CLIMATE CHANGE IMPACT ON ROUS WATER SUPPLY

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Abstract

Climate change poses significant risks to the security of water resources in many parts of Australia. This study investigated the implications for secure yields of a regional water supplier in NSW. The aim of the study was to estimate future secure yields, using the Integrated Quantity and Quality Model (IQQM) and a range of climate change scenarios, to identify the most appropriate time horizon for making new investments in infrastructure. The assessment concluded that, when taking into consideration impacts of global warming, the need for a new source will be most likely after 2018, consequently planning needs to commence in 2008.

Introduction

There is an increasing body of research that supports a picture of a warming world with significant changes in regional climate systems (IPCC, 2001; IPCC, 2007). This has significant implications for the reliability of water supplies across Australia (Jones and Preston, 2006). It is important to consider the risk that climate change poses to catchment yield within the context of changing demand.

This project investigated the implications that climate change may have on Rous Water's regional water supplies. The aim of the study was to help identify the most appropriate time horizon for making new investments in infrastructure.

The first section provides an overview of Rous Water's regional water supply scheme, the second discusses the projected climate change profile for New South Wales (NSW). The third section describes the framework built to assess climate change impacts on Rous Water's supply. Section four presents and discusses the assessment procedure and subsequent results, and section five summarises the main conclusions of the study.

The need for a new source is most likely in 2018: planning should start in 2008.

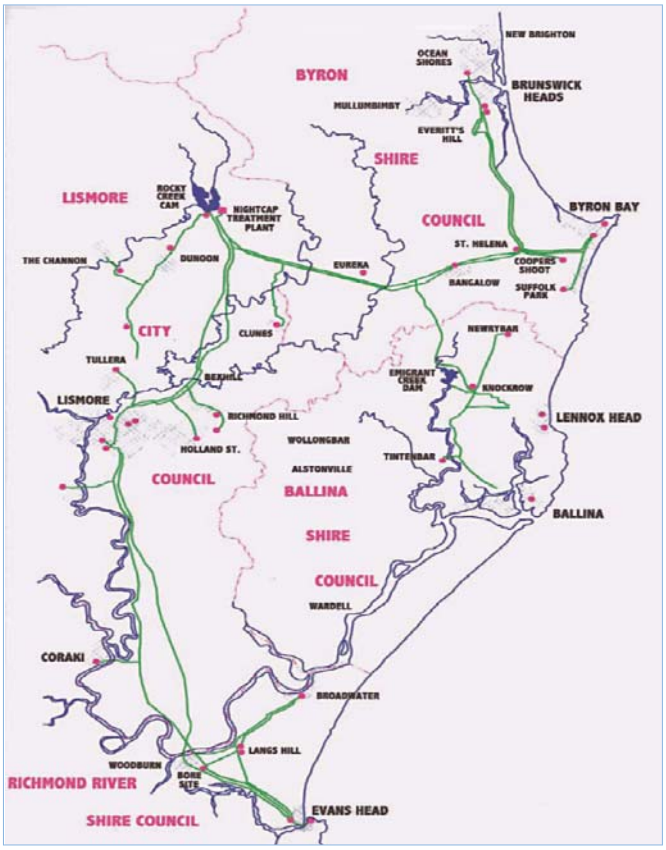

Figure 1. Rous Water scheme (Rous Water, 2006).

Overview of Rous Water Regional Water Supply

Rous County is located in northeastern NSW and is part of the Wilsons River catchment, from Lofts Pinnacle in the west, along Nightcap and Koonyum ranges near the coast (Figure 1). Rous Water is the regional water supply authority providing water in bulk to a number of Councils, from Lismore to Ballina, with an approximate population of 93,000. The supply system was designed based on the former NSW Department of Public Works and Services definition of 'secure yield'. Under this scheme the secure yield is defined as the annual demand that can be supplied from the headworks over the 103 year historic record and which satisfies the 5/10/20 rule, i.e.:

- restrictions of any kind should not be applied for more than 5% of the time (> 1862 days);
- restrictions of any kind should not be imposed more than one year in ten on average (> 10 years); and
- the system should be able to supply 80% of normal demand (i.e. 20% reduction in consumption) through a repeat of the worst drought on record.

Water presently comes from two main supply storages: Rocky Creek Dam and Emigrant Creek Dam. The former has a storage capacity of 13,956 ML and a safe yield of about 9,600 ML/annum (DIPNR, 2004) while the latter has a capacity of 820 ML with a safe yield of about 1,100 ML/annum. There are also some other small sources under Council control with a combined safe yield of about 900 ML/annum.

Based on population projections and other considerations, GeoLINK (2005) estimated that the best estimate of the likely future demand from the Rous Water scheme in the year 2030 is around 18,000 ML/annum. This equates to an increase of 43% over the current demand of 12,600 ML/annum. To manage this growth in demand, Rous Water adopted a water management strategy in 1995 that was amended in 2004. The strategy provides a range of options to meet water requirements. One key objective of Rous Water's strategy is to implement effective demand management, the target being a minimum 10% reduction in per capita demand by the year 2011, relative to 2005.

Recognising future demand may outstrip existing sustainable yield, the strategy identified two additional supplies, Lismore source and Dunoon Dam. Lismore source is a medium-term solution which is able to assist in meeting the high demand projection up to 2024. It consists of a pumping station capable of abstracting up to 30 ML/day from the upper reaches of the tidal pool in the Wilsons River, which is only utilised when Rocky Creek Dam is below 95% capacity and is subject to abstraction licence constraints. The proposed Dunoon Dam is located downstream of Rocky Creek Dam and captures local inflows as well as Rocky Creek dam spills (CMPS&F, 1995).

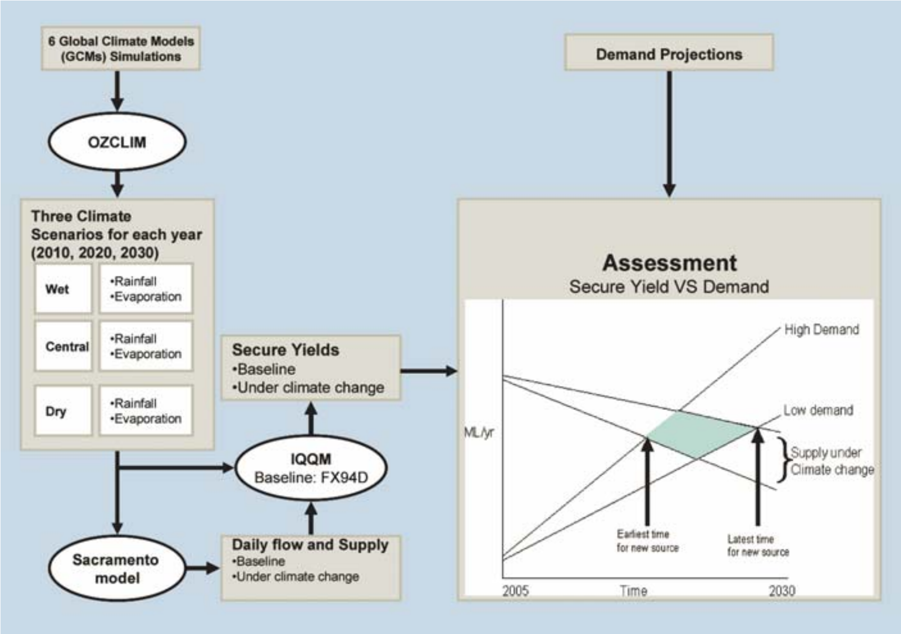

Figure 2. Framework for climate change impact assessment for Rous Water Scheme.

An Overview of Climate Change in NSW

During the 20th century, the globally averaged surface temperature increased by 0.6 ± 0.2°C with the warmest year being 1998, followed by 2005 (WMO, 2005). In NSW, the temperature has also been steadily increasing over the last fifty years (BOM, 2006). In northeastern NSW, temperatures have increased at the rate of approximately 0.4°C per decade. The BOM (2006) has also shown that rainfall has been declining in the non summer months at a rate of roughly -20 to -50 mm per decade. In summer, the rainfall has been increasing at a rate of approximately +10 to +20 mm per decade. Lismore rainfall records show that the annual rainfall has been decreasing slightly at a rate of -6 mm per decade from the late 1880s to present. Winter rainfall has been decreasing at a rate of -5 mm per decade, whereas the summer rainfall has been increasing at a rate of +1 mm per decade. However it should be noted that the trends in Lismore's rainfall are not statistically significant at a 95% confidence level.

The climate system is highly complex, and therefore it is inappropriate to simply extrapolate past trends to predict future conditions. To estimate future climate change, scientists have developed climate scenarios from global climate models (GCMs). Best estimates for globally average surface air warming are expected to range between 1.8°C to 4.0°C at 2090-2099 relative to 1980-1999 (IPCC, 2007). In Australia, CSIRO uses both global and regional climate models in the development of regional climate change projections. According to Hennessy *et al* (2004), the models tend to simulate decreasing annual-average rainfall over NSW, particularly in winter and spring. In autumn the direction of the change is uncertain, while in summer there is a tendency for increases in the north-east. Annual-average potential evaporation is projected to increase across NSW. The largest changes are projected in winter with the smallest changes in summer. Compared to changes in the other areas of NSW, the projected changes in the north-east, where Rous Water is located, are relatively small.

Framework for Impact Assessment

Impact and risk assessment is one stage in a larger risk management framework. Ideally, risk management involves all related stakeholders. The decision-making process is commonly circular to allow the performance of chosen decisions to be reviewed and revisited as new information on climate change and its impacts are available.

Most research on the hydrologic impact of climate change uses a predictive approach. It begins with generating climate change scenarios. Climate information is then fed into hydrologic models and/or water-management systems to evaluate the differences in system performance under different climate scenarios. Adaptations can then be designed to manage those changes. Through consultations with stakeholders, the assessment framework for climate change impacts and adaptation for Rous

Water has been established and is presented in Figure 2. Details about the main steps in this framework are described as follows.

First step: preparing climate change scenarios

As described previously, future climate scenarios are commonly developed through GCMs. Currently, there is a range of available GCMs, each developed by a different scientific group across the world. These models differ in their approaches to simulating the climate, hence different models may project different climate futures, even when driven by the same scenario of future emissions. The standard measure to compare climate models is their 'sensitivity' defined by how much eventual warming they project when the-pre-industrial atmospheric concentration of CO_2 is doubled from around 270 to 550 parts per million by volume (p.p.m) (today's atmospheric CO_2 is about 380 p.p.m). GCMs use a particular emissions scenario as the input to generate a projection of climate change over the next century. The IPCC commissioned a range of scenarios of greenhouse gas and sulfate aerosols emissions up to the year 2100. The scenarios were reported in the Special Report on Emissions Scenarios (SRES, 2000). For example, the SRES-A1 scenario depicts a very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies (IPCC, 2001).

For this study, scenarios of regional change as a function of global warming (percent change per °C of global warming) for potential evaporation (Ep) and precipitation (P) were prepared based on six GCM simulations through the use of the CSIRO Climate Scenario generator, OzClim. OzClim is a PC-based climate scenario generator that simplifies the process of calculating scenarios from climate change model outputs, applies scenarios to impact models and manages uncertainty (Page and Jones, 2001). A range of GCM, emission scenarios and climate sensitivities can be harnessed using this system. For this assessment, multiple climate change simulations were conducted for the years 2010, 2020, and 2030. These were based on six climate models assuming a range of climate sensitivities (low, medium and high) and the SRES A1B, A1F and B1 scenarios. The A1 scenarios can be considered as a pessimistic as they give high CO_2 emissions. A1B depicts a balance across all sources, while A1F depicts a fossil intensive situation. The B1 scenario may be considered as a more optimistic future. It describes a convergent world with the global population that peaks in mid-century and declines thereafter, rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies (IPCC, 2001). This step produced a total of 18 simulations for each year and for every station used in the Wilsons River IQQM.

Second step: estimating supply under climate change

The climate scenarios were applied to the Integrated Quantity Quality (IQQM) hydrologic, river system simulation package (Simons *et al.* 1996) to generate climate change flow sequences. IQQM consists of the Sacramento rainfall-runoff model and river routing, water demand and allocation routines to simulate river flow and river regulation. This software has been implemented in most regulated and a large number of unregulated river systems in NSW and Queensland. This study used the Wilsons River IQQM implementation which is described in detail in DIPNR (2004).

The number of observed rainfall, evaporation, and stream flow stations used in the Wilsons River model are 8, 1, and 14, respectively. Rainfall data was used to account for soil moisture (which governs the crop water demands of irrigators) and to apply rainfall to the water surfaces of reservoirs and river reaches. Rainfall data was also required for calculating catchment inflows. The evaporation data were used to estimate evapotranspiration from crops, evaporation from reservoirs and river reaches, and to synthesise streamflow. The model incorporates existing irrigation development (3,000 ha); system demands (11 urban/rural demand centres); sources of supply (Rocky Creek Dam, Emigrant Creek Dam, and Borefields); scheme operating rules and access constraints to streamflows at Lismore source.

The published results for the Wilsons River model (DIPNR, 2004) are based on a model scenario known as FX04D. However, subsequent to this report, the Lismore source access rules have been investigated further, resulting in a revised scenario known as FX94D, which is as yet unpublished. Based on a discussion with Rous Water, this study has adopted the FX94D model scenario as the baseline from which to assess the impacts of climate changes. To assess the 20% rule a variation of the FX94D model was created for this study. In this variation the storages are configured to 55% capacity, which represents the capacity at which restrictions are imposed on the system. This configuration is used to verify the 20% rule.

To be able to assess the impacts on flow due to changes in climate the time series inputs used in IQQM were modified. In the FX94D scenario IQQM uses a mixture of observed and predicted flows that vary between sites. The Sacramento rainfall runoff model was used to extend flows for most of the tributaries. Emigrant Creek Dam was based on the Australian Water Balance Model (AWBM) rainfall-runoff model while Rocky Creek dam was based on a monthly correlation with a nearby gauge and then disaggregated by a mixture of techniques. For this study all tributaries needed to be modelled using rainfall-runoff models and to be consistent the Sacramento model was used for all tributaries. DIPNR had already developed Sacramento models for Rocky Creek Dam and Emigrant Creek Dam that had a good match with the short periods of observed data and these were adopted.

Simulations with the Sacramento model generally matched well with observed flows at all sites. However, when the observed data were replaced with the simulated data, the result for secure yield was different to that from the original FX94D model. As the model is most sensitive to inflows from Rocky Creek Dam and Emigrant Creek Dam, the Sacramento models for these tributaries were adjusted with an aim to reproduce the original secure yield of 14,900 ML/annum. Unfortunately this was not quite possible due to very small differences (<2%) in critical events for the 5% and 10% rules. The best that could be achieved was a secure yield of 15,000 ML/annum while keeping the difference in overall volume at Emigrant Ck and Rocky Ck within 2%. Consequently, for this study, all secure yields are compared against a baseline secure yield of 15,000 ML/annum rather than the 14,900 ML/annum obtained by DIPNR in the FX94D scenario.

Estimation of the secure yield for each climate scenario was estimated based upon the minimum yield required to meet the 5/10/20 rule. The estimation of secure yield was determined by an iterative solution that successively modifies and runs IQQM until the demand was just met in accordance with the 5/10/20 rule. This process was carried out for each of the 18 climate scenarios, for a total of 54 scenarios (i.e. 18 scenarios for each of the years 2010, 2020 and 2030). To solve each scenario, IQQM was run approximately 10 times, resulting in approximately 540 runs to cover all of the climate scenarios and time periods.

Third step: risk assessment

The issue of climate change is beset by uncertainties. These uncertainties include the magnitude of global warming, regional changes in rainfall and evaporation, and regional supply sensitivity and coping capacity. Quantifying the uncertainties in climate change and its downstream consequences in units of probability or likelihood helps to identify robust adaptation strategies (Jones and Hennessy, 2000). In this study an event-based probability, where the likelihood of recurring events is estimated, was used to describe the future state of climate change under the enhanced greenhouse effect. To do this, Monte Carlo methods (repeated random sampling) were employed to stochastically generate probabilistic estimates of future climate change and its impacts on Rous Water's secure yields.

An assessment was then performed by comparing the projected future supply, after accounting for climate change, with projected future demand. In this study the demand projections were taken from the results of the GeoLINK (2005) study that were slightly modified so that they have the same starting point with the actual demand trend in 2006 (i.e. approximately 11,973 ML). The trends in actual demand were also estimated based on the available historical demand from 1996 to 2005.

Assessment Results and Recommendations

Assessment

Simulations with future climate scenarios within IQQM resulted in a range of estimated future secure yields for the Rous Water scheme in 2010, 2020 and 2030. These results were subsequently used to generate cumulative probability distributions for projected yields. The increases in supply are found to be very unlikely (<10% probability), whereas the declines in supply are likely (>66% probability). This suggests that the probability of changes in water supply is skewed towards the "decrease in future supply" scenarios. The best estimate (50% probability) changes in secure yields in 2010, 2020, and 2030 are -1.7%, -5.8%, and -8.1% respectively.

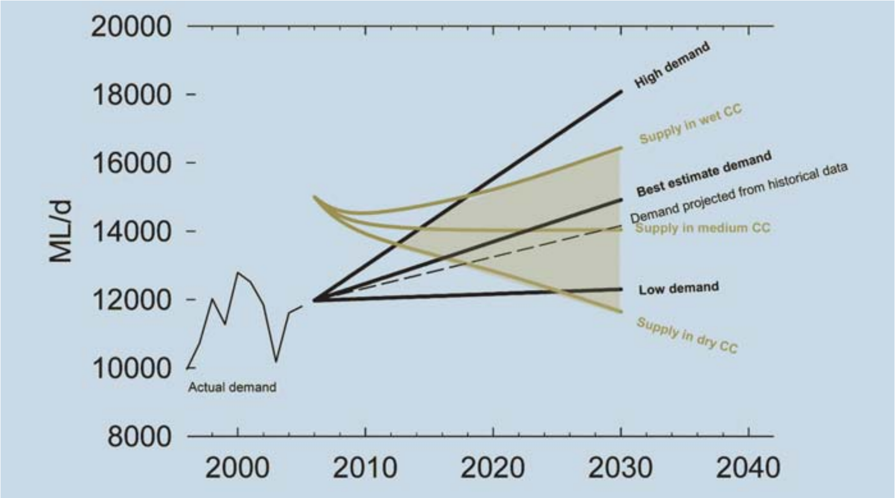

Figure 3. Supply projections due to climate change (CC) versus demand projection. Note: the high demand, best estimate demand, and low demand curves are taken and modified from GeoLINK (2005).

For assessment purposes, the 5th, 50th, and 95th percentiles of the probability distribution are then considered as the "wet", "medium" and "dry" scenarios as depicted in Figure 3.

- In the **wet climate change scenarios**, over the near term, the secure yield will fall in 2010 before increasing to above the present supply in 2020 and will continue to rise to more than 16,000 ML in 2030. The slight fall in 2010 is hypothesised due to a relative similar rate of change in both rainfall and evaporation (i.e. 2% above current value by 2010). As the models are more sensitive to the change in evaporation this causes a slight decrease in yield in 2010. In 2020 and 2030, the increase in rainfall is much higher than the increase in evaporation, hence the yield increases.
- In the **medium climate change scenarios**, the secure yield will decline to around 14,000 ML in 2030.
- In the **dry climate change scenario**, the secure yield will decline to approximately 11,600 ML in 2030.

The projections of the future demand (estimated by GeoLINK, 2005) are plotted in Figure 3. To represent the actual demand and its trend, the historical record from 1996 to 2005 and its trend projection are also presented. The demand projections (either based on the GeoLINK, 2005, or based on the trend analysis of the historic demand) show an obvious increase. The slope of the actual demand trend is similar to the best-estimate demand provided by GeoLINK (2005), suggesting that the two are relatively comparable. Demand is likely to increase to more than 14,150 ML (according to the trend analysis) or more than 14,900 ML (according to GeoLINK, 2005) by 2030.

The points of concern are where a given supply scenario encounters a particular demand scenario as summarised in Table 1.

In the combination of "Wet supply and Low demand", "Wet supply and Medium demand", and "Medium supply and Low demand" scenarios, the supply will keep pace with the demand, therefore no further action would be required.

- In the combination of "Wet supply and High demand" scenario, however, the need for a new source will be in 2018.
- In the combination of "Medium supply and High demand", and "Medium Supply and Medium demand" scenarios, there is a need for a new source in 2014 and 2023, respectively.
- In the combination of "Dry supply and High demand", "Dry supply and Medium Demand", and "Dry supply and Low demand", the need for a new source will be in 2012, 2016, and 2025, respectively.

Table 1. Options on the appropriate time to have a new source, according to the different supply and demand scenarios.

	Supply scenarios		
	Wet	**Medium**	**Dry**
Demand scenarios			
Low	-	-	2025
Medium	-	2023	2016
High	2018	2014	2012

Recommendations

The assessment provides several options on the most appropriate time to build a new water source, according to the different supply and demand scenarios. In terms of the future supply, this study has shown that the probability of changes in water supply is skewed towards the "decrease in future supply" (hence the "medium" and "dry") scenarios. In terms of the future demand, GeoLINK (2005) has estimated that the probability of the future demand is skewed towards the high and medium demand scenarios. This suggests the followings.

- The earliest time for a new source for the Rous Water system is after 2018. Thus, taking into consideration a 10 year planning and construction time from the time of this report there is only two years before commissioning of a new source has to be initiated.
- The medium time for a new source for the Rous Water system is 2023. Thus, from the time of this report there is about seven years time before commissioning of a new source has to be initiated.

Within that time, it is recommended that actual demand be closely monitored. This is because estimates of when a new source is required are highly sensitive to demand assumptions. In the case of a dry climate change scenario, for instance, GeoLINK's demand projection leads to a relatively similar suggestion with that of the actual trend of demand (i.e. only 2 years difference). In the case of medium climate change scenario, however, this differential becomes larger (i.e. 5 years). In addition, given a high demand and a dry-supply scenario, a crisis may occur in around 2012, by which point supply will be unable to meet the demand yet it will already be too late to commission a new source to address the supply/demand gap. Thus, information regarding the demand is valuable in updating the plan as to when a new source has to be built.

The results of the current study indicates that, ideally, the demand will not be more than the driest supply projection (i.e. about 13,000 ML in around 2018). This means that the maximum tolerable increase of demand by 2018 is only approximately 10% of the current demand. If the wet supply scenario is taken into account, the maximum tolerable increase of demand by 2018 is about 25% of the current demand. Therefore, ongoing monitoring of rainfall patterns is also recommended.

To interpret the results appropriately, there is another factor that needs to be taken into account, specifically, climate variability (e.g. periods of anomalous drought or rainfall) not represented by the historical record or model simulations that could also affect water supply within the time horizon in question. Changes in decadal mean rainfall may occur due to other factors other than the greenhouse effect (e.g. long term variations in natural climate), so there may be additional changes and risks above and beyond those accounted for here.

Conclusions

This paper has described the framework and the results of a climate change risk assessment of Rous Water's supplies based upon The Wilsons river IQQM. Results of the risk analysis suggest that decreases in secure yields are likely in the future. The best estimate (50% probability) changes in secure yields in 2010, 2020, and 2030 are -1.7%, -5.8%, and -8.1% respectively. The assessment suggests the earliest time to have a new source is 2018. Given that a ten-year time lead is considered the minimum required to commission a new water source, the plan has to be started in at least 2008.

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References

BOM. 2006. Australian Bureau of Meteorology. *www.bom.gov.au*.

CMPS&F. 1995. *Rous Regional Water Supply Strategy Planning Study*, Scheme Options, Final Report. May 1995.

DIPNR. 2004. *Rous Water – Augmentation of Regional Water Supply Scheme, Hydrologic modelling study using Wilsons River IQQM*. Issue 3. NSW Department of Infrastructure, Planning and Natural Resource

GeoLINK. 2005. Dunoon Dam, Population and demand projections. *Draft report*, 19-08-2005.

Hennessy, K., Page, C., McInnes, K., Jones, R., Bathols, J., Collins, D. and Jones, D. 2004. *Climate change in New South Wales, Part 1: Past climate variability and projected changes in average climate*. Consultancy report for the New South Wales Greenhouse Office.

IPCC. 2001. *Climate Change 2001: The scientific basis*. Summary for policymakers. In Houghton, J.T., Ding, Y., Griggs., D.J., Noguer, M., Van Der Linden, P.J. and Xioaosu, D (eds) Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC, 2007. *Climate change 2007: The physical science basis*. Summary for policymakers. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change.

Jones, R.N. and Hennessy, K.J. 2000. Climate change impacts in the Hunter Valley, A risk assessment of heat stress affecting dairy cattle. *A research report*, CSIRO Atmospheric Research, Victoria.

Jones, R.N. and Preston, B.L. 2006. Climate change impacts, risk and the benefits of mitigation. *A report for the Energy Futures Forum*, CSIRO Marine and Atmospheric Research, Victoria.

Page, C.M., and Jones, R.N. 2001. OzClim: the development of a climate scenario generator for Australia. In: *MODSIM 2001: International Congress on Modelling and Simulation: proceedings, Australian National University*, F. Ghassemi, *and others* (editors). Canberra, ACT: Modelling and Simulation Society of Australia and New Zealand. p. 667-671.

Rous Water. 2004. *Demand management plan, 2004-2009*. Rous Water Regional Water Supply, Adopted Council Meeting March 2004.

Simons, M., Podger, G. and Cooke, R. 1996. IQQM – A hydrologic modelling tool for water resource and salinity management. *Environmental Software*, **Vol 11, Nos. 1-3**, pp 185-192, 1996

SRES. 2000. Special report on emissions scenarios (SRES). Special report on the Intergovernmental Panel on Climate Change. N. Nakicenovic and R. Swart (eds), Cambridge 2000. http://www.ipcc.ch

WMO (2005) *WMO statement on the status of the global climate in 2005*. World Meteorological Organisation. http://www.wmo.ch/web/Press/index.html