Harmonising consumptive use and the environment through a Regional Irrigation Business Approach

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Abstract

The needs of irrigated agriculture and environmental sustainability have often been seen as two entirely competitive endeavours. However, with demand for food supply steadily increasing in future as a result of population growth, and greater society emphasis in maintaining environmental quality of surface and groundwater supplies, it is imperative that a new approach to meeting both demands is implemented.

System harmonisation is a business driven approach that seeks to identify opportunities for irrigators to become an integral part of an environmental services industry aimed at maximising productivity and environmental outcomes. The system harmonisation framework consists of two main domains: (a) a research domain designed to characterise and analyse the catchment water cycle and determine the key options for interventions leading to improved productivity and environmental outcomes, the environmental and economic evaluation of economic and environmental impacts of these options and, the social, institutional and social aspects of the proposed interventions, and (b) A regional business framework termed Regional Irrigation Business Partnerships (RIBP) designed to implement the proposed changes.

The water cycle phase of the system harmonisation framework is analysed and intervention responses analysed for two RIBP sites which represent a wide range of hydrological, geological and agricultural conditions: The Coleambally Irrigation Area (NSW), and the McIntyre-Brook catchment (Queensland). The analysis focuses primarily on the quantification of the water and solutes components of the water cycle together with the proposed interventions in each site. The economic and environmental costs and benefits of each intervention are also presented for the Murrumbidgee catchment and a proposed research framework is described for the MacIntyre Brook catchment.

Seven alternative interventions were identified and responses analysed in the Murrumbidgee catchment to reduce the summer concentration of flows. These interventions were evaluated for 10% and 20% reduction in water availability. Results show a trade-off between peak demand reduction and agricultural income. The extent of the trade-off depend on the type of demand management option considered. Spreading water demand through new crop mixes is shown to be the most cost-effective irrigation demand management option to reduce the seasonality of flows.

System harmonisation in The MacIntyre Brook catchment focuses on the shift from a fixed allocation of water resource to a continuous accounting arrangement whereby individual users will manage their own annual allocation; the environmental impacts of water application onto the

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landscape and the ability to provide environmental flows in the river. Research into the water cycle in this catchment is centred on the ability to forecast seasonal water allocations to enable irrigators to plan their operation and the management of surface-groundwater interactions within the irrigated landscape. A water cycle analysis research framework currently in progress for this catchment is presented.

1. Introduction

The needs of irrigated agriculture and environmental sustainability have often been seen as two entirely competitive endeavours. However, with demand for food supply steadily increasing in future as a result of population growth, and greater society emphasis in maintaining environmental quality of surface and groundwater supplies, it is imperative that a new approach to meeting both demands is attempted.

In many river basins worldwide are facing significant water shortages as result of steady increases in water diversions for agriculture over the last decades. Typical examples are provided by the Yellow River Basin, China and the Krishna river basin, India where often end-of-river flows cease as a signal that the basin is reaching its closing stage. This situation ultimately translate into significant environmental impacts on the aquatic ecosystems of these rivers systems.

In Australia, The Murray Darling Basin covers most of inland south-eastern Australia. It includes much of the country's farmland and over 2 million people. Located in the south-east part of Australia, the Murray-Darling Basin covers 1,061,469 square kilometres, equivalent to 14% of the country's total area (MDBC, 2008) The Basin's extends over three-quarters of New South Wales; more than half of Victoria, significant portions of Queensland and South Australia, and includes the whole of the Australian Capital Territory. The Murray-Darling basin has experienced a continuous increase in diversions for irrigation and other uses in past decades until the implementation of the Cap on diversions in 1994 which saw the level of diversions limited to the level of infrastructure development existing at that point in time. A further reduction in irrigation diversions of 500GL are envisaged in the more recent Living Murray initiative to be implemented by the Murray Darling Basin Commission, the basin governing agency (MDBC,

A key challenge in implementing these initiatives is to ensure that productive and environmental win-win outcomes are achieved as a result of these interventions. This entails a system-wide approach to "harmonising" the needs of irrigated agriculture as well as the environment. Khan et al (2008). The authors termed this process "System Harmonisation" and proposed the following definition that encapsulates this integrated approach to improving the multifunctional productivity of water:

> '*A strategy to improve cross-organisational communication and system-wide management to improve production and environmental outcomes in a whole of catchment context"*

The fundamental concept underlying this process is that irrigation systems must be considered an integral part of the catchment landscape and form part of the regional economic and governance system.

2. System Harmonisation Conceptual Framework

At the centre of the system harmonisation concept is the identification and implemention of actions that lead to productive and environmental benefits. System harmonisation is based on taking a holistic and systemic approach to understanding water resource systems and, in particular, the insertion of irrigation systems within catchment systems. Water resource systems involve many subsystems which are all intricately linked to one another not only in the physical domain but across within the environmental and economic domain. Figure 1 shows an idealised view of the biophysical water system.

System harmonisation seeks to act on the key pressure points in the system which lie on the key interfaces between irrigation and the rest of the catchment system. It is important to point out, however, that pressure points can also be of economic, social, environmental or institution nature. In fact, system harmonisation provides a framework to identify these pressure points in the biophysical system leading to interventions of a physical, economic or social nature that must take place in order to effect these changes. Typical examples of these interventions are changes in crop mixes to reverse seasonality of flows in rivers that may have developed as a result of intensive river regulation (Khan et al, forthcoming), use of on-farm storages to capture irrigation runoff and/or rejected water orders to avoid negative environmental impacts downstream (Berrisford, et al, forthcoming) or the conjunctive management of surface and groundwater resources in hydrologically connected catchments.

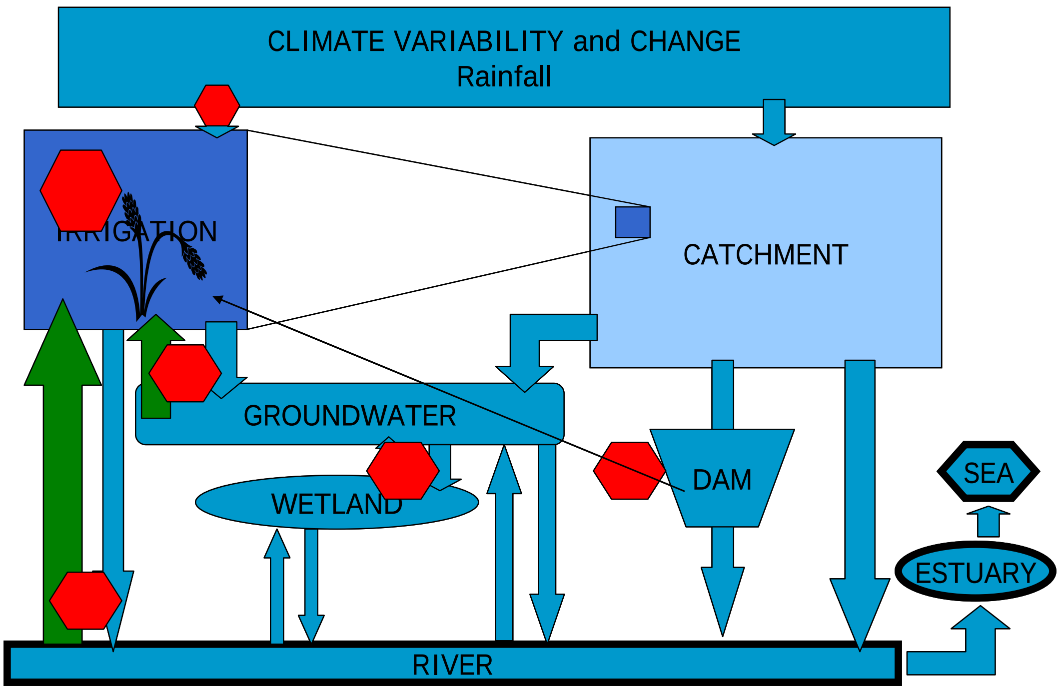


Figure 1. Key pressure points in the irrigated catchment water cycle (Pressure points shown as hexagon dots)

System Harmonisation Phases

System harmonisation involves the integration of research and implementation of system changes in a business context. Figure 2 shows schematically the development and implementation process leading to system harmonisation. The research phase of the process is needed to create new science and understanding to identify the key biophysical, economic and socio-institutional changes needed to achieve productive and environmental outcomes. The delivery and implementation phase is designed to operationalise the changes identified in the research phase. This process entails bringing a wide array of stakeholders together who share in the benefits of irrigation and the environment. It is important to stress that benefits arising from system harmonisation flow not only to irrigation and environment but also to other sectors of the economy with different multiplier effects.

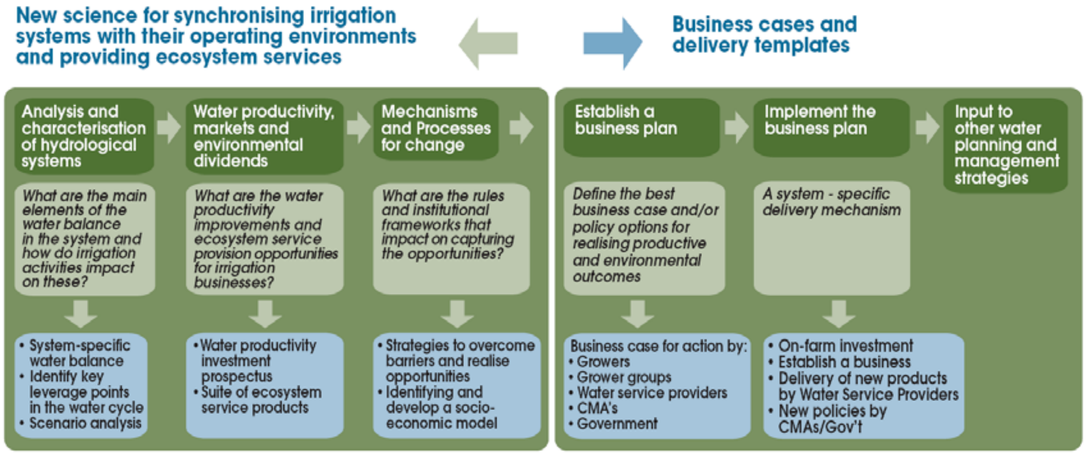


Figure 2. . Five way feasibility leading to SHARP implementation (After Khan, et al, forthcoming)

Analysis and characterisation of hydrological systems

This feasibility step involves hydrological characteristics of the region and seeks to build a water and pollutants balance of the water cycle. In addition to establishing the base position of the region this feasibility stage also identifies some of the key pressure points in the system, in particular the capacity to optimise system performance and water demand patterns to deliver productive and environmental dividends. This phase leads to a better understanding and quantification of the impacts of alternative interventions on the biophysical water system. Critical to achieve this outcome is the development of a sound modelling framework capable of quantifying the various proposed management interventions. The modelling framework is developed in parallel to the consultative process that takes place to identify the appropriate interventions that will develop into business cases.

Water productivity, markets and environmental dividends

Establishing the production and non-production related, product and/or services most in demand within the region, and identifying which ones can be delivered by the irrigation industry acting either independently or in partnership with others is the main focus of this phase. From an environmental perspective these can be identified by reviewing the associated ecosystems and their products and services. The delivery of identified ecosystem products and services must be examined in two ways. Firstly, possible adjustments to the current water supply and hydrologic patterns are examined to assess how modified irrigation practices can lead to better ecosystem services. Secondly, the knowledge of ecosystem requirements can be used to build a hydrologic regime for regulated river system which can deliver improved ecosystem services.

From an economic perspective this stage will help assess costs involved in improved environmental management (lost opportunity, infrastructure investment, structural and pricing reforms etc) and how transaction costs can be minimised by attributing these costs to local, regional and national stakeholders. The end point of this process is a list of defined products and/or services with realistic economic assessments undertaken of the key market variables of demand and price in place.

Mechanisms and process for change

An understanding of the most appropriate change management strategies and institutional and policy settings is needed to facilitate movement towards a more productive and sustainable irrigation environment. This process involves a comprehensive scan of the business environment to identify the social, cultural, legislative and institutional barriers and opportunities. At the operation level the provision of "harmonisation services" within a market context is new and as such it will be necessary to identify and/or establish mechanisms and processes to enter new markets and trading facilities.

Regional Irrigation Business Partnerships

The research outputs associated with the above three main areas must lead to actual interventions that are implemented in a business context. This must be achieved through the development of a business plan for improved water management within a particular area and its subsequent implementation by the partners concerned and others within the region. This can only take place after having identified the market, defined the product and established a legislatively and institutionally acceptable route to implementing system harmonisation. During this phase detailed biophysical and socio/cultural analysis of the feasibility of providing the products and/or services required at the market defined price/volume relationships previously identified are undertaken in conjunction with feasibility stages 1, 2 and 3.

A key feature of the market place will be the need to create a business model which manages to convert the largely public good nature of individually positive actions into a collective output which can be privately implemented and traded. This will require not only a sound understanding and demonstration of the biophysical realities of the region but the establishment of robust cooperative business structures and regional investment partnerships.

3. Case Studies: Focus on the Water Cycle

This paper focuses on the analysis and characterisation phase of system harmonisation. The main aim of the paper is to present the conceptual framework and analysis of the water cycle carried out in the Murrumbidgee Catchment of New South Wales and the MacIntyre Brook catchment of Queensland, Australia. This analysis identifies the pressure points (possible interventions) and the subsequent conceptual framework to analyse system responses associated with a range of interventions that emerged from the respective stakeholder consultative process.

Background

The Murrumbidgee River is a subbasin of the Murray-Darling basin with a catchment area of around 84,000 km^2 and a length of 1,600 km from its source in the Snowy Mountains to its junction with the Murray River (Figure 3). It is also one of the most regulated rivers in Murray Darling basin (MDBC 2001),The Murrumbidgee River has two main head dams that regulate the river: Burrinjuck dam and Blowering dam (1,632,000 ML).

Key harmonisation issues

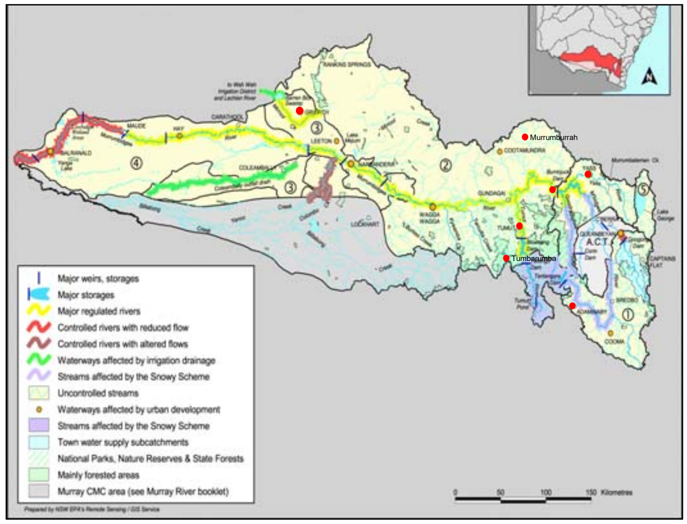


Figure 3. Location of the Murrumbidgee River Valley

Due to the high level to regulation in the river over most of last century, the natural seasonality of the river has been dramatically altered in order to satisfy irrigation demand (Figures 4a & 4b).

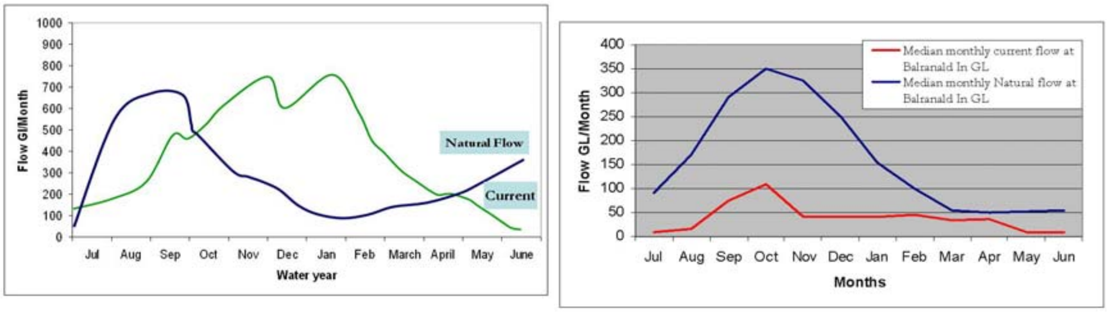
As a result, the associated wetlands and floodplains have changed significantly from their natural state with the use of water for agriculture, recreation, industry and domestic needs. Irrigation and other diversions today account for 50% of natural flows on average and maintain a significant agriculture economic activity in the region. It is the combined effect of diverting a large proportion of the flow and changing the seasonal distribution of flows that determines the key pressure point in this river. Most of the irrigation diversions take place in the upper river reaches and by the time the flow reaches Hay and Balranald in the lower reaches a large proportion of the water has been diverted. This situation has led to decreased breeding opportunities for native wildlife and fish populations and has increased frequency of algal blooms.

One of the key pressure points that can be acted upon in this system to reverse or ameliorate the changes in seasonal flows caused by river regulation is the interface between the river and the MIA and CIA irrigation systems. Several biophysical options are available to effect this change including changes in the irrigated crop mix to reduce the peak consumption in summer and use of on-farm or en-route water storages that enable releases from the main storages to take place prior to the peak summer demand; and use of groundwater storage banking to achieve the same result.

The main irrigation areas in the catchment are the Murrumbidgee Irrigation Area (MIA), Coleambally Irrigation Area (CIA) and the Lowerbidgee Irrigation Area. The study was confined to two irrigation areas, MIA and CIA. Major irrigated crops in both districts include grapes, citrus, rice, wheat, barley, oats, canola, soybeans, maize and sunflowers. Lucerne and pastures for sheep and cattle are also irrigated.

The MIA is located in middle to the lower reach (southern central NSW) of the Murrumbidgee River covering approximately 3,624km^2. It consists of the Yanco, Mirrool, Benerembah, Wah Wah and Tabbita irrigation districts. The MIA receives irrigation from two major storage dams: Burrinjuck and Blowering. The natural drainage-way of the MIA is Mirrool Creek.

The Coleambally Irrigation Area (CIA) is located to the south of the Murrumbidgee River. It was developed during the 1960's to make use of water diverted westward as a result of the Snowy Mountains Hydro-Electric Scheme. Water for the Coleambally Irrigation Co-operative Limited (CICL) are stored in the Burrinjuck and Blowering Dams and are diverted to the area from the Murrumbidgee River at the Gogeldrie Weir. Drainage water flows via Yanco and Billabong Creeks before entering the Murray River. Much of the drainage water is reused downstream of the irrigation district.



(a) **(b)**

Figure 4. Natural and current flow in the upper reaches of the Murrumbidgee river (a) and Lower reaches of the Murrumbidgee river (b) (After Elmahdi, 2007)

Options assessment

Modification of the seasonal flow pattern requires the implementation of a demand management strategy involving a reduction in the level and/or timing of demand of water (White and Fane, 2001

A set of options for demand management were developed in consultation with the stakeholders as described in Table 1.

Table 1. System harmonisation optiosn for the Murrumbidgee catchment

No	Option	Description
1	Market based reduction in surface water demand	Water to restore the environment and ecosystem services is obtained from the open market. An environmental managers buys water for environment requirements at market price which is allocated for environmental flows.
2	Conjunctive water use (Managed aquifer recharge (MAR) and aquifer storage and recovery (ASR)	Conjunctive water, groundwater and surface water, provides an alternative that aims to provide water at peak demands, reducing the burden from a single source of irrigation. Through the development of artificial storage recovery (ASR) and managed aquifer recharge (MAR), current storage can be utilised recharge the groundwater system therefore adding to the total water in storages in the region. This stored water can be utilised during peak flow demand thus maintaining security of water supply for consumptive use and environmental requirements.
3	Spreading water demand by changing cropping	Agriculture is the largest water user. Reallocation of crops both temporally and spatially will likely result in reduced demand for water. Changing the crop mix by

No	Option	Description
	mix	focusing on both winter and summer crops will help to improve environmental outcome by reducing the peak summer demand and increasing the winter-spring demand.
4	Increase end use efficiency (Water saving irrigation technologies)	By improving on-farm efficiency, less water will be required by the farmers to maintain same level of production. This can be achieved by introducing various water saving irrigation practices (drip irrigation, sprinkler irrigation, etc) and better farm management practices. Saved water can be used to improve the seasonal flows provided the efficiency gains can be captured and return to the environment.
5	Substitute water use (En-route storages)	This is similar to option 2. Providing water using alternative source of water; this can be achieved by arranging small water storage facilities closer to farmer's field that are capable to supply water in peak demand. This will shift dam releases from the middle of summer to winter and autumn thus reducing the summer peak demand. It is feasible to build three 50 GL storage facilities or one 250 GL storage facility in the system.
6	Increase system efficiency (Canal lining)	System level increase in efficiency can be achieved by reducing system distribution losses (seepage, leakage, evaporation). Saved water can be used to improve the seasonal flows provided the efficiency gains can be captured and return to the environment. Currently, the delivery efficiency in MIA and CIA is about 80% and there are is about 2566km – 2050km in MIA and 516km in CIA of unlined canals.

The performance of each option was analysed by applying a combined hydrologic and economic modelling framework to assess the impacts of the proposed changes at two levels: (1) direct production and economic effects of reduced water supply on agriculture (crop acreage, water use, irrigation system costs and farm-level revenue) and (2) effects of the agricultural adjustments on system-level. In this presentation, only the impacts at the system-level will be discussed. Further details on this study can be found in Khan et al (2006).

The regional/system level impact was assessed by evaluating each option for the aggregate MIA and CIA irrigation systems. To effectively compare various proposed demand management options, all costs and benefits were converted to annualised costs and benefits. Table 1 and Table 2 shows the comparison of baseline conditions with the proposed demand management options on agricultural income and water use, after a reduction of surface water availability of about 10% and 20%.

The new crop mix translates into a gain to agriculture of $5.49 million after the reduction of 10% demand of surface water. However, when the irrigation water demand was reduced to 20%, there was a relatively small loss of $4.79 million to agricultural production.

Conjunctive water use through addition extraction or infiltration and extraction of groundwater provided alternative option capable of reducing over 215GL of surface water with as compared to 2000/2001 water demand with minimum cost ($3.23 million in case of groundwater extraction only and $8.96 million in case of groundwater infiltration and extraction) to agriculture.

To secure over 200 GL of water through the construction of three 50GL storages and one 250 GL storage facilities requires a capital investment of approximately $4.58 million and $7.02 million annually over a period of 35 years, with an annual operating cost of about $2 million.

Among all options, the most expensive option was through canal lining because of high labour and material costs. It would require $33 million annual investment to secure about 215 GL of water per year through increasing the delivery efficiency up to 90%.

The results show a trade-off between peak demand reduction and agricultural income. However, the extent of the trade-off depends upon the type of demand management option considered. For example, securing 215GL of water for environmental purposes through alternative cropping mixes required $4.79 per year from agricultural return as compare with canal lining which requires $35.68 million of investment per year. Spreading water demand through new crop mixes was shown to be the most cost-effective irrigation demand management option for improving the seasonality of flow. Conjunctive water use was another option for making additional surface water available for environment during the peak demand months by substituting surface water with groundwater. Increasing on-farm water use efficiency through better irrigation technology can benefit the farmers productivity and the saved water can be used to enhance environmental flows provided that the on-farm savings can be captured for this purpose. This necessitates an appropriate set of measures that involves the farmer relinquishing their entitlement on the water savings. However, farmers will need to invest $303/ML for drip irrigation and $83/ML for sprinkler irrigation to implement these technologies which must be subsidised through an appropriate cost share arrangement with governments or environmental providers.

Case study 2: Macintyre-Brook catchment system

Background

The Macintyre-Brook water supply scheme is located in the Mcintyre_Brook catchment in South eastern Queensland, Australia (Figure The Macintyre Brook river supplies water to 2,020 ha of irrigated area. The scheme is entitled to 19,692 ML of water annually although the actually usage on average is 9,800 ML/annum. Irrigated agriculture in the scheme comprises approximately 90 mixed cropping properties including beef cattle (67%), dryland pasture (62%) and sheep for wool (58%)

The main reservoir in the system, Coolmunda Dam is the major storage that serves water users along the Macintyre Brook and the township of Inglewood and other uses including feedlots and poultry farms. The bulk entitlements of water in the catchment include 24,512 ML of medium priority entitlements and 488 ML of high priority entitlements.

Table 2. Comparison of water use and income of baseline conditions with proposed demand options at system level after a reduction of surface water demand by 10% (after Khan et al., 200)

Scenarios	Gross return ($million)	Benefit or loss to agriculture ($million)	Construction costs ($million)	Other cost* ($million)	Surface water use (GL)	Groundwater use (GL)	Total water use (GL)	Available water (GL)
Baseline	292.30	0.00	0.00	0.00	1,399.26	0.00	1,399.26	0.00
Conjunctive water use								
Groundwater infiltration + extraction (ASR development)	287.78	-4.49	0.00	0.00	1,284.81	114.45	1,399.26	114.45
Spreading water demand with improved cropping mix	297.43	5.49	0.00	0.00	1,282.07	0.00	1,282.07	115.74
Increase system efficiency	292.30	0.00	18.72	1.18	1,399.26	0.00	1,399.26	114.45
Increase end use efficiency	284.41	-7.89	0.00	0.00	1,216.77	0.00	1,216.77	182.50
Substitute water use (En-route storages)	292.30	0.00	4.58	2.00	1,399.26	0.00	1,399.26	119.00

*O&M cost etc.

Table 3. Comparison of water use and income of baseline conditions with proposed demand options at system level after a reduction of surface water demand by 20% (After Khan et al, 2006)

Scenarios	**Gross return** ($million)	**Benefit or loss to agriculture** ($million)	**Construction costs** ($million)	**Other cost*** ($million)	**Surface water use** (GL)	**Groundwater use** (GL)	**Total water use** (GL)	**Available water** (GL)
Baseline	292.30	0.00	0.00	0.00	1,399.26	0.00	1,399.26	0.00
Conjunctive water use								
Groundwater infiltration + extraction (ASR development)	283.29	-8.96	0.00	0.00	1,183.03	216.24	1,399.26	216.24
Spreading water demand with improved cropping mix	287.16	-4.79	0.00	0.00	1,181.77	0.0	1,181.77	216.04
Increase system efficiency	292.30	0.00	35.68	7.35	1,399.26	0.00	1,399.26	216.24
Increase end use efficiency	280.69	-11.61	0.00	0.00	1,155.92	0.00	1,155.92	243.35
Substitute water use (En-route storages)	292.30	0.00	7.02	2.00	1,399.26	0.00	1,399.26	203.00

*O&M cost etc.

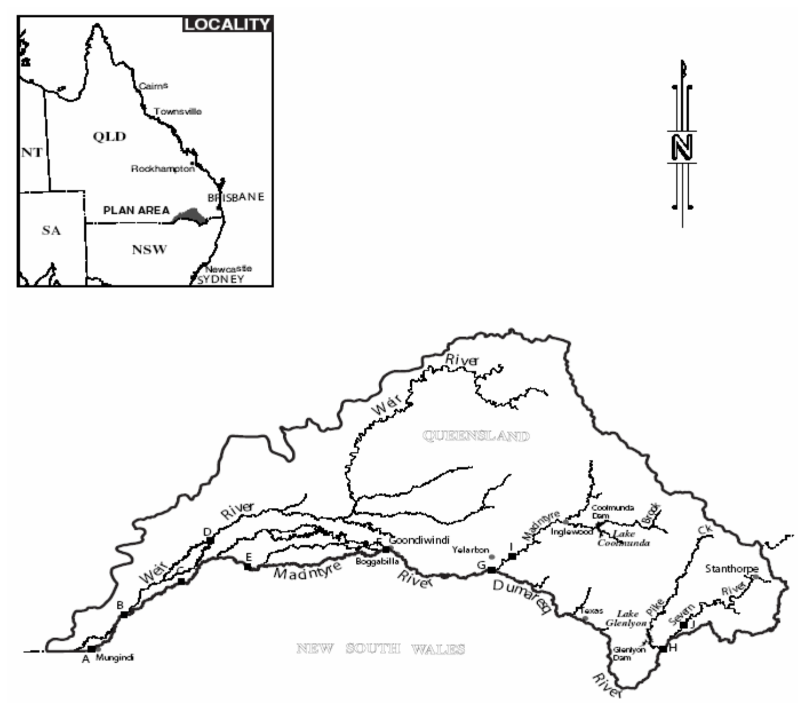


Figure 5. Geographic location of the Macintire Brook catchment.

Key harmonisation issues

The catchment is currently undergoing several physical, economic and social changes which have prompted the key regional stakeholders to focus their attention on issues of future sustainability of irrigated agriculture and environmental performance. These include:

- Change in water allocation system from fixed allocation to continuous accounting
- Conjunctive use of surface and groundwater in the catchment
- Integrated land and water planning for multiple users including agriculture and urban
- Impact of irrigation on the catchment landscape with special attention to interactions between surface and shallow groundwater aquifer.

Options assessment

Using a similar stakeholder consultation process to that used in the Murrumbidgee catchment illustrated above, the following selected options for system harmonisation were identified:

No	Option	Description
1	System forecasting under capacity sharing and water	A new system of continuous accounting is to be implemented to manage the farmers' annual water

	trading	allocation. The system will enable irrigators to manage their share of available water and provide the ability to carry over excess allocation to the following year. The new system can potentially enable farmers to improve their individual water management and planning for which new water management DSS tools are needed to assist irrigators in their water demand and trading decisions.
2	Managing surface-groundwater interactions	Several areas of the district can be adversely affected by shallow water tables. Adequate conjunctive management of surface and groundwater are critical to ensure the sustainability of irrigation in the district.

The proposed research framework to characterise the water cycle in this catchment involves at range of measurement and modelling tasks that are underway at the time of this writing.

System harmonisation in this catchment focuses on optimizing the short and long term benefits of water sharing arrangements through assessment and management of climate and environmental risks. The system has been operated using a fixed annual allocation arrangement in the past. In order to improve the allocation efficiency of the catchment, the system will move to a continuous accounting arrangement whereby individual irrigators will be able to manage their share of water in the reservoir independently of other users but subject to specific constraints. Under the new accounting criteria, the responsibility for resource management shifts from the water management authority to the irrigator. The focus of the water cycle research in this catchment will focus on developing DSS tools to assist irrigators in management their share of the resource. The DSS is based on a combination of past hydrologic reliability of supply and prediction of future seasonal demand options.

Environmental performance is another key aspect of the system harmonisation framework in this catchment. There are two environmental management issues in this catchment: (a) Interactions between surface and shallow groundwater that pose the key risk of waterlogging and salinisation of the catchment; and (b) the reduction of water losses in river and reservoir while providing water to satisfy downstream entitlements. The assessment of potential impacts of irrigation on groundwater management involves three main tasks: (a) a geophysical survey to delineate waterlogging prone areas in the catchment, (b) identification of the important water and solute components in the catchment, and; (c) a characterization of the spatial water balance based on spatial distribution of Et and modelling the crop-water-soil system to determine potential groundwater accessions.

Conclusions

System harmonisation is a business driven approach that seeks to identify opportunities for maximising the productivity of irrigated agriculture and enhance environmental performance. This approach is designed to integrate the multifunctional nature of surface and groundwater systems to meet consumptive and environmental demands.

The system harmonisation framework consists of two main domains: (a) a research domain designed to characterise and analyse the catchment water cycle and determine the key options for interventions leading to improved productivity and environmental outcomes, the environmental and economic evaluation of economic and environmental impacts of these options and, the social, institutional and social aspects of the proposed interventions, and (b) A regional business framework termed Regional Irrigation Business Partnerships (RIBP) designed to implement the proposed changes. This paper focuses on the characterisation and analysis of the water cycle phase of system harmonisation in two irrigated catchments: the Murrumbidgee river catchment of New South Wales and the MacIntyre Brook catchment of Queensland, Australia.

Seven alternative interventions were identified and responses analysed in the Murrumbidgee catchment to reduce the summer concentration of flows. These interventions were evaluated for 10% and 20% reduction in water availability. Results show a trade-off between peak demand reduction and agricultural income. The extent of the trade-off depend on the type of demand management option considered. Spreading water demand through new crop mixes is shown to be the most cost-effective irrigation demand management option to reduce the seasonality of flows.

System harmonisation in The MacIntyre Brook catchment focuses on the shift from a fixed allocation of water resource to a continuous accounting arrangement whereby individual users will manage their own annual allocation; the environmental impacts of water application onto the landscape and the ability to provide environmental flows in the river. The research focus in this catchment is centred on the ability to forecast seasonal water allocations to enable irrigators to plan their operation and the management of surface-groundwater interactions within the irrigated landscape. A water cycle analysis research framework currently in progress for this catchment is presented.

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