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Economics of Drought, Water Diversions, Water Recovery and Climate Change in the Murray-Darling Basin

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Executive Summary

This report was prepared to provide an economic analysis of current water reform for the Wentworth Group of Concerned Scientists. The key findings include:

- Reductions in agricultural income in the past decade are directly attributable to the current drought and not market-based water recovery;
- Planned (~1,500 GL) water recovery in the *Water for the Future* package is predicted to have only a minimal impact net economic returns in agriculture (less than 10% decline based on 2000-2001 agricultural surface water diversions) and employment in the Basin, but will have a relatively larger economic impact in particular catchments and locations;
- The on-farm losses from reduced water diversions from the voluntary sale of water entitlements are fully compensated by the proceeds of such sales. The net effect on the regional community of sales is dependent on how the proceeds are reinvested (on or off-farm and whether in the region or not);
- The direct on-farm losses from market-based water recovery of equivalent volumes of water are greater the smaller are the average net inflows. This finding, in turn, provides support for timely and effective water buybacks in the presence of climate change;
- Current Australian government budget allocations ($3.1 billion for the entire Basin) for planned water buybacks (~1,500 GL for the MDB or about 20% of 2005-2006 agricultural surface water diversions) is a little more than (using a 5% discount rate) to the estimated direct losses of reduced water diversions given unrestricted water trading and optimal targeting in terms of where the water is purchased;
- To acquire extra volumes of water from buybacks alone consistent with ~1,500 GL of environmental flows in MDB (20% buyback with 2005-2006 agricultural surface water diversions) will require extra funding of between $0.54 billion and $1.4 billion in addition to the $3.1 billion allocated under the *Water for the Future* package
- To acquire extra volumes of water consistent with Wentworth minimum environmental flows (~2,148 GL in the Murray-Darling Basin), and from water buybacks alone, will require extra funding of between $2.0 billion and $3.3 billion in addition to the $3.1 billion allocated under the *Water for the Future* package;
- To acquire extra volumes of water for the environment a 50% buyback (based on 2005-2006 agricultural surface water diversions), would require additional funding of between $6.05 and $8.64 billion over and above the $3.1 billion allocated under the *Water for the Future* package. To acquire volumes consistent with a 40% buyback (based on 2005-2006 agricultural surface water diversions), it would require additional funding of between $4.21 and $6.23 billion over and above the funds currently allocated for buyback;
- Market-based water recovery is marginally more cost effective when purchases are targeted to locations with lower value-added irrigated agriculture, primarily in the upper and south-eastern catchments of the Basin;
- Market-based water recovery for the environment is a much more cost-effective method of acquiring water for the environment than providing subsidies for on-farm water efficiency;

The economic costs of climate change on irrigation agriculture are substantially reduced if there are no restrictions on water trading; and

Restrictions on water trading that are not implemented for environmental reasons substantially increase the costs of adapting to climate change and adapting to market-based water recovery.

Economics of Drought, Water Diversions, Water Recovery and Climate Change in the Murray-Darling Basin

1. Introduction

The Murray-Darling Basin (MDB) is suffering its worst ever recorded drought that is having a devastating impact on communities, agriculture and the environment. The current water crisis has led to important water reforms over the past decade including: the 2004 *National Water Initiative*, the *Water Act 2007* and the 2008 *Water for the Future* package. Full integration of these worthy initiatives, with particular attention to: (1) society and communities; (2) the economics of water reform; and (3) the long-term sustainability of the environment offers the promise of a viable future for those who work and enjoy the benefits of living in the MDB.

The current drought has reduced seasonal allocations of water that has created an understandable angst among farmers and their communities about any further reductions in water diversions planned under the *Water for the Future* package. Existing research, however, suggests that both past and planned water recovery will only have a minimal impact on the overall value-added of agriculture in the Basin provided that water trading is unrestricted. Although the effects of planned water buybacks are small Basin-wide, compared to the impacts of the current drought and future climate change, the impact will be much larger in some regions than in others. By promoting economic efficiency and sustainable extractions, while also assisting affected farmers and communities to autonomously and flexibly adapt to lower water availability, current water reforms can help ensure a sustainable future for the Basin.

Using the existing literature and some additional modelling, an economic assessment of the Basin is provided in terms of the:

(1) Effects of the current drought and water trading;
(2) Water diversions;
(3) Economic effects of water buybacks;
(4) Economic effects of water buybacks versus investments in on-farm irrigation efficiency; and
(5) Economic effects of climate change.

2. Effects of the current drought and water trading

Since 2001 the Basin has suffered a sustained drought. For the period 2002-2007 average annual net inflows in the Murray River totalled 3,986 GL — the lowest recorded for a five year period. This is much less than in any other recorded drought. For instance, net inflows averaged 5,501 GL over the period 1940-45 and 5,707 GL over the period 1897-1902 during the Federation Drought (see Figure1). As a result, water diversions have declined since the start of the current drought (see Figure 2).

The impact of low inflows is illustrated by recorded outflows at the barrages at the mouth of the River Murray over the past 40 years. There have been no recorded flows at the Murray Mouth since November 2006 and positive flows have been recorded in only 19 of the past 90 months (see Figure 3). At the end of July 2009 active water storages in the Southern MDB were about 26% of their long-term average for July, and 17% of total storage capacity (Murray-Darling Basin Authority 2009, p. 1).

Horridge et al. (2005) developed a 'bottom-up' Computable General Equilibrium (CGE) model (TERM) of Australia and used it to analyse the economic impacts of the 2002-2003 drought on Australian Gross Domestic Product (GDP). They found that the drought directly reduced GDP by 1%, and a further 0.6% indirectly via negative multiplier effects (Horridge et al. 2005, p. 300). The relatively small impact on the overall economy is because agriculture accounts for only 3.6% of Australian GDP. By contrast, the drought had a large and negative impact on agricultural output that fell by about 30% nationally. Some regions, however, suffered even larger losses with a fall in agricultural production in New South Wales of about 45% due to the 2002-2003 drought.

The importance of water trading in helping to maintain incomes during droughts is shown by Peterson et al. (2004; 2005) who find that the benefits of water trading compared to no trading are much greater in drier years. For instance, they calculate that the increase in the Gross Regional Product (GRP) of the Southern MDB from water trading is about 550 million dollars in a dry year with both interregional and intraregional trade while in a wet year the gains from water trading are about $200 million (Peterson et al. 2004, p. 43). The additional gains, however, from allowing interregional trade (including across states) versus only intraregional trade are less, but are still substantial. Qureshi et al. (2009) estimate the gains from allowing interregional trade compared to only intraregional trade at some $88 million/year.

3. Water diversions

The impact of the drought on the environment has been exacerbated because environmental flows have been reduced by proportionally more than water diversions (Connell and Grafton 2008, p. 76), as illustrated in Figure 4. This is also shown in Table 1 that gives the decadal annual average ratio of water diversions to net inflows along the Murray River since the 1930s. In the 1980s and 1990s water diversions accounted for a little less than half of net inflows, but since 2000 water diversions account for over three quarters of net inflows.

If water diversions exceed 80% of net inflows then this is viewed as insufficient to even maintain ecosystems in a 'fair' or 'moderate modified' condition (International Water Management Institute 2005). The annual average quantity water not used for water diversions since 2000 on the Murray River is about 1,100 GL/year which is essentially the water required to convey or to transport seasonal allocations used by irrigators downstream of storages and to meet supply obligations for South Australia. In other words, after accounting for the water required to ensure the delivery of seasonal allocations (delivery water), and also to meet needs in South Australia (conveyance water) that includes a minimum flow requirement to maintain water quality levels at Murray Bridge (~ 350 GL), there is no water left in the Murray River specifically for environmental purposes.

Figure 5 shows diversions and net inflows for the Murray River since 1930, and Figure 6 illustrates diversions by each state and in total along with net inflows since 1994. The increased proportion of water allocated to irrigation during the drought is a direct result of giving priority in dry years to water diversions relative to environmental flows. As a result, the National Water Commission (NWC) in its 2009 Second Biennial Assessment of Progress in Implementation of the National Water Initiative, observes that it is "…increasingly concerned about the security of environmental water access entitlements and rules-based environmental water, particularly during drought. The Commission considers that water plans should clearly and transparently specify desired environmental outcomes and fully define environmental watering protocols to achieve them under all inflow scenarios (including sequences of dry years)." (NWC 2009, p. viii).

4. Economic effects of water buybacks

The effects of water buybacks can be estimated using models of the hydrology and economics of agriculture of the Basin. Models differ in terms of their specification, parameter values, method of solution and spatial dimensions. In all cases, the comparison is to a 'business-as-usual' scenario without a water buyback. Business as usual presumes that agricultural production and current water diversions are sustainable in the absence of increased environmental flows. In other words, the models implicitly assume that current agricultural practices with existing levels of diversions can be maintained indefinitely.

Overview of the existing models and results

Peterson et al. (2004) used the TERM-WATER model to analyse the impacts of water trading in the southern MDB. A key finding of their work is that water trading substantially reduces the impact of reductions in irrigation water availability. They found that using 1996/97 water availability, a 30% water buyback would reduce gross regional product (GRP) in the southern MDB by about 2%, and Australian GDP by 0.024%.

Dixon et al. (2009) used the TERM-H2O model to analyse the economic impacts of a water buyback (1,500 GL) in the southern MDB. They calculated that the impact of such a buyback on the southern MDB economy is small, and predict it would reduce real GRP by less than 1%. This is a fraction of the negative impact that would arise from even a moderate drought and the associated reductions in seasonal water allocations. The reason why water buybacks have a much smaller impact than equivalent declines in diversions due to drought is because farmers are:
(1) Directly compensated for the loss of water;
(2) Reduced diversions with a buyback are accounted for in the planning and planting decisions of affected farmers; and
(3) Less profitable irrigation activities are reduced by a much greater proportion with a buyback than with an equivalent reduction in water use in a drought.

Based on the historical inflows of the Murray River for 1980 to 1999, Mainuddin et al. (2007) developed a model to assess the effects on irrigated agriculture from increased environmental water allocations (250, 350, ..., 1,500 GL/year). These environmental allocations of water in GL are *not* the same as GL of water entitlements because water entitlements have different levels of reliability. The amount of water allocated to an entitlement in a given irrigation season depends on the water entitlement's level of reliability (such as 'High Security' or 'General Security' entitlements that determine the preferential access to the consumptive pool), the overall Cap for the Basin, diversion limits by catchment, expected inflows and water storage levels.

The integrated hydrologic-economic model of Mainuddin et al. (2007, p. 128) was calibrated to 2000-2001 conditions in the Southern MDB with agricultural surface water use of 8,317 GL versus the reported figure of 8,319 GL (Murray-Darling Basin Commission 2002). Mainuddin et al. (2007) found that economic activity after the water buy back following a 1,500 GL buyback, at least in the short run, is virtually unchanged and note "Notwithstanding the large impact on irrigated areas and crops, the overall economic profit remains almost unchanged from the base case..." (Mainuddin et al. 2007, p. 130).

A summary of the key results by crops in the TERM-H2O and Mainuddin et al. (2007) models is provided in Table 2 and their regional impacts by model and catchment is provided in Table 3. Their predicted results from a 1,500 GL buyback of water include:

(1) To minimise the opportunity cost of water purchases for the environment, most of the water should be acquired from the Murray-Riverina and also the Murrumbidgee catchments. These two regions alone provide 75% of the water acquired for the environment. Although the Ovens catchment and the Upper Murray provide much smaller quantities of water in absolute terms, their proportional decline in water use is the largest in the basin, or approximately 75% of their catchment water use;
(2) Water buybacks would have the greatest change in production in terms of irrigated cereal and also rice crops. However, the biggest reduction in water use occurs in terms of irrigated pasture used in livestock farming; and
(3) The loss in GRP in the regions from a water buyback will likely be the greatest in the Murray (Upper Murray and Riverina) and Murrumbidgee catchments although the estimated decline in the Basin as a whole is small, or about 2%.

These results only address the question of where acquiring water in the southern MDB imposes the lowest opportunity cost on irrigated agriculture. An equally important issue is the environmental benefits associated with acquiring water from different catchments within the southern MDB, and what this might imply in terms of optimal environmental watering.

Targeted buybacks and water trading

Qureshi et al. (2007) examine the economic effects of water buybacks in the southern MDB. Their key finding is that a proportional (equal share) buyback of water for the environment is *not* as cost effective as a targeted buyback from catchments where water has lower value in use. This supports a similar finding by Mainuddin et al. (2007). Qureshi et al. (2007) find that net revenues are $2 million/year higher with a targeted buyback and unrestricted interregional (across catchment) water trading than with a pro rata water buyback and unrestricted interregional trade. Net revenues would be $117 million/year higher with a targeted buyback and unrestricted interregional trade compared to a pro rata water recovery and no interregional water trade. Thus, targeting water buybacks to particular locations where the value added in agriculture is relatively low, and especially the freeing up of water trade, reduce the costs associated with water buybacks.

Wentworth minimum flow and 2/3 rule water buybacks

We develop our own hydro-economic model of the Murray-Darling Basin based on the catchments boundaries used by CSIRO in the development of its sustainable yields of the Basin. Based on previous hydrological studies in the MDB and static data from various sources, an integrated irrigated agriculture water model (IIAWM) is built up to simulate the river flow and agricultural production in the MDB (Jiang 2010). In the hydrological component, the IIAWM includes water delivery loss rates between regions, water availability predications and climate change scenarios from the CSIRO sustainable yields project (CSIRO 2008). In the economic component, the IIAWM uses data from the Australian Bureau of Statistics and Bryan and Marvanek (2004). The value of the model is that it provides a quantitative assessment of the opportunity costs in terms of irrigated agriculture from reduced water diversions associated with market-based water recovery by catchment and across the Basin as a whole. The model assesses short-run effects of reduced water diversion at two points in time — 2000-2001 which was a 'normal' year in terms of inflows and 2005-2006 which was a 'dry' year in terms of inflows. Thus, it provides a useful comparison as to the opportunity costs at different levels of inflows and prices and costs.

One of the buyback alternatives evaluated by the model is a 'Wentworth Minimum Flow' that represents the minimum environmental flows needed to satisfy existing water sharing rules (rules-based water) in the Basin as modelled by Marsh et al. (2009) that approximately equals 2,148 GL/year. The other buyback alternatives are defined as proportion of the agricultural surface water available for diversions in the MDB rather than as fixed quantities of water and include 10, 20, 30, 40 and 50% buybacks of this available water. A 20% buyback (1,544 GL) approximates a 1,500 GL flows given 2005-2006 agricultural surface water. A 40% buyback approximates a '2/3 rule' that would, on average, ensure that at the mouth of Murray River would receive 2/3 of its natural flow. A 50% buyback approximates a '2/3 rule' for the MDB and tries to mimic the flows at the end of each river valley equivalent to about 2/3 of the natural flows.

The results, in terms of the change in water use by catchment, are summarised in Tables 4 and 5 for a 'normal' year of inflows in 2000-2001 (agricultural surface water diversions is 10,147 GL/year) and a 'dry' year of inflows in 2005-2006 (agricultural surface water diversions is 7,720 GL). Care should be taken when comparing these inflows to other sources of data in different periods and across catchments where the hydrological boundaries may be defined differently.

Using 2000-2001 data that has the highest average agricultural surface water diversions, Table 4 shows that a 40% buyback of average water diversions that approximates the '2/3' rule for the Murray River would be equivalent to about 4,059 GL of actual water recovered and a 50% buyback would be equivalent to about 5,073.7 GL, and would approximate a '2/3' rule for each valley in the MDB. About half of the acquired water with a 40% or 50% buyback would come from the Murrumbidgee and Murray regions. However, substantial quantities would also be acquired from the Loddon–Avoca and Campaspe catchments. If the base flows were lower, as they were in 2005-2006 (see Table 5), a 40% buyback would generate about 3,088 GL or an amount slightly more than the Wentworth Minimum Flow while a 50% buyback would generate about 3,860 GL.

Under the 2000-2001 agricultural surface water diversions scenario, a Wentworth Minimum Flow buyback would generate additional environmental flows that would be equivalent to about 20% of actual surface water diversions for agriculture. Under the 2005-2006 agricultural surface water diversions scenario, a Wentworth Minimum Flow buyback would generate additional environmental flows equivalent to 28% of actual surface water diversions for agriculture.

Using agricultural surface water diversions over the two periods (2000-2001 and 2005-2006) Tables 6 and 7 present the effect on annual net returns in agriculture in the MDB. Using the 2000-2001 agricultural surface water diversions, Table 6 indicates that with an optimal allocation of water across all water, uses a 40% buyback (equivalent to about 4,059 GL) lowers the annual net returns in agriculture by about $254 million which is a 16% reduction in annual net returns relative to the base case of no water buyback. A 50% buyback (equivalent to about 5,073 GL) lowers the annual returns by $367 million which is about a one quarter reduction in annual net returns relative to the base case of no water buyback. By contrast, with an optimal allocation of water across all water uses, the Wentworth Minimum Flow (equivalent to 2,148 GL) lowers annual net returns by about $149 million and would reduce overall annual net returns in the Basin by less than 10%.

If agricultural surface water diversions are substantially less, as they were in 2005-2006 (Australian Bureau of Statistics 2008, p. 65-67), then the reduction in annual net returns from water buybacks increases because the marginal value of water is greater for farmers. Thus, Table 7 shows that a 40% buyback lowers the annual net returns in agriculture by about some $300 million which is equivalent to about a 20% reduction in annual net returns relative to the base case of no water buyback. A 50% buyback lowers the annual net returns in agriculture by $386 million which is equivalent to about a 26% reduction in annual net returns relative to the base case of no water buyback. A Wentworth Minimum Flow would reduce annual net economic returns by about $292 million, or about 20% reduction in the base case net economic returns.

The proportional change from water buybacks, however, varies considerably across the Basin with some regions barely affected (such as Condamine-Warrego) using 2000-2001 agricultural surface water diversions, even with substantial reduction in water diversions. By contrast, other catchments suffer relatively larger reductions in net returns (such as Murrumbidgee, Murray region, Loddon–Avoca and Campaspe regions). Any increased net returns from floodplains agriculture associated with increased environmental flows are not accounted for in these calculations.

Indirect and employment effects of water buybacks

The economic effects of a water buyback include:
(1) Direct impacts on-farm incomes fully compensated from the proceeds associated with the voluntary sale of water entitlements by farmers; and

(2) Possible indirect impacts to upstream and downstream industries and the regional economy.

The indirect impacts can be measured by negative multiplier effects associated with a contraction in the value-added of agriculture that reduces expenditures in the economy. Horridge et al. (2005) have used the TERM model to predict that the 2002-2003 drought caused a 1% reduction in national GDP that, in turn, caused a further 0.6% reduction (negative multiplier of 0.6) in GDP due to negative multiplier effects (Horridge et al., p. 300, 2005). The Australian Bureau of Statistics (ABS) has also calculated multipliers in its input-output models to account for changes in agricultural output. The ABS calculates that a supply shock in agriculture would generate a simple multiplier of 0.793 from production-induced effects in all other sectors or industries (ABS 2001, p. 81). Consumption-induced multipliers should not be included when assessing the effect of a water buyback because the negative consumption effects of the direct losses of the net returns in agriculture are very likely to be offset by any increases in consumption associated with the proceeds from the sale of water entitlements. This view is supported by Dixon et al. (2009, p. 25) who find, using the TERM model, that even if all proceeds from a 1,500 GL buyback leaked from the regions where the entitlements were held there would still only be a very small impact on regional aggregate consumption.

The negative multipliers associated with reduced agricultural net returns from lower water diversions must be offset by positive multipliers associated with the investments made by farmers from the proceeds of their sales of water entitlements. Unfortunately, it is not possible to calculate the size of this offsetting effect without knowing how the proceeds are invested from water buybacks. A 2008 survey of 20 sellers of water entitlements to the Commonwealth government for environmental purposes, however, suggests that these positive offsetting effects are likely to be substantial. For instance, it found that 11 farmers used the funds to retire debt, six reinvested on their farms, five used the proceeds to stay farming but to reinvest off farm, and three used the proceeds to stop farming and reinvest off farm (Hyder Consulting and Access Economics, 2008, p. 39).

An upper-end estimate of the direct employment losses from a Wentworth Minimum Flow buyback (2,148 GL) and 40% (about 4,059 GL) water buyback assuming 2000-2001 agricultural surface water diversions is about 6,309 and 11,861 workers, respectively. These estimates are based on the assumption that one full-time worker is employed per 55.6 ha of irrigated land. Some workers from irrigated agriculture would, however, be re-employed in dry-land agriculture and other agricultural activities, but many would also need to find employment in other sectors and possibly in other locations.

Present value economic effects of water buybacks

The present value of the reductions in annual net returns from water buybacks are presented in Tables 8 and 9 for the two surface water diversions periods (2000-2001 and 2005-2006). Different present values are calculated depending on the chosen discount rate (3%, 5% or 10%) over a 50-year time horizon. The higher the discount rate, the lower are the present value losses because a dollar loss in the future is worth less the more the future is discounted. The direct losses in present value terms are calculated as the sum of the discounted direct annual losses over a 50 year period where these losses are obtained from the model results in Tables 6 and 7 for the corresponding average net inflow periods.

Using the 0.793 multiplier from ABS, a 'high-end' estimate of the indirect impact on the regional (and national) economy in present value terms of reduced water diversions due to water buybacks can be calculated. These are defined as 'Indirect Losses' and are determined by multiplying the direct on-farm losses by the ABS multiplier (0.793). The direct (but not indirect) losses would be fully compensated if the reduced water diversions arise from a voluntary water buyback. The sum of direct and indirect losses *less* the proceeds paid to sellers of water entitlements with water buybacks is the maximum expected loss to the regional economy from reduced water diversions. The *actual* regional impact from water buybacks would be less than the maximum expected loss due to:

(1) Leakage of expenditures to the rest of the economy from irrigation agriculture that would lower the size of the negative multiplier;
(2) Expenditures and investments in the regional economy from the proceeds of the sale of water entitlements that would provide a positive and offsetting multiplier in others sectors; and
(3) Agricultural economic net returns in the base case (no water buyback) scenario are unlikely to be sustainable due to the loss of ecosystem services because of the very high ratio of water diversions to net inflows (76% in the Murray River) since 2000.

Table 8 indicates that using a discount rate of 5%, a Wentworth Minimum Flow buyback (equivalent to 2,148 GL reduction in diversions), and assuming agricultural surface water diversions over the 2000-2001 period, the maximum direct losses in present value terms from reduced water diversions is a little less than $3 billion. This loss is similar to the $3.1 billion allocated to reduce water over allocation in the Basin under the *Water for the Future* package. Maximum total losses would be higher if there were negative multiplier effects and would be about $4.9 billion. If there were a buyback equal to 40% of agricultural surface water diversions the direct losses would be $4.7 billion and total (direct and indirect) losses would be $8.3 billion with a 5% discount rate. A 50% buyback would result in direct losses of $6.7 billion with a 5% discount rate.

The losses are substantially higher for a fixed volume of water acquired if agricultural surface water diversions in the MDB were at their 2005-2006 levels. For instance, using 2005-2006 agricultural surface water diversions (see Table 9), the direct losses with a 5% discount rate to agriculture from a Wentworth Minimum Flow buyback would be about $5.3 billion, about $5.5 billion with a 40% buyback, and some $7 billion for a 50% buyback. The reasons for the higher loss relative to 2000-2001 is because the less water there is available, the greater is the marginal value of water from a given reduction in diversions.

Monte Carlo simulations

Another way to estimate the potential losses in net economic returns in agriculture with different inflows and buybacks is to generate Monte Carlo simulations, based on the actual probability distribution of inflows into the Murray River over the two periods, 1980-1999 and 2000-2008, as defined in Table 10. These probability distributions were then calibrated in terms of probabilities for agricultural surface water diversions in the Murray River. Using the relationship between agricultural surface water diversions for the two periods (2000-2001 and 2005-2006) and net economic returns (see Tables 6 and 7), and also the calibrated probability distribution, probability density functions were derived in a Monte Carlo simulation for a Wentworth Minimum Flow and 40% buyback. In the Monte Carlo method the annual net economic returns from agriculture are calculated from 5,000 iterations. Table 11 presents the results of the Monte Carlo analysis in terms of the mean net economic returns with no buyback and various buyback options calibrated to 2000-2001 agricultural surface water diversions. Table 12 presents the results calibrated to 2005-2006 agricultural surface water diversions.

Table 11 shows that using the 1980-1999 probability of inflows calibrated to 2000-2001 agricultural surface water diversions, a Wentworth Minimum Flow buyback would reduce mean net economic returns by about 9%, or about $153 million/year. A 40% buyback would lower annual net returns by about 17% or $290 million. Table 12 indicates that using the 2000-2008 probability of inflows calibrated to 2005-2006 agricultural surface water diversions, a Wentworth Minimum Flow buyback and similarly a 40% buyback would reduce mean net economic returns by 17-24%, or between $210 and $302 million/year. These percentage declines are similar to those calculated in Tables 6 and 7 that use a simple average and do not account for the change in the distribution of inflows over the two periods.

Figures 7 and 8 present the probability density function and cumulative density function of the annual net economic returns, respectively, for a Wentworth Minimum Flow buyback and a 40% water buyback based on the probabilities of net inflows over the period 1980-1999 calibrated to 2000-2001 agricultural surface water diversions. Figures 9 and 10 present the same information as Figures 7 and 8, but use the probabilities of net inflows over the period 2000-2008 calibrated to 2005-2006 agricultural surface water diversions. Using the annual net inflow probabilities for the period 1980-1999, a 90% confidence interval for the expected annual net economic returns with a Wentworth Minimum Flow buyback is $1.1billion to $1.94 billion, while with a 40% buyback the confidence interval is $0.96 billion to $1.8 billion. Using the annual net inflow probabilities for the 2000-2008 period, a 90% confidence interval for the expected annual net economic returns with a Wentworth Minimum Flow buyback is calculated to be between 0.71 billion and $1.44 billion. A similar sized confidence interval was estimated for a 40% buyback.

Overall, the direct farm losses from reduced water diversions due to water buybacks are greatest when average net inflows are smaller. This provides a justification for timely and effective market-based water recovery if climate change, as is expected, reduces net inflows into the Basin versus long-term average inflows. By purchasing water entitlements for environmental purposes from willing sellers water buybacks allow farmers and their communities to shift to lower water use, sooner rather than later, and assist them to autonomously adapt to reductions in water availability associated with climate change.

Restoring the balance in the Murray-Darling Basin

The Australian government is committed to spend \$3.1 billion to purchase water entitlements from willing sellers for the environment in what is called, *Restoring the Balance in the Murray-Darling Basin*. The amount the Australian government needs to pay to achieve a desired quantity of water for environmental flows depends on the price paid per ML of water entitlement which, in turn, depends on the reliability or security of the purchased entitlements.

Tables 13 and 14 provide an indication of the additional expenditures required by the Australian government under different buybacks scenarios, over and above the \$900 million already spent (or contracted for), to acquire 612 GL of water entitlements by the Australian government under the *Water for the Future* package, as at end of October 2009. The two tables show the volumes of water allocated for diversions and environmental flows under the various buyback scenarios for the MDB. The quantities for water entitlements and environmental flows differ because water entitlements have a reliability of less than 100% such that the amount of water allocated to the entitlement every year is less than the nominal quantity assigned to the entitlement. The average reliability is calculated using the long-term cap equivalent for the water entitlements already purchased, or in the process of being purchased by the Commonwealth government, and is approximately 64%. In general, the higher is the reliability of the water entitlement the higher is its price.

The actual water that will be allocated to the Commonwealth environmental water entitlements in the next year, however, will likely be much less than is implied by the long-term cap average reliability because of current low water storages due to a sequence of dry years in the MDB since 2001. Waterfind, a national waterbroker, estimates that the actual water deliveries in 2009/10 based on the water entitlement holdings by the Commonwealth as of 30 August 2009 (545 GL) would be about 32 GL (Waterfind 2009, p. 18).

Tables 13 and 14 show that, based on the average reliability (64%) and price paid per ML (\$1,522/ML) of water entitlements in 2008/09, but multiplied by the 612 GL already contracted for by the Australian government as of 30 September 2009, a Wentworth Minimum Flow buyback would require an additional 2,745 GL in water entitlements at a cost of about \$4 billion. To achieve this level of environmental flows, the \$3.1 billion currently allocated for water buybacks in the *Water for the Future* package would have to be increased by about \$2.0 billion, or alternatives found to generate the equivalent volume of water for the environment. At a higher price of water entitlements of \$2,000/ML, the cost of acquiring about 2,745 GL in water entitlements would need an additional \$3.3 billion over and above the \$3.1 billion allocated in the *Water for the Future* package. These expenditures do not take into account water entitlements held by the states for environmental purposes which, if were used for environmental flows would reduce the quantity of entitlements needed to be purchased by the Commonwealth.

The budget required to achieve a 2/3 natural flow, approximated by a 40% water buyback in reference to the Murray River and 50% buyback for all river valleys in the MDB, depends on average net inflows. A small net inflow requires less water to achieve the same proportional end of flow at the end of the catchment and, thus, a smaller budget if prices are constant across the scenarios. However, the market price of water entitlements, for at least high security entitlements, will likely be higher if average inflows were permanently lower. In our analysis we assume that the market price for water entitlements is the same for both scenarios although inflows were much lower in 2005-2006 compared to 2000-2001.

Using the agricultural surface water diversions that occurred in 2000-2001, a 40% buyback would cost an additional $9.3 billion (at $2,000/ML) and $6.5 billion (at $1,522/ML) in excess of the amount budgeted in Restoring the Balance in the Murray-Darling Basin under the *Water for the Future Package*. A 50% buyback would cost an additional $12.4 billion (at $2,000/ML) and $8.9 billion (at $1,522/ML) in excess of the amount budgeted in Restoring the Balance in the Murray-Darling Basin.

5. Economic effects of water buybacks versus investments in on-farm water-use efficiency

The *Water for the Future* package allocates fixed amounts of funding to water buybacks ($3.1 billion) and investments in on and off-farm water use efficiency ($5.8 billion). To ensure cost effectiveness, the two approaches should return an equivalent quantity of water for the same price or $/ML.

A comparison of the cost effectiveness of water buybacks and water efficiency investments associated with the Living Murray Initiative is provided in Table 15. Based on the market price of water entitlements and the cost of acquiring water via efficiency investments, the Social and Economics Reference Panel for the Murray-Darling Basin Commission concluded in April 2008, in a period of low-water availability, that water buybacks are a cost effective method of acquiring water.

Research by Qureshi et al. (in press) in the Murrumbidgee supports the conclusion that market-based water recovery is cost effective. In their modelling they account for return flows from irrigation that subsequently becomes available for downstream and aquifer users while also augmenting environmental flows. An improvement in on-farm efficiency that reduces return flows will have an offsetting and negative impact on environmental flows. As a result, in locations where there are lower levels of irrigation efficiency and return flows are larger, the cost effectiveness of water buybacks is enhanced relative to infrastructure subsidies. Qureshi et al. (in press) further argue that a key reason for cost effectiveness of water buybacks is that, in contrast to infrastructure subsidies, they provide farmers with flexibility as to how to use less water. Farmers that voluntarily choose to sell their water in a buyback and remain farming can employ deficit irrigation, change their land use and/or tillage practices or invest in improvements in irrigation efficiency. In the subsidy approach, water is acquired only through efficiency improvements whether it is the least costly method or not. Water efficiency improvements may also have a ‘rebound’ effect in terms of reduced return flows.

Market-based water recovery is a more flexible approach to water recovery in a temporal sense. This is because it allows farmers to reinvest funds from the sale of water entitlements, and to autonomously adapt to lower water diversions in ways that best suit them. By contrast, infrastructure subsidies ‘lock in’ current irrigation systems and water use that reduces flexibility to adapt to climate change and climate variability. Subsidies also economically disadvantage irrigators and irrigation districts that, at their own expense, have already installed efficient irrigation systems.

6. Economic effects of climate change

Climate change is expected to reduce inflows into the south-eastern part of the Basin from increased evaporation due to higher temperatures and reduced rainfall in areas that generate the most inflows. It is also expected to increase the frequency of extreme events.

A given proportional decline in terms of inflows will cause a larger proportional reduction in water available for use because ‘base’ flows or conveyance water has to be maintained to ensure delivery of water to downstream irrigators and environmental sites. This effect is illustrated in Figure 11 for a 20% drop in inflows for a river that previously had 100 GL inflows and needs to maintain 20 GL base, delivery or conveyance flows assuming that previously 20 GL were allocated for environmental water and 60 GL for water diversions. In this case, a 20% reduction in inflows results in a 25% reduction in both water diversions and environmental water, assuming an equi-proportional drop in use and non-use, because conveyance water is a ‘fixed cost’ of transporting water that must be maintained regardless of the level total inflows. If the proportional reductions in environmental water were twice as much as that for water diversions, there would be 40% reduction in environmental flows and only a 20% drop in water diversions. This issue of base, delivery or conveyance water and environmental flows is important because of the unprecedented decline in net inflows over the past decade, and the expectation of lower net inflows in the southern MDB relative to long-term averages due to climate change.

Adamson et al. (2009) have assessed the effects of irrigated agriculture under different climate scenarios and states of nature (wet with a 30% probability, normal with 50% probability and dry with a 20% probability). They use inflow projections by Jones et al. (2007) for 2030 and find under their global solution (optimal adaptation to reduced water availability), the social value in the Basin declines by $200 million/year and up to $500 million/year (Adamson et al. 2009, p. 363). The losses occur because of reduced revenues from lower yields due to deficit irrigation, a smaller area in irrigation and because of increased costs from accessing water. In the optimal adaptation scenario there is a proportionately greater reduction in water use in the upstream parts of the Basin. Their results, in terms of water reductions due to climate change, are broadly consistent with the finding that it is optimal to target water acquisition with buybacks in the upper and south-eastern parts of the Basin.

Connor et al. (2009) use a different model to evaluate the economic impacts on irrigated agriculture from climate change. They assess the effects of three scenarios: (1) mild climate change with 13%, (2) moderate climate change with 38% and (3) severe climate change with 63% reduction in inflows in the Basin. They find that farmers can effectively adapt to mild or moderate climate change given unrestricted water markets. As water availability decreases, irrigators apply less water (deficit irrigation) and fallow more land. Provided water markets are unrestricted, they find reductions in profits are much less than the decline in inflows. For example, with moderate climate change net returns in Victorian and South Australian agriculture decline by 5% and 11%, respectively, with unrestricted water trading. By contrast, in the absence of such trades the decline in net returns in Victorian and South Australian agriculture are 19% and 54%.

Goesch et al. (2009) provide another model to assess the effects of climate change in the Basin. They show declines in water diversions would result in a much lower proportional decline in irrigation income as farmers are able to adapt their practices to counter the effects of reduced water availability. Using the CSIRO (2008) medium climate scenario projections where water surface availability falls, on average by 11%, they predict overall diversions would fall by about 4% while irrigators' incomes would drop by about 1%. In this scenario, the largest proportional decline in water use occurs with broad-acre agriculture (5.8%), grains (4.5%), dairy (4.2%) and rice (3.4%) with an overall reduction in the area of irrigated farmland of about 1.2%. They also find that if the water sharing plans were changed so that if environment water and water diversions are reduced by the same proportion with climate change, irrigators' income would decline by about 3.2%.

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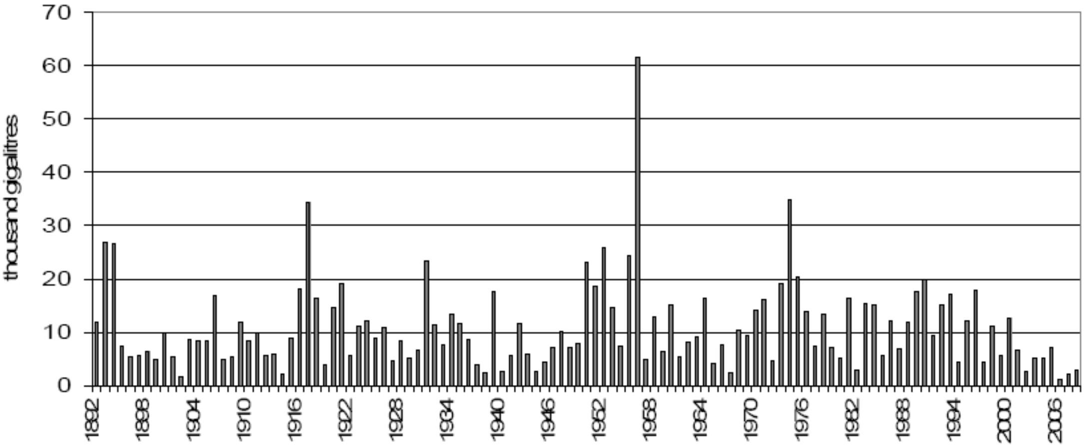
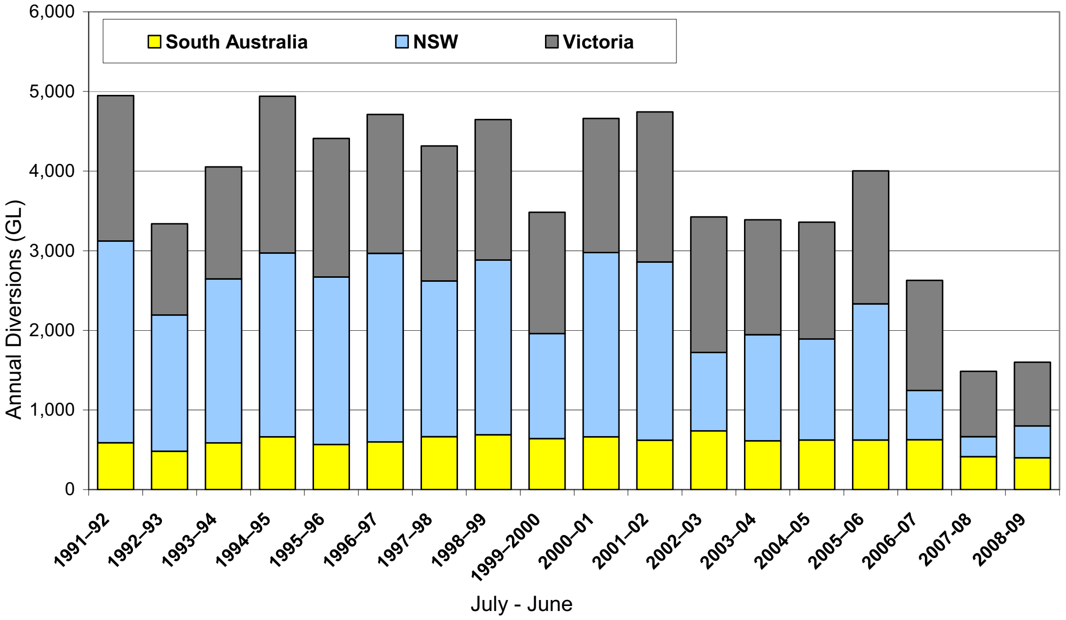
Figure 1 Murray system inflows (including Darling), 1892 to 2008



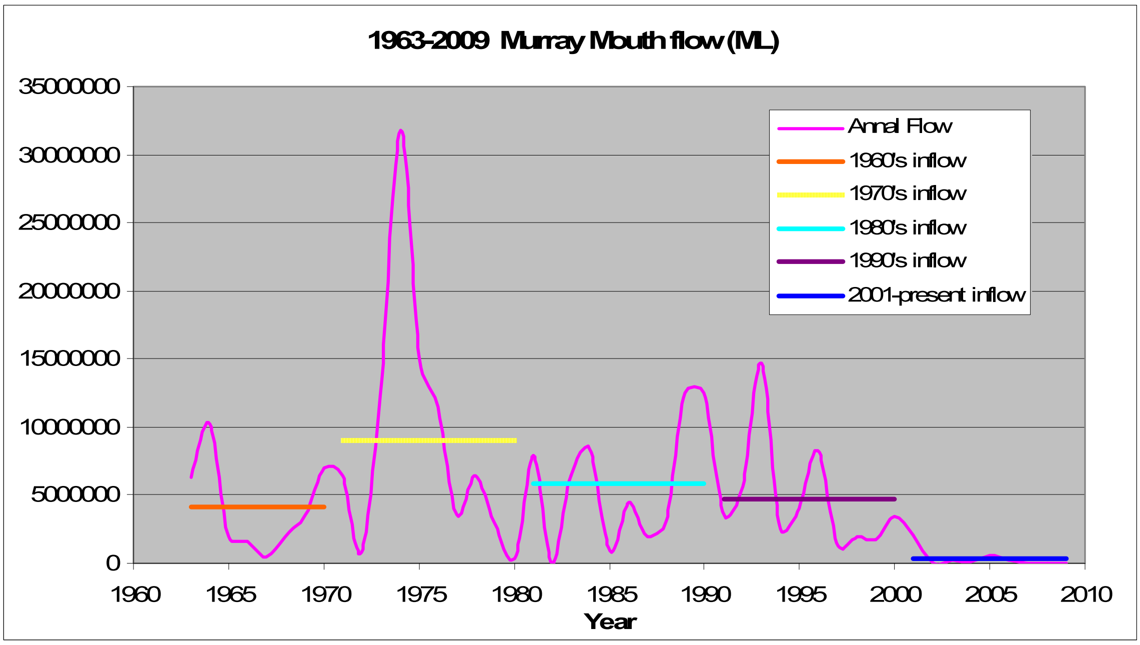
Source: Productivity Commission (2009a, p. XXI)

Figure 2: Murray River Water Diversions 1991-2009



Source: Murray-Darling Basin Authority

Figure 3: Flows at the Murray Mouth 1963-2009

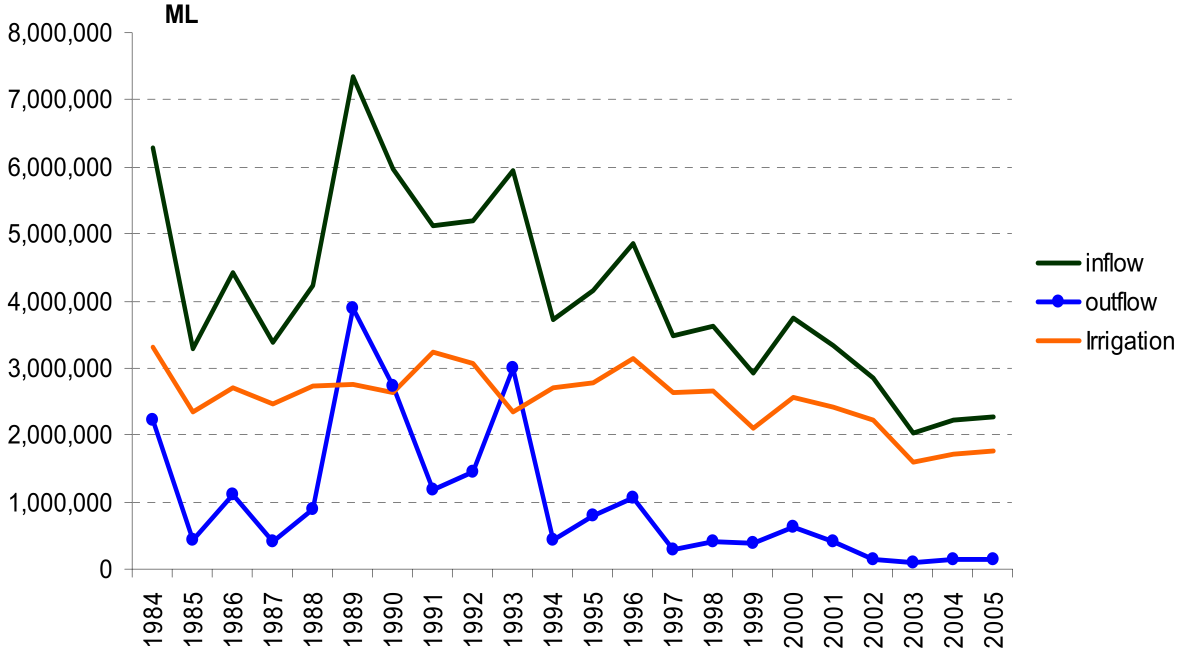


Data Source: Murray-Darling Basin Official Water System Database

Notes:

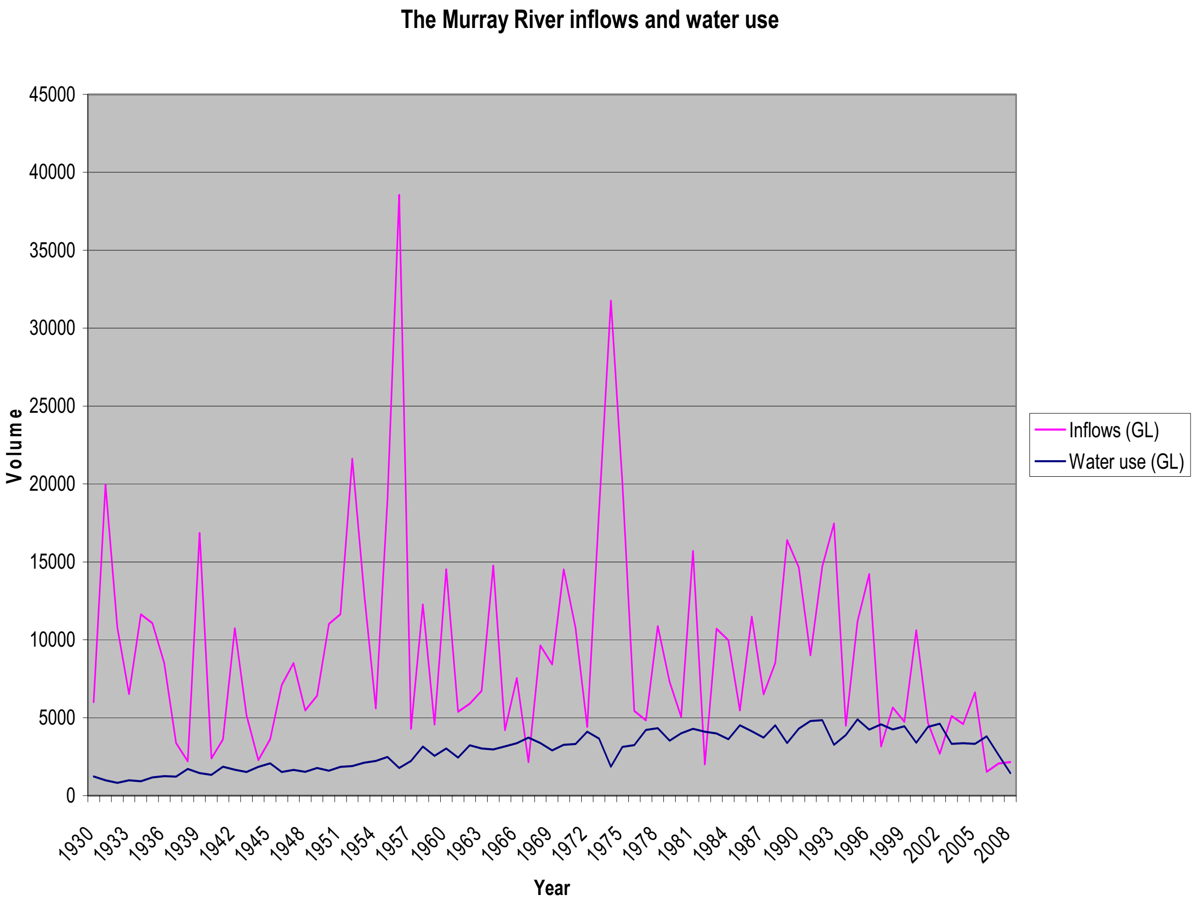
1. Flow is measured at the barrages near the Murray River Mouth.

Figure 4: Annual Inflow, Outflow and Irrigation Use on the Murrumbidgee River, Australia 1984-2005



Source: Grafton (2009, p. xvi)

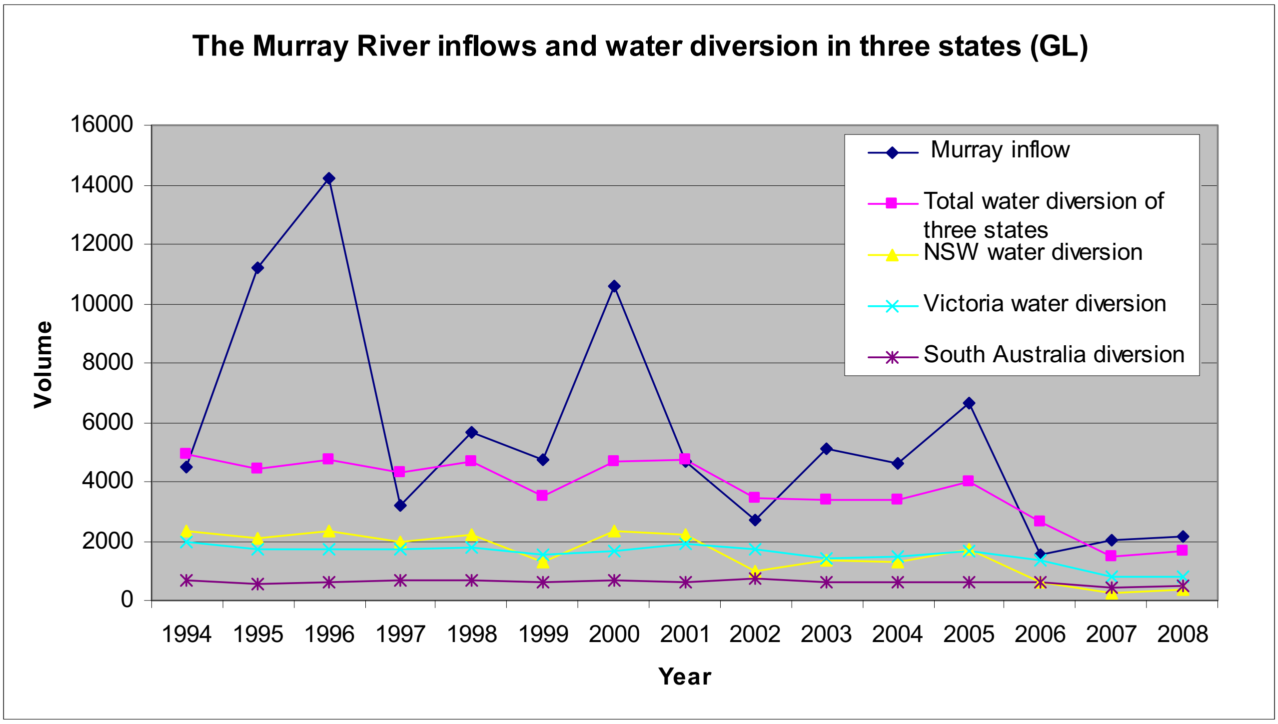
Figure 5: Murray River Net Inflows and Water Diversions 1930-2008



Data source: Murray-Darling Basin Official Water System Database
Notes:

1. Net inflows are from the first column (Murray System Inflows — no Darling River or Snowy River inflows) in the Murray River inflows table.
2. Water use is the sum of Murray River (NSW) Total Diversion, Total South Australia Diversion in MDB and River Murray (Victoria) Gross Diversion in the Murray River water use table.
3. Data is for the Murray River only and does not include other regions of the southern Murray-Darling Basin.

Figure 6: Murray River Net Inflows and Water Diversions 1994-2008



Data source: Murray-Darling Basin Official Water System Database

1. Net inflows are from the first column (Murray System Inflows — no Darling River or Snowy River inflows) in the Murray River inflows table.
2. Water use is the sum of Murray System diversions in NSW, in Victoria and South Australia.
3. Data is for the Murray River only and does not include other regions of the southern Murray-Darling Basin.

Figure 7: Probability (and Cumulative) Density Function for Wentworth Minimum Flow (2,148GL) Water Buyback based on probability distribution of 1980-1999 inflows in the Murray River and calibrated to 2000-2001 agricultural surface water diversions in the Murray-Darling Basin

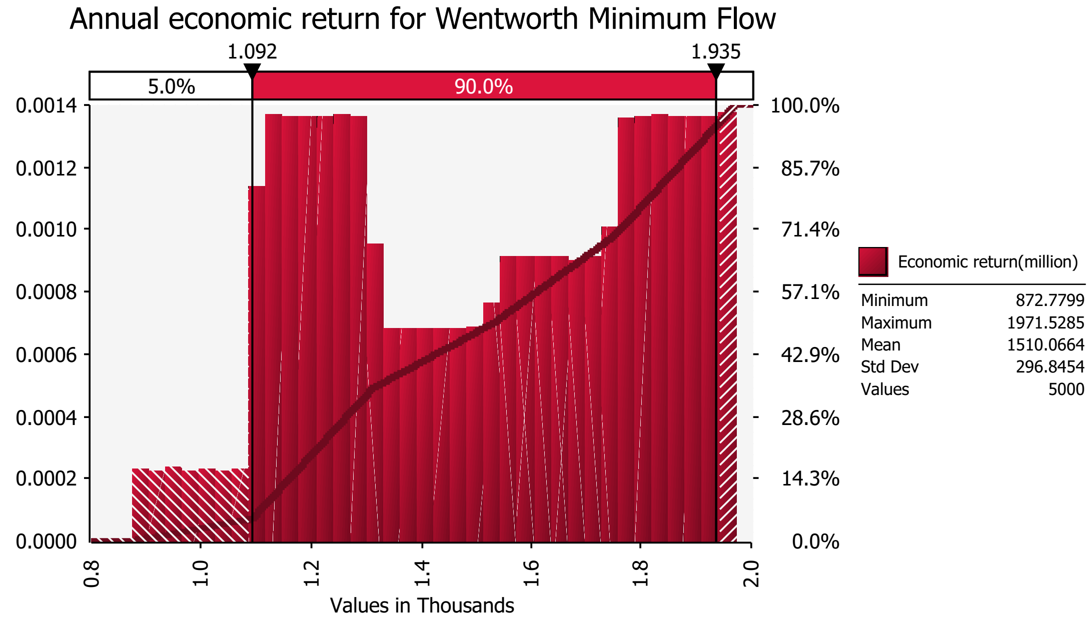


Figure 8: Probability (and Cumulative) Density Function for a 40% Water Buyback based probability distribution of 1980-1999 inflows in the Murray River and calibrated to 2000-2001 agricultural surface water diversions in the Murray-Darling Basin

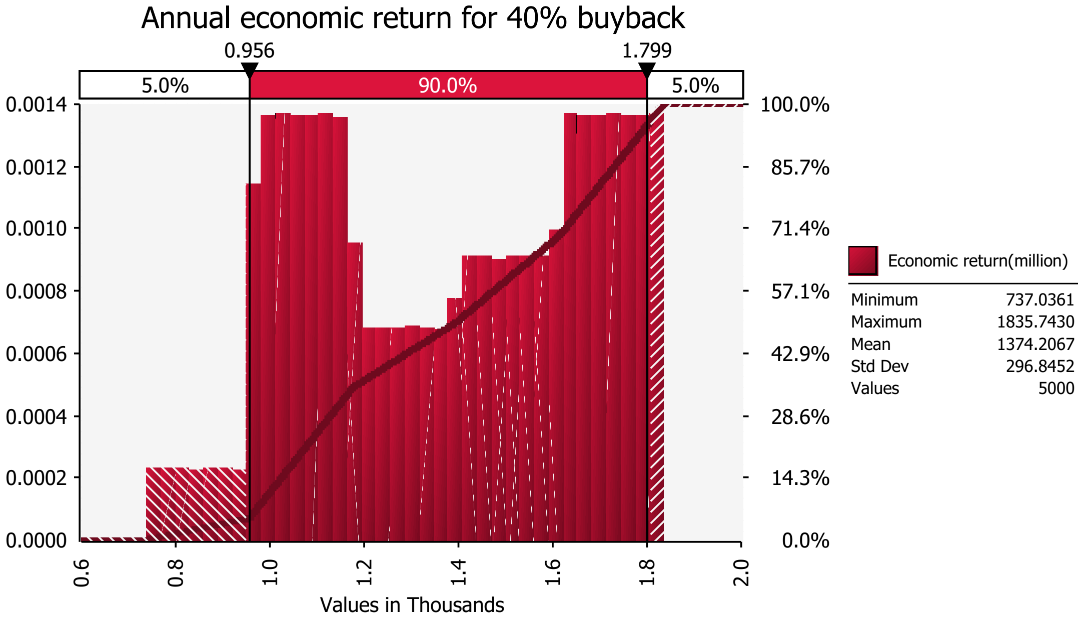


Figure 9: Probability (and Cumulative) Density Function for Wentworth Minimum Flow (2,148GL) Water Buyback based on probability distribution of 2000-2008 inflows in the Murray River and calibrated to 2005-2006 agricultural surface water diversions in the Murray-Darling Basin

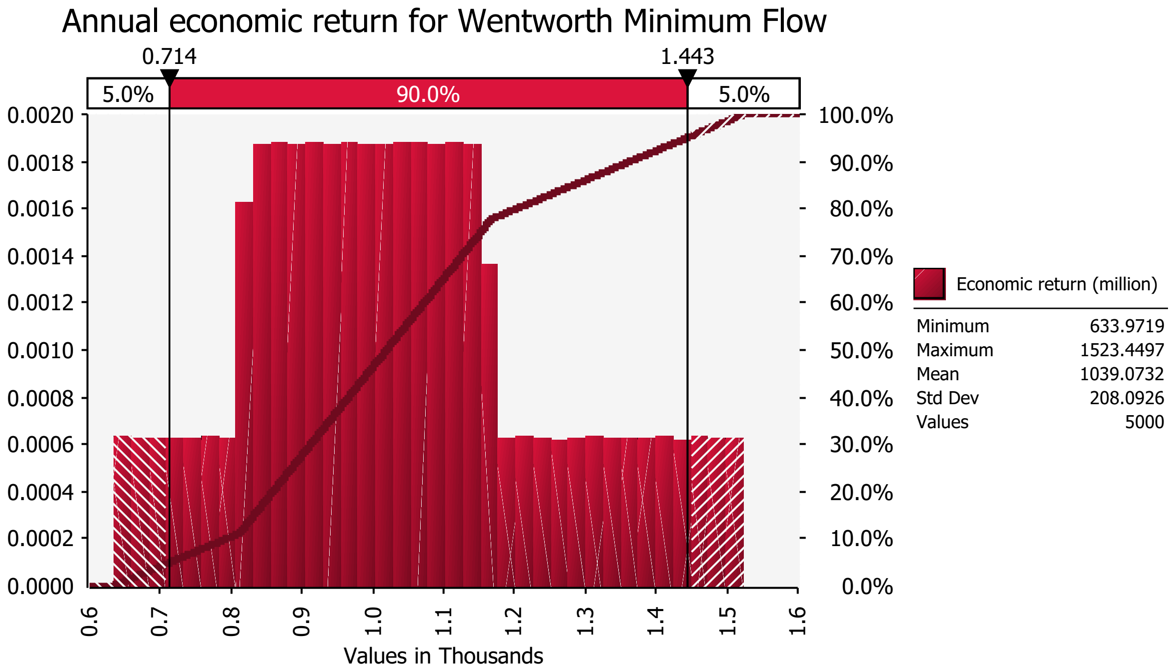


Figure 10: Probability (and Cumulative) Density Function for a 40% Water Buyback based on probability distribution of 2000-2008 inflows in the Murray River and calibrated to 2005-2006 agricultural surface water diversions in the Murray-Darling Basin

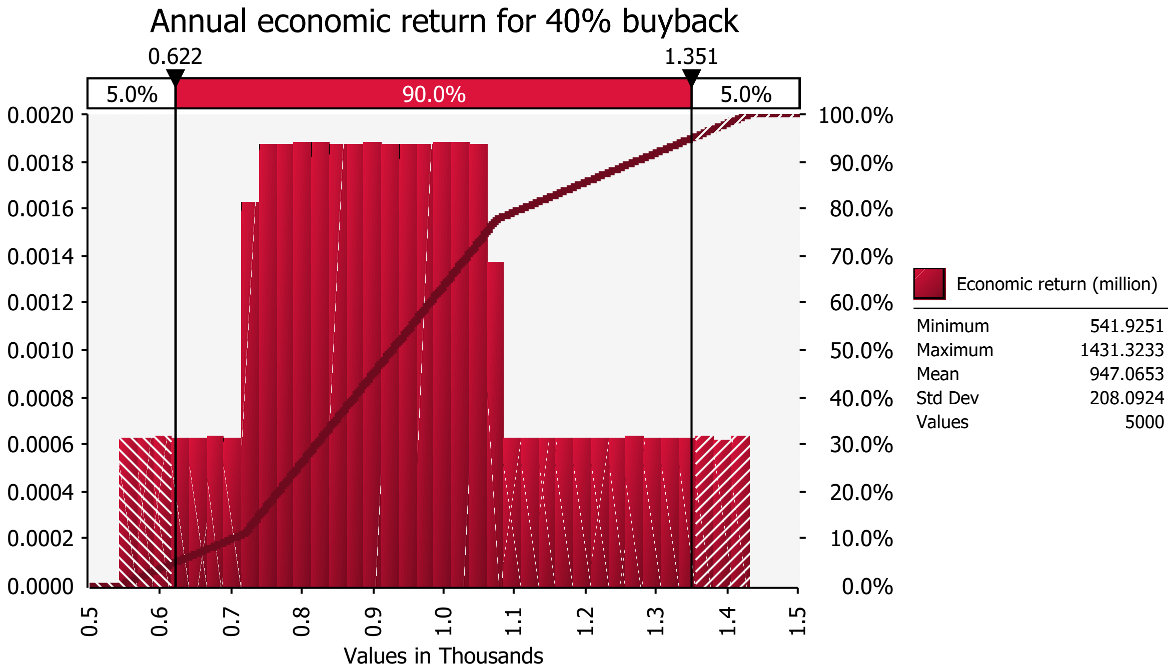


Figure 11: Effect of Lower Inflows from an Equi-proportional Decline in Water Diversions and Environmental Water with a Fixed Level of Conveyance

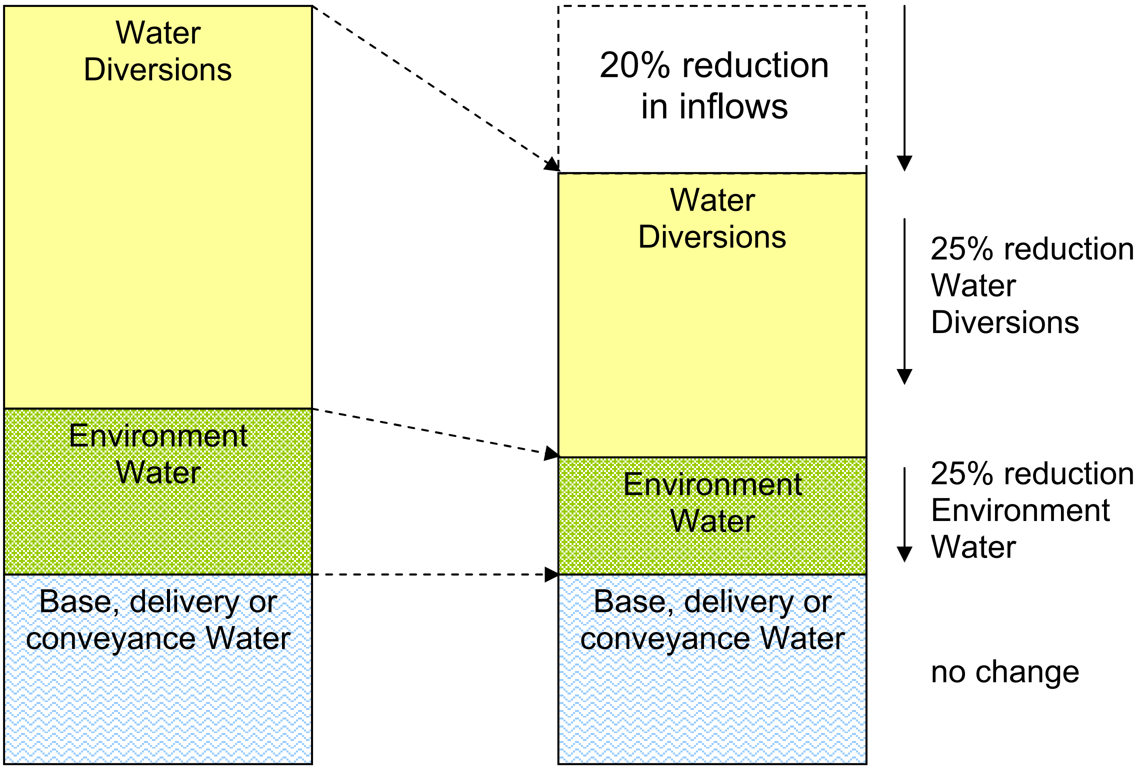


Table 1: Average Annual Net Inflows in the Murray River and Total Water Diversions by Decade

	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2008
Net Inflows (GL)	8,893	5,529	14,160	7,928	12,822	9,181	9,932	4,449
Water use (GL)	1,178	1,676	2,185	3,119	3,465	4,025	4,351	3,368
Percentage Diverted	13%	30%	15%	39%	27%	44%	44%	76%

Data source: MDBA (2009)

Notes:

1. Net inflows are from the first column (Murray System Inflows — no Darling or Snowy River inflows) in the Murray River inflows table.
2. Water use is the sum of Murray River (NSW) Total Diversion, Total South Australia Diversion in MDB and River Murray (Victoria) Gross Diversion in the Murray River water use table.
3. Data is for the Murray River only and does not include other regions of the southern Murray Darling Basin.

Table 2: The effects of targeted water buyback in various crops of the Southern Murray Darling Basin (SMDB)

TERM-H2O model with 1,500 GL buyback			**TERM WATER model with 1,500 GL buyback**		**Mainuddin et al. (2007) model with 1,500 GL buyback**	
Crop	Production change (%)	Water use change (%)	Crop	GRP change (%)	Crop	Buy back volume (GL)
Cereal Irrigated	-33.2	-49.1	Diary	-4	Rice	0
Rice	-21.8	-29.1	Perennial horticulture	-0.7	Grape	0
DairyCatIrig	-1.9	-4.1	Rice	-20	Pasture-Beef	495
OthLivstoIrg	-9.7	-16			Pasture-Dairy	750
CottonIrig	-2.2	-5.2			Pasture-Sheep	225
Grapes	-1.1	-4			Oilseeds	0
Vegetables	0.3	0.6			Deciduous Fruits	0
FruitIrig	0.3	0.8			Citrus Fruits	0
OthAgriIrig	-18.3	-23.4			Legumes	15
SMDB Total	-7.2	-25.8			Cereals	0
					Potatoes	0
					Vegetables	0

Notes:
1. 1,500 GL is 33% of 2004-05 water use in the SMDB. Dixon et al. (2009, pp. 18 -20) predict that 1,500 GL will be 25.8 % of water used in the southern Murray-Darling Basin in 2017.

Sources: Adapted from (Peterson et al. 2004, p. X), Dixon et al. (2009, pp. 18 -20) and Mainuddin et al. (2007, p.129).

Table 3: The effects of targeted water buyback in various regions of the SMDB

TERM WATER model[1]				**Mainuddin et al. (2007) model**[2]	
Buyback scenario	10% buyback	20% buyback	30% buyback	1500 GL buy back	
Region	GRP change (%)	GRP change (%)	GRP change (%)	Region	Buy back volume (GL) and change in water use %
Murrumbidgee	–0.87	–1.92	–3.23	Upper Murray	15GL and -75%
Murray	–1.21	–2.65	–4.42	Kiewa	0
Mallee	–0.41	–0.98	–1.78	Ovens	15GL and -45%
Goulburn	–0.39	–0.94	–1.72	Broken	0
Loddon	–0.13	–0.31	–0.58	Goulburn	0
Ovens	–0.06	–0.13	–0.24	Campaspe	0
Murray land	–0.30	–0.70	–1.27	Loddon	210Gl and -14%
Total	–0.52	–1.17	–2.02	Avoca	30GL and -20%
				Murray-Riverina	705GL and -37%
				Murrumbidgee	420GL and -20%
				Mallee	30GL and -9%
				Wimmera-Avon	0
				Lower Murray	90GL and -38%

Notes:

1. 10%, 20% and 30% buyback is defined as 10%, 20% and 30% reduction in the 1996-1997 mean irrigation water use of the southern Murray-Darling Basin, see Peterson et al. (2004, p. 31).

2. Mainuddin et al. (2007) model is calibrated to agricultural surface water diversions in 2000-2001 (8,317 GL). The change in water use by catchment calculated using last column of Table 2 (% acquired of total across basin) converted into GL and as a percentage of the base case scenario.

3. GRP = Gross Regional product.

Sources: Adapted from Peterson et al. (2004) and Mainuddin et al. (2007).

Table 4: Water use in the Murray-Darling Basin under different water buyback scenarios (GL) based on 2000-2001 agricultural surface water diversions

Catchment	Base Case (no buyback)	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Paroo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Warrego	1.54	1.54	1.54	1.54	1.54	1.54	1.54
Condamine-Balonne	610.70	605.35	560.24	560.24	560.24	478.34	478.34
Moonie	33.17	33.11	32.88	32.88	32.88	21.12	21.12
Border Rivers	445.83	445.83	430.17	430.17	430.17	409.59	409.59
Gwydir	564.53	555.15	555.25	555.25	555.25	549.79	549.79
Namoi	628.23	627.47	572.84	572.84	572.84	533.36	533.36
Macquarie-Castlereagh	436.83	426.14	408.41	408.41	408.41	368.09	368.09
Barwon-Darling	389.64	282.66	382.10	382.10	382.10	374.96	374.96
Lachlan	212.75	196.11	174.11	165.86	165.86	67.39	54.56
Murrumbidgee	2508.90	2339.69	2026.98	1934.95	804.08	707.61	371.43
Murray	3138.25	1378.10	2823.12	1908.65	2041.90	1812.18	1479.31
Ovens	36.49	36.49	36.20	36.20	36.20	20.66	20.66
Goulburn-Broken	775.25	727.93	764.98	764.98	747.86	651.39	318.52
Campaspe	127.10	113.26	127.10	127.10	127.10	2.34	2.34
Loddon-Avoca	142.00	142.00	142.00	142.00	142.00	22.62	22.62
Wimmera	32.19	32.19	31.90	31.90	31.90	26.86	26.86
Eastern Mt Lofty Ranges	64.02	56.24	62.86	62.86	62.86	40.60	40.60
Total	10147.42	7999.24	9132.68	8117.94	7103.19	6088.45	5073.71

Notes:

1. The actual agricultural water use in 2000-01 is 10,516 GL. In Jiang et al. (2009), based on 2000-01 land use, the simulated agricultural water use is 10,147 GL. We use the simulated 2000-2001 agricultural surface water diversions (10,147 GL) as the baseline for water use reductions.

2. For the whole basin Wentworth Minimum flow (2,148 GL) indicates 2,148 GL additional water for environmental flows is required at the basin level (Marsh et al. 2009). In our simulations, individual regional additional environmental water requirements are also applied to each region in the Murray Darling Basin. Compared with the 2000-2001 base case, the simulated basin water use under Wentworth Minimum flow rule is 7,999 GL.
3. Results are derived from a model described in Jiang et al. (2010).

Table 5: Water use in the Murray-Darling Basin under different water buyback scenarios (GL) based on 2005-06 agricultural surface water diversions

Catchment	Base Case (no buyback)	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Paroo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Warrego	1.54	1.54	1.54	1.54	1.54	1.54	1.54
Condamine-Balonne	560.24	554.89	544.10	450.57	478.34	478.34	478.34
Moonie	32.88	32.82	16.74	0.00	21.12	21.12	21.12
Border Rivers	430.17	430.17	409.12	382.07	409.59	409.59	409.59
Gwydir	555.25	545.87	539.54	516.33	549.79	549.79	549.79
Namoi	572.84	572.08	552.05	524.67	533.36	533.36	533.36
Macquarie-Castlereagh	408.41	397.72	383.94	360.18	368.09	368.09	368.09
Barwon-Darling	382.10	275.12	366.39	341.41	374.96	374.96	374.96
Lachlan	180.86	164.22	141.39	135.12	54.56	54.56	54.56
Murrumbidgee	813.41	644.20	779.61	715.70	481.53	381.20	332.00
Murray	2617.25	857.11	2349.43	1893.90	1589.40	833.95	542.67
Ovens	36.20	36.20	28.42	21.46	20.66	20.66	20.66
Goulburn-Broken	764.98	717.66	734.63	733.12	428.64	512.42	80.90
Campaspe	127.10	113.26	2.78	2.34	2.34	2.34	2.34
Loddon-Avoca	142.00	142.00	21.64	22.62	22.62	22.62	22.62
Wimmera	31.90	31.90	21.60	26.86	26.86	26.86	26.86
Eastern Mt Lofty Ranges	62.86	55.08	55.08	48.12	40.60	40.60	40.60
Total	7720.00	5571.81	6948.00	6176.00	5404.00	4632.00	3860.00

Notes:

1. The actual agricultural water use in 2005-06 is 7,720GL. We use the actual 2005-2006 agricultural surface water diversions as the baseline (7,720 GL),

2. For the whole basin Wentworth Minimum flow (2,148 GL) indicates 2,148 GL additional water for environmental flows is required at the basin level (Marsh et al. 2009). In our simulations, individual regional additional environmental water requirements are also applied to each region in the Murray Darling Basin. Compared with the 2005-2006 base case, the simulated basin water use under Wentworth Minimum flow rule is 5,571 GL.
3. Results are derived from a model described in Jiang et al. (2010).

Table 6: Annual net returns in the Murray-Darling Basin under different water buyback scenarios (million $) based on 2000-2001 agricultural surface water diversions

Catchment	Base Case (no buyback)	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Paroo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Warrego	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Condamine-Balonne	81.27	81.10	79.64	79.64	79.64	70.57	70.57
Moonie	3.80	3.80	3.79	3.79	3.79	2.49	2.49
Border Rivers	74.91	74.91	74.41	74.41	74.41	72.13	72.13
Gwydir	67.79	67.48	67.49	67.49	67.49	66.89	66.89
Namoi	80.41	80.38	78.62	78.62	78.62	74.24	74.24
Macquarie-Castlereagh	65.84	65.50	64.93	64.93	64.93	60.46	60.46
Barwon-Darling	47.65	35.71	47.41	47.41	47.41	46.62	46.62
Lachlan	41.35	40.82	39.95	39.50	39.50	28.59	27.17
Murrumbidgee	306.31	300.84	290.73	285.66	223.37	212.69	175.44
Murray	569.57	445.41	554.56	504.19	511.53	493.50	456.63
Ovens	16.68	16.68	16.67	16.67	16.67	14.95	14.95
Goulburn-Broken	126.78	123.29	126.44	126.44	125.50	114.81	77.94
Campaspe	15.29	13.76	15.29	15.29	15.29	1.47	1.47
Loddon-Avoca	30.42	30.42	30.42	30.42	30.42	17.20	17.20
Wimmera	17.91	17.91	17.90	17.90	17.90	17.34	17.34
Eastern Mt Lofty Ranges	30.90	30.13	30.86	30.86	30.86	28.40	28.40
Total	1577.78	1429.03	1540.01	1484.12	1428.22	1323.23	1210.81

Notes:

1. Net returns = Gross value – variable costs – fixed and labour costs

2. Gross value is equals the price of the product multiplied by the yield (quantity of production) per hectare. Gross values in this study are from Bryan and Marvanek (2004, p 86).
3. Variable costs include the quantity dependent costs, area dependent costs and water costs. Variable costs in this study are from Bryan and Marvanek (2004, p 86).
4. Fixed and labour costs include operating, depreciation and labour costs. These costs are also represented in $/ha. Fixed costs in this study are from Bryan and Marvanek (2004, p 86).
5. Results are derived from a model described in Jiang et al. (2010).

Table 7: Annual net returns in the Murray-Darling Basin under different water buyback scenarios (million $) based on 2005-06 agricultural surface water diversions

Catchment	Base Case (no buyback)	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Paroo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Warrego	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Condamine-Balonne	79.64	79.05	77.78	66.84	70.57	70.57	70.57
Moonie	3.79	3.78	1.92	0.00	2.49	2.49	2.49
Border Rivers	74.41	74.41	69.58	68.85	72.13	72.13	72.13
Gwydir	67.49	66.39	65.67	62.95	66.89	66.89	66.89
Namoi	78.62	77.85	73.97	73.05	74.24	74.24	74.24
Macquarie-Castlereagh	64.93	63.74	57.90	59.35	60.46	60.46	60.46
Barwon-Darling	47.41	34.82	45.59	42.67	46.62	46.62	46.62
Lachlan	40.32	39.31	32.45	35.98	27.17	27.17	27.17
Murrumbidgee	223.89	192.50	216.34	213.08	187.64	176.53	171.08
Murray	543.22	306.34	523.49	502.55	468.82	385.13	352.86
Ovens	16.67	16.67	13.98	15.03	14.95	14.95	14.95
Goulburn-Broken	126.44	122.15	119.77	123.87	90.14	99.42	51.61
Campaspe	15.29	13.76	1.52	1.47	1.47	1.47	1.47
Loddon-Avoca	30.42	30.42	16.51	17.19	17.20	17.20	17.19
Wimmera	17.90	17.90	13.81	17.34	17.34	17.34	17.34
Eastern Mt Lofty Ranges	30.86	30.00	28.18	29.23	28.40	28.40	28.40
Total	1462.20	1170.00	1359.35	1330.36	1247.40	1161.88	1076.35

Notes:

6. Net returns = Gross value – variable costs – fixed and labour costs
7. Gross value is equals the price of the product multiplied by the yield (quantity of production) per hectare. Gross value in this study are from Bryan and Marvanek (2009, p 86).

8. Variable costs include the quantity dependent costs, area dependent costs and water costs. Variable costs in this study are from Bryan and Marvanek (2009, p 86).
9. Fixed and labour costs include operating, depreciation and labour costs. These costs are also represented in $/ha. Fixed costs in this study are from Bryan and Marvanek (2009, p 86).
10. All price and cost data are based on 2000-2001 data .
11. Results are derived from a model described in Jiang et al. (2010).

Table 8: Present Value (million $) of Losses from Reduced Water Diversions in the Murray-Darling Basin based on 2000-2001 agricultural surface water diversions

	Wentworth Minimum Flow	**10% reduction**	**20% reduction**	**30% reduction**	**40% reduction**	**50% reduction**
Direct Annual Loss	148.75	37.77	93.67	149.56	254.56	366.97
Indirect Annual Loss	117.96	29.95	74.28	118.60	201.86	291.01
Total Annual Loss	266.71	67.73	167.95	268.16	456.42	657.98
3% Discount Rate						
Direct Loss	3827.36	971.89	2410.04	3848.19	6549.66	9442.11
Indirect Loss	3035.10	770.71	1911.16	3051.61	5193.88	7487.59
Total Loss	6862.46	1742.60	4321.20	6899.80	11743.54	16929.71
5% Discount Rate						
Direct Loss	2715.61	689.58	1709.98	2730.39	4647.15	6699.42
Indirect Loss	2153.48	546.84	1356.02	2165.20	3685.19	5312.64
Total Loss	4869.09	1236.42	3066.00	4895.58	8332.34	12012.06
10% Discount Rate						
Direct Loss	1474.85	374.51	928.69	1482.88	2523.87	3638.46
Indirect Loss	1169.56	296.99	736.45	1175.92	2001.43	2885.30
Total Loss	2644.41	671.50	1665.15	2658.80	4525.31	6523.76

Notes:

1. Direct losses are reduced on-farm net economic returns (see Table 6). These would be fully compensated for with voluntary market-based water recovery.
2. Indirect losses represent the highest expected reduced economic activity via a negative multiplier based on national input-output model (ABS 2001, p. 81) assuming no positive multipliers from the use of the proceeds of the sale of water entitlements.
3. Present value is calculated over a 50-year time horizon.

Table 9: Present Value (million $) of Losses from Reduced Water Diversions in the Murray-Darling Basin based on 2005-2006 agricultural surface water diversions

	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Direct Annual Loss	292.20	102.84	131.84	214.80	300.32	385.84
Indirect Annual Loss	231.72	81.56	104.55	170.33	238.15	305.97
Total Annual Loss	523.92	184.40	236.39	385.13	538.47	691.82
3% Discount Rate						
Direct Loss	7518.30	2646.16	3392.21	5526.63	7727.16	9927.69
Indirect Loss	5962.02	2098.41	2690.02	4382.62	6127.64	7872.66
Total Loss	13480.32	4744.57	6082.23	9909.24	13854.80	17800.35
5% Discount Rate						
Direct Loss	5334.43	1877.52	2406.86	3921.28	5482.62	7043.95
Indirect Loss	4230.20	1488.87	1908.64	3109.58	4347.72	5585.85
Total Loss	9564.63	3366.39	4315.50	7030.86	9830.33	12629.80
10% Discount Rate						
Direct Loss	2897.13	1019.68	1307.17	2129.65	2977.62	3825.58
Indirect Loss	2297.43	808.61	1036.58	1688.82	2361.25	3033.68
Total Loss	5194.56	1828.29	2343.75	3818.47	5338.86	6859.26

Notes:

1. Direct losses are reduced on-farm net economic returns (see Table 7). These would be fully compensated for with voluntary market-based water recovery.
2. Indirect losses represent the highest expected reduced economic activity via a negative multiplier based on national input-output model (ABS 2001, p. 81) assuming no positive multipliers from the use of the proceeds of the sale of water entitlements.
3. Present value is calculated over a 50-year time horizon.

Table 10: Probability of Annual Inflows Occurring in the Murray River (GL)

1980-1999 Inflows		2000-2008 Inflows	
Inflows (GL)	Probability	Inflows (GL)	Probability
2,005 or less	0.05	1,526 or less	0.11
2,006-5,869	0.30	1,527-3,798	0.33
5,870-9,735	0.15	3,799-6,070	0.33
9,736-13,599	0.20	6,071-8,343	0.11
13,600-17,463 or more	0.30	8,344-10,615 or more	0.11

Table 11: Change in net economic returns ($ million/year) based on probability of 1980-1999 inflows in the Murray River assuming 2000-2001 agricultural surface water diversions in the Murray-Darling Basin and different water buyback scenarios (GL)

	No buy back	Wentworth Minimum Flow	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Mean Net Economic Returns	1662.8	1510	1590.7	1518.5	1446.4	1374.2	1302
Standard Deviation of Net Economic Returns	296.85	296.85	296.85	296.85	296.85	296.85	296.85
Net change to base case	0.00%	-9.19%	-4.34%	-8.68%	-13.01%	-17.36%	-21.70%

1. Net change is the proportional reduction in mean net economic returns relative to the no buy back scenario.

Table 12: Change in net economic returns ($ million/year) based on probability of 2000-2008 inflows in the Murray River assuming 2005-2006 agricultural surface water diversions in the Murray-Darling Basin and different water buyback scenarios (GL)

	No buy back	**Wentworth Minimum Flow**	**10% reduction**	**20% reduction**	**30% reduction**	**40% reduction**	**50% reduction**
Mean Net Economic Returns	1249.4	1039.1	1173.8	1098.2	1022.7	947.1	871.5
Standard Deviation of Net Economic Returns	208.1	208.1	208.1	208.1	208.1	208.1	208.1
Net change to base case	0.00%	-16.83%	-6.05%	-12.10%	-18.14%	-24.20%	-30.25%

1. Net change is the proportional reduction in mean net economic returns relative to the no buy back scenario.

Table 13: Government expenditure in the Murray-Darling Basin under different water buyback scenarios (GL) assuming 2000-2001 agricultural surface water diversions

	Base Case (no buyback)	**Wentworth Minimum Flow**	**10% reduction**	**20% reduction**	**30% reduction**	**40% reduction**	**50% reduction**
Diversions	10147.42	7999.24	9132.68	8117.94	7103.19	6088.45	5073.71
Desired environmental flows	0	2148.19	1014.75	2029.49	3044.23	4058.97	5073.71
Entitlement purchases required for the environment	0	3356.54	1585.54	3171.08	4756.61	6342.15	7927.68
Entitlement already purchased or in process	612	612	612	612	612	612	612
Additional entitlement purchase required	612	2744.54	973.54	2559.08	4144.61	5730.15	7315.68
Additional government expenditure (Billions) at $2,000/ML	0	5.49	1.95	5.12	8.29	11.46	14.63
Additional government expenditure (Billions) at $2,000/ML in excess of $3.1 billion in the Water for the Future Package	0	3.29	-0.25	2.92	6.09	9.26	12.43
Additional government expenditure (Billions) at $1,522/ML	0	4.18	1.48	3.89	6.31	8.72	11.13
Additional government expenditure (Billions) at $1,522/ML in excess of $3.1 billion in the Water for the Future Package	0	1.98	-0.72	1.69	4.11	6.52	8.93

1. Wentworth Minimum flow is 2148 GL (Marsh et al. 2009).
2. Current entitlement purchase (and in process) is set to 612 GL that represents purchases recorded on 30 September 2009. Thus, additional entitlement purchase represents the additional entitlements in GL required to be purchased to ensure an environmental flow under the buy-back scenarios. The conversion ratio of water entitlements in GL to environmental flow is 0.64 which represents the expected long-term average volume of water available (GL) as a proportion of the water entitlements and licences (GL) acquired by the Australian government as of 30 September 2009.
3. $2,000/ML is the assumed upper-end price for water entitlements acquired for the environment. The $1,522 /ML price of water is the average purchase price of water entitlements acquired by the Australian government for its water acquisitions in 2008/09 (Productivity Commission, 2009b p. 10).
4. Negative numbers indicate that there are funds left over from acquiring water entitlements assuming a $3.1 billion budget.
5. Assumed that as of 30 September 2009 the Australian government had $2.2 billion not yet spent or contracted from its $3.1 billion Restoring the Balance in the Murray-Darling Basin.

Table 14: Government expenditure in the Murray-Darling Basin under different water buyback scenarios (GL) assuming 2005-2006 agricultural surface water diversions

	Base Case (no buyback)	**Wentworth Minimum Flow**	**10% reduction**	**20% reduction**	**30% reduction**	**40% reduction**	**50% reduction**
Diversions	7720.00	5571.81	6948.00	6176.00	5404.00	4632.00	3860.00
Desired environmental flows	0	2148.19	772.00	1544.00	2316.00	3088.00	3860.00
Entitlement purchases required for the environment	0	3356.54	1206.25	2412.50	3618.75	4825.00	6031.25
Entitlement already purchased or in process	612	612	612	612	612	612	612
Additional entitlement purchase required	612	2744.54	594.25	1800.50	3006.75	4213.00	5419.25
Additional government expenditure (Billions) at $2,000/ML	0	5.49	1.19	3.60	6.01	8.43	10.84
Additional government expenditure (Billions) at $2,000/ML in excess of $3.1 billion in the Water for the Future Package	0	3.29	-1.01	1.40	3.81	6.23	8.64
Additional government expenditure (Billions) at $1,522/ML	0	4.18	0.90	2.74	4.58	6.41	8.25
Additional government expenditure (Billions) at $1,522/ML in excess of $3.1 billion in the Water for the Future Package	0	1.98	-1.30	0.54	2.38	4.21	6.05

1. Wentworth Minimum flow is 2,148 GL (Marsh et al. 2009).
2. Current entitlement purchase (and in process) is set to 612 GL that represents purchases recorded on 30 September 2009. Thus, additional entitlement purchase represents the additional entitlements in GL required to be purchased to ensure an environmental flow under the buy-back scenarios. The conversion ratio of water entitlements in GL to environmental flow is 0.64 which represents the expected long-term average volume of water available (GL) as a proportion of the water entitlements and licences (GL) acquired by the Australian government as of 30 September 2009.
3. $2,000/ML is the assumed upper-end price for water entitlements acquired for the environment. The $1,522 /ML price of water is the average purchase price of water entitlements acquired by the Australian government for its water acquisitions in 2008/09 (Productivity Commission, 2009b p. 10).
4. Negative numbers indicate that there are funds left over from acquiring water entitlements assuming a $3.1 billion budget.
5. Assumed that as of 30 September 2009 the Australian government had $2.2 billion not yet spent or contracted from in its $3.1 billion Restoring the Balance in the Murray-Darling Basin.

Table 15: Estimated Water Cost Savings ($/ML) from Infrastructure Investments

Infrastructure project	**Current estimate of the approximate $ per ML of Long Term Cap Equivalent**	**Reliability of water recovered**
Great Darling Anabranch Pipeline	$1,000/ML	High
Coleambally Main Canal – Seepage and Leakage Savings Project	Up to $2,700/ML	High
Shepparton Irrigation Area Modernisation Project	$2,860/ML	High
NSW Wetlands Water Recovery – Stage 1	$2,500/ML	High
Water Recovery from SA River Murray Wetlands – Stage 2: the feasibility of generating water savings and environmental benefits	$4,000/ML	High
Metering accuracy, water use efficiency study and evaluation of infrastructure options for water recovery for the West Corurgan Private Irrigation District in Southern NSW	$5,000/ML	High
Investigation of the potential to recover water by the construction of a 30GL en-route storage 'The Drop' on the Mulwala Canal in the Murray Irrigation Ltd area of operation	>$5,000/ML	High
Ricegrowers' Association	>$2,500/ML	Mix

Source: Social and Economics Reference Panel for the Murray-Darling basin Commission (2008, p. 8).