mean precipitation by month 2030 (A1FI and ensemble of 5 GCMs)

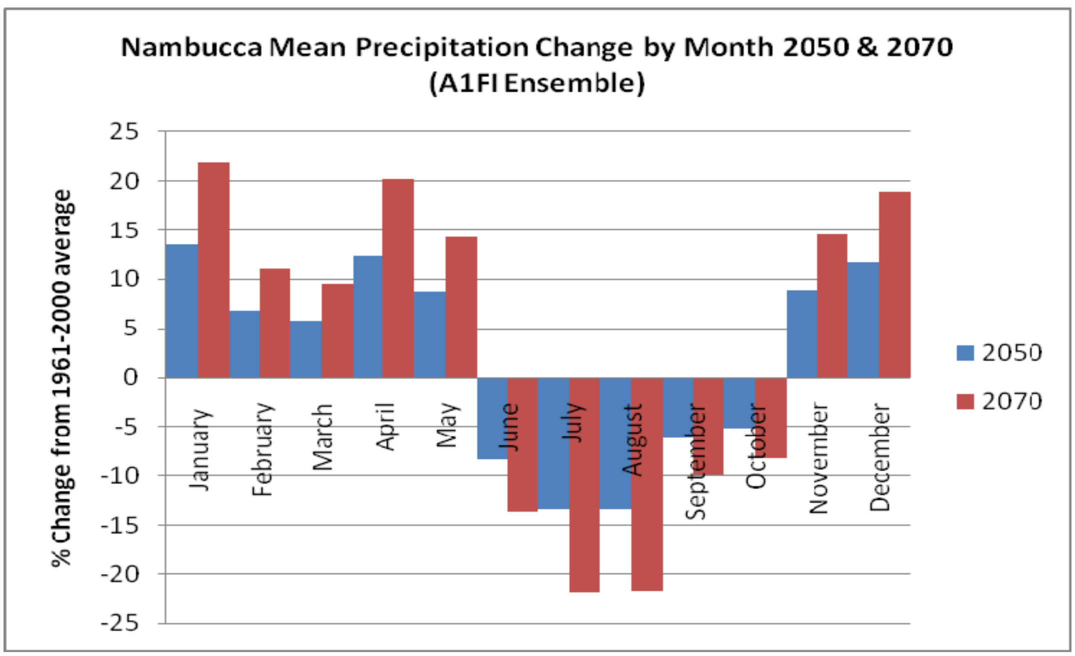


Figure 15. Nambucca mean precipitation by month for 2050 & 2070 (A1FI and ensemble of 5 GCMs)

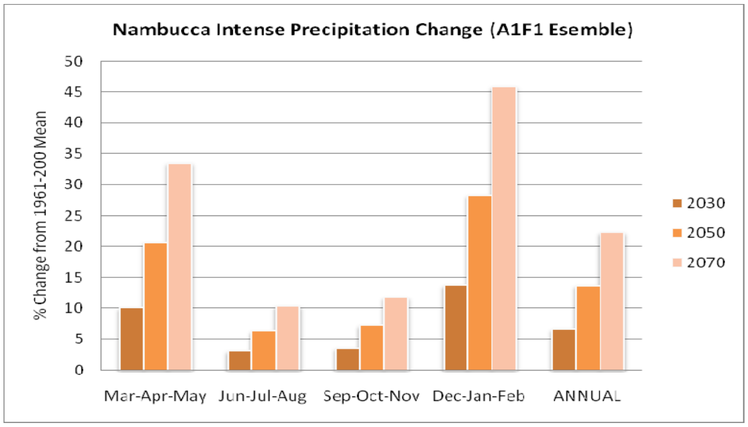


Figure 16. Percentage changes to extreme rainfall by season (A1FI and Ensemble of 5 GCMs).

Table 6. Changes in return rate for 3-day intense precipitation (mm) (A1FI and Ensemble of 5 GCMs). Climate change may shift the three-day intense rainfall return rate. This may make current planning thresholds ineffective for flood management (eg existing 1-in-100 year event may occur as a 1-in-50 year event in 2050).

	Existing	2030	2050	2070
1 in 5 year	279	290	302	316
1 in 10 year	338	354	372	393
1 in 20 year	396	418	442	471
1 in 50 year	475	506	540	581
1 in 100 year	536	576	619	671

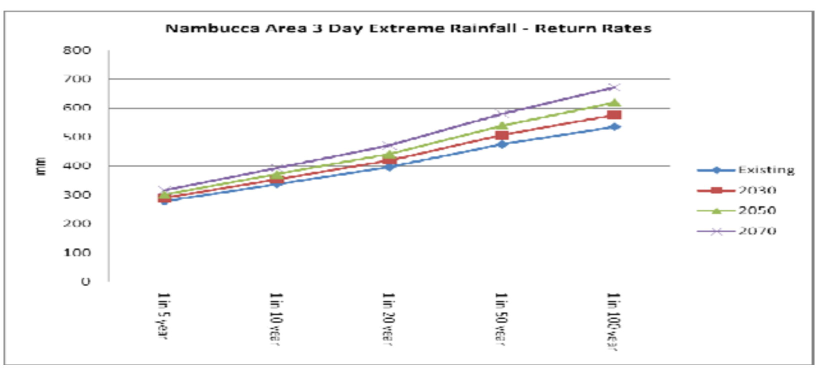


Figure 17. Changes to Nambucca return rates for extreme rainfall (A1FI & 5 GCMs).

7.2 Temperature Increases

As for mean maximum temperatures, the results from the ensemble of five GCMs highlight the significant warming expected in the Nambucca area. Annually the mean monthly maximum temperatures are projected to increase by approximately 6% in 2030; 14% in 2050; and 22% by 2070 (Figure 18). This trend of increase is seen accross all months of the year, with a noticable peak in the month of December. For the periods 2030, 2050 and 2070, the average annual maximum temperatures are project to increase by 0.89 °C, 1.77 °C and 2.92 °C respectively. Alarmingly, the projections show average maximum temperatures in December may increase by over 2°C by 2050 and 4 °C by 2070.

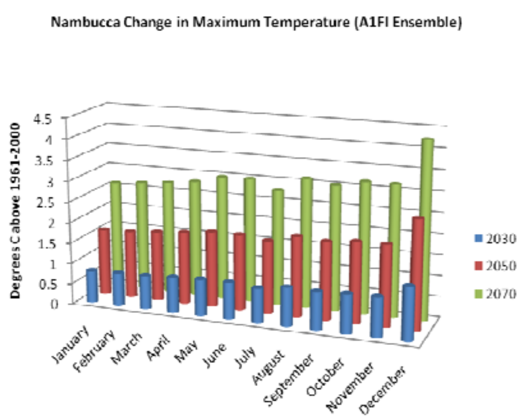


Figure 18. Mean monthly maximum temperatures at 2030, 2050 and 2070.

As well as an increase in average maximum temperatures, the projections show an anticipated decrease in the return rate of heatwaves (consecutive days over 35°C); that is, heatwaves could become more frequent. For this project, CLIMSystems has estimated the return periods for very persistent heatwaves (usually defined as three or five days with maximum temperatures exceeding 35°C, but without accounting for other heat stress variables, night-time cooling relief, or the effects of acclimatisation over the season). The return periods (see below) do shorten quite dramatically. At present periods of five or more consecutive days over 35°C occur every 12.71 years, yet this rate could change to once every 1.2 years by 2070 (Figure 19).

	Existing			
	12.71	2030	2050	2070
50th Percentile		6.08	3.33	1.59
10th Percentile		7.67	5.44	2.71
90th Percentile		5.09	1.95	1.2

Figure 19. Return periods for heatwaves at 2030, 2050 and 2070.

As well as considerable changes to the heatwave return period, the ensemble of five GCMs projects an increase in the number of days over 35°C. The mean number of such days increases, from 1-3 per year for the 1961-2000 average, to a climate in which parts of Nambucca experience up to 14-16 days over 35°C per year by 2070.

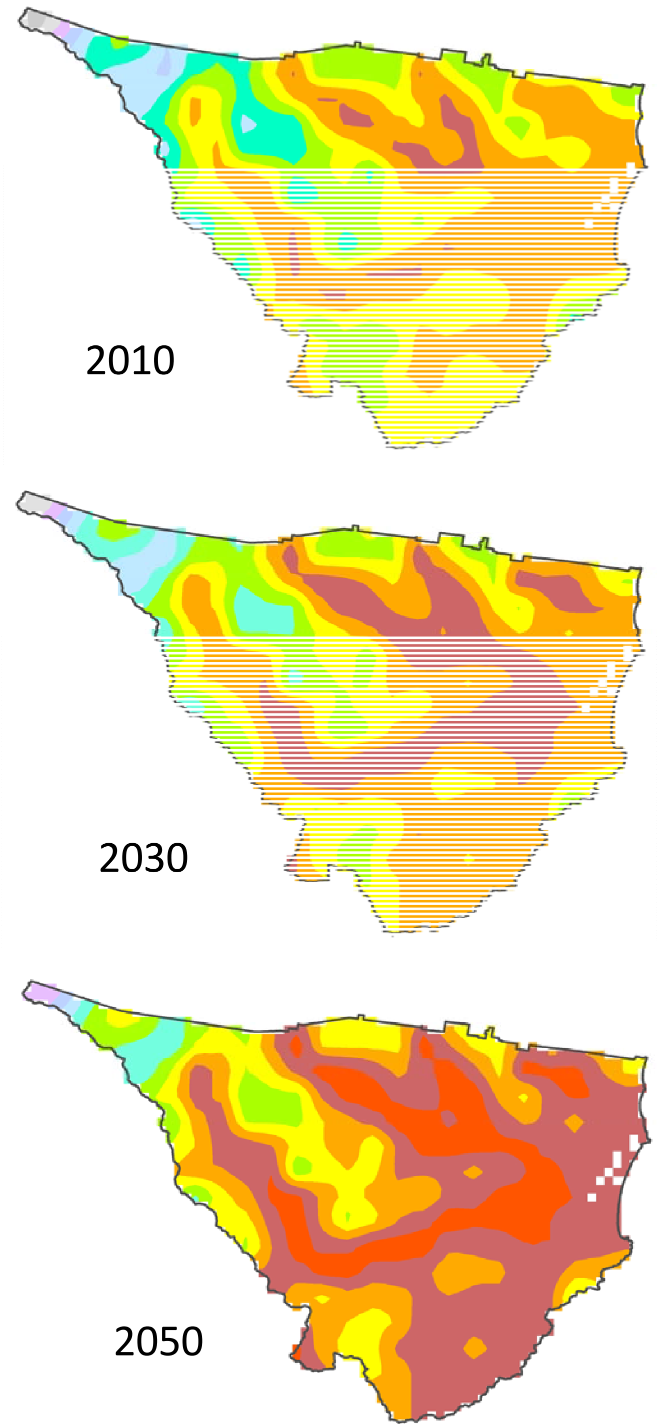
Expected increases in annual average temperature over the next 60 years vary little between the three council regions but will be different between coastal and highland areas. A small seasonal variation is expected, with larger increases in spring.

On a seasonal basis, the temperature variability is expected to be partially determined by ocean and atmospheric states, such as ENSO, and atmospheric 'blocking' that can lead to multi-day periods of north-westerly winds which convey desert air over the region.

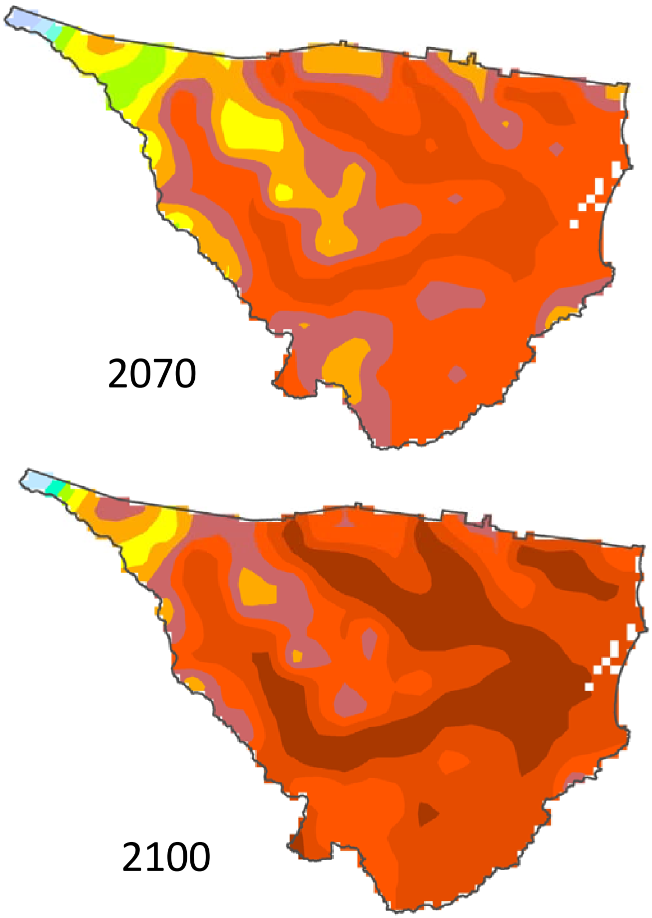
Over time, the increases in annual average temperature is expected to change the exceedance probabilities[2] for various comfort

[2] The probability that a certain value will be exceeded.

thresholds, on a daily and monthly scale. However, more detailed consideration is required to look at the clustering of events that cause heatwaves. Deo *et al.* (2009) used post-1950 temperature and humidity observations to calculate three-day averages of apparent body temperature as a heat index for thermal stress for a range of sites across Australia. The upward trends for Port Macquarie and Yamba were particularly strong.



Climate Risk



Tmax Summer	Days over 35	Days over 40
20	0.1	0.0
21	0.1	0.0
22	0.3	0.0
23	0.4	0.0
24	0.7	0.0
25	0.9	0.1
26	1.5	0.1
27	2.2	0.3
28	4.0	0.4
29	6.8	0.7
30	10.2	0.9
31	17.7	1.5
32	27.0	2.2
33	39.0	4.0
34	51.4	6.8

Figure 20. Average daily maximum temperature for Summer (Tmax-summer) for 2010 through 2100, with table of associated number of very hot days over 35°C and 40°C (A1FI, 23 GCM ensemble).

7.3 Sea Level Rise

CLIMsystems were commissioned to generate sea level rise projections for the area, using an IPCC-based methodology. Given a dearth of statistically useful tidal data for the Nambucca area, CLIMSytems inferred the effects based on tidal data from Port Kembla and Roslyn Bay (with Nambucca presumed as the mid-way point). The projections from this method show a maximum sea level rise from 63.95cm by 2100 (above 1990 levels) (see Appendix C).

However, it is critical that Council view these results in light of limitations of current sea level rise models. The model results do not consider additional contributions from potential ice-sheet dynamic processes (ie melting of ice sheets). There are many uncertainties surrounding sea level rise projections (including data availability and non-consideration of climate variability) and it is imperative that Council considers the following discussion.

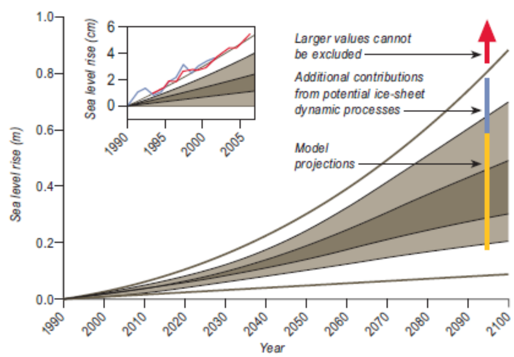


Figure 21. Illustration of the limitations of model projections, showing additional potential contributions (DCC 2009).

Currently, the greatest contributor to sea level rise is thermal expansion of the ocean caused by an increase in global average temperature. However, the melting of glaciers and polar ice sheets are additional factors also currently contributing to sea level rise. Since 1900, sea levels have risen by 19cm; the current rate of sea level rise is approximately 3.1cm per decade (3.1mm per year), up from a rate of 1.8mm per year seen during the 1960s.

The NSW sea level rise policy benchmarks are based on a projected increase above 1990 mean sea levels of 40 cm by 2050 and 90 cm by 2100 (NSW 2009). The Australian Government's latest report provides guidance on sea level rise, indicating that an increase of up to 1.1m is possible, based on the current trajectory of high GHG emissions (DCC 2009).

Year	Scenario 1 (B1)	Scenario 2 (A1FI)	Scenario 3 (High end)
2030	0.132	0.146	0.200
2070	0.333	0.471	0.700
2100	0.496	0.819	1.100

Scenario 1 (B1) considers sea-level rise in the context of a global agreement that brings about dramatic reductions in global emissions. This scenario
represents sea-level rise that is likely to be unavoidable.

Scenario 2 (A1FI) represents the upper end of IPCC AR4 'A1FI' projections and is in line with recent global emissions and observations of sea-level rise.

Scenario 3 (High end) considers the possible high-end
risk identified in AR4 and includes some new evidence
on ice sheet dynamics published since 2006 and after IPCC AR4.

Figure 22. Sea level rise values in metres, according to three scenarios. (Source: ACE CRC in Australian Government 2009.)

However, this report also states that, ‘very recent research suggests that a 1.1 metre sea level scenario by the end of the century may not reflect the upper end of potential risk, and that risk assessments could be “*informed by a higher level*”’ [emphasis added].

Therefore it should be cautioned that the DCC 2009 report is not setting out benchmarks for planning, or setting enforceable standards, and the caveats would inidicate that they suggest prudent risk management may require higher levels to be used than 1.1m. This puts Council in an position where is cannot reconcile State and Federal positions given the State Government’s required benchmarks of 0.9m by 2100.

Estimates recently published in the journal Science consider the constraints on glacial melt and state, ‘we consider glaciological conditions required for large sea-level rise to occur by 2100 and conclude that increases in excess of 2 meters are physically untenable’ (Pfeffer *et al.* 2008). However, there is a body of literature which suggests that sea level rise of greater than 2 meters by 2100 cannot be ruled out entirely. These largest of sea level rise scenarios are termed the H+ scenarios and are generally derived from models projecting the greatest changes based on observations of past sea level from periods analogous to the 21st century. Importantly, the probability of the H+ scenario range occurring is unknown; it is currently believed that the top of the H+ scenario has a very low probability of occurring by 2100. Of course, depending on the nature of coastal development envisaged, post-2100 H+ sea level scenarios will in all likelihood be more probable, and thus should be considered in planning decisions made today. Based on the uncertainty in the science, it has been suggested that a useful range for analysis is between 0.8m and 2.0m by 2100 (Pfeffer *et al.* 2008). This range is supported by scientific modelling presented in a recent peer reviewed journal (Grinsted *et. al.* 2010).

It is also important to note a general agreement in the scientific community that sea levels will rise more rapidly as the century progresses, and will continue to rise for possibly several centuries post-2100. While this should not be interpreted as meaning such large rates of increase in sea level are likely to occur this century, such rises cannot yet be ruled out with current observations and computer models. It is prudent to at least assess the vulnerability of coastal assets or plan for the possibility of these large increases.

Table 7. Projected global mean sea-level rise for the last decade of the 21st century (relative to 1980 to 1999) for the six SRES marker scenarios (from Table 10.7 in Meehl et al. [2007]) combining sea level rise with scaled up ice discharge to create an H+ value for each scenario. The top of the H+ range comes from assuming 1.6m at 2100 and linear growth in this term during the 21st century.

			SRES marker scenario						
			Scenario class	**B1**	**B2**	**A1B**	**A1T**	**A2**	**A1FI**
2025	Mid value (m)		M	0.09	0.08	0.10	0.11	0.08	0.09
	Range (m)	Extreme	H+	0.12-0.4	0.11-0.4	0.13-0.4	0.15-0.4	0.09-0.4	0.11-0.4
		Max	H	0.12	0.11	0.13	0.14	0.09	0.10
		Min	L	0.06	0.06	0.07	0.08	0.07	0.07
2055	Mid value (m)		M	0.17	0.17	0.19	0.21	0.18	0.21
	Range (m)	Extreme	H+	0.25-0.8	0.25-0.8	0.29-0.8	0.30-0.8	0.25-0.8	0.30-0.8
		Max	H	0.23	0.23	0.26	0.27	0.23	0.26
		Min	L	0.12	0.10	0.12	0.15	0.13	0.15
2085	Mid value (m)		M	0.25	0.26	0.30	0.31	0.31	0.36
	Range (m)	Extreme	H+	0.39-1.2	0.43-1.2	0.48-1.2	0.47-1.2	0.49-1.2	0.58-1.2
		Max	H	0.34	0.38	0.42	0.40	0.43	0.50
		Min	L	0.16	0.15	0.17	0.22	0.19	0.23
2095	Mid value (m)		M	0.28	0.29	0.33	0.35	0.36	0.43
	Range (m)	Extreme	H+	0.43-1.6	0.50-1.6	0.56-1.6	0.53-1.6	0.59-1.6	0.69-1.6
		Max	H	0.38	0.43	0.48	0.45	0.51	0.59
		Min	L	0.18	0.16	0.19	0.24	0.21	0.26

* Notes: The IPCC have created global emissions storylines (see abbrevations and acronynms page for further information).

7.4 Storms and Storm Surge

Recently several studies have been made of the variability of coastal storms for New South Wales (You and Lord 2008; McInnes et al, 2007; Speer et al 2009). The probability distributions of storm peak wave height and yearly mean SOI both follow a Gumbel type, that is, extreme wave height and yearly mean SOI appear to be well-related in linear fashion. Coastal recession and increased coastal damage may be expected in La Niña years, while beach recovery and reduced coastal threat may be expected in El Niño years. Past CSIRO research on sea swell and storm surge using local wave-rider buoy information at Wooli Creek area near Byron (McInnes *et al.* 2007) has shown some conflict between models for various parameters. Wave height and frequency of swell occurrence seem to change in a minor way.

During a prolonged period of low pressure the local sea level can be lifted above normal levels. As described by CSIRO, storms can have a considerable impact on the coast:

"Changes in atmospheric pressure also produce changes in sea level (lower atmospheric pressure leading to higher sea levels), so the effect of a severe storm (very low atmospheric pressure) with strong onshore winds can lead to very high coastal sea levels (Storm Surges) with, at times, severe coastal damage, especially when the large waves produced by the strong winds are added"(CSIRO & ACE CRC, 2008)

Depending on the tide, wind speed, direction and physical characteristics of the coast a surge of water can reach considerable distances inland. According to the NSW Coastline Management Manual (NSW 1990) a "storm increases coastal water levels in four distinct ways: by setup due to barometric, wind and wave effects and by wave runup". Combined these can result in water level elevation of 4.0m -8.0m above the prevailing astronomical tide level (NSW 1990)[3].

Sea level rise can dramatically alter the return rate of storm surge projections. Although storm surge modelling has not been commissioned for this project, a recent Australian Government report (DCC 2009) shows that:

"Changes in the frequency and magnitude of extreme sea level events, such as storm surges combined with higher mean sea level, will lead to escalating risks of coastal inundation. Under the highest sea-level rise scenario by mid-century, inundations that previously occurred once every hundred years could happen several times a year."

The above statement is based on modelling work on climate change impacts on the south eastern coast of Australia. The findings concluded that:

"A 10% increase in annual mean wind speed over Bass Strait, which is consistent with a high-end estimate of mean sea level rise by 2070, results in an additional increase in storm tide heights that is sufficiently large to reduce the average recurrence interval for the late 20th century 1 in 100 year level to between 1 and 2 years along much of the coastline. However, it should be noted that, since much of the reductions in average recurrence interval are due to mean sea level rise, not all storm tides of the height of the late 20thcentury 1 in 100 year level will be accompanied by particularly severe storms." (McInnes et al 2009, p. 133)

[3] For more information on elevated sea levels and coastal processes see http://www.environment.gov.au/coasts/publications/nswmanual/appendixb4.html

Tropical storms can sometimes affect the Nambucca area. Recent simulations of the influence of climate change and variability on tropical cyclones and hail suggest that intense events are likely to travel further south into the region over the next 30-40 years (Leslie *et al.* 2007, 2008). The damage caused by tropical cyclones and East Coast Lows, which also cause coastal storms, are discussed further below.

8 Types of Climate Change Hazards

8.1 Weather and Climate

The Mid North Coast region encompassing Bellingen, Kempsey and Nambucca shires shares with other parts of Australia's east coast many characteristic susceptibilities to major weather-related interruptions. These include prolonged and intense rains that can lead to flooding and disruption of normal activities, heat waves and associated bushfires, severe wind storms and hail, and extended periods of drought. The Mid North Coast is a transition zone between temperate and sub-tropical climates and is thus subject to a more diverse range of climate drivers (determining influences) than further north in, say, the more heavily populated South East Queensland region.

Tropical cyclones (such as Cyclone Hamish, which recently threatened to isolate the coastal strip in Harvey Bay, South East Queensland, by cutting off road access to the north and south) very rarely affect Northern New South Wales. However, smaller-scale convective storms such as East Coast Lows have caused major rainfall events in the Mid North Coast, with major flooding and interruptions to transport, education and commercial activities.

Such coastal storms can cause more long-lasting damage to the tourism industry by occurring and persisting in the main holiday periods (leading to cancellations of bookings for the rest of the season) or by leading to other environmental effects (eg such as oil spills, as occurred along Moreton Island in 2009). These events can be taxing for councils, if they draw upon resources to repair the physical environment or alter the public perception of the region as a desirable tourism destination.

When analysing climate change risks it is important to consider the local climate drivers and climate variability. The main climate drivers for the Nambucca area include ENSO, PDO, and the IDO. The various weather hazards and climate drivers as they affect Council operations are summarised here.

The Mid North Coast region does not experience temperatures quite as high as other areas (although low-lying areas away from the coastal strip may experience maximum temperatures exceeding 40 °C). Nonetheless, the susceptibility of elderly or infirm people to heat can still be an issue, especially when coupled with high humidity and sunlight exposure or with the presence of wind-blown dust.

Activities in each shire are affected by the influences of short-term weather, seasonal climate and longer-term climate changes. Extreme weather events are an important subset of climate conditions that can threaten the viability or efficiency of such activities. Summarised here, these extreme weather events are also described in Chapter 9, with particular reference to their relevance to council activities.

- Heat waves
- Prolonged or extremely intense rainfall which can lead to flooding
- Prolonged drought
- Convective storms that may result in hail or lightning damage
- Severe marine-related storms

The various weather hazards and climate drivers as they affect Council operations might be summarised as follows (the trends are often uncertain and are denoted by "?") (Table 8).

Weather hazard	Areas affected	Duration	Fluctuations/trend	Comments
Storm surge (coastal flooding, marine activities)	Coastal strips	3-5 days	30 yr, ↑	Cyclones and East Coast lows
Intense rainfall (disrupts many activities)	Highlands especially	3-5 days	30 yr, ↑?	SOI phase 2, SAM, blocking indices more prominent than others
Prolonged rainfall (discourages tourism)	All areas, especially coast?	1-3 weeks	?	SOI/PDO interactions?
Heatwave (absentees, health)	Lowland especially	3-5 days	3-5 yrs, ↑?	Blocking highs augment
Cold spells (agriculture)	Highlands	Various	PDO?,↓?	
Drought (agriculture, buildings, water supplies)	Lowland especially	3-120 months	SOI/PDO/IDO, ↑?	Complex set of factors likely
Hail/severe convection (maintenance, damage, disruptions)	Highlands/lowlands	0-6 hours	SOI?, ↑?	Neutral SOI enhances

Table 8. A summary description of key weather hazards and climate drivers. Arrows refer to anticipated increase or decrease and question marks recognise uncertainty.

These weather hazards are often referred to as direct or primary climate change hazards. Secondary hazards, arising from responses to climate change, can also present local governments with an array of risks, such as regulatory hazards. These are discussed below.

8.2 Regulatory Change

Australian and State responses to climate change are in a state of flux. During the past two years an array of legislative and policy responses have either released or presented in draft form. It is possible that further regulatory requirements may unfold. Given this state of flux, much of the legislation and policy direction described below recognises the rapid evolution of the science surrounding climate change impacts.

8.2.1 Carbon Pricing

The Commonwealth Government has a stated commitment to implementing a system to reduce national greenhouse emissions. An emissions trading scheme is a market based mechanism which aims to reduce carbon pollution by creating a cap on total national greenhouse gas emissions across a wide range of economic sectors.

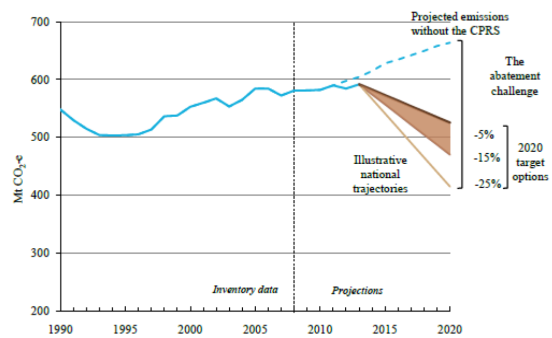


Figure 22. Illustrative national carbon trajectories under the previously proposed Carbon Pollution Reduction Scheme (source: Australian Government 2009)

According to the Australian Local Government Association an emissions trading scheme such as the CPRS would increase Australian local government operational costs significantly. The biggest challenge to local governments from such a scheme arises from increased costs associated with fleet and plant fuel, cost of bitumen, and cost of energy and electricity supply for the services it provides to the community. Although the Commonwealth has indicated that there will be no net increase in transport fuel costs for the next three years,

Climate Risk

these would be very likely to rise after a transition period. Even a few cents per litre can increase the Councils' fuel bills substantially. With oil supply vulnerability on the horizon, this problem is exacerbated for the community, which already feels the strain of increased fuel prices, yet has limited access to public transport services and facilities.

8.2.2 Planning and Other Controls

A range of planning and other types of regulation pose direct and indirect risks for councils. The scale and rapid increase of climate-change-specific policies creates a substantial workload and cost for local governments which must collate, synthesise and implement them. Choosing to focus on one policy over another (eg mitigation over adaptation) may create competition for resources, and cause some measures to be implemented more thoroughly than others. Evolving policies also create an environment of changing regulatory risk, including failure to comply, litigation and planning challenges. The NSW Government is due to release a Draft Climate Change Action Plan for public consultation; however no official date for its release has yet been set.

PART B: CLIMATE CHANGE RISK ANALYSIS

9 Water Quality, Availability and Storage

9.1 Climate Change, the Hydrosphere and Changes in Water Quality and Quantity

Water is involved in all components of the climate system (atmosphere, hydrosphere, cryosphere, land surface and biosphere) (Bates *et al.*, 2008). In turn, climate change thus affects the quality and quantity of water supplies via a number of mechanisms. Climate change model simulations have consistently predicted that the likely impacts of climate change on the Northern NSW region include: an increase in mean annual temperature, a decrease in mean annual precipitation and an increase in severe weather events (flooding and droughts). These changes will impact on the quantity and quality of water available for human and environmental use in Bellingen, Nambucca and Kempsey Shire Councils.

Implicit in the theory of global warming is a positive feedback: increasing greenhouse gas concentrations cause warming, which causes more water vapour to be absorbed into the air, which in turn leads to further warming (because water vapour is also a greenhouse gas) and an intensification of the hydrologic cycle (Stokes & Howden 2008). Put another way, this essentially means higher evaporation rates, higher absolute atmospheric humidity and higher rainfall. However, the locations where evaporation increases may not necessarily the same as those where rainfall increases.

The bulk of Australia's water supply and distribution systems were developed during the latter half of the 20th century, a period of generally favourable rainfall (Stokes & Howden 2008). Security of supply during that period was high, leading many water managers and users to believe that their systems were largely 'climate proof'. However, there is now recognition that climate variations across the scale of decades can have significant impacts. Widely accepted climate change scenarios suggest more frequent droughts in summer, as well as flash-flooding, leading to uncontrolled discharges from urban areas into receiving water courses and estuaries (Whitehead *et al.* 2009). These uncontrolled discharges from urban environments are likely to contain high concentrations of pollutants (total nitrogen, total phosphorous, total suspended solids , metals and toxic chemicals), reducing water quality in the receiving waters.

9.2 Runoff

Runoff is a direct measure of climate change's impact on water resources. Runoff integrates the combined impacts of changes in rainfall, temperature, and evapotranspiration; however, runoff values are most sensitive to changing rainfall. In Australian catchments a 1% change in mean annual rainfall will result in a 2-3% change in mean annual runoff (Stokes & Howden 2008). Declines are greatest along the west coast, western Victoria/eastern South Australia, and north-east New South Wales to south-eastern Queensland (Stokes and Howden 2008). Using the above assumption, combined with the climate change modelling commissioned for this report, the average annual runoff changes are presented in the table below.

Table 9: Projected changes to Nambucca runoff (based on assumption that for each percent change in rainfall, runoff changes by a factor of 2-3; and scenarios for projections of average annual rainfall in Nambucca as per A1F1, ensemble of five GCMs). These do not include evapotranspiration correlations and are a simplistic extrapolation for indicative purposes.

Year	Average Annual Changes to Runoff	Average Winter Changes to Runoff
	Based on Ensemble of 5 GCMs	Based on Ensemble of 5 GCMs
2030	+ 4.8% - 7.2%	(10.8%) – (16.1%)
2050	+ 9.9% - 14.8%	(22.3%) – (32.4%)
2070	+ 16.0% - 24%	(36.2%) - (54.2%)

The above table shows that there is considerable variability between the results of the ensemble of five GCMs and those from the CSIRO MK3.5 model. Interestingly both the ensemble and CSIRO models identify a trend of reduced rainfall (and hence runoff) for winter.

9.3 Precipitation Intensity and Variability

Increased precipitation intensity and variability are projected to elevate the risks of flooding and drought in many areas (Bates *et al.* 2008; Whitehead *et al.* 2009). The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will very likely increase over most areas during the 21st century, with consequences for risk of rain-generated floods (Bates *et al.* 2008).

This has implications for Council infrastructure. Current Council stormwater infrastructure may be overwhelmed by the volume of water during these events, and put under long-term stress due to more frequent events. At the same time, the proportion of land surface undergoing extreme drought at any one time is projected to increase, in addition to a tendency in continental interiors for drying during summer, especially in the sub-tropics, and low and mid-latitudes.

Both drying and flooding will be evident in the region. Potential evapotranspiration rates in the three Shires will increase significantly. With increased flow there will be changes in stream power, and hence sediment loads, with potential to alter river morphology and transfer sediments to lakes, thereby impacting the water quality of freshwater habitats in both lake and stream systems (Whitehead *et al.* 2009).

Implications for Nambucca are diverse. For example, Council infrastructure will require increased capabilities to efficiently capture water supplies resulting from heavy rainfall events. Water storage and use patterns may need to change in order to save collected water for expected longer periods of drought. Currently Councils lift water restrictions after heavy rainfall events; yet given the expectation of long periods of drought accompanied by high evapotranspiration, a longer term approach to the management of surplus water will be important.

9.4 Declining Surface Water Quality

Rivers already under pressure due to salinity, over allocation and declining water quality are likely to be placed under increased stress due to climate change (Beare and Heaney 2002). Higher water temperatures and increases in extreme hydrological events, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution. This would have possible negative impacts on ecosystems, human health, and water system reliability and operating costs (Bates *et al.* 2008; DCC 2009b). Changed climatic conditions are also likely to produce conditions that favour riparian and aquatic weeds and algal blooms (DCC 2009b). Soil drying-rewetting cycles and increased solar radiation may also have considerable effects on water quality.

Temperature is a key factor affecting almost all biological reactions and physico-chemical equilibriums (Whitehead *et al.* 2009; Delpla *et al.* 2009). As water temperature increases, so does the concentration of dissolved substances it contains; while the concentration of dissolved gases decreases (Prathumratana *et al.* 2008; Van Vliet and Zwolsman 2008). This last point is very important with respect to dissolved oxygen in water; its saturation concentration decreases by almost 10% with a 3 °C temperature increase (Delpla *et al.* 2009).

Increased air temperature will increase the loss of surface water and soil moisture through evaporation. This will lead to lower flows and reduced flow velocities. Where water remains longer in rivers and lakes, the risk of toxic algal blooms will be enhanced, and levels of dissolved oxygen reduced (Whitehead *et al.* 2009). Lower flows and velocities will have some positive effects, however, in that the concentration of some pollutants may decrease (as aquatic plants assimilate nutrients, and through adsorption/complexation of heavy metals on suspended matter and settling).

Climate change is expected to increase both the severity and frequency of drought conditions, which would exacerbate erosion and downstream sedimentation (DCC 2009b). Storms that terminate drought periods will flush nutrients from urban and rural areas or generate acid pulses in acidified upland catchments (Whitehead *et al.* 2009).

Climate change is likely to increase bush fire frequency and severity (Hennessy *et al.* 2005) due to increased temperatures and decreased rainfall. Under normal climatic conditions, erosion rates increase following fire, when compared to pre-fire levels (Wallbrink *et al.* 2004). In pre-fire conditions raindrops caught by a forest canopy evaporate relatively readily, decreasing the amount of rainfall reaching the ground (Wallbrink *et al.* 2004). Severe fires have the potential to increase the amount of rainfall reaching the ground. The severity of erosion after fires is substantially dependent on the timing and characteristics of post-fire rainfall. In particular, intense rainfall on fire-affected hillslopes is an important contributor to soil erosion rates (Wallbrink *et al.* 2004). For example, the Sydney 2001 bushfires in the Nattai River Catchment had a significant impact on downstream water quality in Lake Burragorong/Warragamba Dam, preliminary evidence suggests (Wallbrink *et al.* 2004).

Decline in the quality of water supplies used by Councils is an important risk to community health, and also to Council infrastructure. Current treatment systems may not be able to safely deal with increased contaminant and sediment levels. For example, sediment may accumulate and block pipe or filter infrastructure, and algal blooms may become more frequent and untreatable by current means. Supply and treatment infrastructure will also wear more quickly when exposed to greater sediment and contaminant loads.

9.5 Climate Change and Groundwater

Climate change will affect not only surface water availability and quality, but also groundwater. The same mechanisms that affect surface water affect groundwater. Groundwater recharge will be negatively affected by: any decrease in mean annual rainfall; increased temperature leading to increased evapotranspiration; and changes in the periodicity of rainfall (increased dry years compared to wet years). Ground water discharge can be affected by evapotranspiration, and this could cause surface water levels to drop and lead to increased draw from groundwater, changing water use patterns by vegetation in areas of shallow water tables. Changes in the balance between groundwater recharge and discharge may impact on the following management issues: groundwater allocation for irrigation and other uses; soil salinity; protection of groundwater-dependent ecosystems; stream depletion caused by groundwater extraction; and deteriorating groundwater quality (Stokes and Howden 2008).

Nambucca Shire Council occupies a coastal region with unique natural assets. It is imperative to assess the likely impacts of climate change on the coastal, freshwater, estuarine and terrestrial habitats within the Nambucca-Bellingen-Kempsey study area. The economic benefits derived from nature-based tourism in each Council provide strong grounds to ensure all are prepared for climate threats.

To frame this discussion in terms of the specific threats relevant to each area, this section identifies the key environmental issues outlined in the Council's State of Environment report which will be exposed to significant climate risk. Two key areas are discussed:

- the impacts of a changing climate on the dynamics of an aquatic environment[4] and,
- the impacts of climate change on biodiversity[5]

9.6 Impacts on the Aquatic Environments

Figure 23 indicates how existing pressures within the Councils, such as urban development, will interact with predicted aspects of climate change to result in impacts on marine, estuarine and freshwater environments.

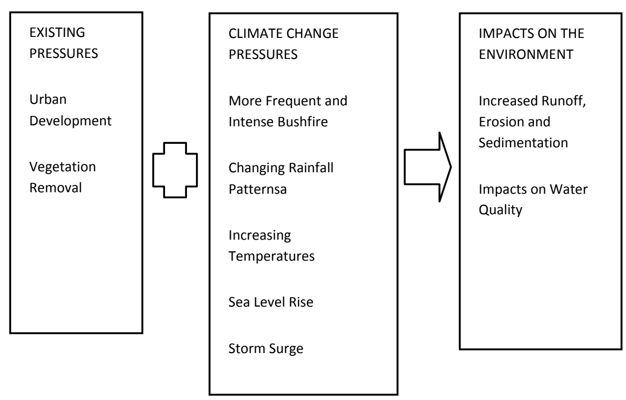


Figure 23. Predicted climate changes will interact with existing pressures within the region resulting in impacts on the aquatic environment.

[4] 'Aquatic environment' is used in this report to refer to the total of marine, estuarine and freshwater environments in the region.

[5] Biodiversity is defined by the Australian Federal Government as 'the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part' (DEWHA 2009).

9.7 Current Erosion, Runoff and Sedimentation Pressures

The Nambucca State of the Environment Report identifies exacerbated erosion, runoff and sedimentation processes as key environmental issues, impacting heavily on aquatic environments (NSC 2009). Changing climatic pressures will interact with existing factors to exacerbate erosion, runoff and sedimentation in all three of the Council areas. Exacerbated erosion, runoff and sedimentation result in a number of flow-on impacts for Council.

9.8 Existing Pressures on the Natural Environment: Urban Development

Urban development is a key cause of erosion, runoff and sedimentation. The increase in impermeable surfaces and removal of vegetation associated with urban development result in less water permeating the earth when rainfall hits. Over impermeable surfaces, this increased runoff collects in greater volumes, and travels at a greater speed. Due to this higher speed, and the lack of vegetation in urban environments, the amount of sediment collected by the water is greater when the runoff hits natural ground. Without appropriate mechanisms, planned residential expansion in Nambucca Shire will continue to exacerbate these issues.

Since European settlement began, agricultural development, logging, gravel extraction and general population growth has significantly altered the region's natural environment, including the Nambucca River catchment (NSC 2009). The entrance and main channel of the Nambucca River has been impacted by development including construction of break walls and dredging (NSC 2009). Combined, these development pressures cause land degradation and loss of riparian vegetation, and result in accelerated erosion and deposition of sediment, altering the floodplain, coastal and riverine zones.

9.9 Degradation of Riparian Vegetation

Urban development is associated with removal and destruction of riparian vegetation (ie vegetation where land and waterways meet). Climate change will increase the riparian vegetation loss rate through increased bushfire, changing habitat suitability and sea level rise. Changing fire and environmental pressures can exceed the ability of riparian vegetation to adapt, eventually causing possible extinction (DECC 2008). The Nambucca River's vegetation is 60% cleared. Taylors Arm and Deep Creek only have thin fringing vegetation. As such, bank erosion and loss of stability are key issues (NSC 2009).

Loss of riparian vegetation results in reduced bank stability, reduced woody debris within the stream, and extreme stream flows during inundation events. Consequently, increased runoff, erosion and sedimentation occurs (NSC 2009). Reduced riparian vegetation can also increase water temperature resulting in water quality impacts such as algal blooms. Overall, these impacts will cause greater erosion and sedimentation into local rivers, their floodplains and the region's estuarine and coastal environments, resulting in declining freshwater, estuarine and marine water quality. For Council, this will lead to a number of impacts on aquatic environments, including:

- reduced general environmental health;
- reduced aesthetic value of the area; and,

- reduced opportunities for recreational and tourism activities including fishing, swimming and nature-based tourism

9.10 Increasing Temperature

Projected air temperature increases can be expected to adversely impact water quality. Changes in chemical reaction kinetics due to increasing temperatures will increase the mobility and dilution of contaminants in water. Increased eutrophication also occurs as increasing water temperatures interact with increased nutrient levels associated with changing runoff patterns. The Councils will be faced with environmental water quality problems such as: decreasing aesthetic value of rivers and estuarine areas used frequently for recreation; decreased availability of fish; and the challenge of developing water quality management plans which can cope with these changing climate impacts.

9.11 Sea level rise and storm surge

Sea level rise will not only result in direct erosion problems, but also the penetration of saline water and waves inland. The short-term penetration of saline water into freshwater environments can result in fish kills and other adverse affects on local fauna and flora populations. More frequent storm surge can be expected to be associated with increased coastal erosion, changing sedimentation patterns, and disruption of estuarine environments. In addition, high wave events are likely to significantly alter the sediment patterns of estuarine areas. Beaches and estuarine areas within the region may be washed away, or have high level of debris and pollutants washed onto them - reducing their aesthetic, natural and recreational value. Impacts on both the natural and built environment could be significant.

9.12 Bushfire

An increase in bushfire frequency and intensity is expected due the combined impacts of increased temperatures, increased wind speeds, more frequent drought conditions and increased fuel loads (as a result of increased atmospheric CO_2) (Hennessey *et al.* 2007; Pitman *et al.* 2007; Hyder Consulting Pty Ltd 2008). Research indicates that currently the Nambucca Shire is an area of moderate to high fire risk, particularly from the months of September to December (NSC 2009).

The impact of bushfire on vegetation and soil includes increased erosion and runoff. Such runoff is likely to be polluted with volumes of ash and soil. Once again, the water quality and ecosystem integrity of aquatic environments within the three Councils will be affected.

9.13 Resulting Runoff, Erosion and Sedimentation Impacts

With the interaction of existing and predicted climatic pressures, changes in runoff, erosion and sedimentation regimes have been identified. These are covered in the following three sections.

9.14 Impacts of Changing Rainfall

Intense periods of rainfall occurring after drought and bushfire will promote erosion. Reduced vegetation will compound these factors resulting in larger quantities of runoff, erosion and therefore sediment deposition in aquatic environments. Loss of river banks and coastal land is predicted, and changes in the region's river and estuarine form are likely due to build up of sediments. Blockages within the Nambucca catchments could occur. In addition, nutrients and pollutants will build up within the soil during periods of drought and will be released into the aquatic environment. Agricultural pollutants are likely to dominate in this region.

Previous hydrological modelling and management has assessed past relationships between rainfall, runoff, erosion and sedimentation. With changing climate, it is recommended that the Councils develop new hydrological models based on projected patterns of rainfall and erosion (Stokes and Howden 2008).

Particular issues facing Nambucca which will be exacerbated by climate change include:

- The mix of urban and agricultural environments in the region result in stormwater runoff containing pollutants and increased sediment loads. This is already one of the greatest pressures on Nambucca Shire Council's aquatic environments (NSC 2009).
- The impact of polluted stormwater is of particular importance for the oyster and fishing industry reliant on the Nambucca River (NSC 2009). Increased pollution as a result of climate change is a major concern and has the potential to result in the closure of oyster farming. Increased stormwater containing nitrogen, phosphorus, metals (lead, zinc, copper), hydrocarbons, faecal bacteria and grease and sediment is directly impacting on the oyster industry of the Nambucca River (NSC 2009).
- 'Sedimentation of the Nambucca River entrance is likely to be perceived as the largest problem in the waterway', according to Nambucca Shire Council (2009, p24). Areas of key concern include: the impact of significant storm and high wave events on aquatic environments; the scouring action of runoff on the river entrance and coastal zone; potential closure of the river entrance due to sedimentation; and, greater flooding due to increased runoff (NSC 2009).

9.15 Impacts on Coastal Environments

The coastal habitats within the region, including coastal wetlands, are of significant environmental value. They provide diverse habitat for many aquatic and terrestrial organisms. Importantly, the region has a number of coastal lakes and lagoons which:

"...typically have intermittently open entrances to the ocean. The lakes are unique in their biodiversity and their ecological and physical processes. They can alternate between freshwater and saltwater regimes. These lakes are highly susceptible to impact from climate change and urban activities." (Department of Planning 2009b, p28)

Of concern for the preservation of these Intermittently Closed and Open Lake or Lagoons (ICOLLs), changing sedimentation is highly likely to change this regime. In addition, changing sea level is likely to inundate these bodies with salt water, increasing salinity and altering the changing freshwater and saltwater regimes. Each of the Shires has important estuarine environments which may be altered due to changing sediment loads, for example:

- The Nambucca River has a wave-dominated, low sediment trapping delta (NSC 2009). Changes in sediment loads, interacting with storm surge and more intense stream flows, may result in increased release of sediments into the local coastline. Changing sediments may build up and block the river mouth, or be washed out during extreme flow events.

9.16 Impacts of Bushfire

As rainfall patterns alternate between intensely wet and intensely dry periods, the increase in bushfire is expected to interact with these processes and increase runoff, erosion and sedimentation. This will impact heavily on the region's aquatic environment. The Department of Climate Change (2009B, p3 of 4) notes that, 'higher sediment loads enter rivers following extreme rainfall events after extreme bushfire events, both of which are projected to increase with climate change.' For areas of steep slopes, for example, the Great Dividing Range which bounds the western rim of the region, erosion will be pronounced (Wallbrink *et al.* 2004). Impacts of bushfire on the local environment include:

- Prevention of the absorption of water into the soil, promoting increased runoff and soil erosion (as fire causes soil to be water repellent, or 'hydrophobic') (Wallbrink *et al.* 2004).
- Reduction in vegetation cover and the efficiency of vegetation to use water, thereby resulting in increased runoff and increased raindrop erosion (Wallbrink *et al.* 2004).

Particularly relevant for Nambucca is the impact of bushfire on river and estuarine erosion, as noted by Wallbrink *et al.* 2004, p7:

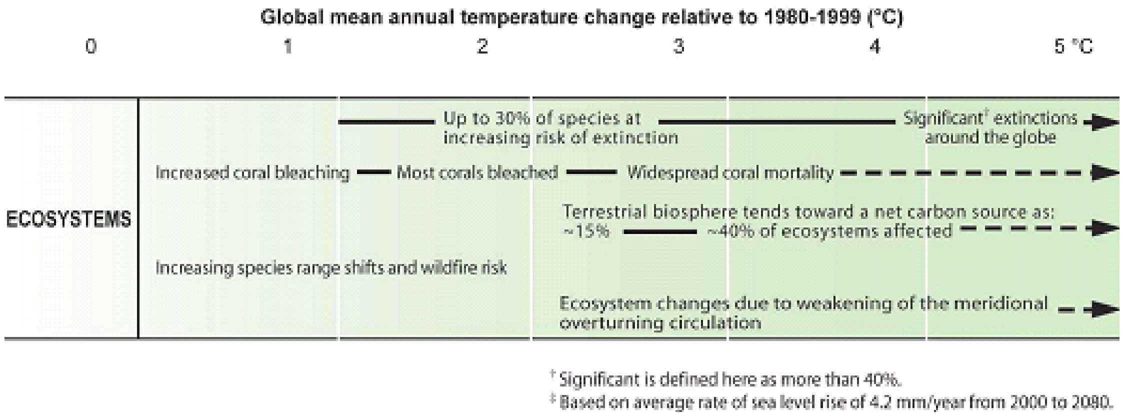
"...the expansion of alluvial fans following fires, this process in turn causing morphological changes including both increasing and decreasing channel gradients both upstream and downstream of fans. This increased sediment storage in the fans. This increased sediment storage in the fans was also associated with widening of floodplains and side-channels and the creation of terraces."

10 Ecosystem Integrity and Biodiversity

Predicted effects of climate change include rising temperatures, changing rainfall patterns, rising sea level and associated salinity changes, increased storm surge and increased bushfire risk. These will impact upon the natural environment in the region. Environmental factors such as moisture, temperature, soil salinity, and carbon dioxide concentration will also change. Combined with existing environmental pressures, the resilience and integrity of aquatic and terrestrial ecosystems will be threatened (Nally, Cunningham *et al.* 2008). Impacts will be manifested in the form of changes to species' distributions, greater pressures on threatened species, and broad changes to ecosystem composition and structure. Examples of ecosystem impacts associated with temperature increases are indicated in Figure 24.

It is important to consider the cascading effects of any one change in an environmental characteristic throughout the interconnected ecosystem. In coastal communities such as the three Councils, climate change will have a significant impact on biodiversity (Voice *et al.* 2006).

Figure 24. Changing ecosystem characteristics with increasing global mean annual temperature. (from Stokes and Howden 2008, p35.)



10.1 Species Distribution

Environmental factors influence and determine the distribution of flora and fauna. Temperature, rainfall, carbon dioxide concentration, and soil and water salinity are key determinants (Hughes 2003; NSC 2009). Changes in these factors with climate change will encourage shifts in species distributions – pushing species to a more suitable habitat (Hughes 2003; Hyder Consulting Pty Ltd 2008). As species' distribution change, the structure and composition of these natural communities will be altered.

Climate change may fragment and reduce habitat areas (Hughes 2003, p430), inhibiting the ability of some species to disperse to more suitable habitat. Species which are in the upper limit of, for example, their temperature range, or within a fragmented area, are at greatest risk. 'Many Australian plant species are restricted in geographic and climatic range and may therefore be predisposed to early extinction or displacement under climate change,' according to Hughes (2003, p430). The impacts of climate change combined with increasing population growth and urban development will result in reduced movement corridors for fauna, preventing dispersal to more suitable areas. For the Nambucca-Bellingen-Kempsey study area, this may result in lower population densities or extinction of locally significant fauna and flora. The flow-on impacts for the community may include reduced visible fauna and therefore fewer tourists visiting the area.

Hughes (2003, using *BIOCLIM* modelling) discusses the impact of climate change on the distribution of a number of Australian flora and fauna:

A 1 – 3°C temperature rise will significantly threaten a number of threatened status vertebrate fauna species in south-east Australia (Hughes 2003).

The coastal fauna of these communities will be highly impacted as marine invertebrates are highly susceptible to water temperature changes (Hughes 2003)*;*

A conservative temperature increase of 0.8 – 1.4°C by 2050 will result in an 88% decrease of butterfly species bioclimates (Hughes 2003, p432).

An important concern identified for the region is lack of appropriate management for biodiversity in the face of climate change. The Mid North Coast Regional Strategy directs that where new land releases for urban development may impact on biodiversity, offsets or habitat corridors should be provided (Department of Planning, 2009). However, the possibility that these corridors, or potentially fragmented areas, may no longer be suitable habitat under climate scenarios does not appear to be considered. Therefore corridors may not play the role they were identified.

Finally, for an indication of the potential effect climate change on the flora and fauna of Nambucca Shire, it is useful to consider the region's threatened species. Climate change can potentially exacerbate current threats and place a greater strain on existing populations. Appendix D includes the Environmental Protection and Biodiversity Conservation Act Protected Matters Reports for Nambucca. These indicate flora and fauna species identified in the region which are federally listed as endangered or vulnerable. To prevent their extinction will require managing them with recognition of the role of climate change. Further field research should also be carried out to determine the presence of these species within the area, and any additional species likely to become endangered as a result of lost habitat.

Threatened and notable biodiversity within Nambucca Shire includes:

- 21 threatened species of flora (NSC 2009)
- 74 threatened species of fauna (NSC 2009)

Threatened species include: the Pouched Frog, Stephens Banded Snake, Red-legged Pademelon, Glossy Black Cockatoo, Wompoo Fruit Dove, Powerful Owl, Masked Owl, Rufous Scrub-Bird, and the Koala (NSC 2009).

A diverse range of subtropical and temperate fauna and flora (NSC 2009).

A coastal sclerophyll vegetation complex between Nambucca and Scotts Heads is identified as having the highest diversity of flora and fauna in the Shire (NSC 2009). As a restricted tract of habitat on the coast, this area is at risk from climate change - particularly from changing salinity and inundation by the sea.

Mangrove Jack and Australian Salmon are listed in the area. This is the southern and northern limits of these species, respectively (NSC 2009). Changes in climate may prevent their presence in the area.

Nambucca Shire sits within the middle of the North Coast Bioregion (NSC 2009). This may be construed as a positive factor for local fauna and flora biodiversity faced with climate change as it indicates that, in general, similar habitat exists around the Shire, therefore potentially allowing for species dispersal.

10.2 Climate Change Impacts on Life Cycles

Climatic change will affect the life cycles of flora and fauna, for example, their flowering, reproductive timing, egg development, sex ratio, and migration (Hughes 2003; Hyder Consulting Pty Ltd 2008) may be specifically linked to temperature and seasonality (Dunlop and Brown 2008).

As climate changes and affects these processes over the longer term, species may evolve genetically in response to this changing environment (Dunlop and Brown 2008).

10.3 Climate Change Impacts on Marine Biodiversity

The predominant impact of climate change on the biodiversity of marine environments will be the 'warming of the oceans, changes in circulation patterns and changes in ocean chemistry' (Stokes and Howden 2008). Rising sea levels, more frequent storm surge and accompanying sedimentation will also have impacts. For example, according to Stokes & Howden (2008):

Increased stratification and reduced nutrient cycling due to water temperature increases is expected, altering productivity.

There will be a decreased ability to absorb CO_2 as oceanic CO_2 concentrations rise. This will increase ocean acidity and reduce calcium carbonate available for the protective shells of some species.

Sea level rise and inland penetration of saline water will impact on estuarine environments, which are important nurseries for aquatic species. Changes in the estuarine gradient and patterns of freshwater delivery are also expected to be an impact on coastal and estuarine areas (Boesch 2002).

Climate change will therefore reduce the habitat suitability for flora and fauna inhabiting coastal and estuarine environments in Nambucca, Bellingen and Kempsey. This will likely impact on the NSW seafood industry, because most species caught spend a large majority of their life cycle within estuarine environments (Department of Planning 2009b).

Loss and decline of seagrass is a key issue in the region. In total, 50% of seagrass habitat has been lost over in recent decades (BSC 2008; NSC 2009). This loss is concentrated around the major population centres, and evidence suggests continued decline in Nambucca River and Deep Creek (NSC, 2009). Saltmarsh and mangrove environments are also at risk. Since the 1960s saltmarsh loss has ranged to up to 80% in parts of Australia (Hughes 2003). Areas of saltmarsh in Bellingen, and across the region are severely contracting. Increases in rainfall, altered tidal regimes, sedimentation, unnatural flow regimes, nitrification, erosion, and introduced species have had impacts on aquatic vegetation (Hughes 2003; NSC 2009). Because each one of these factors is expected to become more intense and frequent with climate change, aquatic vegetation in the region will face greater risk. Building on existing study in these areas, incorporating climate change concerns into field research is recommended.

As previously identified, increased sediment loads will also alter aquatic fauna. In Nambucca Shire Council area, Australian Bass is identified as a key species which prefers deep water holes. As sedimentation increases with climate change, this important fish habitat will be lost (NSC 2009). Aquatic invertebrates, including the high benthic[6] macroinvertebrate diversity of the intertidal mudflats in Nambucca Shire, will be threatened by sediment (NSC 2009).

The coastline largely defines the region's environment, and therefore each Council's identity, and is a major drawcard for residents and tourists. Changes in marine biodiversity will impact on the coastal environment as a whole. Council may also experience increasing costs as they attempt to maintain the coastline environment and infrastructure, and enact management plans to preserve biodiversity.

[6] The benthic zone refers to the ecological region at the lowest level of a lake or ocean.

10.4 Weeds, Invasive and Exotic Species

Invasive species may begin to pose a greater threat to native biodiversity with climate change. Invasive species are often able to tolerate a wide range of environmental conditions. With climate change, weed infestations and the areas in which weeds and pests are found are likely to increase (Dunlop and Brown 2008). In addition, as climatic changes place increased pressure on native species, exotic invasive species may take over. Invasive fauna threats present in the area include the cane toad, rabbits, foxes, feral cats and dogs (NSC 2009).

A key issue for each of the three Councils is weed infestation of native vegetation, including remnant vegetation communities, and the general incursion of weeds from gardens and nurseries (BSC 2008; KSC 2009; NSC 2009). Weed invasion threatens species biodiversity and degrades land quality. Climate change will exacerbate this problem. For the local region, a problematic factor is the frequency of flooding in the region – floods wash weeds previously contained in residential gardens into areas of native vegetation and national parks.

10.5 Elevated Bushfire Threat s

Increased fire intensity and frequency for the region have been identified above. Changing fire regimes and increased fire events can significantly impact on biodiversity within an area. Impacts include:

- A decline in biological communities due to their inability to adapt to changing fire regimes in a short time period (Dunlop and Brown 2008; Bushfire CRC 2008).
- Changes in soil and vegetation nutrient & water balances (Dunlop & Brown 2008).
- Decreased presence or extinction of less resilient species (Dunlop & Brown 2008).
- Loss of large older trees which provide habitat and nest hollows (Dunlop and Brown 2008).

Intense bushfires also have short-term impacts, for fauna unable to avoid the fire, and for survivors which may be subsequently exposed to starvation and predation (NSC 2009, p36).

11 Council Specific Risks

Council activities are affected by the influences of short-term weather, seasonal climate and longer-term climate changes. The important council activities include:

the provision, operation and maintenance of important infrastructure (such as water treatment and sewage disposal, roads and other forms of transport),

the maintenance of general residential and commercial activity (by ensuring the health and safety of local communities, and the general viability and competiveness of local and regional businesses),

the provision of sustainable planning, disaster management and emergency services (in association with State and Federal agencies), the policing of legal, environmental and social requirements entrusted to the council.

Council activity is also important to support the sustainability of the region's main industrial and commercial activities. In so doing, councils support the growth of council income from rates and other charges. Council is under considerable pressure to provide services within a limited budget. Without tight asset management controls and adaptive behaviour, the impacts from climate change are likely to exacerbate this considerably.

Extreme weather events are an important subset of conditions that can threaten the viability or efficiency of the above activities. These include:

Heat waves that can cause stress and health impacts on local human communities (especially for sensitive sub-groups such as the elderly, the sick and the young), farming operations (and their associated activities in rural townships), animal husbandry (especially the intense operations of cattle feedlots and broiler farms), commercial efficiencies (the provision of essential services such as power, water, rail transport and telecommunications, tourism, heat-sensitive industries, and indirect effects on such services via the greater potential for disruptions caused by bushfires).

Prolonged or extremely intense rainfall that can lead to flooding that disrupts activities or even destroys infrastructure.

Prolonged drought that can affect the operations of water-based infrastructure, the efficiency and viability of agriculture in the region.

Convective storms that may result in hail or lightning damage to local infrastructure, or wind damage to buildings, and, if occurring in clusters, can discourage tourism.

Severe marine-related storms that can lead to damage and disruption of coastal infrastructure and marine activities, especially if coinciding with high tides.

This chapter examines the potential climate change impacts on Council operations.

11.1 Roads and Bridges: Higher Stresses & Costs

Extreme temperatures and increased average temperatures place a considerable strain on the built environment. For roads, increased temperatures during summer can prematurely crack surfaces and damage pavement's water proofing potential. This damage can be exacerbated by intense rainfall and flooding. A recent AusRoads report showed a 2°C increase in average temperatures would increase road maintenance by 17% (AusRoads 2007).

As well as such primary climate change risks, road maintenance costs are also affected by carbon prices. Asphalt roads are carbon-intensive, and according to VicRoads (2008) "[r]oad construction in Australia generates an estimated 750 tonnes CO_2-e per kilometre of road". A report by the Western Australian Local Government Association WALGA (2009) finds that, due to this carbon intensity, road creation and maintenance costs will increase by 4% - 5% with a carbon price of $20 per tonne.

In combination with carbon prices and other external factors, the increased costs associated with climate change impacts on roads will place considerable strain on Council resources. This may be further exacerbated by external factors such as peak oil.

Nambucca Council is responsible for approximately 194 km of rural sealed roads and 862,000 m^2 of urban road networks. According to the recent Nambucca Shire Annual Report, "approximately 5% of the network is rehabilitated annually," at an estimated annual cost of $3,659,000 to maintain current standards. When a carbon price of $20 per tonne is realised (which is likely within the next five years) a 5% increase in road costs would equate to an extra $183,000 to maintain current standards (no discount rate). However, with the carbon price estimated at $84 per tonne by 2030 it is likely that business as usual (BAU) road maintenance will represent a significant proportion of the council expenditure in the future.

This increase would be compounded further by climate-induced increases in maintenance costs (eg 17% with 2°C warming, as noted above). With this assumption, the no-discount rate increase in BAU road maintenance in 2050 would equate to an extra $620,000 in annual expenditure.

Post-disaster cleanup (clearing roads, replacing bridges) already places a strain on Council resources, even with state or federal disaster funding support. The NSW Natural Disaster Assistance Scheme provides financial support for eligible restorations (75% of the first $116,000 expenditure and 100% beyond that level). This means that although the restorations are subsidised, there are still out-of-pocket expenses for Council. Moreover, it is important to note that NSW Government funding is limited to 'the reinstatement of roads and bridges to their pre-disaster standard and level of service' (RTA 2008, p. P.7). This implies rebuilding to a standard that would not reduce the risk profile. Furthermore, the RTA considers that bridges not maintained to adequate standards may be ineligible for funding. As of January 2010 the following roads and bridges remained closed due to flooding events in 2009:

- John's Bridge, Missabotti Road
- Deep Creek Bridge, Valla
- Bellingen Road (Bellingen to Bowraville)

Given the limited resources of regional councils, some bridges may not be re-opened post disaster. Nambucca Council is presently reviewing bridge maintenance, with at least one bridge being closed indefinitely after the recent flooding of 2009. With Council responsible for numerous bridges, the decision not to replace some bridges remains a contentious point within the community.

Although some increase in expenditure may be managed through increased Section 94 developer contributions, this is unlikely to cover all anticipated cost increases (especially if multiple climate-related events ensue over a short time period). Other funding sources, including grants, rate rises and other service charges or levies may need to be considered.

11.2 Water Supply: Increased Security Concerns

Climate change projections indicate that Nambucca will experience increased temperatures, increased periods of reduced rainfall, and increased rainfall variability. Changes in frequency of extreme weather events, including flooding, are also anticipated. These factors will combine to increase pressure on Council water resources already struggling to keep up with demand.

Reduced precipitation and increased evaporation are likely to lead to water security problems in the region. Nambucca is already dealing with scarce water resources in both urban and rural environments. Catchments and groundwater systems with water resources fully- to over-allocated have limited resilience and capacity to adapt to climate change. Such areas have limited flexibility, on the supply side of the water balance equation, to address growing demand, long-term reductions in rainfall and runoff, or periodic shocks such as droughts. For some regions that currently have the capacity for further resource development, the impacts of climate change on rainfall and runoff, combined with other changes, may be large enough to erode that capacity. In part, this depends on whether the rate of climate change exceeds that of the planning and implementation of adaptation strategies which aim to tackle these climate risks (Stokes & Howden 2008).

In the past the Nambucca Shire's water reserves have fallen to as low as 60 days supply (eg 2002/2003 drought; GHD 2009). Increasing population, in combination with increasing temperatures and annual dry days, demand a solution to the water security issue.

Nambucca Shire Council is in the process of assessing the environmental viability of the proposed Bowraville Off-River Water Storage Project. This is part of a shire-wide Integrated Water Cycle Management (IWCM) – an approach to water management encouraged by the State for all NSW Councils. Currently supply from the existing aquifer adjacent to the river 'leaks and cannot meet the demands for the Nambucca system during extended drought periods,' according to NSC (2006, p1).

The Bowraville project aims to secure supplies for the future, managing the impact of drought on river and estuarine health and ensuring security of supply during drought. The Bowraville Storage will collect and store bore water for use during low river flow, aiming to reduce impact on environmental flows and prevent low town water supplies. The priorities of this project to ensure water security in the face of climate change will reduce Nambucca Shire Council's climate risk.

However, it is important to ensure that all aspects of climate change are given appropriate weighting in the decision-making process. For example, it would be prudent to analyse the interaction between groundwater and surface water health during drought, and assess climate change impacts on water quality as well as quantity for both environmental flows and town supplies.

11.3 Bushfire Management Under Climate Change

The association between increased temperatures and elevated bushfire danger is well documented (William *et al.* 2001; Hennessey *et al.* 2007; Pitman *et al.* 2007). A recent Australian study predicted that climate change could see a 100% increase in bushfire and grassland fires.

Bushfire is a significant existing threat for Nambucca. According to the recent State of the Environment Report, 'The Nambucca Shire is generally considered to be an area of moderate to high fire risk, especially during the period from September to December' (NSC 2009, p.36). With climate change, hotter and drier conditions are projected for Nambucca. The combination of anticipated winter rainfall reductions, increased mean maximum monthly temperatures, and a large increase in number of days over 35°C may produce a longer bushfire risk season (commencing earlier and finishing later).

As the February 2009 Victorian bushfire tragedy showed, multiple emergency egress points are critical for safety. Yet there are single entry/exit roads for much of the shire's rural population and tourist attractions. A large fire in a tourist locality (eg Scotts Head) could result in isolation and create emergency exit challenges for the community and tourists (who may not be familiar with bushfire risk or alternative exit points).

If the costs of bushfire management increase (eg due to carbon pricing), then Council is faced with the decision to either increase bushfire maintenance budget to cover the same area, or decrease the physical area it maintains.

11.4 Waste Management Challenges

For waste management, Nambucca Shire Council maintains a partnership with Coffs Harbour City Council, Bellingen City Council and Handybin Waste Services. Climate change can create a range of challenges for waste management. The risks include:

- disruptions to refuse collection during storms
- increased green waste during post-storm clean up
- leaching of pollutants due to storms / heavy rainfall
- increased vermin
- OHS issues for staff (eg exposure to heatwaves)
- emissions reporting expenses

In addition to the above, there are some responses to climate change which pose new risks to the community and the environment. For example, new Australian Government regulation will require that all incandescent bulbs are phased out by 2010 and replaced with energy-efficient compact fluorescents. The most widely used replacement bulbs in offices contain methyl mercury (the most toxic form of mercury) and breakages of these bulbs may create challenges for OHS and disposal methods. Furthermore, once the entire community switches to these bulbs there may be risks associated with the disposal of these in landfill sites, exposing staff and the wider environment to methyl mercury. In the US States of California, Minnesota, Ohio, Illinois, Indiana, Michigan, and Wisconsin it is illegal to treat light bulbs that contain mercury as general waste, and special requirements must be followed (USEPA 2008). While Council encourages community members not to throw out light bulbs it is unclear how effective the education campaign is.

For Nambucca, disruptions to waste collection services caused by storms and flooding are likely to pose the most significant challenges. Even if Nambucca is not directly affected by a regional flooding event, it is possible that neighbouring councils with which it shares waste collection services may be disrupted.

11.5 Urban Development and Planning Under Climate Change

Climate change presents myriad challenges for urban development. In addition to challenges from physical changes, planners must also consider regulatory risks, such as interpreting State planning policies and directions, identifying the science upon which to base decisions, and litigation and planning challenges stemming from the community and developers. These issues add considerable strain to the already challenging task of strategic planning and development assessment.

Climate change may affect current and future zones in the following ways:

Land identified (or zoned) as good quality agricultural land may need to be reviewed if climate change erodes its potential;

The proportion of bushfire-prone land may increase;

Urban release land may have new (or future hazards) not identified when the parcels were first gazetted (eg new risks from storm surge, flooding, heatwaves, bushfires, etc). This is especially so for parcels zoned some time ago.

As shown by recent publications (England 2007; McDonald 2008) climate change presents an array of legal challenges for Local Governments. This is especially so with planning issues; a significant risk facing Council is potential litigation for approving development in the future (or in the past). Perhaps one of the most significant risks facing council in this area surrounds sea level rise information used to generate its coastal and riverine planning.

As was shown in Part A of this report, there is a significant range of sea level rise projections and council must decide on which methods / outputs to follow. The NSW benchmarks are 20cm lower than those used by the Australian Government in a recent report (for 2100) and considerably lower than the work of Pfeffer *et al.* (2008), all of which state that a range of 0.8m – 2.0m should be considered for sea level rise by the end of the century.

The risk of differing inputs can also be seen in flood planning. Nambucca Shire Council has recently commissioned a flood study for Nambucca heads (in draft stages). Although this study considers climate change, its estimations of changes to extreme precipitation (they factor in an increase of 10%), are lower than projections generated for this report. The latter projections show summer 99th percentile rainfall increasing by 13% in 2030, 28% in 2050 and 45% in 2070 (Figure 25). By 2050, the change in precipitation for the three-day intense rainfall event also surpasses the draft flood study's figure of 10% for changes to extreme precipitation (Figure 26). The consultant generating the flood study has followed the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* released by the NSW DECC. Future flood studies should consider increasing by a significant amount.

11.6 Potential Risks to Future Urban Development

There are three main areas identified for future urban expansion. A scoping review of these areas identifies he following potential challenges related to climate change (Table 10).

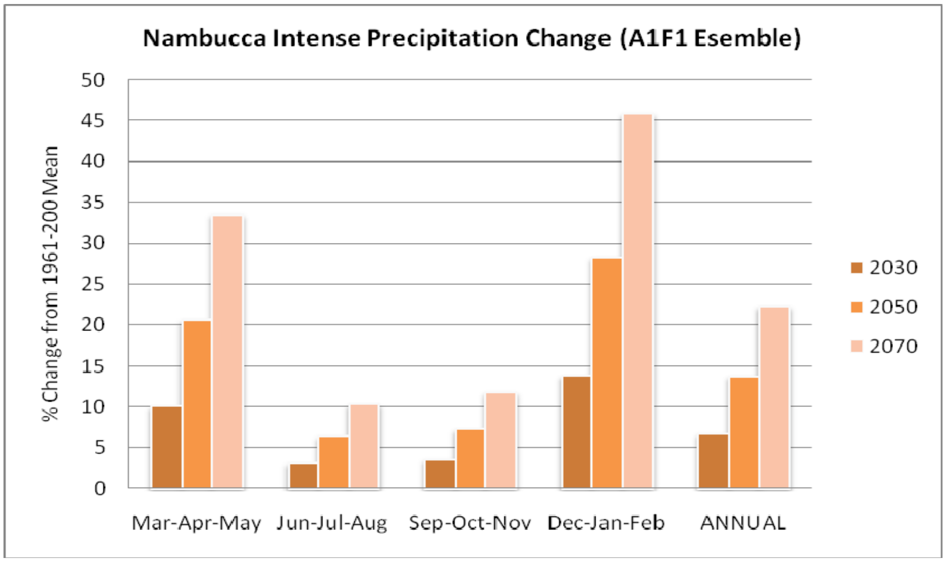


Figure 25. Changes to extreme rainfall in mm (A1FI and ensemble of 5 GCMs).

Return Period	A1FI_2030	A1FI_2050	A1FI_2070
5 year	4%	8.10%	13.20%
10 year	4.80%	10%	16.30%
20 year	5.70%	11.60%	18.90%
50 year	6.70%	13.80%	22.40%
100 year	7.60%	15.60%	25.40%

Figure 26. Changes in return rate for 3-day intense precipitation (mm).

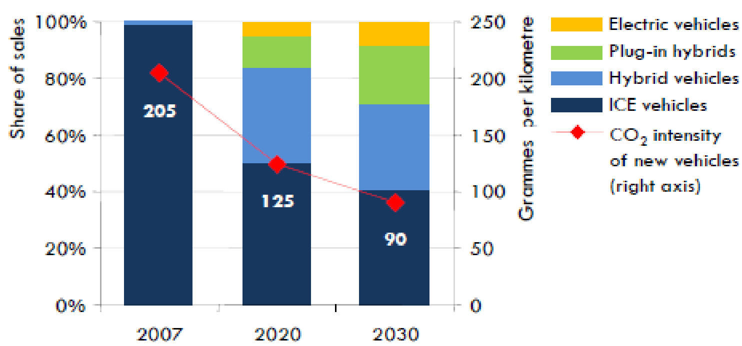


Figure 27. World share of passenger vehicle sales, by technology, and average new vehicle on-road CO_2 intensity in the 450 ppm scenario (IEA 2009, p.323)

Future Urban Release Area	Potential Climate Change Risk
Valla	Potential bushfire risk (depending on vegetation profile post-development). Potential localised flooding (dependent on impervious surfaces, land design etc). Potential short-term isolation due to road flooding (area is located in the high range of intense rainfall – see Figure 28).
Scotts Head	Potential isolation from flooding. Distance to regional centres and towns – more expensive to travel / commute if energy prices increase. Potential bushfire risk (depending on vegetation profile post-development). Potential risks to existing infrastructure from sea level rise (dependent on specific location).
South Macksville	Bushfire Localised flooding

Table 10. Summary of potential climate change risks for proposed urban land release

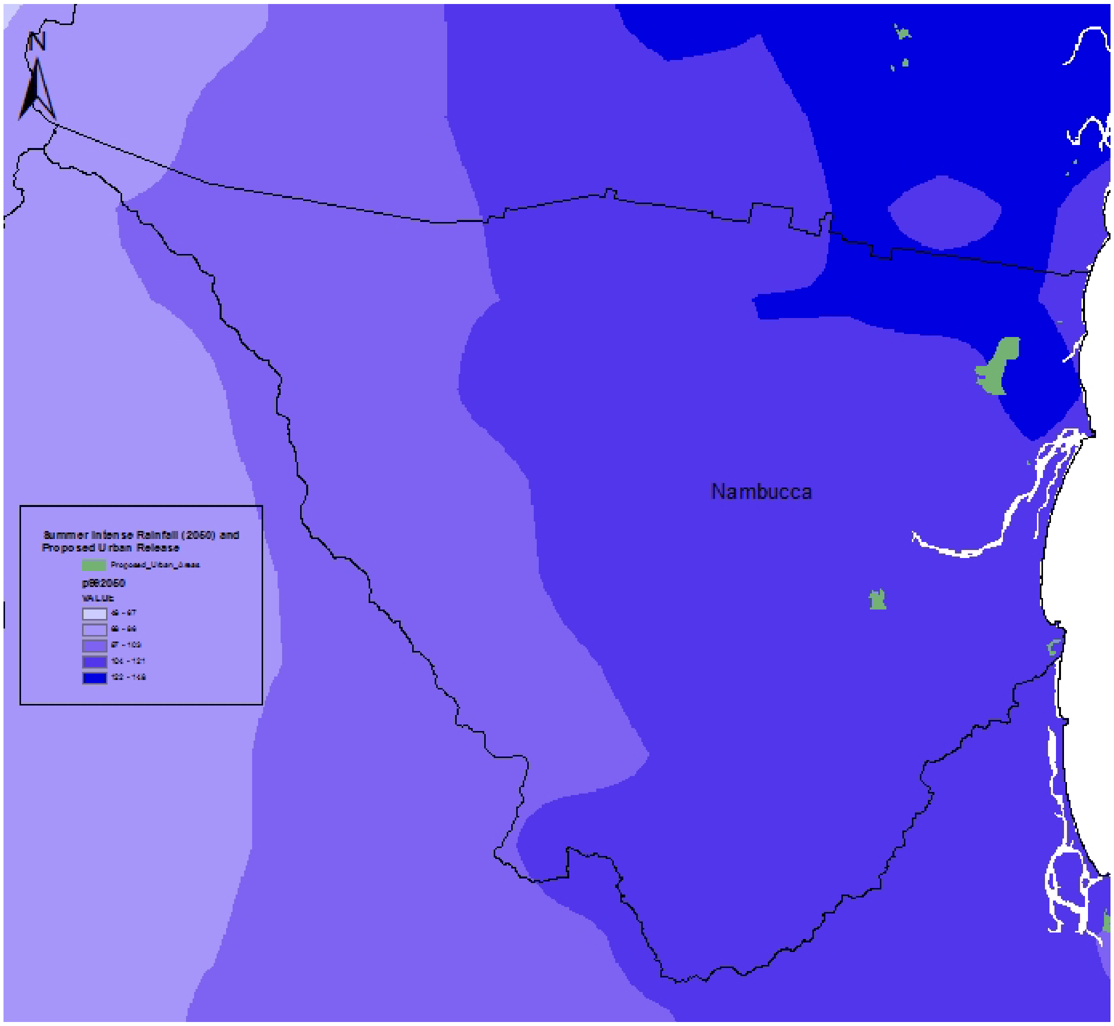


Figure 28. Location of summer intense rainfall (mm) and proposed urban land release (in green).

11.7 Carbon Constraints

Planning for a carbon-constrained economy places considerable pressure on councils to consider future scenarios and planning mechanisms which support its community, economy and operational services. According to the International Energy Association (IEA) if the world is to commit to a carbon-constrained economy there will doubtless be paradigm shifts in the transport sector. For example, the IEA anticipates that if a 450ppm GHG global emissions target were implemented, by 2020 more than 40% of new car sales would be for vehicles which do not have internal combustion engines. By 2030 this figure would increase to almost 60% (Figure 27).

A shift to electric and plug-in electric vehicles would present a risk for council if they fail to consider this paradigm shift in their future planning mechanisms. Council needs to immediately assess whether its current planning mechanisms and infrastructure development will support these vehicles types. For instance, Council may wish to implement development controls which ensure new developments and buildings proactively support electric charge points and identify potential hazards. At present this is not evident in Council's current planning mechanisms.

11.8 Potential Risks to Future Urban Development

There are three main areas identified for future urban expansion. A scoping review of these areas identifies the following potential challenges related to climate change (Table 10).

There are likely to be existing properties exposed to a range of anticipated impacts. Although this project does not explore risks down to the lot level, it is certain that Council will need to implement contingency plans for specific properties when they are identified. Planning responses to climate change / extreme weather are not without their risks to Council. For example, Byron Bay Council has implemented a paradigm of planned retreat, allowing for natural coastal processes to play out. This has caused considerable concern for some property owners who were restricted in their scope to engineer solutions which would prevent erosion of their assets, with results from litigation still outstanding.

11.9 Energy: Risks and Higher Costs

Affordable and reliable energy is critical to Council functioning. The combination of carbon-constraints and strains on electricity lines during peak periods will pose challenges to the deliverability of Council services. As such, Council may need to investigate ways to ensure future energy security. Building new and maintaining existing infrastructure under climate change will be a challenging task for Council. During the prolonged Melbourne 2009 heatwave, for example, power outages occurred as the demand for electricity soared, and some transmitters collapsed under the mounting strain. The fourth report by the IPCC notes that:

"Increased damage [from climate change related events] is likely for buildings (eg, concrete joints, steel, asphalt, protective cladding, sealants), transport structures (eg, roads, railways, ports, airports, bridges, tunnels), energy services [wind power stations, electricity transmission and distribution networks, oil and gas product storage and transport facilities], telecommunications (eg, cables, towers, manholes), and water services" (Hennessey *et al.* 2007; pp. 521-522).

The confluence of increased damage to infrastructure and assets and carbon-constraints is likely to increase Council expenses (as was discussed above with regard to roads and bridges). Council's ability to maintain its regular development and maintenance schedule may be affected as certain projects take precedence (for example, responding to infrastructure damage after a severe storm).

The cost of emissions under a CPRS scheme will be decided by the market, together with Government-imposed price caps. A 2009 report by the Municipal Association of Victoria (MAV) examined the financial implications of carbon emissions trading on Victorian councils, revealing results shown in the following table.

	Impact on Total Expenses @ \$25 CO_2e per tonne	Impact on Total Expenses @ \$40 CO_2e per tonne
Automotive Fuel	0.05%	0.10%
Construction	0.50%	0.80%
Gas & Electricity	0.26%	0.41%
Waste Disposal	0.94%	1.50%
Sub-total	1.75%	2.81%
Other Contracts & Materials	unknown	unknown
Total	**Potentially 2.0%**	**Potentially 3%**

Table 11. Impact of two carbon price levels on costs for councils in Victoria (MAV 2009). The 3% amount is likely to be surpassed by mid decade.

The above table suggests that the previously proposed CPRS alone could bring about an approximately 3% increase in operational costs by mid decade. Australian Treasury estimates that by 2030 the price of carbon will be approximately \$84 per tonne of CO_2-e, and by 2050 may reach as high as \$200. The degree of impact of this carbon price on Council energy prices would depend on the costs of alternative materials (ie for roads) and vehicle energy systems (eg electric or biodiesel).

11.10 Natural Resource Management in the Face of Climate Risk

The natural environment is intrinsic to Nambucca Shire's identity. This environment provides Council with the basis for a vibrant economy and a means to attract new residents and tourists. Natural heritage provides a sense of place for each of these communities. As climate change places increasing pressures on their environment, the identity and economy of each of these communities will be threatened.

As discussed earlier, climate change has the potential to significantly impact the natural environment (see sections 7 & 8 for detail discussion on potential impacts). Council will need to undertake a triage approach to natural resource management, or locate more resources to cope with an anticipated increase in management demands.

11.11 Staff Capacity and Concerns

Although council has a small number of staff members adequately skilled to deal with climate change issues, soon-to-be released regulations and anticipated climate change impacts will put these staff under considerable strain. There is increasing demand for employees with climate change expertise, and Council is now competing against other councils and the private sector to engage such staff.

More generally, climate change will affect all staff in different ways. Some staff will need to deal with elderly community members who must manage more heat stress, others with more flooding, and still other staff with developers which challenge adaptive measure implemented by council, and so on. Staff well equipped to deal with new challenges are likely to stay; if they become overly strained by these challenges, they may leave. Should Council decide to take a lead on climate change, it will need to address issues surrounding resources, capacity and authority to deliver climate adaptive change. These include:

- Adequate budgets
- Suitably trained staff
- State government decisions

This capacity will be essential in the delivery of an adaptation plan, which is explored in the next stage of this project.

Prior to commencing this climate change risk assessment, Climate Risk Pty Ltd undertook an internal Council survey. The survey was designed to assess staff awareness of climate change issues. Of the 18 staff who responded to the survey, more than a quarter (5) responded that they have a good understanding of climate change, and no staff indicated a poor understanding (Figure 29). It is important to note that these results are based on staff members' self-assessment of awareness and capacity.

Staff members were asked about potential obstacles to managing climate change risks in Nambucca Shire. A summary of the results are presented below (in order of number of answers):

- Lack of resources (11)
- Councillor view on climate change and lack of leadership (7)
- Staff knowledge (5)
- Allocated climate change positions in staff (1)
- Misconceptions and conflicting science (1)

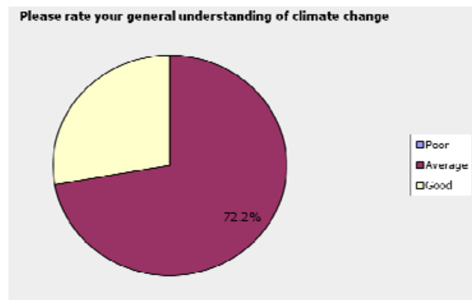


Figure 29. Staff self assessment of their understanding of climate change.

When questioned about current council activities to manage climate change, most responded that very little is being undertaken. The survey indicates that Council staff are apparently most concerned about impacts of sea level rise, temperature increases, and elevated flooding risks.

11.12 Reduced Revenue Considerations

It is important to note that, due to an ageing population in the shire, the percentage of rateable properties which receive concessions is expected to increase. At present 25% of properties in Nambucca receive rate concessions, which leaves a full-paying rate base of 6,781 properties. By 2030, accounting for the expected increase in properties eligible to receive concessions, the total number of full-paying properties would increase by 652 to 7,432.

While the total number of rate assessable properties is expected to grow by an estimated 25% over this period, the increase in full-paying properties would grow by only approximately 8%. This means that there will be an increase in concession paying properties.

The NSW Government reimburses 55% of concessions given, however, the 'balance of the rebate (ie 45 per cent) must be financed by the council out of its general revenue' (Dollery *et al.* 2008, p.478).

This foregone rate base income would be further compounded by the reduction in grant funding typically being received by NSW councils, as well as increased service requirements, and increased agency fees (Dollerey *et al.* 2008). This projected shortfall may pose challenges for a council expected to undergo increased operational costs from climate change impacts and carbon constraints.

12 Economic Risks

The objective of this part of the project – undertaken jointly by Climate Risk Pty Ltd and ACIL Tasman - has been to provide a first pass insight into the economic impacts of climate change impacts and regulation, be they positive or negative, on the local economy. This may be the first time that the downscaled impacts of climate change have been used to undertake macro-economic modeling to provide economic data at the regional scale in this way.

It is envisaged the results of this economic analysis can guide adaptation priorities to reduce risks, reduce negative economic effects and capitalize on opportunities for resilience and strategic advantage.

This methodological approach has been to draw upon the results of previous parts of the risk assessment to provide quantified climate affected hazard levels, with the results combines with the associated consequences to inform disruptions to the top thres industries is the region.

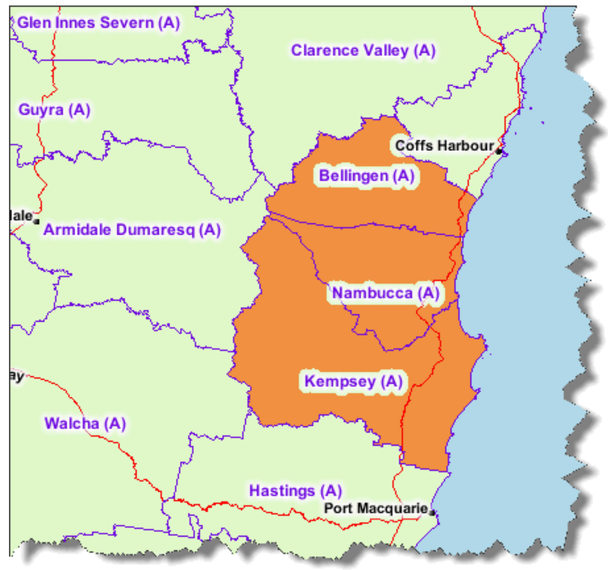
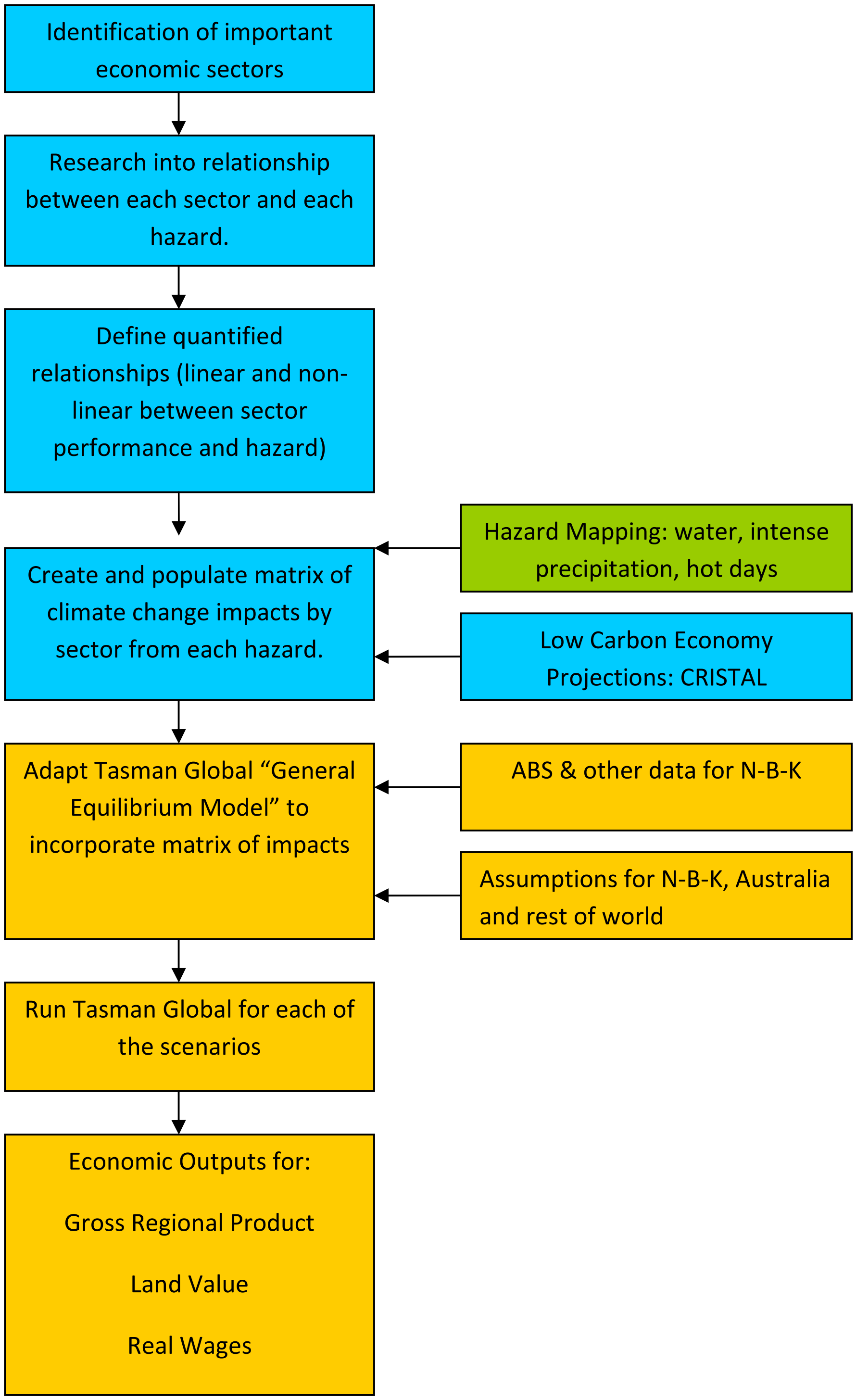


Figure 1 The area which defines the Nambucca–Bellingen–Kempsey (N-B-K) study area for the macro-economic modelling.

Because of the increased complexity of looking at multiple hazards, and multiple economic sectors simultaneously, the three major climate affected hazards have been selected which impact the three most significant economic activities in the Nambucca-Bellingen-Kempsey area (N-B-K). The resulting matrix considers the effects individually, and also in overall combination. The following figure outlines the process and how different information has been incorporated.



12.1

Figure 2 Outline of process used for the economic modelling with climate change perturbations (Climate Risk tasks shown in yellow, CLIM systems in green and ACIL Tasman in yellow.

Quantifying the Interactions

During the project it emerged that there needs to be provision for both linear and non-linear effects. For example if a road is closed to a factory for a day such that staff cannot arrive at work, then one days production is lost, which is a direct and linear effect. If on the other hand a heat wave causes a tourist to not venture out for three days, there is a direct impact from their spending, but there may be a magnified effect if they never return and contribute to a negative perception of the area by potential tourists – an amplified effect which may increase faster than the underling hazard – which is a non-linear effect. At its extreme a non-linear effect can be more like a step change – such as the sudden loss of an entire industry, but such step-change impacts have not been identified within this project.

Therefore to take impacts from the spatial mapping and transfer them to something useable for the economic modeling the matrix uses the following equation, where K is the key climate hazard parameter, L is the linear sensitivity coefficient and N is the non-linear sensitivity coefficient.

Economic Impact Coefficient $= 1 - (L \times K^{1/N})$

Taking the tourism example, the mapping of intense rainfall indicates that in 2050 there will be a 4% risk of a (historical) 1 in 50 flooding event occurring that year, this is the key climate hazard parameter, K. The impact on tourism is deemed to have a linear sensitivity (L) of 1.0 and non-linear sensitivity (N) of 2.0, ie if it happens very infrequently it has only a small effect, but if it happens more frequently its effect is magnified.

For this first pass assessment only direct linear impacts have been used unless there is compelling evidence or logic to the contrary.

Table 1. **First pass matrix relating key parameters to economic impacts on the associated sectors. ** Increased days over 35 based on ensemble of 5 GCMs with average of councils for Dec, Jan and Feb. * Percentage change based on ensemble of 5 GCMs with average change for each council for June, July and August. ^ Percentage increased based on ensemble of 5 GCMs with average change of each council for 1-in-20 year precipitation. # Based on study by Jones and Hennessy - assumption is that Nambucca region has similar risks to Hunter Valley taking their 4% change in 2030 and 6% change in productivity by 2070 - for 2050 we assume 5% change.**

	Tourism				
Climate Hazard	Definition of key parameter	Value of key parameter	Linear sensitivity	Non-Linear Sensitivity	Economic Impact Coefficient
Temperature extremes	(Increased days > 35) / 90 (duration of tourism season)**	0.018	1.000	1.000	0.982
Water availability	No effect modelled	0.000	1.000	1.000	1.000
Intense Precipitation	Future annual risk of *current* 1 in 50 year intense rainfall	0.040	1.000	2.000	0.800
Carbon Cuts	Change in aviation levels (from CRISTAL CS2, 2 degree scenario)	-0.300	1.000	1.000	1.300
	Agriculture				
Climate Hazard	Definition of key parameter	Value of key parameter	Linear sensitivity	Non-Linear Sensitivity	Economic Impact Coefficient
Temperature extremes	Reduced ag production from Hunter Study by CSIRO#	0.060	1.000	1.000	0.940
Water availability	Percentage change in winter water availability*	0.113	0.500	1.000	0.944
Intense Precipitation	Percentage annual risk of the *current* 1-in-20 year event in future	0.080	0.200	1.000	0.984
Carbon Cuts	Emission level in 2050 (causing increase in value of ag wastes for bioenergy and land for renewable energy)	-0.900	0.300	1.000	1.270
	Manufacturing				
Climate Hazard	Definition of key parameter	Value of key parameter	Linear sensitivity	Non-Linear Sensitivity	Economic Impact Coefficient
Temperature extremes	Annual fraction of increased days over 35 degrees	0.060	0.050	1.000	0.997
Water availability	No Effect	0.000	1.000	1.000	1.000
Intense Precipitation	Percentage annual risk of the *current* 1-in-50 year event in future	0.040	0.500	1.000	0.980
Carbon Cuts	No effect modelled (not including secondary processing for Ag. sector)	0.000	1.000	1.000	1.000

Table 13: Industry/Commodity aggregation used in Tasman Global modelling

	Industry/Commodity		Industry/Commodity
1	Vegetables and fruits	17	Metals
2	Grains and livestock	18	Non-metallic minerals (including cement, plaster, lime, gravel)
3	Other agriculture	19	Chemicals, rubber, plastics
4	Dairying	20	Machinery and equipment
5	Forestry	21	Other manufacturing
6	Fishing	22	Gas distribution
7	Processed food	23	Water
8	Coal	24	Construction
9	Oil	25	Trade services (includes all retail and wholesale trade, hotels and restaurants)
10	Gas	26	Transport services
11	Electricity	27	Financial, insurance, real estate services
12	Petroleum & coal products	28	Communications services
13	Textiles, clothing, footwear	29	Other business services
14	Wood products	30	Recreational and other services
15	Paper and paper products; including publishing and printing	31	Government services (including public administration and defence)
16	Other mining	32	Dwellings

12.2 Framework of analysis

(The following section has been prepared by Guy Jakeman of ACIL Tasman and provides a detailed explanation of the economic modeling.)

For the analysis of economic impacts of climate change to the areas in question is analysis Climate Risk worked with ACIL Tasman who employed their Computational General Equilibrium (CGE) model, Tasman Global.

Tasman Global is a large scale, dynamic, computable general equilibrium model of the world economy that has been developed in-house by ACIL Tasman. Tasman Global is a powerful tool for undertaking economic analysis at the regional, state, national and global levels.

CGE models such as Tasman Global mimic the workings of the economy through a system of interdependent behavioural and accounting equations which are linked to an input-output database. These models provide a representation of the whole economy, set in a national and international trading context, using a 'bottom-up approach' – starting with individual markets, producers and consumers and building up the system via demands and production from each component. When an economic shock or disturbance such as an increase in a sector's rate of growth is applied to the model, each of the markets adjusts to a new equilibrium according to the set of behavioural parameters[7] which are underpinned by economic theory.

In addition to recognising the linkages between industries in an economy, general equilibrium models also recognise economic constraints. For example, increased demand for labour may increase real wages if there is full employment.

A key advantage of CGE models is that they capture both the direct and indirect impacts of economic changes while taking account of economic constraints. For example, Tasman Global captures the expansion in economic activity driven by an investment, and at the same time accounts for the constraints faced by an economy in terms of availability of labour, capital and other inputs. Another key advantage of CGE models is that they capture a wide range of economic impacts across a wide range of industries in a single consistent framework that enables rigorous assessment of a range of policy scenarios.

More detail of the Tasman Global model is provided in Appendix E.

12.3 Database Aggregation

The database which underpins the model contains a wealth of sectoral and regional detail. The foundation of this information is the input-output tables that underpin the database. Industries and regions in the model can be aggregated or disaggregated as required for a specific project. For this project the model has been aggregated to:

- Four economies, namely the Bellingen/ Nambucca/Kempsey region, the Rest of New South Wales, the Rest of Australia and the Rest of the World.
- The 32 industries/commodities

[7] An example of a behavioural parameter is the *price elasticity of demand* – the responsiveness of demand for a commodity to a change in the price of that commodity. Each of these markets, for example the market for a commodity or a factor such as labour or land or the market for capital goods, is then linked through trade and investment flows.

The aggregation was chosen to provide the maximum detail possible for the key industries in the Bellingen/Nambucca/ Kempsey economies while providing groups which share a common response to important climate change hazards (including outputs of the Climate Risk Industry Sector Allocation Model In the base case scenario, the pattern and rate of real economic growth is a function of assumptions on:

- Changes in population – particularly changes in the number of people of working age (15 years old and over).
- Changes in workforce participation rates – defined here as the average number of hours worked in the labour force by all people of working age. This measure encompasses changes in participation rates by age by gender, the unemployment rate and average hours worked.
- Growth in labour productivity – defined here as the average output per hour worked.

The projection of each of these elements is discussed in the following sections.

12.3.1 Population growth

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for 112 international regions and the 8 states and territories of Australia represented in the Tasman Global database has been projected using ACIL Tasman's in-house demographic model.8 The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.

For each of the 120 regions, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc). Participation rates are a function of life expectancy as well expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

For this analysis, global population is projected to increase over the projection period by 0.83 per cent a year, increasing the global population from around 6.7 billion in 2008 to 8.03 billion in 2030. Most of this growth occurs in the next decade, with the average annual growth projected to be 0.95 per cent a year to 2020, falling to 0.67 per cent a year between 2020 and 2030. The slowing rate of growth is due to continuing declines in fertility rates across developing countries coupled with ageing population effects across developed economies and some

[8] For the modelling in this report the population of all Australian states and territories other than Queensland have been aggregated to form the population for the rest of Australia.

developing economies such as China. For example, Japan's population is projected to begin declining in the 2009 calendar year while the population of the European Union over the period is projected to increase moderately before falling back to current levels around 2022.

Population growth for the eight Australian states and territories incorporates all the latest ABS information on population levels, fertility, mortality and migration rates The total Australian population in 2030 is projected to be 29.1 million, with the population of New South Wales projected to be 8.7 million. By 2050, the New South Wales and Australian population is projected to be 9.5 and 33.9 million, respectively9.

Population growth in the B-N-K region is assumed to match the NSW Department of Planning10 projections of the projected growth rate for the Mid-North Coast. By 2030, the population in the B-N-K region is projected to reach 75,434, increasing to 85,186 by 2050.

The population growth rate assumptions used for the regions modelled in this analysis are shown in Figure 4.

[9] This projection is approximately the same as the most current ABS Series B projection of 33.96 million by 2050 (see ABS catalogue number 3222.0 released in September 2008), but is less than the recently released Treasury projection of 35.4 million by 2050. The largest driver of the different projections appears to be the assumed migration rate.

[10] NSW Department of Planning (2008), *New South Wales State and Regional Population Projections, 2006-2036: 2008 Release*, available at: http://www.planning.nsw.gov.au/.

12.3.2 Labour supply

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects. Some developing economies, notably China, are also projected to have slower growth in labour supply compared to total population. The labour supply growth assumptions used for the regions modelled in this analysis are shown in Figure 5.

12.3.3 Unemployment

In addition to tracking the available workforce through the changes in population demographics and participation rates, Tasman Global also tracks unemployment rates. It should be noted that unemployment and participation rates are largely interchangeable in affecting the number of people available for work in the model. Separate identification of the components is undertaken to allow a more representative labour market. In general, when unemployment is high, increases in labour demand can largely be supplied by reducing the unemployment rate but when unemployment is low, increases in labour demand will largely be met by increasing participation rates (and/or hours worked). Changes in participation rates in Tasman Global are driven by changes in the real wages offered by employers.

Figure 3 presents the historical unemployment rates in the Richmond-Tweed & Mid-North Coast region (which include the B-N-K local government areas). It can be seen that the

Richmond-Tweed & Mid-North Coast region has traditionally experienced higher levels of unemployment than New South Wales as a whole. Although this differential has trended down in the last few years the region has still experienced higher unemployment than the state as a whole.

For the current modelling it has been assumed that the B-N-K region will continue to experience similar differential in the levels of unemployment compared to New South Wales as a whole. It has been assumed that the unemployment rate in the B-N-K region will trend toward 6.0 per cent by around 2015, while the assumed unemployment rate in New South Wales and Australia are projected to trend toward 4.5 per cent.

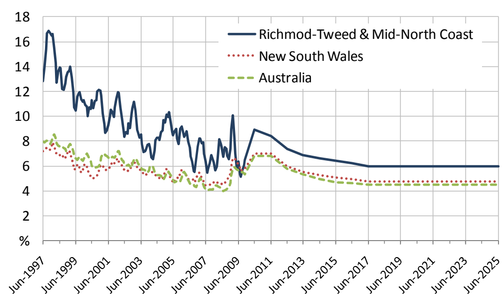


Figure 3. Historical and assumed unemployment rate by region, reference case. Data source: ABS Detailed Labour Force by region statistics, catalogue number 6291.0.55.001 (three month rolling average) and ACIL Tasman assumptions.

12.3.4 Labour productivity growth

Labour productivity is a measure of the quantity of goods and services per unit of time worked. Growth in labour productivity is highly variable on a year to year basis and is influenced by many developments in the economy, including changes in capital intensity and the composition of the work-force (Treasury, 2008).

Over the past 30 years Australian labour productivity growth has averaged 1.75 per cent a year and 1.8 per cent over the past 40 years (Treasury, 2008). Near term labour productivity growth is based on projections of labour supply and real GDP. In the reference case, the annual growth in Australian labour productivity is assumed to gradually slow from around 1.75 at the end of the next decade to 1.5 per cent a year over the remaining projection period as the composition of the Australian economy continues to shift toward services, which has historically had lower rates of productivity growth compared to the rest of the economy.

12.3.5 Real economic output growth

In Tasman Global, base case growth in economic output (GDP and GSP) is based on a mixture of historical data, near-term projections by the Commonwealth and State Treasuries and medium-long run projections. Australian historical GSP growth to 2009 is sourced from the ABS national accounts, while historical growth for the rest of the World is sourced from the IMF World Economic Outlook. Near term projections (to 2017) for Australia as a whole are sourced from the latest Commonwealth Budget papers. The projections for the rest of the World (to 2014) are sourced from the IMF World Economic Outlook (October 2009). Projections for economic growth past these points are determined using ACIL Tasman's projections of labour supply and labour productivity.

The impacts of the current financial crisis are expected to take a couple of years to move through the system, with the global economy returning to historical growth trends by 2012. Real economic growth assumptions used for the reference case for this analysis are shown in Figure 6

Based on these economic growth assumptions, the level of Australia's real GDP rises from $1.25 trillion in 2008-09 to $3.6 trillion in 2049-50. Over the same period the GSP of New South Wales is assumed to grow from approximately $402 billion in 2008-09 to $1,003 billion in 2049-50.

12.3.6 Labour market assumptions

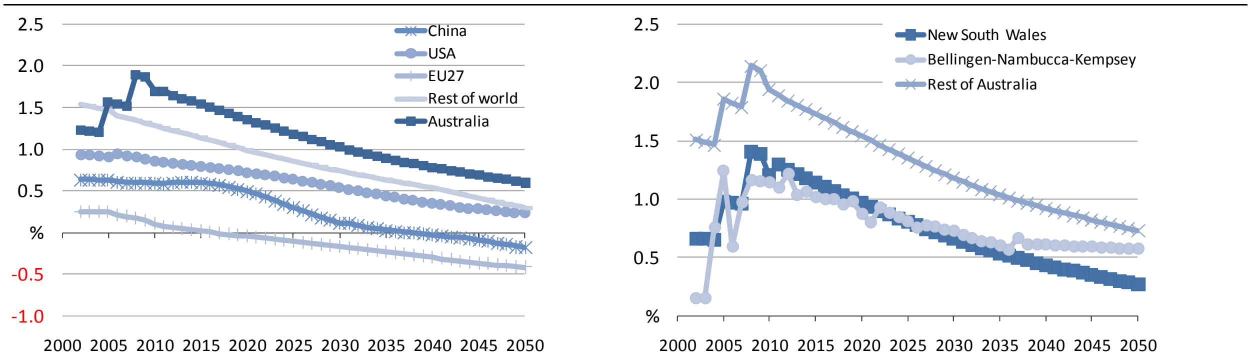
In the simulations performed with Tasman Global the labour market can be treated in a number of ways. Traditionally, CGE modelling utilises one of three labour market assumptions:

- Fixed labour supply (the full employment approach) and zero labour mobility between Australian regions
- Medium term adjustment to labour supply and zero labour mobility between Australian regions
- Full labour mobility between regions so that changes to wages are equalised across Australian regions.

Labour market assumption 2 simply allows local supply to vary in the medium term (five to ten years) before returning to its long run position. It provides a temporary reprieve from labour market constraints.

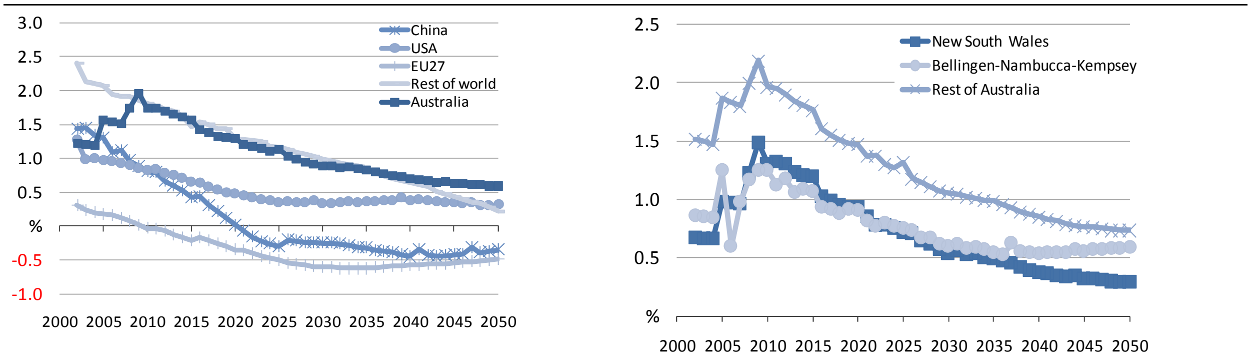
Labour market assumptions 1 and 3 are more extreme. Under assumption 1, the proposed developments would have to be accomplished with only the current labour available in the Mackay region with some allowance for natural growth, ie no new labour could be drawn to the Mackay region as a result of the projects. Under assumption 3 changes to wages in the Mackay region would be the same as changes to wages in all Australian regions, with labour shifting between Australian regions until changes to wages equalise. Modelling under assumption 3 provides the largest movement in labour across regions.

Tasman Global includes a labour market module that allows for constrained movement between regions of the Australian economy. For this project, we have elected to use a hybrid labour market assumption (which allows for some medium term adjustment potential), rather than resort to the use of assumption 2. But what level of constraint is appropriate (ie what level of labour movement between Australian regions makes sense)? In previous work the model has been calibrated to replicate the observed movement of labour between Australia's States and Territories during the period from 2001 to 2006. It is these settings that are used for the modelling the future outcomes in this analysis.



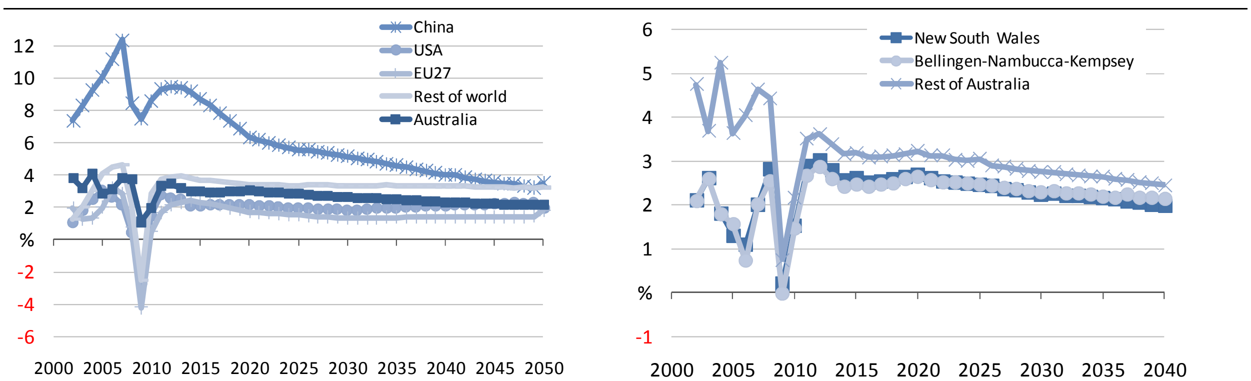
Source: ACIL Tasman projections

Figure 4: Assumed growth in population, reference case (per cent, year on year)



Source: ACIL Tasman projections

Figure 5 Assumed growth in labour supply, reference case (per cent, year on year)



Source: ACIL Tasman projections

Figure 6 Growth in real economic output by region, reference case (per cent, year on year).

12.4 Economic Impact of Physical Hazards

12.4.1 Gross Regional Product

The impact on Gross Regional Product for the N-B-K region has been projected on an annual basis over the period 2010 to 2050, based on real 2008-09 Australian dollars.

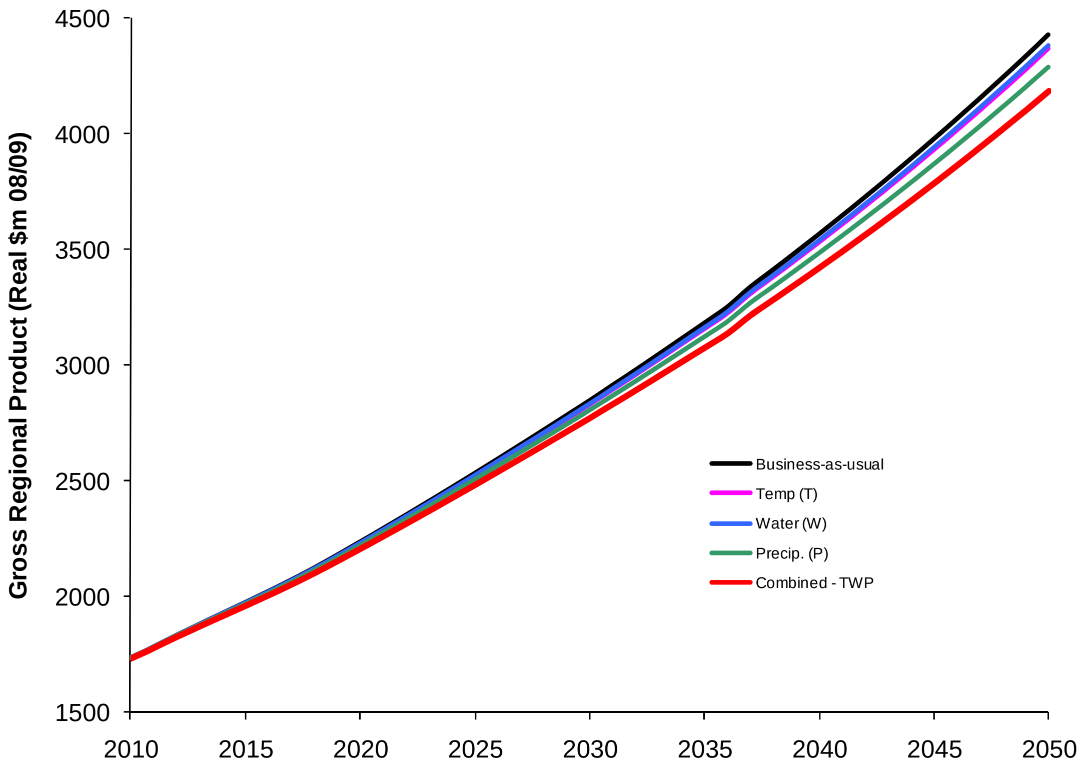


Figure 7 Effect of primary (direct physical) climate change hazards on Gross Regional Product for the N-B-K region over the period 2010 to 2050, based on real 2008-09 Australian dollars.

The following tables set out the deviations from the base-line projections for gross regional product in decadal steps in dollars and as a percentage effects.

Table 2 The Effect of primary (direct physical) climate change hazards on Gross Regional Product for the N-B-K region for the years 2010, 2020, 2030, 2040 and 2050 in real 2008-09 Australian dollars (000,000).

Year		2010	2020	2030	2040	2050
Business-as-usual	2008-09 A$m	1734	2235	2845	3564	4426
Temp	2008-09 A$m	-0.41	-6.77	-18.19	-35.79	-60.61
Water	2008-09 A$m	-0.30	-4.92	-13.27	-26.08	-43.90
Precipitation	2008-09 A$m	-1.01	-16.02	-41.96	-81.66	-139.08
Cumulative	2008-09 A$m	-1.75	-28.10	-74.10	-144.08	-243.23

Table 3 The Effect of primary (direct physical) climate change hazards on Gross Regional Product for the N-B-K region for the years 2010, 2020,2030, 2040 and 2050 as a percentage change from the base-line.

Year		2010	2020	2030	2040	2050
Business-as-usual	2008-09 $m	1734	2235	2845	3564	4426
Temp	%	-0.02	-0.30	-0.64	-1.00	-1.37
Water	%	-0.02	-0.22	-0.47	-0.73	-0.99
Precipitation	%	-0.06	-0.72	-1.48	-2.29	-3.14
Cumulative	%	-0.10	-1.26	-2.60	-4.04	-5.50

The contributors to the GRP can be broken down into those on the income and expenditure sides and these are set out for two time steps 2030, and 2050 below.

Table 4 The breakdown of contributors to GRP for the 2030 and 2050 time steps for the primary (direct physical) climate change hazards considered.

	Temp	Water	Precip.	Cumulative	Temp	Water	Precip.	Cumulative
	2030	2030	2030	2030	2050	2050	2050	2050
	2008-09 $m	2008-09 $m	2008-09 $m	2008-09 $m	2008-09 $m	2008-09 $m	2008-09 $m	2008-09 $m
Income side								
Change in value added	-4.72	-3.14	-13.56	-21.52	-17.76	-11.48	-52.83	-81.81
Change in tax revenues	-2.35	-1.54	-7.03	-10.97	-8.26	-5.29	-25.01	-38.47
Change in productivity	-11.12	-8.60	-21.38	-41.60	-34.58	-27.13	-61.24	-122.95
Expenditure side								
Change in private consumption	-15.99	-11.91	-34.64	-63.19	-51.73	-38.18	-112.41	-202.38
Change in government consumption	-1.72	-1.37	-2.96	-6.12	-6.48	-5.08	-11.71	-23.29
Change in investment	-3.17	-2.29	-7.56	-13.13	-10.58	-7.56	-25.60	-43.59
Change in exports	-9.78	-6.84	-21.69	-38.70	-31.18	-20.53	-79.82	-131.08
Change in imports	12.47	9.14	24.89	47.04	39.37	27.45	90.45	157.10
Change in real GDP	-18.19	-13.27	-41.96	-74.10	-60.61	-43.90	-139.08	-243.23
% change in real GDP	-0.64	-0.47	-1.48	-2.60	-1.37	-0.99	-3.14	-5.49
% change in real land price	-4.51	-4.27	-1.05	-10.07	-7.33	-6.94	-1.74	-16.13
% change in real wages	-0.26	-0.18	-0.70	-1.15	-0.53	-0.34	-1.51	-2.40

12.4.1.1 Real Wages

The impact of primary hazards on Real Wages for the N-B-K region has been projected on an annual basis over the period 2010 to 2050, based on real 2008-09 Australian dollars.

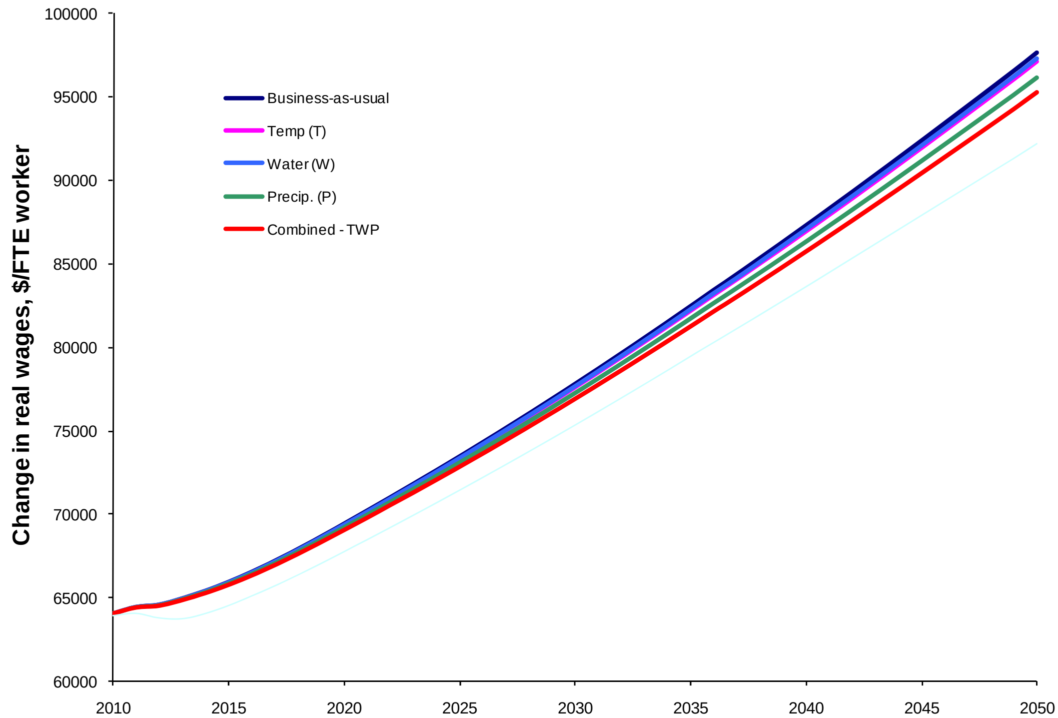


Figure 8 Effect of primary (direct physical) climate change hazards on Real Wages for the N-B-K region over the period 2010 to 2050, in real 2008-09 Australian dollars.

The following table sets out the deviations from the base-line projections in decadal steps.

Table 13: The Effect of primary (direct physical) climate change hazards on Real Wages for the N-B-K region for the years 2010, 2020,2030, 2040 and 2050 as a percentage change from the base-line

Year		2010	2020	2030	2040	2050
Business-as-usual		64073	69426	77788	87266	2050
Temp	% deviation	-0.01	-0.13	-0.26	-0.40	-0.53
Water	% deviation	-0.01	-0.09	-0.18	-0.26	-0.34
Precip.	% deviation	-0.03	-0.34	-0.70	-1.09	-1.51
Cumulative	% deviation	-0.05	-0.57	-1.15	-1.77	-2.40

12.4.2 Land Prices

The impact on Land Prices for the N-B-K region has been projected on an annual basis over the period 2010 to 2050, indexed from a 2010.

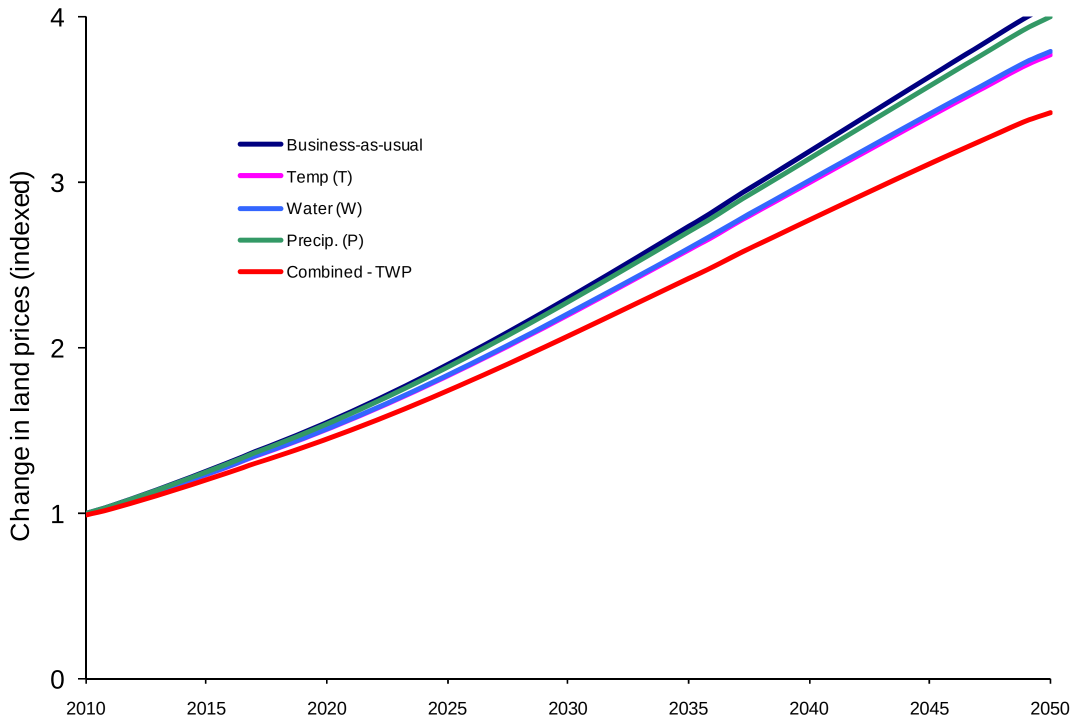


Figure 9 Effect of primary (direct physical) climate change hazards on Land Prices for the N-B-K region over the period 2010 to 2050, indexed relative to 2010.

The following table sets out the percentage deviations from the base-line projections in decadal steps.

Table 5 The Effect of primary (direct physical) climate change hazards on Land Prices for the N-B-K region for the years 2010, 2020,2030, 2040 and 2050 as a percentage change from the base-line, indexed relative to 2010.

Year		2010	2020	2030	2040	2050
Business-as-usual		64073	69426	77788	87266	2050
Temp	% deviation	-0.01	-0.13	-0.26	-0.40	-0.53
Water	% deviation	-0.01	-0.09	-0.18	-0.26	-0.34
Precip.	% deviation	-0.03	-0.34	-0.70	-1.09	-1.51
Cumulative	% deviation	-0.05	-0.57	-1.15	-1.77	-2.40

12.5 The Economic Impact of Carbon Prices and Transition to a Low Carbon Economy

The first pass economic modelling has been extended to consider the effect of a transition to a low carbon economy (LCE) and the effects of carbon prices more generally.

Carbon prices affect not just the regional economy, but act nationally and internationally. The Tasman Global model has a provision to capture the effects of emissions regulation by using a carbon price. A carbon price can be introduced into the model affecting any and all commodities that directly or indirectly produce greenhouse gases in their production and transportation. This has been used for tasks such as the economic modelling of various national policy settings for the Australian Government. The carbon price is set at a national and international level in the model with trading of emission permits allowed.

The effects of a transition to a low carbon economy have been modelled as a bottom up process where we have considered such effects as increases to domestic tourism arising from constraints or costs associated with aviation. We have also modelled a boost to agricultural value, with additional revenue streams becoming available from the conversion of agricultural wastes to energy and fuels.

In the following we provide the effects of the carbon impacts alone and then in combination with the physical hazards discussed above.

1.5.1 Gross Regional Product

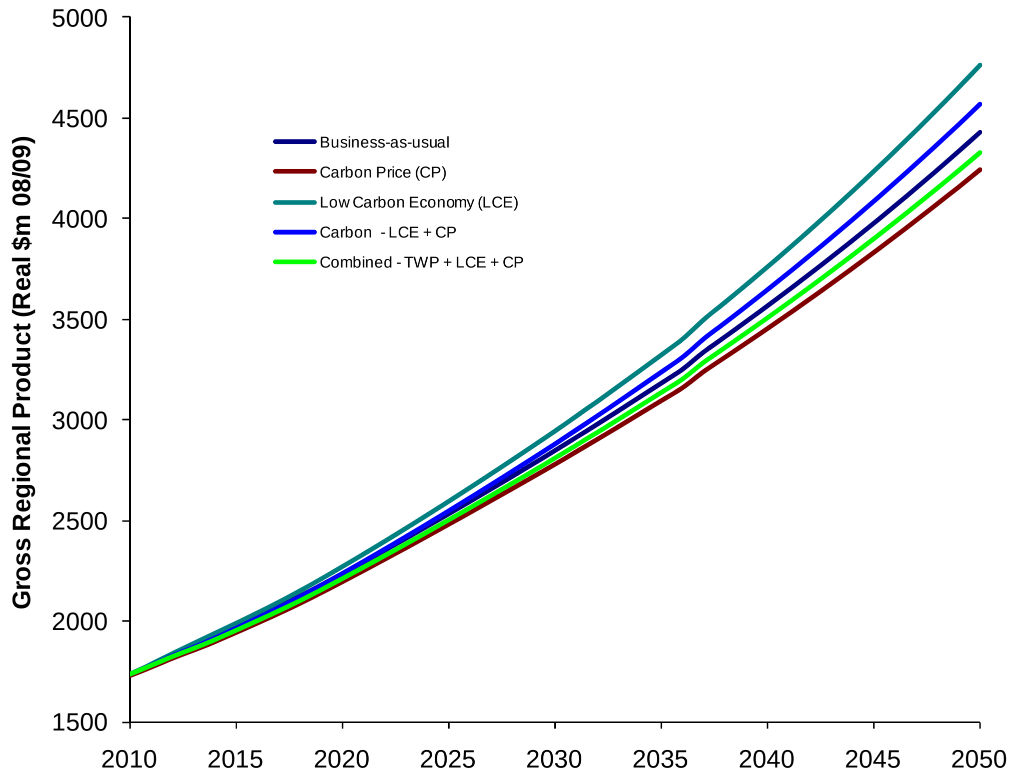


Figure 10: Effect of carbon prices (CP), low carbon economy (LCE) on the Gross Regional product and in combination with the combined physical hazards (TWP).

The effects on GRP show that carbon prices will tend to cause a modest decrease in GRP, where as the opportunities for the region will tend to increase GRP, with the net effect being positive. The positive net effect will also act to lessen the impacts on GRP from the three major physical hazards.

1.5.2 Real Wages

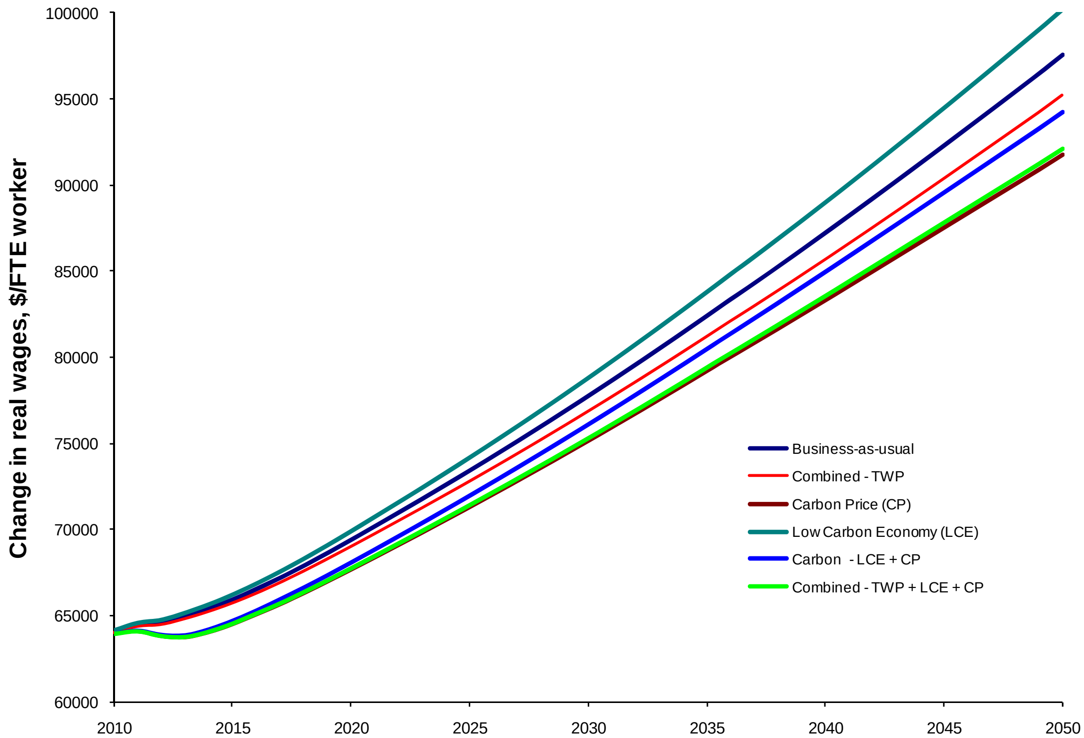


Figure 11: Effect of carbon prices (CP), low carbon economy (LCE) on the Real Wages and in combination with the combined physical hazards (TWP).

The effects on Real Wages follow a similar path to GRP and similar scale (effects less than 10% in 2050). However in this case the Carbon Price is more dominant than LCE opportunities and so pulls the combined impact below business as usual. This means that the effects of carbon constraint will combine with physical hazards to almost double the negative effect on Real Wages.

1.5.3 Land Prices

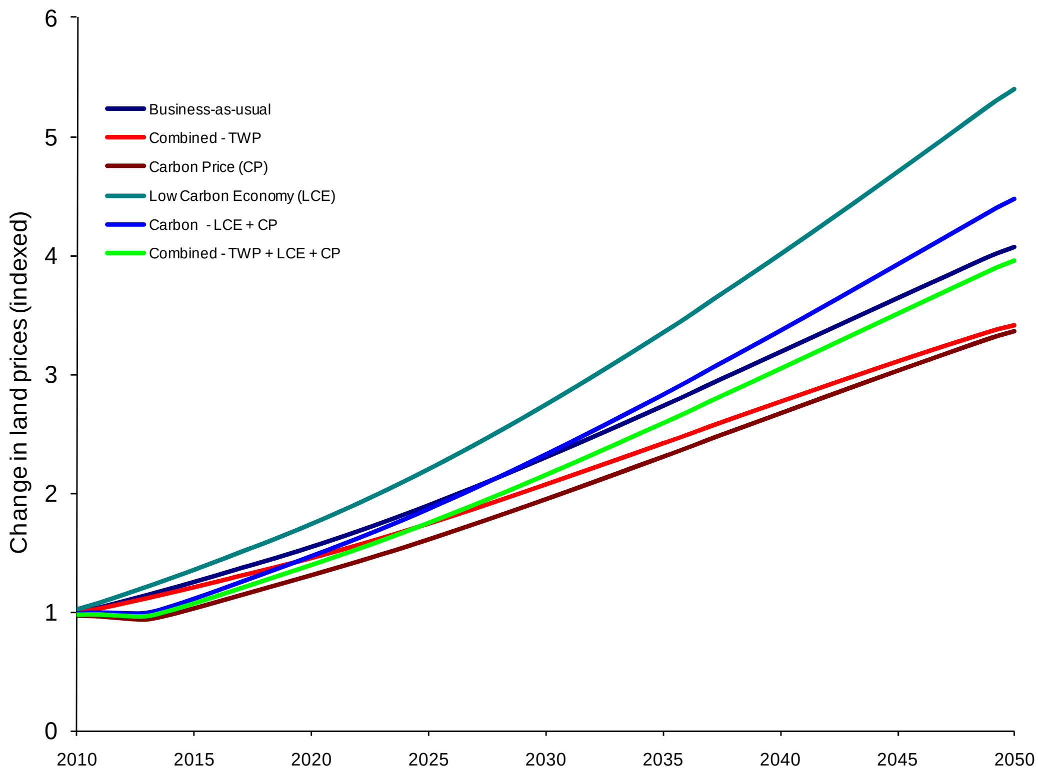


Figure 12: Effect of carbon prices (CP), low carbon economy (LCE) on the Real Wages and in combination with the combined physical hazards (TWP).

As with GRP, the effect on land prices is more balanced with the LCE impacts creating a very strong lift for land prices exceeding 20%. In combination with carbon prices and physical impacts the net effect is close to Business as Usual.

Climate Risk

12.6 Conclusions of Economic Analysis

This first pass economic modelling indicates that each of the primary hazards will have a significant impact on the overall economy in terms of Gross Regional Product, with a cumulative impact of 5.5% by 2050 on the base-line regional economy. Over the period 2010 to 2050 the cumulative impact of the reductions in GRP due to the three climate primary hazards considered is about 3.7 billion dollars.

Of the contributing hazards it would appear to be the effect of flooding due to intensified precipitation that will be the major contributor, itself responsible for a deviation in GRP of over 3% by 2050. While increases in hot days contributed about a 1.4% deviation and changes in water availability about 1%.

The impacts on real wages were more modest overall, with the cumulative deviation of about 2.4% from the base-line projections, with a similar relative contribution from each of the hazards as per GRP.

However, the deviation in land prices was considerably larger than for GRP, with a 16% deviation from the base-line projection by 2050. And interestingly, the contributions to this change were not dominated by flooding, but by changes in water availability (especially seasonal availability) and increases in the number of hot days in roughly equal measure (a deviation of roughly 7% each). It may be inferred that these hazards, if unmitigated, act to reduce the relative economic attractiveness of the agricultural land.

These results are positive in that they do not indicate a catastrophic risk to the region, however they do give ample reason for investment in adaptive measures that may avoid losses to wages, land value and the regional economy as a whole. The incentive to avoid or reduce the loss of 3.7 billion from the N-B-K regional economy may also provide adequate budgetary incentive for the required investments by the private sector and all levels of government.

The opportunities for increased value for the region in tourism and agricultural output under a regulatory forced transition to a low carbon economy will tend to boost GRP, wages and land prices, and could off-set a substantial part of the negative impacts due to carbon pricing.

13 Community Risks

Climate change presents a plethora of risks to the Nambucca community. To explore this problem, this chapter will first introduce results from two community survey. The socio-demographic composition of the area will then be outlined, followed by an exploration of the potential challenges that climate change may present out to 2030 and 2050.

13.1 Community Concern

At this project's outset, two surveys were undertaken to ascertain elements of community concern. While the response rate for the Climate Risk Pty Ltd survey was not statistical relevant (at only 55 responses) the Nambucca Shire Council survey was (with a telephone survey of 400 residents).

Respondents of the Climate Risk Pty Ltd survey evinced an overwhelming concern ('very concerned') for climate change risks (80%), and only 3.6% of respondents indicating they had no concern at all (Figure 30).

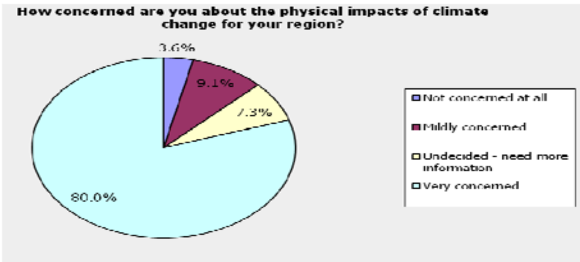


Figure 30. Climate Risk Pty Ltd Community Survey Results

In November 2009 Nambucca commissioned Jetty Research's CATI facility to undertake a survey of randomly selected Nambucca Shire ratepayers. The survey covered a range of subjects, including climate change. The majority of respondents of the survey expressed concern that climate change would result in a number of impacts, including sea level rise, increased storm damage, less reliable rainfall and more droughts.

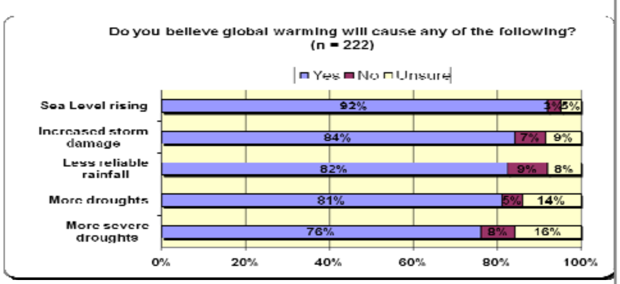


Figure 32. Distribution of results from a residential survey on climate change impacts (Jetty Research 2009)

A significant proportion of respondents (77%) considered that Council should be planning for risks associated with climate change (figure 33).

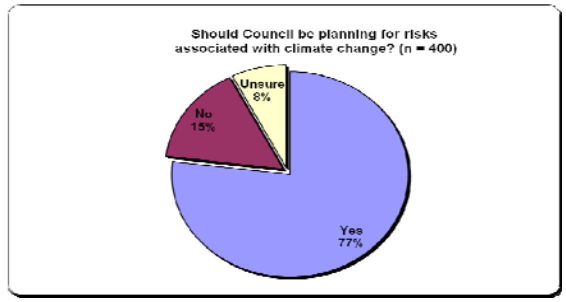


Figure 33. Distribution of results from a residential survey on planning for climate change impacts (Jetty Research 2009)

13.2 Demographic Information

At the 2006 Census the population of Nambucca was 18,633. The population is anticipated to grow to 20,740 by 2030. Nambucca has an ageing population with 22% of the population over 65, considerably higher than the NSW average of 13.8% (ABS 2009). By 2030 the over-65 proportion is anticipated to reach 36.3% (ABS & NCAHS 2010) (Figure 34).

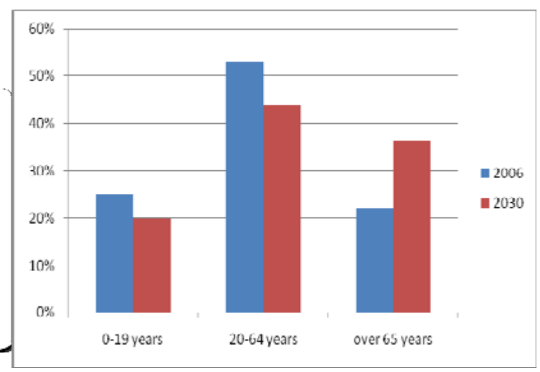
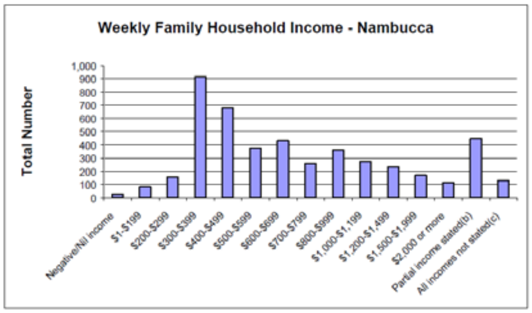


Figure 34. Nambucca population age distribution in 2006 and anticipated figures for 2030 (source: ABS 2009 & NCAHS 2010)

Climate Risk



Source: ABS 2001 Census

(a) Includes all Households identifying as family & excludes 'Other not classifiable households' and 'Visitor only households'.

Figure 35. Weekly family household income for Nambucca.

The majority of the population live in the urban environments of Nambucca Heads (6,268) Macksville (2,704), Valla Beach (1,017), Bowraville (946) and Scotts Head (858) (NSC 2009). According to BHill (2005) the average weekly household income for the Nambucca "is approximately 20% less than that of Coffs harbour and almost half of the average across NSW". Recent ABS (2006) data indicates a relatively high unemployment rate for Nambucca, 13% compared to the state average of 6.8%.

13.3 Health and Wellbeing in a Warmer World

Probably the most significant health-related hazard is the expected change in return rate of extreme heat days (or heatwaves). The definition of a heatwave differs across the globe, but generally it "can be defined as a prolonged period of excessive heat. The difficulty in defining a heat wave in Australia has been in establishing an appropriate heat index with an acceptable event threshold and duration, and relating it to the climatology of the area under investigation," according to BOM (2008). Heatwaves have caused more fatalities than any other natural hazard in Australia (Granger & Haye 2000). Heatwaves can have serious human health ramifications, especially on the elderly and infirm. They can also place considerable strain on infrastructure and energy supply, and can increase livestock and crop losses (Granger & Hayne 2000).

Projections from the ensemble of five GCMs used for this project indicate that heatwaves will occur more often. Heatwaves have the potential to impact the health of the Council's aging population, especially in areas under financial pressure.

CLIMsystems has estimated the return periods for very persistent heatwaves. (These are usually defined as three or five days with maximum temperatures exceeding 35 °C, but without accounting for other heat stress variables, night-time cooling relief, or the effects of acclimatisation over the season). The modelling results indicate that the average return period for heatwaves shortens considerably, halving every 20 years. That is, such heatwaves become more frequent, with the existing return rate of one occurrence in every 12 years shortening to once every six years in 2030, every three years in 2050, and every 18 months in 2070.

13.4 Isolation Due to Climate Events

There are many settlements in Nambucca which are prone to isolation. Isolation can occur in a physical sense (eg transport corridors) or in a non-physical sense (communication, electricity, water and sewerage). Presently, the most significant driver of physical isolation arises from extreme rainfall and flooding. Floods can isolate communities, as occurred in Bowarville in 2009, leading to reduced access to health care, food, work and social networks. Larger towns such as Macksville and Nambucca Heads have also experienced periods of isolation due to flooding. Since rainfall intensities are anticipated to increase due to climate change, more associated flooding in the region is highly likely. A

Climate Risk

confluence of sea level rise and increases in intense precipitation events may result in more frequent physical isolation of these coastal communities.

Non-physical isolation can often lead to serious challenges. Hurricane Katrina's disastrous impact on New Orleans is a reminder of the challenges a system faces when its communication and critical service lines are down.

Other drivers of isolation also include bushfires (which can restrict emergency egress, electricity and ICT networks) and the price of carbon (which may result in community members being 'priced out' of some selected movement).

Particular areas of concern for Nambucca are Gumma, Scotts Head and rural communities with limited access. Residents and tourists also face isolation risks at Nambucca Heads if Wellington Drive access is cut from flooding and landslides.

13.5 Increased Cost of Living in a Carbon Constrained Economy

As noted above, the Nambucca area has higher unemployment and lower household income than much of the rest of NSW. If climate change, as projected, damages crops, increases insurance costs and results in higher fossil fuel prices, the community will be further disadvantaged. Furthermore current oil price volatility, combined with increased mortgage and rent stress, exacerbates those already vulnerable to climate change impacts.

Recently-released modelling on emissions targets suggests that a CPRS will correlate to between 17% and 28% increase in electricity charges (Commonwealth Treasury 2008; Garnaut 2008). Although it is envisaged that this would be supported by some compensatory measures, those in the lower socio-economic bracket will no doubt feel the pressure of an unsupported carbon-constrained economy (Figure 33).

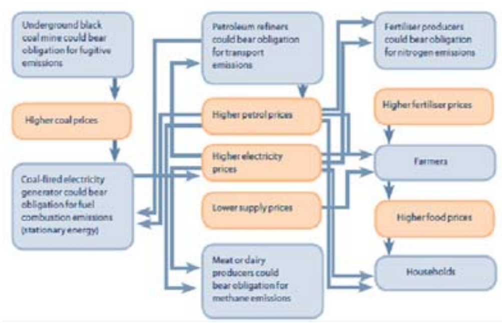


Figure 36. An illustration of how a carbon-constrained economy may impact the cost of living for householders (source: Garnaut 2008).

14 Risk Assessment Workshops

A climate change risk workshop was undertaken with council staff to further explore potential challenges for Council. In these workshops, participants (with support from Climate Risk P/L) were tasked with identifying the probability and likelihood of certain primary, secondary and tertiary climate change hazards.

The internal stakeholder workshop was held on December 8th 2009. During the workshop a presentation provided an overview of the current scientific modelling and an outline of risk management in the context of climate change. The detailed workshop that followed was attended by 10 staff representing all sectors of Council. A pre-reading document prepared by Climate Risk Pty Ltd and titled "An Introduction to Climate Change Hazards for Local Government" was circulated to invited staff for their information prior to the workshop. The aim of this was to introduce climate change issues and what they mean for Local Government.

Staff where given scenarios based on the IPCC A1FI storyline and tasked with the process of identifying potential hazards and assigning likelihoods and consequences for a range of these risks. The descriptions used for the likelihood and consequences are shown below (Tables 16 and 17).

In the first part of the detailed workshop small multidisciplinary groups identified potential impacts arising from climate variables and determined Council's vulnerability to these impacts. The second component of the workshop was to then assign likelihood ratings to each of the impacts. Using a combination of the likelihood and vulnerability ratings, a final risk rating was identified for each of the potential impacts. At the end of the day, a prioritised list of potential climate change impacts that will possibly influence Council's core business provision now and in the future was developed.

Table 19 Likelihood descriptor used in the workshop

Likliehood	Descriptor	Probability of occurrence
Rare	May occur only in exceptional circumstances	More than 20 years
Unlikely	Could occur at some time	Within 10-20 years
Possible	Might occur at some time	Within 3-5 years
Likely	Will probably occur in most circumstances	Within 2 years
Almost certain	Expected to occur in most circumstances	Within 1 year

Table 20 Consequence descriptor used for the workshop

Consequences	Description
Insignificant	No injuries, low financial loss (less than $10,000)
Minor	First aid treatment, on-site release immediately contained, medium financial loss ($10,000 - $50,000)
Moderate	Medical treatment required, on-site release contained with outside assistance, high financial loss ($50,000 - $200,000)
Major	Extensive injuries, loss of production capacity, off-site release with no detrimental effects, major financial loss ($200,000 - $1,000,000)
Catastrophic	Deaths, toxic release off-site with detrimental effect, huge financial loss (more than $1M)

The resulting output is a priority ranking of risks ranging from low to extreme. The qualitative weighting of these priorities follows the DCC workbook (DCC 2006) (Figure 37).

- Extreme priority risks demand urgent attention at the most senior level and can not be simply accepted as part of routine operations without executive sanction.
- High priority risks are the most severe that can be accepted as a part of routine operations without executive sanction but they will be the responsibility of the most senior operational management.
- Medium priority risks can be expected to form part of routine operations but they will be explicitly assigned to relevant managers for action and maintained under review.
- Low priority risks will be maintained under review but it is expected that existing controls will be sufficient.

Figure 13 Qualitative weighting used for priorities (DCC 2006)

In the first part of the detailed workshop small multidisciplinary groups identified potential impacts arising from climate variables and determined Council's vulnerability to these impacts. The second component of the workshop was to then assign likelihood ratings to each of the impacts. Using a combination of the likelihood and vulnerability ratings, a final risk rating was identified for each of the potential impacts. At the end of the day, a prioritised list of potential climate change impacts that will possibly influence Council's core business provision now and in the future was developed.

14.1 Summary of Workshop Risks / Risk Prioritisation

Twenty six specific risks, across seven categories, were identified in the internal workshop. The majority of the risks stemmed from the categories of increased rainfall, temperature, and storm surge/sea level rise (see Table 3).

Of the risks, five were classed as 'very high priority' for 2030. These were temperature and sea level rise threats to biodiversity; sea level rise and drainage failure; and the expected stresses of reduced rainfall, infrastructure damage from storms, damage to bridges and temperature impacts on water supply. Eighteen risks were classed as 'high' and three 'medium'.

In the longer-term future, for 2050, in addition to the above-mentioned 'very high priority' rankings, a further four risks were upgraded. These included salinity threats to aquifers, increased risks of flooding from storm surge, the impacts of a carbon-constrained economy on council fleet costs, as well as on building and operational costs.

Table 21 Workshop findings

Hazard	Risk	Direct Exposure	Likelihood 2030	Likelihood 2050	Consequence 2030	Consequence 2050	Risk Prioritisation 2030	Risk Prioritisation 2050
Sea level rise	Aquifer salinity	Community / Council	L	P	Maj	Maj	High	V High
Sea level rise	Urban development zones	Council / Economy	AC	P	Maj	Maj	High	High
Storms	Infrastructure and asset damage	Council	p	AC	Maj	Maj	V High	V High
Temperature	Increased electrical use from higher temperatures - supply issues	Council / Community	L	P	Maj	Maj	High	High
Temperature / Rainfall	Bushfire risk to property and life	Community	L	P	Maj	Maj	High	High
Storms	Reduced tourism	Community /Economy	AC	AC	Maj	Maj	High	High
Storm surge	Coastal erosion	Council / Community	AC	AC	Maj	Maj	High	High
Legal	Liability from existing approvals - community seeking redress from council	Council	P	L	Min	Maj	Med	High
Legal	Current & future development	Council	P	L	Mod	Maj	High	High
Carbon Price	Council fleet costs	Council	L	AC	Mod	Maj	High	V High
Carbon Price	Increased building and operational costs	Council	P	AC	Mod	Maj	High	V High
Rainfall / Temperature / Sea level rise	Changes to agricultural production	Community / Economy	P	L	Mod	Maj	High	High
Storm surge	Flooding	Council / Community	L	AC	Mod	Maj	High	V High

			Likelihood		Consequence		Risk Prioritisation	
Hazard	Risk	Direct Exposure	2030	2050	2030	2050	2030	2050
Temperature	Damage to infrastructure (eg playgrounds)	Council	L	AC	Min	Mod	Med	High
Popn shift	Popn moves away from coast to flood liable land	Council / Community	P	L	Mod	Maj	High	High
Temperature / Sea level rise	Pressure on biodiversity and habitat	Council / Community / Environment	AC	AC	Maj	Cat	V High	V High
Sea level rise	Drainage failure	Council	AC	AC	Maj	Maj	V High	V High
Temperature / Rainfall	Mosquitoes	Community	L	L	Mod	Mod	High	High
Storms / Sea level rise	Landslides, riverine erosion, potholes	Council and Community	L	L	Mod	Mod	High	High
Rainfall	Damage to bridges	Council / Community / Economy	P	AC	Maj	Maj	V High	V High
Rainfall / Sea level rise	Damage to sewerage pump stations	Council / Community	L	AC	Mod	Mod	High	High
Rainfall	More homes flooded	Community	L	AC	Mod	Mod	High	High
Mal-adaptation	New bypass creates a levee east of Macksville	Community	P	P	Mod	Mod	High	High
Rainfall / Temperature	Stress on water supply	Council and Community	P	AC	Maj	Maj	V High	V High
Rainfall / Sea level rise	Oysters less viable industry	Economy	P	L	Min	Min	Med	Med
Rainfall / Temperature	Local food production under stress	Community	P	L	Mod	Mod	High	High

15 Conclusion

It is evident from this project that climate change and associated strategies will present an array of specific risks for council, the community it represents and the natural environment. On their own each identified risk presents challenges which will no doubt strain Council's capacity to provide a high quality of services. However what is of considerable concern is that by 2030 Council is likely to feel the ramifications from the confluence of the following impacts:

- Significant changes to runoff
- Increased bushfire risks
- A stressed economy
- Business interruption
- Increased cost of living
- Increased maintenance regimes
- An ageing population
- Considerable increases in oil prices
- Increased intensity of storms (and storm clean-up costs)
- Increased operational costs
- Diminishing proportion of full-paying rateable properties
- Concurrent extreme weather periods
- State policies inconsistent with changing climate science

All aspects of the above impacts will place a strain on the financial viability of Council. Council will need to make challenging decisions regarding the cost-benefit of early, mid and late term adaptation options. Increased energy and maintenance costs are virtually certain, placing strains on Council's ability to provide other adaptive measures to support community. Increased maintenance and operational costs will likely run into millions of dollars (and even more if tort-based litigation occurs).

Even with appropriate adaptation commenced immediately, expenses will increase due to climate change, although evidence suggests that these can be reduced substantially with good management.

There are clear cost implications, as resources will have to be found to:

a Upgrade the capital stock and systems to be climate resilient

b Cover high operational and maintenance costs

c Cover the increased risk of potential liabilities

d Undertake further detailed research/analysis

The above risks have been further explored by Climate Risk Pty Ltd, Nambucca Shire Council and the community in the Climate Change Adaptation Plan due for community consultation.

Recommendations which will be explored in the Adaptation Plan include the need for a detailed assessment of critical infrastructure; research of storm surge and sea level rise (down to lot level); flood analysis (based on current data); and identification of resources to drive adaptation.

Given the limited resources available to the Council it is recommended that the Adaptation Plan focus on the identification of win-win actions (that help resilience to climate change as well as other ancillary benefits).

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17 Appendices

Appendix A: Description of the specific methodologies and assumptions used in this report.

Mapping Methodology

Nambucca data file name explanation:

'Projection_': projection

'Change_pct_': change percent from baseline for precipitation related variables, change of days for Tmaxgt35, degree for Tmax

'Baseline': Baseline

'csiro3_5__' : CSIRO MK35 GCM

'ensemble__': 5 GCM ensemble

'percent10_': 10th percentile

'percent50_' : 50th percentile

'percent90_': 90th percentile

SRES: IPCC A1F1 and IPCC A2

Month: 'Jan','Feb','Mar','Apr','May', 'Jun','Jul','Aug','Sep','Oct', 'Nov', 'Dec': month 1-12

'MAM','JJA', 'SON', 'DJF': season: Mar-Apr-May, Jun-Jul-Aug, Sep-Oct-Nov, Dec-Jan-Feb

'Ann': annual

Year slice: 2030, 2050, 2070

Variable	Description	File name code	Sample filename	Format	Number of files
(1)	Maximum temperature	**Tmax**	Tmax__A1F1_2030_Projection_percent10_Feb.txt	ARCGIS ASCII 1084 columns * 1496 rows, 100m resolution	1037 ARCGIS ASCII +3 statistical summary Excel files
(2)	Precipitation	**Precip**	Precip__A1F1_2030_Change_pct_percent50_SON.txt	As above	1037 ARCGIS ASCII +3 statistical summary Excel files
(3)	Average no days max temp > 35ºC	**Tmaxgt35**	Tmaxgt35_A1F1_2030_Change_pct_csiro3_5__Apr.txt	As above	305 ARCGIS ASCII +3 statistical summary Excel files
(4)	99th percentile daily precipitation intensity (mm/day)	**Prec_Z99**	Prec_Z99_A1F1_2030_Change_pct_csiro3_5__Apr.txt	As above	305 ARCGIS ASCII +3 statistical summary Excel files
(5)	Mean number of days where precipitation is < 1mm	**DRYD**	DRYD__A1F1_2030_Projection_csiro3_5__Feb.txt	As above	305 ARCGIS ASCII +3 statistical summary Excel files
(6)	Sea level rise				
(7)	3 day extreme rainfall	3dayXtremeP		Excel	6
(8)	5 day extreme temperature	Extreme Temperautre		Word	1

Data Source Methodologies:

1. Maximum temperature and precipitation baseline data source is 0.05*0.05 degree gridded daily dataset from BOM of Australia. Baseline period is 1961-2000.

2. 5 GCMs selected by Climate Risk Ltd are: CSIRO_MK35, ECHO_G, IPSL_CM40, MIROC_MED, MRI_CGCM2.

3. The baseline of all variables are derived from the BOM latitude longitude gridded data, projected to MGA projection, and interpolated to 100m resolution using bilinear interpolation method.

4. SRES A1B GCM monthly dataset of each selected GCM were used for monthly maximum temperature, precipitation, Tmax > 35 degree, and heat wave analysis employed CSIRO pattern scaling approach.

5. For 99th percentile precipitation and number of dry days, and 3 days extreme rainfall analysis, considering the high uncertainty of these variables, all 3 SRES, A1B, A2, and B1 daily dataset were included, the ensemble results were used for final analysis.

Appendix B: Examples comparing the outputs between the ensemble of five GCMs, and individual CSIRO Mk 3.5 model.

Nambucca 3 day annual extreme precipition changes (%)

Source	Return Period	A1FI_2030	A1FI_2050	A1FI_2070	A2_2030	A2_2050	A2_2070
CSIRO_MK35	5	4.1862	8.6024	13.9846	3.7262	6.8543	10.8565
	10	3.487	7.1655	11.6488	3.1038	5.7094	9.0431
	20	2.1489	4.4159	7.1787	1.9128	3.5185	5.573
	50	-0.3047	-0.6262	-1.018	-0.2713	-0.499	-0.7903
	100	-2.5244	-5.1876	-8.4333	-2.247	-4.1334	-6.5469
Ensemble of 5 GCMs	5	3.9623	8.1423	13.2367	3.5269	6.4877	10.2758
	10	4.8695	10.0065	16.2673	4.3344	7.9731	12.6286
	20	5.6524	11.6154	18.8828	5.0313	9.255	14.659
	50	6.6946	13.757	22.3644	5.9589	10.962	17.3618
	100	7.5967	15.6109	25.3781	6.7619	12.439	19.7014
Lowest	5	-3.9413	-8.0992	-13.1667	-3.5082	-6.4534	-10.222
	10	-0.7074	-1.4537	-2.3633	-0.6297	-1.1583	-1.8346
	20	2.1489	4.4159	7.1787	1.9128	3.5185	5.573
	50	-0.3047	-0.6262	-1.018	-0.2713	-0.499	-0.7903
	100	-2.5244	-5.1876	-8.4333	-2.247	-4.1334	-6.5469
Middle	5	4.1862	8.6024	13.9846	3.7262	6.8543	10.8565
	10	3.487	7.1655	11.6488	3.1038	5.7094	9.0431
	20	3.3083	6.7983	11.0517	2.9447	5.4168	8.5796
	50	9.8	20.1385	32.7385	8.7231	16.046	25.4154
	100	10.455	21.4844	34.9266	9.3061	17.119	27.1141
Highest	5	10.0826	20.7191	33.6824	8.9746	16.509	26.1482
	10	10.6833	21.9536	35.6893	9.5093	17.492	27.7061
	20	11.3863	23.3983	38.0378	10.1351	18.644	29.5294
	50	12.5413	25.7716	41.8961	11.1631	20.535	32.5246
	100	15.733	32.3304	52.5585	14.0041	25.761	40.802

Nambucca area 3 day extremes precipitation baseline(location from BOM grid data -30.61,152.81)

return period(year)	mm
5	279.0482
10	337.7884
20	396.0898
50	474.5072
100	535.5344

3 day extreme precipition changes

Source	Return Period (year)	A1FI_2030	A1FI_2050	A1FI_2070	A2_2030	A2_2050	A2_2070
CSIRO_MK35	5	290.7297	303.053	318.0721	289.446	298.175	309.343
	10	349.567	361.9927	377.1366	348.2726	357.0742	368.335
	20	404.6013	413.5806	424.524	403.666	410.0263	418.1637
	50	473.0612	471.5357	469.6765	473.2201	472.1396	470.7571
	100	522.0151	507.7531	490.3712	523.5008	513.3985	500.4735
Ensemble of 5 GCM	5	290.1049	301.7691	315.9849	288.8899	297.152	307.7227
	10	354.237	371.5893	392.7375	352.4295	364.7207	380.4463
	20	418.4784	442.0971	470.8825	416.0181	432.748	454.1526
	50	506.2736	539.7853	580.6277	502.7828	526.5203	556.8903
	100	576.2176	619.1361	671.4431	571.7469	602.1475	641.0424

Change % of number of dry days in Nambucca shire

		A1FI			A2		
		2030	2050	2070	2030	2050	2070
Mar-Apr-May	CSIROMK35	2.14	4.4	7.16	1.91	3.51	5.55
	ENSEMBLE	-1.93	-3.96	-6.43	-1.71	-3.15	-4.99
	10 PERCENTILE	-3.57	-7.33	-11.92	-3.18	-5.84	-9.25
	50 PERCENTILE	-0.19	-0.4	-0.64	-0.17	-0.32	-0.5
	90 PERCENTILE	2.14	4.4	7.16	1.91	3.51	5.55
Jun-Jul-Aug	CSIROMK35	1.25	2.56	4.16	1.11	2.04	3.23
	ENSEMBLE	1.56	3.2	5.21	1.39	2.55	4.04
	10 PERCENTILE	0.46	0.94	1.52	0.41	0.75	1.18
	50 PERCENTILE	0.7	1.44	2.34	0.62	1.15	1.82
	90 PERCENTILE	1.25	2.56	4.16	1.11	2.04	3.23
Sep-Oct-Nov	CSIROMK35	1.97	4.05	6.59	1.75	3.23	5.12
	ENSEMBLE	0.48	0.99	1.62	0.43	0.79	1.26
	10 PERCENTILE	-0.72	-1.48	-2.41	-0.64	-1.18	-1.87
	50 PERCENTILE	-0.05	-0.1	-0.17	-0.04	-0.08	-0.13
	90 PERCENTILE	1.97	4.05	6.59	1.75	3.23	5.12
Dec-Jan-Feb	CSIROMK35	1.82	3.75	6.09	1.62	2.99	4.73
	ENSEMBLE	-1.98	-4.07	-6.61	-1.76	-3.24	-5.13
	10 PERCENTILE	-2.93	-6.02	-9.78	-2.61	-4.79	-7.59
	50 PERCENTILE	-1.13	-2.32	-3.77	-1.01	-1.85	-2.93
	90 PERCENTILE	1.82	3.75	6.09	1.62	2.99	4.73
ANNUAL	CSIROMK35	1.77	3.63	5.9	1.57	2.89	4.58
	ENSEMBLE	-0.39	-0.8	-1.3	-0.35	-0.64	-1.01
	10 PERCENTILE	-1.47	-3.01	-4.9	-1.31	-2.4	-3.8
	50 PERCENTILE	-0.3	-0.62	-1.01	-0.27	-0.49	-0.78
	90 PERCENTILE	1.77	3.63	5.9	1.57	2.89	4.58

Change % of 99th percentile precipitation intensity of Nambucca shire

		A1FI			A2		
		2030	2050	2070	2030	2050	2070
Mar-Apr-May	CSIROMK35	9.25	19.01	30.9	8.23	15.15	23.99
	ENSEMBLE	10.01	20.57	33.44	8.91	16.39	25.96
	10 PERCENTILE	2	4.12	6.69	1.78	3.28	5.2
	50 PERCENTILE	5.15	10.59	17.22	4.59	8.44	13.37
	90 PERCENTILE	9.25	19.01	30.9	8.23	15.15	23.99
Jun-Jul-Aug	CSIROMK35	-8.48	-17.43	-28.33	-7.55	-13.88	-21.99
	ENSEMBLE	3.08	6.33	10.29	2.74	5.05	7.99
	10 PERCENTILE	-8.48	-17.43	-28.33	-7.55	-13.88	-21.99
	50 PERCENTILE	4.24	8.7	14.15	3.77	6.94	10.99
	90 PERCENTILE	7.39	15.18	24.68	6.58	12.1	19.16
Sep-Oct-Nov	CSIROMK35	3.87	7.96	12.94	3.45	6.34	10.05
	ENSEMBLE	3.51	7.22	11.73	3.13	5.75	9.11
	10 PERCENTILE	-3.92	-8.05	-13.09	-3.49	-6.42	-10.16
	50 PERCENTILE	3.25	6.68	10.86	2.89	5.32	8.43
	90 PERCENTILE	3.88	7.98	12.97	3.46	6.36	10.07
Dec-Jan-Feb	CSIROMK35	4.56	9.37	15.23	4.06	7.47	11.82
	ENSEMBLE	13.71	28.17	45.79	12.2	22.44	35.55
	10 PERCENTILE	3.08	6.34	10.3	2.75	5.05	8
	50 PERCENTILE	6.39	13.12	21.33	5.68	10.46	16.56
	90 PERCENTILE	13.04	26.8	43.57	11.61	21.36	33.83
ANNUAL	CSIROMK35	7.21	14.82	24.1	6.42	11.81	18.71
	ENSEMBLE	6.65	13.67	22.21	5.92	10.89	17.25
	10 PERCENTILE	-3.96	-8.14	-13.23	-3.52	-6.48	-10.27
	50 PERCENTILE	4.05	8.32	13.52	3.6	6.63	10.5
	90 PERCENTILE	7.21	14.82	24.1	6.42	11.81	18.71

Appendix C: Sea Level Rise Methodology

Nambucca Sea Level Rise report

Dr. Peter Kouwenhoven

CLIMsystems, **December 2009/January 2010**

Introduction

This report analyses sea level rise for the Nambucca, Bellingen and Kempsey Areas (New South Wales, Australia), for 2030, 2050 and 2070, based on IPCC emissions scenarios (best and worst case), considering vertical land movement inferred from tidal observations in two locations (Port Kembla and Rosslyn Bay).

The Australian Bureau of Meteorology lists 2 tidal data stations close to Nambucca Heads (the main locality):

locality	LAT	LON	tidal data
Nambucca Heads	-30.709	152.990	none
Port Kembla (462 km S)	-34.483	150.917	Jul 1991 – Nov 2009
Rosslyn Bay (866 km N)	-23.167	150.783	Mar 1993 – Nov 2009

Analysis of tidal data

The tidal data can be analysed for a long term linear trend, the result of the combined vertical land-movement and the sea level rise over that period.

locality	mm/yr	intercept	R^2	avg (m)	n
Port Kembla	3.188	-5.481	0.0780	0.897	221
Rosslyn Bay	1.458	-0.5031	0.0089	2.415	201

mm/yr : slope of the long term trend
intercept : intercept of the long term trend
R2 : variation explained by linear relationship (expected to be low)
avg : average of all observations
n : number of observations

Once the observations are de-trended, an extreme event analysis can be done:

Return period(yrs)	Port Kembla	Rosslyn Bay
2	1.185	2.599
5	1.249	2.692
10	1.282	2.731
20	1.308	2.759
50	1.335	2.783
100	1.352	2.795

Analysis of sea level rise scenarios

There are 3 components to an estimation of local sea level rise:

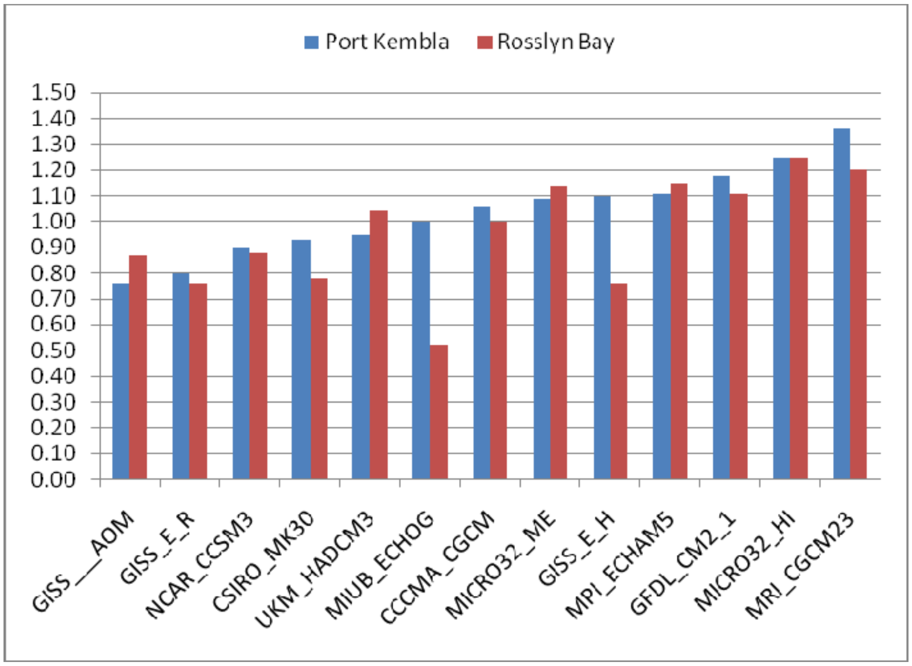
a the global sea level rise (depending on the chosen IPCC emission scenario)

b the local trend (here a combination of sea level rise and vertical land movement inferred from tidal data)

c the General Circulation Model used (that describes how many cm the local SLR will be when the global SLR is 1 cm, thus cm/cm)

Starting with the GCM, the coefficients for Port Kembla and Rosslyn Bay are:

#	model	Port Kembla	Rosslyn Bay
1	GISS___AOM	0.76	0.87
2	GISS_E_R	0.80	0.76
3	NCAR_CCSM3	0.90	0.88
4	CSIRO_MK30	0.93	0.78
5	UKM_HADCM3	0.95	1.04
6	MIUB_ECHOG	1.00	0.52
7	CCCMA_CGCM	1.06	1.00
8	MICRO32_ME	1.09	1.14
9	GISS_E_H	1.10	0.76
10	MPI_ECHAM5	1.11	1.15
11	GFDL_CM2_1	1.18	1.11
12	MICRO32_HI	1.25	1.25
13	MRI_CGCM23	1.36	1.20



The accepted approach is to take the median result from the model-ensemble, in this case 1.06 for Port Kembla and 1.00 for Rosslyn Bay.

The projections for global sea level rise for 2030, 2050 and 2070 for the 6 IPCC scenarios are:

	2030			2050			2070		
SRES	**low**	**mid**	**high**	**low**	**mid**	**high**	**low**	**mid**	**high**
A1B	7.60	10.14	12.69	11.63	16.95	22.28	15.76	24.50	33.24
A1FI	8.37	10.57	12.77	13.34	18.43	23.51	18.74	28.02	37.30
A1T	7.65	10.62	13.38	11.61	16.99	22.37	15.49	24.02	32.56
A2	7.20	9.35	11.31	11.52	15.97	20.42	16.17	24.18	32.18
B1	7.19	9.31	11.42	10.70	15.00	19.30	14.06	20.89	27.72
B2	7.27	9.36	11.44	11.03	15.43	19.83	14.91	22.22	29.54

	2100		
SRES	**low**	**mid**	**high**
A1B	22.05	36.53	51.00
A1FI	27.51	45.73	<u>63.95</u>
A1T	20.84	34.07	47.31
A2	24.53	39.94	55.35
B1	<u>18.74</u>	29.33	39.92
B2	21.06	33.44	45.82

(lowest and highest values underlined)

Using these projections with the median GCM coefficients, combined with the estimates for the local trend (Port Kembla: 3.188 mm/yr and Rosslyn Bay: 1.458 mm/yr), gives these best estimates for SLR (cm):

	Port Kembla (1.06)		Rosslyn Bay (1.00)	
year	**low**	**high**	**low**	**high**
2030	12.67(B1)	18.66(A1T)	5.83(B1)	11.58(A1T)
2050	18.89(B1)	32.26(A1FI)	8.66(B1)	21.47(A1FI)
2070	24.95(B1)	49.20(A1FI)	11.34(B1)	34.58(A1FI)
2100	33.73(B1)	80.84(A1FI)	15.00(B1)	60.21(A1FI)

Caveats

The given results might not meet certain expectations about sea level rise: the media regularly report sea level rise figures in excess of over 1 metre, which is rather a lot higher than the maximum listed here (81 cm). For a proper interpretation the following considerations must be taken into account:

- *Time horizon:*
  Sea level rise has two components: a) increased ice-melt (because of increasing temperature) from glaciers and Greenland and Antarctic ice-sheets, b) expansion of the water volume because of increased sea water temperatures. The present ratio is 40% from ice-melt

and 60% from thermal expansion. This will shift to almost 100% from thermal expansion at the end of the century. Thermal expansion is a very slow process and will continue a long long time (centuries) after atmospheric temperatures have stabilized. By setting the time horizon past 2100, sea level rise will get over 1 meter. This can be of relevance when adaptation measures are planned that have to do with built infrastructure with long projected life-spans. In such cases projections of up to 250 years might be required.

- *Vertical land movement:*
  Land is moving upward or downward at a given location. The magnitude of this process is comparable with the rate of sea level rise. If land moves up, it decreases the effect of sea level rise, if it increases it compounds sea level rise. The combined effect of vertical land movement and sea level rise can be extracted from tidal data. The trend in the data reflects how both processes are working. The reliability of the estimation increases with the length of the tidal time series; 30 years is recommended. The 18+ years of available data at Port Kembla show that the combined effect gives 3.188 mm/yr, while the 16+ years of data at Rosslyn Bay give 1.458 mm/yr. Thus Rosslyn Bay experiences less net sea level rise than Port Kembla. Ideally longer time series should be used, but these are not available. There is another counter-intuitive aspect that one should be aware of. Given the combined effect, the assumption of low climate sensitivity gives a bigger vertical land movement component than the assumption of high climate sensitivity. So when extrapolating in the future under low climate sensitivity, the net sea level rise will be driven by vertical land movement, while under high climate sensitivity, it will be driven by the climate change. Their future projections will thus differ less than expected based solely on climate change (because the high climate sensitivity comes with a low estimated vertical land movement, while the low climate sensitivity comes with a high estimated vertical land movement).
- *Local sea conditions:*
  Depending on existing water temperatures, currents, the global climate change can be locally amplified (or dampened). In the case of Port Kembla (6% amplification) and Rosslyn Bay (no change from global) this is not significant.
- *Local coastal conditions:*
  Coastal systems are impacted by erosion and sedimentation, both of which can be impacted by many climate change effects: sea level rise itself, but also wind, precipitation, tropical cyclones and changes in human behaviour because of climate change and adaptation measures. Only direct sea level rise had been analysed here.
- *Representation:*
  The two tidal stations (Port Kembla and Rosslyn Bay) are at the outside of the area that is of interest. The two stations show a relatively big difference in sea level rise effects. It is not clear how different the area between the stations will behave and thus how representative the tidal stations are for the vertical land movement process.

Appendix D: Environmental Protection and Biodiversity Conservation Act Protected Matters Reports for Nambucca.

Australian Government
Department of the Environment, Water, Heritage and the Arts

Protected Matters Search Tool

You are here: Environment Home > EPBC Act > Search

11 December 2009 16:51

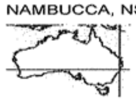
EPBC Act Protected Matters Report

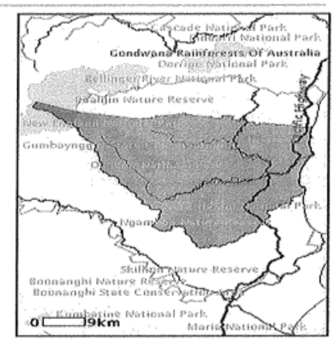
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

The Australian Natural Resources Atlas at http://www.environment.gov.au/atlas may provide further environmental information relevant to your selected area. Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

Search Region: NAMBUCCA, NSW





This map may contain data which are © Commonwealth of Australia (Geoscience Australia) © PSMA Australia Limited

Report Contents: Summary
Details
- Matters of NES
- Other matters protected by the EPBC Act
- Extra Information

Caveat
Acknowledgments

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Significance: (Ramsar Sites)	None
Commonwealth Marine Areas:	None
Threatened Ecological Communities:	2

http://www.environment.gov.au/cgi-bin/erin/ert/epbc/epbc_report.pl?loc_lga=NAM... 11-Dec-2009

Threatened Species:	54
Migratory Species:	61

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html.

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.au/epbc/permits/index.html.

Commonwealth Lands:	3
Commonwealth Heritage Places:	None
Places on the RNE:	5
Listed Marine Species:	87
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	9
Other Commonwealth Reserves:	None
Regional Forest Agreements:	1

Details

Matters of National Environmental Significance

World Heritage Properties [Dataset Information]

Gondwana Rainforests of Australia NSW

National Heritage Places [Dataset Information]

Gondwana Rainforests of Australia NSW

Threatened Ecological Communities [Dataset Information]	Status	Type of Presence
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	Critically Endangered	Community likely to occur within area
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Community may occur within area
Threatened Species [Dataset Information]	Status	Type of Presence

Birds		
Anthochaera phrygia Regent Honeyeater	Endangered	Species or species habitat likely to occur within area
Diomedea exulans antipodensis Antipodean Albatross	Vulnerable	Species or species habitat may occur within area
Diomedea exulans gibsoni Gibson's Albatross	Vulnerable	Species or species habitat may occur within area
Lathamus discolor Swift Parrot	Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Vulnerable	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western)	Vulnerable	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe	Vulnerable	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris impavida Campbell Albatross	Vulnerable	Species or species habitat may occur within area
Turnix melanogaster Black-breasted Button-quail	Vulnerable	Species or species habitat likely to occur within area
Frogs		
Litoria aurea Green and Golden Bell Frog	Vulnerable	Species or species habitat may occur within area
Litoria booroolongensis Booroolong Frog	Endangered	Species or species habitat may occur within area
Litoria olongburensis Wallum Sedge Frog	Vulnerable	Species or species habitat may occur within area
Mixophyes balbus Stuttering Frog, Southern Barred Frog (in Victoria)	Vulnerable	Species or species habitat likely to occur within area
Mixophyes iteratus Southern Barred Frog, Giant Barred Frog	Endangered	Species or species habitat likely to occur within area
Insects		
Phyllodes imperialis (southern subsp. - ANIC 3333) Pink Underwing Moth	Endangered	Species or species habitat likely to occur within area
Mammals		
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat	Vulnerable	Species or species habitat may occur within area
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population)	Endangered	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale	Vulnerable	Species or species habitat known to occur within area
Potorous tridactylus tridactylus Long-nosed Potoroo (SE mainland)	Vulnerable	Species or species habitat may occur within area
Pseudomys oralis Hastings River Mouse	Endangered	Species or species habitat likely to occur within area

Pteropus poliocephalus Grey-headed Flying-fox	Vulnerable	Roosting known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Endangered	Species or species habitat may occur within area
Chelonia mydas Green Turtle	Vulnerable	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Endangered	Species or species habitat may occur within area
Emydura macquarii signata (Bellinger River, NSW) Bellinger River Emydura	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharias taurus (east coast population) Grey Nurse Shark (east coast population)	Critically Endangered	Species or species habitat may occur within area
Carcharodon carcharias Great White Shark	Vulnerable	Species or species habitat may occur within area
Galeorhinus galeus School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark	Conservation Dependent	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark	Vulnerable	Species or species habitat may occur within area
Plants		
Acronychia littoralis Scented Acronychia	Endangered	Species or species habitat likely to occur within area
Allocasuarina defungens Dwarf Heath Casuarina	Endangered	Species or species habitat likely to occur within area
Arthraxon hispidus Hairy-joint Grass	Vulnerable	Species or species habitat likely to occur within area
Callistemon pungens	Vulnerable	Species or species habitat likely to occur within area
Cryptostylis hunteriana Leafless Tongue-orchid	Vulnerable	Species or species habitat may occur within area
Cynanchum elegans White-flowered Wax Plant	Endangered	Species or species habitat likely to occur within area
Gaultheria viridicarpa J.B.Williams subsp. viridicarpa ms.	Vulnerable	Species or species habitat may occur within area
Gingidia montana Mountain Angelica, Broad-leafed Carrot	Endangered	Species or species habitat likely to occur within area
Hicksbeachia pinnatifolia Monkey Nut, Bopple Nut, Red Bopple, Red Bopple Nut, Red Nut, Beef Nut, Red Apple Nut, Red Boppel Nut, Ivory Silky Oak	Vulnerable	Species or species habitat likely to occur within area
Marsdenia longiloba Clear Milkvine	Vulnerable	Species or species habitat likely to occur within area
Neoastelia spectabilis	Vulnerable	Species or species habitat likely to occur within area
Parsonsia dorrigoensis Milky Silkpod	Endangered	Species or species habitat likely to occur within area
Quassia sp. Moonee Creek (J.King s.n. 1949) NSW Herbarium	Endangered	Species or species habitat likely to occur within area
Styphelia perileuca	Vulnerable	Species or species habitat likely to occur within area
Taeniophyllum muelleri Minute Orchid, Ribbon-root Orchid	Vulnerable	Species or species habitat may occur within area

Species	Status	Type of Presence
Tasmannia glaucifolia Fragrant Pepperbush	Vulnerable	Species or species habitat likely to occur within area
Thesium australe Austral Toadflax, Toadflax	Vulnerable	Species or species habitat likely to occur within area
Tylophora woollsii	Endangered	Species or species habitat likely to occur within area
Zieria lasiocaulis	Endangered	Species or species habitat likely to occur within area
Migratory Species [Dataset Information]	Status	Type of Presence
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail	Migratory	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch	Migratory	Breeding may occur within area
Monarcha trivirgatus Spectacled Monarch	Migratory	Breeding likely to occur within area
Myiagra cyanoleuca Satin Flycatcher	Migratory	Breeding likely to occur within area
Rhipidura rufifrons Rufous Fantail	Migratory	Breeding may occur within area
Xanthomyza phrygia Regent Honeyeater	Migratory	Species or species habitat likely to occur within area
Migratory Wetland Species		
Birds		
Actitis hypoleucos Common Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Ardea alba Great Egret, White Egret	Migratory	Breeding likely to occur within area
Ardea ibis Cattle Egret	Migratory	Breeding likely to occur within area
Arenaria interpres Ruddy Turnstone	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper	Migratory	Foraging, feeding or related behaviour known to occur within area
Calidris alba Sanderling	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris canutus Red Knot, Knot	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris ferruginea Curlew Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Calidris ruficollis Red-necked Stint	Migratory	Foraging, feeding or related behaviour known to occur within area
Calidris tenuirostris Great Knot	Migratory	Foraging, feeding or related behaviour likely to occur within area
Charadrius bicinctus Double-banded Plover	Migratory	Foraging, feeding or related behaviour known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area

Charadrius veredus Oriental Plover, Oriental Dotterel	Migratory	Foraging, feeding or related behaviour likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Migratory	Foraging, feeding or related behaviour known to occur within area
Glareola maldivarum Oriental Pratincole	Migratory	Foraging, feeding or related behaviour likely to occur within area
Heteroscelus brevipes Grey-tailed Tattler	Migratory	Foraging, feeding or related behaviour likely to occur within area
Limicola falcinellus Broad-billed Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Limosa lapponica Bar-tailed Godwit	Migratory	Foraging, feeding or related behaviour known to occur within area
Limosa limosa Black-tailed Godwit	Migratory	Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew	Migratory	Foraging, feeding or related behaviour known to occur within area
Numenius minutus Little Curlew, Little Whimbrel	Migratory	Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel	Migratory	Foraging, feeding or related behaviour known to occur within area
Pluvialis fulva Pacific Golden Plover	Migratory	Foraging, feeding or related behaviour known to occur within area
Pluvialis squatarola Grey Plover	Migratory	Foraging, feeding or related behaviour likely to occur within area
Rostratula benghalensis s. lat. Painted Snipe	Migratory	Species or species habitat may occur within area
Tringa glareola Wood Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Tringa nebularia Common Greenshank, Greenshank	Migratory	Foraging, feeding or related behaviour known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank	Migratory	Foraging, feeding or related behaviour known to occur within area
Xenus cinereus Terek Sandpiper	Migratory	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Migratory	Breeding likely to occur within area
Ardea ibis Cattle Egret	Migratory	Breeding likely to occur within area
Diomedea antipodensis Antipodean Albatross	Migratory	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Migratory	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Migratory	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Migratory	Species or species habitat may occur within area
Sterna albifrons Little Tern	Migratory	Breeding likely to occur within area
Thalassarche bulleri Buller's Albatross	Migratory	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross	Migratory	Species or species habitat may occur within area
Thalassarche impavida	Migratory	Species or species habitat may occur within

Campbell Albatross		area
Thalassarche steadi White-capped Albatross	Migratory	Species or species habitat may occur within area
Migratory Marine Species		
Mammals		
Balaenoptera edeni Bryde's Whale	Migratory	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale	Migratory	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Migratory	Species or species habitat likely to occur within area
Lagenorhynchus obscurus Dusky Dolphin	Migratory	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Migratory	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca	Migratory	Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Migratory	Species or species habitat may occur within area
Chelonia mydas Green Turtle	Migratory	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Migratory	Species or species habitat may occur within area
Sharks		
Carcharodon carcharias Great White Shark	Migratory	Species or species habitat may occur within area
Rhincodon typus Whale Shark	Migratory	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Dataset Information]	Status	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper	Listed	Foraging, feeding or related behaviour likely to occur within area
Apus pacificus Fork-tailed Swift	Listed - overfly marine area	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Breeding likely to occur within area
Ardea ibis Cattle Egret	Listed - overfly marine area	Breeding likely to occur within area
Arenaria interpres Ruddy Turnstone	Listed	Foraging, feeding or related behaviour likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper	Listed	Foraging, feeding or related behaviour known to occur within area
Calidris alba Sanderling	Listed	Foraging, feeding or related behaviour likely to occur within area
Calidris canutus Red Knot, Knot	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area

Calidris ferruginea Curlew Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris melanotos Pectoral Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris ruficollis Red-necked Stint	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Calidris subminuta Long-toed Stint	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Calidris tenuirostris Great Knot	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Charadrius bicinctus Double-banded Plover	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Charadrius dubius Little Ringed Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover	Listed	Foraging, feeding or related behaviour likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover	Listed	Foraging, feeding or related behaviour likely to occur within area
Charadrius ruficapillus Red-capped Plover	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Diomedea antipodensis Antipodean Albatross	Listed	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Listed	Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Gallinago megala Swinhoe's Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Gallinago stenura Pin-tailed Snipe	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Glareola maldivarum Oriental Pratincole	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Haliaeetus leucogaster	Listed	Species or species habitat likely to occur

White-bellied Sea-Eagle		within area
Heteroscelus brevipes Grey-tailed Tattler	Listed	Foraging, feeding or related behaviour likely to occur within area
Heteroscelus incanus Wandering Tattler	Listed	Foraging, feeding or related behaviour likely to occur within area
Himantopus himantopus Black-winged Stilt	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Hirundapus caudacutus White-throated Needletail	Listed - overfly marine area	Species or species habitat may occur within area
Lathamus discolor Swift Parrot	Listed - overfly marine area	Species or species habitat likely to occur within area
Limicola falcinellus Broad-billed Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Limnodromus semipalmatus Asian Dowitcher	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Limosa lapponica Bar-tailed Godwit	Listed	Foraging, feeding or related behaviour known to occur within area
Limosa limosa Black-tailed Godwit	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Macronectes giganteus Southern Giant-Petrel	Listed	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Listed	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch	Listed - overfly marine area	Breeding may occur within area
Monarcha trivirgatus Spectacled Monarch	Listed - overfly marine area	Breeding likely to occur within area
Myiagra cyanoleuca Satin Flycatcher	Listed - overfly marine area	Breeding likely to occur within area
Numenius madagascariensis Eastern Curlew	Listed	Foraging, feeding or related behaviour known to occur within area
Numenius minutus Little Curlew, Little Whimbrel	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel	Listed	Foraging, feeding or related behaviour known to occur within area
Phalaropus lobatus	Listed	Foraging, feeding or related behaviour likely

Red-necked Phalarope		to occur within area
Philomachus pugnax Ruff (Reeve)	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Pluvialis fulva Pacific Golden Plover	Listed	Foraging, feeding or related behaviour known to occur within area
Pluvialis squatarola Grey Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Rhipidura rufifrons Rufous Fantail	Listed - overfly marine area	Breeding may occur within area
Rostratula benghalensis s. lat. Painted Snipe	Listed - overfly marine area	Species or species habitat may occur within area
Sterna albifrons Little Tern	Listed	Breeding likely to occur within area
Stiltia isabella Australian Pratincole	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Thalassarche bulleri Buller's Albatross	Listed	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross	Listed	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Listed	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross	Listed	Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa glareola Wood Sandpiper	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Tringa nebularia Common Greenshank, Greenshank	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank	Listed - overfly marine area	Foraging, feeding or related behaviour known to occur within area
Tringa totanus Common Redshank, Redshank	Listed - overfly marine area	Foraging, feeding or related behaviour likely to occur within area
Xenus cinereus Terek Sandpiper	Listed - overfly marine	Foraging, feeding or related behaviour likely to occur within area

	area	
Ray-finned fishes		
Acentronura tentaculata Hairy Pygmy Pipehorse	Listed	Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish	Listed	Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish	Listed	Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish	Listed	Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish	Listed	Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish	Listed	Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse	Listed	Species or species habitat may occur within area
Histiogamphelus briggsii Briggs' Crested Pipefish, Briggs' Pipefish	Listed	Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish	Listed	Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish	Listed	Species or species habitat may occur within area
Solegnathus dunckeri Duncker's Pipehorse	Listed	Species or species habitat may occur within area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse	Listed	Species or species habitat may occur within area
Solenostomus cyanopterus Blue-finned Ghost Pipefish, Robust Ghost Pipefish	Listed	Species or species habitat may occur within area
Solenostomus paradoxus Harlequin Ghost Pipefish, Ornate Ghost Pipefish	Listed	Species or species habitat may occur within area
Stigmatopora nigra Wide-bodied Pipefish, Black Pipefish	Listed	Species or species habitat may occur within area
Syngnathoides biaculeatus Double-ended Pipehorse, Alligator Pipefish	Listed	Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bend Stick Pipefish, Short-tailed Pipefish	Listed	Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish	Listed	Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish	Listed	Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Listed	Species or species habitat may occur within area
Chelonia mydas Green Turtle	Listed	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Listed	Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake	Listed	Species or species habitat may occur within area
Pelamis platurus Yellow-bellied Seasnake	Listed	Species or species habitat may occur within area
Whales and Other Cetaceans [Dataset Information]	Status	Type of Presence
Balaenoptera acutorostrata Minke Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera edeni	Cetacean	Species or species habitat may occur within

Bryde's Whale		area
Caperea marginata Pygmy Right Whale	Cetacean	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin	Cetacean	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Cetacean	Species or species habitat likely to occur within area
Grampus griseus Risso's Dolphin, Grampus	Cetacean	Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin	Cetacean	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Cetacean	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca	Cetacean	Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin	Cetacean	Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin	Cetacean	Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin	Cetacean	Species or species habitat may occur within area

Commonwealth Lands [Dataset Information]

Communications, Information Technology and the Arts - Australian Postal Corporation

Communications, Information Technology and the Arts - Telstra Corporation Limited

Defence

Places on the RNE [Dataset Information]
Note that not all Indigenous sites may be listed.

Indigenous

Nambucca Aboriginal Area NSW

Natural

Bowraville Nature Reserve NSW

Nambucca North Headland NSW

New England National Park (1978 boundary) NSW

Warrell Creek Coastal Forest NSW

Extra Information

State and Territory Reserves [Dataset Information]

Bollanolla Nature Reserve, NSW

Bowraville Nature Reserve, NSW

Dunggir National Park, NSW

Ganay Nature Reserve, NSW

Jagun Nature Reserve, NSW

Juugawaarri Nature Reserve, NSW

New England National Park, NSW

Ngambaa Nature Reserve, NSW

Valla Nature Reserve, NSW

Regional Forest Agreements [Dataset Information]
Note that all RFA areas including those still under consideration have been included.

Lower North East NSW RFA, New South Wales

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the *Environment Protection and Biodiversity Conservation Act 1999*. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under "type of presence". For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the migratory and marine provisions of the Act have been mapped.

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites;
- seals which have only been mapped for breeding sites near the Australian continent.

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgments

This database has been compiled from a range of data sources. The Department acknowledges the following custodians who have contributed valuable data and advice:

- New South Wales National Parks and Wildlife Service
- Department of Sustainability and Environment, Victoria
- Department of Primary Industries, Water and Environment, Tasmania
- Department of Environment and Heritage, South Australia Planning SA
- Parks and Wildlife Commission of the Northern Territory
- Environmental Protection Agency, Queensland
- Birds Australia
- Australian Bird and Bat Banding Scheme
- Australian National Wildlife Collection

- Natural history museums of Australia
- Queensland Herbarium
- National Herbarium of NSW
- Royal Botanic Gardens and National Herbarium of Victoria
- Tasmanian Herbarium
- State Herbarium of South Australia
- Northern Territory Herbarium
- Western Australian Herbarium
- Australian National Herbarium, Atherton and Canberra
- University of New England
- Other groups and individuals

ANUCliM Version 1.8, Centre for Resource and Environmental Studies, Australian National University was used extensively for the production of draft maps of species distribution. Environment Australia is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Last updated: Thursday, 20-Nov-2008 14:17:56 EST

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Appendix E: The Tasman Global model

ACIL Tasman's computable general equilibrium model *Tasman Global* is a powerful tool for undertaking economic impact analysis at the regional, state, national and global level.

There are various types of economic models and modelling techniques. Many of these are based on partial equilibrium analysis that usually considers a single market. However, in economic analysis, linkages between markets and how these linkages develop and change over time can be critical. *Tasman Global* has been developed to meet this need.

Tasman Global is an analytical tool that can capture these linkages on a regional, state, national and global scale. *Tasman Global* is a large-scale computable general equilibrium model which is designed to account for all sectors within an economy and all economies across the world. ACIL Tasman uses this modelling platform to undertake industry, project, scenario and policy analyses. The model is able to analyse issues at the industry, global, national, state and regional levels and to determine the impacts of various economic changes on production, consumption and trade at the macroeconomic and industry levels.

A Dynamic model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

In applications of the *Tasman Global* model, a reference case simulation forms a "business-as-usual" basis with which to compare the results of various simulations. The reference case provides projections of growth in the absence of the changes to be examined. The impact of the change to be examined is then simulated and the results interpreted as deviations from the reference case.

The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the latest Global Trade Analysis Project (GTAP) database which was released in 2008. This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities.

The GTAP model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

Tasman Global builds on the GTAP model's equation structure and database by adding five important features: dynamics (including detailed population and labour market dynamics), detailed technology representation within key industries (such as electricity generation and iron and steel production), the ability to repatriate labour and capital income, a detailed emissions accounting abatement framework and explicit representation of the states and territories of Australia.

Nominally the *Tasman Global* database divides the world economy into 120 regions although in reality the regions are frequently disaggregated further.

The GTAP database also contains a wealth of sectoral detail (Table **Error! No text of specified style in document.** AE). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, diesel and iron and steel sectors are modelled using a 'technology bundle' approach. With this approach, different known production methods are used to generate a homogeneous output for the 'technology bundle' industry. For example, electricity can be generated using coal, petroleum, gas, nuclear, hydro or non-hydro renewable based technologies – each of which have their own cost structure.

Table **Error! No text of specified style in document.**E **Sectors in the *Tasman Global* database**

	Sector		Sector
1	Paddy rice	31	Paper products, publishing
2	Wheat	32	Diesel (incl. nonconventional diesel)
3	Cereal grains nec	33	Other petroleum, coal products
4	Vegetables, fruit, nuts	34	Chemical, rubber, plastic products
5	Oil seeds	35	Mineral products nec
6	Sugar cane, sugar beef	36	Ferrous metals
7	Plant- based fibres	37	Metals nec
8	Crops nec	38	Metal products
9	Bovine cattle, sheep, goats, horses	39	Motor vehicle and parts
10	Animal products nec	40	Transport equipment nec
11	Raw milk	41	Electronic equipment
12	Wool, silk worm cocoons	42	Machinery and equipment nec
13	Forestry	43	Manufactures nec
14	Fishing	44	Electricity
15	Coal	45	Gas manufacture, distribution
16	Oil	46	Water
17	Gas	47	Construction
18	Minerals nec	48	Trade
19	Bovine meat products	49	Road transport
20	Meat products nec	50	Rail and pipeline transport
21	Vegetables oils and fats	51	Water transport
22	Dairy products	52	Air transport
23	Processed rice	53	Transport nec
24	Sugar	54	Communication
25	Food products nec	55	Financial services nec
26	Beverages and tobacco products	56	Insurance
27	Textiles	57	Business services nec
28	Wearing apparel	58	Recreational and other services
29	Leather products	59	Public Administration, Defence, Education, Health
30	Wood products	60	Dwellings

Note: nec = not elsewhere classified

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

Factors of production

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates through investment (less depreciation) in each period. Land is used only in agriculture industries and is fixed in each region. *Tasman Global* explicitly models natural resource inputs as a sector specific factor of production in resource based sectors (coal mining, oil and gas extraction, other mining, forestry and fishing).

Population growth and labour supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for the 112 international regions and for the 8 states and territories of Australia represented in the *Tasman Global* database is projected using ACIL Tasman's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.

The demographic model was derived from the CHIMP (Fisher et al 2006) and GTEM (Pant 2007) demographic models with updated parameter specifications based on the latest data from the ILO, UN (2006), ABS (2008) as well as ACIL Tasman's own estimates. For each of the 120 regions in Tasman Global, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. As with the CHIMP specification, changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Tasman's demographics module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

The Australian labour market

Tasman Global has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations
- changes to participation rates (or average hours worked) due to changes in real wages
- changes to unemployment rates due to changes in labour demand
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour, and
- limited labour mobility between states.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms who hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state rise relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level.

The labour market structure of Tasman Global is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three stage process:

1 labour makes itself available to the workforce based on movements in the real wage and the unemployment rate

2 labour chooses between occupations in a state based on relative real wages within the state, and

3 labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all general equilibrium models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case with other markets in the model).

Greenhouse gas emissions

The model has a detailed greenhouse gas emissions accounting, trading and abatement framework that tracks the status of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6). Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled.

The greenhouse modelling framework not only allows accounting of changes in greenhouse gas emissions, but also allows various policy responses such as carbon taxes or emissions trading to be employed and assessed within a consistent framework. For example, the model can be used to measure the economic and emission impacts of a fixed emissions penalty in single or multiple regions whether trading is allowed or not. Or, it can used to model the emissions penalty required to achieve a desired cut in emissions based on various trading and taxation criteria.

Detailed energy sector

Tasman Global contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to bottom-up models such as ACIL Tasman's *GasMark* and *PowerMar*k models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies different electricity generation technologies (brown coal, black coal, oil, gas, hydro, nuclear and other renewables).

Model results

Tasman Global solves equations covering industry sales and consumption, private consumption, government consumption, investment and trade. The model therefore produces detailed microeconomic results, such as:

- output by industry
- employment by industry, and
- industry imports and exports.

Tasman Global also produces a full range of macroeconomic results, for each Australian state and the rest of the World including:

- total economic output
- total employment
- gross national product (GNP)
- gross domestic product (GDP)
- gross state product (GSP)
- private consumption
- public consumption
- investment
- imports, and
- exports.

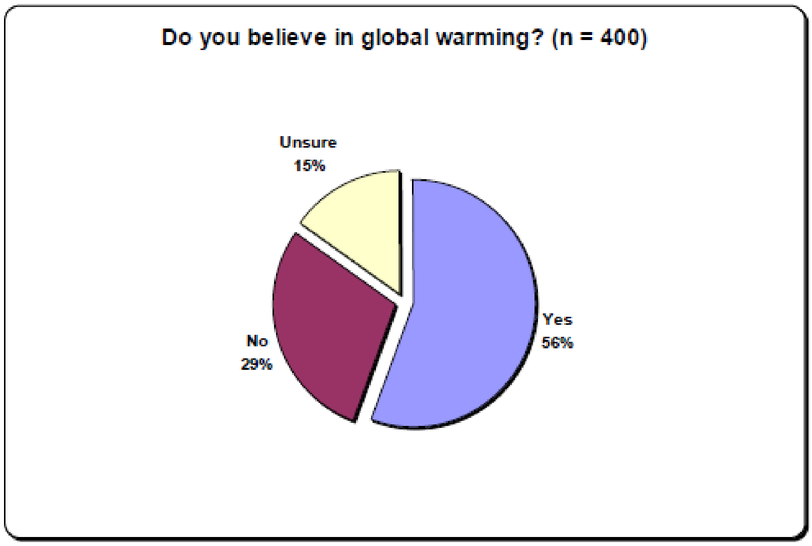
The model can also produce details of greenhouse gas emissions, measured in thousand tonnes of CO_2 equivalent per annum.

All of these results (and more) are produced on a year-by-year basis. Frequently a 20 year projection is produced; however, this can be altered to fit the needs of the particular economic impact assessment being undertaken.

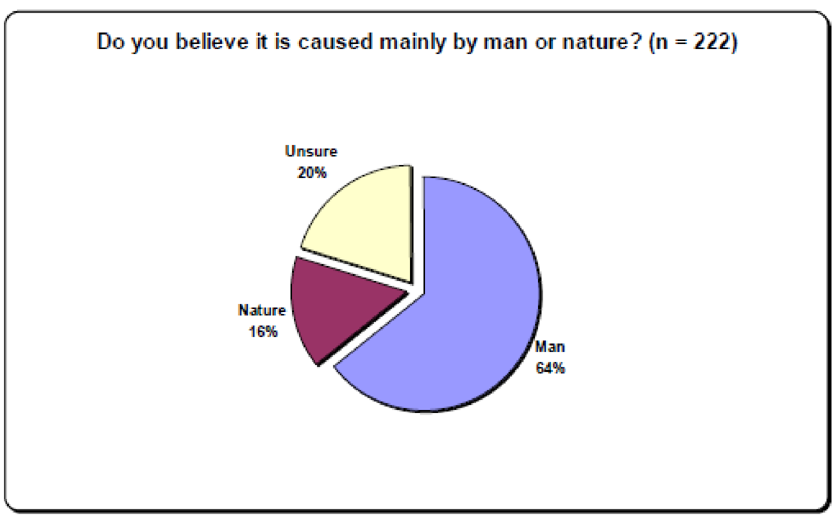
Appendix G: Nambucca Shire Community Survey (climate change section only) (Jetty Research 2009).

Questions 20-22: Belief in climate change

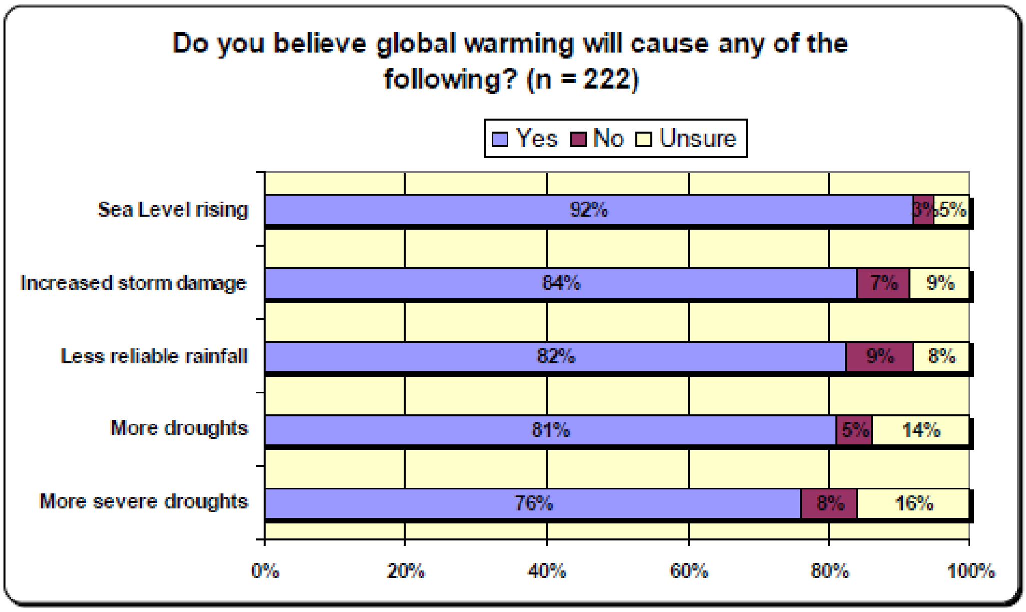
Graph 20.1: Do you believe we are currently going through a period of global warming?



Graph 21.1: (If yes) And do you believe this global warming is caused predominantly by man or nature?



Graph 22.1: (If yes to Q20) Do you believe global warming will cause any of the following?



Comment:

More than half of all respondents (56 per cent) believed that we are currently facing a period of global warming (graph 20.1), with 29 per cent disagreeing and the balance unsure. Removing the undecideds, those believing in global warming outweighed the climate change skeptics by a factor of almost two to one.

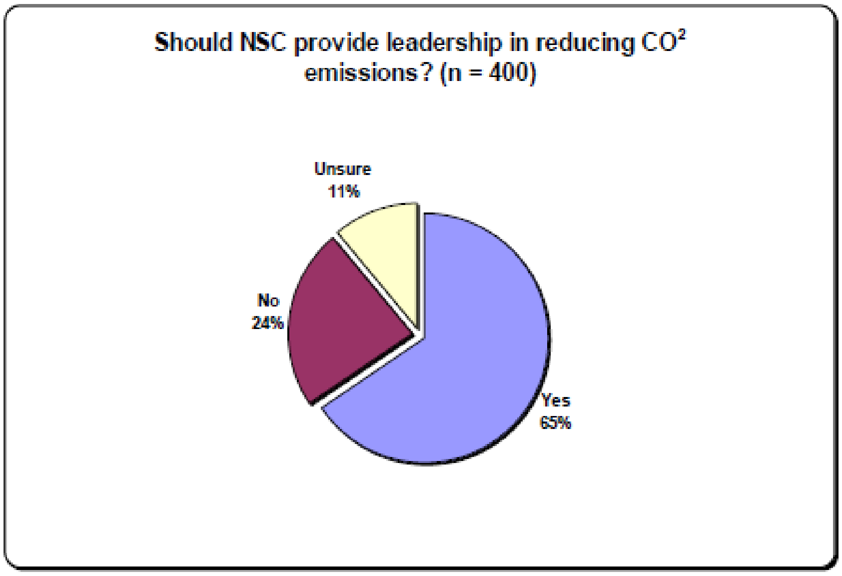
Of those who believed we are currently encountering global warming, almost two-thirds (64 per cent) believed this phenomenon was predominantly man-made (graph 21.1). Just 16 per cent felt it was mainly caused by nature, with the remaining 20 per cent unsure.

Of the global warming believers, more than nine in ten believed it would lead to rising sea levels (graph 22.1). They were also relatively pessimistic in their agreement that it would also cause increased storm damage (84 per cent), less reliable rainfall (82 per cent), more droughts (81 per cent) and more severe droughts (76 per cent).

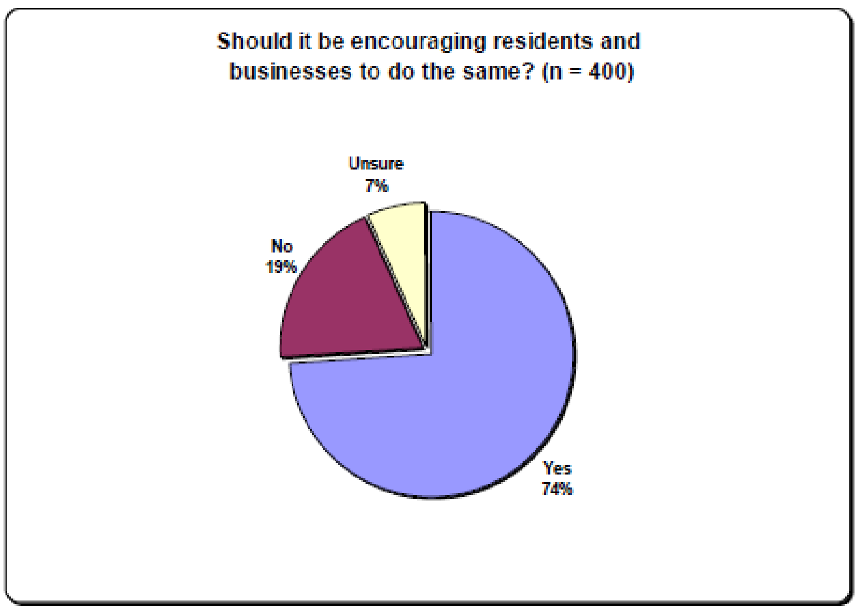
It's important to remember, however, that these questions were not asked of climate change skeptics, the vast majority of whom (one would need to assume) disagreed with such beliefs.

Questions 23-26: Role of local government in climate change

Graph 23.1: Do you believe NSC should provide leadership in reducing its CO² emissions?

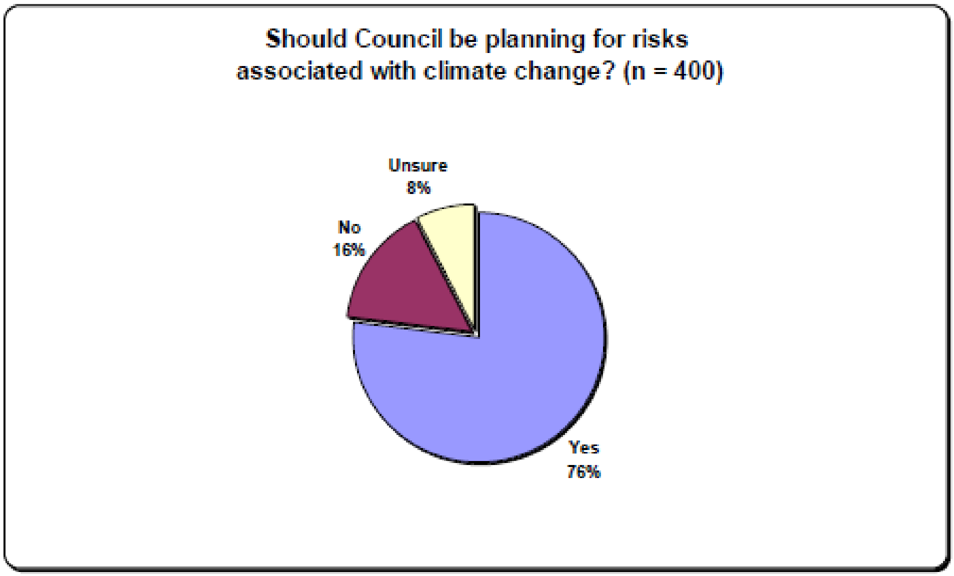


Graph 24.1: Should it be actively encouraging local residents and businesses to do the same?

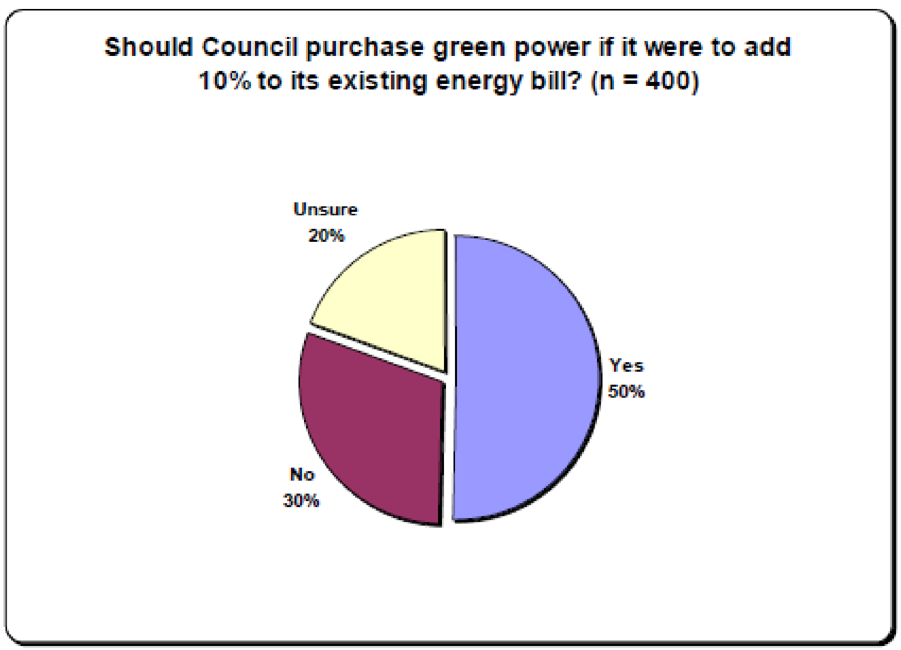


Nambucca Shire Council Environmental Levy Survey **19**

Graph 25.1: Should Council be planning for risks associated with climate change, for example increase storm damage, fires or drought?



Graph 26.1: Should Council purchase green power, assuming it were to add, say 10 per cent to its energy bill?



Nambucca Shire Council Environmental Levy Survey **20**
© Jetty Research, January 2010

Comment:

All ratepayers (i.e. regardless of belief on global warming and its causes) were then asked what role council should play in reducing carbon dioxide emissions. Respondents were generally supportive of the strategies proposed in these questions, with 65 per cent agreeing that Council should play a leadership role in reducing CO^2 emissions, and 74 per cent believing it should be encouraging local residents and businesses to do the same. More than three in four felt Council should be planning for risks associated with climate change, and half agreed with the notion of Council buying green power, even if this raised its overall energy bill by 10 per cent (graphs 23.1 to 26.1).

Not surprisingly, these results differed greatly according to whether the respondent was a climate change believer of skeptic. For example 83 per cent of those answering "yes" to question 20 felt Council should take a leadership role in reducing CO^2 emissions, against just 30 per cent of those who answered "no".

Likewise, 91 per cent of global warming believers thought Council should be planning for risks associated with climate change, against "just" 52 per cent of non-believers (who presumably are prepared to hedge their bets in this respect).

Although there may be some element of social desirability bias[5] in these figures, they nonetheless show that a clear majority of Nambucca shire ratepayers believe both in global warming, and the need of Council to play a leadership role in addressing its impact.

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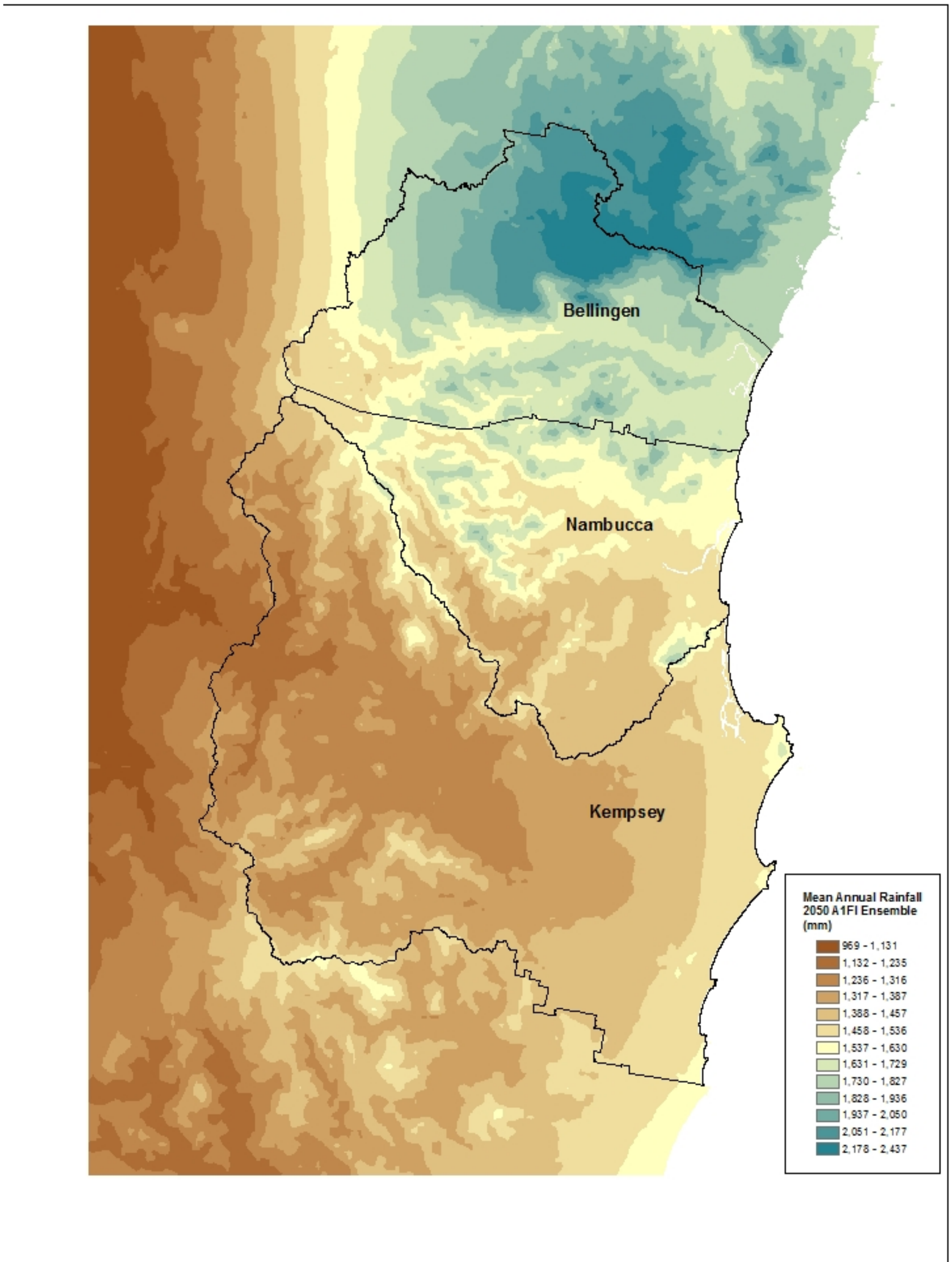
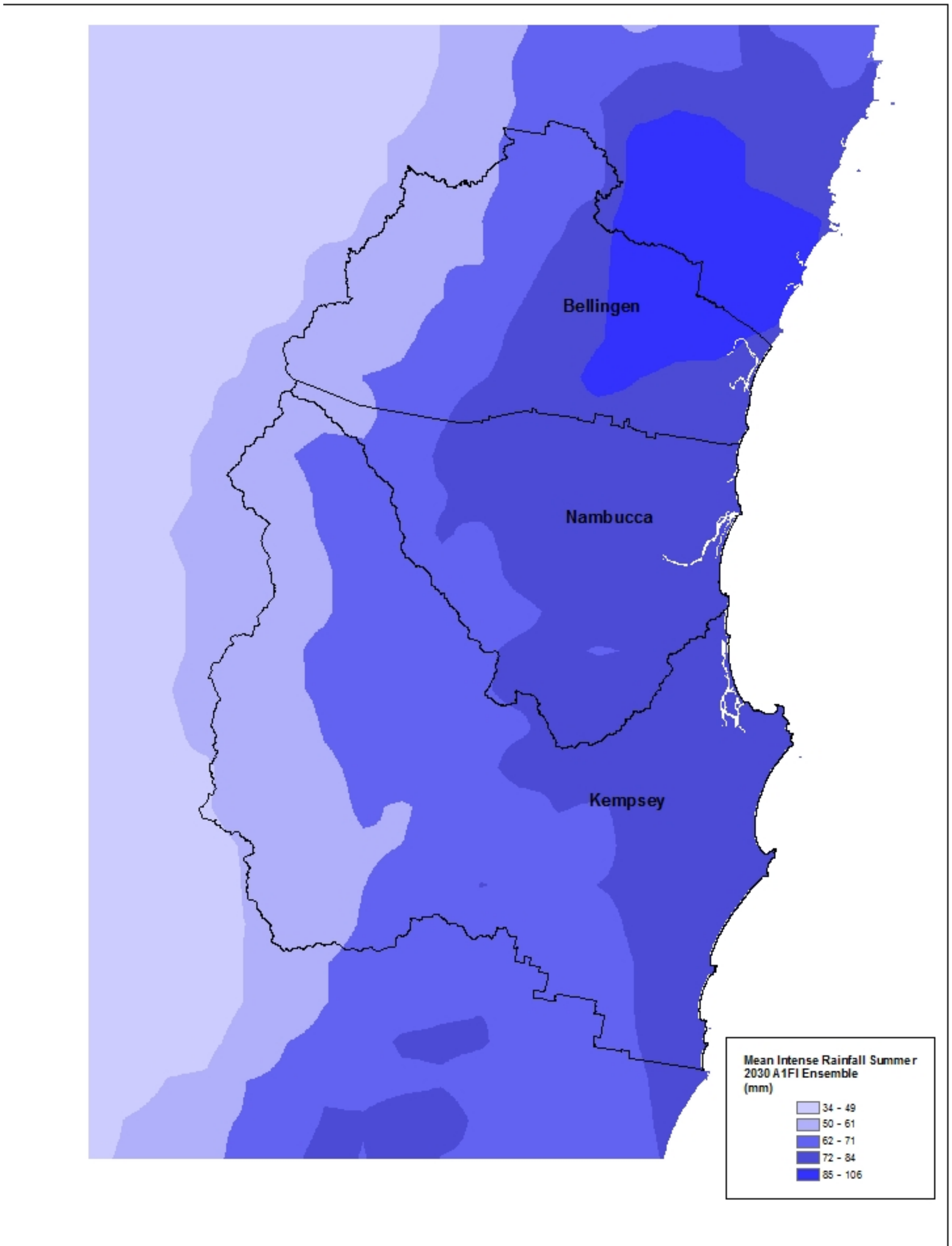
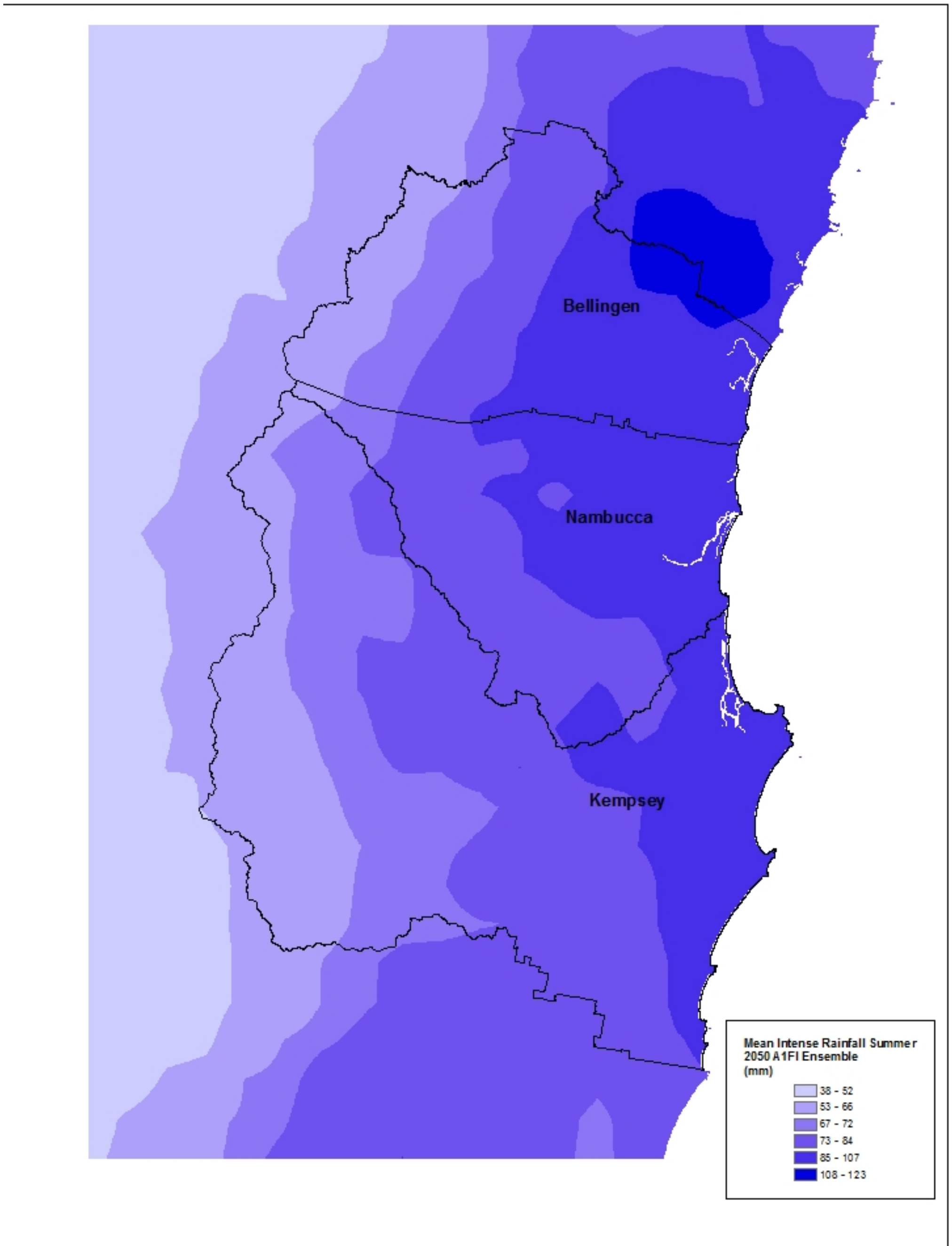
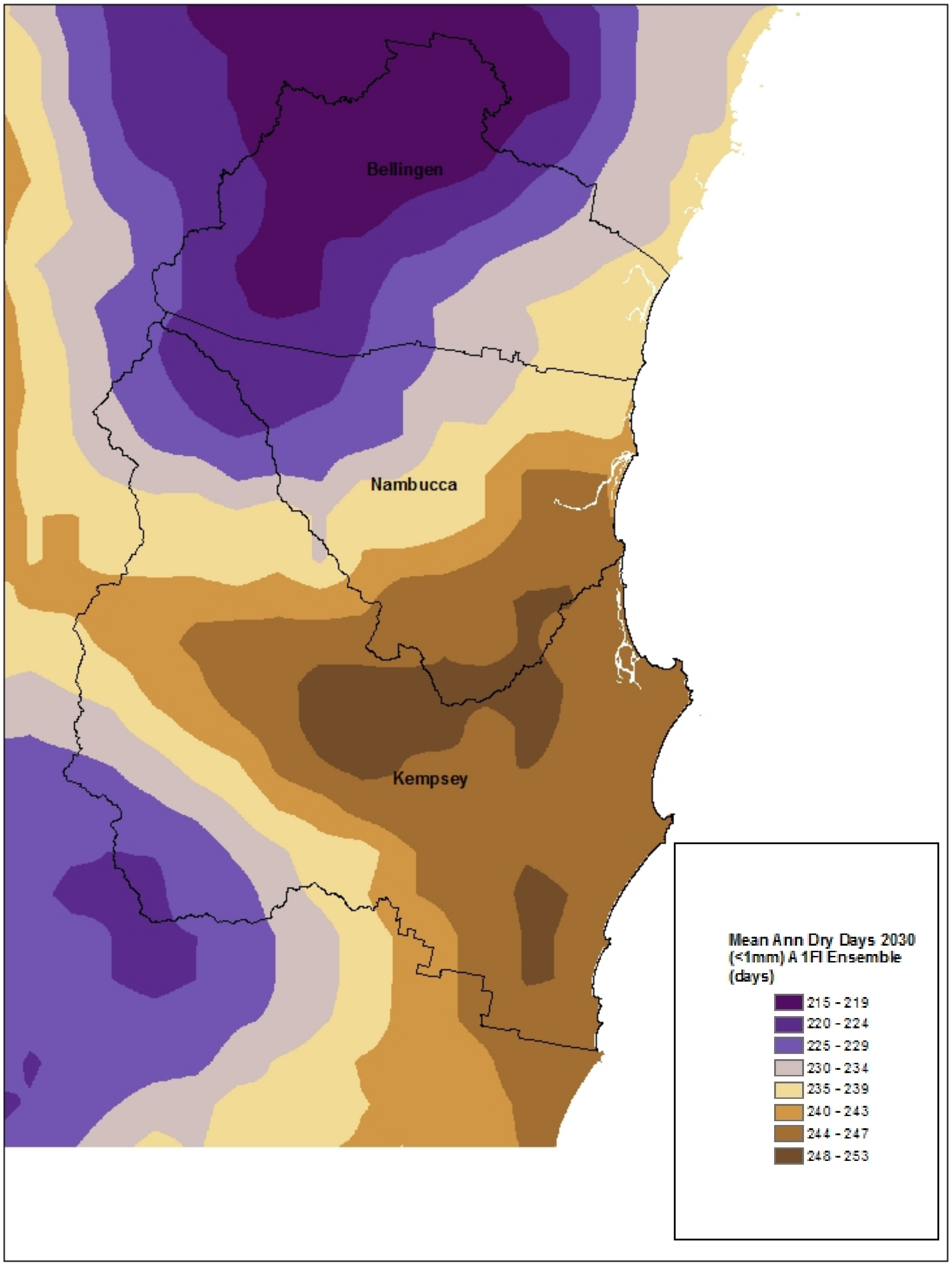
[5] An established research phenomenon whereby some respondents wish their opinions to be viewed favourably in the eyes of the interviewer

Appendix H: Climatological maps for Nambucca, Kempsey and Bellingen.



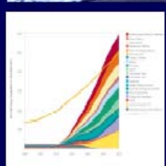

Bellingen
Nambucca
Kempsey
Mean Intense Rainfall Summer
2030 A1FI Ensemble
(mm)
34 - 49
50 - 61
62 - 71
72 - 84
85 - 106


Bellingen
Nambucca
Kempsey
Mean Intense Rainfall Summer 2050 A1FI Ensemble (mm)
38 - 52
53 - 66
67 - 72
73 - 84
85 - 107
108 - 123



Bellingen
Nambucca
Kempsey
Mean Ann Dry Days 2030 (<1mm) A 1FI Ensemble (days)
215 - 219
220 - 224
225 - 229
230 - 234
235 - 239
240 - 243
244 - 247
248 - 253



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