Land Use and Water Resources Research

Moving from piecemeal accounting to a pragmatic economic approach to water pricing in Australia

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Abstract

It is often said that water is under-priced and that if the full cost of water were charged, water use would be more sustainable. Moving from a statement to actual practice requires a shift in thinking about the fundamental economics. Australia has embarked on a process of economic reform and part of the reform package in the water sector has required States within Australia to report on progress towards full cost pricing, including the set of costs and, in some circumstances, benefits, through changes to the environment. Economists refer to these costs and benefits as externalities. Identifying the potential set of externalities is context-specific and requires a multidisciplinary approach. In this paper the environmental externalities related to water use are described for the River Murray, the largest river in Australia. A pragmatic approach, grounded in economic principles, is suggested to incorporate externality costs in the price of water.

Introduction

Australia is characterised by highly variable patterns of rainfall and naturally erratic flow regimes of its major rivers. Australia has, for instance, some of the wettest areas on Earth with western Tasmania and tropical northern Queensland, and some of the driest areas with half the continent receiving less than 300 mm of rain per year (AATSE, 1999). Capturing and storing water for irrigation and urban use has been critical for economic development in Australia. Figure 1 is a map of Australia, indicating the States and Territories and the location of the Murray-Darling Basin. The Murray-Darling Basin is approximately 1.5 million hectares in size and is responsible for approximately 40% of the value of agricultural production from Australia (Crabb, 1997). Approximately 80% of the profits from agriculture were derived from irrigated agriculture involving 2% of the land area of the nation, and most of this is in the Murray-Darling Basin (Young *et al*., 2003).

The Murray Darling Basin extends across four States and the Australian Capital Territory in Australia. As responsibility for water resides largely with the States, the Basin is managed through a complex set of inter-jurisdictional institutional arrangements. In particular, the Murray Darling Basin Ministerial Council (consisting of the relevant Ministers from across the States) and the Murray Darling Basin Commission (consisting of an independent president, commissioners and deputies representing the various participating governments) are able to make decisions with the necessary political power for the Basin as a whole. These structures require consensus decisions and, as a result, decision-making can be slow.

The management of the Basin has changed from a system for storing and managing the flow of water for navigation and later for agriculture, to a management structure that takes into consideration not only the States and their economic reliance on the water but also a complex set of ecological issues. In particular, the management of salinity levels, blue-green algae blooms, sustainable fish

Figure 1. The Murray-Darling Basin, Australia

Map courtesy of CSIRO Land and Water Communications

populations, migratory birds and some significant ecological assets such as forests on floodplains require Basin-wide strategies. Recent audits of the health of the river indicate that current levels of water use are not sustainable (MDBC, 2002). In addition, current practices threaten the long-term use of the river as a water supply due to rising salinity levels. Australia has also been embarking on a process of reform across sectors of the economy through agreements made by the Council of Australian Governments (CoAG) which is a peak intergovernmental body that represents the Commonwealth government, State, Territories and Local governments. CoAG initiates, develops and monitors the implementation of policy reforms which are of national significance and which require cooperative action by Australian governments. The reform process, including endorsement of the National Competition Policy (NCP), is fuelled by a system of payments, from national to state governments, which are contingent upon meeting certain targets by the participating governments.

The overall intention of the reform process is to strengthen the competitive nature of the economy, eliminate unfair advantage of public entities in the market place and improve access to publicly owned infrastructure. Initially, these changes were viewed as influencing sectors of the economy such as manufacturing, transportation or public sector enterprises with only peripheral implications for natural resource management. With the implementation agreements setting out the reform obligations in national markets for electricity, gas and water, it is becoming clear that there are far-reaching implications for the management of the environment. In the water sector, there will be public policy choices on how to manage catchments, river basins and the suite of environmental impacts associated with the extraction, storage, regulation, distribution, use and subsequent return of water to the environment.

Sweeping institutional changes in the water sector have shaped how water is priced, traded and ultimately used as a result of agreements in 1994 and later re-affirmed in communiqués and the Intergovernmental Agreement (IGA) on a National Water Initiative (CoAG, 2004). With the latest round of assessment, there is a requirement for the price of water to reflect the full cost, including impacts upon other users such as the environment. These third party impacts are referred to as externalities in the CoAG communiqués and National Competition Council documents (CoAG, 2003; NCC, 2003a,b). Under the IGA, States and Territories continue to examine the appropriateness of using pricing that includes externalities where feasible (CoAG, 2004, 73iii).

In this paper we define environmental externalities as the final impacts upon other water users and the environment which are outside the transactions relating to the water cycle, including the extraction, storage, distribution, regulation, use and finally the return of the water to the environment. This includes any final impacts upon the environment that have implications for people, either directly or indirectly. As externalities are often context-specific, we focus our attention on the southern connected River Murray system, defined as the whole of the River Murray, the Murrumbidgee system, the Darling River and its anabranches below the Menindee Lakes. When considering the southern connected Murray system, referred to as the Murray system for succinctness, many of the environmental externalities associated with urban water are inextricably linked with rural irrigation as the water comes from the same riverine environment and relies on the same infrastructure.

Background on water pricing

Water pricing for urban and rural irrigation is administered differently across the States. Concentrating on the critical common aspects of water pricing for the three States in the Murray system which crosses the State borders of New South Wales (NSW), Victoria (VIC) and South Australia (SA), irrigation water is delivered via an irrigation scheme or pumped directly from a river. Many of the irrigation schemes in the Murray system have been privatised and are recovering operating costs and some portion of the opportunity cost of the investment in infrastructure. For instance, the difficulties of establishing the ‘opportunity cost’ of infrastructure or the value of infrastructure in its next best alternative, is outlined in Musgrave (1999) for the Independent Pricing and Regulatory Tribunal (IPART) in NSW. In SA, but not VIC or NSW, irrigators pay catchment levies which offset the cost of some of the monitoring and catchment management functions undertaken by catchment boards. Despite progress in incorporating capital costs in a fair and transparent way, the approach is still piecemeal across the States.

Alongside irrigation, the Murray system also serves as a drinking water supply for the city of Adelaide (population 1.1 million people) in South Australia and a number of small towns. Generally, water must be treated to potable standards for most urban uses. Most urban users in South Australia, and Australia more generally, currently pay a two-part price system consisting of a fixed charge and a volumetric charge. In South Australia, property owners connected to the reticulated potable water system pay a River Murray levy, which is used for River Murray environmental projects. This levy is over and above any catchment board levies. Urban water utilities have been required by their respective regulators (or agencies responsible) to demonstrate that the volumetric pricing of water reflects the marginal cost of delivering the water to the customer.

Obligations under Intergovernmental Agreements

The States have agreed under the IGA to implement best practice water pricing and institutional arrangements which promote economically efficient and sustainable use of water resources and infrastructure assets. In particular, States have agreed to continue to manage externalities through a range of regulatory measures but also to explore and implement where feasible the use of market-based instruments such as pricing in the management of externalities. In the pricing of rural irrigation water, the States have agreed to move towards lower bound pricing which includes the operational, maintenance and administrative costs, externalities, taxes or tax equivalence rates, cost of interest, dividends and provision for future asset replacement and refurbishment. In urban water, the States have agreed to move towards upper bound pricing which is to include the additional costs associated with asset consumption and the cost of capital.

Environmental externalities of water in the lower Murray System

The modifications of the Murray system to accommodate its role as an irrigation and a drinking water supply have had far reaching impacts on the environment, including key assets that Australia has agreed to protect under international agreements. These include several wetlands protected under the RAMSAR convention, the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA). Externalities associated with parts of the water cycle can be grouped as extraction, storage, distribution and regulation of a surface water system (supply externalities), use externalities (related to the application of water) and return externalities (related to the return of water to the environment). This framework is used to identify a series of hydrological consequences and ecological impacts in Table 1.

Loss of natural flow regime

The flow regime is the key driver of riverine ecosystems and includes a number of attributes, including the annual flow volume and the timing, magnitude, frequency and duration of different flow events (Poff *et al*., 1997). Most species will have critical features of their life cycle linked to specific flow regime attributes. For example, some fish species require floods at the right time of the year in order

Table 1 Summary of the impacts of River Murray flow management on its hydrological regime, with implications for environmental externalities.

Management Action	*Hydrological consequences*	*Ecological outcomes*
Water extraction	Decreased median annual flows	River salinisation Closure of the Murray mouth
Storage	Interception and attenuation of floods	Barriers to fish migration Loss of spawning cue for native fishes Decreased recruitment of floodplain vegetation Floodplain salinisation
Distribution	Higher flows during summer	Channel erosion Coldwater releases impair native fish recruitment
Regulation through weirs and barrages in the lower reaches	Maintenance of permanently elevated surface and groundwater levels in the floodplain	Floodplain salinisation Increased incidences of blue-green algal blooms
	Loss of wetting/drying cycles in wetlands	Drowning of red gum forests
	Loss of tidal influence in the Lower Lakes	Loss of estuarine habitats Barriers to fish migration Reduced fish and bird biodiversity
Application	Development of groundwater mounds under irrigation areas. Increased discharge of saline groundwater in the river and the floodplain	Red gum forest dieback, wetland salinisation
Return to the Environment	Return of excess irrigation water on the floodplain and the river	River and floodplain salinisation

to spawn successfully and many floodplain plants are adapted to habitats with specific inundation regimes. The variability in the flow regime of natural rivers promotes species diversity as conditions will be optimal for different species from year to year. When the natural flow regime is modified by river regulation, species either tolerate the new flow regime or disappear. However, they cannot *adapt* to the new regime because the rate of change following regulation (days to decades) is too rapid for evolution by natural selection (a slow process generally occurring over hundreds to thousands of generations).

In the River Murray, the modifications to the natural flow regime have been an important but not the only factor involved in the significant environmental degradation of the ecosystem in past decades. Under natural conditions, floods could occur at any time but were more frequent in early spring following snowmelt in the upper reaches of the Basin. Nowadays, most of the spring runoff is caught in upstream reservoirs and released during summer when required for irrigation. Several weirs and barrages also control flow and maintain elevated water levels along the middle and lower sections of the river, resulting in much of the system now behaving more like a lake than a river. Due to extraction and increased evaporation losses, the mean annual flow at the border of NSW and SA is now only 38% of mean natural flow. The duration and frequency of small and medium-size floods has been significantly reduced. These smaller flood events are thought to have the greatest ecological benefits.

As the ecological impacts begin to be understood by the institutions which manage the Murray system, there have been growing calls for more water for the environment. There is support for more water to flow through the Murray system by the Australian public who live in largely urban coastal areas. The Living Murray process, CoAG communiqués and catchment management plans (MDBC, 2002; RMCWMB, 2003a,b) have expressed these aspirations as commitments to mitigate the environmental degradation by returning the Murray system, *as far as realistically feasible*, to a more natural flow regime. There is recognition that not all environmental externalities can be mitigated.

Returning to a more natural flow regime will have two components:

- more water will need to be allocated to the environment and
- the infrastructure controlling water flows in the catchments will need to be modified and managed to allow the generation of environmental flows.

Full cost pricing holds potential as a means of resetting the balance between the use of water for economic purposes and water for the environment. However, other environmental externalities will not be addressed by improved environmental flows. For example, some of the salinity impacts, such as those caused by increased saline groundwater discharge near irrigation areas, will not be mitigated to a satisfactory level by environmental flows alone.

There is an ongoing debate on how much water should be returned to the River Murray to provide enhanced environmental flows. To put this debate in perspective, the natural median flow reaching South Australia has been modelled as 12 760 GL (1 GL = 1 000 000 000 litres) per year but the current median is 4850 GL per year. Proposals and potential implications are summarised in Figure 2 for increasing the flow of water to improve the health of the river, known as environmental flows (E-Flows), based on Close (2002) and RMCWMB (2003a).

Proposals were recently considered to give back between 350 to 1500 GL per year to the river for environmental purposes (MDBC, 2000). With the announcement of $500M in funding, 500 GL has been chosen effectively as a first step (MDBMC, 2003). While the 500 GL per year falls well below the targets set out to stop the decline in river health, it will provide an opportunity to establish the feasibility and the economic, social and management frameworks required to collect and return water to the river.

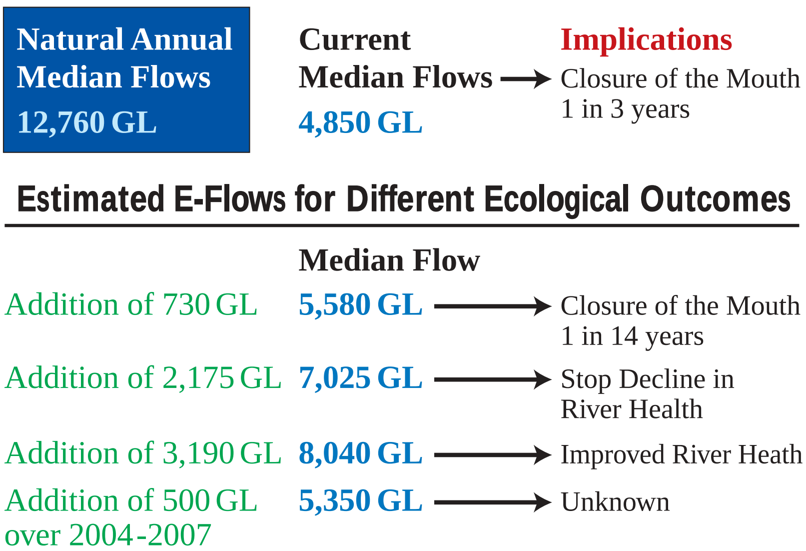

Figure 2. Summary of proposals for returning water to the Murray system

The policy framework surrounding the economics of water

Developing initiatives to release environmental flows are in train in Australia, South Africa and the United States (Dyson *et al*., 2003). Incorporating the cost of the environment into the price of water has been suggested in the literature (Rogers *et al*., 2002) but has not been implemented in a systematic way. Other jurisdictions, including municipalities in the USA and water utilities in the EU, have used alternative approaches to retro-fit residential customers with water efficient devices through subsidies and promotional give-aways (Bjornlund *et al*., 2001).

This is an opportune time to look at the environmental impacts associated with aspects of the water cycle, from extraction through to the return of water to the environment, as State governments will be reporting on how externalities are to be dealt with in the price of water and potentially passed on to water users as part of the price (NCC, 2003b). There is, however, more theory than actual practice in the area of measuring and accounting for the cost of externalities relating to water. The implications of these policies need to be thought through carefully as there are environmental, economic and social costs associated with this full cost pricing approach.

Conflicting principles inherent to pricing

Economic efficiency, cost recovery, regional equity, ability to pay and demand management are often cited as some of the potential, practical objectives in setting an administered price of water. These goals may be considered quite reasonable on their own. However, many of these goals are not simultaneously achievable and as a result social and political choices are often required.

This NCP requirement to incorporate externality costs in the price of water, in theory, could result in water users internalising the full cost of their water-related consumption and production decisions, including costs imposed on the environment. This would result from striking a fine balance among water users and the environment. It is important that pricing water for the purposes of demand management or cost recovery is not confused with incorporating the cost of externalities in the price of water. Demand management may be employed to reach a particular target level of consumption to avoid large infrastructure costs such as building a dam. Countries such as Denmark have engaged in demand management pricing that has resulted in dramatic decreases in consumption (DEPA, 1999). Demand management and externality pricing are different concepts and are unlikely to coincide in practice unless the demand management target coincides with the balance that would be achieved by all water users if they all had to take the full suite of costs of their actions into account. If demand management is used without regard to the economic implications of the strategy, unintended reductions in current and future economic activity may occur. Cost recovery is about ensuring that costs are covered over a given time. Incorporating externalities in the price of water requires extensive knowledge of the incremental environmental damage (measured in dollars) associated with an incremental change in the volume of water. This will necessarily involve some first-order approximations but is very different from cost recovery strategies.

Incorporating externality costs in the price of water is in fact consistent with the meaning of economic efficiency, which is achieved by maximising the net value of water use to society. Traditionally, the net value would be calculated based on the value customers receive minus the cost of supply. The cost of supply is now being thought to include externalities. Thus, what is required is an expansion of the well-established marginal cost pricing rule, where the optimal volume to be supplied is based on where the marginal cost equals the marginal willingness to pay. However, there are short run and long run aspects to this rule. In the short run, infrastructure such as dams cannot be easily altered and as a result, marginal cost is based on the factors that are variable in the short run such as labour and pumping costs. As long as there is capacity in the system, this pricing rule will result in an economically efficient solution. However, a water utility or an irrigation district may not generate sufficient revenue to cover all its costs, especially if there are significant fixed costs associated with infrastructure such as distribution systems or wastewater treatment in the case of urban water (McNeil and Tate, 1991). Thus, goals of cost recovery and economic efficiency are not necessarily compatible in the face of large fixed costs.

A well-established solution to this problem is to use what is commonly referred to as a two-part price (Call and Holahahn, 1983). This approach fulfils the cost recovery objective while still retaining efficiency aspects. The two-part price consists of a fixed charge and a volumetric charge based on the marginal cost of supplying water. A number of utilities in Australia and in other industrialised nations (OECD, 1999) employ this strategy. This strategy allows the utility to recover costs through the fixed cost component and send economic signals through the volumetric component.

As a pragmatic approach, the current two-part price structure used by many water utilities might be adapted to incorporate some of the externalities listed in Table 1. The adapted two-part price approach in Figure 3 allows for the utility to cover costs, including the fixed externality costs, while the volumetric charge approximates long run marginal costs. The marginal cost component sends a clear signal to users to treat the resource as scarce, whether rural or urban. For instance, one-time costs to adapt the existing infrastructure to mitigate the volume-unrelated externalities such as removing weirs or installing variable off-takes as part of upgrades of dams would be included in the long run marginal cost component. The volume-related externality costs are directly related to each unit of water. From the list of externalities listed in Table 1, the loss of median flows due to water being extracted from the river and stored for use in irrigation and urban areas would be a good example of an externality that could enter the volumetric cost component. The externality charges and increases in long run marginal costs as reflected in the volumetric component would signal that there are costs associated with each unit of water.

Figure 3 represents a first step in incorporating environmental costs into the price of water. This pricing approach includes externalities and financial costs and would need to be reviewed and updated periodically. The externality charges might eventually take into account summer and winter conditions.

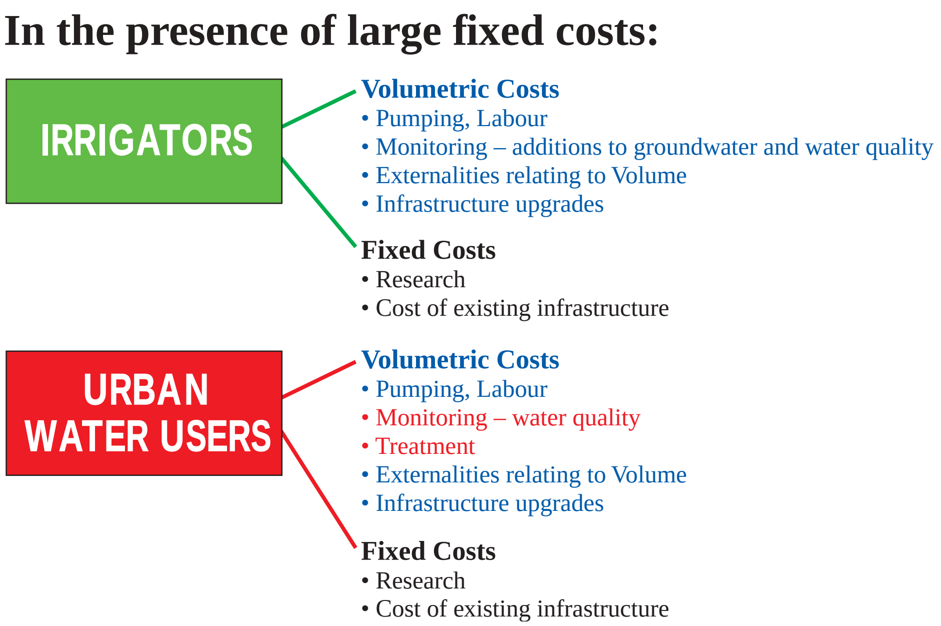

Figure 3. A two-part price involving externalities

Infrastructure and operational issues associated with environmental flows

To be environmentally useful, the natural flow regime will need to be reproduced, including the quality and temperature of the water released. The desired flow regime to enhance the health of the River Murray has been estimated and is set out in Table 2. In general, what is needed is the return of floods of sufficient volume during the right period of the year to inundate floodplains and the maintenance of minimum flows during the dry season: this is quite different from the requirements of irrigated agriculture.

The infrastructure to store and transfer water in the River Murray is currently not well adapted to reproduce a natural flow regime. For example, in the major reservoirs (Dartmouth, Hume, etc.) coldwater pollution presents a problem as dam off-takes are located in the hypolimnion of the reservoirs (i.e. in the colder bottom layer of water when the reservoirs are thermally stratified). Coldwater pollution is problematic because one of the important goals of generating floods is to induce spawning in native fishes. Most native fishes will not spawn unless water temperature is greater than 16°C, well above the temperature of hypolimnetic releases from many reservoirs (MDBC, 2000). The potential infrastructure costs to manage environmental flows varies from minor with improvements such as fish ladders to significant with infrastructure such as variable off-takes on the major reservoirs to prevent coldwater pollution.

Operational issues

In addition to the one-time costs associated with the upgrade of infrastructure, a series of less tractable operational costs will be associated with the generation of environmental flows. The timing of environmental flows will not always be optimal for other users of the water. For example, draw-down events could impact the tourism and recreation industry by impeding boat traffic, diminishing the value of recreational property along the Murray system and reducing the ability of some irrigators to pump directly from the River. As another example, at Dartmouth Dam, one of the environmental flow recommendations is to not have releases at channel capacity for more than five days in a row. This

Table 2 Summary of the improved flow regime proposed for the River Murray entering South Australia

River	*Flow regime*
River Murray – Main channel	• 40 000 ML/d for up to 8 weeks 1 year out of two (late spring) • Two month draw down in late spring–early winter accompanied with 10 000 ML/d flows (to prevent blue-green algal blooms)
River Murray – Floodplain	• 80 000 ML/d once every 3 years for up to 8 weeks (spring) • 110 000 ML/d once every 5 years for up to 8 weeks (spring) • 150 000 ML/d once every 10 years for up to 8 weeks (spring)

Note: 1 ML = 1 000 000 litres = 1000 m^3 of water
Source: RMCWMB (2003a)

would reduce how much water can be released for irrigators on a monthly time scale. However, this would be partially offset by an increased potential for hydroelectric power generation.

Work is ongoing to establish how environmental flows could be managed. It is likely that an incremental approach towards the upgrade of infrastructure will be taken. For example, environmental releases from reservoirs will first be attempted using coldwater releases. However, over time, if the environmental benefits of coldwater releases appear limited, off-takes may have to be upgraded to enable releases from variable depths within reservoirs.

Externalities not addressed by volumetric externality charges

One environmental externality that would not be fully addressed by environmental flows alone is salinity. Due to a number of factors (Allison *et al*., 1990; Jolly *et al*., 2001), the salinity of the river is increasing and may compromise its use for drinking and irrigation in the future. States in the Murray-Darling Basin have set a series of salinity targets. These salinity targets are currently met through a combination of dilution flows and salt interception schemes where highly saline groundwater is pumped out before entering the river.

The increase in salinity also has other significant environmental implications, especially in the floodplains of the river. In semi-arid climates, floodplains are often the most ecologically productive component of the landscape and include riparian forests, wetlands, anabranches, etc. (see Jolly, 1996, for a summary of salinity impacts on floodplains). Approximately 25% of the floodplain area of the Murray system is currently affected by salinity, with this proportion potentially increasing to 50% by 2050 without remedial action (RMCWMB, 2003a). Politically, several floodplain areas have been targeted as key ecological assets or icon sites in the Murray-Darling Basin. Overall, floodplain salinity appears likely to be the environmental externality that will be most difficult to manage in the River Murray. Increased environmental flows will have the indirect benefit of improving salinity in the main channel through increased dilution flows. Environmental flows, especially the return of more frequent small and medium-size floods, would also help to alleviate floodplain salinity. Because of the modest size of the increased environmental flows recently announced, 'engineering options' will also have to be considered to mitigate floodplain salinity. Groundwater intervention schemes adapted to mitigate floodplain salinity will not be sufficient in some of the more highly effected areas. The costs of new salinity interception schemes would be an example of the types of costs that would enter long run marginal costs for irrigators and urban water users.

Other components of the floodplain salinity externality will be difficult to attribute to particular users. For example, raised water levels behind weir pools increase waterlogging in the floodplain and induce salinisation. Almost all users of the river derive some benefits from the presence of weir pools, including irrigators, cities, boat users, etc. However, it is not clear at present which group or groups of users or agencies have responsibility for the environmental externalities generated by weir pools and how this cost should be shared.

Implications of full cost pricing for land-use and infrastructure

The pricing approach suggested in Figure 2 provides a way of incorporating the full suite of costs in the price of water while ensuring that all fixed and operational costs are covered. The externality costs can enter on either the fixed or volumetric side of the price of water depending on whether or not the externality was directly related to the volume of water extracted and used.

In our example of the lower reaches of the River Murray, the city of Adelaide draws approximately 40 to 70% of its water from the River Murray with the remainder coming from the Mount Lofty region. Thus a volumetric externality charge for urban water users in Adelaide might entail a Mount Lofty component and a Murray component which could be quite different from year to year. A volumetric externality charge relating to location of extraction, if transparently conveyed, has the potential to drive spot markets for water. The current mix of water sources for the Adelaide metropolitan area is based on availability, sustainable yield of aquifers and water quality. The environmental externality costs would enter as one more factor to be considered.

It is important to remember that Adelaide is a small user of River Murray water compared to irrigation. Based on Adelaide's permanent allocation of River Murray water, which is approximately 130 GL per annum (650 GL five-year rolling average), urban water represents 1% of the Murray-Darling Basin long-term diversion cap by valley (11 561 GL). Returning environmental flows will require more than water conservation in Adelaide. Further, it will be important that an externality charge be applied to all water users whether rural or urban. If only urban users or some irrigation districts pay an environmental externality charge, water pricing will be further distorted from a full cost pricing approach.

By pricing urban and rural irrigation water to reflect the full costs including environmental externalities, there is an opportunity to use water according to its highest value. This pricing approach has the potential to shift how and where water is used in both rural and urban environments. A volumetric externality charge would convey the incremental costs to the environment of losses in environmental flows. As these signals are conveyed, irrigators may elect to invest in water saving irrigation systems or sell their entitlements. Urban users may reduce their discretionary use of water. The externality charge will not eliminate all externalities but will adjust the quantities of water being used by the environment and water users. This is the crucial difference between incorporating an externality charge in the price of water and adjusting prices for demand management. Externality charges attempt to strike a balance between competing uses and avoid over-investment while demand management seeks to contain water use below a particular level.

In Australia, the CoAG water reforms represent an opportunity to place water use and future infrastructure development on a more sustainable footing through the incorporation of externalities in the price of water. There is, however, a real possibility of moving water to other uses and potentially stranding existing irrigation assets in parts of the Murray-Darling Basin. If too many irrigators in a particular area sell their rights to water, the irrigation group may not be viable and this clearly has social costs and implications for the surrounding communities. Further, rural communities have questioned the economic and social costs of buying back water because of the anticipated limited benefits of current environmental flow proposals. Adapting and upgrading infrastructure and other non-flow expenditures may be a better investment, according to these communities.

As a society, Australia will have to consider the costs and benefits of introducing externality charges along with other policies for managing externalities where charges are not feasible. There are a whole set of tangible and intangible benefits to consider as well as the costs of establishing the cost of externalities. The timing and pace of change will be important for the communities affected and the environment as there are distributional implications.

There is an opportunity to link the bio-physical sciences closely with the economics of water to establish a sound scientific basis for water pricing. By including externalities charges where feasible and the cost of improved infrastructure in long run marginal cost of water for irrigators and urban users, water consumption will be moving closer to an economically efficient and environmentally sustainable basis. Future research in this area will require close collaboration between disciplines in order to establish these externality charges.

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References

Australian Academy of Technological Sciences and Engineering and the Institution of Engineers. 1999. *Water and the Australian Economy*, Australian Academy of Technological Sciences and Engineering, Parkville, Vic.

Allison, G.B., Cook, P.G., Barnett, S.R., Walker, G.R., Jolly, I.D. & Hughes, M.W. 1990. Land clearance and river salinisation in the western Murray Basin, Australia. *J. Hydrol.*, **119**, 1–20.

Bjornlund, H., McKay, J. and Pisaniello, J. 2001. *Water: Waste Not, Want Not*, Consultation Report for the Water Conservation Partnership Project, [Online] Available from: http://www.environment.sa.gov.au/sustainability/pdfs/water_report.pdf

Call, S. T. and Holahan, W. L. 1980. *Microeconomics*, 2nd ed., Wadsworth Publishing, U.S.

Close, A. 2002. *Options for reducing the risks of closure of the River Murray Mouth*, *MDBC Technical Report*, No. 2, Murray-Darling Basin Commission, Canberra.

Council of Australian Governments [CoAG]. 2003. *Communiqué*, 29 August 2003, http://www.dpmc.gov.au/docs/coag290803.cfm

Council of Australian Governments [CoAG] 2004. *Intergovernmental Agreement on a National Water Initiative*. 25 June 2004.

Crabb, P. 1997. *Murray-Darling Basin Resources*. Murray-Darling Basin Commission, Canberra.

Danish Environmental Protection Agency. 1999. *Economic Instruments in Environmental Protection in Denmark*, Ministry of Environment and Energy, Copenhagen.

Dyson, M., Bergkamp, G. and Scanlon J. 2003. *The Essentials of Environmental Flows*. International Union for Conservation of Nature, Gland, Switzerland.

Jolly, I.D. 1996. The effects of river management on the hydrology and hydroecology of arid and semi-arid floodplains. In: *Floodplain Processes,* M.G. Anderson and P.D.Bates (Eds), Wiley, New York.

Jolly, I.D. *et al*. 2001. Historical stream salinity trends and catchment salt balances in the Murray-Darling Basin, Australia. *Marin. Freshwater Res.*, **52**, 53–63.

McNeill, R. and Tate, D. 1991. *Guidelines for municipal water pricing. Social Science Series* No. 25, Environment Canada, Ottawa.

Murray-Darling Basin Commission. 2000. *Report of the River Murray scientific panel on environmental flows*. Murray-Darling Basin Commission, Canberra, Australia.

Murray-Darling Basin Commission. 2002, *The Living Murray: A discussion paper on restoring the health of the Murray-Darling Basin*. Murray-Darling Basin Commission, Canberra, Australia.

Murray-Darling Basin Ministerial Council. 2003. *Murray-Darling Basin Commission Ministerial Communiqué, 14 Nov*., Murray-Darling Basin Ministerial Council, Canberra, Australia.

Musgrave, W. 1999. The political economy of price reform in Australia. In: *The Political Economy of Water Pricing Reforms*, A. Dinar (Ed.), Oxford University Press, New York.

National Competition Council. 2003a. *Assessment of government's progress in implementing the National Competition Policy and related reforms: Overview of the National Competition Policy and related reforms*, [Online], Available at: http://www.ncc.gov.au/pdf/AST5Ov-010.pdf

National Competition Council. 2003b. *The 2003 National Competition Policy Assessment Framework for Water Reform*, National Competition Council, Canberra, Australia.

Organisation for Economic Co-operation and Development. 1999. *The price of water: trends in OECD countries*. Organisation for Economic Co-operation and Development, Paris.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E. and Stromberg, J.C. 1997. The natural flow regime. *Bioscience*, **47**, 769–784.

River Murray Catchment Water Management Board. 2003a. *Catchment water management plan for the River Murray in South Australia 2003 – 2008.* Government of South Australia.

River Murray Catchment Water Management Board. 2003b. *Understanding the Water Allocation Plan for the River Murray*. Government of South Australia.

Rogers, P., de Silva, R. and Bhatia, R. 2002. Water as an economic good: how to use prices to promote equity, efficiency and sustainability. *Water Policy,* **4**, 1–17.

South Australia Department of Water Resources. 2000. *State Water Plan*. Department of Water Resources, Adelaide, Australia.

Young, M., Gillooly, J. and Marvanek, S. 2003. *Quantifying and valuing land-use change for ICM evaluation in the Murray-Darling Basin*. CSIRO Land and Water Project Report.