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Targeting Environmental Water from Irrigators in the Murray Darling Basin

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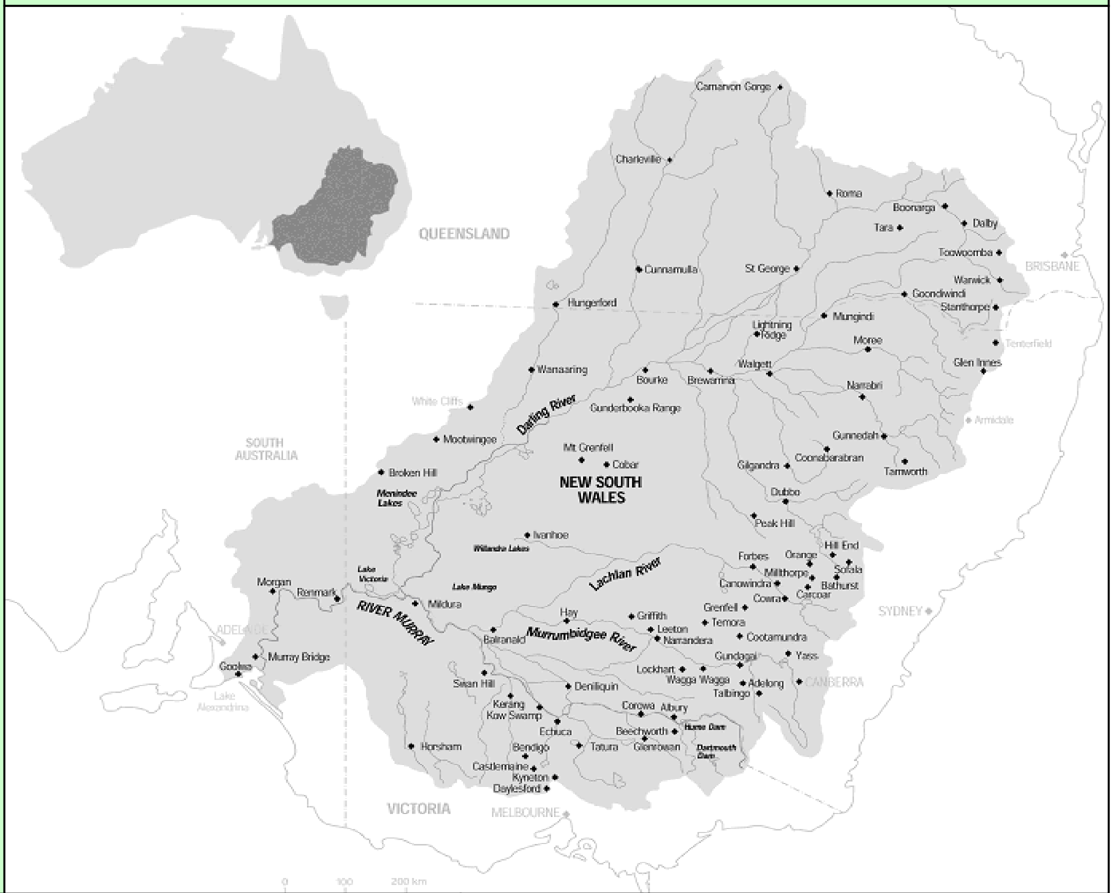

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Targeting Environmental Water from Irrigators in the Murray Darling Basin

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Abstract

The extended dry conditions in the Murray Darling Basin have resulted in unprecedented levels of reduced water availability for both irrigators and the environment. Concerns over environmental degradation and the health of the river Murray have prompted the Federal and State Governments to cooperate in a range of environmental water restoration programs, including environmental water purchases. These programs have been subjected to varying levels of criticism as to the environmental effectiveness and the economic merit in addressing the central problem of overallocation of a spatially distributed multiple use resource. This paper investigates the economic-environmental tradeoffs under the assumption of unrestricted trade in the Basin. Using a bio-economic model of the Murray Darling Basin we will investigate the opportunity costs of not allowing unrestricted trade, and then consider alternative Environmental Water Allocations (EWAs) to environmental Icon Sites. The model suggests that if unrestricted trade was implemented across the Basin, there would be potential for massive water savings compared to the current long term average cap, and benefits to trade in the order of $96 million. The model also suggests that, under unrestricted trade, the provision of large EWA's will lead to large reductions in water use (40 percent), however the relative reduction in agricultural value will be much less (12 percent). This brings to question the current objective of the government buybacks as a transition to the Water Act 2009 Sustainable Diversions while allowing State enforced barriers to trade.

Introduction

The health of the rivers in the Murray Darling Basin (hereafter Basin) have been degraded as a result of developments that have diverted natural flow, and inflow variability which has exacerbated water scarcity. It has been recognised that in some catchments water is 'over-allocated'. That is, the allocated rights to water withdrawal exceeds the physical capacity of the system to supply (Council of Australian Governments 2004). This in part is due a high degree of uncertainty surrounding the supply of water in the Basin. Sources of uncertainty include the complex nature of the spatial-temporal interactions of supply and demand, and the multi-jurisdictional management of the water resource. The Council of Australian Governments (COAG) has resolved to reduce overallocation and increase environmental flows in the Basin.

The COAG agreements of 1994 and 2004 have attempted to develop a national framework to water management. This has included the implementation of a Cap on water extractions and the introduction of water trading between some irrigation districts and catchments, moving towards a set of nationally tradeable water entitlements. It is expected that improved trade and pricing of water in the Basin should lead to greater water productivity (Qureshi 2007; Roberts 2006). Therefore trade has the potential to reduce consumptive water use and improve economic and environmental outcomes. However barriers to trade have been imposed to limit the flow of resources out of irrigation districts, such as the limits set by the Victorian and New South Wales Governments.

In order to increase Environmental Water Allocations[1] (EWAs) in the Basin, the State and Federal Governments have implemented a number of programs with the goal of restoring water to the environment. These programs have attempted to reallocate water from consumptive users to the environment through a variety of methods including water savings from infrastructure improvements and buybacks schemes. The Living Murray (TLM) program was implemented to secure 500 gigalitres (GL) of EWA for six important wetland and riverine environments along the Murray River, labeled Icon Sites. The Restoring the Balance (RTB) program committed $3.1billion to be used to buy water from willing sellers through a tender system. This program supports a "no regrets" policy where it is assumed the risk of purchasing "wrong" water is low. However in order to achieve maximum environmental benefit, entitlements for EWAs should be spatially targeted to ensure they are capable of achieving specific ecological objectives (Productivity Commission 2009a).

The aim of this paper is to investigate the policy issues of environmental degradation and water scarcity in the Basin by examining alternative options for allocating water to the environment. Ideally, policies should aim to secure EWAs for important environmental sites while minimising production losses. The modelling approach incorporates three Icon Sites (Barmah-Millewa; Chowilla; and the Coorong), within the state-contingent Murray Darling Basin Model of land and water allocation as described in Adamson, Quiggin and Mallawaarachchi (2007). From this analysis we would like to answer the following questions:

1. *Under the current management of the Basin what would be the costs involved in diverting sufficient water to the icon sites?*
2. What is the opportunity cost of not allowing unrestricted trade in water throughout Basin?
3. What is the opportunity cost of providing EWAs to icon sites under unrestricted trade?

*The first question will require the model to find a second best solution, based on current water management policy. Water for the environment will be given a value based on the Federal Government water buybacks. This method provides the optimal solution for each catchment in the directed network of flows. It is similar to the current situation of water use in the Basin, where the opportunity costs of upstream use are not taken into account. *Note- this has not been run through the model yet**

The second and third questions will require the model to find the first best solution under different EWA scenarios. It assumes free trade throughout the Basin to allow available water to move to its highest value use. Three EWA scenarios will be investigated in question three:

1. TLM agreed EWA of 500 GL
2. TLM upper limit EWA of 1500 GL
3. The EWA required to meet the ecological objectives of three Icon Sites outlined by TLM of 5695 GL

The EWAs will be allocated to the environment first before land use is optimised. This method provides the optimal solution for the Basin (What should be in the Basin Plan). The implications of increasing environmental flows in the Basin will be investigated for each catchment by looking at changes in water use, economic value and production activities.

The paper will be structured as follows. Section 2 provides a background to water use and management, Basin condition, environmental demand for water, and methods for recovering EWAs. Section 3 outlines the state contingent model of land and water allocation in the Basin developed by Adamson et al (2007) and outline how Icon Sites and environmental flows are incorporated into the model. Section 4 gives an overview of the results of the estimated impact of increased environmental flows. In section 5 implications for policy and further analysis and discussed and conclusions are drawn.

[1] Legally binding entitlements for the environment based on scientific information

Background Murray Darling Basin

Water Use and Management

Over 40 percent of Australia's total agricultural production is produced in the Basin, which was worth $15 billion to Australia's economy in 2007-08 (Australian Bureau of Statistics 2009). From an irrigated area of 1.7 million hectares in the Basin, irrigated agriculture accounted for $4.6 billion. The Basin includes over 1.9 million hectares of important wetlands (ANCA 2001). Ten of these wetlands have been recognized under the Ramsar convention for their high ecological significance as essential breeding grounds for diverse water bird and fish species. Figure 1 illustrates the Catchment Management Regions (CMRs) of the Basin, the locations of irrigated areas, and important wetlands, including Ramsar Wetlands.

There are over 2.7 million people living in the Basin (Murray Darling Basin Commission 2006), all of whom are in some way dependent on water flowing in the Basin as a source of potable drinking water, for industry, for recreation activities and for community networks. A further 1.1 million people in Adelaide rely on the Basin to provide drinking water (Australian Bureau of Statistics 2006).

Under the Australian constitution, the responsibility of managing water lies with the States, which means that water resource Acts have been based on political rather than catchment/hydrological boundaries (Khan 2008). The extraction of water for agricultural and domestic use was allowed under licenses that were fixed in duration and tied to specific pieces of land (Quiggin 2001). Water use has matured to the extent that in 2008, close to 50 percent of average annual surface water flows are diverted for consumptive use (CSIRO 2008). Irrigated agriculture is the biggest consumer of water, with a 75 percent share of total use.

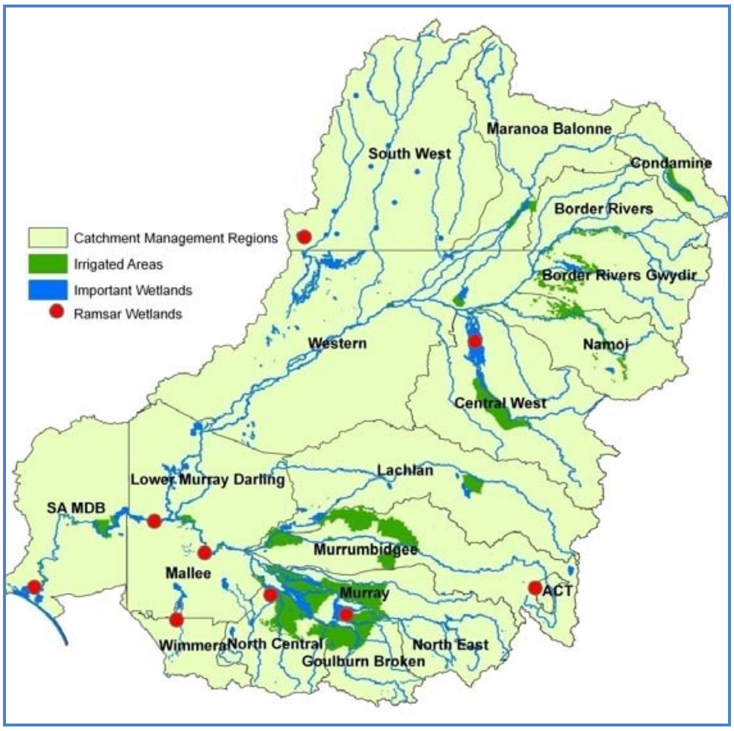


Figure 1 the Murray Darling Basin

Among the world's major river systems the Murray Darling has both the lowest average rainfall and the greatest proportional variability. Annual and inter-annual variability in water availability is managed via infrastructure (regulation by dams) and institutional arrangements (security of entitlements). The river system of the southern Basin (the Murray and its tributaries) is highly regulated by three major dams the Hume, Eildon and Menindee

Lakes. While managing inter-annual and seasonal variability this has altered the natural winter dominated flow cycle. In the northern Basin supplies are unregulated, and water users must have flexible production systems or build private dams to manage their supplies. Although slightly different across states, water entitlements deliver an allocation based on its security and the water available in a season. For example in the regulated markets of Victoria there are high and low reliability water shares, and in New South Wales there are general and high security shares. These provide different probabilities of receiving the full entitlement depending on the average and the current water availability in the catchment. Water markets allow irrigators to sell all or part of their allocations in a given season.

The markets for water in the Murray Darling Basin have been developing over the decades as water scarcity has revealed the benefits to trade. Water trading allows for the efficient reallocation of water among competing users. Water markets have been recognised as important tools in the current buyback arrangements under Restoring the Balance (Productivity Commission 2009b).

Participation is higher in the temporary water markets for allocations compared to the permanent market for entitlements, which were 40 percent and 7 percent respectively in New South Wales 2004 (Singh 2008). It is a similar story in Victoria where there were over 10,000 transactions of temporary entitlement transfers compared to just over 700 transactions of permanent entitlement transfers in the 2006/07 season (Victorian Government Department of Sustainability and Environment 2008).

Since 2004 the National Water Initiative has been moving towards a system of nationally compatible entitlements, markets and registers and a separation of land and water rights (Council of Australian Governments 2004). However the markets vary substantially over regions in the Basin, with both hydrological and political barriers to trade. Currently the major barriers to trade include the four percent annual limit on the amount of water that can be traded out of Victorian Irrigation areas, and the limits on trade out of New South Wales, as well as high exit fees. The Australian Competition and Consumer Commission is working towards changing the rules of trade in an attempt to remove these barriers (ACCC 2008).

Environmental water use and management

The rivers of the Basin have been degraded as a result of regulation by dams, drainage of wetlands, diversion of flows, abstraction of water for irrigation and rising water tables (Davis 2001), which have all resulted in alterations to the natural flow. Compared to natural flow, current water consumption has reduced the amount of water reaching the river mouth by 61 percent (CSIRO 2008). This result reaffirms that the health of the rivers are determined by their ability to maintain key ecological processes of both in-channel and floodplain/wetland environments (Arthington 2003). These ecological processes require highly variable natural flooding regimes in order to function efficiently.

The 2008 Sustainable Rivers Audit (SRA) provided an assessment of the ecosystem health of the 23 major river valleys in the Murray Darling Basin[2] (Davies 2008). Figure 2 illustrates the rank of the river valleys from best (1) to worst (9). The unregulated catchments of the north were in the best condition, where natural flooding and drying events are still able to occur. Catchments in New South Wales and Victoria were in the poorest condition, and the Murrumbidgee and Goulburn-Broken valleys ranked lowest.

[2] This study is based on hydrology, fish and macroinvertebrates data gathered in 2004-07

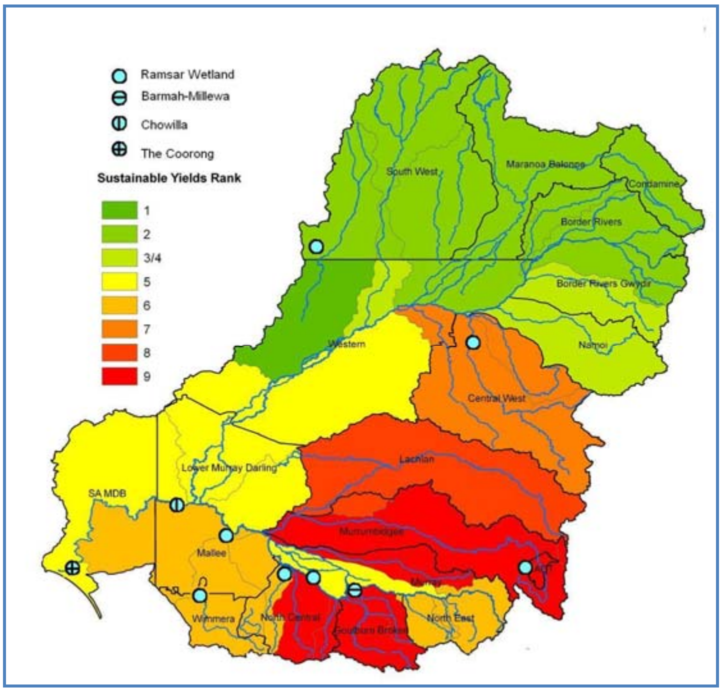


Figure 2 Rank of river valley ecosystem health in the Murray Darling Basin

The Australian Government operates a number of programs with the goal of restoring water for the environment including TLM initiative and the RTB program.

TLM initiative was established in 2002 by the Murray Darling Basin Ministerial Council (MDBMC) with the aim of restoring the health of the River Murray. This initiative received funding from COAG and other sources of $775 million to address water over-allocation. The Living Murray *First Step* was to recover an estimated average of 500 GL of water, with a focus on maximising environmental benefits to six Icon Sites. The Living Murray initiative obtained environmental water in a number of water saving schemes such as upgrading infrastructure and pipelining to reduce delivery losses; investing in on-farm water use efficiency including changes in land use practices (Independent Audit Group 2008). However these methods failed to deliver sufficient quantities of explicitly defined entitlements for use by the environment. In 2007 the NSW Market Purchase Measure was initiated by the New South Wales Government buy water entitlements through a tender process (DECC 2007).

In 2008, the Labor Federal Government introduced the RTB another buyback scheme which allocated $3.1 billion to purchase water entitlements from irrigators based on a value for money basis (Department of the Environment 2008). This was part of a long-term strategy to provide a permanent rebalancing between consumptive water use and the environment. The RTB supports a “no regrets” policy where it is assumed the risk of purchasing the “wrong” water is low. However due to the thin trade in some water markets and the high transaction costs associated with water purchases, this presumption will become increasingly contentious (Productivity Commission 2009b).

The retirement of water rights by consumptive users will lead to an opportunity cost from the loss of the marginal product of the retired water. It has been found that the opportunity costs to agriculture can be reduced if the acquisition of environmental water is spatially targeted from low opportunity cost regions (Qureshi 2007). In addition the environmental benefit from purchased water would increase if purchasing priorities were given to water products most able to meet ecological objectives of highly valued environmental assets.

Environmental water demand and requirements

The demand for water by the environment has typically been very poorly defined, due to the mostly non-market value of the benefits. However public and government action has indicated that society does value environmental integrity, the most obvious indicator is the wide support for the $3.1 billion dollar RTB program. However the inability to accurately assess society's willingness to pay means that environmental demand will be based on the environmental requirements of achieving priority ecological objectives.

The 1994 COAG affirmed that environmental requirements are to be determined using the best scientific information available. The Department of the Environment, Water, Heritage and the Arts (DEWHA) which is responsible to managing the water acquired by the RTB has in large part relied on the previously mentioned CSIRO Sustainable Yields project and the MDBC Sustainable Rivers Audit in setting purchasing priorities (Productivity Commission 2009b). However these do not address the ecological responses to watering particular sites. The Management Plans of TLM Icon Sites outline the estimated requirements for water needed to meet the specific ecological objectives of each site (The Living Murray 2006a). An example of the ecological objectives and the estimated annual water requirement for the three Icon Sites is shown in table 1.

Table 1 Ecological objectives and estimated water requirements of Icon Sites in the Basin

Icon Site	Ecological Objectives	Estimated annual water requirement
Barmah-Millewa	1. Successful breeding of colonial waterbirds in at least three years in ten 2. Healthy vegetation in at least 55% of the area of the forest (including virtually all of the Giant Rush, Moira Grass, River Red Gum forest, and some River Red Gum woodland).	~1,365 GL/year
Chowilla	1. High value wetlands maintained; 2. Current area of River Red Gum maintained; 3. At least 20% of the original area of Black Box vegetation maintained.	~3,600 GL/year
The Coorong	1. Open Murray Mouth; 2. More frequent estuarine fish spawning; 3. Enhanced migratory wader bird habitat in the Lower Lakes.	~730 GL/year

Source: (The Living Murray 2006a, 2006b, 2006c). [3]

There is a need for a coordinated and targeted approach to water recovery which takes into account the opportunity costs of water, and the needs of the environment. This model will attempt to demonstrate the optimal allocation of resources given a fixed allocation to the environment. This will demonstrate where water should be targeted from and should assist policy makers through the difficult decision-making process.

Method and model scenarios

The model

This analysis is an adaptation of the state contingent Murray-Darling Basin Model documented by Adamson, Mallawaarachchi and Quiggin (2007). The model simulates land and water allocations for irrigation production systems operating under alternative irrigation property rights (Adamson et al 2006). Problems that have been analysed include options for salinity mitigation (Schrobback, Adamson & Quiggin 2008), climate change (Adamson & Quiggin 2008), restoring flows to the Snowy River (Wagner, Quiggin & Adamson 2008), and changes to the cap on irrigation use for water (Adamson, Mallawaarachchi & Quiggin 2006).

The model uses a linear program to maximise the economic return for the Basin at a CMR scale. In this analysis there are 23 regions (k= 1…23): 19 catchments[4], three Icon Sites, and Adelaide (Figure 3). By incorporating the

[3] Based on information from the Icon Site Management Plans Estimations are outlined in Appendix 1.

Icon Sites as individual nodes within the structure of the model we can explicitly assign them a defined EWA rather than the current approach of treating environmental flows as part of the conveyance loss. The flow of water out of any given catchment is equal to the inflows, minus conveyance losses, minus extractions, plus return flows. The return flow refers to the amount of water that returns to the system once it has been used for irrigation purposes, and includes an increase in salt. Salinity is used as a general measure of water quality.

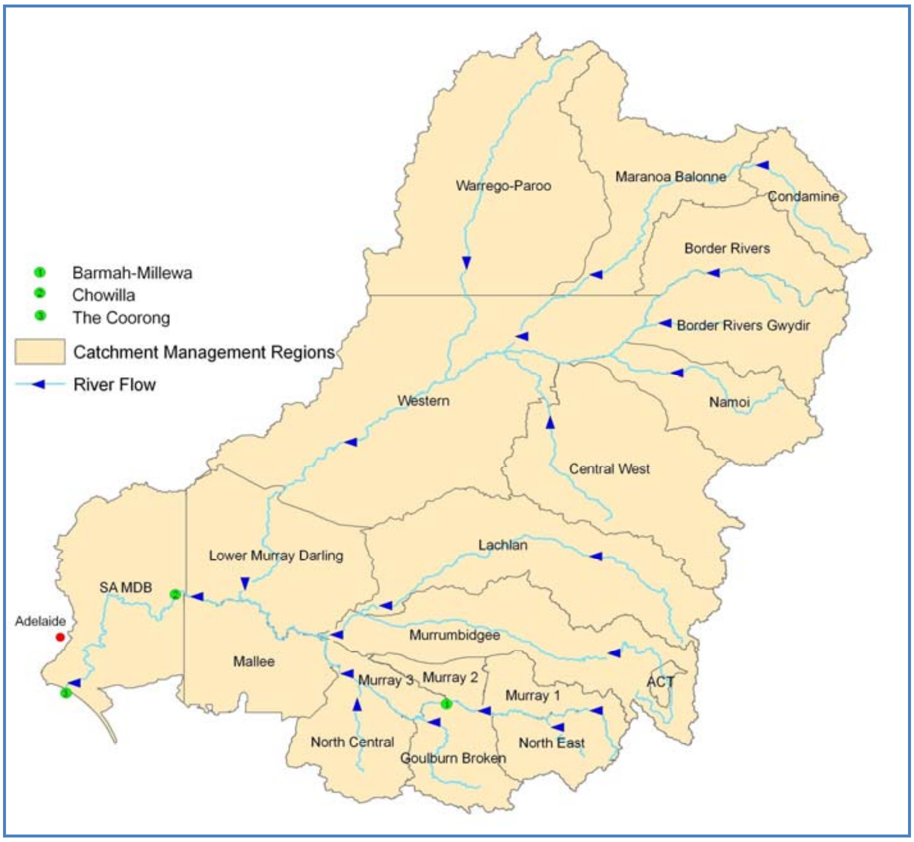


Figure 3 Directed flow network of the Basin

This model consists of three states of nature, which represent wet, normal and drought states. The states of nature are defined by their probability of occurrence and the amount of inflows representative of the state (Table 2). Water is therefore the major constraint to production which is also state contingent. The model now optimises economic return by choosing between 15 major commodities (M), which make up 25 production systems[5] that use alternative levels of inputs and deliver differing outputs (yield) that respond to the availability of land, labour, capital and water volume in a given state. State contingent modelling such as this investigation, relies on a defined number of possible states S, which correspond to different levels of precipitation and other climatic conditions. The model describes production types for each major commodity under each possible states of nature (M*S).

[4] The Murray CMR has been broken into three parts to better model the shared flow of the river Murray between catchments, and Wimmera has been excluded as it is not connected by any major tributary to the Murray system.

[5] For example the 'Rice' production system is estimated at 1/3 rice and 2/3 wheat as producers can only plant 1/3 of their total area to rice.

Table 2 Definition of Inflows by States of Nature

	Normal	Drought	Wet
Probability of occurrence	0.5	0.2	0.3
Percentage inflow	1	0.6	1.2

The model can be solved using two different solution approaches a sequential solution and a global solution. The sequential model solution optimises economic returns in each catchment, subject to their specific resource constraints (labour, land, water allocation and end of basin salinity targets), as water flows down the directed flow network. Water use in each catchment is constrained by the end of valley salinity targets, and downstream water use is constrained by upstream water use. Results from the sequential solution are more in line with actual current water use in the Basin, as it is constrained by actual institutional arrangements, and does not allow for full trade.

The global solution optimises the returns for the Basin as a whole, maximising returns from irrigated and non-irrigated agriculture, urban water use in Adelaide and the estimated social value of environmental flows. Water use is constrained by the direction of flows and conveyance losses as well as ensuring that the salinity arriving at Adelaide is less that 800EC rather than constraining to end of valley targets. This then allows for better allocation of resources so that areas with higher returns from water use can use a greater proportion of their current water rights at the expense of areas where returns are less. By allowing the water to move to where it is of highest value throughout the Basin, the results implicitly demonstrate full water trade. Results from the global solution are considered a benchmark against alternative institutional arrangements.

Water use in each catchment is constrained by its long term Annual Cap allocation. The marginal value of an extra unit of water above this constraint is the Shadow Price. Table 3 below provides the annual cap and the shadow prices associated with each catchment from the Global Base solution to give an indication of where water has its highest value.

Table 3 Annual cap allocations and modelled shadow price of water for Basin catchments

Catchment	Annual Cap (GL)	Shadow Price $
Condamine	308	$188
Border Rivers, QLD	209	$35
Warrego-Paroo	47	$36
Namoi	568	$410
Central West	669	$127
Maranoa-Balonne	268	$35
Border Rivers-Gwydir	816	$43
Western	577	$119
Lachlan	585	$75
Murrumbidgee	2,535	$19
North East	120	$137
Murray 1	70	$125
Goulburn-Broken	2,049	$142
Murray 2	940	$125
North Central	1,643	$130
Murray 3	719	$125
Mallee	213	$137
Lower Murray Darling	135	$6
SA MDB	554	$114
Adelaide	206	$700
Total	**13,231**	

Scenarios

This analysis will compare five scenarios, which are outlined in Table 4. There are two base scenarios of Current trade and Full trade. Current trade is calculated using sequential optimisation, which simulates the current restricted trade of water between catchments at the current cap. However in order to answer the question of where to optimally source EWAs it is necessary to allow full trade of water between catchments. To do this we use global optimisation. The Full trade base scenario shows this optimal solution at current cap.

The next three scenarios will investigate the optimal reallocation of resources when the three Icon Sites are given an environmental water allocation. In the optimisation the water will be allocated to the environment first, and remaining Cap water will be allocated to agriculture. The LM500 scenario represents the initial Living Murray objective of allocating an extra 500 GL to the Icon Sites. The LM1500 represents the upper bound of the Living Murray recommended EWAs. These scenarios will divide the 500 GL and 1,500 GL equally between the Icon Sites. The Ecological scenario will allocate each of the Icon Sites the estimated annual water requirements as outlined in their management plans.

Table 4 Scenarios and Environmental Water Allocation

Scenarios and EWAs (GL)	Barmah-Millewa	Chowilla	The Coorong	Total EWA volume
Current Trade	0	0	0	0
Full Trade	0	0	0	0
LM500	167	167	167	500
LM1500	500	500	500	1,500
Ecological	1,365	3,600	730	5,695

Assumptions

1. Environmental water requirements are state contingent

As mentioned in the background, the water requirements of the environment are determined by the volume, timing, duration and frequency of natural flooding events. In this analysis we will assume that the water requirements of the Icon Sites are state contingent.

In this model we will set a both state contingent and constant allocations to the environment depending on the ecological objectives. Environmental water use in Barmah-Millewa and Chowilla will be state contingent 175 percent in a wet year, 85 percent in a normal year, and 30 percent in a dry year. Water allocations will be constant for the Coorong due to minimum flows required to keep the Murray mouth open. The state contingent water requirements for the Ecological objectives scenario is provided in Table 5.

Table 5 State contingent water requirements of Icon Sites in the Ecological objectives scenario

Icon Sites	State Contingent Water Requirement (GL/year)			
	Normal	Drought	Wet	Average
Barmah Millewa	2,389	2,030	609	1,365
Percentage inflow	6,300	5,355	1,607	3,600
The Coorong	730	730	730	730

2. Reflow from the Icon Sites is assumed to be 70 percent (O'Connor 2008)

Personal communication with a Red Gum Ecologist from Barmah-Millewa has identified reflow characteristics from previous deliveries of environmental water allocations. Watering the wetland from dry leads to conveyance losses in the order of 30 percent. In the case of applying EWA on top of a natural flood (as per the case in 2005-

06) conveyance losses are in the order of 5 to 8 percent. However for this analysis we will assume that all watering is applied to a dry wetland.

3. There would be NO change in salt loads as the water passes through the wetlands (O'Connor 2008)

Wetlands acts as giant water filters and reduce sediment and nutrient loads in the river water. However they are not known to have any impact on salt loads. This model will not attempt to incorporate any changes in water quality as a result of wetland use.

Results and Discussion

The main results that will be analysed in this next section are the water use results including the quantity and location water sourced for EWAs and the changes in water use patterns. Next the impact on salinity as a result of the EWA scenarios will be outlined. Finally the resulting changes in production will be discussed including the opportunity costs to agriculture and changes in land use patterns.

Water Use

The summary results of water use are found in Table 6. First of all to compare the Base scenarios we can see that less water is used under Full Trade, as a result of more efficient allocation of resources between the catchments. Under the Current Trade situation there are perverse incentives for producers to maximize water use in their catchments without concern for downstream opportunity costs. Another interesting note is that the average optimal water use under Current Trade is more than 2,000GL less than the Basin long term average Cap. This indicates that there are excellent opportunities to reduce overallocation through better distribution of the resource through trade. The water use in the wet period decreases to 13,849 GL, and 6,885 GL in the dry, which represents a decrease in the variance of water use between states, and a more stable supply of irrigation water. Full trade also allows greater volumes of water to be available for the environment. In Table 6 Environmental water use is reported as the total amount of water that, quantity of water used by Icon Sites as well as flows to the sea.

Table 6 Summary Results Water use

Scenario	Reduction in Cap (GL)	Agricultural Water Use (GL)				Environmental Water Use (GL)			
	AVG	Normal	Drought	Wet	AVG	Normal	Drought	Wet	AVG
Current Trade	2,141	10,982	6,939	14,036	11,090	5,467	1,540	7,417	5,267
Full Trade	2,310	10,778	6,885	13,850	10,921	5,609	1,589	7,529	5,381
LM500	2,310	10,778	6,885	13,850	10,921	5,974	1,814	8,104	5,781
LM1500	2,500	10,601	6,701	13,635	10,731	6,829	2,430	9,383	6,715
Ecological	6,465	5,185	2,800	9,611	6,036	12,698	6,208	16,446	12,524

The LM500 scenario shows no changes in agricultural water use from the Full Trade scenario, indicating that if resources were better reallocated amongst current water users there would be sufficient unused water to meet the initial Living Murray target of 500 GL. The average environmental water use increases by 400 GL, implying that more water used in wetlands slightly decreases the amount of water going to the sea. The LM1500 scenario leads to a reduction in agricultural water use across all states of nature. With 1500 GL allocated to the environmental (500 GL to each icon site) we find that average agricultural water use decreases by 360 GL, or 3 percent reduction from current water use. That is 400 GL less is used in the wet, and 240 GL less is used in the dry, further reducing the variance between states.

The ecological scenario sees average annual water use fall to half of the current long term Cap amount, and the environment becomes the dominant water user in the basin. The proportional reduction by state is greatest in the drought (60 percent) and normal state (50 percent), and less in the wet state (30 percent), which indicates a move to more flexible production systems that allow for water use to alter depending on seasonal availability.

Figure 4 illustrates catchment water use in the Current Trade scenario, and the source of water targeted to deliver EWAs for the Ecological scenario. The Ecological scenario provides an extra 4,323 GL of water for environmental purposes compared to the Current trade scenario. This is slightly less than the total EWA amount of 5,695 GL because of the reflow rate and the ability of environmental water to be used in multiple wetlands as it makes its way down the Basin.

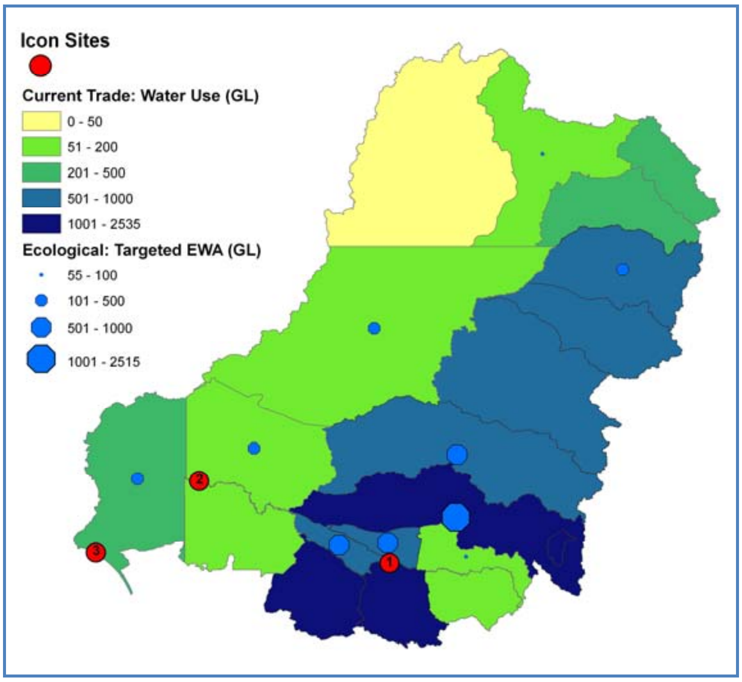


Figure 4 Location and Quantity of targeted water

The Barmah-Millewa (1) EWA is sourced entirely from the Murray catchments (1,555 GL). It is interesting to note that this reduction is only from the New South Wales side of the border, while the Victorian catchments retain their entitlements. The Chowilla (2) and Coorong (3) EWAs are largely sourced from the Murrumbidgee (1,634 GL), Lachlan (578 GL), Western (150.5 GL) and Lower MDB (128 GL). Other smaller quantities are taken from more distant catchments such as Border Rivers and Maranoa Balonne however it is likely that this reduction is a result of the reallocation to higher value production systems downstream.

In reality it is unlikely that the Lachlan would be able to provide sufficient flows to the icon sites. Flows from the Lachlan river flow into the Lowbidgee wetlands and in most years do not reach the Murumbidgee. This highlights the deficiencies of the current model to take into account detailed spatial and hydrological relationships within the basin in its current form. Further work must be done to improve the accuracy of the model.

Agricultural water use as a proportion of total flow is shown in

Table 7. The highest proportional water use is in the drought state in all scenarios except in the Ecological scenario when the highest water use is in the wet state. The LM500 and LM1500 scenarios do not cause large reductions in water use. The average proportional reduction in water use is 1 percent in the LM1500 scenario, but the ecological scenario causes a 20 percent reduction. This indicates that in the ecological scenario there is a move to more opportunistic cropping systems that require less irrigation in the droughts and more in the wet.

Table 7 Agricultural water use as a proportion of total flow

Scenario	Proportion of water used			
	Normal	Drought	Wet	AVG
Current Trade	57%	61%	60%	58%
Full Trade	56%	60%	59%	58%
LM500	56%	60%	59%	58%
LM1500	55%	58%	58%	57%
Ecological	31%	31%	44%	36%
Total Flow (GL)	19,378	11,463	23,336	18,983

Salinity

Salinity at Adelaide is outlined for each scenario by state in Table 8 below. Salinity is always highest in the wet state because this is when agricultural water use is greatest. There is a fall in average salinity at Adelaide by more than 50EC as a result of improved trade, when we compare Current with Full trade scenario. LM500 and LM1500 actually cause an increase in average salinity (from the Full trade scenario). However salinity decreases with large increases of EWA in the Ecological scenario which provides increased dilution of salts.

Table 8 Summary of Results: Salinity

Scenario	Salinity at Adelaide (EC)			
	Normal	Drought	Wet	AVG
Current Trade	491	328	578	485
Full Trade	442	262	517	428
LM500	455	268	538	442
LM1500	469	255	569	456
Ecological	280	69	541	316

Production and economic value

For the purpose of this study we have provided environmental water with a value as a proxy for its social value. This is valued at $100/ML for the icon sites, and $50/ML for the flows to sea.

There is an economic benefit to agriculture as a result of the move from Current trade to Full trade, despite the reduction in agricultural water use. Although value is higher under Current trade in the normal and dry states, the increase in value from Full trade is experienced in the wet states, when water is able to be redistributed to take full advantage of opportunistic cropping throughout the Basin. As a result of the reduction in water use (as discussed above) the total area of irrigated land decreases by 20,000ha. Overall the opportunity cost of decreased water to agriculture is offset by benefits from trade. The opportunity cost of not allowing unrestricted trade in the Basin is $96 million.

There is no difference in agricultural value between the Current and the LM500 scenario, but there is an average loss of $9 million in the LM1500 scenario. Surprisingly this is still higher than the average agricultural value under Current trade due to the benefits to trade. The increased value of environmental water is $182 million, more than ten times the value of the opportunity cost to agriculture. Due to the decrease in water use in the LM1500 scenario, irrigated area falls by around 400,000 Ha (18 percent) from Current trade.

Agricultural value in the Ecological scenario is lowest of all scenarios. It falls by $381million (12 percent) from Full trade and $285million (9 percent) from Current trade. The environmental value EWAs in this scenario is $969 on average, more than three times the value of the opportunity cost to agriculture under our assumptions. Irrigated area falls by 820,000 Ha (38 percent) from Current trade.

Table 9 Summary Results: Production and Economic Value

Scenario	Irr Area (000ha)	Agricultural Value ($million)				Environmental Value ($million)			
	AVG	Normal	Dry	Wet	AVG	Normal	Dry	Wet	AVG
Current Trade	2,138	3,047	1,540	3,828	2,980	273	77	371	263
Full Trade	2,108	2,951	1,484	4,344	3,076	280	79	376	269
LM500	2,108	2,951	1,484	4,344	3,076	338	103	459	327
LM1500	1,686	2,955	1,432	4,344	3,067	459	159	632	451
Ecological	1,319	2,484	1,327	3,959	2,695	955	409	1,366	969

As most water is targeted from the southern catchments, it is not surprising that the fall in the value of production is greatest in the south, while most northern catchments retain their value (Figure 5). The greatest losses are experienced in the Murray catchments ($125 million), Murrumbidgee ($121 million), Lachlan ($38 million). Note how all of these regions are in New South Wales, which has policy implications for where adjustment packages should be focused. The only catchment that experiences an increase in the value of production is South Australia ($87 million). The benefit to South Australia is a result of increased security of water availability across the states of nature and better quality water which allows for higher production of horticultural crops.

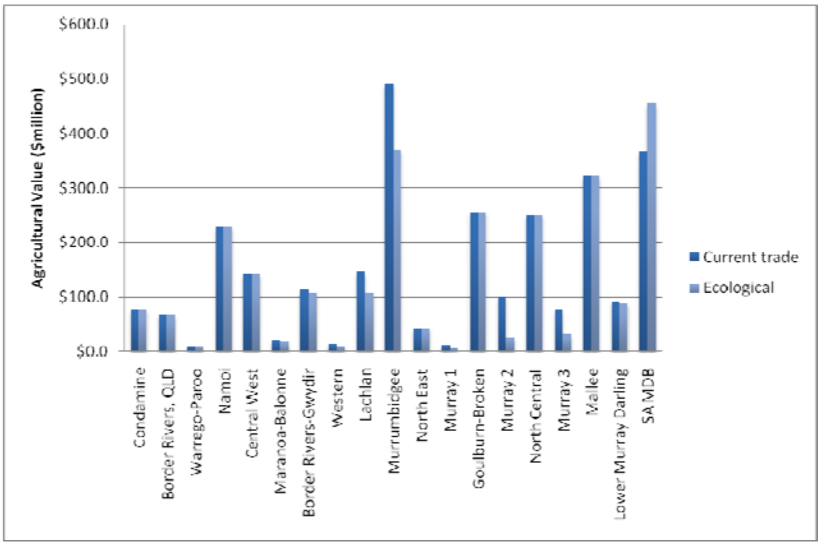


Figure 5 Value of Agricultural Production by Catchment: Current trade and Ecological

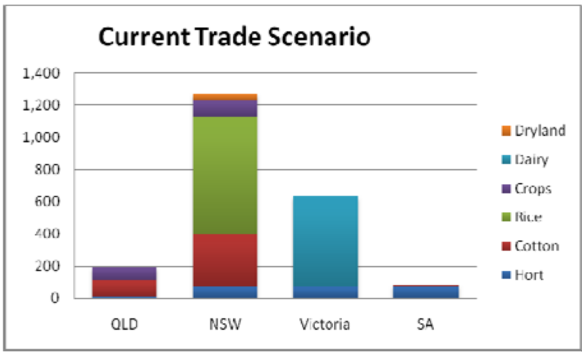
Adaptability

The reallocation of water to the environment will lead to changes in water use, irrigated land area, economic value and salinity throughout the Basin. The model has shown that the move from Current trade to the Ecological scenario results in a reduction of total agricultural water use by 39 percent, a decrease in irrigated land by 21 percent, and a fall in agricultural economic value by 10 percent (Table 10). The lower proportional reduction in economic value illustrates the law of diminishing returns to agricultural water use, and the ability of producers to adapt to conditions of decreased water availability through land use change. In reality producers have proven to be very flexible in their production systems. From 2000-01 to 2007-08 the Basin has experienced reduced rainfall and drought conditions, which has led to a reduction in total agricultural water use by 70 percent, a decrease in irrigated land area by 50 percent, and a fall in agricultural economic value by 20 percent. This information supports the results of this model by verifying that producers are capable of producing more with less if they are given the opportunity to maximise efficiency through trade.

Table 10 Proportional Change by Catchment: Current Trade to Ecological

Catchment	State	Water Use	Irrigated Land	Economic Value	Salinity
Condamine	QLD	0%	0%	0%	0%
Border Rivers, QLD	QLD	0%	0%	0%	0%
Warrego-Paroo	QLD	0%	0%	0%	0%
Namoi	NSW	0%	0%	0%	0%
Central West	NSW	0%	0%	0%	0%
Maranoa-Balonne	QLD	-37%	0%	-12%	0%
Border Rivers-Gwydir	NSW	-16%	-23%	-6%	0%
Western	NSW	-100%	-97%	-20%	-23%
Lachlan	NSW	-99%	-86%	-26%	0%
Murrumbidgee	NSW	-64%	0%	-25%	0%
North East	Victoria	0%	0%	0%	0%
Murray 1	NSW	-91%	-94%	-42%	0%
Goulburn-Broken	Victoria	0%	0%	0%	-1%
Murray 2	NSW	-98%	-99%	-74%	-2%
North Central	Victoria	0%	0%	0%	-17%
Murray 3	NSW	-79%	-57%	-58%	-18%
Mallee	Victoria	0%	0%	0%	-44%
Lower Murray Darling	NSW	-95%	-43%	-4%	-38%
SA MDB	SA	-35%	-27%	24%	-35%
TOTAL Agriculture	MDB	-39%	-21%	-10%	
TOTAL Environment	MDB	138%		268%	

Some catchments are worse affected than others as a result of the EWA increases. There are huge reductions in water use in the Lower Murray Darling, Murray catchments, and Murrumbidgee, and water use is virtually stopped in the Western, and Lachlan. This has varying affects on the area of irrigated land and the economic value within the catchments. The discrepancies are related to the ability on the optimal adaptation options available in the catchment. For example in Murray 2, the main production system under Current trade is Rice Production Systems and under the Ecological scenario all of this land is converted to Dryland. This reduces water use by 98 percent and irrigated land by 99 percent. However the land still has productive value under Dryland use so economic value only decreases by 42 percent. In the Murrumbidgee catchment water use decreases by 67 percent due to shifts in irrigated land use, this is why irrigated land does not reduce. Optimal production shifts from Citrus, Grapes and Rice Production Systems to Citrus and Rice Wet. Both of these systems are less water intensive.



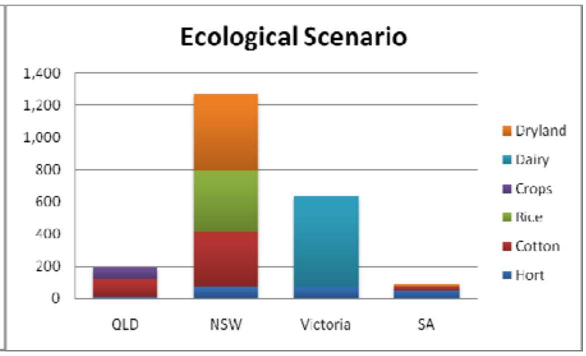


Figure 6 Land Use by State

The results of this study show that if large quantities of water are to be purchased for these Icon Sites, this water should be targeted from New South Wales. The first reason is proximity. The second reason is that New South Wales farmers have greater flexibility in their production systems and a lower opportunity cost for water than Victorian farmers. Adaptation strategies should focus on assisting New South Wales farmers to cope with the changes associated with reduced agricultural water availability. This model suggests the optimum change in land use will involve a shift from rice and crops to dryland, in order to conserve water, yet maintain value to the land Figure 6. Queensland will not be affected because it is located far from the icon sites. Victoria is not affected because the shadow price for water is higher. The dominant production systems in Victoria are horticulture and dairy which are both permanent and inflexible production systems that require high security water and provide high returns.

Conclusion and further study

The model suggests that if unrestricted trade was implemented across the Basin, there would be potential for massive water savings compared to the current long term average cap, and benefits to trade in the order of $96 million. In addition, the provision of TLM EWAs under the unrestricted trade would cause no to minimal extra impact on water use and agricultural value compared to current system. This suggests that as an alternative to governments “manually” reducing water use by purchasing entitlements, such has been the case with the buybacks. It may be worth their while to focus instead on making the difficult changes to allow unrestricted trade to “automatically” achieve their goals.

The model also suggests that, under unrestricted trade, the provision of large EWA’s will lead to large reductions in water use (40 percent), however the relative reduction in agricultural value will be much less (12 percent). This is due to the retention of horticultural production, a shift to more flexible production systems, and the assumption that producers can shift to dryland production and still maintain a viable business.

There are several limitations to this study. The last point is probably the weakest, as the value of dryland production in the Basin is currently fixed across the entire Basin, however catchment specific dryland gross margin budgets should be considered. This model currently lacks the level of hydrological integrity to take into account flow barriers, such as the Lowbidgee wetlands between Lachlan and the Lower MBD. For this reason catchment specific conveyance losses between CMRs needs to be reanalysed to allow for more meaningful results. The EWA scenarios were chosen based on policy at the time of writing. Currently major changes are occurring most notably the creation of the *Basin Plan* and the assignment of *Sustainable Diversions Limits* for each catchment in the Basin. In addition 18 sites of environmental priority have now been named by the MDBA. It is hoped that much more research will go into understanding the water requirements of the ecological services provided by these sites, to aid future analysis of agricultural-environmental tradeoffs.

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