Modern Agriculture Under Stress – Lessons from the Murray-Darling

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The Murray-Darling Basin (MDB) in south eastern Australia is the nation's 'foodbowl' (figure 1). It is experiencing its lowest inflows in 116 years. A naturally highly variable system, the Basin is characterised by droughts and floods. However, the unprecedented longevity and severity of continuing dry conditions is resulting in significant impacts to communities, irrigators and the environment.

The Murray-Darling Basin Commission (MDBC) is a natural resource management agency which works with six governments to supply water for irrigators, urban consumers and to deliver environmental programs. This paper describes patterns of water consumption in the Basin; explains the factors which have contributed to the current extended drought conditions and details the responses by the MDBC and irrigators to these conditions. The immediate challenges of the drought and the future challenges associated with climate change and other 'risks' to water resources are examined.

Geography of the Basin

The MDB covers 14% of south eastern Australia, approximately 1 million square kilometres and roughly twice the size of Spain. Two million people live in the Basin and are dependent on it for their drinking water, as are another 1.2 million residents of the city of Adelaide. Long term average rainfall in the Basin is approximately 500,000 GL per annum, yet the vast majority of this evaporates. Average annual runoff is 24,300 GL with 11,400 GL of long term average diversions.

There are significant differences in rainfall and inflow reliability between the northern (Darling River) and southern (Murray River) parts of the Basin. These differences have influenced irrigation development, water use and planning. Historically, the most reliable rainfall in the Basin occurs in the alpine regions of the Southeast, which supplies the Murray River system. The mountainous relief of this high rainfall, high reliability region (shown in purple in figure 1) has facilitated the construction of major dams to store runoff. The Murray River is highly regulated, with over $2b USD of infrastructure. The two largest dams are Hume Dam (3033GL) and Dartmouth Dam (3905GL). The historically high reliability of inflows into these dams has supported the creation of very high reliability irrigation water entitlements and supplied urban and domestic water supplies throughout the Southern Basin.

The Northern Basin is very flat and has far less reliable inflows than the south. Eposodic rainfall events lead to major flooding approximately every decade, leading to opportunistic water use by irrigators. When in flood, the Darling River can contribute significant flows to the Murray system. However, these flows cannot be relied upon for high security Murray River entitlements. Most of the flow from the high rainfall areas of the Northern Basin is diminished by transmission losses and evaporation before reaching the Murray.

In the Murray River, there are also substantial distances between the point of water interception, mostly in Hume and Dartmouth dams and the locations at which it is consumed. Losses of approximately 1000GL are incurred annually between Hume dam and the South Australian border (approximately 1500km). Evaporation, channel capacity issues and fluctuating demand can create significant challenges, especially in dry periods when tributary inflows cannot be relied upon to augment storage releases.

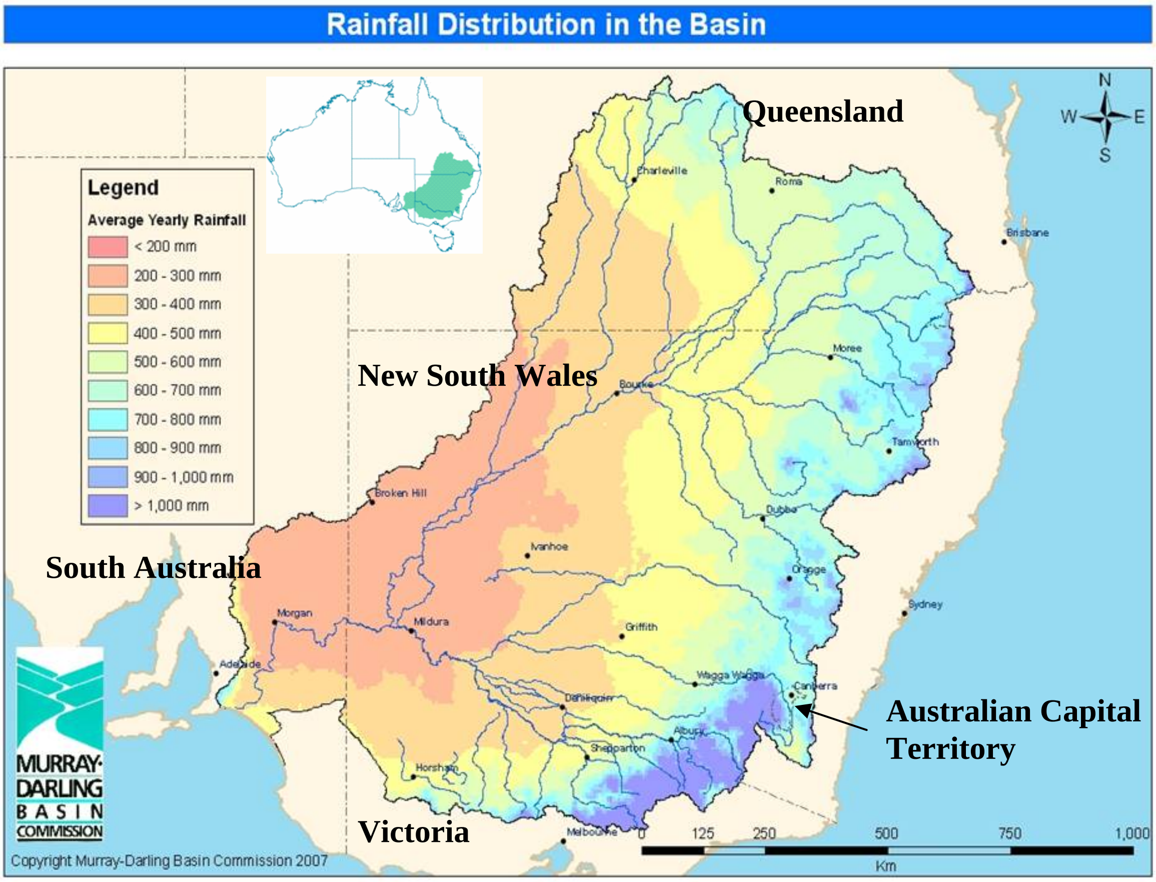

Figure 1: Rainfall distribution in the Murray-Darling Basin.

The balance of this paper focuses on the expected impact of climate change and the experience of the current drought on the high reliability Southern Basin (the Murray River system). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) estimates that the largest impacts of climate change will be in the Murray system. The capacity of the Murray to continue to supply water, at levels based on historical averages, for human consumption and irrigation has come into question.

General water use in the MDB

The MDB accounts for 40% of the value of Australia's agricultural output (ABS 2008, p91). The vast bulk of agricultural land in the MDB is not irrigated; only 2% of MDB land is irrigated and yet this produces 70% of the value of Australia's irrigated agricultural output. Water use in the Basin reflects the reliability of its supply. Annual cropping, such as cotton and grain, suits the episodic water availability of the Northern Basin (characterised by extremely variable rainfall). Consequently, Northern Basin permanent horticulture relies mostly on groundwater. The Southern (Murray) system, with its more reliable surface water supply, supports significant permanent horticulture as well as annual cropping and irrigated pastures, including for the diary industry.

Long term average water diversion in the Murray system is approximately 4068GL. However, there is a total of 5280GL of Murray River water entitlements. There is approximately 2487GL of high reliability water entitlements, and approximately 2793GL of low reliability water entitlements. The specific attributes of high and low reliability irrigation water entitlements vary between States and river valleys. On the Murray River, the long term average allocation against the high reliability Victorian entitlement, called a 'water right' is 99%. The long term average allocation against the low reliability Victorian entitlement, called 'sales water' is 80%. Approximately 350 GL of Murray River Water is used by urban and domestic consumers each year. The largest consumer of this water is the city of Adelaide (200GL), near the end of the Murray River.

The history of the Murray-Darling Basin Commission

The MDBC is an unincorporated joint venture between six governments. Unlike other 'Commissions' or 'Authorities', the MDBC was formed by an agreement between the six governments of the Basin: New South Wales, Victoria, South Australia, Queensland, the Australian Capital Territory and the Australian Government. The Murray-Darling Basin Agreement 1992 (the Agreement), is underpinned by parallel legislation in each jurisdiction. The Agreement encourages a collaborative approach, since all major decisions must be unanimously agreed at the Ministerial Council level; all partner governments contribute funding and many MDBC programs are delivered through state governments.

The Agreement's predecessor was the River Murray Waters Agreement, was first signed in 1914. Negotiations on this agreement occurred during a period when Federation and the Australian Constitution were being negotiated and use of the Basin's water resources was contested. Sandford Clark, an expert on legal issues in the Basin, believes that conflicting plans for utilising the Murray River had significant implications for the Australian Constitution (Clark 2002, p11).

In the early days of federation discussions (the later stages of the 19th century), the Murray River was primarily used for navigation and trade. In an effort to protect its interests in river navigability, South Australia (the most downstream State) argued to include section 98 of the Australian Constitution, which gave the Commonwealth power to pass laws with respect to navigation and shipping (Clark 2002, p11). New South Wales and Victoria, (upstream states) which had started to develop irrigation settlements on the Murray and its tributaries, insisted on a balancing provision. Section 100 states that "the Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a state or the residents therein to the reasonable use of water for conservation and irrigation". This Section defines rights with regard to water management and necessitated a cooperative approach, between all the MDB governments to share and manage its water resources (Clark 2002, p11).

The original 1914 Agreement had three objectives which ensured continued navigatability, but allowed irrigation development:

- joint funding arrangements for a number of water storages, and river regulation structures, that were to be built along the river;
- specification of water sharing rules between New South Wales, Victoria and South Australia. These rules effectively shared the River Murray's flow between New South Wales and Victoria, provided a specific annual and monthly volume was allowed to flow into South Australia, including dilution flow; and
- the establishment of a Commission that would oversee the construction and maintenance of new structures, ensure water was shared according to the rules and coordinate ongoing water management.

The Agreement that exists today has been altered twelve times, most recently in 1992, but it largely reflects the original principles. Through the power of the MDB Ministerial Council (Land, Water and Conservation Ministers of Basin jurisdictions) to direct the MDBC to perform additional functions, within the scope of the agreement, numerous natural resource management programs, which take a broad catchment approach, have evolved in addition to the MDBC's operational water and asset responsibilities prescribed by the Agreement. The MDBC's functions can be broadly grouped into three categories: day-to-day river and asset management, sustainable resource management and planning for the future.

Day-to-day River and Asset Management – The MDBC performs three key functions in this role. (1) Water availability assessments. These assessments, conducted throughout the irrigation year, are based on the amount of water in storage, the minimum expected inflows, minus expected losses. This water availability information is used by State governments to update irrigation allocations throughout the year. (2) River operations. The MDBC directs flow releases from the headwater storages and manages the flows along the river's series of weirs to meet all consumptive requirement upstream of SA border and deliver specified monthly water quantities over the SA border. (3) The MDBC controls (on behalf of the partner governments) and maintains over $2billion (USD) worth of water storage and river regulation structures.

Sustainable Resource Management – The MDBC coordinates a number of environmental and natural resource management programs. These programs include: the Cap on diversions, which limits mostly primary irrigation diversions throughout the Basin, to 1993/94 levels of development; The Living Murray, an environmental recovery program, which is returning 500GL of water to the Murray System and delivering it to icon sites; the Native Fish Strategy, which aims to restore native fish population to 60% of pre-European settlement level; and the Basin Salinity Management Strategy, which aims to 'hold the line' on salinity for environmental and consumptive use benefits.

Planning for the Future – The MDBC is coordinating a recurring Basin-wide survey of river health, called the Sustainable Rivers Audit, which will inform future decision-making and environmental management initiatives; The Risks to Shared Water Resources Program was created in response to the threat that groundwater extraction, farm dam surface water interception, bushfires, changed land use practices and climate change pose on the reliability of water resources. The MDBC is active in developing and coordinating policy in numerous areas to facilitate efficient water use and achieve environmental outcomes.

The History of the Current Drought - Chronology

During the early phase of the current drought (1996-2005), annual inflows remained within the MDBC's planning minimums and historical variability of the system. 'High reliability' entitlements were consistently close to 100% allocated and critical stock, urban and domestic water supplies were always secure. The bulk of the drought's impact on irrigators was felt by those with traditionally 'lower' reliability entitlements. The average Victorian 'sales water entitlement' (a low reliability entitlement) allocation during this time was 54%, compared to a long term average of 80%. The environment also suffered during this period. Without significant natural floodplain inundation in the Murray valley since 1993, there was wide-spread decline in the health of floodplain ecosystems.

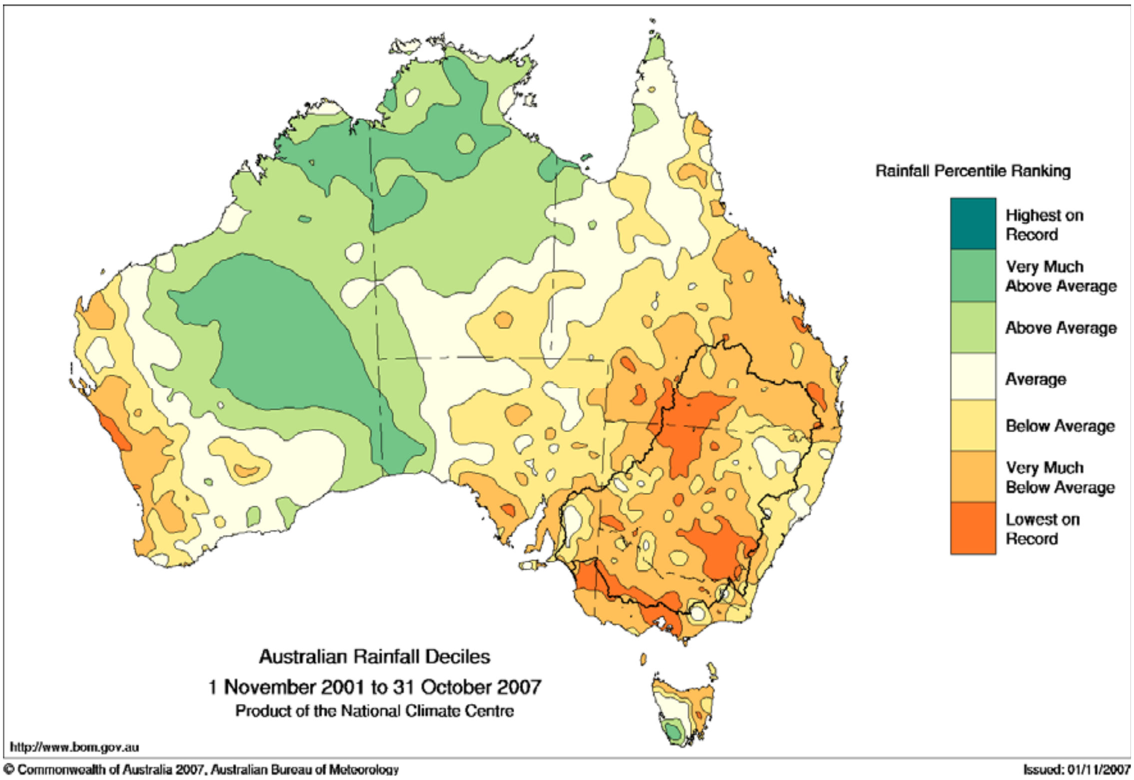

Figure 2: Australian rainfall deciles from the period 1 November 2001 – 31 October 2007 (Australian Bureau of Meteorology).

In 2006, conditions deteriorated significantly. By September 2006, it was evident that the autumn, winter and spring inflows had completely failed (figure 3). The September 2006 MDBC drought update forecast that 'total River Murray system storage could be drawn down to very low levels by the end of the 2006/07 season'.

By November 2006, NSW Murray and South Australian allocations, had been reduced for the first time on record. This was because allocation announcements had been based on the amount of water in storage and the minimum expected inflows for the remainder of the season. This strategy was underpinned by the assumption that the minimum inflow would exceed the record of 1920GL set in 1914/15. At the end of 2006/07, total Murray River annual inflows had set a new record low of 1040GL, approximately 60% below the 1914/15 record (figure 3).

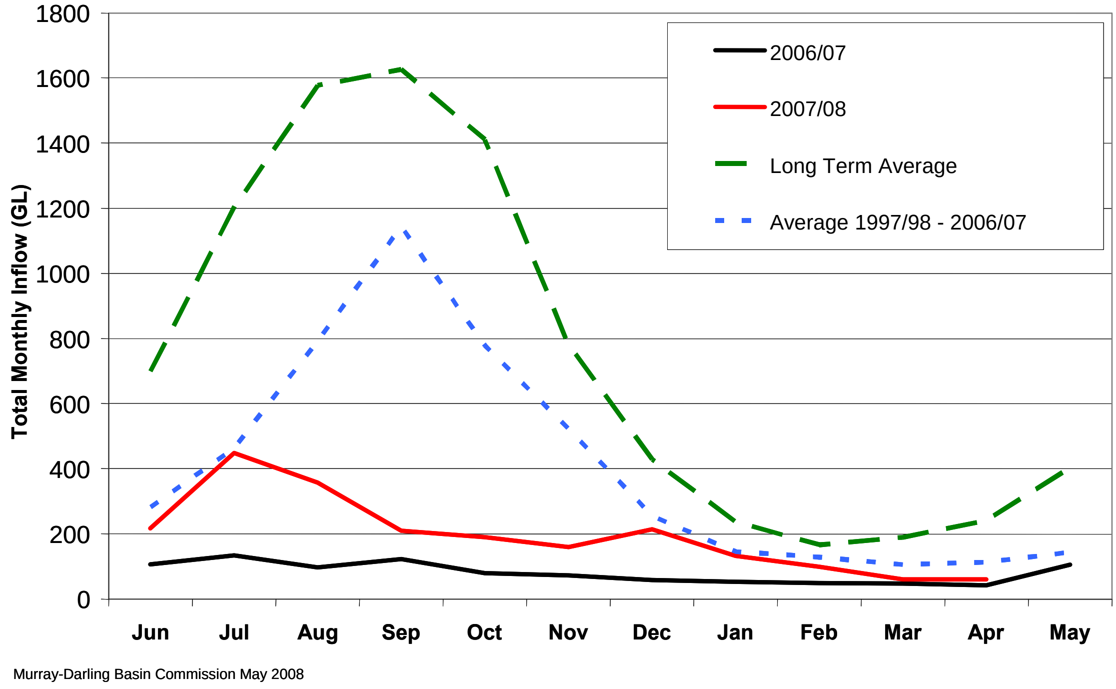

Figure 3: Monthly inflows into the Murray River system.

The combination of extremely low end of 2006/07 storage levels and the potential for very dry conditions to continue, threatened the guaranteed delivery of critical urban, stock and domestic water supplies during 2007/08. In response to this threat, on 6 November 2006, the Prime Minister convened a summit with the Premiers of the Basin states. The Prime Minister and Premiers agreed to form a contingency planning group which could reasonably assure critical human water delivery for the coming year. The MDBC Office was part of this group, providing water availability data and the development of water saving measures such as changed river operations and wetland disconnection.

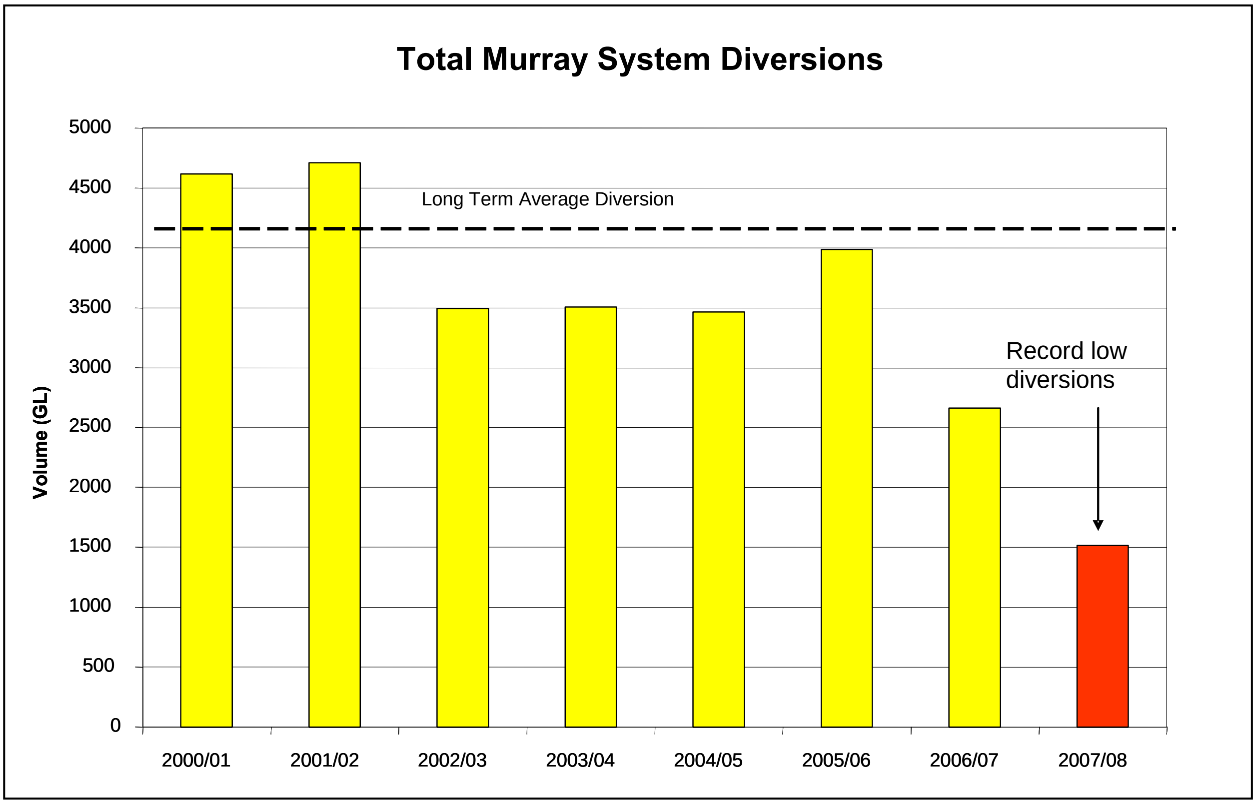

Figure 4: Murray River system total annual irrigation diversions.

Storage levels at the beginning of 2007/08 were very low. Opening allocations, even of high security entitlements, were zero in all states. Allocations would be entirely dependent on future rainfall dependent inflows during the year. At the time of writing, 2007/08 annual inflows remain in the bottom 5% of recorded years and MDBC river operations have focused on minimising evaporation and maximising consumptive water availability. Some improvements to allocations have occurred throughout the year. April allocations, effectively the end of the irrigation season are provided in figure 5.

The ability of individual irrigators to trade water allocations has significantly reduced the economic impact of drought, especially considering the disproportionate impact of water shortages on different valleys. Preliminary estimates indicate that approximately 30% of available water has been traded during this period. Prior to 2006, ‘leased’ water was traded for a maximum of approximately $200AUD. During 2007-08 ‘leased’ water reached a maximum price of above $1100AUD.

Entitlement	Allocation in April 2008	Long term average April allocation
Victorian Murray high	43%	98%
South Australian Murray high	32%	99%
NSW Murray high*	0%	85%
NSW Murrumbidgee high	90%	98%

* The 0% allocation against NSW high security Murray River Entitlements is a result of the need to ‘pay back’ the water that was withheld during 2006/07.

Figure 5: Murray River system allocations in April 2008, compared to long term average.

Why has this drought been so severe?

Rainfall during this drought has been comparable to previous dry periods (figure 6). However, inflows and water availability have been considerably lower. Five factors have made this drought worse than in the past.

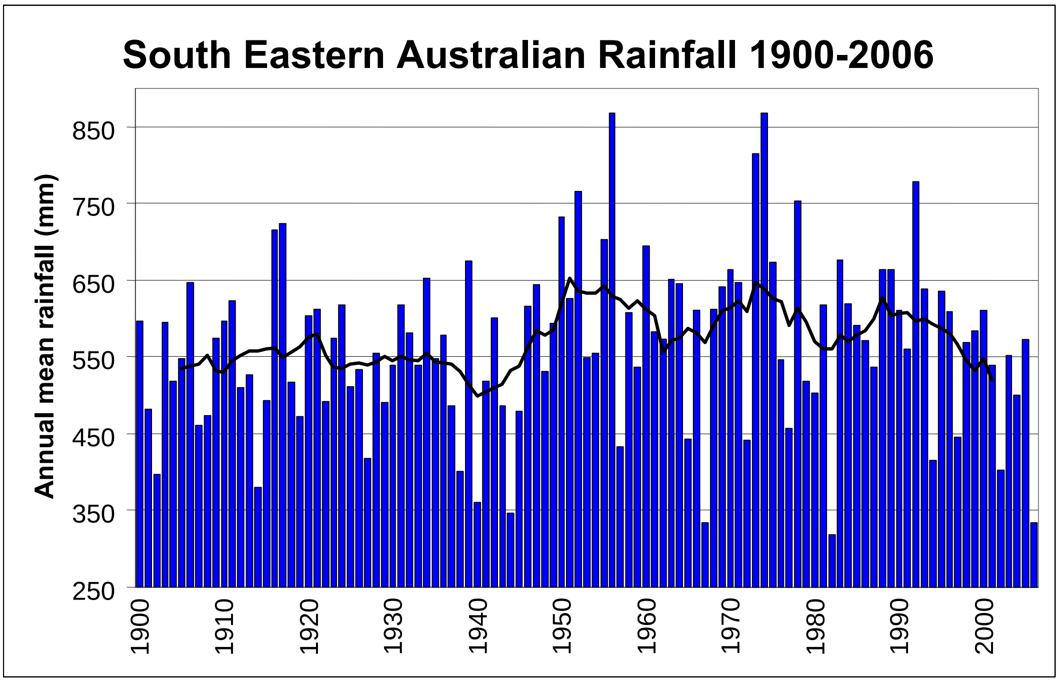

Figure 6: South Eastern Australian Rainfall 1900-2006 (Murphy and Timbal 2007).

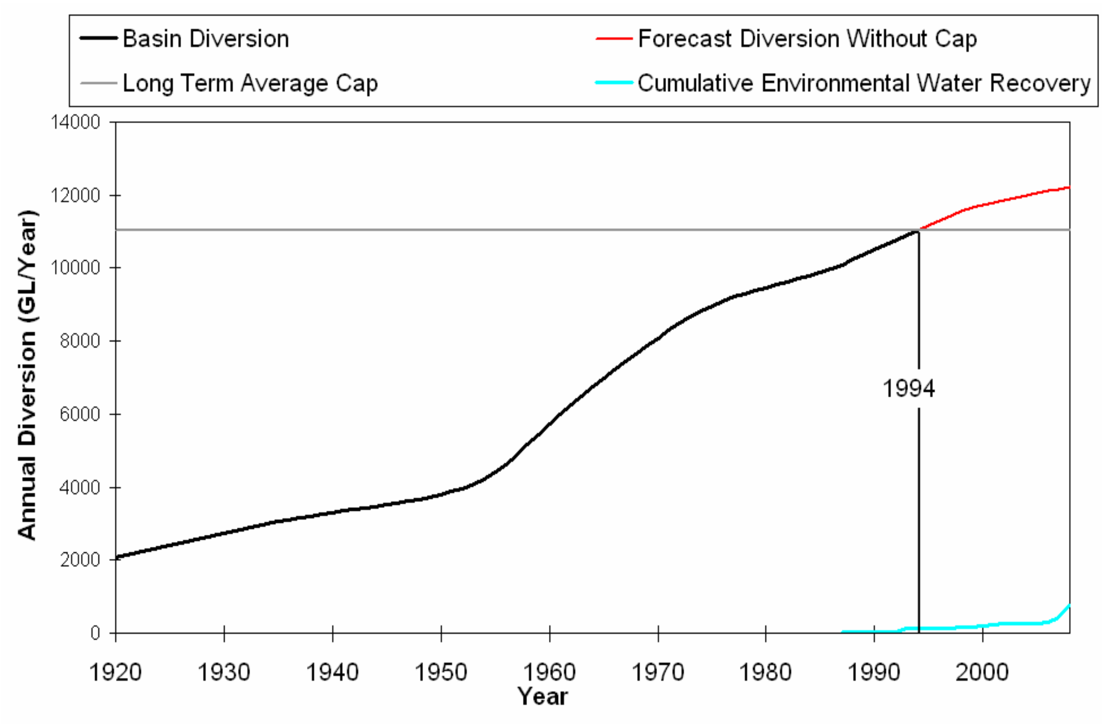

Figure 7: Total modelled MDB irrigation diversions (assumes average inflows).

Over allocation – the second half of the 21st century was significantly wetter than the first half. Consistently wet weather, dam construction between the 1950s and 1990, and the accepted wisdom that only a percentage of new entitlements would be utilised[1], underpinned an expansion in irrigation entitlements. A larger number of irrigators dependent on the resource than previous droughts exacerbates impact of the water shortage. The Cap, introduced in June 1995, limits water extraction to 1993/94 levels of development (figure 7). However, whilst the mechanisms of the Cap prevent further expansion in water diversions, the 1993/94 Cap levels do not necessarily reflect an environmentally sustainable level of extraction.

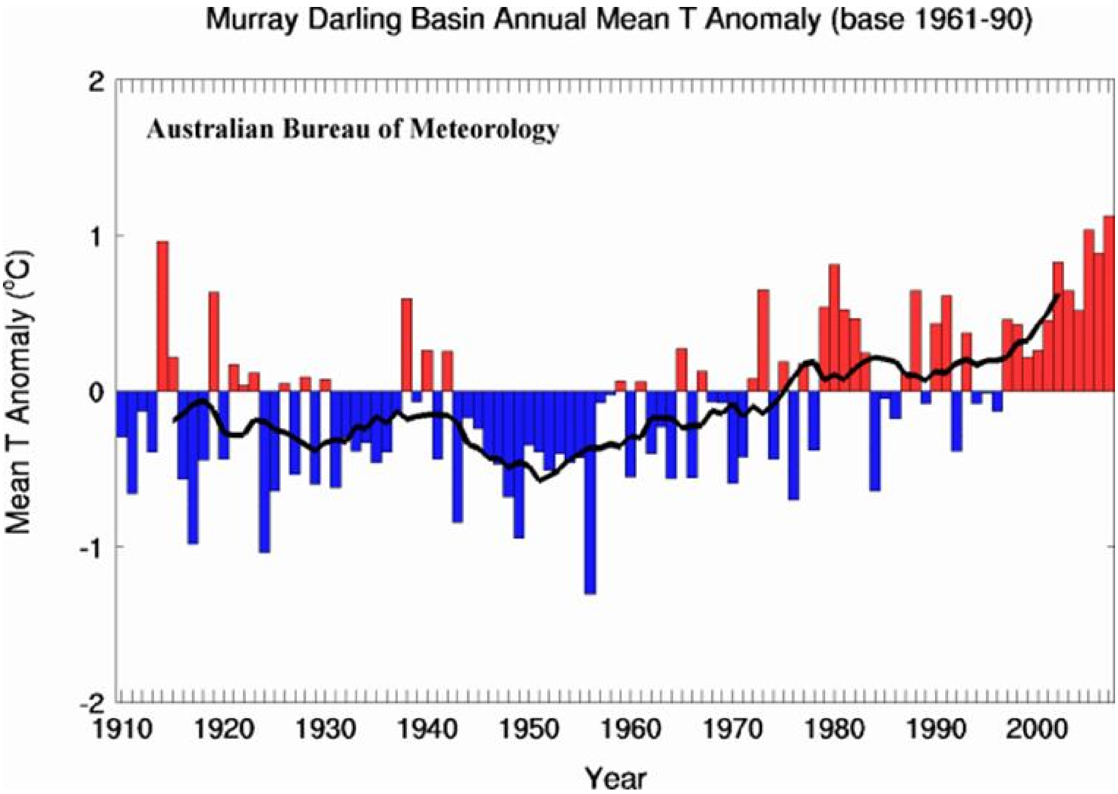

Figure 8: Murray-Darling Basin annual mean temperature annomally (Australian Bureau of Meteorology 2008)

Higher temperatures – according to the Bureau of Meteorology, three of the last five years, in the Basin, have been the hottest on record (of approximately 100 years of records). Higher temperatures increase evaporation and dry the catchment, resulting in less runoff. CSIRO

[1] In 1995, the MDBC conducted and *Audit of Water use in the Murray-Darling Basin* which revealed that only 63% of entitlements were activated.

research indicates that a 1°C increase in temperature will reduce runoff by 15% (Cai and Cowan 2008). The impact of higher temperatures and a drier catchment have been clearly evident since September 2007 when a La Nina system bought above average rainfall to most of the Murray River catchment between September 2007 and March 2008, yet inflows remained very low.

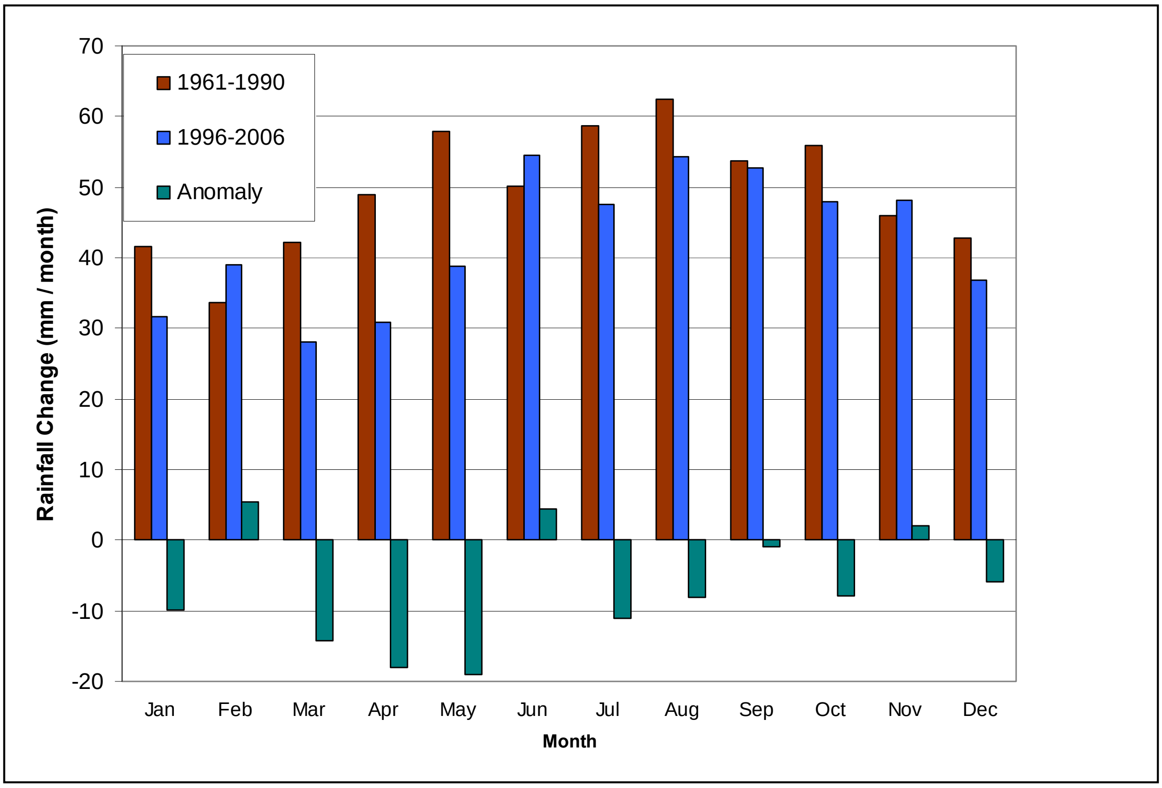

Figure 9: Monthly mean south eastern Australia rainfall, 1961-1990, 1996-2006 and anomaly (Murphy and Timbal 2007).

Changed rainfall patterns – Research by Murphy and Timbal (2007) indicates that a significant reduction in autumn rainfall has occurred over the MDB. Murphy and Timbal found that March, April and May have been proportionally more impacted by lower rainfall in the last decade than other months, when compared to 1961-90 (figure 9)[2]. The explanation offered by Murphy and Timbal is the strengthening of a 'subtropical ridge' of high pressure

[2] The MDBC has identified a high correlation between low inflows during the autumn months and a below average annual inflows.

over the Basin during the autumn months. Their research indicates that historically, the subtropical ridge is present in summer but weakens and moves rapidly north during autumn, allowing frontal systems to bring rain to the Basin (and south eastern Australia generally). Murphy and Timbal link the persisting southerly subtropical ridge to climate change and the effect diverting autumn storm systems to the south of the Basin (Murphy and Timbal 2007, and references therein).

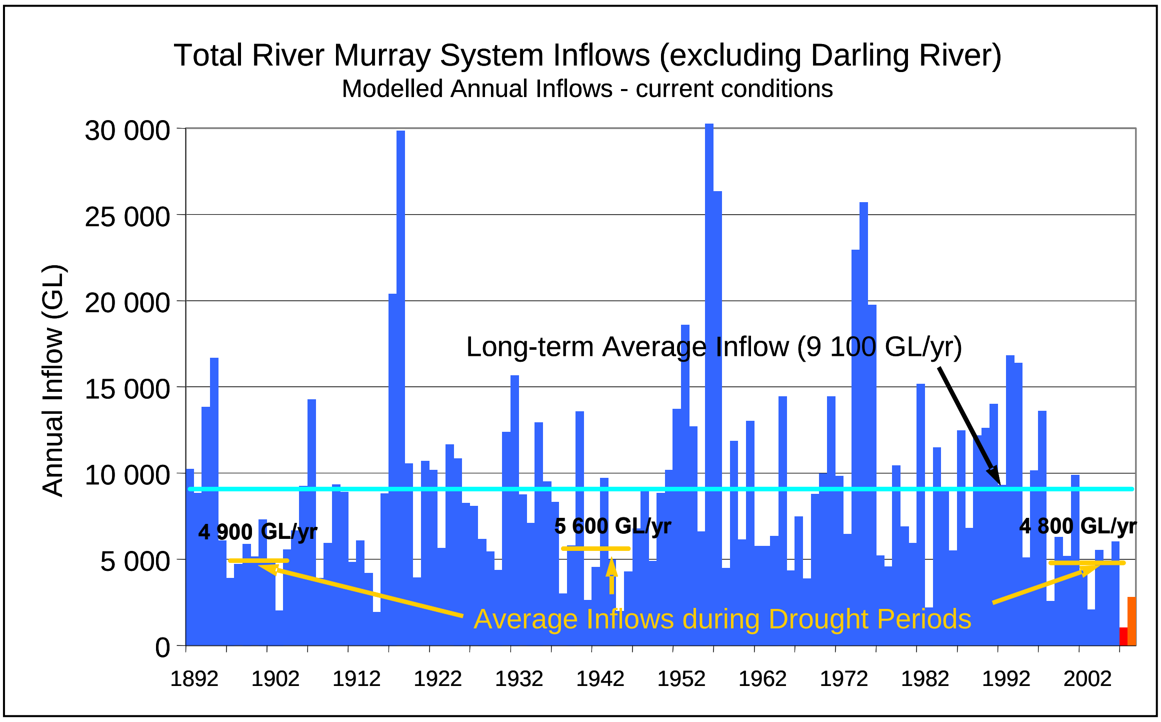

Figure 9: Total Murray system inflow, all years on record.

The lowest inflow year on record – total annual Murray River system inflow during 2006/07 was 1040GL, approximately 60% below the previous record minimum. Such an unprecedented dry year almost completely exhausted the Murray River's main drought storage, Dartmouth Dam. This has resulted in today's situation of allocations being almost entirely dependent on inflows. At the beginning of July 2006 Dartmouth Dam was approximately 65% of capacity, despite several years of very dry conditions. At the end of June 2007 it was approximately 13% of capacity. Such use of Dartmouth Dam is a measure of last resort under extreme dry conditions. Even if Murray River inflows return to long term average, under existing allocation policy, it will take several years for Dartmouth Dam storage levels to recover.

Two consecutive very dry years – following 2006/07, the driest year on record, 2007/08 has also been a very dry year. Never before, in the historical record, has an extreme dry year, been followed by another very dry year. Previously, the driest years on record 1902/03, 1914/15 and 1982/83 were followed by significantly wetter years, 5557GL, 8830GL and 11232GL respectively.

2006/08 drought mitigation strategies

Partner governments have responded to the unprecedented experiences of the 2006/08 by developing and implementing a range of strategies to reduce the impact of the drought on communities and irrigators and maximise water availability.

Carry over – during periods of very low water availability, the capacity to carry-over part of an allocation is an important individual risk management strategy. Until 2007/08, individual allocation carry over was only possible for some NSW irrigators and risk was essentially carried by governments. However, recent experience has demonstrated the advantages of allowing all Murray River system irrigators to carry over part of their allocations from one season to the next. Allowing more carry over, with minimal restrictions, is only possible because storages are at such low levels. Transparent rules will be required for carry over as storage levels recover and dam spilling is more likely.

Effectiveness of contingency measures – the MDBC, as a part of the contingency planning group, developed a series of water saving measures (for example disconnecting wetlands, increasing use of weirpools and reducing winter minimum flows) in order to secure critical urban, stock and domestic water supplies in 2007/08, should extremely dry conditions continue. The experience gained by implementing these measures will provide valuable operational experience should it be required in the future.

Flexibility of River operations – during very dry periods, when tributary inflows are very low, all demands must be met by releases from the headwater storages. The unprecedented dry conditions required changes to historical river operation strategies in order to minimise losses and maximise water availability. Lowering the water level at some weirs (weirpools) can capture tributary inflows and minimise releases from headwater storages. The impact that these strategies have on the recreational use of the river and weirpools must be balanced against the potential water savings.

Planning minimums – the planning minimum, pre 2006/07, was the 1914/15 record low Murray System annual inflow. This amount 1920 GL is sufficient to meet all critical urban stock and domestic requirements along the Murray, without a dedicated carryover. The 2006/07 experience has forced the MDBC and the States to re-evaluate the way critical requirements are guaranteed. State governments have carried over water sufficient to meet critical requirements should 2006/07 inflows be repeated during 2007/08 and 2008/09. As with irrigation allocation carryover, this measure can be implemented with zero impact on irrigators, while storage levels remain low. However, there is a trade-off between storing water for a critical requirements and allocating water for irrigation when storage levels increase.

The benefits of water trade – the Australian Productivity Commission estimates that 'moving from no trade to intra- and interregional trade together more than halves the impact of the reductions in water on the gross regional product (GRP) of the southern MDB'. Irrigators in the River Murray system have endured unprecedented water shortages during 2007/08. However, with the opportunity to buy or sell water, individual irrigators have greater flexibility to meet the challenges imposed by the drought. Preliminary estimates indicate that 35% of allocations have been traded during 2007/08.

Ongoing Issues

Looking to the 2008/09, critical water requirements have been reasonably secured, a number of contingency measures have been implemented and the water market has significantly decreased the economic cost of the drought. However, there are a number of persisting issues, relating to the continuing dry conditions.

Acid Sulphate Soils – the extended drought conditions have dried a number of previously permanently inundated wetlands. The permanently wet status of these wetlands, a result of river regulation, changed the soil chemistry and caused the build up of potentially acidic sediments. As the wetlands dry, the sediment can become acidic with considerable detrimental impacts to water quality and the environment. Additionally, recent research is indicating that re-wetting dried acid-sulphate sediments can lead to heavy metal mobilisation. The MDBC is currently focusing on reducing the acidification risk at these sites. Rehabilitation will be a costly and long-term process.

Ongoing environmental issues – As a result of past decisions to maximise irrigation water availability, the environment suffers a proportionally greater impact of water shortage than irrigators. Although floodplain ecosystems have adapted to climatic variability, the combined effect of ongoing severe drought and over allocation are exceeding the ecosystems capacity to survive. Under natural conditions, significant flooding will occur approximately every six years. Without existing irrigation developments, significant flooding would have occurred in 2001. However, there has been with virtually no natural floodplain inundation since 1992. The MDBC has engaged in critical environmental watering during 2006/07 and 2007/08. The total amount of water used for environmental purposes, during these two years represents about 1% of the total amount available to irrigators.

Storage levels – under average inflow conditions, and with existing allocation policy, it will take approximately seven years for Dartmouth Dam to refill. Historically, 'wet' years are required to replenish storage levels after extended drought. In dry and average years there is little net change to storage levels, because most of the inflows are allocated. Continuing dry conditions will prevent storage levels from recovering. This will reduce our future capacity to endure very dry years.

Continuing record low inflows are likely to result in very low storage levels at the beginning of the 2008/09 irrigation year. Annual allocations are, again, likely to be substantially dependent on next year's inflow. However, with critical water supplies reasonably assured and the option of carryover available, for irrigators the 2008/09 outlook is brighter than 2007/08.

Is agriculture under stress?

Analysis done by the Victorian government (2008, p45) indicates that average inflows during the past ten years (in the Victorian part of the Basin) are comparable to a 'high impact' climate change scenario, by 2055. Therefore, the experiences of the past decade can offer insight into the capacity of existing agricultural systems to adapt to such a 'high impact' climate change scenario.

Anecdotal evidence suggests that higher commodity prices have partially off-set the impact of the drought and many irrigators have effectively used the water market, either to sell water as the price increased, or buy to supplement their allocations. A leading Victorian dairy farmer recently described his management strategy at the ABARE Outlook 2008 Conference (ABARE 2008). He made the decision to sell his water allocation as prices approached $1,100 per ML, in October 2007. Whereas using the water in his property would produce 1 tonne of dry feed per ML, he was able to purchase of 3 tonnes of dry feed for every ML of water sold. At the season’s end, the dairy herd was 8% larger and production was 40% higher than the previous year. However, not all experiences have been positive. Significant areas of citrus and low-value permanent irrigated plantings have been removed, the Basin’s rice crop fell 83% in 2006/07 (ABARE 2007) and an unknown number of farming families exited the industry.

In 2007, the total Australian wine grape harvest was almost 1.4m tonnes (though between 1.55 and 1.65m tonnes expected in 2008), compared to an average of 1.9m tonnes per annum (Australian Wine and Brandy Corporation 2008). However, the reduction in quantity (relative to average production) has been matched by an increase in quality. Many vineyards have benefited from dry conditions, since less grape splitting occurs. In South Australia, despite allocations reaching only 32% (figure 5), some viticulturalist are expecting one of the best crops ever (*The Australian* 2008).

The Australian Bureau of Agricultural and Resource Economics (ABARE) conducted economic analysis of the impact of water shortage on irrigation in the MDB (Goesh et al 2008). The analysis utilised a climatic model which applied a 20% reduction in water availability across the Basin (the outcome of a ‘moderate’ climate change scenario), a water trade model, which simulated optimal water trade within regions, but not between regions and a general equilibrium model, which estimated the economic impact. The results, outlined in figure 10, indicate that a 20% reduction in water availability will result in a 5.5% reduction in farm profits.

Region	Long Term Avg Farm Profit ($m)	Farm Profit Δ with - 20% Cap
Queensland	375	- 5.8 %
Nth NSW	533	- 6.2 %
Riverina	849	- 6.8 %
West NSW	144	- 5.4 %
East Vic	389	- 6.6 %
West Vic	614	- 5.5 %
SA	569	- 1.6 %
Total	3 473	- 5.5 %

Figure 10: The impact of 20% lower water availability on annual farm profit (ABARE 2008).

Managing the impact of water scarcity

Agriculture in the MDB is under severe stress. However, history suggests that Australian farmers are extremely adaptable. The role of the MDBC is implement public risk management strategies while providing timely and accurate information, which will maximise the opportunities for private risk management.

Private risk management – Irrigators will make rational profit maximising decisions given the constraints that are faced. It is the responsibility of water management agencies to reduce the transaction costs associated these decisions.

Individual carry-over provides for greater inter-annual flexibility to manage supply variability. However, current policies regarding carry-over, can be short-term measures only. In order to allow carryover in the long-term, existing dam capacity must be dedicated to storing it and channel capacity must be dedicated to delivering it to irrigators. This introduces a number of very complex issues pertaining to the MDB Agreements' water sharing arrangement, the security of existing entitlements, environmental water management arrangements and river operating constraints. These issues must be addressed in an effective long-term carry-over policy.

Temporary and permanent water trade has significantly reduced the economic impact of the drought. However, barriers, including the length of time required to process a trade, and restrictions on the amount of water that can be traded permanently from an irrigation district, must be addressed. Water trade can have numerous externalities including on: salinity, river channel capacity, water delivery infrastructure and river operations. The impact of a trade on these factors must be assessed in order to process the trade.

Public risk management – the MDB water sharing arrangements must share water in both wet and dry conditions. Currently Murray River water sharing arrangements are based on a formula which allocates minimum monthly flows to South Australia, with the balance shared between New South Wales and Victoria. These arrangements are a function of the South Australian objective to maintain river navigatability. Strict adherence to this water sharing protocol would have allocated the vast majority of 2006/08 inflows to South Australia. The MDB Ministerial Council has agreed to a special water sharing regime, based on the Agreement, during this period, to share available water equitably.

Under conditions of severe water shortage, sharing arrangements have been based on the principle that everybody gets a reasonable share. However, as with carry-over, long-term changes to water sharing arrangement have considerable consequences for the security of existing entitlements, environmental water management arrangements and river operations, which must be addressed.

Planning minimums must be set to guarantee critical water delivery for human consumption should a repeat of 06/07 inflows eventuate. The development of specific risk profile for critical water requirement has been unnecessary whilst the planning minimum remained at the 1914/15 level. The potential for annual inflows to be so low that critical water supplies cannot be delivered introduces the possibility that such low inflows could occur on two consecutive years. For how many extreme dry years, should critical reserves be stored? As above, critical water requirement carry-over will have considerable consequences for the security of existing entitlements, environmental water management arrangements and river operations, which must be addressed.

Conclusion

It is evident that the MDB may not need to wait until 2055 to experience severe impacts of climate change. However, agricultural production figures indicate that such conditions will not necessarily result in a dramatic reduction in agricultural output. This paper has described numerous adaptive measures that have been developed in response to severe water shortage. Public and private carry-over, special water sharing arrangements and drought contingency measures are ‘short-term’ strategies have been successfully implemented during this very dry period. The challenges of climate change necessitate a policy framework which accommodates wet and dry conditions. However, the ‘short-term’ strategies that have been developed, cannot be carried forward as an incremental adjustment to the impacts of climate change. A fundamental shift is required in a policy framework which establishes water sharing arrangements for consumption and environmental protection over a range of climate change possibilities for the long-term.

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