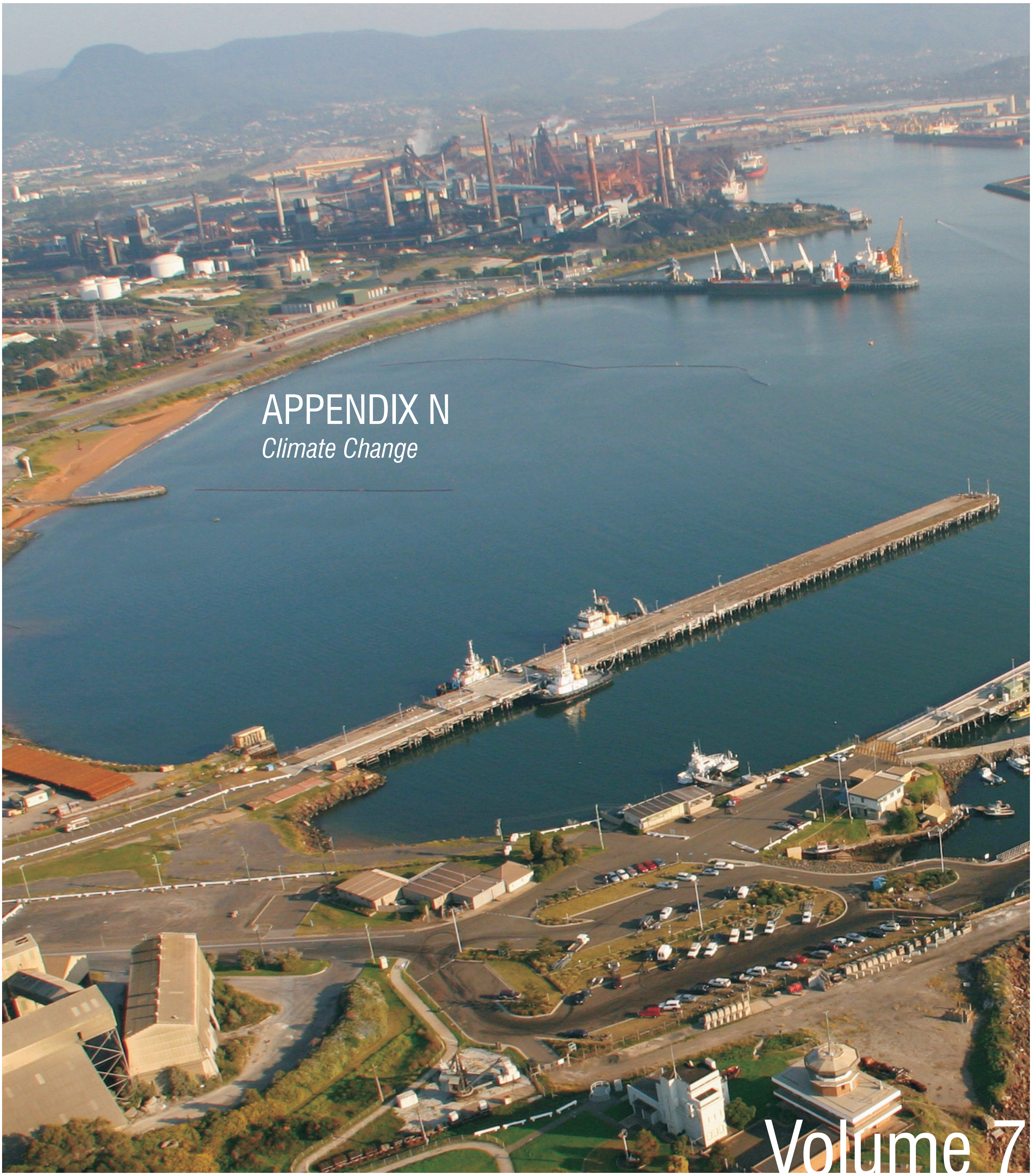

APPENDIX N

Climate Change

Volume 7

Port Kembla Port Corporation

11 February 2010

Port Kembla Outer Harbour Development

Climate Change

Port Kembla Outer Harbour Development

Climate Change

Prepared for

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1	11-Feb-2010	For Environmental Assessment	Stephen Bargwanna Technical Director - Sustainability	

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1.0 Climate Change Scenarios

1.1 Overview

Australia and NSW have already experienced a range of observable climate changes. Climate projections prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BOM) in 2007 suggest that the future climate of eastern Australia will generally be characterised by:

- Lower average rainfall
- More intense extreme rainfall events
- Higher sea level and storm surge events
- Higher average temperatures
- More frequent occurrence of extreme temperatures and
- More frequent extreme fire danger days.

Small changes in annual and seasonal temperature and rainfall conditions can be associated with large changes in extreme weather events, such as heatwaves, storms, stronger winds, increased lightning and higher intensity rainfall, which are potentially of greater significance to infrastructure design, construction and operation than changes in average conditions. Changes in extreme weather events that are projected for eastern Australia include:

- An increase in the frequency of hot days and warm nights, and a decrease in the frequency of cold nights;
- An increase in both daily precipitation intensity (rain per rain-day) and the number of dry days, leading to longer dry spells interrupted by heavier rainfall events; and
- El Niño events becoming drier and La Niña events becoming wetter (CSIRO and BOM, 2007).

Consistent with scientific literature on climate change risks, it can be expected that there will be changes in the flood, bushfire, and storm risk associated with the above changes in average climate conditions and extreme weather events.

1.2 Observed Climate Change in Australia and New South Wales

1.2.1 Sea-levels

Global sea levels rose by approximately 17 cm during the 20th Century, and by around 10 cm from 1920 to 2000 at monitored Australian coastal sites. Substantial warming has also occurred in the three oceans surrounding Australia, particularly off the south-east coast and in the Indian Ocean. The average rate between 1950 and 2000 was 1.8 ± 0.3 mm per year, and for the period when satellite data became available (i.e. from 1993), the rate was over 3 mm per year (Church and White 2006). Figure 1 shows mean sea levels observed in Australia from 1920 to 2000. The observed tide-gauge records are monthly average values (CSIRO and BOM, 2007).

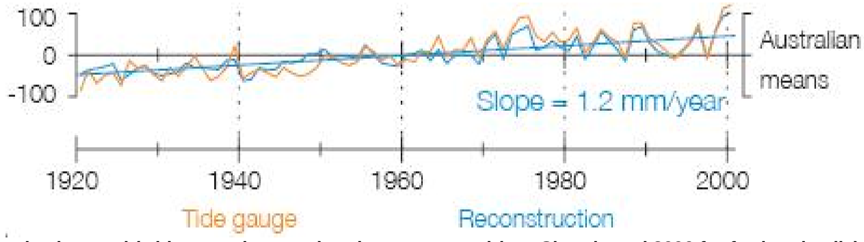

Figure 1: Sea levels observed (with coastal gauges) and reconstructed (see Church et al 2006 for further details) for the period 1920 to 2000 in the Australian region.

1.2.2 Temperature

Australian average (mean) temperatures have increased by about 0.9°C from 1910–2004 (Nicholls and Collins, 2006), with the majority of increase occurring after 1950. The frequency of hot days and nights has increased and the frequency of cold days and nights has declined (Collins *et al*., 2000).

Figure 2 illustrates the increase of Australia's mean temperature anomaly. Figures 3 and 4 show the trends of the annual mean temperatures for Australia and New South Wales (CSIRO and BOM, 2007).

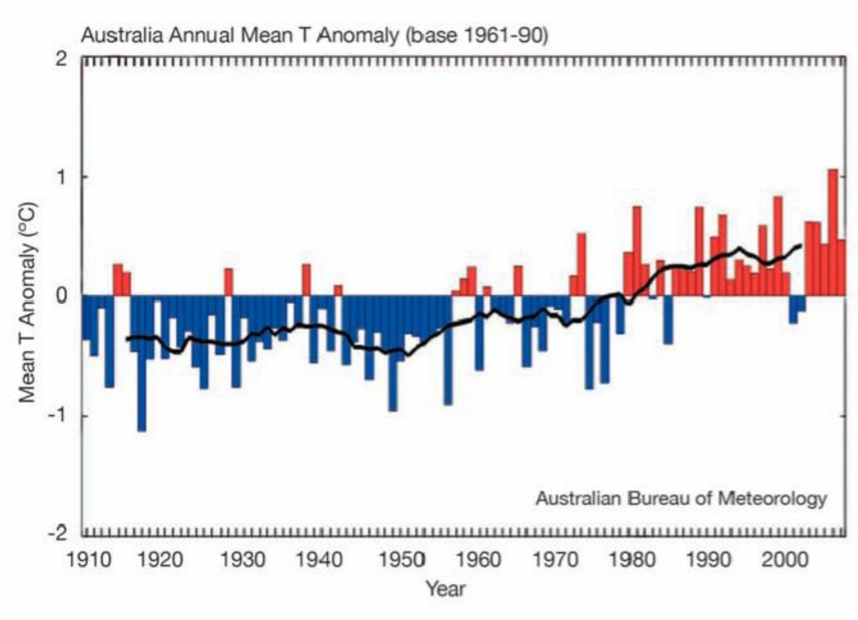

Figure 2: Annual mean Australian temperatures taken as anomalies from the 30-year 1961 to 1990 average. The black line is an 11 year running mean (CSIRO and BOM, 2007)

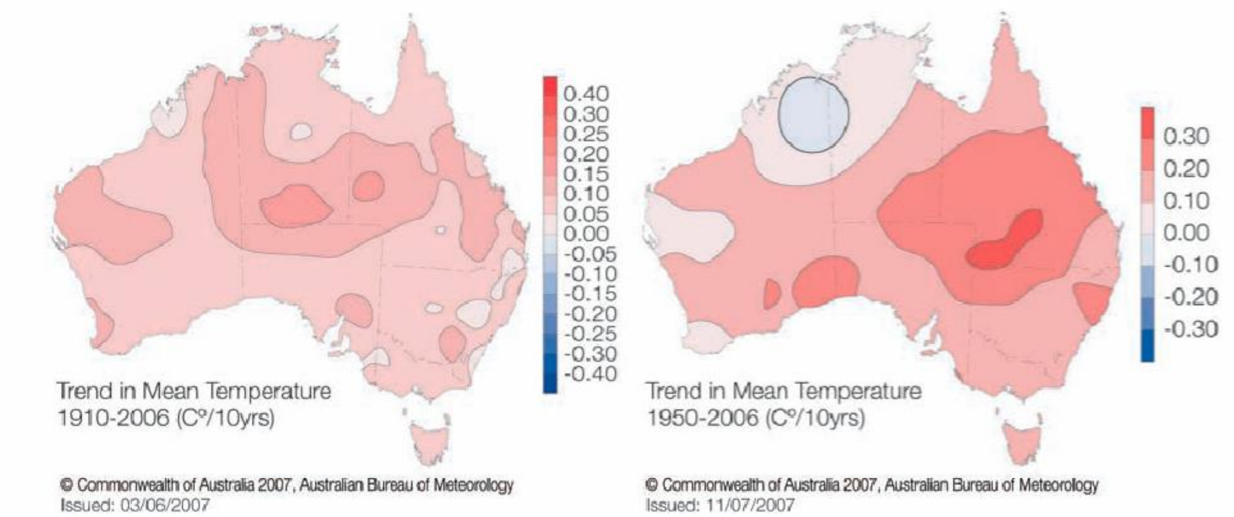

Figure 3: Trend in annual mean Australian temperatures since 1910 (left) and 1950 (right) - units are ºC per decade (CSIRO 2007 and BOM)

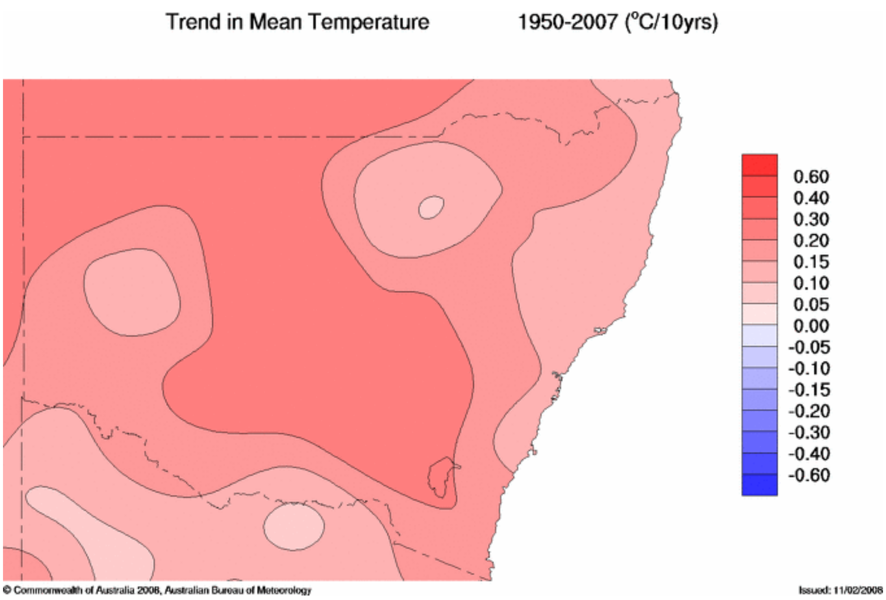

Figure 4: Trend in annual mean New South Wales temperatures since 1950 - units are ºC per decade (CSIRO 2007 and BOM)

1.2.3 Rainfall

Since 1950, most of eastern and south-western Australia has experienced substantial rainfall declines. Across New South Wales and Queensland these rainfall trends partly reflect a very wet period around the 1950s, though recent years have been unusually dry. In contrast, north-west Australia has become wetter over this period, mostly during summer (CSIRO and BOM 2007).

From 1950 to 2005, extreme daily rainfall intensity and frequency has increased in north-western and central Australia and over the western tablelands of New South Wales, but decreased in the south-east and south-west and along the central east coast (CSIRO and BOM 2007). Figures 5 and 6 show the trends of the annual mean rainfall for Australia and New South Wales since 1950.

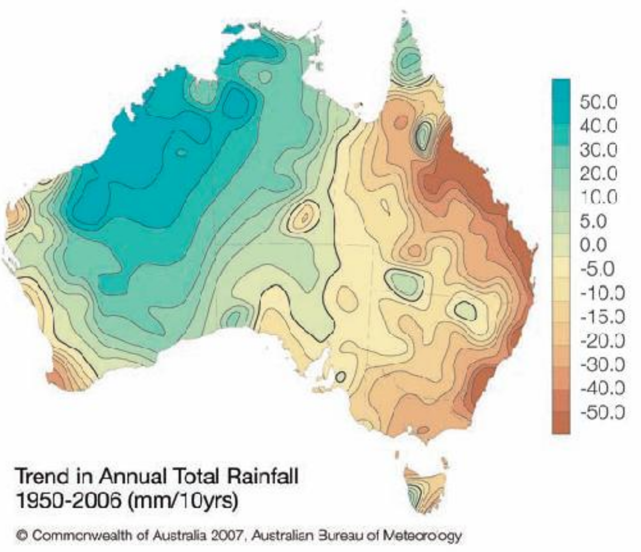

Figure 5: Trend in annual mean Australian rainfall since 1950 - units are mm per decade (CSIRO 2007 and BOM)

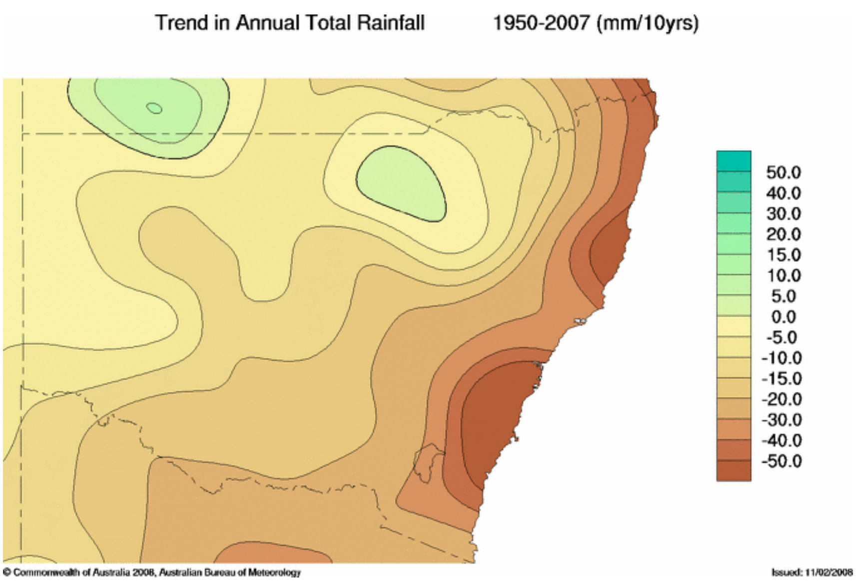

Figure 6: Trend in annual mean New South Wales rainfall since 1950. Units are mm per decade (CSIRO 2007 and BOM)

1.3 Climate change scenarios

These climate change projections have been extracted from the *Climate Change in Australia: Technical Report (2007),* published by the CSIRO and the BOM which builds on the climate change research for the Australian region conducted in recent years. This Technical Report contains the most recent climate change projections for Australia. Where appropriate this information has also been supplemented with more recent reports prepared by the CSIRO and other scientific organisations.

The projections give an estimate of the average climate around 2030 and 2070, but individual years can vary markedly within any climate period, so the values can be taken as representative of the decade around the single year stated, i.e. projections for 2030 are representative of 2026-2035. Even then, natural variability may also modify the actual means for the decade, particularly for a small region. Seasonal variation is presented where relevant and will need to be considered in the risk assessment.

1.3.1 Sea-level rise

McInnes et al (2007) have concluded that sea-level rise along the NSW coast will be slightly higher than global average conditions due to a strong warming of the sea surface temperatures in the region and a strengthening of the East Australian Current. Combining the relevant global and local information indicates that the best estimate sea level rise on the NSW coast will be around 0.20 - 0.90 m in 2100 and 0.05 - 0.40 m in 2050 above 1990 levels. The IPCC is still assessing potential risk from land ice melt.

The best estimate for sea level rise in the Sydney region is therefore 0.20 - 0.90 m in 2100 and 0.05 - 0.40 m in 2050 above 1990 levels. These values are consistent with the recently issued *NSW DECC Draft Sea Level Rise Policy*. Medium level estimates were adopted based on the average of the upper and lower values, these being 0.55 m for 2100 and 0.23 m for 2050. Table 1 summarises these values.

Table 1: Sea level rise projections for Port Kembla (IPCC 2001, 2007 & NSW DECC 2009)

Sea Level Rise Scenario	Year 2050	Year 2100
Lower Bound Estimate	0.05 m	0.20 m
Medium Estimate	0.23 m	0.55 m
Upper Bound Estimate	0.40 m	0.90 m

The proposed reclamation levels have been set to be sustainable for predicted extreme sea level rises for the design life of the facilities, with a freeboard suitable to cater for further sea level rise predictions to 2100. As an adaption strategy, the reclamation would be designed to accommodate both 2050 and 2100 Sea Level Rise projections. Design finished reclamation surface levels for this project, therefore, for a 100 year planning period would need to be above:

2.4 m PKHD (1,000 year ARI) + 0.9 Sea Level Rise + 0.2 m long wave activity

+ 0.4 m (half of H_s significant wave height) = 3.9 m PKHD

The Concept Plan development provides for a reclamation level of 4 m and pavements of 1.2 m. The final hardstand level would stand at 5.2 m, comfortably within the Sea Level Rise predictions for both 2050 and 2100.More information on sea level rise is provided in Appendix F.

1.3.2 Extreme sea level events (storm surges)

The frequency and heights of storm surges are expected to change with climate change. Based on historical extreme water levels in Sydney Harbour, a current 100 year annual return interval (ARI) is just under 1.5 metres. It has been projected that this 1 in 100 year event could be a 1 in 8 year event by 2030 (Preston *et al*, 2008).

A study conducted by the CSIRO for the then NSW Department of Environment and Climate Change indicates that storm surge heights could increase by about 1 percent by 2030 and up to 4 percent by 2070 could be expected along the NSW coast, depending on local geomorphology (McInnes et al., 2007).

A recent study has highlighted that for every 0.1 m sea level rise, the frequency of extreme events increases by a factor of three. It further concludes that sea level rise during the 21st century will result in annual events becoming daily events (Hunter, 2008).

1.3.3 Temperature

In NSW it is projected to be warmer on average, although coastal regions may warm less quickly due to the moderating influence of the ocean. The CSIRO and BOM (2007) best estimate (50th percentile) projected changes for eastern Australia (relative to a baseline period 1980-1999) include:

- An increase of annual mean temperatures of around 1°C by 2030; and
- An increase in annual mean temperatures of between 1.8°C and 3.5°C by 2070.

This increase in temperature is projected to have minimum seasonal variation, with warming in winter only slightly less than in the other seasons. Projected temperature increases for New South Wales for 2030 and 2070 are provided in Figure 7.

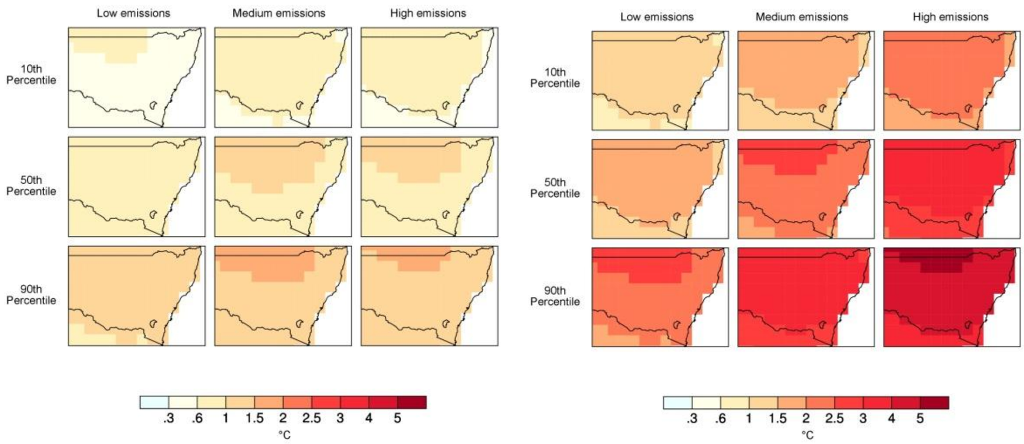

Figure 7: Projected temperature change for 2030 (left) and 2070 (right) – units °C and the deeper the colour red the higher the temperature increase (CSIRO and BOM, 2007)

In 2008, the then DECC and UNSW published a summary report presenting interim findings for climate change forecasts for the Illawarra Region (DECC and UNSW, 2008). This study projects that the climate will be between 1.5°C and 3°C hotter over all seasons with both minimum and maximum temperatures rising over time (Figure 8).

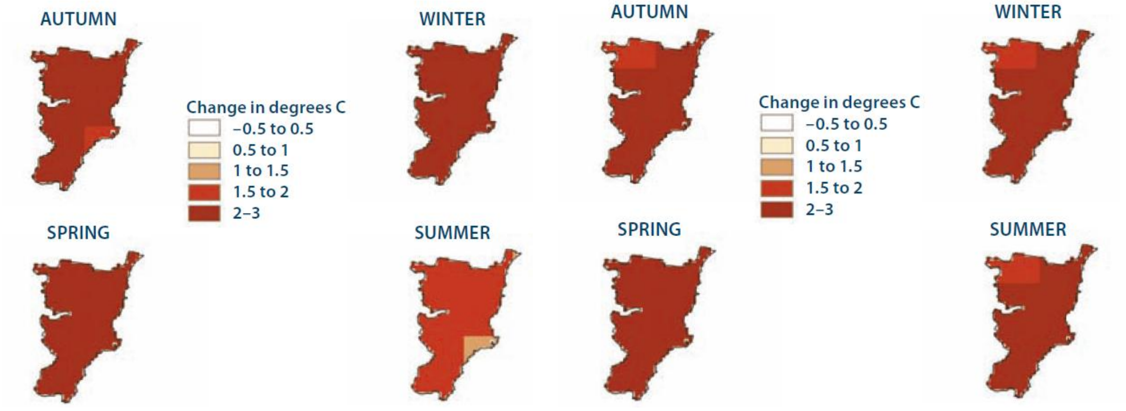

Figure 8: Projected change in mean maximum (left) and minimum (right) temperature in the Illawarra Region (DECC and UNSW 2008)

It is important to note that associated with the warming is a projected strong increase in frequency of hot days and warm nights (CSIRO and BOM, 2007). The number of days per annum where daily temperatures are projected to be over 35°C for 2030 and 2070 are provided for Sydney in Table 2. Port Kembla will likely experience similar conditions.

Table 2: Days over 35°C for a range of locations

Location	Current Days over 35°C	2030 50^{th} percentile	Percentage increase on current	2070 50^{th} percentile	Percentage increase on current
Sydney	3.5	4.4	25.7	8.2	134.3

1.3.4 Rainfall

The future climate of eastern Australia is projected to be drier on average. The CSIRO and BOM (2007) best estimate (50^{th} percentile) projected changes for eastern Australia include:

- A decrease in annual precipitation of between 2% and 5% by 2030; and
- A decrease in annual precipitation of between 5% and 10% by 2070.

Projected rainfall increases for NSW for 2030 and 2070 are provided in Figure 9.

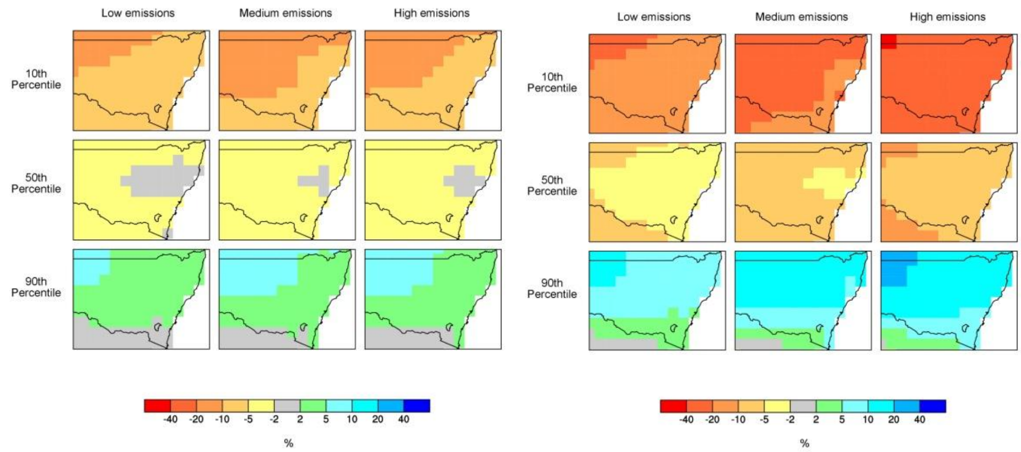

Figure 9: Projected rainfall change for 2030 (left) and 2070 (right) – units percentage change and red indicates rainfall decline, whereas blue indicates rainfall increase (CSIRO and BOM, 2007)

The then DECC and UNSW projections for the Illawarra Region, project a substantial increase in summer rainfall and a moderate increase in autumn and spring rainfall. The autumn and spring rainfall combined with evapotranspiration produces a drier net effect (Figure 10).

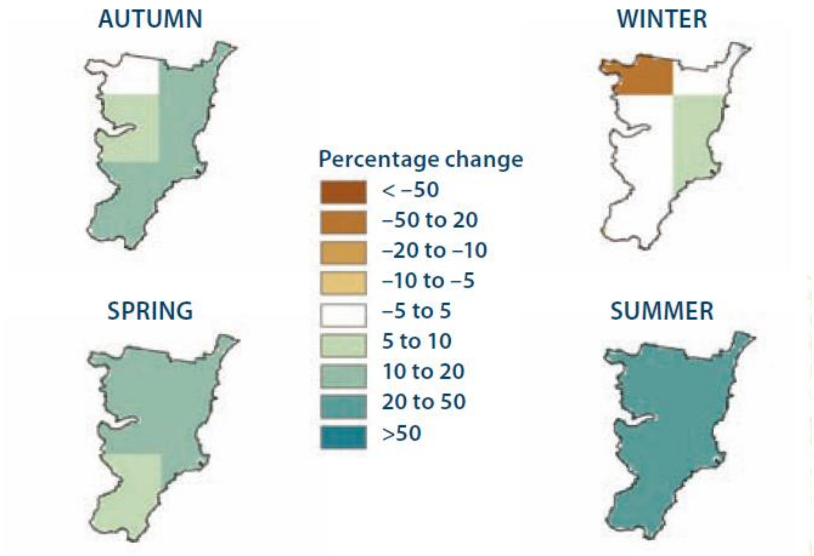

Figure 10: Projected rainfall changes in the Illawarra Region (DECC and UNSW 2008)

1.3.5 Extreme rainfall

The future climate of many parts of the State are projected to not only be drier but the character of daily rainfall is also predicted to change. An increase in daily rainfall intensity (rain per rain-day), intensity of extreme rainfall and the number of dry days is likely. The climate is projected to have longer dry spells interrupted by heavier precipitation events (CSIRO and BOM, 2007). By 2030 the highest predicted increase in rainfall intensity occurs in central and southeast NSW. By 2070, these same trends are much more prominent (CSIRO, 2004). The likelihood of an increase in 1-day extreme rainfall for 2030 and 2070 relative to the current climate is provided in Figure 11.

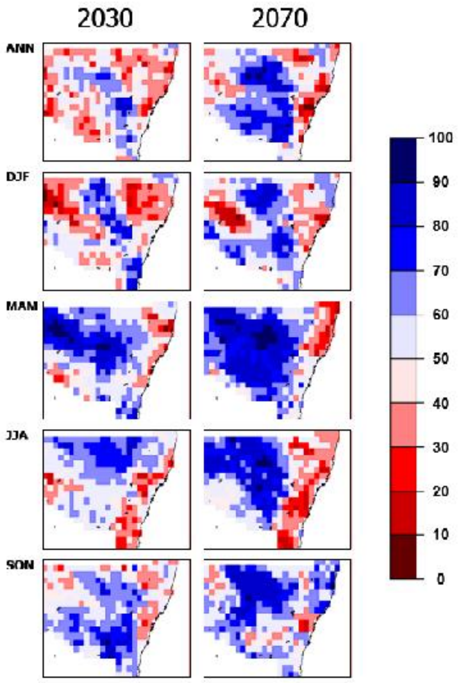

Figure 11: The likelihood of an increase in 1-day extreme rainfall for 2030 and 2070 relative to the current climate - blue indicates an increase in rainfall intensity (CSIRO, 2004)

The magnitude of future extreme events is projected to increase and the size of this increase is greater in 2070 than in 2030. Shorter duration events will experience the greatest increase in intensity (Abbs and Rafter, 2008). There is considerable geographic variance in the regions of extreme rainfall increase and the magnitude of that increase.

1.3.6 Evaporation

The CSIRO and BOM (2007) best estimate (50^{th} percentile) projected changes for eastern Australia include:

- An increase in annual potential evapotranspiration of 2% by 2030; and
- An increase in annual potential evapotranspiration of between 6% and 10% by 2070.

Projected evapotranspiration increases for NSW for 2030 and 2070 are provided in Figure 12.

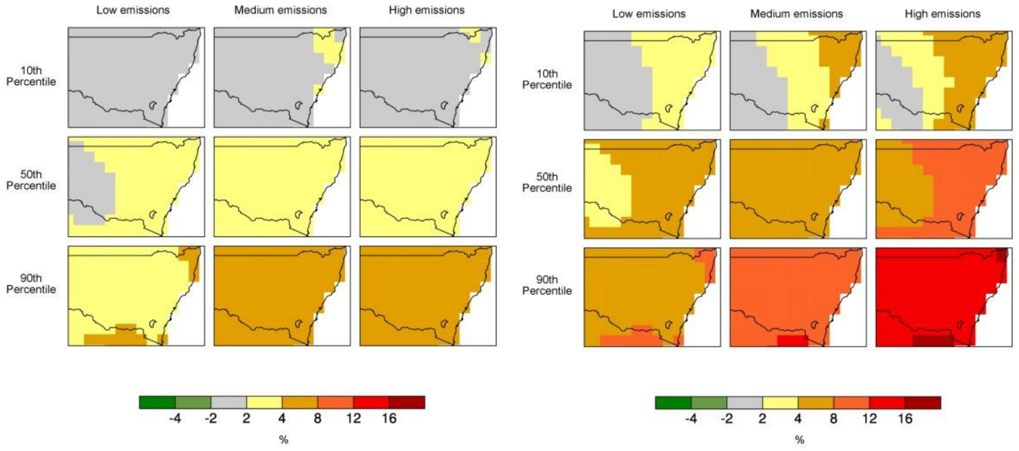

Figure 12: Projected evapotranspiration change for 2030 (left) and 2070 (right) – units percentage change and red indicates the areas of greatest increase (CSIRO and BOM, 2007)

1.3.7 Wind speed

Projections of future climate conditions indicate that average wind speeds in eastern Australia will increase (CSIRO and BOM, 2007). Projected wind-speed changes for NSW for 2030 and 2070 are provided in Figure 13.

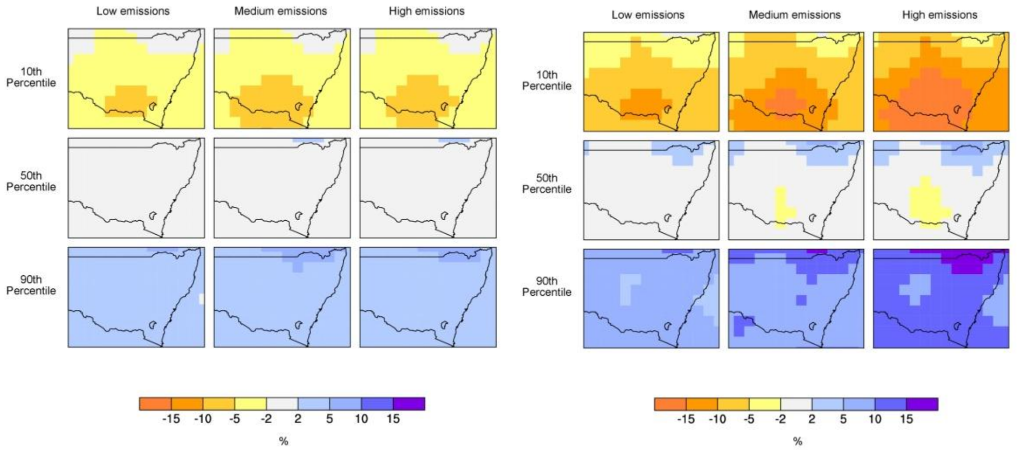

Figure 13: Projected wind-speed change for 2030 (left) and 2070 (right) – units percentage change and purple indicates the areas of greatest increase (CSIRO and BOM, 2007)

Extreme winds, particularly summer winds, are likely to be governed by small scale systems that are not adequately captured by the resolution of the climate models (CSIRO and BOM, 2007). Small changes in maximum wind speed can have an exponential impact on infrastructure. For example, bridges, power lines and buildings are designed to withstand current wind loadings and suffer minor damage in extreme events, but increased wind loadings would correspond exponentially to the damage caused from future events, resulting in power outages and structural failure.

1.3.8 Bushfire

Fire weather conditions are expected to worsen due to climate change. A study by Lucas *et al* (2007) found that climate change can exacerbate the fire-weather risk of any given day (leading to increased frequency or intensity of extreme fire weather days) and result in a longer fire season.

The findings of the study also suggest that fire seasons will start earlier and end slightly later, while being generally more intense throughout their length. This effect is most pronounced by 2050, although it should be apparent by 2020 (note the shift in timeframe).

The implication of this is a change in the annual return interval (ARI) (the number of years between events) for 'very extreme' fire conditions. Lucas et al (2007) found that the ARI could be reduced, i.e. a higher frequency of 'very extreme' fire conditions. The increase in bushfire risk is greatest in inland areas than for coastal locations. Changes to the annual return period for 'very extreme' fire conditions for Sydney is provided in Table 3.

Table 3: Changes in the annual return period for 'very extreme' fire conditions

Location	Current Annual Return Period	2020 Annual Return Period	2050 Annual Return Period
Sydney	5.5	3.3	1.0

1.4 Conclusion

Climatic changes have been observed and documented over the past century and it is projected that further changes will occur in the future during the design life of new developments. Climate change will occur through changed average conditions (e.g. mean temperature increase, mean rainfall decrease and sea level rise) and increases in the frequency and intensity of extreme events (e.g. storm surges, extreme rainfall, days over 35°C and bushfires). The Illawarra region is projected to experience temperature rise, increased rainfall in summer, autumn and spring; increased evaporation; sea level rise; and more intense storm surges. The projected climatic changes are likely to have effects on infrastructure through accelerated degradation of materials and structures and damage or failure during extreme events. Refer to Section 26 for discussion on the potential impacts of climate change on the proposed Port Kembla Outer Harbour Development.

1.5 Literature Review

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