Water Banking –conjunctive water use management Approach For water saving and Improve Productivity and Environmental Performance

The research question: Is underground banking the new water-storage and saving solution?

1. Describe the innovation

Opportunities to manipulate seasonal irrigation water demand and supply in ways that could change how water resources are managed have been identified in new University of Melbourne research (my PhD research). These findings, based on work on the Murrumbidgee River system, Australia (see figure 1), have helped increase understanding of how to improve the environmental quality of the river through better irrigation demand management to save water for environment and the use of an underground dam (Water Banking) downstream.

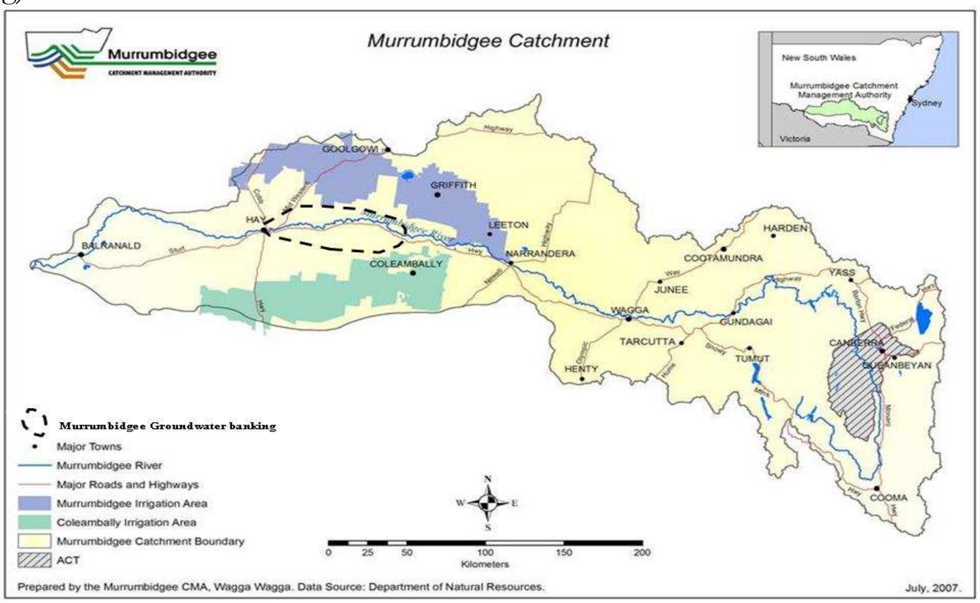

Figure 1 Murrumbidgee catchment and water banking location

1.1 Context for the research

All around the world, including in Australia, communities are facing water related issues such as reduced water availability, conflicting water uses and other water-related environmental problems. And significant problems of water shortage and deteriorating water quality are contributing to a growing water crisis in many countries. Integrated water management in irrigated agricultural areas could be the best strategy to optimise the use of the available water resources.

1.2 The research

This study is considered one of the first attempts to discuss the water banking concept with farmers—a critical step in its design and operation.

This research investigates storing water in an aquifer (an underground layer of gravel or porous stone that yields water), creating a ‘water bank’ 50 m or deeper underground. Water banking refers to delivering water earlier than it is required and storing it into groundwater so it is available to be pumped when required. In other words redirect surface water to subsurface water until it is required with zero evaporation losses. Water banking is a new management approach to managing water resources with ability to test and asses the impact of options for the allocation of limited water resources between agricultural production and the environment. In this research, water banking is defined as the use, storage and management of all of surface and groundwater water resources available as one single resource (by using aquifer as storage system). The goal of water banking is to efficiently allocate all water resources to achieve economic growth while achieving environmental sustainability. Water banking is able to better manage biophysical demand, and enhance in-stream flows that are biologically and ecologically significant. Water bank could help in: i) add flexibility in conjunctive water management, ii) enhance in-stream flows that are biologically and ecologically significant, iii) reduce water use in over appropriate areas, iv) reduce impact of water pumping on to stream, and v) facilitates the legal transfer and market exchange of various types of surface, ground water and storage entitlement. Therefore, this study attempted to present and investigate the concept of water banking for farmers as it is critical as its design and operation before put it into action.

1.3 Potential for water savings and constraints

By combining system dynamics and multi-objective optimization with spatial and modelling data, an integrated hydrological-economic environmental model has been developed which will help land and water managers make decisions based on an evaluation of trade-offs between environmental, social and economic factors. Farm, system and catchment managers will be able to collectively optimise water resource management and distribution at both the short-term tactical and long-term strategic levels.

It is possible to use this approach to save water in the Murrumbidgee by using the aquifer downstream. System losses from the Murrumbidgee have been estimated at 200 GL, which range from 12 to 14% river loss and 12 to 20% channel loss in Coleambally and Murrumbidgee Irrigation areas. Deep groundwater pressures have declined by between 10 and 20 m over most of the area and this drawdown will not recover naturally within 20 to 30 years through the natural recharge processes (see Figure 2A and 2B for two piezometric before and after water banking). This offers water banking potential opportunity by artificial recharge using good quality water with low salinity through dedicated or existing bores.

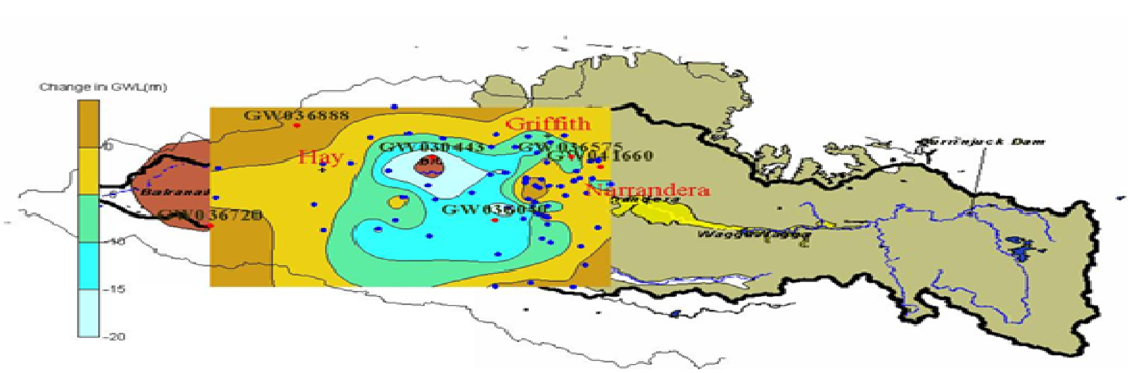

Figure 2A. Changes in Deeper Groundwater Levels between Narrandera and Hay from 1990 to 2003

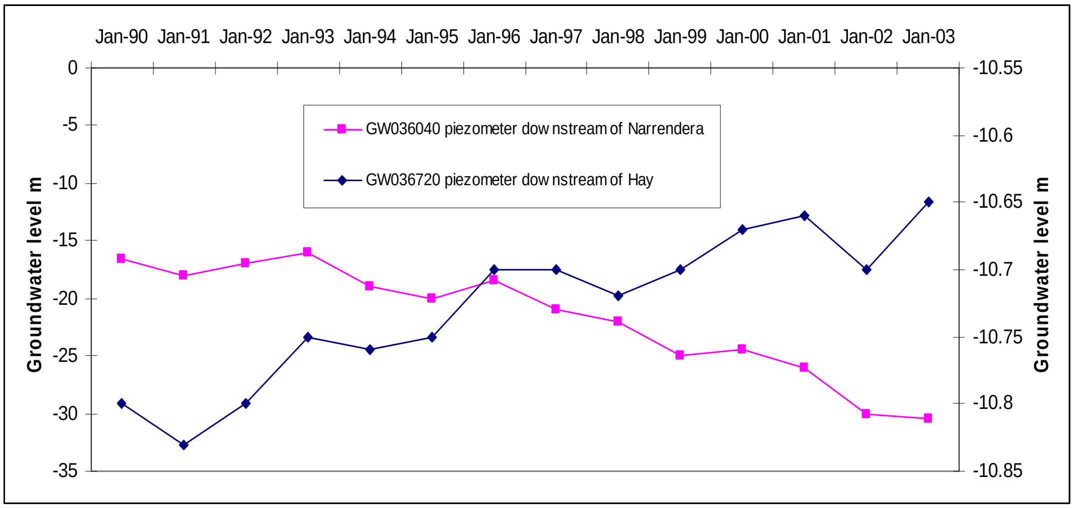

Figure 2B.Deep Groundwater Levels at downstream of Narrendera and Hay (data source: Khan S. et al 2004)

1.4 Constraints to water banking

Water banking has several constraints; one of the main ones being spatial constraints, where water might be banked behind dams, on-stream, off-stream and underground (aquifer). The research indicates there is potential to store up to 200 GL of water in the aquifer. One advantage of storing water underground is that no water is lost to evaporation or leakage – any water lost from the aquifer simply seeps back into the river system. Climate variability is an important issue that imposes the greatest stress on the hydrologic system. Expectations of in-stream flow volumes and water banking volume available should take this variability into account. This could happen by allowing management options to be varied based on climatic conditions. For example, it may not be beneficial to allow pumping during wet years when excess water is available and extra water may not be needed. In this situation, the wet year conditions could be used to passively or actively recover water levels in the aquifer system for use during dry seasons/years. Groundwater could be a viable source of water during dry periods. During periods of pumping, groundwater would be removed from storage or aquifer and water levels would decline. With the return of wet conditions, the groundwater system should be allowed to recover through natural or artificial recharge of water into wells during times of peak wintertime flow. Water banking could be planned for long term or short term according to climatic conditions.

2. A working water bank

For a water banking to work, several issues must be taken into consideration, such as institutional arrangements to legalise short-term and long-term release and delivery of banked water, adequate hydrological capacity to allow storage and delivery without significant potential water loss, economic and environmental validity, and social considerations. How the concept is presented to irrigators will be as critical as its design and operation. It is beyond the scope of this study to look at all the constraints/issues of water banking in aquifer such as water quality, salinity, recharge rate and cost involved issues. This study suggests with each year that passes an improved scientific understanding of the hydrologic system, the role and capabilities of the water bank can be further developed. Strategies will require modification and adjustment as varying water year types and series of water year types are experienced. Management schemes will require adaptation to continually improve the water banking activities in the basin by learning from each year's operational plans. Implementation of a viable water banking program will require a long-term commitment to adaptive management.

Using the aquifer improves the efficiency of the water distribution system, as well as the natural seasonal flow of the river, by releasing water from the head dams during the winter or wet months and storing it for recovery during dry months, the high demand period (see Figure 3). This in turn improves the health of the river by freeing more water to the environment and mimicking the river's natural flow.

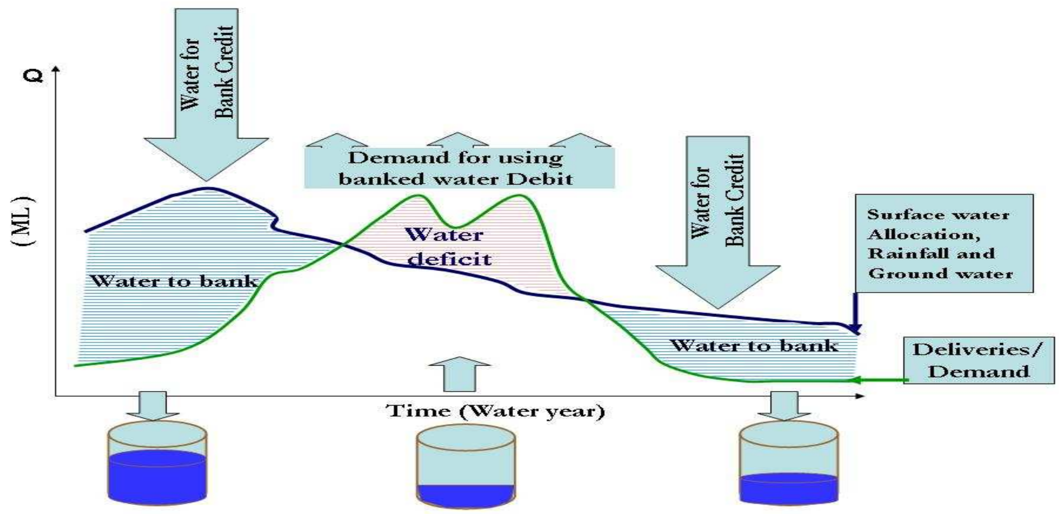

Figure 3 Water bank operational concept

3. Water banking and water trading

The water market is considered one of the best mechanisms to ensure the most economically efficient use of water, by moving water from low value to high value crops. Regulation and prohibited trade rules between basins and catchments are ways of minimising the environmental impacts of trading water. In this research context, water trading has been tested under water banking to facilitate water movement between irrigation areas or water banks.

Figure 4 shows the water banking and water trading conceptual framework, assuming two main irrigation areas A and B (MIA and CIA) on both side of the river. Each irrigation area has or will develop its water bank which is able to manage its water resources (surface and ground water) as one system. Where water availability exceeds biophysical crop water requirements, the irrigation area will intend to store water in its aquifer by using artificial recharge. Where biophysical crop water requirements exceed the total water available (surface and ground water) to the area and its water bank, this irrigation area will intend to buy its needs from other areas' water bank based on average historical average price within system constraints such as groundwater pumping capacity, environmental flow rules, river channel capacity and trading limitations. This water trading mechanism can facilitate the water movement and achieve better management of the whole system (surface and ground water) with achieving economic benefits.

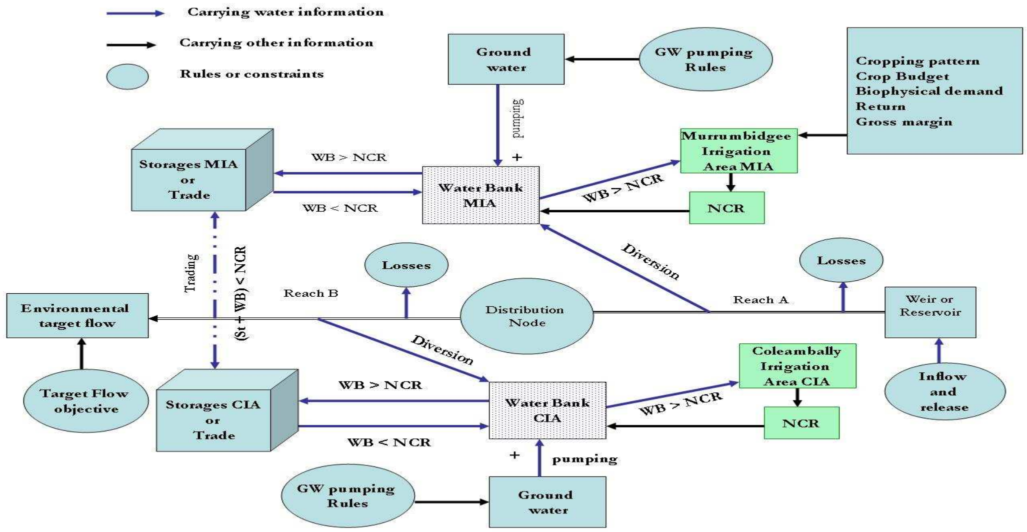

Figure 4 Water banking modelling conceptual approach

4. Water banking has potential (the innovation saves water)

Two artificial recharge methods were considered in this study with a changing crop mix option. The analysis indicates that there is a clear trade off between agricultural income and environmental performance to improve the seasonality of flows (see Figure 5). Water banking (storage and recovery water system underground scenario) by using infiltration and injection artificial recharge methods with changing crop mix was able to improve agricultural income by 3 to 10% with potential water savings between 76 to 80 GL.

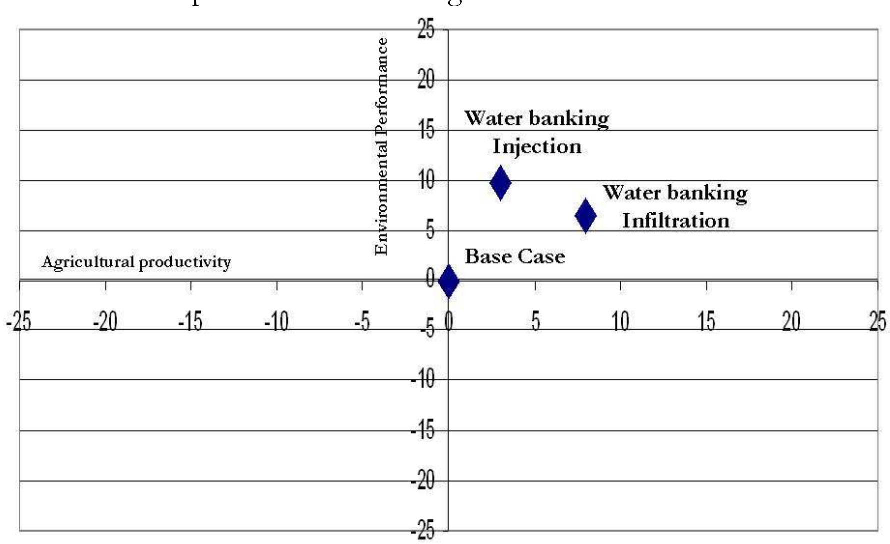

Figure 5 The trade off

These savings could be returned to the environmental. Using this approach, groundwater use could be reduced by between 4 and 8%. The infiltration recharge method is likely to be more cost effective than injection where the river and aquifer system are connected. The associated capital and operating cost of water banking could be recovered by positive environmental impacts, which could lead to tourism and recreation activities with an annual value of between $20-21 million. This option is considered a feasible demand management option. While knowledge of groundwater systems and their connectivity with surface water systems has increased in recent years, the reality is that many of these systems remain poorly understood. Where this is the case, it would be prudent for policy makers to be conservative and considered additional aspects such as improved water quality, prevention of saltwater instruction and nutrient reduction in agriculture for future research.

Consultation mechanisms:
This project has a multi-disciplinary and integrated approach. That is, every relevant form of expertise has been sought to be harnessed and ideas captured. These have been brought together to fashion a cohesive, whole-of-valley solution to the water sustainability challenge.

5. Lessons learnt

In the Murray-Darling Basin and the Murrumbidgee River system, Australia, the major concern is the availability and quality of water under current and future climatic, economic and environmental scenarios. The urgent needs of river ecosystems and a possible decline in future rainfall and runoff mean that supplies for irrigation may become more limited.
Research is showing that big water savings are possible (**80-200 GL based on Climate conditions**) while maintaining crop yields and reducing negative environmental impacts. Production from irrigation need not decline with reduced water availability. There are good opportunities to improve the efficiency of delivering and using irrigation water through targeted application of technology, smart water management and better climate forecasts.

6. How the innovation will be introduced and spread

The research approach, concept and developed tool are presented to catchment management Authority, water managers and natural resource management board. The integrated modelling framework NSM (hydrological-economic and environmental)developed in this study is adequate for estimating potential water savings, associated costs and levels of seasonal and environmental flow improvements under each promising demand and supply management option. The developed integrated modelling framework (NSM) is a useful policy and planning tool for catchment managers, water supply irrigation authorities, policy and decisions makers and irrigators. It is not a detailed catchment hydrology model, but a tool that has the potential to help stakeholders simulate and optimise the system, by evaluating and analysing key decision variables. It is not a program that only computes one optimised solution. Also, the analysis indicates that the tool developed in this study using system dynamics can provide system overviews of water uses. It also can provide a basis for examining the impact of physical changes to the system and for interactions with agricultural productivity, economics and livelihoods to be predicted. Now the tool is used by catchment management authority for catchment management and applying the water banking.

7. Describe the scope for further expansion of the innovation

- A complete environmental cost and benefit analysis. In particular, the application of water banking needs a detailed study to determine the best technological applications and to quantify the additional environmental costs and benefits associated with different suggested level of management (irrigation area, catchment).

- Potential for artificial recharge sites using infiltration basins should be explored in detail to provide knowledge of evaporation-free, secure underground water dams. A detailed investigation into the hydrogeology of the connections between the river, the shallow aquifer and the deep aquifer must be considered. Also, any artificial recharge water banking approach needs to consider both elastic and inelastic recovery behaviour of clay layers and associated land subsidence issues.
- Detailed social studies with irrigation communities about changing the seasonality of flows. Further social study is required to determine who will invest in water saving options such water banking, who will manage and operate and who will collect the benefits. How farmers are introduced to the concept of water banking is as critical as the actual design and operation.
- Additional economic water analysis needs to determine the water value under each use, such as environment, agriculture and industry. Other uses must be properly estimated with clear water accounting. Also, there is a need to investigate leasing water to non-agricultural users. The associated economic and social impacts must be considered, as it may lead to a diminishing demand for agricultural labour. Leaving land without water as fallow fields may encourage invasive weed infestation which will need weed control and incur additional cost.
- Adding the rain (as it is the global water resource) and soil moisture water (which exhaled during plant growth as vapour flow from the land to the atmosphere) dimensions to integrated catchment management and IWRM opens a broader perspective with new degrees of freedom for water use to support both direct and indirect water needs. These could be facilitated by using a water banking approach to capture and manage different water resources with zero evaporation losses. Hydrological consideration of capacity, automated flow measurements and canal infrastructure (which may be concrete-lined and consolidated), is also required.

8. Describe the roles of the individual nominees

This research and innovation is part of my PhD research at Melbourne University, under my supervisors.

9. Research in the Professional Media

- http://www.irrigation.org.au/download/journal/Irrigation%20Spring%2007.pdf
- http://uninews.unimelb.edu.au/articleid_3738.html
- http://www.civenv.unimelb.edu.au/(read:Underground dams - the new water-storage solution?)
- http://www.dreamlarge.edu.au/

10. Supported document and publications

Journal

- **Elmahdi,**A., Malano, H. and Etchells, T. (2008) Water Banking and Irrigation Demand Management Approach to Improve River Productivity and Environmental Performance Water Resour Manage (2008) **(accepted)**

- **Elmahdi, A** (2007) Irrigation Research" is underground the new water-storage solution?" Journal of Irrigation Australia 2007 Vol 23 No. 03, pp 21-24.
- **Elmahdi,**A., Malano, H. and Etchells, T. (2007) System dynamics and Auto-calibration framework for NSM Model: Murrumbidgee River. *Int. J. Water*, Vol. 3, No. 4, pp.381–396.
- **Elmahdi,**A., H. Malano and T. Etchells (2007) Using System Dynamics to Model Water Reallocation, Environmentalist journal 2007, vol 27 , No. 1, pp 3-12 (http://dx.doi.org/10.1007/s10669-007-9010-2).
- **Elmahdi,**A., Malano, H. and Etchells, T. (2007) System dynamics and Auto-calibration framework for NSM Model: Murrumbidgee River. *Int. J. Water*, Vol. 3, No. 4, pp.381–396.
- **Elmahdi**, A. Malano H, and Khan, S. (2006).Using A System Dynamics Approach to Model Sustainability Indicator for the Irrigation system-Australia, Natural Resource Modelling Journal Vol 19.no.4, winter 2006. http://rmmc.asu.edu/abstracts/nrm/vol19-4/elmapag1.pdf

Conferences

- **Elmahdi, A**., and H. Malano (2008) Water Banking –Crop Mixes Approach to Improve River Productivity and Environmental Performance. Water down under Adelaide 15-17 April 2008confrence, 31st Hydrology and Water Resources Symposium.
- **Elmahdi,A**., and Malano, H. (2007) Water banking-conjunctive water management approach to improve river environmental performance. E-CReW (environmental and Resource Economics conference November 2007 http://www.ecrew.org.au/contact.html , Bathurst , NSW, Australia.