

# **Economic Analysis of Investment in Stream –Aquifer Interaction – Technical and Management Challenges (Project SKP11)**

## **Background**

Australian water resources have come under increasing pressure in the past decade due to over allocation and below average rainfall particularly in the south of the country.

A National Water Initiative was established between the Commonwealth and the states in 2004, key elements of which were (Cullen, 2006):

- Entitlements giving security to those holding water access licences
- A planning framework to drive environmentally sustainable levels of extraction
- Water resource accounting for each catchment
- A nationally consistent water market and water trading
- Best practice water pricing

The rationale to this Land and Water Australia (LWA) project included the lack of a national approach to managing Australian groundwater resources and no nationally agreed method for assessing the relationship of groundwater to stream surface flows. Australian groundwater contributes about 17% of the currently available water resource but makes up 30% of total water consumption.

The LWA investment in this project was made through a Senior Research Fellowship granted by LWA to Dr Richard Evans. The project was initiated in November 2004 and the final report submitted in March 2007.

The LWA Senior Research Fellowships were established to support scientists to carry out studies to challenge the way natural resources are managed in Australia. The thinking and findings produced by the Fellows are expected to be leading edge and designed to contribute to improved management of Australian natural resources.

Water resource management has been particularly topical in the past decade as first salinity and then drought conditions challenged the management of the quantity and quality of water available for various uses. The subject of the fellowship evaluated here has been highly topical in the past few years and will continue to be topical in the years ahead.

Dr Evans had already written one major report and 3 papers on the issue before the Fellowship commenced. It was recognised that not all of the technical, management and policy issues could be solved by the study. The approach was to highlight the key issues and identify the research needs for the future. Broad scale ownership of solutions was recognised as difficult to achieve within the time frame of the project.

## The project

### Project objectives

The Fellowship aimed:

1. To provide a strong technical underpinning and then support and develop practical management approaches to address the issue of stream-aquifer interaction in Australia.
2. To explore technical and management issues associated with better defining surface water-groundwater interaction in Australia. Specifically these included the technical issues of timelags, baseflow management and catchment water balances and the management options at both catchment scale and local scale.

### Investment costs

Details of the funding of the project are provided in Table 1.

Table 1: Resources Invested by year by LWA (nominal dollars)

Year	LWA	Research Organisation (a)	Total
2004–05	80,000	60,000	140,000
2005–06	20,000	20,000	40,000
Total	100,000	80,000	180,000

(a) Sinclair Knight Merz

### Investment description

The study was undertaken part time over a period of several years and used simple analyses and modelling as well as case studies.

Activities included a study tour to the USA which was completed in October 2004. This activity included visits to the Departments of Water Resources in Colorado and Idaho where major issues associated with the interaction between groundwater and surface flows were being faced.

A literature review on fundamental processes, time lags and catchment water balances was effected with a focus mainly on United States literature. Very little information was available on catchment water balances.

Some case study examples of water interactions from both the USA and Australia were explored. These included the Republican River in Kansas, the Eastern Snake Plains aquifer, the Lachlan River (NSW) and the Ovens River (Victoria).

The next phase of the study focused on analyses of the time periods between groundwater pumping and surface water depletion (timelag analyses). This was most important given the analysts view that the time lag was critical but difficult to ascertain and that it masked the relationship between groundwater pumping and any depletion of stream surface flows.

Baseflow analyses were then addressed. This part of the study attempted to place the contribution of groundwater to stream surface flow in perspective and focused on the relative significance of groundwater discharge to other components of the water balance (e.g. bank storage, unsaturated zone flow, delayed surface water and groundwater flow).

A review of stream flow data in the Australian eastern states followed, with a focus on examples where groundwater and stream flow interactions had already been investigated.

The last few stages of the project identified management options and management models for both catchment management and local area management. This identification of options built on a NHT project on national policy development. Catchment scale options used a total water balance approach, leading to catchment restrictions. Local scale options used a zoned approach, and time related impacts were managed by restrictions and rosters.

The final stage of the project addressed general policy/management issues and developed conclusions and recommendations about the future management of the groundwater interactions.

Another part of the study was assistance rendered to the environmental water allocation program managed by Richard Davis.

## **Principal outputs**

A summary of the principal outputs and findings from the project is:

- Australian groundwater use increased by 58% from 2,634 GL per annum in 1983/84 to 4,171 GL per annum in 1996/97; this is a 188 GL per annum increase if a linear trend is assumed.
- Since 1996/97 use has continued to grow at an increasing rate due to drought and limited surface water availability.
- Drought continues to disguise effects of groundwater pumping on stream flows.
- The principal finding was the groundwater pumping will, in many circumstances, lead to a decline in river flows, sometimes immediately and sometimes later. Streamflow can also be lost to groundwater as well as groundwater pumping reducing stream flow.
- The interaction between groundwater and stream flow is a poorly understood process.
- When groundwater pumping occurs there is commonly a time lag between pumping and reduced stream flow; this time lag is not often defined or recognised. Bores located within 10 km of a stream (assumed alluvial soil) would be expected to have an impact within several decades, but time lags very considerably. As a result this has precluded groundwater being taken into account in water resource planning processes in Australia.

- There has been double counting of groundwater and surface water allocations due to interactions between the two water resources.
- Separate management systems have been developed resulting in double accounting for the two water resources but the extent of this double accounting is unknown. Groundwater and surface water have commonly been treated as separate resources and have often been managed by different government departments.
- Estimates of double counting for the Murray Darling Basin suggest a double count of the order of 500 GL per annum over the next few decades or so (Evans, 2005). While many surface water catchments are fully capped, this does not apply to groundwater.
- Baseflow is the integrating mechanism between surface and groundwater; very little data exists on trends in baseflow over time; baseflow analysis is poorly understood and is underused; greater use would be beneficial.
- Baseflow separation techniques are available that enable the proportion of water flow to a river to be estimated from gauged streamflow data; there are a number of methods available, each of which has different strengths and applicability. Care is needed in undertaking baseflow analysis as it generally overestimates groundwater discharge; more understanding in this regard and use of hydrogeological models are needed.
- Baseflow separation, trends in baseflow over time, and knowledge of catchment conditions provide a technique to identify and quantify groundwater impacts on stream flow.
- Catchment scale total water balances are required to define the problem and specific management responses needed to be included in stream management plans to ensure minimum environmental flows are met. Catchment water balances could be supported by zonal management for groundwater pumping. Different lags would be important for pumping from different zones.
- Evans suggests a possible national methodology for assessing groundwater/surface water interactions in three steps – (1) define the degree of connectivity; (2) define the impact of interaction and (3) define the combined surface/groundwater yield. Applying this national approach would require significant technical work.
- Management changes due to double allocations (e.g. not issuing new licences, cancelling or buying back existing licences, pumping restrictions, water trading entitlements) need to apply to all water users, not just groundwater users.
- A major technical issue highlighted during the Fellowship was the importance of evapotranspiration in understanding the surface water-groundwater interactions (Evans, 2006)

### **Recommendations**

A series of recommendations was made for moving forward. These were:

- An assessment of double accounting
- A national approach to groundwater and assessment of its links to surface water
- Integration of management plans in every catchment
- Use of whole of catchment water balances to identify double accounting
- Studies to close the water balance to build confidence in methods in the technical report

- Studies to define how much pumped groundwater is intercepted discharge to streams and how much from other sources
- Agreement by the states on a national toolbox of assessment methods
- Identification of groundwater management units
- Assessment of impact of climate change
- Adoption of integrated management measures that treat all water users equally (licensing)
- Public education program on links between groundwater and surface water to help achieve national cultural change

### **Communication**

A wide range of communication activities was undertaken during the project. Policy briefings were offered to key policy personnel by LWA in early 2007 before the report was released.

A summary of the communication outputs is:

- Paper presented at 29th Hydrology Conference. Canberra, February 2005. Awarded the “best paper” at the conference (Evans and Neal, 2005).
- Paper presented at Outlook Conference. Canberra, ‘Double Accounting of Surfacewater and Groundwater Resources - The Tyranny of the Time Lag’, February 2005.
- Paper presented at International Association of Hydrogeologists Conference on SW-GW Interaction. Darwin. Keynote speaker. ‘Groundwater- surface water interaction in the tropics.’ May 2005.
- Condamine Catchment lectures. Attendance at each of the 3 talks was between 50 to 100 people, June 2005.
- Paper submitted to IAH Auckland ‘Baseflow analysis as a tool for Groundwater – Surface Water Interaction Assessment’, December 2005.
- Presentation at Joint Meeting of Great Artesian Basin and Lake Eyre Basin Management Committees (Keynote speaker), March 2006.
- Ministerial Briefings including Minister for Agriculture Fisheries and Forestry, Parliamentary Secretary to the Minister for Agriculture, Fisheries and Forestry, Minister for Environment and Heritage, March 2007.
- Briefing to Parliamentary Secretary to the Prime Minister with responsibility for Water (Malcolm Turnbull). July 2006.  
Key messages from research quoted by Malcolm Turnbull on multiple occasions e.g. Confronting our Water Challenge: Speech to the Brisbane Institute July 2006 ‘Most groundwater and surfacewater resources are connected. If we extract a mega litre from a bore the odds are, in most parts of southern Australia, that this will mean a mega litre will not find its way to a river.’
- Paper presented at Murray Darling Basin Groundwater Conference, “SW/GW Interaction”, September, 2006.
- Paper (Keynote Speaker) at IAH Conference on SW/GW Interaction in the Arid Zone, Alice Springs, September 2006.

- Final reports available via hard copy and electronically on LWA website, March 2007.
- Presentations to National Water Commission, National Farmers Federation, Australian Conservation Foundation, March 2007.
- Briefing to State Government, CSIRO and others, March 2007.
- Open Policy briefing and BRS Seminar, March 2007.

## **Principal outcomes**

The report and its findings were aimed at water managers and planners, government policy makers, industry, and industry peak bodies.

### **Expected outcome**

A key expected outcome was the raising of awareness of the potentially long-term and substantial impacts on river flows in southern Australia from an unknown but most likely significant level of double counting of the same water resource. If the findings were taken seriously there would be large impacts on water management planning throughout Australia.

### **Actual outcomes up to 2007**

Specific and related actions known at the end of the study included:

1. A National Water Commission (NWC) project on measurement in 10 catchments in QLD and NSW commenced in 2007.
2. A NWC project on mapping surface water-groundwater connectivity was under negotiation.
3. A CSIRO project on Murray Darling Basin (MDB) water resources was to include an assessment of surface water-groundwater interaction.
4. In January 2007, the Prime Minister announced his desire to include groundwater along with surface water in a new MDB cap.

### **Further actual outcomes**

An \$82 million National Groundwater Action Plan was announced by the National Water Commission in 2007. The Action Plan consists of three components ([www.connectedwaters.unsw.edu/resources/articles/position\\_statement.html](http://www.connectedwaters.unsw.edu/resources/articles/position_statement.html)).

1. The National Groundwater Assessment Initiative (\$50 million) to improve the understanding of groundwater resources and support NWI implementation, harmonise groundwater terminology and foster best practice management. A range of projects are planned and many have already been announced across eight priority themes, including:
  - (i) Groundwater definitions and standards and improved governance and management practices
  - (ii) Northern Australia Groundwater stocktake
  - (iii) National assessment of sites suitable for managed aquifer recharge and recovery
  - (iv) Vulnerability of groundwater dependent ecosystems
  - (v) Investigation of groundwater-surface water connectivity
  - (vi) Strategic aquifer characterisation to quantify sustainable yields
  - (vii) National review of groundwater potential for deep fresh, saline and brackish waters

(viii) Managing risk to groundwater quality

The assessment initiative is the principal element in the action plan by funding hydrogeological investigations to fill critical groundwater knowledge gaps.

2. A National Centre for Groundwater Research and Training to develop research skills and expertise including the training of a new generation of groundwater managers and experts. In 2009, a new \$60 million National Centre for Groundwater Research and Training was launched. The Centre is to be led by Flinders University (\$30 million from the NWC and Australian Research Council plus \$30 million over 5 years from the partners who include a range of university and state and commonwealth research agencies).

3. A knowledge and capacity building component (\$2 million) to communicate learnings from the Plan and raise public awareness of the challenges to adequately manage groundwater resources.

The announcement urged as a top priority that action needs to be taken to return over-allocated systems to sustainable levels as the ongoing use of groundwater for consumptive purposes from a number of stressed aquifers and connected water systems was an unacceptable risk. Other priorities included the need for nationally integrated groundwater measurement standards and definitions, a groundwater stocktake in Northern Australia, better understanding of groundwater dependent ecosystems and overcoming institutional barriers to manage aquifer recharge developments. Further, the following principles were stated to guide future groundwater reform:

- Groundwater and surface water planning and management should be integrated, to recognise their connectivity, with best available science to underpin the setting of environmentally sustainable levels of extraction;
- Integrated water management should include compatible charging regimes for groundwater and surface water;
- Unless otherwise established, it should be assumed that all surface and groundwater systems are connected and that the eventual impact of groundwater pumping on surface water flow may be as high as 100%;
- Improved management of stressed water resources should include urgent implementation of a sustainable integrated groundwater and surface water cap in the Murray-Darling Basin;
- All groundwater extractions should be licensed and metered (except stock and domestic bores where use is less than a defined limit, say 2-5 ML per year);
- Environmental water should be managed separately from agencies responsible for the provision of surface water/groundwater for consumptive use;
- Managed aquifer recharge, storage and reuse of surface runoff that is excess to environmental requirements is a water supply option that should be considered alongside others, subject to suitable water quality treatment to protect the groundwater resource.

The NWC has established a Groundwater Technical Advisory Committee (GTAC) to advise on groundwater priorities and investments. Richard Evans is a member of the Group.

In 2007 and 2008, the Murray Darling Basin Sustainable Yields team undertook a water resource assessment for the groundwater and surface waters of the Murray-Darling Basin. The assessment was lead by CSIRO's Water for a Healthy Country Flagship Program. The team of scientists was awarded the CSIRO Chairman's medal and the team included Richard Evans who accepted the medal on behalf of the SKM team involved in the project. The results of the assessment, together with other information available to the Murray-Darling Basin Authority, are now being used to develop the new sustainable diversion limits for the Murray-Darling Basin.

In March 2008, the Council of Australian Governments expanded the assessment (including groundwater) to provide a comprehensive scientific assessment of the water yield in all major water systems across the country to allow a consistent analytical framework for water policy decisions throughout the nation. Regions currently being studied as a part of this expansion are Northern Australia, South-West Western Australia and Tasmania (SKM, 2008).

In summary, it can be concluded that initial actions along the lines suggested in the Fellowship report are currently taking place.

#### **Attribution of these outcomes to the LWA Fellowship**

All three components of the Action Plan bear close resemblance to many of the outputs of the LWA investment and the recommendations made. However, the attribution of the changes to the Fellowship funding should bear in mind:

- Richard Evans had been drawing attention to these issues for some time before the Fellowship was funded
- Other people had also been warning of the potential for double counting
- The current focus on water resources was conducive to change

Hence, much of the information in the Fellowship Report was not entirely new. In fact, Evans had made earlier statements about surface water-groundwater interactions and double counting of the resource groundwater, in an earlier report (SKM, 2003). However, what the fellowship and report provided was the opportunity to significantly raise the importance of the issue and highlight the potential policy failure to influential personnel, particularly in government.

The NWC Water Audit in 2005 found that in earlier assessments many water managers had mistakenly counted their groundwater and surface water as distinct resources, and that double counting was commonplace. While Commonwealth agencies appear to recognise the likelihood of double counting, there has not been universal agreement on this issue among the states.

A summary of the principal outcomes from the project is:

- Some states and water management organisations were not happy with the findings in the early development of the report as the findings were not compatible with the direction that some of the state water planning processes were taking.
- A national policy framework to address surface water-groundwater interaction was developed as part of the National Water Initiative with four policy principles to address the problem of groundwater pumping and its effect on surface water resources.
- In 2007, after the report was released, a draft national policy on groundwater proposed that all jurisdictions should assess the impact of groundwater pumping on streams. The states were then considering how to do this.
- The key outcome from the Fellowship was a quantum leap in progress made towards an integrated cap that recognises the interaction between the surface water and the groundwater resource.

In summary, the project will have had a large impact on water resource management plans across Australia. However, while serious planning is occurring, implementation of an integrated cap may still be some years away and implementation will probably vary from state to state.

### **Benefits associated with the investment**

The benefits associated with the changes likely to be made as a result of the Fellowship are described in a triple bottom line format in the following:

#### *Economic*

- Improved information on the connectivity of surface and groundwater resources leading to future water resource allocations providing greater water security to users in the long term.
- Optimal level of infrastructure investment in the long term by both surface water and groundwater users. Total irrigation infrastructure costs will be lowered due to reduced replacement expenditure and lower total maintenance costs.
- Lower caps will negatively impact on the quantity of water extracted for irrigation.
- The short term negative impacts on irrigators may be reduced if water purchases by government are focused on those that are not being used (sleeper licences) or where water is currently being used inefficiently. Further, the additional restrictions on water extraction in the short term may ensure that those that maintain their entitlements are encouraged to increase water use efficiency.

#### *Environmental*

- If lowered additional caps on the extraction of the total water resource (both groundwater and surface water) are employed, this will benefit the environmental surface flows/groundwater resources and associated biodiversity in the short and long term e.g. increased ecosystem health (including groundwater dependent ecosystems, reduced number of potential extinctions).

### *Social*

- Indigenous land owners will benefit from improved river health from decisions made to lower caps.
- Irrigation communities will be worse off.

### *Type of benefits*

A summary of the principal types of benefits associated with the investment is shown in Table 2.

Table 2: Categories of Benefits from the Investment

<b>Benefits and Costs</b>
<b>Economic</b> <ul style="list-style-type: none"><li>• Potential lower cap on extraction from the total water resource due to recognition of groundwater-surface water interactions leading to higher long-term water security for both the environment and extractive water uses in the future</li><li>• Cap on extraction from total water resource implemented sooner than without the investment</li><li>• Optimal level of both public and private investment in water extraction infrastructure in the long term</li><li>• Less annual water available for irrigation</li></ul>
<b>Environmental</b> <ul style="list-style-type: none"><li>• Improved environmental flows in rivers arising earlier with associated improvements in ecosystem health</li><li>• More healthy groundwater dependent ecosystems</li></ul>
<b>Social</b> <ul style="list-style-type: none"><li>• Positive impact on Indigenous well-being associated with river health</li><li>• Negative social impacts on irrigation communities</li></ul>

### *Public versus Private Benefits*

Benefits will be captured by the public sector via earlier occurrence of surface stream environmental flows and increased protection of groundwater dependent ecosystems. Also, optimal levels of public infrastructure for extraction will occur in the long term. These benefits will be at the expense of reduced short term extractions for irrigation.

### *Distribution of Benefits Along the Supply Chain*

The supply chains of irrigated products will also be negatively impacted

### *National Priorities*

The Australian Government's national and rural R&D priorities are reproduced in Table 3. In terms of National Research Priorities, the investment addresses National Priority 1. For the Rural Research Priorities, priorities 1 and 3 and to some extent number 4 are supported by the investment.

Table 3: National and Rural R&D Research Priorities 2007-08

<b>Australian Government</b>	
<b>National Research Priorities</b>	<b>Rural Research Priorities</b>
<ol style="list-style-type: none"> <li>1. An environmentally sustainable Australia</li> <li>2. Promoting and maintaining good health</li> <li>3. Frontier technologies for building and transforming Australian industries</li> <li>4. Safeguarding Australia</li> </ol>	<ol style="list-style-type: none"> <li>1. Productivity and adding value</li> <li>2. Supply chain and markets</li> <li>3. Natural resource management</li> <li>4. Climate variability and climate change</li> <li>5. Biosecurity</li> </ol> <p><i>Supporting the priorities:</i></p> <ol style="list-style-type: none"> <li>1. Innovation skills</li> <li>2. Technology</li> </ol>

### **Quantification of benefits**

It is assumed that the fellowship has contributed to the Commonwealth Government policy decision to accept that an integrated cap on the combined surface water/groundwater resource is desirable. This decision is assumed to result in expected benefits to Australia but will depend on policy changes in the states and in individual catchments.

### **Expected Benefit with the Fellowship**

It is assumed that current groundwater use is about 6,000 GL per annum (Evans, 2007, p56). It is further assumed that potentially 50% (or more) of this resource is currently double counted, that is, there could be at least 3,000 GL of water that is counted twice in the estimates of total sustainable resource use (Evans, pers.comm., 2009). However, the estimate of 50% is lowered in the current analysis to 25% or 1,500 GL, based on the premise that some of the surface water models used to estimate flows were calibrated in the 1980s and 1990s, and would already have embedded some of the potential double counting in their estimates. Nevertheless, caps need to be lower than currently if future usage of water resources is to be sustainable and the pool of available water resources for both extraction and the environment is to be prevented from shrinking significantly at some stage in the future.

This scenario reflects what is expected to happen, given the fellowship and other pressures based on scientific knowledge. For example, a new water resource plan that recognises connectivity for the Murray Darling Basin is currently being prepared. The plan is expected to be completed by 2013/14 (possibly earlier) and assumed to be implemented in 2014/15. Plans and implementation dates in other jurisdictions are assumed to be of a similar timing, although it is recognised these parameters will vary widely by location.

Implementation is assumed to include a lowering of water extraction from both surface water and groundwater due to the recognition of groundwater-surface water interactions.

Environmental flows are assumed to increase to the same extent as water extraction falls. Other assumptions are that water is valued the same per ML whether used for irrigation or remaining in streams or as groundwater. However, it could be argued that the value of water for environmental flows should be higher than for water extracted when the current flows are considered unsustainable. This argument is not pursued here.

The probability of lowering water extractions based on the recognition of connectivity being implemented in 2014/15 is assumed to be 75%.

#### *Reduced Capital Replacement Costs*

It is assumed that as a reduced cap is implemented in recognition of the existing imbalance, irrigation water providers will face a reduced capital investment in assets and will therefore avoid having to replace some ageing assets, or avoid investing in new assets that will not be able to be serviced by a sustainable water yield. The reduced capital investment will most likely be distributed across both surface water irrigators as well as groundwater pumpers.

The replacement value of assets of irrigation water providers in 2005/06 has been reported as \$6.4 billion (ANCID, 2007) servicing 13,293 GL per annum. This information is based on 30 irrigation water provider businesses located across Australia. Assuming a 99 year life of new assets (ANCID, 2007), this is equivalent to nearly \$65 million per annum. On this basis a 1,500 GL cap could avoid replacement of  $1,500/13,293 = 11.3\%$  of \$65 million each year = \$7.3 m per annum. This estimate would not include any savings to on-farm infrastructure. For the purposes of this analysis, it is assumed that groundwater pumping infrastructure avoids similar capital costs as surface irrigators. Hence the asset replacement costs saved are estimated at \$7.3 m per annum, an avoided cost due to the cap. These avoided costs include both surface water infrastructure as well as groundwater infrastructure.

#### *Reduced Maintenance Expenditure*

As for reduced asset replacement costs, the introduction of the cap will allow irrigation water providers and groundwater pumpers to reduce maintenance costs due to the lower level of assets supported. For irrigation water providers, maintenance expenditure as a proportion of asset value is assumed to be 0.6% per annum (ANCID, 2007). This is equivalent to \$6.4 billion x 11.3% x 0.6% = \$4.3 m per annum. Again this figure is used as an estimate of all maintenance costs avoided, whether related to surface water or groundwater infrastructure.

### **Counterfactual Scenario**

Without the investment in the fellowship there still would have been pressures to include the groundwater and surface water resource together in estimating sustainable extractions

from the total water pool. There were other pressures to change and to include both water resources in an integrated cap.

Apart from the scientific support for change, the connectivity relationship would have been realised at some point in the future, particularly as the more restricted resource became apparent from observations of reduced water availability. The heightened awareness of water scarcity would have eventually led to integrated caps being applied to the total of both resources.

Without the investment in the Fellowship it is assumed that a sustainable cap recognising the connectivity would have been applied two years later (in 2016/17) than currently expected in 2014/15.

### Summary of assumptions

A summary of all assumptions made is given in Table 4.

Table 4: Assumptions for the Valuation of Benefits from Project

Variable	Value	Source
<i>With Fellowship Scenario</i>		
Groundwater used	6,000 GL per annum	Evans (2007)
Proportion of groundwater pumping potentially impacting on stream flow	50%	Evans, pers. comm., June 2009
Proportion of groundwater pumping potentially impacting on stream flow after allowance for calibrated flow models	25%	Agtrans Research
Volume water involved in surface water/groundwater interaction	1,500 GL per annum	From above assumptions
Reduced level of water allocated due to cap	1,500 GL per annum	Agtrans Research
Year in which cap applied to account for interaction	2014/15	Agtrans Research based on discussions with Rick Evans
Replacement value of assets of irrigation water providers in 2005/06	\$6.4 billion servicing 13,293 GL per annum	ANCID, 2007
Average life of new assets	99 years	
Avoided asset replacement costs	$\$6,400,000,000 / 99 \times 1,500 / 13,293 = \$7.3 \text{ m per annum}$	From above
Maintenance costs of irrigation water providers	0.6% of asset replacement value	ANCID, 2007

Saved maintenance costs due to cap	\$6,400,000,000 x 1,500/13,293 x 0.6% per annum = \$4.3 m per annum	From above
Probability of 2014/15 cap implemented to account for interaction	75%	Agtrans Research
<i>Counterfactual</i>		
Year in which interaction cap applied	2016/17	Agtrans Research
Probability of 2016/17 cap implemented to account for interaction	75%	Agtrans Research

### **Results**

All past costs and benefits were expressed in 2008-09 dollar terms using the CPI. All benefits after 2008-09 were expressed in 2008-09 dollar terms. All costs and benefits were discounted to 2008-09 using a discount rate of 6%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. The base analyses ran for the length of the investment period plus 40 years from the first year of investment to the final year of benefits assumed.

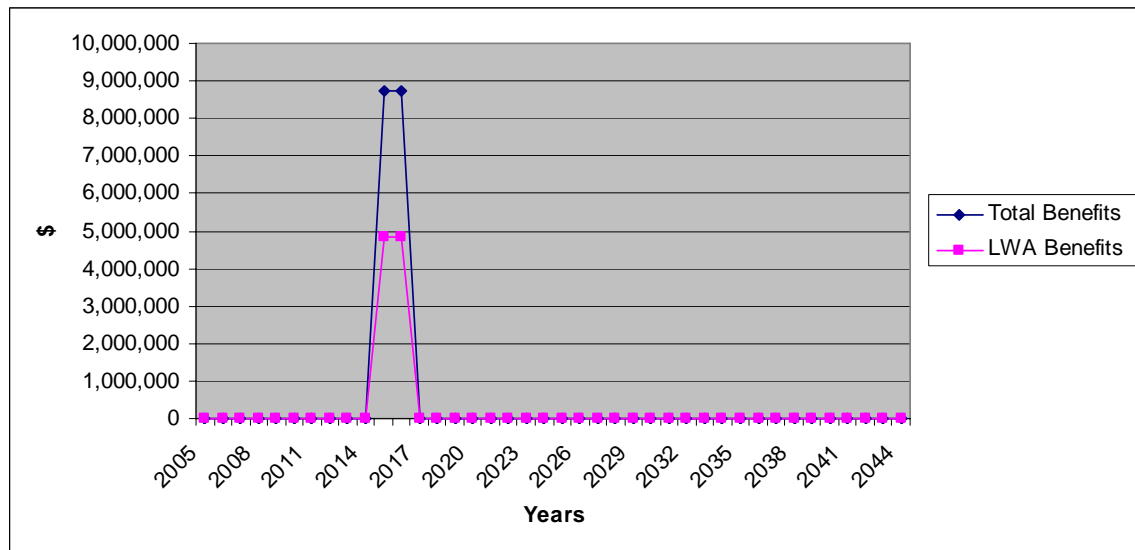
Investment criteria were estimated for total investment and for the LWA investment alone. The investment criteria are reported in Table 5.

Table 5: Investment Criteria for the Investment (discount rate 6%)

<b>Criterion</b>	<b>LWA only</b>	<b>Total</b>
Present value of benefits (\$m)	6.64	11.95
Present value of costs (\$m)	0.14	0.25
Net present value (\$m)	6.50	11.70
Benefit-cost ratio	47.6	47.6
Internal rate of return (%)	54.3	54.4

Figure 1 demonstrates the rate at which undiscounted net benefits accrue for the total investment and for the LWA investment.

Figure 1: Annual Net Benefit Flow



*Sensitivity analysis*

Sensitivity analyses were carried out on several variables and results are reported in Tables 6 to 9. All sensitivity analyses were performed on the LWA investment criteria using a 6% discount rate with benefits taken over 40 years from the first year of investment. All other parameters were held at their base values. Table 6 shows the sensitivity of the investment criteria to the assumed proportion of groundwater pumping contributing to stream flow reductions. The proportion of the 6,000 GL for the investment to provide an internal rate of return of 6% is estimated at 0.5% or about 32 GL.

Table 6: Sensitivity of Investment Criteria to Proportion of Groundwater Pumping Affecting Stream Flow (LWA benefits and costs only)

Criterion	Discount rate 6%		
	10%	25% (Base)	50%
Present value of benefits (\$m)	2.66	6.64	13.29
Present value of costs (\$m)	0.14	0.14	0.14
Net present value (\$m)	2.52	6.50	13.15
Benefit-cost ratio	19.0	47.6	95.1
Internal rate of return (%)	41.1	54.3	65.1

Table 7 shows the sensitivity of the investment criteria to the discount rate.

Table 7: Sensitivity of Investment Criteria to Discount Rate  
(LWA benefits and costs only)

Criterion	Discount rate		
	0%	6% (Base)	10%
Present value of benefits (\$m)	9.70	6.64	5.23
Present value of costs (\$m)	0.11	0.14	0.16
Net present value (\$m)	9.59	6.50	5.06
Benefit-cost ratio	86.7	47.6	32.5
Internal rate of return (%)	54.3	54.3	54.3

Table 8 shows the sensitivity of the investment criteria to the assumed probability of implementation.

Table 8: Sensitivity of Investment Criteria to Probability of Implementation  
(LWA benefits and costs only)

Criterion	Probability of Implementation		
	50%	75% (Base)	100%
Present value of benefits (\$m)	4.43	6.64	8.86
Present value of costs (\$m)	0.14	0.14	0.14
Net present value (\$m)	4.29	6.50	8.72
Benefit-cost ratio	31.7	47.6	63.4
Internal rate of return (%)	48.4	54.3	58.7

Table 9 shows the sensitivity of the investment criteria to the assumed lag in years between an integrated cap being implemented with and without the Fellowship.

Table 9: Sensitivity of Investment Criteria to Implementation Lag  
(LWA benefits and costs only)

Criterion	Implementation Lag		
	1 year	2 years (Base)	5 years
Present value of benefits (\$m)	3.72	6.64	18.18
Present value of costs (\$m)	0.14	0.14	0.14
Net present value (\$m)	3.09	6.50	18.04
Benefit-cost ratio	23.1	47.6	130.1
Internal rate of return (%)	41.6	54.3	91.9

## Conclusions

The pressure on Australian water resources has been increasing in recent years due to over allocation, a series of drought years, decreased runoff due to increasing forestry and farm dams and the threat of climate change. Another factor recently debated has been the

impact of the connectivity between groundwater and surface water flows with implications for sustainable extraction levels.

The LWA Fellowship has heightened the intensity of this debate and exposed scientific thinking regarding the extent of the connectivity and the implications for potentially double counting both surface water and groundwater resources. The implication is that there may be less water than originally estimated and declines in surface water availability may occur or may be already occurring due to the connectivity.

While the Commonwealth agencies are supporting an integrated cap on water resource extraction due to the impact that groundwater pumping may have on surface water flows, state agencies are not acting quickly on the issue.

The Fellowship allowed the issue to be brought to the attention of policy makers and is likely to have sped up expected policy changes addressing the overestimate of the water resource. The analysis assumes a cap being placed on extraction (some combination of surface and groundwater extraction) to pursue a sustainable yield some two years earlier than without the LWA Fellowship. It is assumed that extraction caps need to be lower than currently if future usage of water resources is to be sustainable and the pool of available water resources for both extraction and the environment is to be prevented from shrinking significantly at some stage in the future.

The estimates of the investment criteria made are dependent on a number of uncertain assumptions. The key assumption is that restoring a sustainable extraction yield will avoid some future costs of asset replacement and maintenance of existing irrigation infrastructure. Such investment would be wasted since water will not be available for its utilisation.

The small investment by LWA in the Fellowship is one reason for the high benefit-cost ratio of 47 to 1. The net present value estimated for all investment in the Fellowship was over \$11 million and for LWA over \$6 million, estimated at a 6% discount rate and expressed in 2008/09 \$ terms as of 2004/05 (beginning of investment).

The investment criteria are likely to underestimate benefits from imposing an extraction cap based on groundwater/surface flow connectivity. This is because Australian governments are committed to environmentally sustainable extraction levels and the current analysis values water extracted at the same value as water for environmental flows.

## **Acknowledgments**

Richard Evans, SKM

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## **Addendum 1: An Economic Analysis of Investment in Stream –Aquifer Interaction – Technical and Management Challenges (Project SKP11): Results for CRRDCC Process**

All past costs and benefits were expressed in 2008/09 dollar terms using the CPI. All benefits after 2008/09 were expressed in 2008/09 dollar terms. All costs and benefits were discounted to the year of analysis (2008/09) using a discount rate of 5%. These results are shown in Tables A.1 and A.2 and are reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone.

Table A.1: Investment Criteria for Total Investment and Total Benefits  
(discount rate 5%)

	<b>0 years</b>	<b>5 years</b>	<b>10 years</b>	<b>20 years</b>	<b>25 years</b>	<b>30 years</b>
Present value of benefits (\$m)	0	0	12.71	12.71	12.71	12.71
Present value of costs (\$m)	0.24	0.24	0.24	0.24	0.24	0.24
Net present value (\$m)	-0.24	-0.24	12.46	12.46	12.46	12.46
Benefit-cost ratio	0	0	52.49	52.49	52.49	52.49
Internal rate of return (%)	negative	negative	59.3	59.3	59.3	59.3

Table A.2: Investment Criteria for LWA Investment and LWA Benefits  
(discount rate 5%)

	<b>0 years</b>	<b>5 years</b>	<b>10 years</b>	<b>15 years</b>	<b>20 years</b>	<b>25 years</b>
Present value of benefits (\$m)	0	0	7.06	7.06	7.06	7.06
Present value of costs (\$m)	0.13	0.13	0.13	0.13	0.13	0.13
Net present value (\$m)	-0.13	-0.13	6.93	6.93	6.93	6.93
Benefit-cost ratio	0	0	52.43	52.43	52.43	52.43
Internal rate of return (%)	negative	negative	59.2	59.2	59.2	59.2

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the LWA investment.

Figure A.1: Annual Benefits

