Chapter 7

Climate variability and predictions for future climate change

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7.1 Overview

The NRC has used the best-available science and knowledge to assess the future climate variability and climate change in the Riverina bioregion. This science is telling us that the Riverina bioregion is likely to receive less rainfall and surface run-off, increased temperatures and a general increase in climate variability. These effects are expected to impact on water availability and future flooding regimes in the region, which will in turn have impacts on the functioning of river red gum forest ecosystems.

This chapter supports Steps 3 and 4 of the analytical framework by:

- outlining the current understanding of climate variability and climate change in south-eastern Australia
- outlining implications for planning within the uncertain trajectories of climate change
- defining the climate change scenarios used in the remainder of this assessment.

Chapters 8, 9 and 10 explore the potential implications of climate variability and climate change on water availability, flooding regimes and the economic, social and environmental values of the river red gum forests.

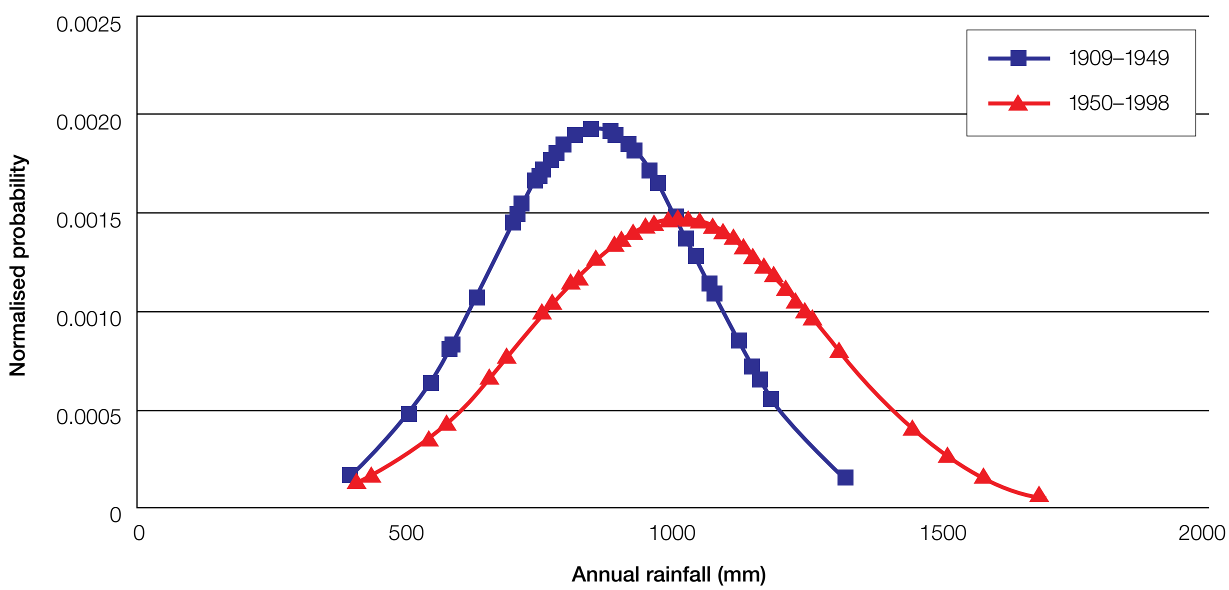
The key findings of this chapter are:

- The long-term rainfall and river flow records for south-eastern Australia show a major climate shift after 1950 to wetter conditions. There is strong evidence that the climate has shifted again over the past decade to conditions of much lower rainfall than the long-term average. This has been accompanied by increasing temperatures.
- There has been a dramatic decline in average inflows to the Murray system compared with the long-term average, although there were periods during 1900 to 1950 where river flows were also very low.
- Reduced rainfall and runoff and warmer temperatures are predicted under climate change scenarios in the south-east of Australia. Climate change may contribute to both a change in average conditions and an increase in variability. These changes can affect catchment hydrology more significantly than the projected changes in average conditions might indicate.
- Climate change is a significant threat to biodiversity, ecosystem functioning and ecosystem resilience. Climate change is likely to cause landscape-scale changes, markedly different hydrological regimes and the transformation of ecosystems and ecosystem function.
- Under a best-estimate (median) prediction of climate change by 2030, average surface water availability for the Murray region would fall by 14 per cent. Under a scenario with continuation of the recent drought, average surface water availability for the Murray region would fall by 30 per cent (CSIRO, 2008a).
- Current water reforms and approaches to water resource planning are seeking to address over-allocated systems and account for the effects of climate variability and climate change. Successful implementation of these reforms is critical to making water available for the river red gum forests. Management arrangements are being developed to respond to dynamic ecological states under different hydrological regimes.

The assessment for this section has drawn on work from well-respected international and Australian scientific institutions including the Intergovernmental Panel on Climate Change and the South Eastern Australian Climate Initiative, a collaborative partnership between the Murray-Darling Basin Authority, Australian Bureau of Meteorology, CSIRO, Australian Government Department of Climate Change, Victorian Department of Sustainability and Environment, and the Managing Climate Variability Program.[1]

The NRC strongly supports initiatives such as these that generate new knowledge and help us to reduce uncertainty and manage risks. This knowledge will be critical in supporting adaptive approaches in managing the future landscapes of the Riverina bioregion.

Figure 7.1: Normalised distribution of annual rainfall at Burrinjuck Dam (Khan, 2008)



7.2 Climate variability

South-eastern Australia has a highly variable climate. It can have inter-decadal shifts in both rainfall and temperature that can last for 40 or 50 years.

In south-eastern Australia, a major shift to a wetter period took place around 1950. For example, in the upper Murrumbidgee River catchment mean annual rainfall and rainfall variability increased after 1950 (see **Figure 7.1**).

As a consequence of this shift, annual flow volumes for the Murrumbidgee River at Wagga Wagga increased from 3,350 GL to 4,700 GL per year[2] (see **Figure 7.2**). This increased 'wetness' at the later part of the 20th century may have led to the over-allocation of surface and groundwater resources in many parts of Australia.

High rainfall in the second half of last century resulted in average surface water availability of 16,500 GL per annum in the Murray-Darling Basin. By comparison, during the first half of the century, water availability was less at only 13,500 GL per annum (**Figure 7.3**).

There is evidence that the climate has again shifted to lower rainfall and higher temperatures than the long-term average.

In the past decade we have seen weather patterns shift, with a dramatic decline in run-off (**Figure 7.3**). The average annual inflow between 1998 and 2005 of 10,500 GL is similar to the 10,300 GL experienced in the Federation drought of 1897–1904, and 10,550 GL in the droughts of 1938–45.

European history of Australia is marked by repeated references to periods of drought. Pigram (1986) found that widespread droughts occurred in Australia in 1864–68, 1880–88, 1895–1903, 1911–16, 1918–20, 1939–45, 1957–58, 1965–68 and 1979–83. Khan (2008) explored similarities between past and present droughts in the Murray-Darling Basin and found that the most severe and prolonged drought in earlier times was between 1895 and 1903. This was the 'Federation drought' which affected most of Australia. The current drought appears to have some similarity in pattern to that of the Federation drought.[3]

Many agencies are working to identify whether the observed rainfall and run-off patterns are part of an extended drought, or a shift to a lower average pattern similar to that which has occurred in the past. This form of climate shift is also known as a climate 'step change'.

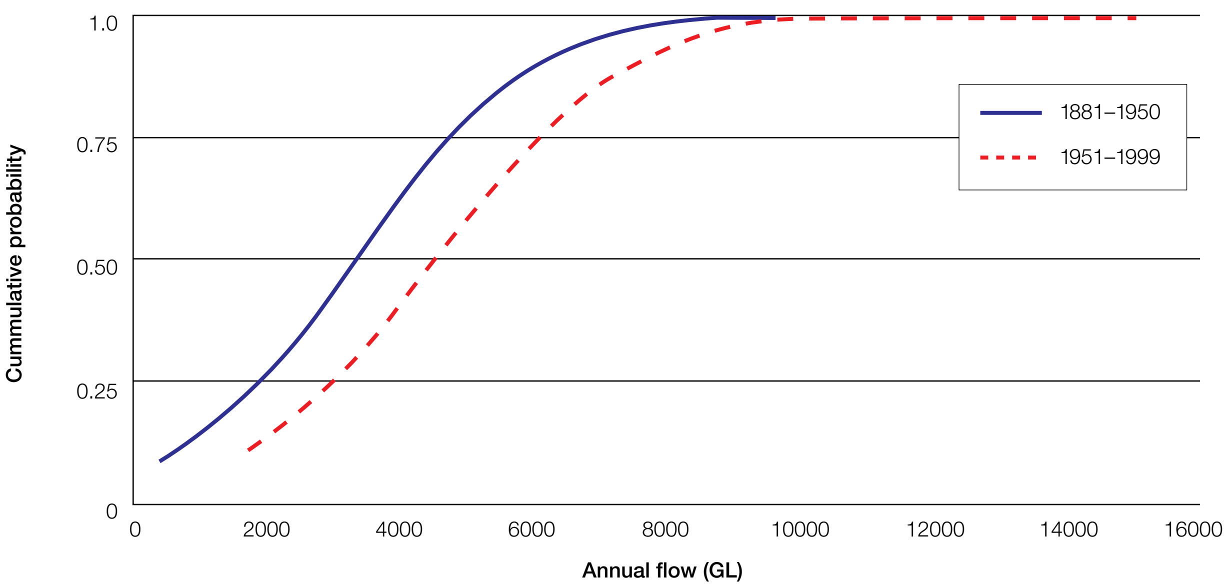
Over the past seven years, rainfall was predominantly very much below average throughout the Riverina bioregion (**Figure 7.4**).

This extended period of low rainfall has had significant impacts on catchment run-off and consequently river inflows.

The MDBA issues regular *Drought Updates*. Issue 21, November 2009, stated that:

As a result of the recent rain, Murray System inflows for the first five months of the 2009–10 water year were 2,200 GL which is significantly better than for the same period during each of the last 3 years, but remains well below the June to October long term average of 6,390 GL. The current water year is tracking as the 17th driest in 118 years of records. (www.mdba.gov.au)

Figure 7.2: Cumulative probability of flows in the Murrumbidgee River at Wagga Wagga (Khan, 2008)

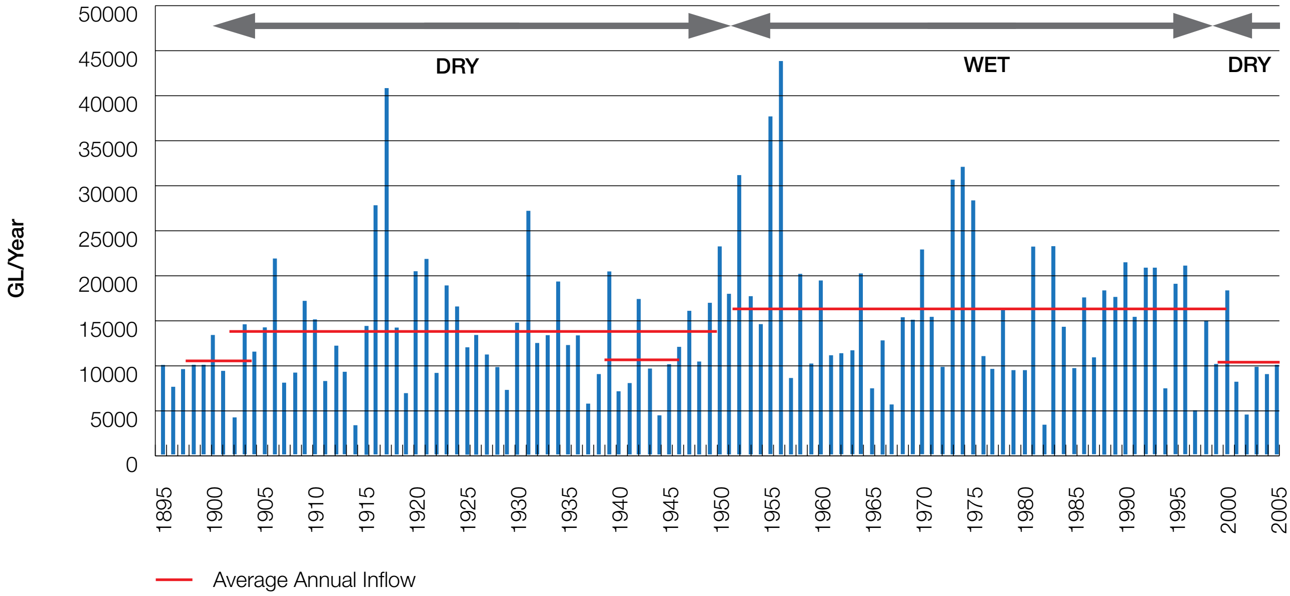


[1] A program set up by the Australian Government, research institutions and agriculture sectors to help Australian farmers manage climate risk on-the-ground and providing tools to incorporate weather and climate information into farm business decisions.

[2] Even discounting for the 500 GL contributed to the river by the Snowy Mountains Scheme, when the eastward flowing Snowy River was diverted inland, the increase was still around 850 GL.

[3] However, the economic impacts of the current drought have been more severe due to Australia's large irrigation sector, and the greater basic needs of a much larger population, coupled with rising temperatures attributed to the onset of climate change.

Figure 7.3: River Murray inflows 1895–2005 (Wentworth Group of Concerned Scientists, 2008)



Note: Data was estimated by the modelling of historic climate and current development for the period 1895 to 2005.

Figure 7.4: Rainfall deciles for the Murray-Darling Basin, for seven years from 1 January 2002 to 31 August 2009 (adapted from www.bom.gov.au)

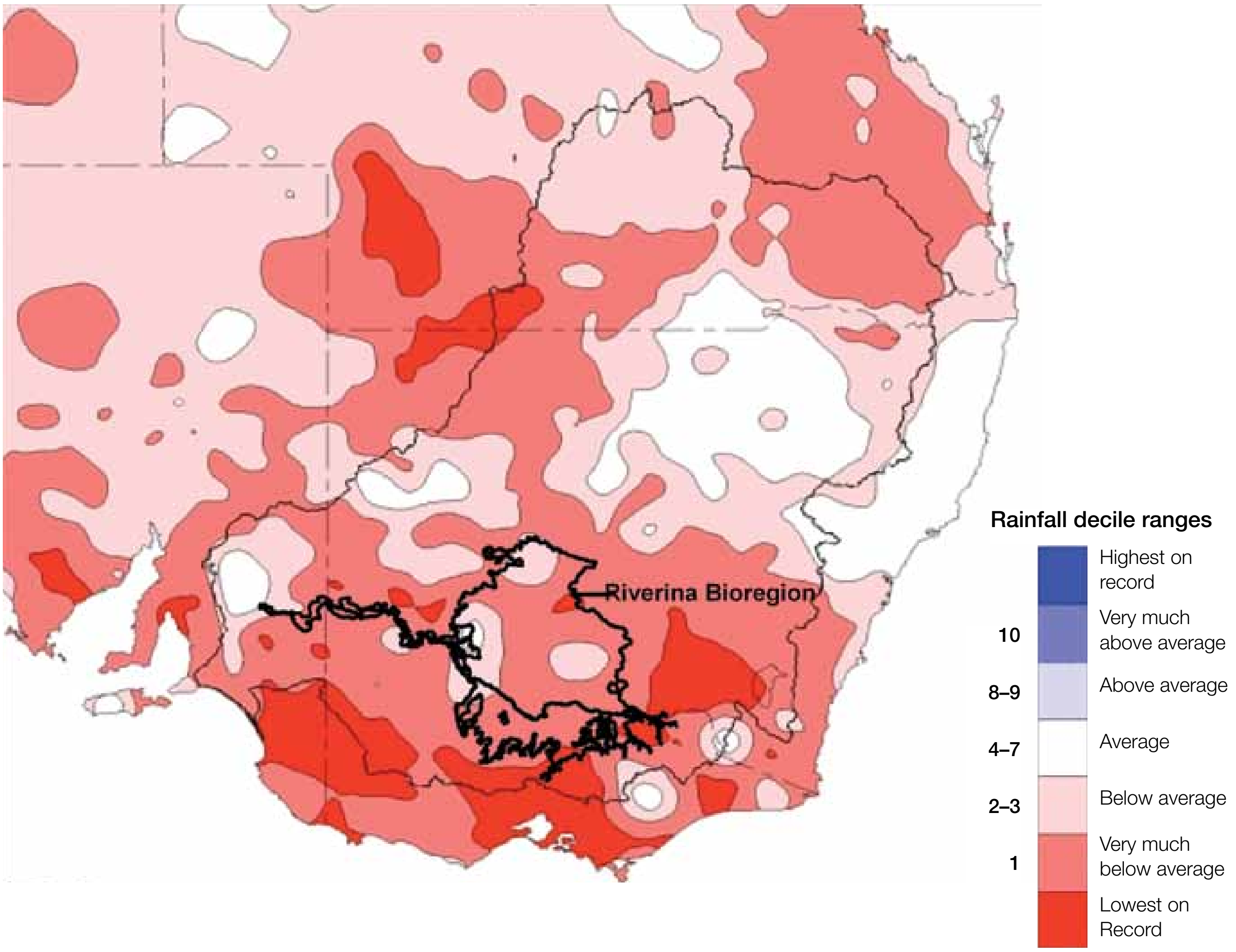


Figure 7.5 shows the substantial decrease in average inflows to the Murray system in recent years compared with the long-term average. It is important to note that the long-term average has within it periods of climate shift and periods of 5–10 years with very low flows (as illustrated in **Figure 7.3**).

Recent temperatures have also shown a sequence that is unprecedented in the historical records. During the 1950s to 1980s, the annual average temperature rise was around 0.1°C per decade.

However, since 1990 annual average temperature rises have been about 0.5°C per decade. Between 1997 and 2007 all years were warmer than average. For NSW as a whole, 2007 was the warmest year on record, and 2005 the third warmest. Since the turn of this century, all years have recorded an annual average mean temperature of more than 0.5°C warmer than the climatological average, with 2007 a record 1.1°C above average.

Figure 7.6 shows the annual mean temperature anomalies for Australia relative to the 1961 to 1990 reference period. This data set clearly highlights the recent sequence of above-average annual temperatures across the country, with many of the warmest years on record having occurred during the 1980s and 1990s.

Figure 7.5: Murray system inflows, excluding Snowy and Menindee inflows (www.mdba.gov.au)

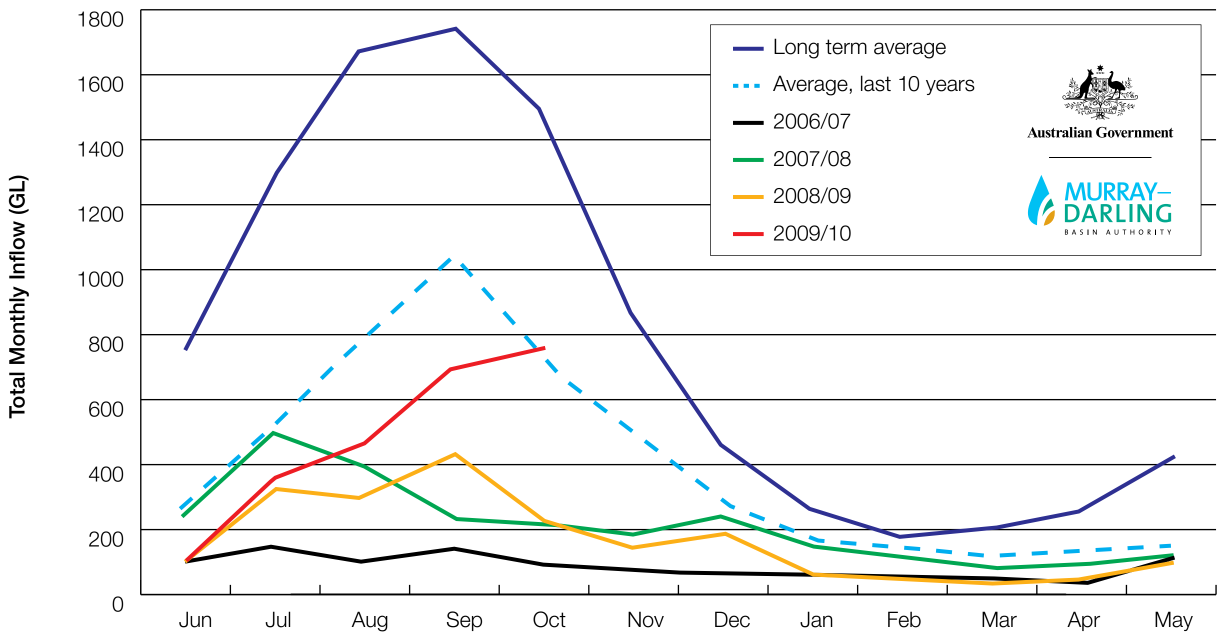


Figure 7.6: Annual mean temperature anomalies for Australia (BOM, 2009, www.bom.gov.au/climate/change/amtemp.shtml)

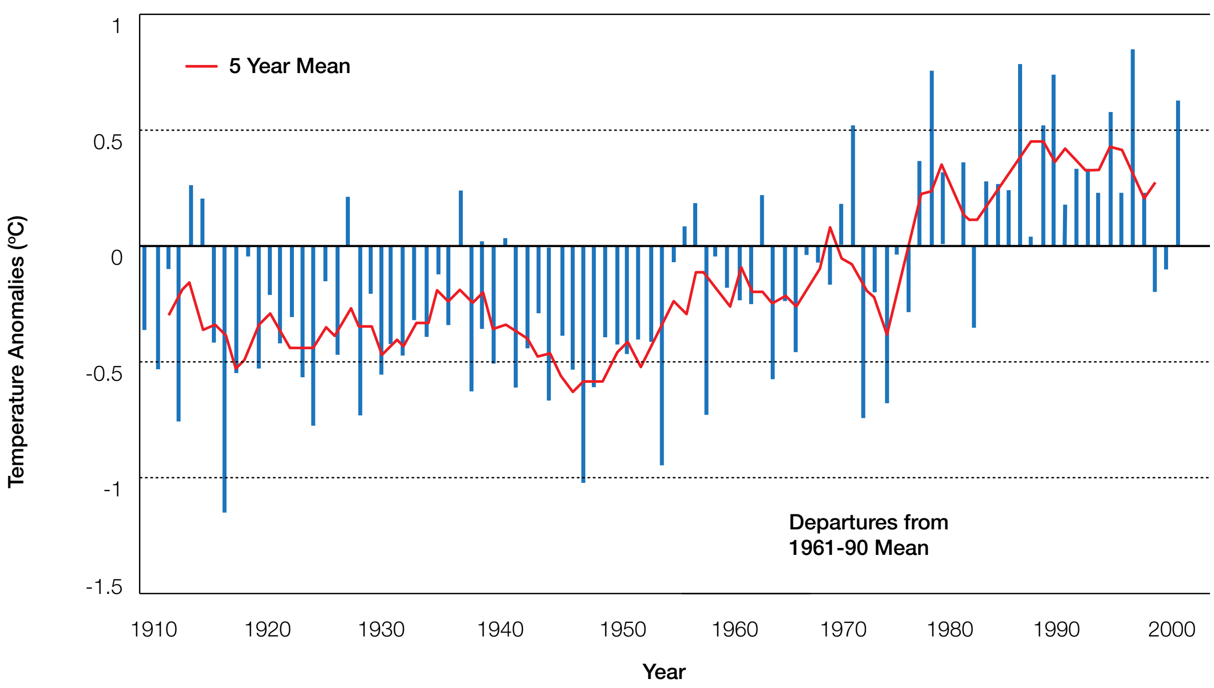


Figure 7.7: Relationship between means and extremes for previous climate and new climate (IPCC, 2007a)

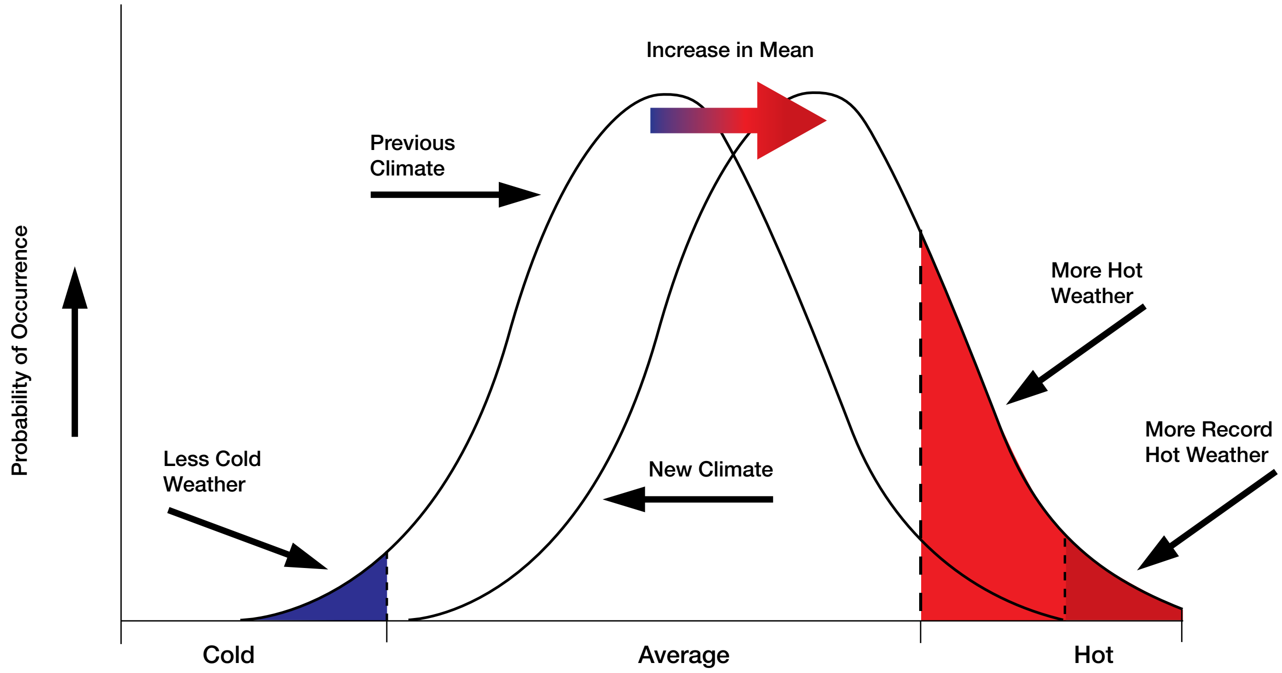
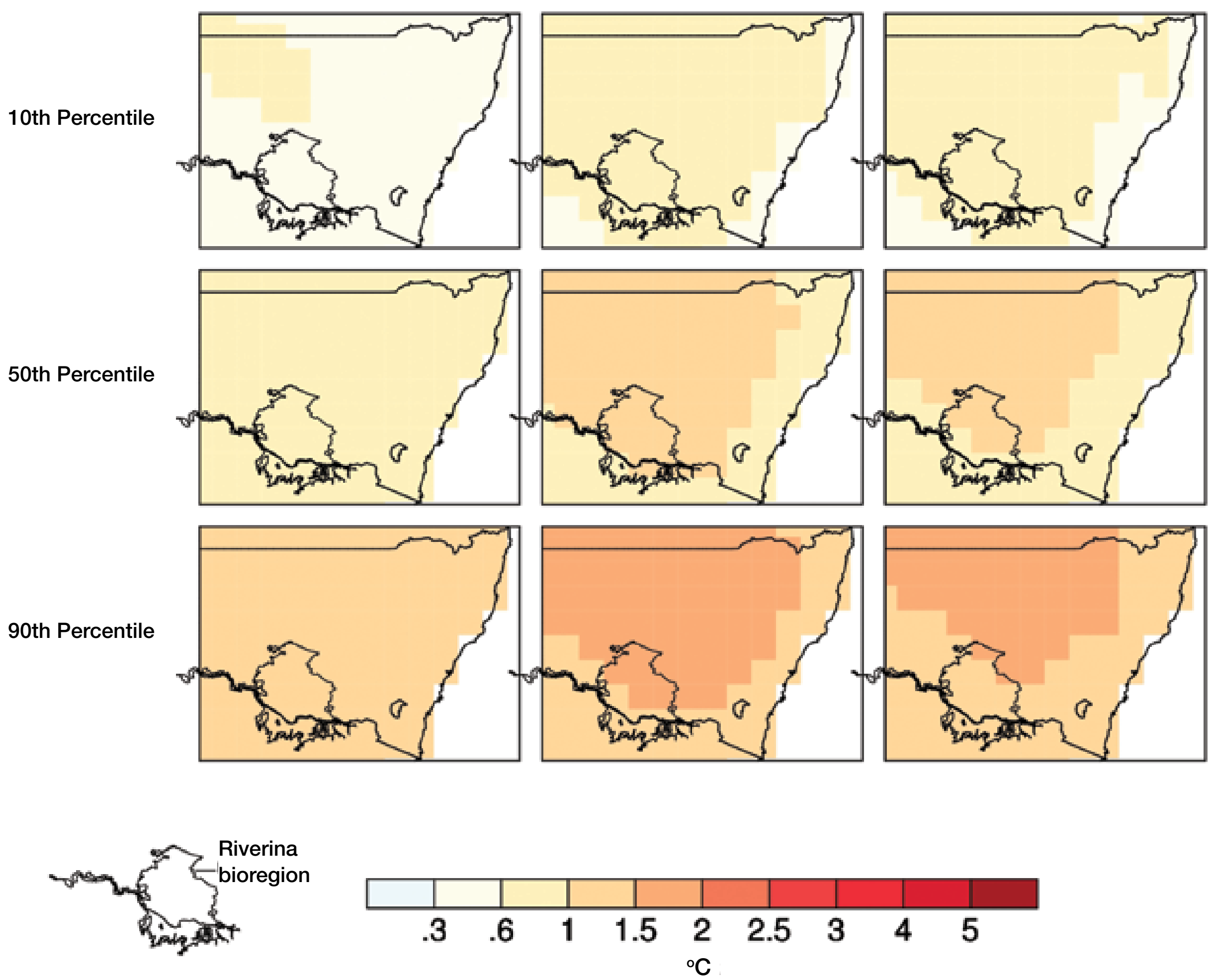


Figure 7.8: Forecast NSW/ACT temperature change 2030 summer. Emissions scenarios are from the IPCC Special Report on Emission Scenarios (adapted from www.climatechangeinaustralia.gov.au)



When examining historical changes to the NSW climate, a cool or even exceptionally hot month or year is less important than a multi-decadal trend. Current climate trends indicate an accelerating increase in average annual temperature in NSW.

Based on the latest climate science published by the IPCC (2007a) and shown in **Figure 7.7**, while there is a precedent for the current hot and dry conditions in the previous climate record, these conditions are likely to be far more prevalent in the new climate record. The arrow shows that hot weather, similar to that currently being experienced, occurs in both climates (previous and new). However, while only a small proportion of events in the previous climate occur in the 'hot zone', a significant proportion of all occurrences in the new climate record occur in the 'hot zone'. In addition, extreme hot events occur that were not observed in the previous climate.

7.3 Predictions for climate change in the bioregion

In 2007 the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment report (IPCC, 2007), concluding that:

- warming of the climate system is unequivocal
- humans are very likely to be causing most of the warming that has been experienced since 1950
- it is very likely that changes in the global climate system will continue well into the future, and that they will be more significant than those seen in the recent past.

These changes have the potential to have a major impact on human and natural systems throughout the world, including Australia.

The South Eastern Australian Climate Initiative (SEACI) is a three-year, $7 million research program investigating the causes and impacts of climate change and climate variability across south-eastern Australia. Launched in 2006, SEACI is a partnership involving government and industry, and is managed by the MDBA. CSIRO and the Bureau of Meteorology are research partners. SEACI has stated that the growing evidence of lower rainfall and reduced runoff in the south-east of Australia is linked to global warming (SEACI, media release, 1 May 2008). Predictions for the future include warmer temperatures and reduced rainfall and runoff.

Figure 7.8 shows the forecast summer temperature change across NSW, including the Riverina bioregion. The temperature is forecast to increase by 1–1.5°C for the projected 2030 summer across the NSW portion of the Riverina bioregion for the 50th percentile, the mid-point of the model results, which provides a best-estimate result.

Figure 7.9 shows forecast changes in rainfall across the NSW portion of the Riverina bioregion. A significant loss of winter rainfall and small increases in summer rainfall are forecast. The forecast changes are possibly outside of historical variation.

The IPCC has developed a range of emissions scenarios to project future climate change. It is difficult to make plans based on such a large variation in the projections. For instance, temperature in south-eastern Australia is projected to rise by 1.1 to 60°C by 2100 (IPCC, 2007).

Figure 7.9: Forecast rainfall changes based on A2 climate-change 2050 scenario (adapted from DECC, 2009b)

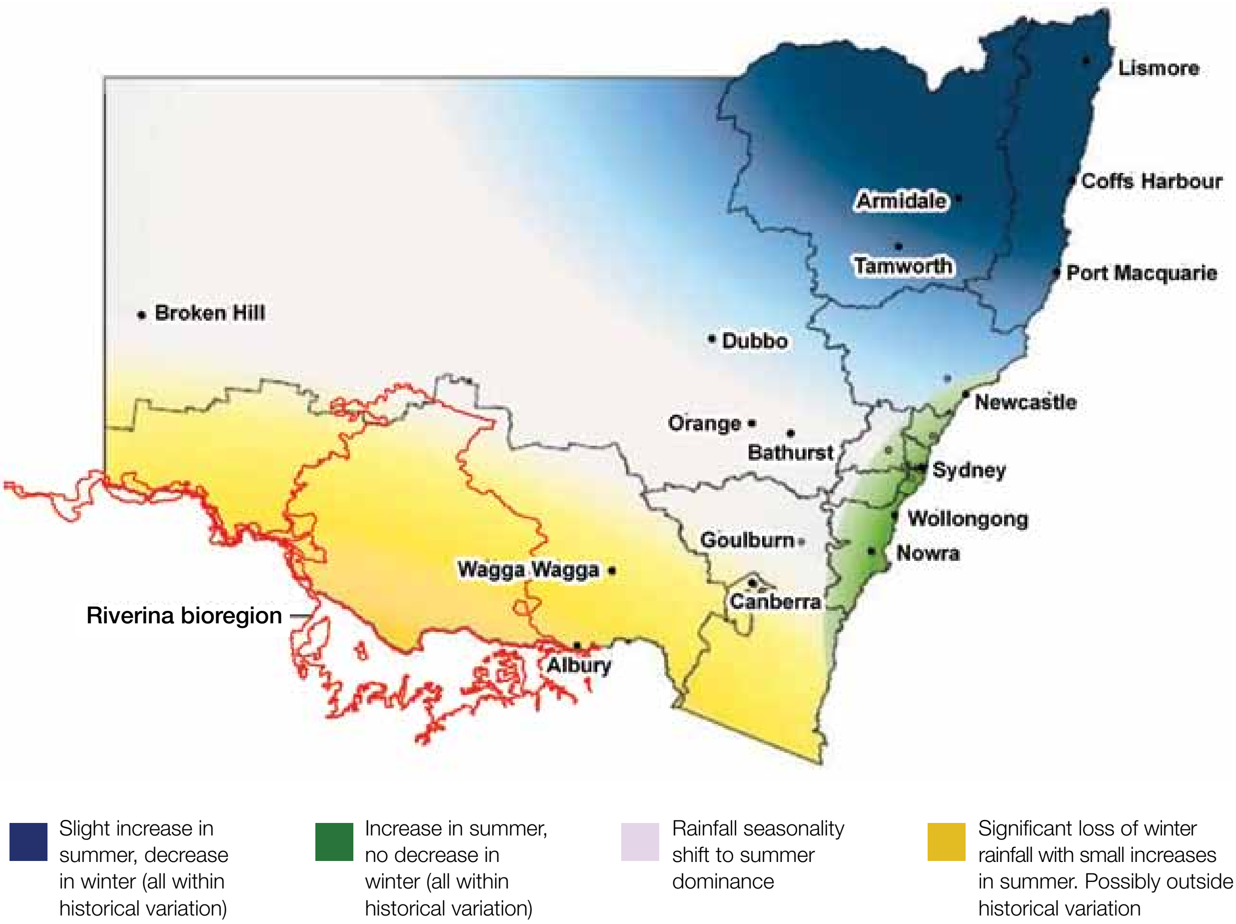


Table 7.1: DECCW expert panel assessments of likely changes in biodiversity

Impact	Comment
The structure, composition and function of ecosystems are likely to change	All ecosystems in NSW, even the most hardy and resilient, are expected to alter in response to climate change. The structure of ecosystems will be influenced by changes in fire regimes and hydrological flows. Changes in species' distributions and abundances will alter the composition of ecosystems.
Distributions of individual species are likely to change	The distribution of individual species is likely to shift in latitude and altitude in response to increased temperatures. Drier conditions over much of the west of NSW, as well as a shift in seasonal patterns of rainfall in the south-west are likely to cause range contraction in a number of species.
Changes in fire frequency and intensity are likely to have widespread impacts	Larger and more intense fires are likely to extend in the future into infrequently burnt wet forests and refuges such as canyons that are protected by their topography, changing forest structure and composition. Species that are highly sensitive to fire are likely to disappear, while those that depend on old or dead hollow-bearing trees and woody debris are likely to have fewer habitats. Small patches of fire-sensitive ecosystems in a matrix of extensive drier vegetation are most at risk. More extensive fire combined with drought stress is likely to decrease the flowering of plants such as banksias and eucalypts in dry forests and heaths, impacting on nectar-feeding animals.
Changes in invertebrate populations are difficult to predict but likely to be substantial	Invertebrates have many functions in ecosystems – for example as pollinators, predators, herbivores, detritus feeders, disease vectors, biological controllers of pests and food for other organisms. Invertebrate ecology and population dynamics are likely to change greatly, with consequences that are likely to be substantial but are generally hard to predict from current knowledge. Changes are already apparent in some of the better known and more significant invertebrates, such as the plague locust *Chortoicetes terminifera*. Breeding adults of this species were observed as early as July in 2008, and it is expected to benefit from warmer and wetter summers and warmer night-time temperatures.
Rainfall decline and reversed seasonality are likely to cause major changes in the Murray Valley	The Riverina and Murray Valley are very likely to suffer major ecological changes as a result of reduced annual rainfall, a shift in rainfall seasonality from winter to summer dominance, declining overall river flows and a loss of spring snow-melt (DECC, 2009b). Species adapted to 'Mediterranean' conditions (wet winters and hot, dry summers) are likely to be displaced or lost. Floodplain and wetland species that have already declined dramatically over the past decade are likely to decrease further. Many ecosystems are likely to collapse.
Species and ecosystems that are stressed by other factors are less likely to resist climate change	Many Australian ecosystems and species have evolved in highly variable climates and consequently are likely to have some capacity to resist expected climate changes. However, many ecological communities and species in NSW have declined severely because of land clearing, water extraction, habitat fragmentation, grazing and introduced pests. Species and ecosystems that are stressed by non-climatic factors are less likely to be resilient to climate change impacts.

The rate of global emissions growth since 2000 has been greater than for the most fossil-fuel intensive of the IPCC's emission scenarios. The Garnaut Climate Change Review concluded that all of the IPCC's emissions scenarios may under-estimate the future growth in emissions in the early 21st century (Garnaut, 2008). Analysis of global mean surface temperatures also shows that the rate of warming is in the upper range of the IPCC's climate projections.

7.4 Planning for climate variability and climate change

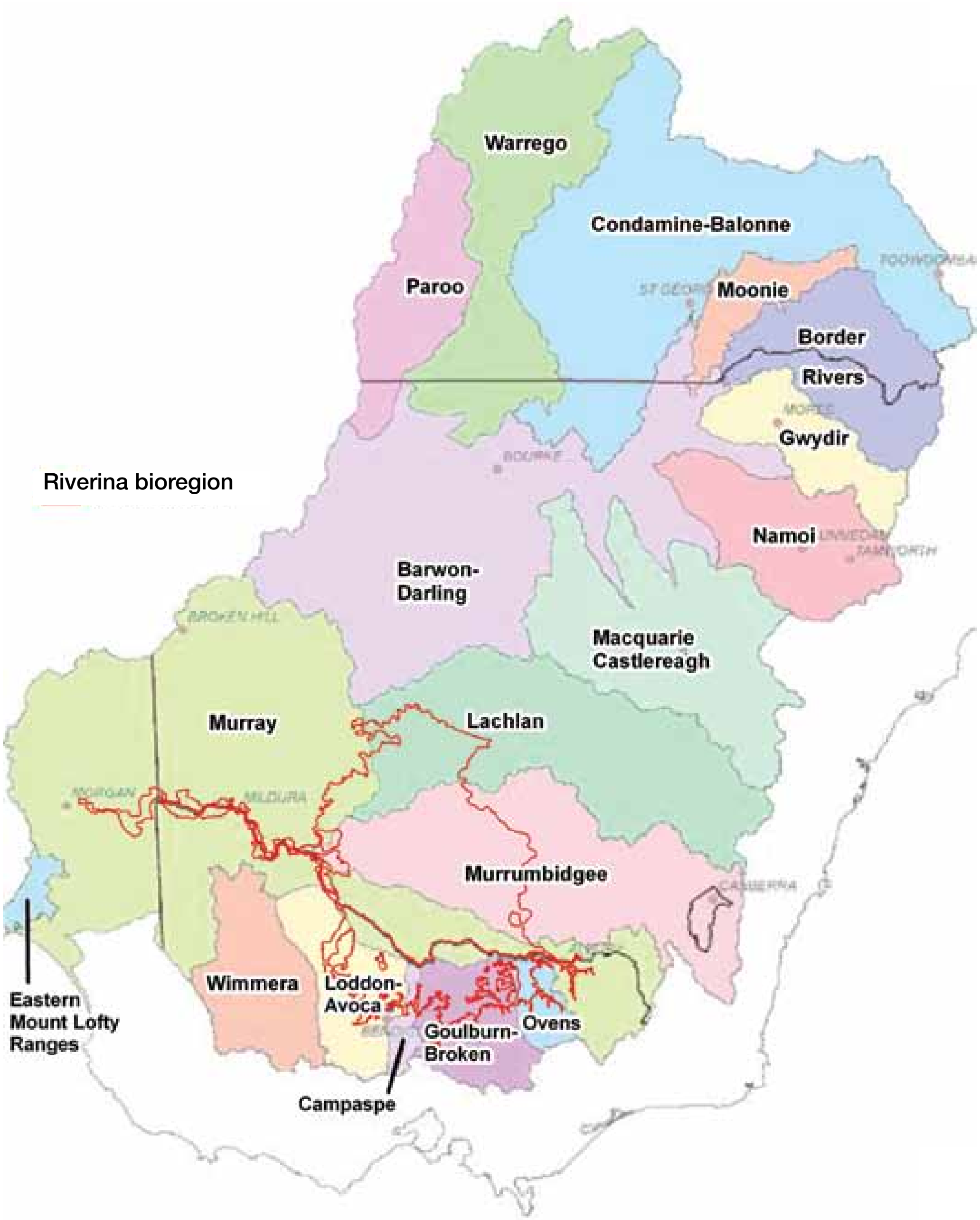
Future climate variability and climate change, and the corresponding effects on water availability, is expected to impact upon the future health of river red gum forests of the Riverina bioregion. Planning the management of the forests will require planning for an uncertain future.

7.4.1 Possible changes in biodiversity from climate change

The impacts of climate change on Australia's biodiversity are already discernible at the genetic, species, community and ecosystem level. The threat to Australia's biodiversity is expected to increase sharply through the 21st century and beyond due to the growing impacts of climate change, the range of existing stressors on biodiversity, and the complex interactions between them (Biodiversity and Climate Change Expert Advisory Group, 2009).

In 2009, the NSW Department of Environment, Climate Change and Water (DECCW) held expert panel assessments of the likely changes in biodiversity as a result of projected climate changes in NSW. The expert panel identified a number of potential impacts on biodiversity and ecosystem function (**Table 7.1**). The predicted impacts on the river red gum forests of the Riverina bioregion are outlined more fully in **Chapter 9**.

Figure 7.10: Assessment and reporting regions within the Murray-Darling Basin (CSIRO, 2008)



7.4.2 Predictions of future water availability

Climate change may contribute to both a change in average conditions and an increase in variability. These changes in turn can affect catchment hydrology more significantly than the projected changes in average conditions might indicate. The current drought and future climate variability will also likely reduce water availability for the majority of red gum stands across the bioregion.

Various scenario modelling exercises indicate a substantial reduction in the magnitude, frequency and duration of floods, particularly large floods.

A considerable amount of work has been completed in recent years assessing likely water availability under future climate scenarios. The most recent and comprehensive of these assessments is CSIRO's Murray-Darling Basin Sustainable Yields Project (MDBSY Project) completed in November 2008. The MDBSY Project is the world's largest basin-scale investigation into the impacts on water resources from:

- catchment development
- changing groundwater extraction
- climate variability, and
- climate change (CSIRO, 2008a).

The findings of the MDBSY Project are presented for 18 reporting regions within the basin (**Figure 7.10**). Some of the key findings from the MDBSY Project relevant to future water availability in the Riverina bioregion are:

- a very substantial decline in surface water availability is possible in the south of the Murray-Darling Basin
- in volumetric terms, the majority of the impact of climate change would be borne by the environment rather than by consumptive water users.

The Murray, Murrumbidgee and Lachlan regions are of particular relevance to the Riverina bioregion. For the Murray region, average surface water availability is 11,162 GL/year (CSIRO, 2008). If the recent (1997-2006) climate were to persist, average surface water availability for the Murray region would fall by 30 per cent; average diversions in the Murray region would fall by 13 per cent; and end-of-system flows would fall by 50 per cent. Under the best-estimate (median) prediction of climate change by 2030, average surface water availability for the Murray region would fall by 14 per cent; average diversions in the Murray region would fall by 4 per cent; and end-of-system flows would fall by 24 per cent.

A range of other factors were also assessed as part of the CSIRO's MDBSY Project work, including groundwater extractions, the expansion of commercial forestry plantations and increases in the total capacity of farm dams. The CSIRO assessment found:

- Current groundwater use is unsustainable in seven of the 20 high-use groundwater areas in the Murray-Darling Basin and will lead to major drawdowns in groundwater levels in the absence of management intervention. Parts of the Lower Lachlan, the Upper Lachlan, the Mid-Murrumbidgee and the Upper Murray are all listed as having unsustainable groundwater use.
- 'Best-estimate' projections of commercial forestry plantations and farm dams indicate only very minor impacts on the total runoff reaching rivers across the Murray-Darling Basin.

The MDBSY project outlines climate projections beyond 2030 (**Figure 7.11**). This work allows some indication of the reduction in run-off that can be expected under two climate change scenarios and how these compare with the reductions in run-off from the 1990 mean (approximately 40 per cent over 1997 to 2006) in the southern Murray-Darling Basin. The reduction over that period is similar to the extreme dry estimate for 2030 (43 per cent under the high global warming scenario) and a greater reduction than the median estimate for 2070 (from the medium global warming scenario).

Under the medium global warming scenario, the reduction in run-off for the southern Murray-Darling Basin is estimated to be approximately 11 per cent in 2030, 17 per cent in 2050 and 27 per cent in 2070. These projected reductions for a medium global warming scenario are less than the 40 per cent reduction experienced over 1997 to 2006. However, under the high global warming scenario, the 1997 to 2006 run-off reduction would be outweighed by the estimated median runoff change in 2070.

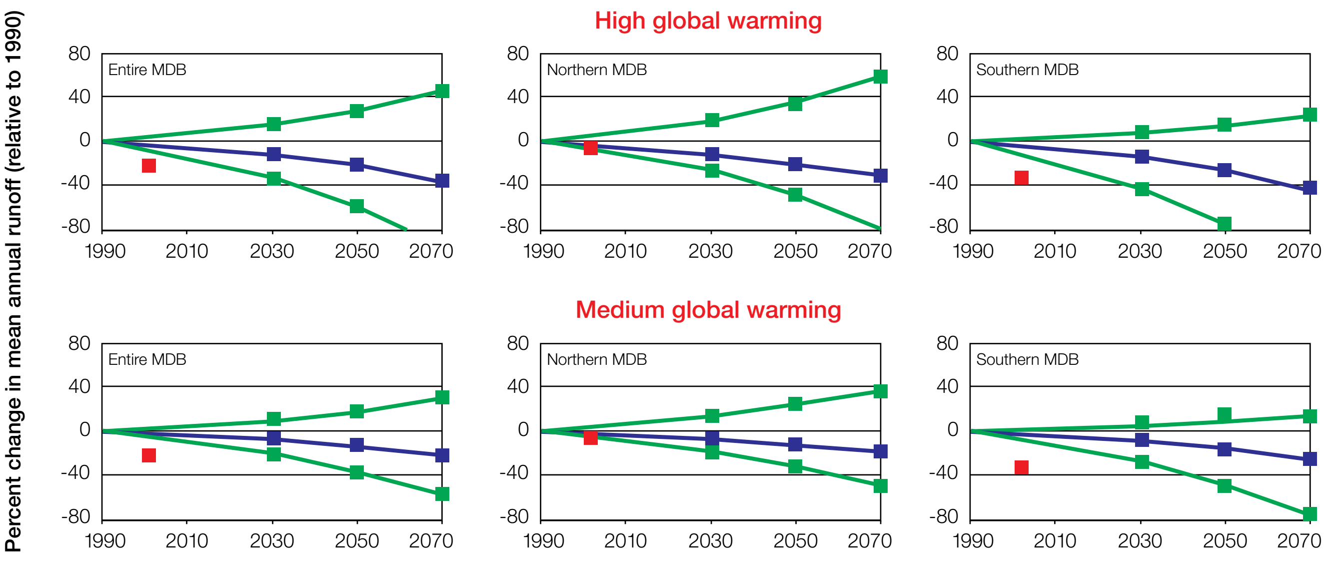
It is important to keep these relative magnitudes in mind as we consider how to manage the bioregion's river red gum forests under the interaction of river regulation, current over-allocation climate variability and climate change. The future of the river red gum forests will depend on whether the current water reform programs are successful in returning water to the over-allocated rivers of the Murray and Murrumbidgee.

7.4.3 Planning for a likely transformation

The forest landscapes within the Riverina region have evolved over long, 'landscape evolution' time periods. Following European settlement, these forests have also been heavily modified as a result of human intervention. They are likely to continue to transform more rapidly due to changes in the climate. As described above, the MDBSY Project suggests we are likely to observe markedly different hydrological regimes over the coming decades (CSIRO, 2008a). It is therefore reasonable, and prudent, to plan for this likely transformation.

The MDBA is in the process of developing a Basin Plan (MDBA, 2009). One of its key elements will be 'sustainable

Figure 7.11: Run-off projections for 2030, 2050 and 2070 relative to 1990 for the entire Murray-Darling Basin (blue lines show trajectory of median runoff change; green lines show breadth of possible range of run-off changes, and red squares indicate the percentage change in run-off associated with the recent (1997–2006) climate) (CSIRO, 2008a)



diversion limits' which will limit the quantity of surface water and groundwater that may be taken from the Basin water resources. Sustainable diversion limits will be set using the best available science and will define the level at which water in the Basin can be taken from a water resource without compromising key environmental assets, ecosystem functions, environmental outcomes or the productive base of the water resource. This will vary in different years and will take into account the effects of climate change and variability.

The revision of sustainable diversion limits within the Basin Plan is the primary tool to achieve fundamental water reform under the National Water Initiative. This work, under the *Water Act 2007*, is designed not only to address over-allocation but also to address the expected reduction in water flows from climate change.

In addition, the Victorian Government's Sustainable Water Strategies are planning for uncertainty in future water availability. For example, the Victorian Government's Draft Northern Region Sustainable Water Strategy, a 50-year water resource plan, states:

The Draft Strategy examines two scenarios in detail – a continuation of recent low inflows … and medium climate change projections… and compares these to the base case. Focusing on (a step change scenario) allows us to plan for the 'worst case' which is less risky than assuming inflows will soon return to average conditions. However, the worst case may not eventuate and therefore it is also important to examine the impacts of medium climate change. Comparing (medium and step change scenarios) against the long-term average ensures that the community is aware of the range of possible water futures. (DSE, 2008)

7.4.4 Framework for considering uncertainty surrounding predictions

The uncertainties inherent in modelling of complex systems need to be acknowledged. The 'best-estimate' predictions from the MDBSY Project involve a median figure from a number of different climate, water use and hydrological models which were calibrated against historical data. At a small temporal or spatial scale the uncertainty of these predictions increases.

The main sources of uncertainty are in the global warming projections and the global climate modelling of local rainfall response to global warming. The uncertainty in the rainfall-runoff modelling of climate change impacts on run-off is small compared with the climate change projections (CSIRO, 2008a). The MDBSY Project takes into account the current uncertainty in climate change projections explicitly by considering results from 15 global climate models and three global warming scenarios based on the IPCC Fourth Assessment Report (IPCC, 2007). The results are then presented as a median estimate of climate change impact on run-off and as the range of the extreme estimates.

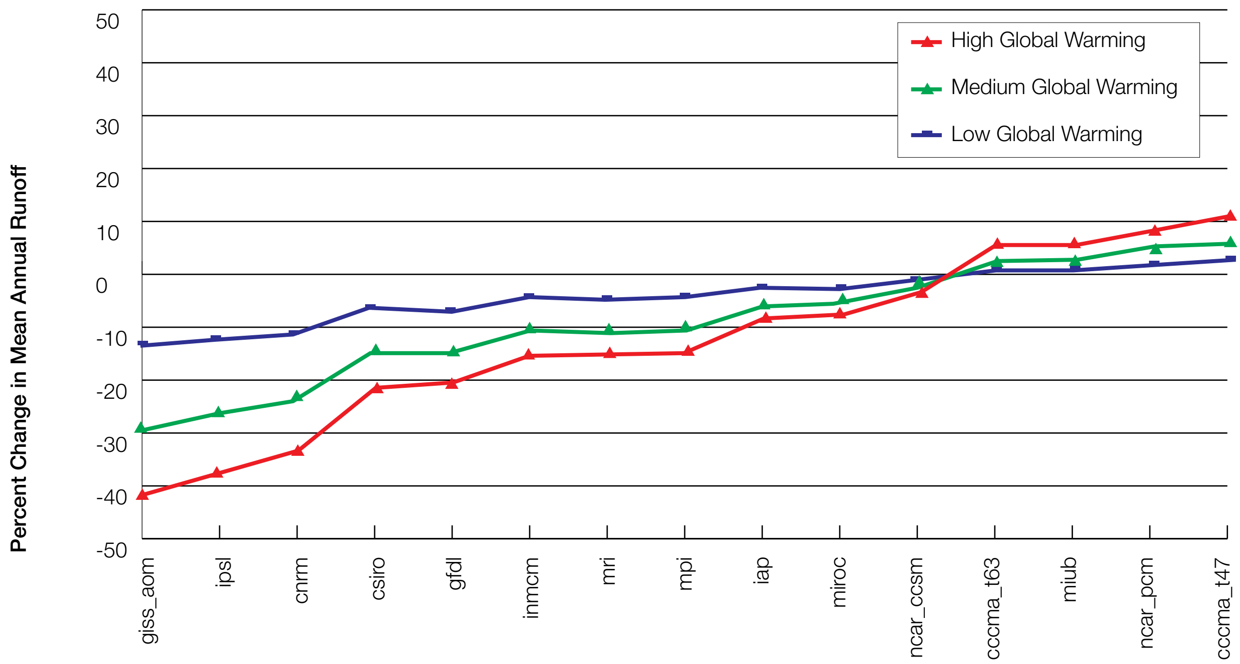
The potential impact of climate change on run-off can be very significant, as shown in **Figure 7.12**. Although there is considerable uncertainty in the estimates, the results indicate that run-off in 2030 in the Murray region is more likely to decrease than increase (CSIRO, 2008a).

Garnaut (2008) describes uncertainty as arising when:

an event is of a kind that has no close precedents, or too few for a probability distribution of outcomes to be defined, or where an event is too far from understood events for related experience to be helpful in foreseeing possible outcomes.

Humans are often required to form judgments about events that are unique, or so unusual that analysis based on secure knowledge and experience is an absent or weak guide. Bayesian decision theory encourages us to treat decisions under uncertainty as if we were taking a risk (Raiffa, 1968; Raiffa and Schlaifer, 1961; cited in Garnaut, 2008). Garnaut (2008) states that we will make the best possible decisions under uncertainty if we force those who are best placed to know to define subjective probabilities that they would place on various outcomes, and work through the implications of those

Figure 7.12: Percentage change in mean annual runoff (2030) in the Murray region under the 45 Scenario C simulations (15 Global Climate Models and three global warming scenarios) relative to Scenario A runoff (CSIRO, 2008a)



assessments as if they were probability distributions based on experience. These subjective probability distributions can then be updated on the basis of experience.

The climate models on which the IPCC assessments are made are diverse and provide numerous observations on possibilities out of their diversity. In addition, each generates numerous results from repeated experiments (Garnaut, 2008). These are the senses in which the IPCC science draws from probability distributions. There are many points at which judgment rather than experience informs the model relationships.

In considering decision-making under conditions of climate change uncertainty, Garnaut (2008) states the following:

Under conditions of such uncertainty, it is sensible to ask whether it would be better to delay decisions while information is gathered and analysed. However, it is as much a decision to do nothing, or to delay action, as it is to decide to take early action. The issue is whether delay would be a good decision. When global warming first became a major international public policy issue nearly two decades ago, it may have been good policy to take modest and low-cost steps on mitigation, while investing heavily in improving the information base for later decisions. In 2008, the costs of delay—in the probabilistic terms that frame a good decision under conditions of uncertainty—are high.

CSIRO proposed a framework for considering the uncertainties of predictions. This framework considered the magnitude and threat of the modelled change and the uncertainty of the analysis (shown in **Figure 7.13**).

The environmental and social implications of the climate modelling suggest a categorisation of 'high threat', therefore calling into question the adequacy of water sharing arrangements regardless of the level of uncertainty. Although the specific trajectory of the future climate at a specific site has a high level of uncertainty, there is a consensus in the predictions about broad-scale trends.

7.5 Climate change scenarios used in this assessment

For the remainder of this assessment, the NRC has based its modelling on the following three climate scenarios drawn from the MDBSY Project (CSIRO, 2008a):

- the historic climate base case (Scenario A)
- the continuation of the recent drought (Scenario B)
- the best-estimate (median) 2030 climate (focusing on the median of the range, and where uncertainty is reported as a wet extreme and a dry extreme in the range) (Scenario C).

Salt scalds at Lake Victoria State Forest

These three climate scenarios (applied in the MDBSY Project) are derived from the latest modelling for the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007).

In the following chapter, the future flooding regimes at selected sites are assessed based on the three climate scenarios outlined above. The MDBSY Project indicates that the wet-extreme 2030 climate would lead to little change in flood frequency for the assessed environmental sites. However, flood events would be somewhat larger, except in the case of the Gunbower-Koondrook-Perricoota Forest, where event size would fall slightly. These hydrological changes would not be expected to have additional impacts on the assessed sites.

The dry-extreme 2030 climate would cause hydrological changes slightly more severe than a long-term continuation of the recent climate. Thus it is considered that the range of possible impacts under climate change for flooding are adequately presented in the selected three scenarios used in this assessment.

Due to divergence in the range of possible greenhouse gas emission trajectories, projections further into the future (that is, beyond a 2030 climate) become increasingly uncertain. By 2070, the median climate under high global warming is expected to be broadly similar to the dry-extreme 2030 climate. Further, as stated earlier, the rate of global emissions growth since 2000 has been greater than for the most fossil-fuel intensive of the IPCC's emission scenarios. CSIRO (2008d) notes that this highlights the need for flexibility and adaptive capacity in water resources management in the Murray-Darling Basin.

Figure 7.13: Framework for considering uncertainty of modelled predictions (adapted from CSIRO, 2008)

	Low threat	High threat
Low uncertainty	Current water sharing arrangements appear sufficient for ongoing management of water resources.	Current water sharing arrangements are likely to be inadequate for ongoing management of water resources, as they do not adequately consider future threats.
High uncertainty	Current water sharing arrangements appear sufficient for ongoing management of water resources, but careful monitoring and adaptive management is recommended.	Current water sharing arrangements are likely to be inadequate for ongoing management of water resources. Further work to reduce the major sources of uncertainty can help guide changes to water sharing arrangements.