Journal of Developments in Sustainable Agriculture 1: 17–24 (2006)

Can Australia Overcome its Water Scarcity Problems?

Colin Chartres[1] and John Williams[2]

[1] Science Advisor, National Water Commission, 95 Northbourne Avenue, Canberra, ACT 2600, Australia (also CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601, Australia)
[2] Chief Scientist, NSW Department of Natural Resources, 23–33 Bridge St., Sydney, NSW 2000 and Member of the Wentworth Group of Concerned Scientists

Australia is a continent of extremes with respect to water resources; relative abundance in the tropical north where few people live and relative scarcity in the more populated, temperate south. In addition, both south and north are affected by wet/dry seasonal climatic conditions and the south, in particular, by increasing climate variability marked generally by declining rainfall. In the south, previous poor governance systems have led to the over allocation of surface and groundwater supplies and there is increasing competition for water from irrigators, urban/domestic, industrial and mining users. As a consequence, there has been a major deleterious impact on the health of many rivers and their associated environments. Therefore, Australia is confronted with a major question; can water productivity and water governance be improved to ensure environmentally sustainable and productive river systems? This paper examines how this may be achieved. It concludes that economic reforms coupled with scientific and management innovation may alleviate many of the water scarcity issues.

Key words: water scarcity, water productivity, policy, innovation, sustainability

Water Resources in Australia

Water scarcity is becoming an increasingly significant problem for many countries. According to an International Water Management Institute definition, a very significant portion of the world is projected to suffer from both physical (1000 m^3 per person/annum renewable water supply) and economic water scarcity by 2025. While Australia's water resources are well in excess of this per capita definition of scarcity there is growing concern that export of "virtual water" in food may be to the detriment of our environment.

Australia's water resources are highly variable (Table 1), and reflect the range of climatic conditions and terrain nationally. In addition, the level of development in Australia's water resources ranges from heavily regulated rivers and groundwater resources to rivers and aquifers in almost pristine condition. Over 65% of Australia's runoff (Fig. 1) is in the three drainage divisions located in the sparsely populated tropical north. In contrast, most large urban cities are situated in southern regions with irrigated agriculture principally located in the Murray Darling Basin where only 6.1% of the national run-off occurs. Therefore, Australia has significant water resources, but the populations and agricultural activities are concentrated where water resources are most limited. Australia has approximately 413,000 gigalitres (GL) of water available annually (Table 2). The best estimate of how much water can be diverted and turned to human use is approximately 105,000 GL.

At present, Australians extract about 70,000 GL and consume about 25,000 GL, of which 16,660 is used in agriculture. However, the consumption in irrigated agriculture is increasing (Fig. 2) —by about 15 percent in the past three years—and as agriculture consumes 70 percent of the water re-

Received: October 27, 2005, Accepted: February 1, 2006
Corresponding Author: Colin Chartres, E-mail: Colin.Chartres@csiro.au

Table 1. Variability of flow in some of the world's major rivers compared with two Australian rivers.

COUNTRY	RIVER	RATIO BETWEEN THE MAXIMUM and the MINIMUM ANNUAL FLOWS
Switzerland	Rhine	1.9
China	Yangtze	2.0
Sudan	White Nile	2.4
USA	Potomac	3.9
South Africa	Orange	16.9
Australia	Murray	15.5
Australia	Hunter	54.3

Table 2. Annual water availability/use in Australia 2000-2001 (NLWRA, 2001; ABS, 2004)

Mean annual run-off	**387,184 GL**
Annual groundwater sustainable yield	**25,780 GL**
Water consumed	**24,908 GL**
· Agriculture	16,660 GL
· Forestry and Fishing	27 GL
· Mining	401 GL
· Manufacturing	866 GL
· Electricity and Gas	1,688 GL
· Water Supply, sewerage and drainage	1,794 GL
· Household water	2,182 GL
· Other(1)	3,973 GL

(1) includes service industry and recreational water uses etc.

sources, Australian agriculture must learn how better to turn that scarce water into wealth and well being for our communities.

Two million hectares of Australia (<1% of the land surface) is irrigated and this generates about 50 percent of our profit from agriculture. Nearly 75% of this irrigated agriculture occurs in the Murray-Darling Basin where water demand and levels of water extraction from rivers and groundwater are now unsustainable. About 75% of the mean annual flow in the basin is diverted with the result that the mouth of the Murray has often closed in recent years of lower rainfall. To cope with climate variability more than twice the average annual flow in the basin is held in storage (Fig. 3). Such high levels of storage and extraction have very damaging impacts on the heath of the rivers, floodplains, wetlands and estuaries of the Murray—Darling. Recognizing this, Australians ruled a line and agreed to cap extractions at 1995 levels in

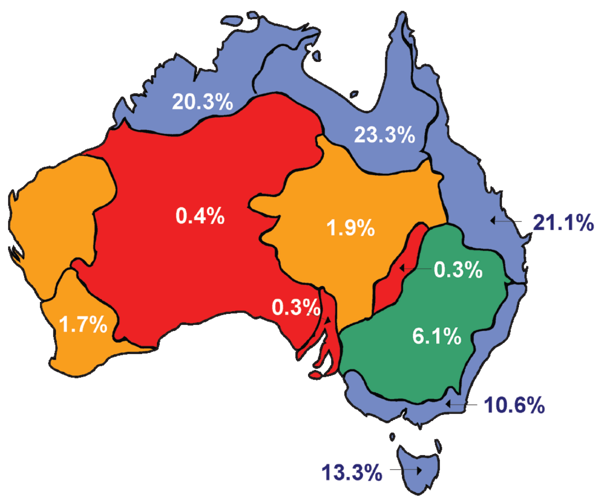

Fig. 1. Australia's distribution of run-off (Source: *Water and the Australian Economy,* April 1999).

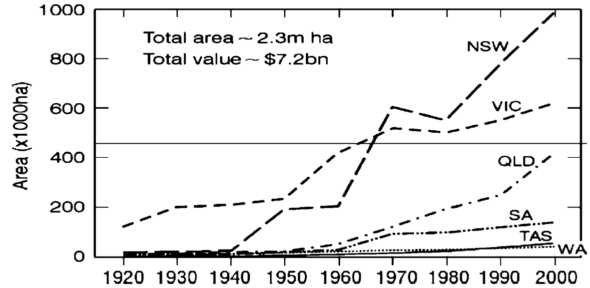

Fig. 2. Development of irrigated areas in Australia.

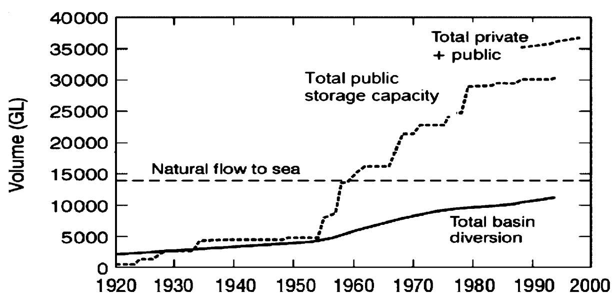

Fig. 3. Storage capacity and diversions in the Murray-Darling Basin from 1920 to 2000.

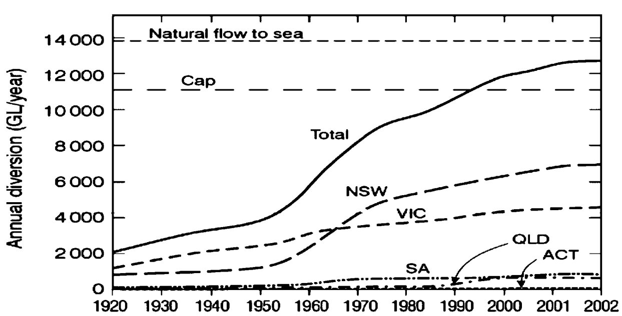

Fig. 4. Growth in water use in Murray-Darling Basin 1920 to 2000.

1994 (Fig. 4). This was one of the first and most important policy decisions in the Murray-Darling, which recognized that the limits of sustainability had been overreached.

The major challenge facing Australia is that of balancing water extractions for irrigation and other uses with provision of appropriate environmental flow to maintain healthy rivers and thus serve the needs of all users of rivers and groundwater. Experience demonstrates that if regulators place a cap on surface water, demand is transferred to groundwater. However, in reality surface and groundwater must be managed conjunctively. While returning increased flows to rivers in southern Australia is a major challenge and absolutely critical to river system health, many other land management factors such as drainage, nutrient and chemical pesticide loading are also very important to the health and ecological function of rivers, groundwater, wetlands, floodplains and estuaries.

Potential Impacts on Water Resources with Changes in Climate and Land Use

Climate Change and Variability

Climate change projections (as summarized by Hennessy, 2003) for Australia show increased potential evaporation, a tendency for decreases in winter-spring rainfall (June-November) over the southern half of the continent and a tendency for increased summer/autumn rainfall (December-May) in northern Australia. The possibility of a longer and more intense Australian monsoon would lead to greater water surpluses in an area where human use is low, so environmental flows would be enhanced. In Southern Australia, where winter and spring rainfall are more important and competition for water between natural and human uses is already high, reductions in water supply appear to be much more likely with the possible exception of Tasmania.

Climatic change and Australian natural climate variability are inextricably linked and while the underpinning science of climatic change is solid, much remains to be understood (Pearman and Hennessy, 2003). This inextricable link between natural long term variability and drivers of climatic change is well illustrated (Fig. 5) by the 100 years data from the Warragamba Dam, the major water supply to Sydney. Since the construction of the Warragamba Dam between 1948 and 1960, the 7 year moving average rainfall and run off to the dam have been declining to levels that appear to be consistent with pre 1950 averages. A return of low inflow to the dam similar to this 1900–1950 period will present real difficulties for Sydney's water supply. It is on this high variable and cyclic pattern of rainfall that climate change (both magnitude and variability) is to express itself.

The evidence is that climatic change will increase the difficulties Australia faces to secure adequate

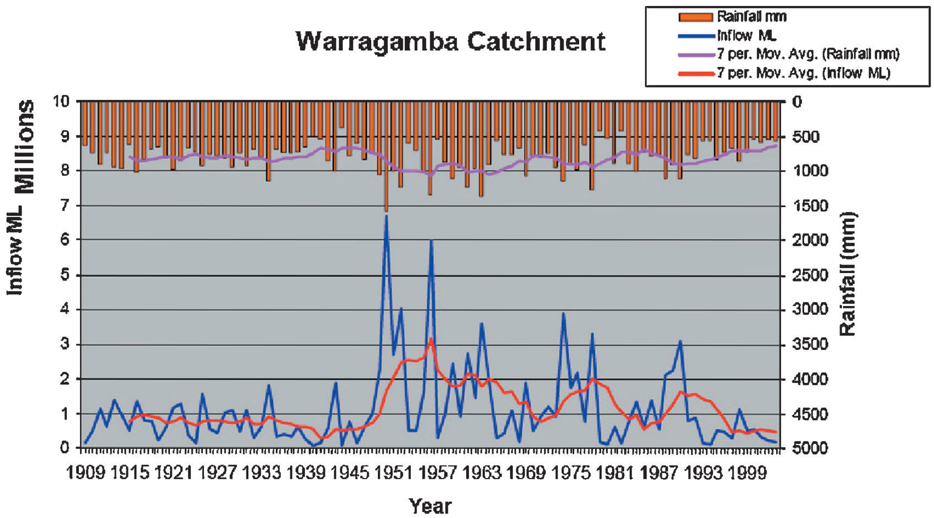

Fig. 5. Rainfall and runoff in the Warragamba catchment from 1900 to 2003 (Source Cox, 2005).

water supplies for cities and irrigation.

Change in Vegetation Cover and Land Use

There has been a surge of investment and activity in plantations, farm forestry and general revegetation in Australia. The essential design criterion of sustainable farming is to ensure that present day flows of water, nutrients, carbon and energy match the magnitude of the flows that have evolved to suit the way our landscape functions. This will require some radical changes in land use, incorporating both commercial tree production and revegetation with tree-dominant native vegetation. Plantation and farm forestry, agro-forestry, new agricultural production systems and restoration of native vegetation present opportunities to create a landscape with a mosaic of vegetation that has a similar water-use pattern to the original native vegetation. This future landscape has the potential to treat both rather the cause of land and water degradation problems and generate wealth sufficient to sustain viable rural communities. Most importantly, this tree-based mosaic has the potential to maintain and enhance biodiversity and deliver a suite of ecosystem services, including carbon sequestration, habitat diversity, salinity control and clean water.

Recent synthesis (CSIRO, 2004) acknowledged that concerns have arisen that, in some situations, expansion of forestry on a large scale could diminish flow to streams and groundwater and threaten water availability and water quality. Competition for water resources between forestry, revegetation with tree-dominant native vegetation and other uses can lead to disruption of industries and resource development, as well as community conflict.

The Water Reform Process in Australia

Water in Australia is vested in the State and Territory governments that allow other parties to access and use water for a variety of purposes, including for irrigation, mining and other industrial uses, and servicing rural and urban communities. As demonstrated previously, by the second half of the last century, it was clear that those natural equilibria essential to the healthy functioning of the natural resource base had been upset by over exploitation of our natural resources. In 1994, all State and Territory governments agreed on a package of reforms covering water prices, allocations and trading, environmental and water quality, and public education. In agreeing to the reforms, the governments formally acknowledged for the first time that Australian rivers, catchments and aquifers do not stop at state boundaries and that development activity in one state can have impacts in other states.

By the late 1990s the Australian Government was sufficiently concerned at the range, breadth and cost of land and water degradation problems that it commissioned a nationwide National Land and Water Resources Audit (NLWRA, 2001), which showed that 26% of Australia's surface water management areas and some groundwater management units were either close to, or overused compared with their sustainable flow regimes.

More recently high levels of water extraction and few, if any, natural flood events have put further stress on the River Murray. In 2003 this was recognised with "The Living Murray" initiative aimed at returning 500 GL of water to the river for environmental flow purposes.

The Council of Australian Government's (CoAG) latest response to ongoing water issues has been to develop an intergovernmental agreement called the National Water Initiative (NWI). The NWI was signed in recognition of the continuing national imperative to increase the productivity and efficiency of Australia's water use, the need to service rural and urban communities, and to ensure the health of river and groundwater systems. It is a comprehensive package of reforms related to water entitlements, trading and sustainable use.

Responses and Opportunities Related to Water Scarcity

Southern Australia, at least, is faced with dealing with the ramifications of a growing population, variable climate and increasing water scarcity. To cope with these the reform process has to include incentives that improve water use efficiency and productivity. Therefore, the NWI is stimulating and guiding the following developments in water management:

Whole-system thinking

Many water scarcities have developed because our management has failed to apply whole-system thinking to water supply, re-use, consumption and return of water to natural water bodies. Stream flow and groundwater are often managed as independent entities as are urban storm water, sewage treatment and effluent reuse. Progress in Australia has built on taking an integrated approach underpinned by recognition of interactions in the water cycles (Fig. 6). For example, rivers are stressed by being dammed and regulated and by water extraction, when the pattern of flow is changed. Over-extraction of water can endanger native fish, increase salinity and the incidence of algal blooms, and damage vegetation in wetlands and floodplains. Changes in river flow regimes affect groundwater recharge and discharge patterns to and from wetlands, billabongs and flood plains. The death of Red River gums in the billabongs and floodplains some distance from the Murray River is the result of declining and increasingly saline groundwater and lack of fresh water recharge.

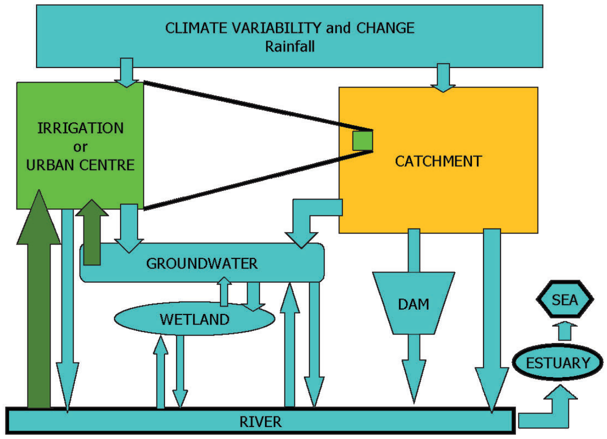

Fig. 6. Water flows to be managed in irrigation within a whole-system approach.

Integrated catchment management is now an operating principle for the implementation of CoAG's water reform initiatives and is central to the establishment of catchment management authorities in Victoria and New South Wales and similar structures in the other states. Regional management of catchments using many of the conceptual frameworks that have evolved from a whole-system approach are now established practices.

Technical Innovations

Technical innovations in the water industry encompass a wide range of possibilities including more effective and cheaper ways of treating waste and saline water for reuse, improved leak detection systems for urban and irrigation water conveyance systems, the use of solar energy to desalinate water, remote sensing technologies that improve our understanding of the vertical and horizontal distribution of fresh and saline water resources, improved modeling of water systems that facilitate adaptive management responses and engineering improvements that reduce the amount of water required to process materials in mining, agricultural value adding and manufacturing.

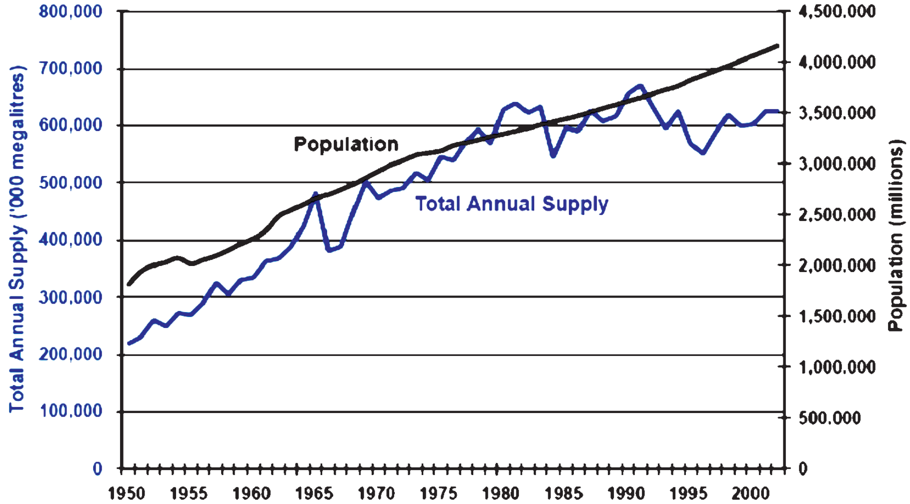

Fig. 7. Sydney's water supply in relation to its population growth (Source WSAA, 2005).

Urban systems

Limited sites for new dams and climatic variability mean that Australian urban communities need increasingly to look at using water more efficiently and conserving scarce supplies. In 2003, water usage in Australia's 22 largest cities was 2,065 GL of which 59% was residential and 28% was used for industrial, commercial, local government, parks and fire fighting. Nationwide about 9% of the total effluent was reported as being recycled. In 2001/02, over 500 sewage treatment plants nationwide contributed to this recycling with less than 200 GL per year. Demand and pricing management have meant that Sydney, for example, has been able to accommodate population growth. Until 1985 population growth and water consumption paralleled each other (Fig. 7). However, subsequently consumption has flattened off enabling the city to accommodate an extra 700,000 people without growth in water demand. Therefore, we have built major infrastructures and enabled Sydney to grow by 3 million people during what appears to be a rainfall sequence that is much wetter than the first 50 years since federation in 1901.

A number of other initiatives that go under the umbrella headings of "integrated water system management" and "water sensitive urban design" include opportunities to incorporate third pipe "grey" water systems for toilet flushing and garden watering in new housing developments, increased treatment of effluent and its reuse for industry and irrigation, sewer mining and treatment for localized irrigation of parks and sports grounds and storm water capture and treatment to substitute for potable water in a wide range of non potable uses. However, non-potable reuse is still faced with considerable regulatory hurdles to overcome. Socially and politically substitution of drinking water by treated effluent and storm water for non-potable uses has a large scope to alleviate the demand for new potable supplies. However, indirect potable reuse of treated sewage will in some instances have to be considered.

Water use efficiency and productivity gains

As elsewhere in the world, Australia's irrigation systems suffer from problems associated with losses in storage and conveyance, on-farm losses and variable water use efficiency. The Murray Darling Basin Commission has demonstrated that for the basin as a whole, 25% of diversions for irrigation are lost during conveyance in rivers, 15% are lost from canals and 24% lost on the farm, meaning that only 36% of irrigation water is actually delivered to plants. Such losses are not atypical across the world. The data for the Murrumbidgee Irrigation Area (MIA) (Table 5) do not include river conveyance losses and indicate on farm losses greater than the overall MDB average. Simply increasing water use efficiency (WUE) is not the solution to better use of irrigation water. Technically, WUE tells us how much water is consumed

Table 5. Surface water irrigation efficiency (personal communication Shahbaz Khan)

Key Indicators	Liuyuankou China	Rechna Doab Pakistan	MIA Australia
Area (ha)	40,724	2,970,000	156,605
Losses from Supply System (%)	35	41	12
Field Losses (%)	18	15	11
Net Surface Water available to crop (%)	46	32	77

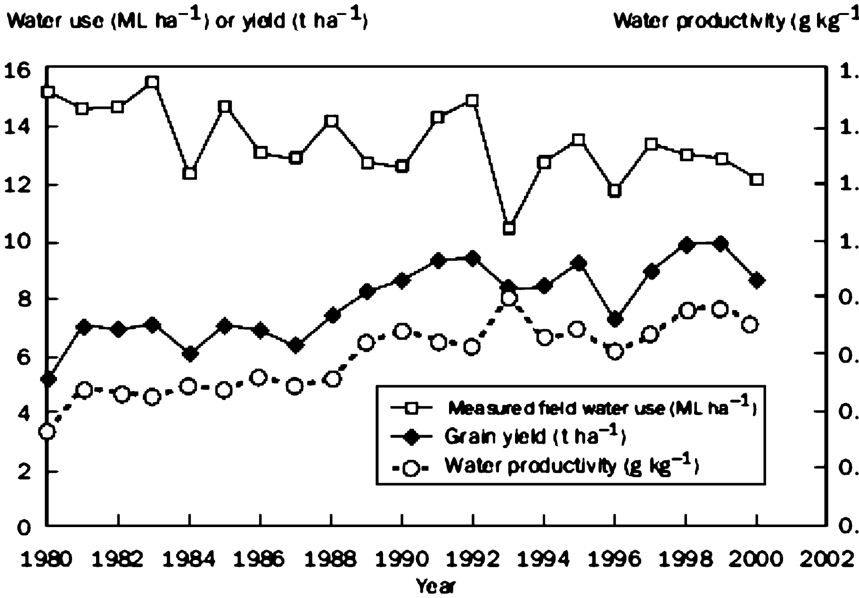

Fig. 8. Rice irrigation water use efficiency trend —Murrumbidgee Irrigation Area (MIA) (Source: CRC for Rice Production (Humphreys and Robinson, 2003).

by the crop and how much wasted. However, the real wastage comes from not being as productive as possible with the water that is consumed. Efficiency can be high with consequent detrimental environmental consequences, while productivity is low. Growing more food with less water alleviates scarcity, contributes to food security and puts less strain on nature. The most effective way to increase water productivity is to shift water use by trading from low value to high value crops. To facilitate this, water entitlements, trading regimes, market factors and other complicated issues such as stranding of assets all have to be taken into account.

Over the last 60 years, Australian agricultural productivity in dry land and irrigated systems has increased on average by 3% per annum (Knopfke *et al.,* 2000). This has kept Australian farmers internationally competitive in the face of declining terms of trade for agricultural products and subsidies on agricultural production offered by some competitors.

While many of these improvements have come from plant breeding, disease and pest management and soil and fertility management, improved use of available water has also been very important. For example, the productivity of Australian rice production has increased from about 0.4 g/kg of water used to 0.8 g/kg over the last 20 years with a concomitant reduction in water used from about 16 to 12.5 Ml/Ha (Fig. 8).

Conclusions

Australia is at the crossroads in terms of its ability to cope with increasing water scarcity in that it has to choose between the more expensive capital and environmental options of more storages and desalination, or minimizes these via better water reuse strategies and increased water productivity. A vigorous reform process is underway that is focusing on governance, productivity and environmental issues. This will require a level of commitment by state and federal governments to drive the reforms and oversee a major re-allocation of water between irrigation activities, from irrigation to river and groundwater flow and some movement of water from irrigation to urban use. Irrigation water will tend to move away from low value production to higher value production for water use. If reforms allow third party access to urban sewage and effluents there will be incentives for innovations in re-cycling and greatly increased water re-use. The capacity to manage periods of adjustment, including through water trading, will be difficult but critical to success. If the reforms are able to establish a framework that allows water trade and economic incentives develop that encourage and support innovation then we can expect to see a significant increase in water productivity across industries while returning sufficient water to our stressed rivers, floodplains, wetlands and estuaries. These reforms may also enable us to avoid mistakes made in the south as our northern rivers come under increasing developmental pressure.

References

ABS. 2004. Australian Water Account (4610.0) 2000-2001. Australian Bureau of Statistics, Canberra.

Cox, D. 2005 Overview of Water Resource Management in Australia. In *Role of Irrigation in Urban Water Conservation: Opportunities and Challenges.* CRC Irrigation Futures, 2005/1.

CSIRO. 2004 Maximizing the benefits of new tree plantations in the Murray-Darling Basin. A joint statement by CSIRO Forestry and Forest Products and CSIRO Land and Water available at http: //www.clw.csiro.au/new/FFP-LW19052004.pdf

Hennessy, K. 2003 Climate Change and its projected Effects on Water Resources Proceedings of the 2003 Invitation Symposium, WATER- The Australian Dilemma, Academy of Technological Sciences and Engineering. Canberra. p.174 (available http: //www.atse.org.au/uploads/Hennessy03.pdf)

Humphreys, E. and Robinson, D., 2003. Improving water productivity in rice cropping systems in Australia: institutions and policy. In: Proceedings of the 16th International Rice Congress. Beijing, 16–20 September 2002. International Rice Research Institute, LosBanos, Philippines.

Knopke, P. O'Donnell, V. and Shepherd, A. 2000. Productivity growth in the Australian Grains Industry. ABARE Research report 2000.1 Canberra.

NLWRA. 2001. Australia's Natural Resources 1997–2002 and beyond. Nation Land and Water Resources Audit, Commonwealth of Australia, Canberra.

Pearman, G.I. and Hennessy, K.J. 2003. Climate science: what do we know? In: Living with climate change: a national conference on climate change impacts and adaptation: Proceedings, Australian Academy of Sciences. Canberra: National Academies Forum. p. 3–31. http: //www.dar.csiro.au/publications/pearman—2003a.pdf

WSAA. 2005. Testing the Water. Urban water in our growing cities: the risks, challenges, innovation and planning. Water Services Association of Australia. WSAA Position Paper No. 1. (http: //www.wsaa.asn.au)