Dear Christine,
I am most grateful for the opportunity to give our evidence before the Senate committee this morning.
Our democracy is so valuable.
Quentin and I agreed to submit to your committee two Wentworth Group Documents which we discussed with you and our paper which appeared in Science in August 2018.
We quoted directly from the Abstract of ***MDB Flows Summary*** to state:
" This assessment found that despite 2,016 GL of water being recovered for the environment (63% of that envisaged under the Basin Plan) at a cost of $8.5 billion, and during the relatively wet period from 2010-2018:
1. Environmental flow targets set by the Murray-Darling Basin Authority, which are required to be met to produce environmental improvements, have failed to be achieved.
2. In general, excluding natural flood events, annual average flows can be up to 40% to 60% smaller than expected under the Basin Plan.
3. In general, observed flows are similar to, or less than, the baseline (pre-Basin Plan) model results, revealing that instead of an increase there has actually been no improvement or even a decline in water flows since the implementation of the Basin Plan."

We referred to our Early work in 2010 (***Sustainable Diversions in the Basin***)which built a case for direct purchase of water from willing sellers plus investment with communities to mitigate the impacts of return of water to the rivers and groundwater to yield healthy working rivers.
See pages 19. 22-25 where we state:
" Option 3: Combining these separate funding amounts into a single fund and working with local communities to acquire water from irrigators for a price equivalent to a 'reasonable return' on lost profits, and funding an economic development program to help regional communities transition to a future with less water."
We attach our recent paper in Science journal and draw to your attention to our statement :
" Reconciling higher freshwater demands with finite freshwater resources remains one of the great policy dilemmas. Given that crop irrigation constitutes 70% of global water extractions, which contributes up to 40% of globally available calories (1), governments often support increases in irrigation efficiency (IE), promoting advanced technologies to improve the "crop per drop." This provides private benefits to irrigators and is justified, in part, on the premise that increases in IE "save" water for reallocation to other sectors, including cities and the environment. Yet substantial scientific evidence (2) has long shown that increased IE rarely delivers the presumed public-good benefits of increased water availability. Decision-makers typically have not known or understood the importance of basin-scale water accounting or of the behavioral responses of irrigators to subsidies to increase IE**. We show that to mitigate global water scarcity, increases in IE must be accompanied by robust water accounting and**

measurements, a cap on extractions, an assessment of uncertainties, the valuation of trade-offs, and a better understanding of the incentives and behavior of irrigators."

Please let us know if we can assist further your committee.

Yours Sincerely
John
John Williams FTSE
Honorary Professor
ANU Crawford School of Public Policy
Canberra
Australia

Attachment 1

Water Flows in the Murray-Darling Basin: Observed versus expected

Summary Report

February 2019

WENTWORTH GROUP OF CONCERNED SCIENTISTS

WENTWORTH GROUP OF CONCERNED SCIENTISTS

IN ASSOCIATION WITH

Dr Paul Carlile, Hydrologist · Environmental Consultant.

Dr Eytan Rocheta, Environmental Engineer · Policy Analyst, Wentworth Group of Concerned Scientists.

Dr Celine Steinfeld, Geographer · Policy Analyst, Wentworth Group of Concerned Scientists.

Karen Grogan, Director, Wentworth Group of Concerned Scientists.

Nadeem Samnakay, Policy Analyst, Wentworth Group of Concerned Scientists.

ACKNOWLEDGEMENTS

The Wentworth Group acknowledges State and Commonwealth government agencies who collected and made available data used in this report. We thank the Purves Environmental Fund, the Australian Environmental Grantmakers Network, and The Ian Potter Foundation for their ongoing financial support.

www.wentworthgroup.org

Abstract

The Wentworth Group of Concerned Scientists has conducted a study to fill a gap in publicly available research that evaluates whether environmental water recovery has led to observable increases in river flows at two key sites along the Murray-Darling Basin; Chowilla and Wilcannia. These sites were chosen as they are representative of the health of the southern and northern basins respectively. This study was undertaken to assess whether recovered water is contributing to increased flows as would be expected.

This assessment found that despite 2,016 GL of water being recovered for the environment (63% of that envisaged under the Basin Plan) at a cost of $8.5 billion, and during the relatively wet period from 2010-2018:

1. Environmental flow targets set by the Murray-Darling Basin Authority, which are required to be met to produce environmental improvements, have failed to be achieved.
2. In general, excluding natural flood events, annual average flows can be up to 40% to 60% smaller than expected under the Basin Plan.
3. In general, observed flows are similar to, or less than, the baseline (pre-Basin Plan) model results, revealing that instead of an increase there has actually been no improvement or even a decline in water flows since the implementation of the Basin Plan.

This summary document complements the technical report which includes the full methodology and analysis and is available at www.wentworthgroup.org.

Introduction

The Murray-Darling Basin Plan is based on an agreement between the Commonwealth and Basin governments to rebalance water use and restore the health of the Murray-Darling Basin. The Basin Plan is underpinned by the Commonwealth Water Act (2007) which requires the Murray-Darling Basin Authority (MDBA) to determine an Environmentally Sustainable Level of Take; the maximum amount of water that can be taken without harming the health of the rivers.

A fundamental element of the Basin Plan is to reduce over-extraction and ensure more water remains in our rivers for environmental outcomes. One third of water in the basin is extracted for human use, and well over 90% of this is used for irrigation. This has meant that returning more water to the rivers has necessitated reducing how much water is used for irrigation.

The Water Act permits the Commonwealth Government to acquire water through purchasing water entitlements, or improving water use efficiency. The Basin Plan established that 3,200 gigalitres (GL) of water needs to be returned, per year, to achieve an Environmentally Sustainable Level of Take. This number was partially based on a set of 124 site-based environmental **flow targets** which, if achieved, would mean the flow was assumed to be sufficient to maintain riverine health. However, the gigalitre value is heavily disputed by independent scientists, including the Wentworth Group of Concerned Scientists, who generally evaluate that the number should be well above 4,000 GL.

As of December 2018, the amount of water recovered for the environment totaled 2,016 GL. As of that same date, there has been no public evaluation of the effectiveness of the water recovered to deliver the intended environmental outcomes as described by the MDBA's environmental health flow indicators or modelling. The Wentworth Group of Concerned Scientists has undertaken this study to assess whether recovered water is contributing to increased flows in the Murray-Darling Basin.

Method

To undertake this assessment, two river gauge sites were chosen which broadly represent flows in the northern and southern basins (Figure 1). These sites are:

a) Chowilla on the Murray River, indicative of the volume of flows to South Australia as well as the health of the Murray River and associated wetlands and floodplains; and
b) Wilcannia on the Darling River, indicative of the health of the Barwon-Darling system upstream of the Menindee Lakes.

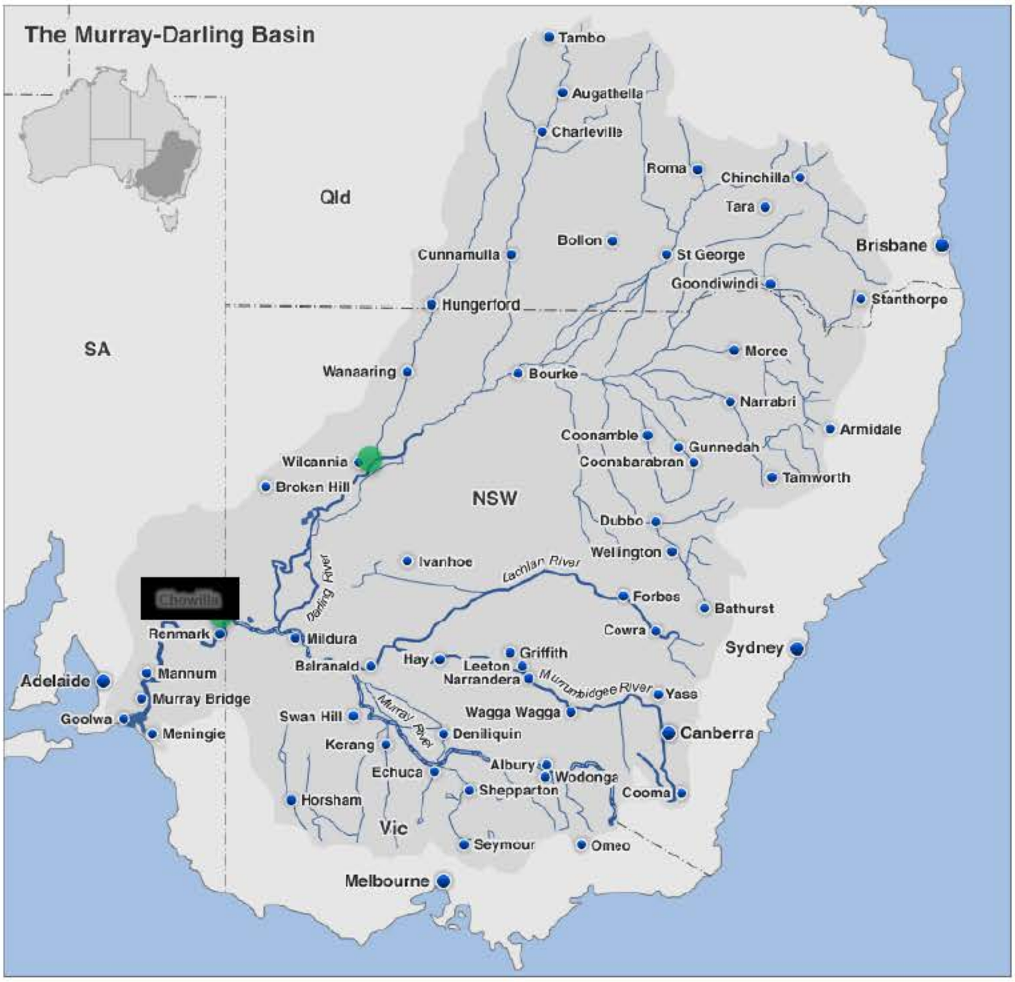


Figure 1: Map of Basin showing location of the Wilcannia on the Darling River above Menindee Lakes, and Chowilla on the Murray River near the South Australian border (source: MDBA).

This investigation looked at the relationship between water recovery and observed changes to river flows since 2010. Two approaches were used to evaluate the:

1. Characteristics of observed flows compared to the MDBA environmental flow targets; and
2. Observed flows compared to MDBA modelled flows under similar climate conditions.

The second approach would have been straightforward if the MDBA had continued to make publicly available annual updated model runs in each valley, that represent modelled river flows without the Basin Plan. These modelled flows could be compared to actual measured flows in the river to determine improvements that are attributable to the Basin Plan. However, these models have not been updated to run beyond 2009. This assessment therefore required using past modelled flows which occurred as a result of similar upstream water availability as a proxy for current expected flows. Detailed methodology for this assessment is available in the technical report.

Observed flow data used in this assessment covered the period 2010 to 2018. This period signifies the timeframe over which water recovered had reached approximately 1,000 GL (in 2010) and increased to 2,016 GL (in 2018). So far $8.5 billion has been spent under the Basin Plan, much of which has been directed to water recovery.

The three primary data sets used in this analysis were:

- **Observed**: Observed flow measured at each site's stream gauge (2010-2018);
- **Baseline**: MDBA modelled results showing expected flow with pre-Basin Plan water recovery (1895-2009);
- **Expected:** MDBA modelled results showing expected flow with Basin Plan water recovery (1985-2009).

The expected results are modelled by the MDBA using 2,145 GL of recovered water (see Box 1). As mentioned, to date, 63% or 2,016 GL of environmental water has been recovered. To match the amount of water in the Basin Plan model, only an additional 129 GL of water needs to be recovered for the environment.

The observed results are compared to MDBA modelled outcomes and are likely to be far less than expected if compared to the original Basin Plan water recovery target of 3,200 GL. Despite this the observed results should show some improvement and be above the baseline (representing no Basin Plan water recovery).

While this analysis is limited in that not all the environmental water has been recovered, a strength is that the last decade has been relatively wet in comparison to the preceding 10-year long millennium drought. As there has been a relative abundance of water in the Basin, the analysis has been undertaken under more favorable water availability conditions compared to droughts. If the last nine years were under drought conditions the results from this analysis would likely be much worse. Additionally, the gap between expected and observed outcomes would be far greater if the comparison was against a model simulation of 3,200 GL of water recovery as originally envisaged by the Basin Plan.

Box 1: How much water recovery was modelled under the Basin Plan?

The agreed water recovery under the Basin Plan was 2,750 GL + 450 GL = 3,200 GL. The 450 GL here is additional water obtained through efficiency measures that require a neutral or positive socio-economics test; none of which has been recovered. From the 3,200 GL total, supply measures were adopted which allow for a reduction of 605 GL by the year 2024.

The Basin Plan modelled water recovery was therefore 3,200 GL – 450 GL – 605 GL = 2,145 GL.

The Basin Plan model also included full implementation of pre-requisite policy measures (policy which has yet to be enacted but was assumed in the model) as well as flow constraint levels from the year 2012.

Results: observed versus target flows

The MDBA developed a methodology to derive the Environmentally Sustainable Level of Take which uses site-based environmental flow targets across the basin (see Box 2). The sites are referred to as hydrological indicator sites and water flow through these sites is measured by flow gauges. The targets are environmental flow indicators and were selected on the assumption that achieving these flow indicators is a necessary precondition to achieve ecological restoration. The targets include a combination of flow characteristics including magnitude, duration, timing and frequency. Full indicator site flow target details are available in the MDBA Environmentally Sustainable Level of Take and Northern Basin Review reports. They are quantified in terms of flow characteristics including magnitude, duration, timing and frequency. Full indicator site flow target details are available in the MDBA Environmentally Sustainable Level of Take and Northern Basin Review reports.

This assessment evaluates the site-based flow targets using observed flows since 2010, and compares against the MDBA Baseline model simulation without water recovery and the expected MDBA model simulation with Basin Plan water recovery. These results are summarised in Table 1.

Table 1: Site-based flow target achievement at Chowilla on the Murray River and Wilcannia on the Darling River.

<table>
<tr><th colspan="3">Site-based environmental flow target</th><th>Flow (ML/d)</th><th>Observed</th><th>Baseline</th><th>Expected</th></tr>
<tr><td rowspan="7">Chowilla</td><td>1</td><td>Base flows lasting two months in winter</td><td>20,000</td><td>Fail</td><td>Fail</td><td>Pass</td></tr>
<tr><td>2</td><td>Small flows lasting a month in winter</td><td>40,000</td><td>Fail</td><td>Fail</td><td>Pass</td></tr>
<tr><td>3</td><td>Small flows lasting three months in winter</td><td>40,000</td><td>Fail</td><td>Fail</td><td>Pass</td></tr>
<tr><td>4</td><td>Medium flows lasting two months in winter</td><td>60,000</td><td>Fail</td><td>Fail</td><td>Pass</td></tr>
<tr><td>5</td><td>Large flows lasting a month any time of year</td><td>80,000</td><td>Fail</td><td>Fail</td><td>Fail</td></tr>
<tr><td>6</td><td>Large scale natural floods</td><td>100,000</td><td colspan="3" rowspan="2">Natural floods not targeted by Basin Plan water recovery</td></tr>
<tr><td>7</td><td>Large scale natural floods</td><td>125,000</td></tr>
<tr><td rowspan="3">Wilcannia</td><td>1</td><td>Base flows any time of year</td><td>2,350 GL</td><td>Fail</td><td>Pass</td><td>Pass</td></tr>
<tr><td>2</td><td>Small flows lasting a week any time of year</td><td>6,000</td><td>Pass</td><td>Pass</td><td>Pass</td></tr>
<tr><td>3</td><td>Large flows lasting a week any time of year</td><td>20,000</td><td>Fail</td><td>Pass</td><td>Pass</td></tr>
</table>

In addition to the listed targets at Chowilla, two flood level descriptors are listed by the MDBA but not targeted for active achievement in the Basin Plan. These descriptors represent flows above 100,000 ML/d and 125,000 ML/d. While they are not actively targeted in the Basin Plan these large flow levels are most important for achieving environmental outcomes linked to watering floodplains and wetlands. In the time period assessed these descriptors failed to be achieved.

From Table 2, for Chowilla, we can see that:

- Under observed water recovery, none of the indicators meet the targets and the flows are failing to achieve requirements for ecological restoration;
- These observed results are no better than the MDBA modelled baseline, so no improvements have been measured in the achievement of the MDBA flow targets over the period of this assessment even with all of the current water recovery;
- However, under the MDBA modelled expected water recovery, all indicators are met, except for very large floods that are beyond influence of water recovery.

For Wilcannia, we see that two out of three observed targets fail to be achieved. Further:

- Under observed water recovery only small flows have passed the target, with base flows and large flows failing to achieve hydrological conditions assumed necessary for ecological restoration.

These site-based environmental flow target evaluations reveal that, for the period 2010-2018, the MDBA targets, assumed to be required to produce environmental outcomes for this section of the river, have failed to be achieved.

Box 2: Why use these environmental flow targets?

The environmental flow targets examined in this report were set by the MDBA in 2012 as part of the Environmentally Sustainable Level of Take methodology which formed the basis for the SDL. They also informed the Basin Watering Strategy which describes the environmental watering requirements that guide the Commonwealth Environmental Water Holder.

These targets were used to develop water recovery amounts and should therefore be used to evaluate the Plan's effectiveness in delivering these amounts. To date, neither the MDBA nor the Commonwealth Environmental Water Holder have used these targets in their effectiveness reporting.

Based on the lack of achievement of these flow targets it is possible to draw inferences about the lack of inundation to wetlands and flood-dependent vegetation area. The MDBA has modelled the relationship and Figure 2 shows this for South Australian floodplain near the Chowilla site.

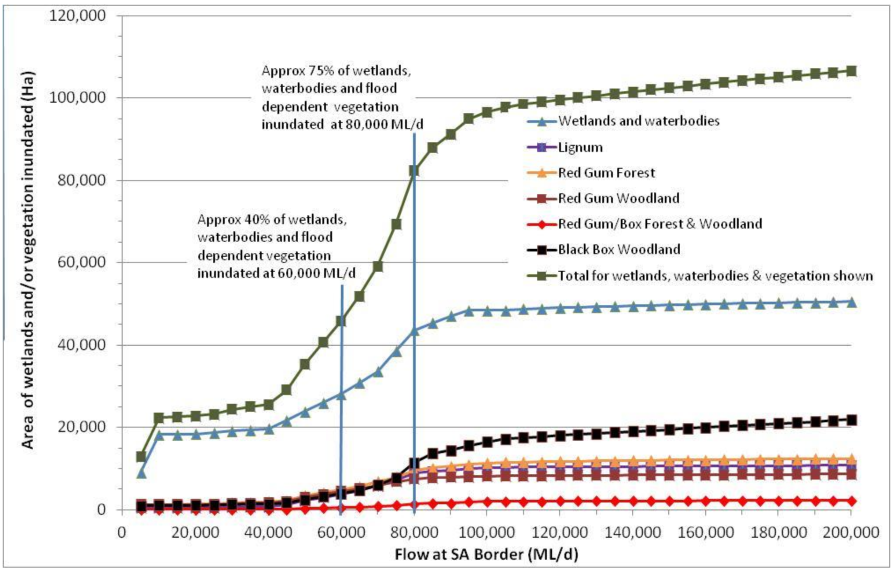


Figure 2: Relationship between inundation of wetlands and flood-dependent vegetation and flow in the Murray River on the South Australian floodplain near Chowilla (Source: MDBA).

Figure 2 shows that:

- Flows of 60,000 ML/d to 80,000 ML/d (blue lines) were expected under the Basin Plan to water at least 45,000 ha (40%) of wetlands and flood-dependent vegetation in the South Australian floodplain. This could be increased to 82,000 ha (75%) with a Constraints Management Strategy.

- As these flow rates were not achieved, only a small portion of the floodplain will be maintained. The only area being watered is 9,000 ha (10%) of floodplain which are under the influence of existing infrastructure built under the Living Murray program. Implementing the Constraints Management Strategy could see up to nine times the area of wetlands and flood-dependent vegetation watered.

These lack of flow achievements are likely to have had an adverse impact on river, wetland and floodplain ecology which depend on at least one moderate flood every decade. Given water availability has been relatively high since 2010, the inability to achieve environmental flow indicators or improve on pre-Basin Plan hydrological outcomes over the past 8-10 years is concerning.

Results: observed versus expected flows

The second approach undertook a comparison of modelled and observed streamflow. This assessment required using past modelled flows, which occurred as a result of similar upstream water availability, as a proxy for current expected flows. This analysis showed the annual difference in observed flow over the period 2010 to 2018 compared to the expected Basin Plan flow (Figure 3).

In this approach, it is logical to expect that we would be achieving flows better than the baseline, and close to what was expected by the MDBA considering how much water has been recovered.

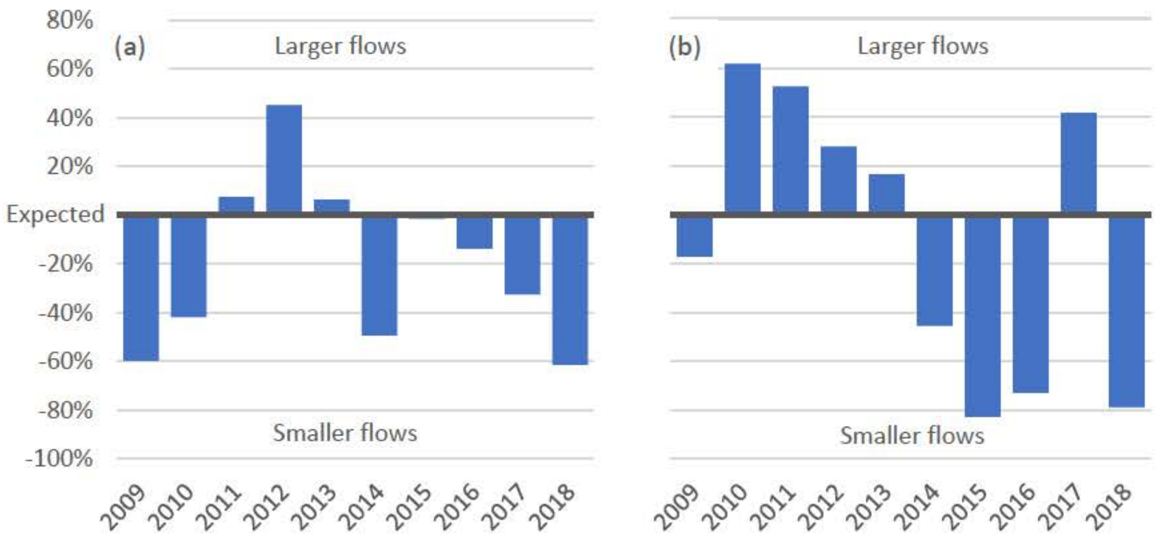


Figure 3: Annual difference in observed flows and expected flows at (a) Chowilla and (b) Wilcannia.

From Figure 3, for Chowilla we see that:

- In the wet years of 2010-2013 and 2017 only a single annual observed flow volume was substantially larger than expected. However, in the majority of all other years, annual observed flows are up to 60% smaller than expected after environmental water recovery.

For Wilcannia we see that:

- Observed flows were well above the Basin Plan expectation over the period 2010-2013 and 2017. These were exceptionally wet years, with large floods. However, as conditions became drier, observed flows have been consistently smaller than expected under the Basin Plan with up to 80% smaller flows than expected.

- Only in the wet years were flows higher than expected. In all other years, they were lower than expected, in most cases substantially lower.

From the volume of environmental water recovered to date, the observed flows should be close to the expected values and larger than the baseline. However, from Figure 4, we see that in both wet and dry years this is generally not the case. In most instances the observed flow is less than expected (and even less than the baseline in several cases). Wilcannia in wet years provides the only exception where the observed flow is greater than expected and this is as a result of natural flood events.

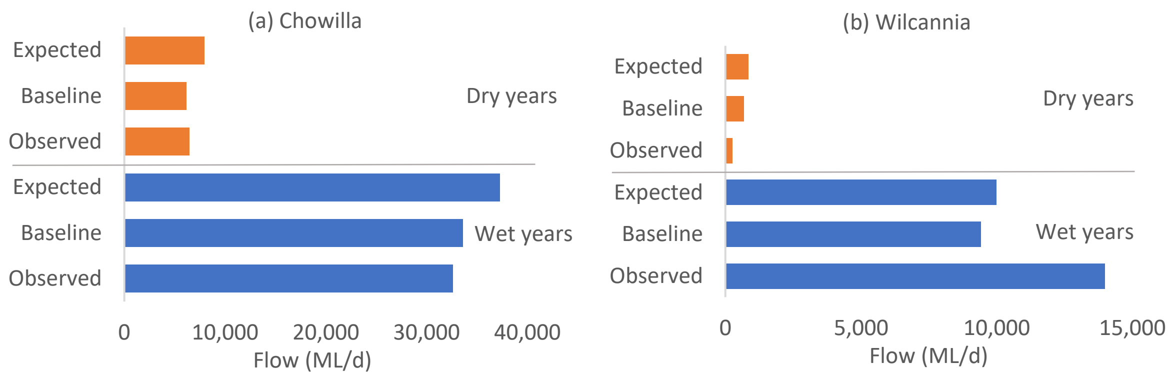


Figure 4: Average daily expected flows (ML/d) over 2010-2018 at (a) Chowilla and (b) Wilcannia compared with baseline and observed, separated into dry and wet years.

These results show that Basin Plan implementation has not improved the flow regimes in the rivers as were expected in the modelling. Additionally in most cases the observed flows are similar to or below the baseline model results, meaning that instead of recording an improvement in the river flows, there has actually been a decline.

It is noted here that in wet years, there is generally a large volume of water for all users. The Basin Plan needs to ensure environmental water is increased, when compared to historical practices, in dry years, when water resources are scarce. Current levels of environmental water should be impacting on the observed 'dry-year' flows and making these closer to the expected results. The results here show that it is unlikely that there have been overall environmental improvements since the beginning of the Basin Plan.

Discussion

There are several factors that might contribute to the apparent failure of water recovery to provide benefits to river flows as expected. Of particular note is the accuracy of the Baseline and Basin Plan models in simulating the Basin and the ability to compare these model outputs with observations. It is also noted that the nine years of flow data used in this assessment are not fully representative of the entire variability in the observed record of Basin flows. Additionally, the 2012 flow targets used to underpin the SDL are not being actively pursued by river managers. Further analysis by the MDBA is required to fully understand the reasons for the poor results presented here, but two reasons are discussed below.

In the Murray River, medium to large floods have reduced in frequency because of increased river regulation through infrastructure (dams and weirs), and changes in the rules (or policies) that govern how much water can be released from dams and under what conditions. These regulatory decisions serve to constrain river flows from what occurs naturally. The Basin Plan requires that the Basin States make every effort to relax these constraints, guided by the MDBA's Constraints Management Strategy. Many of these constraints have not been adequately relaxed by the New South Wales and Victorian governments, and indeed, in some instances (e.g. Goulburn River and Murray River downstream of Yarrawonga), they have been further tightened. The tightening of constraints, and inadequate implementation of the Constraints Management Strategy, explains why River Murray flows at Chowilla are not achieving the objectives of the Water Act.

In addition the Basin Plan requires State governments in the Southern Basin to implement policies which enable environmental water to be called from storage to supplement water already in the river and to recognise this as environmental water as it moves through the system. The ability to call environmental water from storages such as Hume Dam on top of flows already in the river is governed by operational flow constraints which are yet to be relaxed as agreed by governments in 2012.

In the Darling River, the inability to reach two out of the three environmental flow indicators at Wilcannia may be due to insufficient water recovery in the Northern Basin and an overestimation by the MDBA of the ability to deliver these flow outcomes without stronger protection (shepherding) of low flows. Under current NSW water sharing rules in the Barwon-Darling additional environmental water in the river results in irrigators having greater opportunities to pump environmental water legally. This is because pumping rights are linked to river flow rates and there has been no adjustment to these pumping flow rates after environmental water has been purchased.

This means that water that should have been left in rivers, for environmental purposes, can be extracted from the river for consumptive use. Protecting these environmental flows across borders is an essential step in improving the health of the river ecosystems, as well as providing tax payer value for money for environmental water purchases.

Conclusions

The Wentworth Group of Concerned Scientists conducted a study to fill a gap in publicly available research to evaluate whether environmental water recovery has led to observable increases in river flows. This assessment was conducted at Chowilla and Wilcannia sites, which are representative of the health of the southern and northern basins respectively, and the results presented here are likely to be replicated at other locations.

This assessment found that despite 2,016 GL of water being recovered for the environment (63% of that envisaged under the Basin Plan) at a cost of $8.5 billion, and during the relatively wet period from 2010-2018:

1. Environmental flow targets set by the MDBA which are required to be met to produce environmental improvements have failed to be achieved.
2. In general, excluding natural flood events, annual average flows can be up to 40% and 60% smaller than expected under the Basin Plan.
3. In general, observed flows are similar to or less than the baseline (pre-Basin Plan) model results, revealing that instead of an increase, there has actually been no improvement or even a decline in water flows since the implementation of the Basin Plan.

Recommendations

As a result of this study, the Wentworth Group of Concerned Scientists has identified the following recommendations:

1. The Murray-Darling Basin Authority should evaluate the success of water recovery in the Basin Plan using an approach which is based on the measurement of river flows against expected flows, taking into consideration variable climate.
    a. The preferred method is to update the Baseline (pre-Basin Plan) models in each valley every year with observed rainfall, evaporation and storage levels. These results provide a simulation of flows without Basin Plan water recovery and can be directly compared to current observed gauged flows to achieve the objective above.
    b. If the Murray-Darling Basin Authority is unable to undertake the assessment through updating the Baseline models then an alternative method, such as the one presented here, should be adopted.
    c. This evaluation should be conducted at all Murray-Darling Basin Authority hydrological indicator sites, and the model outputs and results should be made publicly available for independent testing and verification.
    d. This assessment should be adopted as a mandatory element of the Murray-Darling Basin Authority's annual Basin Plan effectiveness reporting. This should include full investigations if flow parameters are not achieving expected outcomes. Action should be taken where flows fail to achieve targets.
2. That a single set of flow indicators, reflecting of an Environmentally Sustainable Level of Take, are agreed to by all jurisdictions and used for environmental water planning, management and evaluation.
3. To improve the achievement of all flow indicators at Chowilla we recommend that pre-requisite policy measures (assumptions made when modelling the Basin Plan) be properly implemented to maximise the benefits of environmental water at rates supported by a fully implemented Constraints Management Strategy that enable 80,000 ML/d at Chowilla and into South Australia to be achieved.
4. To improve the condition of high flow indicators at Chowilla and elsewhere in the Goulburn and Murrumbidgee we recommend that the Constraints Management Strategy be implemented in full by the New South Wales and Victorian Governments, which will allow for larger flow volumes during high flow events. The Commonwealth should pursue compulsory implementation if required, as recommended by the South Australian Royal Commission into the Murray-Darling Basin. Without the Constraints Management Strategy significant areas of floodplain in the Basin is likely to perish.
5. To improve low flows at Wilcannia, we recommend greater protections against pumping during periods of low flows, accompanied by protection of event based environmental flows for environmental use downstream and across state borders.

Attachment 2

PHOTO: GRANT FAINT/GETTY IMAGES

WATER

The paradox of irrigation efficiency

Higher efficiency rarely reduces water consumption

By **R. Q. Grafton[1,2], J. Williams[1], C. J. Perry[3], F. Molle[4], C. Ringler[5], P. Steduto[6], B. Udall[7], S. A. Wheeler[8], Y. Wang[9], D. Garrick[10], R. G. Allen[11]**

Reconciling higher freshwater demands with finite freshwater resources remains one of the great policy dilemmas. Given that crop irrigation constitutes 70% of global water extractions, which contributes up to 40% of globally available calories (*1*), governments often support increases in irrigation efficiency (IE), promoting advanced technologies to improve the "crop per drop." This provides private benefits to irrigators and is justified, in part, on the premise that increases in IE "save" water for reallocation to other sectors, including cities and the environment. Yet substantial scientific evidence (*2*) has long shown that increased IE rarely delivers the presumed public-good benefits of increased water availability. Decision-makers typically have not known or understood the importance of basin-scale water accounting or of the behavioral responses of irrigators to subsidies to increase IE. We show that to mitigate global water scarcity, increases in IE must be accompanied by robust water accounting and measurements, a cap on extractions, an assessment of uncertainties, the valuation of trade-offs, and a better understanding of the incentives and behavior of irrigators.

LOGIC AND LIMITS

Field IE is the ratio of the volume of all irrigation water beneficially used on a farmer's field [predominantly, evapotranspiration (ET) by crops and salt removal to maintain soil productivity] to the total volume of irrigation water applied (adjusted for changes in water stored for irrigation in the soil) (*2*). Annually, governments spend billions of dollars subsidizing advanced irrigation technologies, such as sprinklers or drip systems (*3*). Sometimes their goal is to increase IE on the understanding that this will allow water to be reallocated from irrigation to cities (*4*), industry, or the environment, while maintaining or even increasing agricultural production.

But water saved at a farm scale typically does not reduce water consumption at a watershed or basin scale. Increases in IE for field crops are rarely associated with increased water availability at a larger scale (*5*), and an increase in IE that reduces water extractions may have a negligible effect on water consumption. This paradox, that an increase in IE at a farm scale fails to increase the water availability at a watershed and basin scale, is explained by the fact that previously nonconsumed water "losses" at a farm scale (for ex-

Sprinkler irrigation supports grape vines in the Okanagan Basin, British Columbia.

ample, runoff) are frequently recovered and reused at a watershed and basin scale.

Advanced irrigation technologies that increase IE may even increase on-farm water consumption, groundwater extractions (*6*), and water consumption per hectare (*5*). At a farm scale, this can arise from a switch to more water-intensive crops and, with the same crop, may occur when there is a strong marginal yield response from additional water. Moreover, the absence of an increase in water consumption per hectare because of a higher IE does not necessarily mean that the water potentially available for reallocation and reuse (see supplementary materials) at a watershed or basin scale increases. Subsidies for drip irrigation may reduce the water applied per hectare and increase water extractions because a higher IE can induce increases in the irrigated area, as shown for the Lower Rio Grande, New Mexico (*7*).

Although the hydrology related to IE has been known for decades, it is often overlooked or ignored. For example, the United Nations (UN) High-Level Panel on Water, comprising 11 sitting heads of state or government, recommends "…incentives for water users, including irrigators, to use water efficiently" (*8*) but fails to explicitly recognize that this may increase, rather than decrease, water consumption. Similar to IE, there is also confusion in policy circles about the effects of an increase in efficiency or water productivity (the biophysical or monetary output per volume of water inputs) on basin-scale water availability (see supplementary materials). The UN Sustainable Development Goal (SDG) 6.4, for instance, seeks to increase water use efficiency, but this does not necessarily mean reduced water extractions.

There are reasons why this evidence may be overlooked by policy-makers: Evidence resides in a specialized literature; subsidies for IE can promote rent-seeking behavior by beneficiaries who lobby to continue subsidies; and comprehensive water accounting from the scale of the field to that of the watershed or basin is necessary but frequently absent. Such accounting quantifies field water applications; ET by crops and weeds; evaporation from soil and water surfaces; and, particularly, surface and subsurface water flows returned to the environment or utilized elsewhere at the watershed or basin scale.

RESPONDING TO THE PARADOX

We respond to the paradox (*2*, *9*) with two key insights and a research and policy agenda to deliver on SDG 6 ("ensure availability and sustainable management of water and sanitation for all"). First, irrigation systems are frequently managed to maximize irrigated crop production. This provides benefits but means more water is transpired locally and lost for other uses. Second, locally extracted, but not consumed, water flows to surface supplies and groundwater. Such volumes, perceived as losses to farmers and the irrigation system, do not disappear. They frequently have value and are typically recovered and reused elsewhere in a watershed or basin.

The figure visualizes the paradox within a watershed, showing three types of irrigation with different IEs: drip, sprinkler, and surface. Inflows are precipitation and interbasin transfers. Outflows are (i) beneficial water consumption from transpiration by crops; (ii) nonbeneficial water consumption through transpiration by weeds and evaporation from wet soil, foliage, and open water surfaces; (iii) locally recoverable return flows to surface water systems, from drains and surface runoff, and also to aquifers via subsurface recharge; and (iv) nonrecoverable flows to sinks, such as to saline groundwater and the ocean. Inflows less outflows over a given time period equals the change in water storage.

Conservation of mass requires that increased local beneficial water consumption, because of a higher IE, be fully offset by a decline in some combination of nonbeneficial water consumption, recoverable return flows (to surface or groundwater), and nonrecoverable flows to sinks. Thus, a higher IE (typically 90% for drip versus 50% for surface) is associated with lower rates of nonbeneficial water consumption, usually because of reduced soil evaporation (5% for drip and 20% for surface). These changes from a higher IE also result in a reduction in return flows, from 30% of water applied, in the case of surface irrigation, to 5%, for drip.

Studies in several locations confirm the effects of higher IE, including (i) Rajasthan, India, where subsidies for drip irrigation improved farm incomes but also increased the irrigated area and total volume of water applied by farmers (*10*); (ii) Snake River, Idaho, where farmers have increased their IE, but this has reduced groundwater recharge and led to a decline in the Eastern Snake Plain Aquifer by about 30% since the mid-1970s, despite increased precipitation (*11*); (iii) the Rio Grande in the United States, where subsidies for drip irrigation increase crop yields and irrigators' net income but can reduce downstream flows and the water potentially available for other purposes (*7*); and (iv) the Souss and Tensift Basins of Morocco, where the adoption of drip irrigation, supported by subsidies, reduced recoverable return flows, principally to overexploited aquifers. This led to increased water consumption and exacerbated groundwater overexploitation in Morocco because of crop intensification, especially denser tree plantations; increased irrigated area owing to improved control of water; and a greater area of crops with higher water-use requirements (*12*).

TOMORROW'S EARTH
Read more articles online at scim.ag/TomorrowsEarth

These four cases, and others (*5*), show that increases in IE are typically associated with a reduction in recoverable return flows and an increase in crop yields and in crop transpiration. Contrary to the policy intent, however, a higher IE is not usually associated with a decline in water consumption. Only when a commensurate decrease in some combination of nonbeneficial water consumption and nonrecoverable flows is observed is it possible to reallocate water to other uses at a watershed or basin scale after an increase in IE (see supplementary materials).

Scientific understanding of the paradox highlights the importance of a comprehensive evaluation of the public costs of subsidizing increases in IE. This, in turn, requires that the estimated benefits (such as higher yields and farm net incomes) be compared to the external costs from induced reductions in recoverable return flows (such as groundwater degradation, losses to aquatic ecosystems, reduced environmental water volumes, removal of salts from watersheds and basins, and other water uses).

POLICY AND RESEARCH IMPLICATIONS

If increases in IE are to mitigate the global water crisis, then decisive actions, some of which have previously been highlighted (*3*, *5*, *7*, *9*), are required. A key constraint to better decision-making is inadequate estimates of water inflows and outflows at watershed and basin scales. This analysis of water accounts is essential to demonstrate when IE policies are or are not in the public interest. Furthermore, successful integration of science into policy and practice requires several precon-

[1]Crawford School of Public Policy, The Australian National University, ACT 2601, Australia. [2]Groupe de Recherche en Économie Théorique et Appliquée (GREThA), UMR CNRS 5113, University of Bordeaux, 33608 Pessac, France. [3]Consultant, London NW8 8QX, UK. [4]Institut de Recherche pour le Développement (IRD) and G-Eau, University of Montpellier, 34196 Montpellier, France. [5]Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC 20005-3915, USA. [6]Food and Agriculture Organization of the United Nations (FAO), Regional Office for the Near East and North Africa, 12311 Cairo, Egypt. [7]Colorado Water Institute, Colorado State University, Fort Collins, CO 80523-1033, USA. [8]Centre for Global Food and Resources, Faculty of Professions, University of Adelaide, Adelaide, SA 5001, Australia. [9]School of Public Policy and Management–Institute for Contemporary China Studies, Tsinghua University, 100084 Beijing, China. [10]Smith School of Enterprise and the Environment, University of Oxford, Oxford OX1 3QY, UK. [11]Kimberly Research and Extension Centre, University of Idaho, Kimberly, ID 83341, USA. Email: quentin.grafton@anu.edu.au

ditions. To avoid "regulatory capture," there must be transparent and independent auditing of policy processes and data provision. There also needs to be public interest in the issue such that there is a cost to policy-makers who fail to act for the public good. And alignment of public interest–seeking actors, supported by transparent data and evidence, mitigates water misuse and misallocation.

We outline five steps, centered on water accounting and research advances, that promote more effective policy actions. First, physical water accounts need to be developed from the farm-scale to the basin scale to make transparent "who gets what and where" to support decision-making in the public interest. This requires measurement or estimation of all inflows, water consumption, recoverable return flows, and nonrecoverable flows to sinks. Although a priority by the UN High-Level Panel on Water (*13*), robust and transparent water accounting is the exception. In some jurisdictions—such as Spain (*9*), Morocco (*12*), and the Murray-Darling Basin, Australia (*14*)—several billion U.S. dollars have been spent subsidizing IE, including canal lining and drip irrigation, without proper accounting of their effects on recoverable return flows, aquifers, and river ecology. Developments in remote sensing offer the possibility of estimates of water inflows and outflows at a much lower cost and a greater scale than previously available.

Second, reductions in water consumption are achievable by decreases in water extractions through a direct cap on water offtakes (*9*) or on the irrigated area. The need for such caps when promoting IE has been identified in the European Union and the western United States, where water rights have been denominated as net extractions that require the calculation of return flows. Water accounting in California, which includes ET, is providing decision-makers with the information needed to determine how much to reduce water consumption to ensure sustainable extractions. By contrast, in Australia, where water rights are denominated in gross extractions, actions to reduce extractions to reallocate water to the environment have, to date, been neither sufficient nor cost-effective (*14*). To meet environmental flow goals, incentives may be used to make irrigators account for return flows, such as water charges on the reductions in recoverable flows, or financial benefits to maintain such flows by reducing consumption. Incentive-based water reallocations, however, can be constrained by the funding needed to compensate users to facilitate transfers across competing water uses.

Third, to ensure desired outcomes are delivered, risk assessments are needed when evaluating the effects of increased IE, as are accurate measurements from on-the-ground monitoring of flows. Policy-makers must account for uncertainties in key water parameters when calculating water flows (*15*). Advances in decision-making under uncertainty, better data quality and quantity, user-friendly software, and increased computing power all facilitate greater consideration of risks in future water planning.

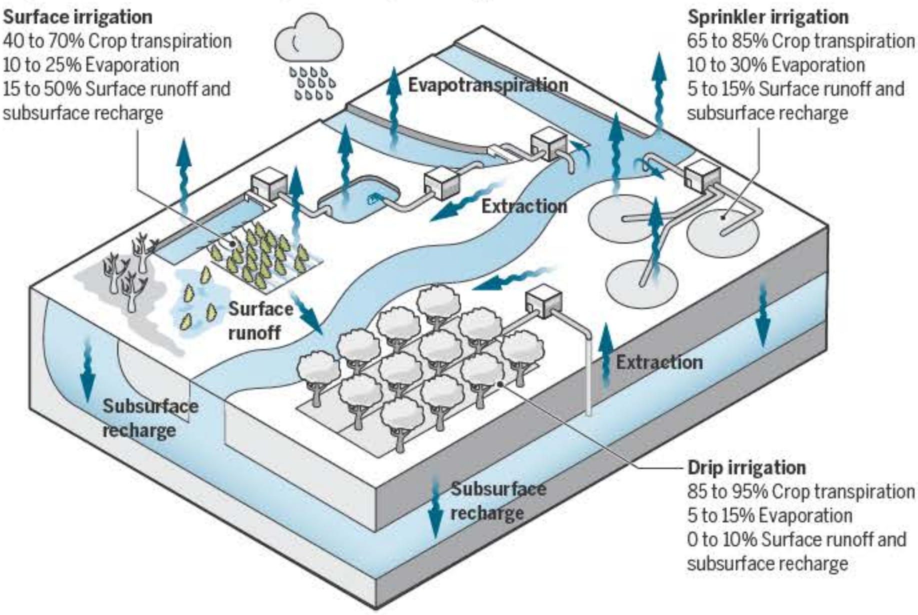
Fourth, although understanding water inflows and outflows is necessary, the payoff from subsidizing IE depends on whether the benefits exceed the costs, including those associated with reduced return flows. Comprehensive methods of valuation can make these trade-offs more explicit, as can advances in water accounting and measurements of changes in water quality.

Finally, the effects of policy actions (*5*) on the behavior of irrigators must be evaluated. Neither IE nor water extractions are constant: They vary by irrigator and differ by land and soil characteristics, crops grown, time of year, and weather conditions. Differences are more readily understood with developments in behavioral and experimental economics and by testing how irrigators' actions change as IE increases. Such methods identify incentives for irrigators to maintain agricultural production with less water extracted.

Overcoming misunderstandings about the paradox of IE is required if SDG 6 is to be achieved. Our five-step reform of the current IE policy agenda—centered on water accounting and reductions in irrigation water extractions which are informed by advances in water valuation, risk assessment, and behavioral economics—offers a pathway to improved global water security. ■

Accounting for water

The paradox of irrigation efficiency (surface, sprinkler, and drip) and the water inflows and outflows can be seen in a watershed example. Ranges of crop transpiration, evaporation, runoff, and recharge are authors' judgment of possible values. These values depend on crop and soil types, weather, and other factors.



REFERENCES AND NOTES

1. R. Q. Grafton *et al.*, *Earths Future* **5**, 449 (2017).
2. C. M. Burt *et al.*, *ASCE J. Irrigation Drainage Eng.* **123**, 423 (1997).
3. S. M. Scheierling *et al.*, *Water Resour. Res.* **41**, W03248 (2006).
4. M. Flörke *et al.*, *Nature Sustainability* **1**, 51 (2018).
5. C. Perry *et al.*, "Does improved irrigation technology save water? A review of the evidence" (Food and Agriculture Organization of the United Nations, Cairo, 2017), p. 42.
6. L. Pfeiffer, C.-Y. C. Lin, *J. Environ. Econ. Manage.* **67**, 189 (2014).
7. F. A. Ward, M. Pulido-Velazquez, *Proc. Natl. Acad. Sci. U.S.A.* **105**, 18215 (2008).
8. United Nations High-Level Panel on Water, "Making Every Drop Count. An Agenda for Water Action" (HPLW Outcome Report, United Nations, 2018).
9. C. A. Scott *et al.*, *Hydrol. Earth Syst. Sci.* **18**, 1339 (2014).
10. T. Birkenholtz, *Water Int.* **42**, 663 (2017).
11. M. McVeigh, A. Wyllie, Memo on irrigation efficiency and ESPA storage changes, State of Idaho Department of Water Resources, 5 March 2018.
12. F. Molle, O. Tanouti, *Agric. Water Manag.* **192**, 170 (2017).
13. Australian Bureau of Meteorology, "Good practice guidelines for water data management policy: World Water Day Initiative" (Bureau of Meteorology, Melbourne, 2017).
14. R. Q. Grafton, S. A. Wheeler, *Ann. Rev. Resour. Economics* **10**, 487 (2018).
15. A. J. Clemmens, C. M. Burt, *J. Irrigation Drainage Eng.* **123**, 443 (1997).

ACKNOWLEDGMENTS

S.A.W. was supported by the Australian Research Council project FT140100773; C.R. was supported by the CGIAR Research Program on Water, Land, and Ecosystems; and F.M. was supported by the Agence Nationale de la Recherche (ANR) AMETHYST project (ANR-12 TMED-0006-01).

SUPPLEMENTARY MATERIALS

www.sciencemag.org/content/361/6404/page/suppl/DC1

10.1126/science.aat9314

GRAPHIC: N. DESAI/SCIENCE

Attachment 3

Sustainable Diversions in the Murray-Darling Basin

An analysis of the options for achieving a sustainable diversion limit in the Murray-Darling Basin

June 2010

Wentworth Group of Concerned Scientists

In Association With

Prof R. Quentin Grafton, Ian Kowalick, Prof Chris Miller, Tim Stubbs, A/Prof Fiona Verity, A/Prof Keith Walker

Wentworth Group of Concerned Scientists

Mr Peter Cosier, Director, Wentworth Group, former policy advisor to the Australian Environment Minister.

Prof Tim Flannery, paleontologist, 2007 Australian of the Year, Author of *The Future Eaters* and *The Weather Makers*.

Dr Ronnie Harding, zoologist, Metropolitan Water Independent Review Panel (NSW), Senior Visiting Fellow Institute of Environmental Studies UNSW.

Prof David Karoly, Professor of Meteorology, University of Melbourne, Co-coordinating Lead Author in the Intergovernmental Panel on Climate Change.

Prof Hugh Possingham FAA, Professor, Mathematics and Zoology, Centre for Australian Environmental Decision Analysis UQ, ARC Research Fellow.

Mr Robert Purves AM, businessman, Director Purves Environmental Trust, Chair, Environment Business Australia.

Dr Denis Saunders AM, ecologist, President WWF Australia, Editor, Pacific Conservation Biology, former Chief Research Scientist, CSIRO.

Prof Bruce Thom AM FTSE, geomorphologist, Chair 2001 Australian State of the Environment Committee, former Vice Chancellor UNE, Chair Australian Coastal Society.

Dr John Williams, agricultural scientist, Commissioner, NSW Natural Resources Commission, and former Chief CSIRO Land and Water.

Prof Mike Young, resource economist, Director, Environment Institute, The University of Adelaide.

In Association With

Prof R. Quentin Grafton, Director, Centre for Water Economics, Environment and Policy, The Crawford School, The Australian National University.

Ian Kowalick, business consultant, former Independent Commissioner, Murray-Darling Basin Commission, former Chief Executive, SA Department of Premier and Cabinet.

Prof Chris Miller, Interim Dean, School of Social and Policy Studies, Faculty of Social and Behavioural Sciences, Flinders University.

Tim Stubbs, environmental engineer, Water Program Manager, Wentworth Group of Concerned Scientists.

Associate Prof Fiona Verity, Head of Department, Social Work and Social Planning, School of Social and Policy Studies, Faculty of Social and Behavioural Sciences, Flinders University.

Associate Prof Keith Walker, river ecologist; Adjunct Associate Professor, School of Earth and Environmental Sciences, The University of Adelaide.

ISBN: 978-0-646-53584-5
June 2010
www.wentworthgroup.org

Summary

For over 100 years Australians have argued over the waters of the Murray-Darling Basin. We are acutely aware that water is a scarce resource. We now know that as we developed extraction industries in the Basin, we have left too little water in the rivers to sustain a healthy river system.

As a result, we face a real risk that the ecosystems supporting the river system will collapse, undermining the businesses and communities that depend on it.

Irrigated agriculture is the biggest consumer of the water we divert from the rivers and aquifers of the Basin. It uses the water to produce high-quality food and fibre. It helps feed us and produces valuable exports. It also provides jobs, and underpins the economies of many communities along the rivers of the Basin.

In 2004, State and Commonwealth Governments agreed on a *National Water Initiative*[1] setting out a broad set of water reforms designed to return a sustainable balance to the Basin.

In 2007, the Australian Parliament passed the Commonwealth *Water Act 2007* (the Water Act) to facilitate the reduction of water extractions to environmentally sustainable levels, and to do this in a way that maximises the economic returns to the businesses and communities in the Basin.

The Federal Government has also allocated nearly $9 billion to help achieve these objectives through its *Water for the Future* program.

The Wentworth Group strongly supports these actions by our governments. The actions represent significant progress towards a sustainable outcome for both the environment and the communities of the Basin.

In line with the requirements of the Water Act, the new Murray-Darling Basin Authority is currently developing a *Basin Plan*. This plan will set 'Sustainable Diversion Limits' that will define the maximum "quantity of water that may be taken from the Basin water resources as a whole"[2].

Once the Sustainable Diversion Limit has been set the challenge for Governments will be to reduce diversions to meet the new limit in the most economically and socially effective ways.

This report seeks to identify the scale of reductions in diversions required within each of the 18 catchments of the Basin. It also seeks to determine the most cost-effective way to obtain the necessary water while also assisting the businesses and communities in the Basin capitalise on opportunities and adapt to a future with less water.

How much water needs to be returned to the environment?

The best-available science suggests there is a substantial risk that a working river will not be in a healthy state when key system level attributes of the flow regime are reduced below two-thirds of their natural level. To achieve a level of two-thirds natural flow in all the catchments of the Basin the environment's share of the existing Cap on diversions would need to be increased by approximately 4,400GL[3] (i.e. 4,400GL long-term Cap equivalent[4]).

This represents a reduction of approximately 40% of the current Cap on diversions. This implies that the Sustainable Diversion Limit for the Basin should be defined in a manner that is equivalent to a Cap of approximately 7,170GL.

Actions by State and Federal Governments over the past few years (including the current *Water for the Future* program and *The Living Murray* and *Water for Rivers* programs), have obtained approximately 1,200GL of water for the environment[5]. Taking this water into account, it means that an additional 3,200GL still needs to be returned to environmental flows. This represents a reduction of approximately 30% of the current Cap on diversions.

A suite of entitlements will need to be obtained to deliver this volume of water in a year of average inflows. In drier periods, when inflows are less than this average, the environment's share would yield less than 4,400GL, just as all entitlements yield less in dry years.

From which catchments should this water be obtained?

The Centre for Water Economics, Environment and Policy at the Australian National University has analysed the economic impacts of achieving sustainable levels of diversion in the Basin. The analysis used a combined economic and hydrologic model to evaluate the net profit per megalitre of water used in each of the 18 catchments.

It then selected water from the least profitable activities in each catchment so that the required volume of environmental water could be obtained at the lowest economic cost.

We have used this analysis to identify the reductions in diversions that would be required in each catchment to achieve a 30% reduction of water use in the Basin at the lowest economic cost (Figure (i)).

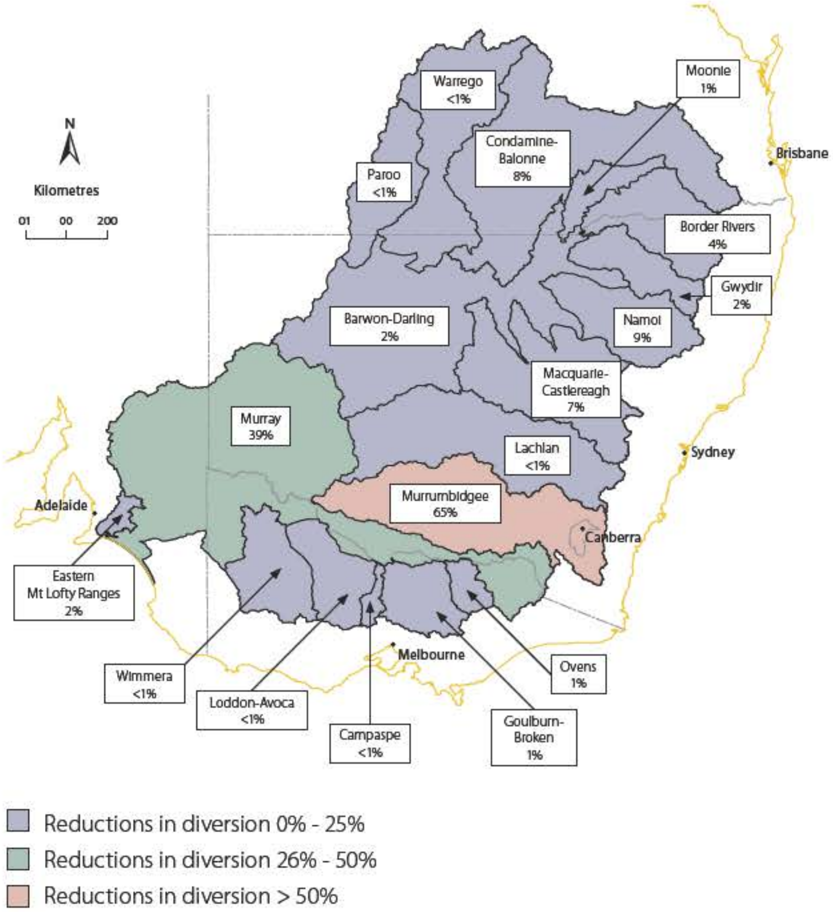


Figure (i): Distribution of reductions in diversions (%) for a 30% reduction in agricultural surface-water diversions from the Murray-Darling Basin

In most catchments, the required reduction is less than 10%. However, in two catchments - the Murray and Murrumbidgee - the reductions are significantly greater, in the order of 39% and 65% respectively.

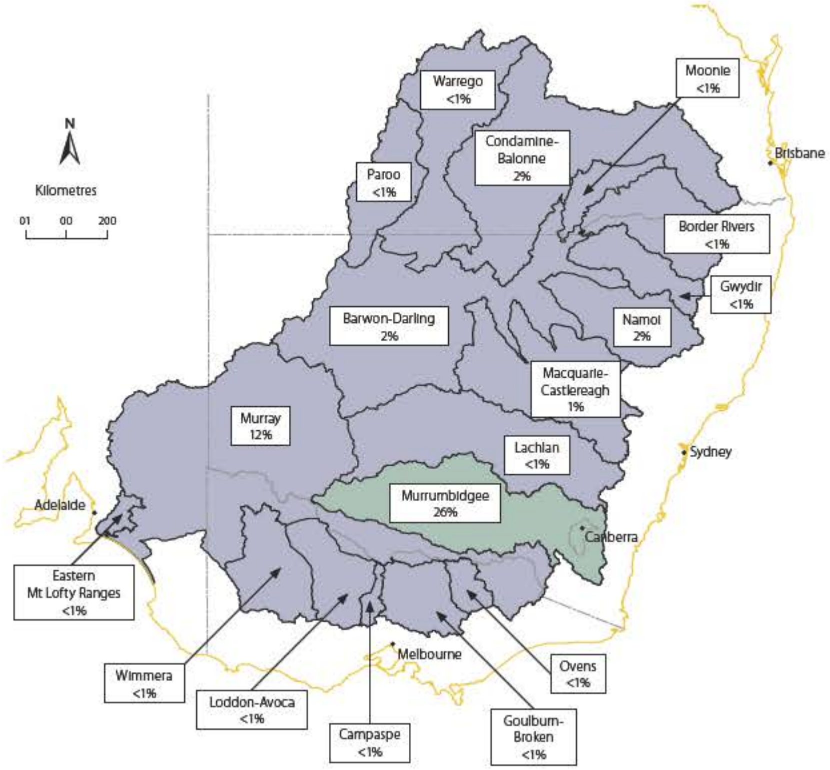
We have also analysed the economic impact of these reductions in diversions in each catchment.

Because the economic model used to derive these reductions preferentially took water from the least profitable activities within each catchment, the relationship between the reduction in diversions and the reduction in profits is not linear.

In most catchments, the reduction in profits would be less than 3%.

In the Murray and Murrumbidgee catchments, the reduction in profits would be in the order of 12% and 26% respectively (Figure (ii)). These are potentially significant dislocations for the communities of these two catchments if undertaken without a process to facilitate the adjustment and assist communities in the Basin capitalise on opportunities and adapt to a future with less water.

Overall, this analysis suggests that the economic impact (expressed as the net present value of the lost profits) resulting from a further 30% reduction in water use in a year of near average diversions would be in the order of \$2.7 billion.



Reductions in profits 0% - 25%

Reductions in profits 26% - 50%

Reductions in profits > 50%

Figure (ii): Distribution of reductions in profits (%) for a 30% reduction in agricultural surface- water diversions in the Murray-Darling Basin

What is the most effective way of achieving sustainable diversions?

The challenge for governments is to identify the most cost-effective and timely approach for delivering the required volume of water while also helping the businesses and communities in the Basin capitalise on opportunities and adapt to a future with less water.

We have evaluated three approaches:

- **Option 1:** Continuing to implement the Federal Government's current *Water for the Future* program, which includes separate funding allocations of $3.1 billion for water buyback and $5.8 billion for water use efficiency.
- **Option 2:** Combining these separate funding programs into a single fund to purchase environmental water through the most cost-effective means (either buyback or infrastructure investment) according to a cost-benefit based environmental benefits index.
- **Option 3:** Combining these separate funding programs into a single fund and working with local communities to acquire water for a price equivalent to a 'reasonable return' on lost profits, and funding an economic development program to assist regional communities transition to a future with less water.

Option 1 – Current *Water for the Future* program

Our analysis suggests that, based on its current design and progress to date, the *Water for the Future* program will only be able to deliver a total of around 2,100GL of water (including 535GL already obtained) for the available $8.9 billion in funds.

This is less than half the total volume required to give a high probability of healthy rivers. This is largely due to the high cost of recovery of water from irrigation infrastructure investments which range from approximately $4,600/ML to approximately $11,400/ML.

Government forecasts indicate that other programs, such as *The Living Murray* and *Water for Rivers*, will deliver approximately 770GL of water for the environment[6]. This will bring the total volume of environmental water to 2,870GL, still well short of the required 4,400GL.

The existing program design has other flaws: it is being rolled out over a period of 10 years. For many environmental assets in the Basin, the period since they were last watered is the longest on record. For these assets, the program's 10 year timeframe is too long, and places their ecosystems at risk of collapse. The timeframe also leads to a long period of economic uncertainty impacting on the ability of the irrigation industry to attract new investments.

Option 2 – Combined water buyback and water use efficiency program

An alternative approach would be to combine the $3.1 billion allocated to water buyback and the $5.8 billion allocated to increasing water use efficiency in the *Water for the Future* program into a single fund, and bring forward the timeframe for expending this money. The fund would be used to either buy water or implement water use efficiency projects. It would use an environmental benefits index to ensure the most cost-effective means of obtaining water are used.

Under this approach, the 4,400GL of water required to give a high probability of a healthy working river would be achieved, at a cost of approximately $8.5 billion. This is based on the price paid for buybacks to date ($2,283/ML) and includes the 1,200GL already obtained through the *Water for the Future* program and other State and Federal Government programs[7].

This option is likely to make approximately $400 million available for investment in water use efficiency projects.

By bringing forward the timeframe for expending the funds, it should also make water available to a number of environmental assets that are in critical need of watering. It would also provide investors with a higher level of certainty in a much shorter timeframe.

Option 3 – Reasonable return and community development program

Under Options 1 and 2, only those with water to sell will receive financial compensation, and only irrigators will benefit from infrastructure improvements. Little assistance is provided to help the broader communities in the affected catchments adjust to a future with less water.

The economic analysis in this report shows that if some irrigators choose to sell part or all of their entitlement for a 'reasonable return' on the profits they would lose as a result (based on net present value of those lost profits), the Federal Government could acquire the additional volume of water required (3,200GL) for an estimated total cost of $2.7 billion.

This would save up to $5 billion, some of which could be used to invest in public infrastructure to assist the communities most affected by reductions in diversions to restructure their economies.

Under this approach, the level of funding available to each affected community would be based on the economic impact resulting from the withdrawal of water for consumptive use in that district. In some of the worst affected communities, these sums could be significant.

With this financial support, some communities may decide to forego irrigation and branch out into new industries. Others may prefer to consolidate their irrigation industry and use the funds to invest in new water technology or to add value to their products. However, this decision would be made for the benefit of the whole community, not just individual irrigators.

This option would enable the Federal Government to continue to support its *Water for the Future* infrastructure spending commitments with the states, by broadening the range of infrastructure projects that could be funded beyond irrigation infrastructure. The due diligence and project selection would be based on an assessment of a project's ability to contribute to a sustainable economic future for the entire community.

A Way Forward

Recent government actions, including the allocation of nearly $9 billion of Australian taxpayers' money, have created a historic opportunity to deliver substantial reforms in the way we use and manage our precious water resources across the Murray-Darling Basin, and restore and protect the health of this Basin for future generations.

The challenge now is to use this opportunity and funding in a way that ensures a sufficient volume of water is returned to the environment and maximises the economic development opportunities for local communities.

Our analysis indicates that the current *Water for the Future* program (Option 1), is not capable of delivering this outcome within the funding allocated.

Under this option, all the available funding will go directly to individual irrigators, or be invested in state and cooperative-owned irrigation infrastructure. It will provide no support to those with no water to sell or who are not directly involved with irrigation. These people represent large sections of the communities of the Basin.

An alternative approach is necessary.

Of the two alternative approaches we evaluated (Options 2 and 3), both are capable of achieving this outcome. The great advantage of the Reasonable Return and Community Development approach is that it can deliver the required volumes of water to satisfy the requirements of Water Act in a much more cost-effective and socially responsible way.

It is most likely to achieve all three objectives of the Water Act and represents much better value for money for Australian taxpayers. In doing so, it can free up significant financial resources that can be used to assist communities re-build their regional economies and adapt to a future with less water.

Figure (iii): Cost-Effectiveness of alternative approaches for obtaining water for the environment

	Volume of water obtained for the environment	Funds for purchase of water for environment	Funds for irrigation infrastructure investment[i]	Funds for infrastructure investment (irrigation and other)
Option 1: *Water for the Future*	2,910 GL ($3,058/ML[ii])	$3.1 billion	$5.8 billion	-
Option 2: Market buyback and infrastructure	4,400 GL ($1,932/ML[ii])	$8.5 billion	-	$400 million
Option 3: Reasonable return and community development	4,400 GL ($886/ML[ii])	$3.9 billion ($1.2 billion plus $2.7 billion)	-	Up to $5 billion

[i] 50% of infrastructure investment savings allocated to environment and are included in 2,910GL
[ii] Average cost/ML of water

What is the reality of the Murray-Darling Basin?

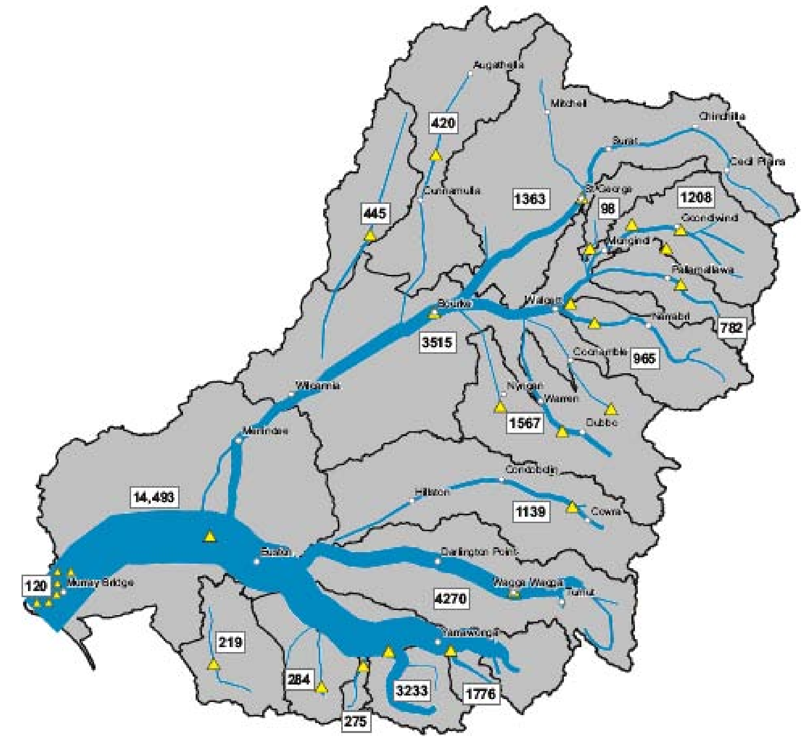
The Murray-Darling Basin provides many social and economic benefits – including water for towns and cities, for irrigation, for stock and domestic use, and for recreation and tourism industries. In addition, the rivers of the Basin are central to the very image of Australia, with their ancient river red gums, grassy banks and native fish such as Murray cod and Macquarie perch.

Many of its natural assets are currently in poor or very poor health. This is partly due to a mix of climatic, social and economic factors. However, it is also due to the nature of the Murray-Darling river system itself, which needs sufficient flows of water and periodic flooding to maintain the ecological functions that keep the system healthy.

Climatic factors

The climate of the Murray-Darling Basin is highly variable, both geographically and over time. This variability affects the amount of water in the river channels, floodplains, wetlands, lakes and groundwater aquifers of the Basin at any given time. Figure 1 shows the average surface water availability for the rivers of the Basin[8]. It shows the relative contributions of the northern and southern parts of the Basin.

Figure 2 is a hydrograph of the annual river flow at Euston on the Murray River over the period 1895 to 2006[10]. It shows the high level of year-to-year variability, as well as over longer periods. For example, the 50 years from 1950 to 2000 were much wetter than the 50 years from 1900 to 1950. In the last 10 years, water availability has been more like the driest periods of last century.



Water availability assessment location

Historical water availability

12 Regional water availability (GL/y) based on assessment locations

Figure 1: Average surface water availability across the Murray-Darling Basin[9]

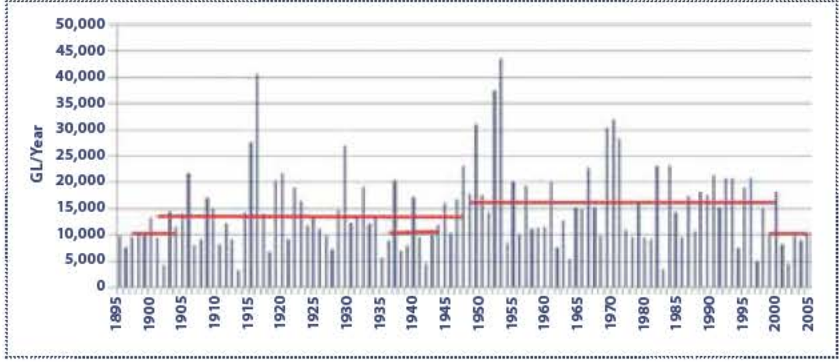


Figure 2: Annual flow at Euston on the Murray River with the red lines showing average flows[11]

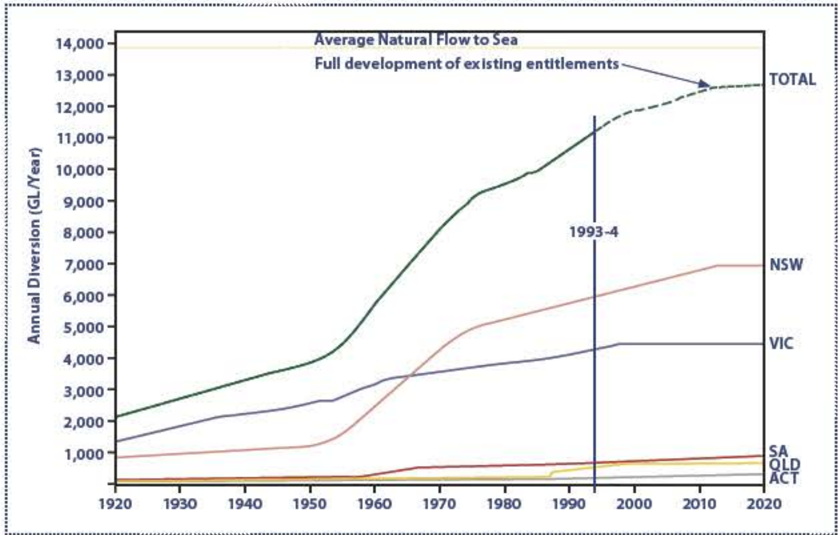


Figure 3: Growth in water use in the Murray-Darling Basin[12]

Social and economic factors

A mix of social and economic factors (including the emergence of new irrigation technology), combined with the fact that there was more water in the system, allowed the irrigation industry in the Murray-Darling Basin to expand significantly in the wetter half of the last century (Figure 3).

Before the development of industries which extracted water, the long-term average end-of-system flow of the Murray-Darling Basin was approximately 12,233GL. With the current levels of development, this has been reduced to around 4,733GL (Figure 4). This is less than 40% of the flow before development.

Figure 4 also shows that under natural conditions, the probability of a flow of less than 5,000GL occurring was about one year in 20. Under the current conditions, this probability has increased to greater than one year in two.

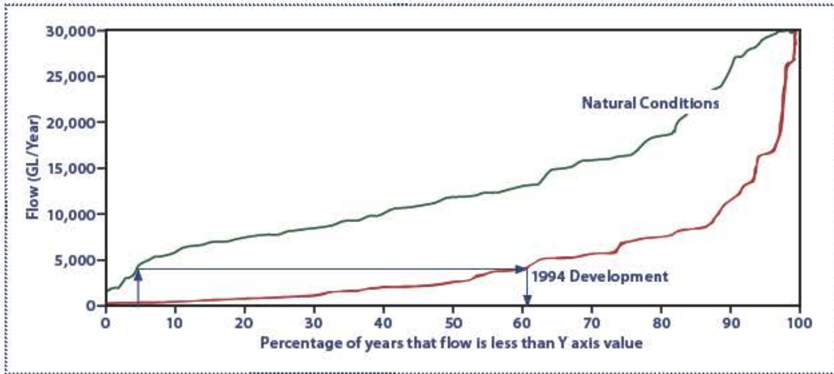


Figure 4: Impact of development on probability of annual flow volumes at the mouth of the Murray[13]

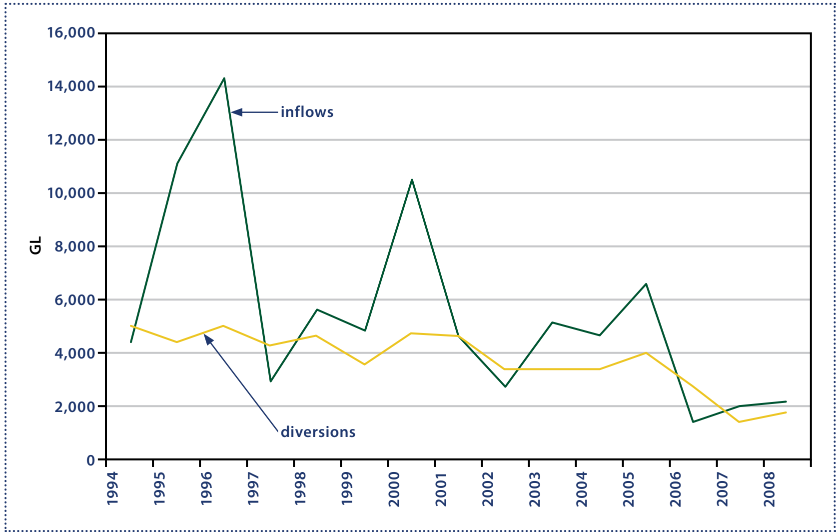


Figure 5: Murray River inflows and total diversions for NSW, Victoria and South Australia, 1994 – 2008[14]

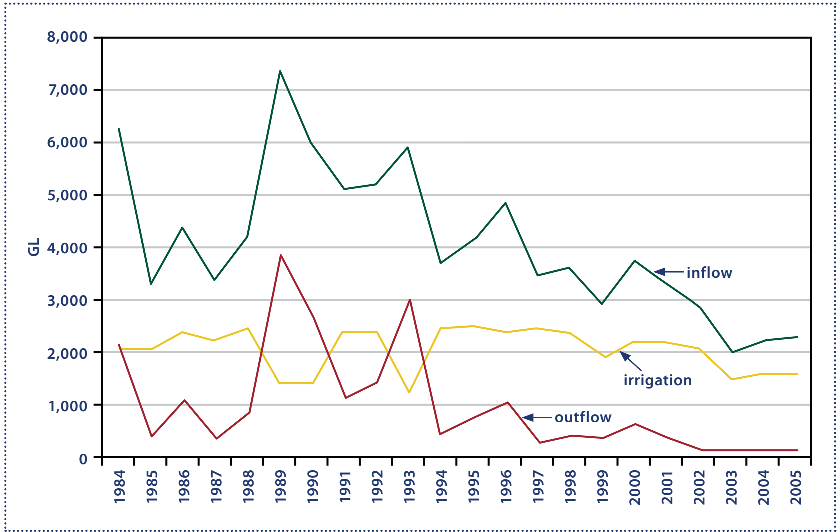


Figure 6: Murrumbidgee River: inflow, outflow and water used for irrigation 1984 - 2005[17]

The manner in which the irrigation industry was developed during the wetter period post 1950 has also meant that as inflows have diminished over the last 10 years, greater and greater proportions of the available surface and groundwater water have been diverted from the river and aquifer systems for consumptive use (Figure 5).

From 1 July 1995, a Cap on extractions was implemented across the Basin[iii]. However, this Cap was designed to halt the growth in diversions of surface water, rather than to achieve sustainability[15]. It restricts diversions to the volume that would have been diverted under 1993-94 development levels (Figure 3).

The combination of a return to a drier cycle[16] and the design of the water-sharing rules have resulted in less water for the environment. This can be seen in Figure 6, which shows the levels of inflows, outflows and water used for irrigation for the Murrumbidgee River. Since 1994, the outflows from this river to the Murray have been negligible, while at the same time, irrigation use has largely remained above 1,500GL.

[iii] Queensland was not a signatory to this agreement

Nature of the Murray-Darling's ecosystems

The nature of the Murray-Darling river system means that it needs sufficient volumes of water flowing through it, at the right time, to maintain the biological functions that keep it healthy. This water is referred to as environmental flows.

The Murray-Darling is a floodplain river system. It is made up of river channels, floodplain woodlands and wetlands (including lakes and billabongs and the creeks and streams that feed the system), and the estuary and mouth of the Murray River. All these parts are important to the health of the river system.

Like other floodplain rivers, it comprises two inter-dependent ecological systems: the river channels and the floodplain woodlands and wetlands. The river channels transport water, sediment, salt, nutrients and other suspended and dissolved materials. They also facilitate the dispersal of aquatic plants and animals.

The floodplain woodlands and wetlands are watered when floodwaters overtop the banks of the river channels. This water moves across the floodplain, soaking the soils. Some of it evaporates but, in many cases, most eventually returns to the river channels further downstream.

When the rivers flood, the energy and nutrients flushed through the wetlands and woodlands drive many of the ecological functions. The water and material the woodlands and wetlands receive from flooding may be stored, and ultimately decomposed and reassembled as new organisms, before it is returned back to the river channel. The processes involved in this transformation are much more complex than those that occur in the channel. For this reason, much of the biodiversity associated with lowland rivers lives in the wetlands and woodlands rather than the channel.

As floodwaters reach the end of the river system, they flush the estuary and the mouth of the Murray, removing the sediments that accumulate and block the system under low-flow conditions. They also carry organic material which plays a critical role in the health of the ecosystems of the estuary, and flush the salts and other toxins which build up and poison the system.

When the waters finally flow into the ocean they contribute to the health of near-shore and marine environments. These flows are not wasted.

For a floodplain river system to function effectively, the connections between the river channels and floodplains must be maintained. This requires regular flooding.

However, in the Murray-Darling system, the extraction of water for consumptive use has significantly reduced the frequency of the mid-range floods that overtop the banks of the river channels. This has impeded the connections, and damaged the health of floodplain woodlands and wetlands.

In some parts of the system, channel and floodplain ecosystems have become isolated. For example, a recent assessment of the flow requirements for the Barmah-Millewah red gum forests on the Murray[18] shows that they require approximately 2,200GL[19] of water every three years. These internationally recognised forests have only received this volume of water once in the last 34 years.

Current health of the system

This combination of factors, but particularly the level of over-development and the current inter-state sharing rules, means there is insufficient water flowing through the Murray-Darling Basin to maintain the long-term health of its rivers and water-dependent ecosystems and meet the aspirations of all users. Climate change is likely to make this situation even worse[20].

Most of the rivers in the Murray-Darling Basin are showing signs of long-term ecological degradation[21, 22, 23]. The first Sustainable Rivers Audit[24], released in June 2008, rated the health of the 23 river valleys in the Basin. It found that only one of these, the Paroo, across the Queensland-NSW border, is in 'good' health. More than half (13 valleys) are in 'very poor' health (Table 1).

Table 1: Health ratings of river valleys of the Murray-Darling Basin[25]

Health Rating	River Valley
Good	Paroo
Moderate	Border Rivers, Condamine
Poor	Namoi, Ovens, Warrego, Gwydir, Darling, Murray Lower, Murray Central
Very poor	**Murray Upper, Wimmera, Avoca, Broken, Macquarie, Campaspe, Castlereagh, Kiewa, Lachlan, Loddon, Mitta Mitta, Murrumbidgee, Goulburn.**

The audit also found that the river valleys in the south are in worse condition. All the valleys in Victoria for example, are either in poor or very poor health.

Other research indicates that the Lower Lakes and the Coorong in South Australia – the 'estuary' of the Murray-Darling Basin – are in a critical condition[26]. Since 2008, freshwater levels in Lake Alexandrina, behind the barrages at the river mouth, have been below sea level.

If Australians are to have a healthy Murray-Darling Basin and enjoy the environment, economic and social benefits this brings, more of the water in the Basin must be allocated to the environment.

Managing the water resources of the Murray-Darling Basin

Commonwealth and State Governments all recognise that we are taking too much water out of the Murray-Darling Basin to maintain its long-term health.

In 2004, the Council of Australian Governments (COAG) agreed to implement the National Water Initiative "in recognition of the continuing national imperative to increase the productivity and efficiency of Australia's water use, the need to service rural and urban communities, and to ensure the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction"[27].

In 2007, the Australian Parliament passed the Water Act giving a statutory foundation to operationalise this initiative.

The objectives of this Act are:

(i) to ensure the return to environmentally sustainable levels of extraction for water resources that are over-allocated or overused; and

(ii) to protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin (taking into account, in particular, the impact that the taking of water has on the watercourses, lakes, wetlands, ground water and water-dependent ecosystems that are part of the Basin water resources and on associated biodiversity); and

(iii) subject to subparagraphs (i) and (ii)—to maximise the net economic returns to the Australian community from the use and management of the Basin water resources.

As required under the Act, the new Murray-Darling Basin Authority is required to produce a Basin Plan[28] which sets 'Sustainable Diversion Limits'[29].

These limits define the level of "water that can be taken from a water resource without compromising the key environmental assets, key ecosystem functions, the productive base of key environmental outcomes of the resource"[30].

The Federal Government has allocated over $12 billion through the *Water for the Future* program to deliver the water reforms and meet the objectives of the Water Act. Of this, approximately $8.9 billion is assigned to meeting these objectives in the Murray-Darling Basin. Some of this money has already been used to obtain water for environmental flows by buying back water entitlements in the Basin.

This represents significant progress. However, two fundamental questions need to be answered to ensure we can meet the objectives of the Water Act, and establish a water management regime that restores and protects the health of the Murray-Darling:

- How much water is required for environmental flows?
- What number and selection of entitlements need to be obtained to provide this amount of water?

How much water is required for environment flows?

The first and fundamental step towards achieving the objectives of the Commonwealth Water Act 2007 is to define what 'sustainable levels of extraction (diversion)' means.

The Wentworth Group considers that to determine what this means, we need to establish how much environmental water is needed in the system to achieve the following:

1. Restore and maintain all major rivers and floodplains in the Murray-Darling Basin in a healthy condition;
2. Manage the Coorong and Lower Lakes as a healthy functioning river estuary; and
3. Improve or maintain the health of wetlands of national and international significance.

The Sustainable Rivers Audit has defined a healthy river as one where "the long-term integrity of the system is preserved while meeting human needs"[31]. It did not suggest that to be healthy, a river must be returned to its 'natural' pre-European state.[32]

In a 2002 report,[33] the (then) Murray-Darling Basin Commission stated that its Expert Reference Panel had concluded that:

> "...there is a substantial risk [that] a working river will not be in a healthy state when key system level attributes of the flow regime are reduced below two-thirds of their natural level."

This conclusion is based on an earlier report[34] which evaluated two studies. The first study analysed six large rivers in the Basin (Condamine-Balonne, Gwydir, Lachlan, Macquarie, Murrumbidgee and Namoi Rivers)[35]. The second study focused on the Condamine-Balonne and the Fitzroy Basin[36].

Future detailed environmental flow assessments will refine these estimates for each catchment of the Basin on the basis of the environmental assets within the catchment and their water needs.

In 2008, the Wentworth Group used this work and estimated that a total volume of 4,350GL water would need to be returned to the environment's share of the long-term average flows of the Murray-Darling system in order to achieve a high probability of restoring the Basin to a healthy condition[37].

Since then, the CSIRO has published catchment-level water resource assessments from its *Sustainable Yields Project*.[38]

This work enables us to refine this estimate by calculating how much environmental water would be required to return flows in each catchment of the Basin to two-thirds of their natural level[39]. Table 2 shows the results of this analysis.

To achieve a level of two-thirds natural flow in all the catchments of the Basin the environment requires a share of the existing Cap on diversions of approximately 4,400GL[41]. The current Cap on diversions in the Basin is (11,576GL[42]).

The above analysis suggests that the Sustainable Diversion Limit for the Basin should be defined in a manner that is equivalent to a Cap of around 7,200GL. It also provides a basis for estimating the catchment-scale Sustainable Diversion Limits. The figures vary significantly from catchment to catchment.

The analysis does not include groundwater. A more detailed analysis which includes groundwater would almost certainly increase the volumes of water required for the environment to meet the recharge needs of the aquifers of the Basin.

Table 2: Additional environmental water (at a catchment scale) required to give a high probability of healthy working rivers in the Murray-Darling Basin in a year of average inflows

Catchment	Additional environmental water (Cap equivalent) required to return flows to two-thirds of the natural level	
	(GL)	% of current total catchment diversions[40]
Paroo	<1	-
Warrego	<1	-
Condamine-Balonne	120.80	17.0
Moonie	<1	-
Border Rivers	14.80	3.6
Gwydir	63.50	20.1
Namoi	10.70	4.1
Macquarie-Castlereagh	<1	-
Barwon-Darling	179.80	78.2
Lachlan	<1	-
Murrumbidgee	291.60	13.0
Murray	3,635.50	84.8
Ovens	<1	-
Goulburn-Broken	63.30	5.9
Campaspe	<1	-
Loddon-Avoca	27.50	7.9
Wimmera	<1	-
Eastern Mt Lofty Ranges	<1	-
Murray-Darling Basin	**4,407**	**40**

What number and selection of entitlements need to be acquired to provide this amount of water?

Since agreeing to the National Water Initiative, the State and Federal Governments have delivered a number of programs aimed at obtaining water for the environment. These include *The Living Murray* initiative, *Water for Rivers* and *Rivers Environmental Restoration Program* and have obtained approximately 670GL of water[43]. It is anticipated that they will obtain a further 100GL,[44] bringing the total to 770GL. In addition, as of 28 February, the Federal Government's *Water for the Future* program had obtained 535GL of water[45].

As a result of these programs, Governments now hold over 1,200GL of environmental water across the Basin. Given our analysis that a total of 4,400GL of environmental water is required to deliver a high probability of a healthy Murray-Darling Basin, this means an additional 3,200GL must be obtained. This represents a reduction of approximately 30% of the current Cap on diversions.

The volumes shown in Table 2 are long-term Cap equivalent volumes. These differ from "entitlements", because a registered entitlement represents only the 'on-paper volume' the owner of the entitlement is entitled to receive in a year. The actual volume the owner receives can be significantly less than their entitlement for two reasons.

First, entitlements are for a share of the available water from regulated rivers. In years when the available water in a valley is less than the total entitlements, the available water is rationed among the various entitlement holders. The percentage of their entitlement they receive will depend on whether they hold a high-reliability or a low-reliability entitlement, and the amount of water available.

Similarly, rules and supplementary entitlements provide for the sharing of unregulated water, such as that found in unregulated rivers and groundwater. These entitlements represent the maximum diversion the owner can make from the specified water resource in any year. However, actual diversions are limited by the availability of surplus flows, pumping rates and flow rates.

River models can be used to estimate the long-term average water allocated to regulated entitlements and available to unregulated entitlements. By its very nature, this average figure will generally be less than the sum of the entitlements.

Second, each valley in the Murray-Darling Basin is subject to the Cap on diversions that the Murray-Darling Basin Ministerial Council set in 1995. In most valleys, this cap reflected the level of development (ie, the level of water that could actually be extracted and used) in 1993-94.

At that time, not all entitlement holders needed to use their full water allocation, so the portion they did not need was allocated among other entitlement holders. Since then, the former may have traded their entitlement or developed their business, and thus need more of or all their allocation. This means that water managers must reduce allocations to all other entitlement holders to ensure that the Cap is not exceeded.

The long-term Cap equivalent takes into account these two factors and reflects the estimated long-term average water use that can be made for a particular entitlement. Long-term Cap equivalent is therefore a much better indication of 'real' water volumes not 'on paper' entitlement volumes.

The variation between entitlement volumes and actual water volumes means that governments must take care that, when obtaining entitlements for the environment, they select a suite of entitlements most likely to deliver the right volume of actual water for the catchment concerned. Three main factors need to be considered in selecting the best suite of entitlements in each catchment. These are:

- The volume, frequency and duration of watering required by the environmental assets within the catchment
- The relationship between reliability and cost (higher reliability, higher cost) within the catchment, and
- The amount of carry over permitted. Some entitlements allow the owner to accumulate some or all of the unused portion of their annual allocation within the dam, and then access this water in subsequent years. This allows them to 'save' some of their water allocation in wetter years, and draw on this water in drier years. If this is the case for environmental water, then cheaper, lower security entitlements may be sufficient. However, if it is not, then more expensive higher security entitlements are required to ensure the environment has the water it needs, when it needs it.

In addition, it is also important to consider the potential adverse impacts of climate change. Less water in the system will mean reduced allocations to lower security entitlements. Under the National Water Initiative, consumptive users are required to bear this risk[46].

Economic impact of acquiring water for the environment

The Centre for Water Economics, Environment and Policy at the Australian National University recently undertook analysis, to give an indication of the economic implications of achieving the sustainable levels of diversion in each of the 18 catchments of the Murray-Darling Basin[47].

This analysis used a combined economic and hydrologic model developed specifically for this work. The model evaluated the Basin at a catchment scale using the same catchment boundaries as the CSIRO's *Sustainable Yields Project*. It assumed that there were no restrictions to water trading in the Basin.

The model estimated the net profit per megalitre (ML) of water used in each catchment. It then preferentially selected water from the lowest profit activity in each catchment (lowest $/ML) to acquire the volume of environmental water required at the Basin level. In doing so, it took account of the hydrologic properties and constraints of the Basin, so that it did not try to take more water than exists from any one catchment of the Basin.

This approach ensures that the required volume of water is obtained at a whole-of -Basin level, but at the lowest economic cost by taking the water from the catchments that have the lowest $/ML return.

We have used the results of the Centre's analysis[48] to identify the percentage of water that should be obtained from each catchment to achieve:

- A 40% reduction in extractions across the Basin (ie, the total volume of water required to be returned to the environment, as set out in Table 2), and
- A 30% reduction (the volume of water required in addition to water already obtained by governments).

In its analysis, the Centre used 2000-01 data. In this year, total diversions from the Basin were 10,147GL, which is close to the long-term average of 11,146GL[49].

The results of this analysis indicate the percentage reduction in diversions required in each catchment to obtain sufficient water to give a high probability of restoring the Murray-Darling Basin system to a healthy condition, and also minimise the loss in profits to the irrigated agriculture industry (Table 3).

The variation in the percentage reduction in diversions required across the Basin reflects the differences in the productivity of water use ($/ML) in each catchment and the hydrologic properties of the river system.

The 'economic distribution' of the reductions in diversions required in each catchment (Table 3) is different to the distribution of reductions implied by our analysis of the environmental water required in each catchment to return river flows to two-thirds of their natural flows (Table 2).

In the main, this is because the economic distribution has redistributed reductions in diversion between the tributaries of the Murray and the Murray itself (reflecting differences in the productivity of water use on the land supplied by these rivers).

However, the redistribution of reductions in diversions between these tributaries and the Murray still meets the two-thirds flow requirement at the end of each tributary and at the mouth of the Murray. The redistribution also meets identified

Table 3: Percentage contributions from each catchment to deliver a 30% and 40% reduction in the total agriculture surface water diversions but minimise loss in profits based on data from 1 July 2000 to 30 June 2001 ('average' year).

Catchment	Catchment contributions to 30% reduction in Basin agriculture diversions	Catchment contributions to 40% reduction in Basin agriculture diversions
	(%)	(%)
Paroo	<1	<1
Warrego	<1	<1
Condamine-Balonne	8	22
Moonie	1	36
Border Rivers	4	8
Gwydir	2	3
Namoi	9	15
Macquarie-Castlereagh	7	16
Barwon-Darling	2	4
Lachlan	<1	<1
Murrumbidgee	65	74
Murray	39	44
Ovens	1	43
Goulburn-Broken	1	22
Campaspe	<1	98
Loddon-Avoca	<1	84
Wimmera	<1	<1
Eastern Mt Lofty Ranges	2	37
Murray-Darling Basin	**30**	**40**

water requirements[50] for important assets along the upper Murray system, including the Barmah-Millewah Forest and the Gunbower-Koondrook-Perricoota Forest.

Using the distribution of reductions in diversions across the catchments shown in Table 3, we have estimated the reduction in direct annual net returns that would be experienced in each catchment as a result. The results of this analysis, shown in Table 4, indicate that a 30% reduction in diversions would result in a reduction in annual net returns of less that 10% across the Murray-Darling Basin as a whole.

This is consistent with a recent socio-economic analysis which shows that although irrigated land area in the Murray-Darling Basin fell by approximately 9% between 2000-01 and 2005-06, the gross value of irrigated agriculture production increased from $5.1 billion to $5.5 billion[51].

We have calculated the net present value of the lost production resulting from reduced diversions, based on the annual net return values shown in Table 4. Using a discount rate of 5% over a 50-year time horizon, the net present value of direct losses from a 30% reduction in agriculture surface water diversions is $2.7 billion, while the net present value of direct losses from a 40% reduction is $4.7 billion.

This analysis suggests that to compensate irrigators for the lost profits resulting from an additional 30% reduction in agricultural surface water diversions (ie, enough to provide the additional environmental water required after the water already obtained by governments is taken into account) based on long-term average inflows would cost approximately $2.7 billion.

Table 4: Reductions in annual net returns from a 30% and 40% reduction in agriculture surface water diversions in the Murray-Darling Basin based on data from 1 July 2000 to 30 June 2001

Catchment	Reduction in annual net returns from a 30% reduction in Basin agriculture diversions	Reduction in annual net returns from a 40% reduction in Basin agriculture diversions
	(%)	(%)
Paroo	-	-
Warrego	-	-
Condamine-Balonne	2.0	13.2
Moonie	0.2	34.6
Border Rivers	0.7	3.7
Gwydir	0.4	1.3
Namoi	2.2	7.7
Macquarie-Castlereagh	1.4	8.2
Barwon-Darling	0.5	2.2
Lachlan	-	-
Murrumbidgee	25.8	32.4
Murray	11.5	14.3
Ovens	0.1	10.4
Goulburn-Broken	0.3	13.8
Campaspe	-	90.4
Loddon-Avoca	-	43.5
Wimmera	-	-
Eastern Mt Lofty Ranges	0.1	8.1
Murray-Darling Basin	**9.5**	**16.3**

Options to secure water for the environment

The best-available science suggests there is a substantial risk that a working river will not be in a healthy state when key system level attributes of the flow regime are reduced below two-thirds of their natural level.

To achieve a level of two-thirds natural flow in all the catchments of the Basin the environment's share of the existing Cap on diversions would need to be increased by approximately 4,400GL.

As of February 2010, State and Federal Governments had obtained approximately 1,200GL of water for the environment by buying back entitlements and increasing water use efficiency in the Murray-Darling Basin. Therefore, a further 3,200GL is required to deliver the required total of 4,400GL[52].

We have identified 3 possible options for obtaining this water using the available funding, and evaluated the economic and social implications of each option across the Basin:

- Option 1: Continuing to implement the Federal Government's current *Water for the Future* program, which includes separate funding allocations of $3.1 billion for water buyback and $5.8 billion for water use efficiency.
- Option 2: Combining these separate funding amounts into a single fund to purchase environmental water through the most cost-effective means (either buyback or infrastructure investment), according to a cost-benefit based environmental benefits index.
- Option 3: Combining these separate funding amounts into a single fund and working with local communities to acquire water from irrigators for a price equivalent to a 'reasonable return' on lost profits, and funding an economic development program to help regional communities transition to a future with less water.

Option 1: Continue the current *Water for the Future* program

The *Water for the Future* program currently allocates $3.1 billion for water buyback and $5.8 billion to increase water use efficiency in the Murray-Darling Basin. The timetable for rolling out this program is 10 years.

Our analysis of the water buyback component, based on the purchases made by the Federal Government as of 28 February 2010, indicates that approximately 799GL of entitlement has been purchased at an average price of $1,529/ML. The water purchased has an average long-term Cap equivalent of 67%, which means that the price paid for actual water (as opposed to entitlement) is $2,283/ML.

If future government purchases reflect the existing high prices and the reliability of those purchases to date, the total $3.1 billion in funding allocated for water buyback will deliver an estimated 1,358GL of water for the environment. However, this volume could be more or less, if the average price of water entitlements in the future is lower or higher than the price paid to date.

Our analysis of proposed infrastructure projects gives an indication of the volumes of environmental water that could potentially be obtained for the $5.8 billion to be spent on improved water use efficiency. The largest of these projects is the Northern Victoria Irrigation Renewal Project. The stated aim of this project is to achieve water savings in the order of 425GL, at a cost of $2 billion. These savings are to be largely achieved by improving metering of water and reducing leakage.

Stage 1 of the project aims to deliver 225GL of savings at a cost of $1 billion, 75GL of which will go to the environment. Stage 2 aims to deliver 200GL of savings at a cost of $1 billion, 100GL of which will go to the environment[53]. Based on these figures, the $2 billion project will deliver 175GL of environmental water, at a cost of $11,429/ML. This is almost five times greater than the cost of the average water buyback undertaken to date.

Other water use efficiency projects already undertaken or planned[54] – including those in the Central Goulburn Irrigation Area, the Macalister Irrigation District, the Shepparton Irrigation Area and the Lake Wyangan Project in the Murrumbidgee Irrigation Area – aim to produce water savings at an average cost of $3,685/ML. These projects do not identify the estimated savings that would go to the environment. Even if half of the anticipated savings go to the environment, the cost for the environmental water would be $7,370/ML. This is more than three times the average cost of water buybacks to date.

Recent government announcements have indicated there is the potential for more cost-effective infrastructure projects. It is claimed the Private Irrigation Infrastructure Operators Program in NSW will deliver approximately 21GL of environmental water at a cost of around $4,810/ML[55]. The Queensland on-farm irrigation infrastructure projects will deliver approximately 12GL of environmental water at a cost of around $3,000/ML.

Our analysis indicates that this level of cost effectiveness in delivering environmental water through infrastructure investment, although still more than double the cost of purchasing water, is the exception rather than the norm.

If the $5.8 billion allocated to increase water use efficiency as part of the *Water for the Future* program delivered water at an average of $11,429/ML, it would yield an estimated 507GL of water for the environment. If it delivered water at $7,370/ML, it would yield an estimated 787GL of water for the environment.

Based on the analysis above, the current *Water for the Future* program is likely to deliver around 2,145GL of water (based on a buyback price of $2,283/ML, and water use efficiency savings gained at the price of $7,370/ML). This suggests that a reasonable estimate of the total volume of environmental water that could be obtained through a combination of the *Water for the Future* program and other separate State and Federal Government water recovery programs would be approximately 2,910GL (1,200GL of which has already been obtained).

This is well below the 4,400 GL our analysis indicates is required to give a high probability of achieving a healthy Murray-Darling Basin.

Therefore, it is highly unlikely that this program will produce the level of water savings necessary to achieve the objectives of the Commonwealth Water Act, 2007. Nor will it be sufficient to meet the anticipated Sustainable Diversion Limits under the 2011 Basin Plan.

As a result, either diversion levels will need to be reduced without compensation to meet the shortfall, or Australian taxpayers will be required to pay more money to deliver water reform.

In addition, investing in irrigation infrastructure to improve water efficiency is a very expensive and very slow way to solve the problems of the Basin. For many environmental assets in the Basin, the period since they were last watered is the longest on record. Therefore, the current 10-year roll-out of the *Water for the Future* program risks the collapse of the ecosystems of these assets. This long roll-out also risks an 'investor strike', as investors are less willing to invest in an industry in a constant state of flux.

Further, government agencies have not been able to demonstrate that irrigation infrastructure will be the best investment in all the catchments of the Basin. Investing in this infrastructure only has the potential to lock communities into a future in irrigation without considering its viability in light of the yet to be published Sustainable Diversion Limits or the potential impacts of adverse climate change.

Option 2: Combine water buyback and water use efficiency

The second option we analysed is to combine the $5.8 billion identified for water use efficiency and the $3.1 billion for water buyback under the *Water for the Future* program into a single fund, and to bring the timeframe for expending these funds forward. This fund could be used to either buy water or undertake water use efficiency projects. However, investments in water use efficiency would be limited to projects that can demonstrate they are as cost-effective in delivering environmental water as the direct purchases of water entitlements.

The cost-effectiveness of both buying water and infrastructure projects would be determined using an environmental benefits index, which prioritises environmental water needs across the Basin. This index could be developed using the data in Table 2 (to determine relative volumes in each valley) and the results of the Sustainable Rivers Audit in Table 1 (to prioritise between catchments).

Using this approach, our analysis indicates that the water required to give a high probability of a healthy Murray-Darling river system would cost approximately $8.5 billion. This is based on the price paid for buybacks to date ($2,283/ML) and includes the 1,200GL already obtained through the *Water for the Future* program and other State and Federal Government programs.

The analysis suggests this option would allow government to acquire a sufficient volume of water to achieve a Sustainable Diversion Limit of approximately 7,200GL, and still leave around $400 million available for irrigation infrastructure where it can demonstrate social and economic benefits. We have suggested a broader range of infrastructure investments would be more appropriate in Option 3. This approach to investments could equally be funded under this option.

Buying back water entitlements at the market rate delivers far greater environmental outcomes at a lower cost to taxpayers than is likely under the existing *Water for the Future* program (Option 1). This option also provides water for environmental assets more quickly than Option 1, and provides greater certainty to investors.

Option 3: Reasonable return and community development

Under Options 1 and 2, only those with water to sell will receive financial compensation, and only irrigators will benefit from infrastructure improvements. Little assistance is provided to help the broader communities in the affected catchments adjust to a future with less water.

The third option we analysed overcomes this flaw. Under this approach, the $5.8 billion identified for water use efficiency and the $3.1 billion for water buyback under the *Water for the Future* program would be combined in a single fund. This money would then be used to acquire 3,200GL of water required for the environment using a reasonable return approach. A portion of the savings could be used to fund investments in public infrastructure to assist communities adjust to the impacts of reduced diversions (a community development approach).

With a reasonable return approach, the price paid for water for the environment would reflect the net present value of the profits irrigators would lose due to reductions in their diversions. As discussed above, our analysis of the economic impact of acquiring water for the environment indicates that with this approach, the cost of acquiring the required 3,200GL would be $2.7 billion.

When this cost is added to the money already spent on water buybacks through the *Water for the Future* program, the total cost comes to approximately $3.9 billion, saving approximately $5 billion of public funding. A portion of these savings could, where justified on social and economic grounds, be used to invest in infrastructure to build communities and help them make the most of the economic opportunities available to them.

Reasonable return

Under the reasonable return approach, the Federal Government would allocate $2.7 billion across the 18 catchments to obtain the 3,200 GL, taking account of the percentage contributions from each catchment to deliver a 30% reduction in extractions while minimising the loss in profits (Table 3). It would then conduct two consecutive reverse tenders, to provide irrigators and other water entitlement holders with opportunities to offer to sell some or all of their entitlement.

Once an offer was accepted, the seller would receive payment. A portion of the volume of water sold would be transferred immediately to the environment's share of the available water to meet the needs of environmental assets currently in a critical condition. The remainder would be available for the seller to use for 24 months after the acceptance of the offer. This transition period will assist irrigators in adjusting to their new circumstances. For some, this will mean adjusting their existing irrigation arrangements, for others it may mean exiting the industry and using the money to build a different future altogether.

A method similar to this was used successfully to acquire statutory fishing licences in Commonwealth fisheries in 2007[56], and in other countries[iv]. For this method to work effectively, to acquire water entitlements in the Murray-Darling Basin, there must be no restrictions to water trading so that irrigators are able to trade water and make adjustments.

In terms of timing, the two-stage reverse tender could begin after the announcement of the draft Basin Plan in July/August 2010,

[iv] British Columbia's salmon fisheries

and be completed prior to the start of the Basin Plan implementation in July 2011.

Taking into account the two-year transition period, this would mean the entire water reform program could be completed in three years. This would inject large amounts of money into communities over a short time so people could afford to make big changes. It would also provide certainty to irrigators. In addition, it would secure water for environmental assets that are currently in a critical condition and could be permanently lost if we wait the 10 years required to complete the timetable of the existing program.

The reasonable return approach does not guarantee that sufficient volumes of environmental water will be acquired in each catchment, because it depends on a voluntary reverse tender process. If sufficient water is not acquired from this process, there may still need to be uncompensated reductions in the reliability of the water entitlements upon implementation of the Sustainable Diversion Limits under the Basin Plan.

Community development

Another advantage of the reasonable return approach is that it is a much more cost-effective approach to acquiring water for the environment, and is likely to leave a significant portion of the available $8.9 billion unspent. Part of this unspent portion can be used to provide financial assistance to the communities in the Murray-Darling catchments – such as investments in public infrastructure to help them adjust to a future with less water.

The School of Social and Policy Studies at Flinders University has developed the '*Thriving Communities*' model based on an inclusive social and economic development approach. This model could provide the basis of this community development approach (see Page 25).

Under this approach, the level of funding available to each affected community would be based on the economic impact resulting from the withdrawal of water for consumptive use in that district. In some of the worst affected communities, these sums could be significant.

With this financial support, some communities may decide to move out of irrigation and branch out into new industries. Others may prefer to consolidate their irrigation industry and use the funds to invest in new water technology or to add value to their products. However, this decision would be made for the benefit of the whole community, not just individual irrigators.

Like any change, there will be risks and uncertainty involved in this approach. However, international evidence suggests a clearly articulated and consistent, strategic approach based on local agreements has long-term benefits. In particular, for rural and regional communities hardest hit by disruption to their regional economy, it ensures viable, planned change with maximum local buy-in[57].

Governance mechanisms between the State and Federal Governments would be needed to ensure the available funds are used to achieve the best social and economic outcomes for all communities affected by the water reform process.

This option would also allow the Federal Government to continue to support its *Water for the Future* infrastructure spending commitments with the states, by broadening the range of infrastructure projects that could be funded beyond irrigation infrastructure. The due diligence process to determine which projects receive funding should assess a proposed project's ability to contribute to a sustainable economic future for the entire community.

Advantages of the reasonable return and community development approach

Option 3 has four advantages over the current *Water for the Future* program:

1. It would allow the full volume of water required to give a high probability of a health river system to be acquired for a cost that is less than the available funding. As a result, it would also release up to $5 billion of this available funding for other purposes. Some of this saving could be used to invest in infrastructure to assist regional communities most affected by water reform to restructure their economic base to adjust to a future with less water.
2. It would allow the Federal Government to honour its *Water for the Future* infrastructure spending commitments with the states, while broadening the range of infrastructure projects that could be funded beyond irrigation infrastructure. The due diligence process to determine which projects receive funding would include assessing their ability to contribute to a sustainable economic future for the entire community.
3. It would more quickly make additional water available to environmental assets that are in critical need of watering, and allow the river system to be returned to sustainable levels of extraction within three years.
4. It would more quickly provide investors with greater certainty.

Thriving Communities model

The scale of the water reform to restore the health of rivers, wetlands, floodplains and the estuary in the Murray-Darling Basin is daunting. It can only be achieved by working with the communities of each catchment affected to bring about these reforms.

The *Thriving Communities* model may provide a useful approach for this work. The model is based on an inclusive social and economic development approach. It respects that the various communities along the Basin live first-hand with the realities of the prolonged drought and the challenge of reducing water extractions. They are experts about the impacts for them, their families and their towns. Communities know better than anyone the history, issues and previous interventions in their particular areas: what has been tried before, what has worked, and what has not. They have the knowledge and deep understanding of local collective assets, capacities and potential available for adjustment processes.

The *Thriving Communities* model involves three steps:[58]

Step 1 ► Bringing people together and sharing knowledge, so they have a more comprehensive picture of the issues, challenges and opportunities they face as a community.

Step 2 ► Focusing on providing the community with an opportunity for structured dialogues. For communities to have a sustainable future the energy, vitality and economic creativity must come from within. The *Thriving Communities* model recognises that people who have different and often competing interests need the opportunity to talk – sometimes with anger and frustration – and to listen and learn from one another, then turn their collective attention to building a better future.

Step 3 ► Developing a plan for the future. This step could be undertaken by a representative body. It could be in the form of a local compact between each community and Local, State and Federal Government. However, implementing the plan would require resources, drawing on both local capital and matching government support, and an organisational framework.

Current State and Federal Government departments do not have the capacity to lead this process. To undertake this process effectively would require a specifically appointed multi-disciplinary National Task Force of expert practitioners in local economic and social development working over a minimum of two years. It would also be essential to have a small team of evaluators attached to the Task Force to ensure an iterative evaluation with lessons learnt from the work incorporated on an ongoing basis.

Conclusion

Late last year, in its second biennial assessment of progress in implementing the 2004 National Water Initiative, the National Water Commission noted that the Agreement aims to complete the return of all currently overallocated or overused systems to environmentally sustainable levels of extraction, and calls for 'substantial progress' in that direction by 2010.

However, it stated that, based on its biennial assessment, it was "disappointed to conclude that this central requirement of water reform will not be met"[59].

We believe that this requirement – along with the other objectives of the Commonwealth Water Act – can be met within a reasonable timeframe and within the available funding if the Federal Government changes its current approach to obtaining water for the environment.

As of February 2010, the Federal and State Governments had obtained over 1,200GL for the environment. This is significant progress. However, our analysis indicates that they need to obtain an additional 3,200GL to ensure that the levels of diversion for consumptive use in this system are sustainable.

Our analysis indicates that the current *Water for the Future* program (Option 1), is not capable of delivering this outcome within the funding allocated for water reform. Therefore, an alternative approach is necessary.

Of the two alternative approaches we evaluated (Options 2 and 3) both are capable of achieving this outcome. However, Option 3 – the Reasonable Return and Community Development approach – can deliver the required volumes of water to satisfy the requirements of the Water Act in a much more cost-effective and socially responsible way.

Therefore, it can also free up financial resources to help communities re-build their regional economies and adapt to a future with less water.

More than $12 billion of Australian taxpayers' money has been allocated to deliver substantial reforms in the way we use and manage our precious water resources, particularly those in the economically important yet environmentally fragile Murray-Darling Basin.

The challenge for government is to use this money in a way that delivers a sufficient volume of water to return this Basin to a healthy condition while also maximising the economic development opportunities for the communities that will be affected by the reductions in diversions needed to obtain this water.

The scientific and economic analysis we have presented in this report shows that this is possible within the existing budget allocations.

Given the social and economic as well as environmental benefits, we urge the Federal Government to consider redesigning its approach to obtaining water for the environment by adopting a Reasonable Return and Community Development approach as described in this paper.

References and Notes

[1]Council of Australian Governments (2004). *Intergovernmental Agreement on a National Water Initiative*, COAG, 2004

[2]Commonwealth Government, Water Act 2007, Act No. 137 of 2007

[3]Note that we did not include groundwater in our analysis. If we had, the required reduction in the level of extractions would almost certainly be higher.

[4]Unless otherwise stated all water volumes within the text of this document are in long-term Cap equivalents. A long-term Cap equivalent is the estimated long-term average water use for an entitlement when all entitlements have been fully developed. Subsequently these volumes are much better representations of 'real water' when compared with entitlements.

[5]Calculated using figures from Appendix B of the report: Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March and data from the website http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/2008-09.html. The analysis also used cap factors provided by the Commonwealth Environmental Water Holder which are based on the report: Webb, McKeown and Associates, *Australian Water Entitlements*.

[6]Calculated using figures from Appendix B of the report: Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March. The analysis also used cap factors provided by the Commonwealth Environmental Water Holder which are based on the report: Webb, McKeown and Associates, *Australian Water Entitlements*.

[7]Calculated using figures from Appendix B of the report: Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March and data from the website http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/2008-09.html. The analysis also used cap factors provided by the Commonwealth Environmental Water Holder which are based on the report: Webb, McKeown and Associates, *Australian Water Entitlements*.

[8]CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia.

[9]Figure taken from CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia.

[10]Developed from data provided by CSIRO from the Sustainable Yields Project. The data represents the historic climate and current development scenario

[11]Developed from data provided by CSIRO from the Sustainable Yields Project. The data represents the historic climate and current development scenario

[12]Murray-Darling Basin Commission (2000). Overview Report – Review of the Operation of the cap. MDBC, August 2000

[13]Khan, S. (2008). *Managing Climate risks in Australia: options for water policy and irrigation management*. Australian Journal of Experimental Agriculture, 48, 265–273

[14]Grafton, R.Q. and Qiang, J. (2010). *Economics of Drought, Water Diversions, Water Recovery and Climate Change in the Murray-Darling Basin*. Australian National University, Canberra, January 2010

[15]Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March.

[16]Khan, S. (2008). *Managing Climate risks in Australia: options for water policy and irrigation management*. Australian Journal of Experimental Agriculture, 48, 265–273

[17]Water, Climate and Economic loss in the Murrumbidgee River and Southern Murray Basin. Professor Tom Kompas, Australian National University

[18]http://www.nrc.nsw.gov.au/Workwedo/Forestassessment/Riverredgumforestsassessment.aspx#redfar

[19]Calculated using 89 days flow at 25GL/d, and 1 days flow at 45GL/d. This calculation is the minimum volume based on the rule contained in Table 38 of the report: NSW Natural Resources Commission. (2009). *Preliminary Assessment Report: Riverina Bioregion Forest Assessment river red gums and woodland forests*. NSW Natural Resources Commission, Sydney, September 2009

[20]CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia.

[21]Gippel, C. J. and Blackham, D. (2002). *Review of environmental impacts of flow regulation and other water resource developments in the River Murray and Lower Darling River system*. Final report by Fluvial Systems Pty Ltd, Stockton to the Murray-Darling Basin Commission, Canberra ACT.

[22]Walker, K. F. (2006). *Serial weirs, cumulative effects: the Lower River Murray, Australia.* In Kingsford R. (ed.),The Ecology of Desert Rivers. CUP: 248-279.

[23]Walker, K. F. (1992). *A semi-arid lowland river: the River Murray, Australia*. In P.A. Calow, G.E. Petts (eds.) The Rivers Handbook, V1. Blackwell Scientific Oxford: 472-492

[24]Davies, P. E., Harris, J. H., Hillman, T. J. and Walker, K. F. (2008). *Sustainable Rivers Audit: A report on the ecological health of rivers in the Murray-Darling Basin, 2004–2007.* Prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council

[25]Davies, P. E., Harris, J. H., Hillman, T. J. and Walker, K. F. (2008). *Sustainable Rivers Audit: A report on the ecological health of rivers in the Murray-Darling Basin, 2004–2007.* Prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council

[26]Paton, D. C. (2010). *At the end of the river: the Coorong and lower lakes.* ATF Press, PO Box 504 Hindmarsh, SA 5007

[27]Council of Australian Governments (2004). *Intergovernmental Agreement on a National Water Initiative*, COAG, 2004

[28]http://www.mdba.gov.au/basin_plan

[29]http://www.mdba.gov.au/programs/engagement/submissions-to-the-sdl-issues-paper

[30]Murray-Darling Basin Authority (2009). *Issues paper: Development of sustainable diversion limits for the Murray-Darling Basin*. Murray-Darling Basin Authority, Canberra, November 2009.

[31]Davies, P. E., Harris, J. H., Hillman, T. J. and Walker, K. F. (2008). *Sustainable Rivers Audit: A report on the ecological health of rivers in the Murray-Darling Basin, 2004–2007.* Prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council

[32]Wentworth Group of Concerned Scientists (2008). *Accounting for Nature: A Model for Building the National Environmental Accounts of Australia*. Wentworth Group of Concerned Scientists

[33]Murray-Darling Basin Commission (2002). *Environmental Flows for the River Murray: Report on the development of options*. Prepared for the Murray-Darling Basin Ministerial Council, April 2002

[34]Jones, G., Hillman, T., Kingsford R., McMahon, T., Walker, K., Arthington, A., Whittington, J. and Cartwright, S. (2002). *Independent Report of the Expert Reference panel on Environmental Flows and Water Quality Requirements for the Murray System*. Cooperative Research Centre for Freshwater Ecology February 2002

[35]Sheldon, F., Thomas, M. C., Berry, O. F. and Puckeridge, J. T. (2000). Using disaster to prevent catastrophe: referencing the impacts of flow changes in large dryland rivers. Regulated Rivers: Research and Management 16: 403-420.

[36]Condamine-Balonne WAMP Environmental Flows Technical Report. (2000). Department of Natural Resources, Queensland; Water Allocation and Management Plan(Fitzroy Basin) 1999 WAMP Department of Natural Resources, Queensland

[37]Wentworth Group of Concerned Scientists (2008). *Submission to the Senate Inquiry into the Urgent Provision of Water to the Coorong and Lower Lakes*. Wentworth Group of Concerned Scientists, Sydney, September 2008

[38]CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia. Appendix A, pp59.

[39]Calculated from the data on page 59 of the report CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia

[40]Values calculated using the "Total surface water diversions" contained Appendix A CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia

[41]Note that we did not include groundwater in our analysis. If we had, the required reduction in the level of diversions would almost certainly higher.

[42]Figure provided by the Murray-Darling Basin Authority as the current cap on extractions, March 2010

[43]Calculated using figures from Appendix B of the report: Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March. The analysis also used cap factors provided by the Commonwealth Environmental Water Holder which are based on the report: Webb, McKeown and Associates, *Australian Water Entitlements*.

[44] Calculated using figures from Appendix B of the report: Productivity Commission (2010). *Market Mechanisms for Recovering Water in the Murray-Darling Basin*, Final Report, March. The analysis also used cap factors provided by the Commonwealth Environmental Water Holder which are based on the report: Webb, McKeown and Associates, *Australian Water Entitlements*.

[45] Calculated from the website http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/2008-09.html as of 28 February 2010

[46] Council of Australian Governments (COAG). *Intergovernmental agreement on a National Water Initiative*. June 2004

[47] Grafton, R.Q. and Qiang, J. (2010). *Economics of Drought, Water Diversions, Water Recovery and Climate Change in the Murray-Darling Basin*. Australian National University, Canberra, January 2010. Available for download at http://cweep.anu.edu.au/pdf/publications/research_papers/10-01_WaterEconomics.pdf

[48] Modelled results in this report differ slightly to the results of Grafton and Jiang (2010) because the flows from the Lachlan are not available for other regions and only 70% of end of catchment flows from the Loddon-Avoca are available for other regions.

[49] CSIRO (2008). *Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*. CSIRO. Australia

[50] http://www.nrc.nsw.gov.au/content/documents/Red%20gum%20-%20FAR%20-%20Complete.pdf

[51] ABS/ABARE/BRS (2009). *Socio-economic context of the Murray-Darling Basin – Descriptive report*, ABS/ABARE/BRS Report to the Murray-Darling Basin Authority, Canberra, September.

[52] Note that we did not include groundwater in our analysis. If we had, the required reduction in the level of extractions would almost certainly be higher.

[53] Capital projects Division (2007). *Modernising Victoria's Food Bowl: Irrigation Modernisation Information Paper* Department of Sustainability and Environment, Department of Innovation, Industry and Regional Development, Victoria June 2007

[54] ACIL Tasman (2009). *Regional economic effects of irrigation efficiency projects*. ACIL Tasman Pty Ltd, Melbourne, September 2009

[55] Value calculated from claimed entitlement volume using 100% conversion of entitlements to long-term Cap equivalent.

[56] For details on the Australian Commonwealth buyback of fishing licences please consult, http://www.daffa.gov.au/fisheries/domestic/fishingfuture/business_exit_assistance

[57] See for example, Quebec's *National Rural Policy, 'Politique nationale de la ruralite'* [www.mamr.gouv.qc.ca]; the network of Regional Trust Organizations created by the Canadian Province of British Columbia [www.nditrust.ca] and in particular the example of the long-standing Columbia Basin Trust; the Canadian Community Futures program run by Western Economic Diversification [www.communityfutures.ca and www.wd.gc.ca/eng/home.asp]; the Manitoba Intergovernmental Affairs Program, 'Neighbourhoods Alive' [www.gov.mb.ca/ia/programs/neighbourhoods]; Scotland's Highlands and Islands Enterprise Board, the largest example of its kind in Europe, [www.hie.co.uk]. What these examples have in common is that they are all focused on a large diversified geographical area occupied by a similarly sized population in equally diverse towns and communities facing rapid economic and social change and covering multiple levels of government and jurisdiction.

[58] Miller, C. and Verity, F. (2009). *"Thriving Communities': Addressing and adjusting to the social impacts of water related changes in the Murray-Darling Basin*. Flinders University 2009

[59] National Water Commission (2009). *Australian Water Reform 2009: Second biennial assessment of progress in implementation of the National Water Initiative*, NWC, Canberra