Valuing Benefits of Increasing Irrigation Water Use Efficiency

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A false expectation based on the notion that it is easy to raise water use efficiency, and that all increases in water use efficiency will also increase net social welfare, will lead to gross underestimation of the economic impact of reduced irrigation allocations in the Murray-Darling Basin. A conventional benefit:cost analysis of policy options founded on an understanding of biophysical processes, sound accounting principles, a knowledge of the appropriate response functions and the economics of best operating conditions will reduce the potential for government failure. Some myths, pitfalls and traps for the unwary analyst or policy maker are outlined.

Key words: Irrigation, water use efficiency, policy, net social welfare.

1. INTRODUCTION

Because of a growing concern about the riverine environment, there are calls to increase environmental flows in the Murray-Darling Basin (WWF Australia, 2002). Allocations for consumptive use in the connected Murray River system would fall under a series of proposed scenarios by 350 gigalitres (GL), 750 GL or 1500 GL (Murray-Darling Basin Commission, 2002); and by 750 GL, 1630 GL or 3350 GL (Young et al, 2002) as shown in Figure 1.

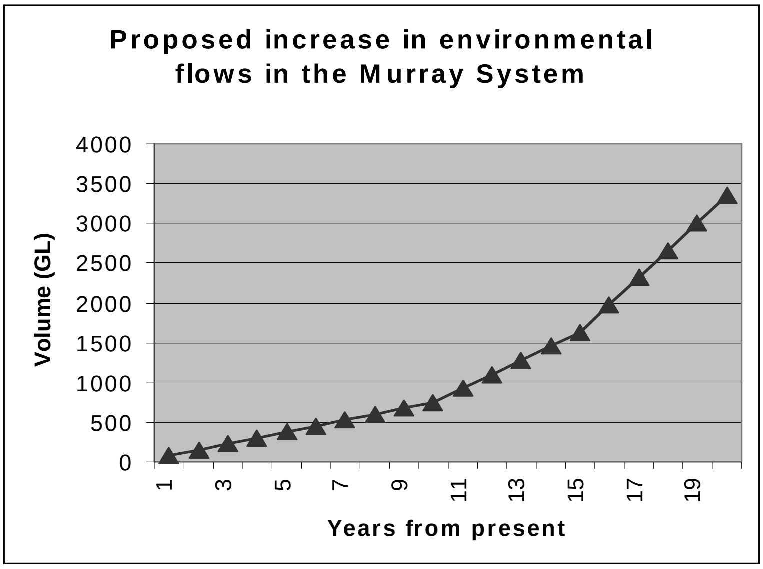

Figure 1: Schedule of increased environmental flows proposed for the Murray System (after Young et al, 2002)

Increasing environmental flows on this scale is a big idea. While there may be some complementary outputs in river management, environmental flows and consumption are ultimately competitive uses. On an area basis, the increased environmental flow scenarios contemplated by Young et al have the potential to reduce the area of irrigated agriculture[1] by 95,000 hectares, 200,000 hectares or 420,000 hectares. This is equivalent to wiping out irrigation in Northern Victoria.

Increasing the efficiency of irrigation water use is seen as a way to offset reduced allocations. Indeed some see increasing water use efficiency as the next quantum leap in water resource

[B] Department of Primary Industries, Tatura, Victoria.

[1] Irrigation intensity of 8 ML/ha

development. Options such as reducing water storage and transmission losses, improving irrigation efficiency and improving plant water use efficiency can help maintain production under reduced water availability. And switching from production of “low value” to “high value” commodities can increase gross value of returns. However the costs of implementing these options must constitute a critical economic constraint to the adoption of these solutions.

Inefficiencies in water use are defined, the illusory nature of some proposed savings is explained and a method for valuation of real savings in comparison to costs of proposals is described. A market estimate of the impact of proposed increased environmental flows is then considered in a policy framework where the capped water resources are re-allocated between consumptive use and environmental flows. This treatment of these issues is of necessity uncomplicated by the exceptions of local situations. This is not a major difficulty if real options are examined in detail using benefit:cost analysis principles before policy changes are made or investment is sunk.

2. NATURE OF INEFFICIENCIES

2.1 Technical Inefficiency

2.1.1 Irrigation System Losses

2.1.1.1 Channel Outfalls and Paddock Tail water

Flows exceeding demand spill over the end of the channel or drain off the end of the irrigated paddock. Estimates of combined gross losses range from 25-50% of stream diversions.

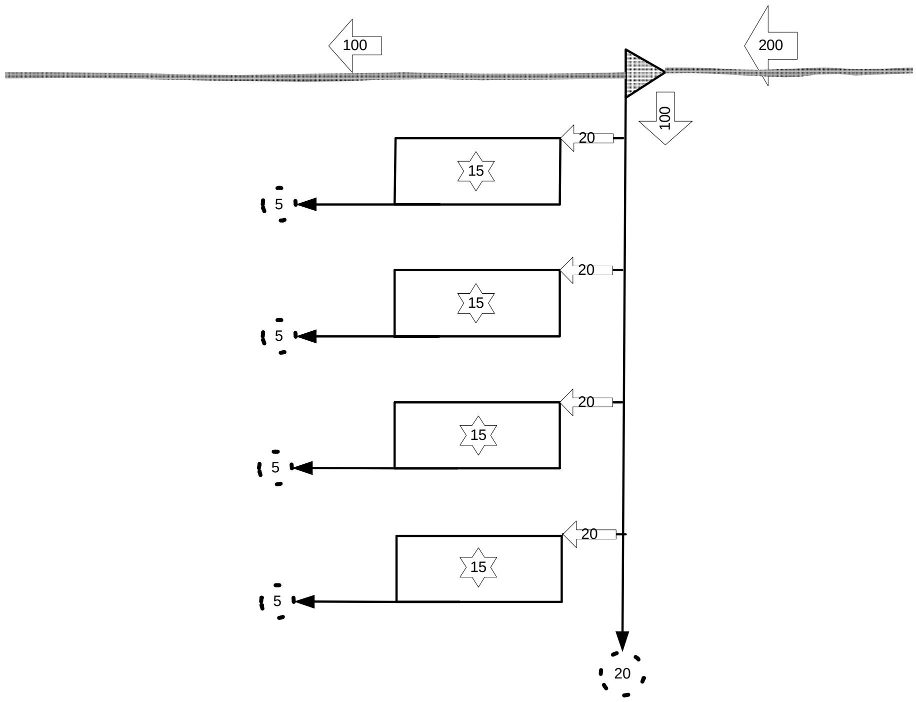

Figure 2: Schematic illustration of water flows for an irrigation system with 40% gross outfall and paddock tail water losses. Arrows show flow volume and direction, star symbols indicate consumptive use and dotted circles show volume of losses

The magnitude of real or net losses depends on the ability to recycle within the irrigation system or return excess flows to the river. Returned flows contribute to environmental flows.

Figure 3 shows the same system where diversions exceeding irrigation demand flow back to the river via the farm and district drainage network. In this example excess flows of 40 GL return to the river. Net diversions are 60 GL

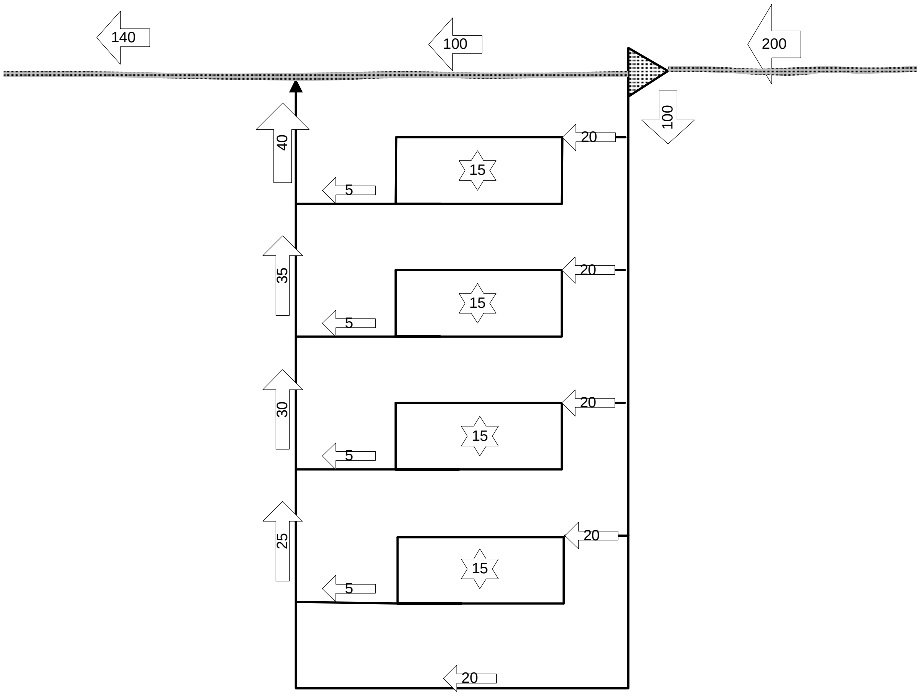

Figure 3: Schematic diagram of water flows for an irrigation system with 40% tailwater and outfall losses returning to the river.

2.1.1.2 Seepage

Water that seeps below the channel bottom or the root-zone in the irrigated paddock. Gross losses depend on channel/pipe materials, length of irrigation season, soil type, irrigation technology and management.

Magnitude of real or net losses depends on the proportion of groundwater returning to the river and the ability of sub-surface drainage systems to recycle groundwater accessions.

2.1.1.3 Evaporation

Gross losses are in the order of 15-20 ML/ha of water surface depending on climate. These losses are not recoverable, except that within irrigation areas increased humidity from evaporation may moderate plant water demand.

2.1.2 Plant Water Use Inefficiency

There are diminishing returns to increasing water use intensity (irrigation or rainfall) as other factors of production become limiting.

2.2 Economic Inefficiency

The assumption here is that, given the market for produce, water resources are irrationally allocated to low value enterprises.

3. IDENTIFYING PROSPECTS FOR REAL SAVINGS

3.1.1 Irrigation System Losses

3.1.1.1 Channel Outfalls and Paddock Tail water

Since returned flows already contribute to downstream allocations there are no system savings obtained from reducing return flows. This simple algebraic reality obliterates the major hope of increasing catchment water resources. Figure 4 shows that eliminating tail water losses and channel outfalls and supplying only crop irrigation demand does not create new water. Net diversions are still 60 GL and downstream flows are not increased above 140 GL

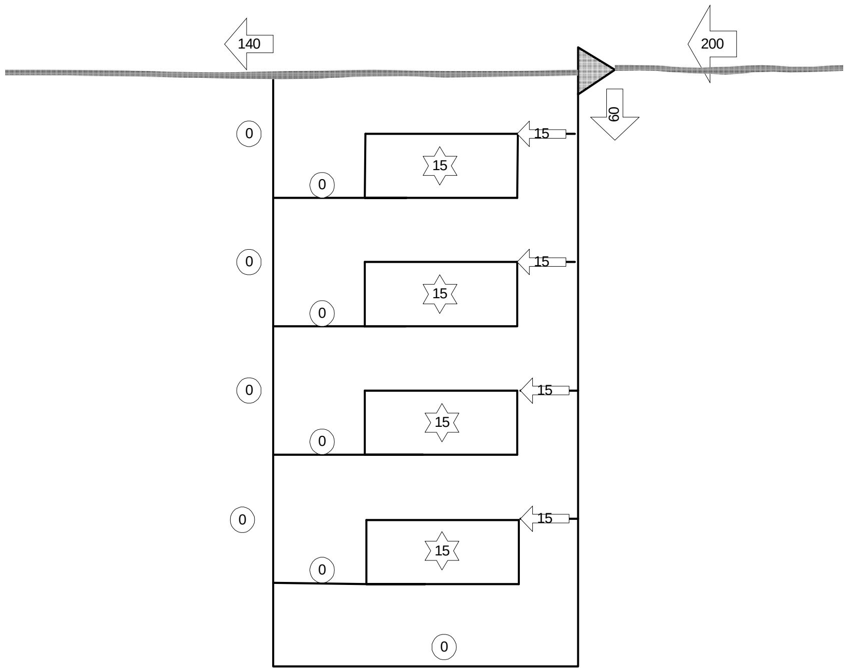

Figure 4: Flows in system when perfect control in water delivery and irrigation water use is attained. No water savings benefit is obtained.

Conceptual difficulties occur when only parts of a system are considered. Outfalls are in fact spillovers. They may be negative spillovers as losses from one part of the system. But they are positive spillovers for the downstream component.

At the basin scale there is basically only one outfall, through the barrages at Goolwa, close to the mouth of the Murray. Calling transfers between jurisdictions “losses” and then aggregating “losses” from each of the *n* jurisdictions introduces an iterative process of nonsensical double counting between jurisdictions all the way down the system.

3.1.1.2 Seepage

Given the interconnectedness of surface and groundwater systems, seepage losses are also spillovers. The prospects for real savings depend on the extent to which seepage is used as a water resource and the time lag between accessions and groundwater pumping.

If seepage is already being recycled by existing groundwater pumps, the only real savings from seepage reduction are reduced operating and maintenance costs for the groundwater pumps.

3.1.1.3 Evaporation

Prospects for real savings depend on opportunities to decrease specific exposure by reducing the surface area exposed to evaporation and/or increasing the water depth of storages. Options include piping open channels and changing system operating rules and decommissioning shallow storages such as Lake Mokoan and Lake Alexandrina (Anon, 2001).

3.1.2 Plant Water Use Efficiency

Given a reasonable standard of management, increased production per unit of water can only be obtained by investing in developing and adopting new production technology. The adoption of higher harvest index semi-dwarf wheats in the 1980s is an outstanding example. Other options include regulated deficit irrigation of peaches and partial root zone drying of winegrapes using drip irrigation technology, amelioration of physical and chemical constraints to soil fertility and development and/or introduction of plant types more suited to the climatic conditions experienced. An example of the latter option would be the replacement of temperate C3 photosynthetic pathway species with more water use efficient sub tropical C4 plants for summer production.

3.2 Economic Efficiency

It is often suggested that because horticulture has high gross margins per megalitre, and modern horticulture can deliver high water use efficiency, that the best policy solution for increasing water use efficiency is to mandate or subsidise horticultural use.

Unfortunately the market reality does not support this policy option (if the objective of policy is to increase net social welfare). Commodity composition is in loose equilibrium with capital markets because the mobility of capital in market economies leads to equal rates of adjusted[2] **net** return in all activities. For commodity composition to change dramatically, extensive changes in demand for irrigated produce is necessary. This may be engendered by trends in global demand (Hooke, 1997) and development of new production technology conferring a comparative advantage to local production. Until then, too rapid expansion into horticulture is a recipe for financial ruin.

4. VALUING WATER SAVINGS

4.1 Market prices

Water markets have been operating for more than a decade (Simon and Anderson, 1990). It might be argued that proxy water markets have operated longer than this through land sales in irrigation regions but the nexus between land and water property rights has only been broken in an institutional sense over the last decade or so. Average prices for permanent transfer of water right in recent years in a number of irrigation areas is shown in Figure 5. The price dispersion can largely be explained by the expected mid to long run average allocation on different systems, by immediate seasonal allocations prevailing and by other factors such as locational variability in terms of institutional arrangements, prices for inputs and commodities and climate (Colby et al, 1993).

[2] Adjusted for market risk, existence of sunk capital, production uncertainty etc..

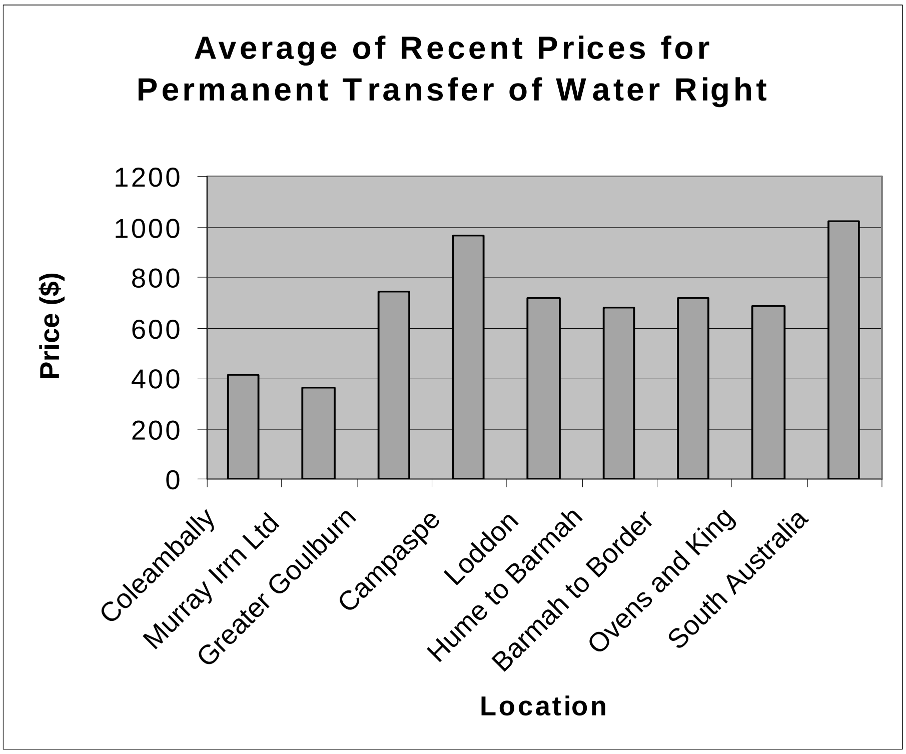

Figure 5: Average recent prices for permanent water right. Because of different allocation policies on different irrigation systems the figure does not indicate the price of permanent entitlement to annual delivery of one megalitre. (Data after Marsden Jacob in ACIL (2002)

When these factors are taken into account a price of $500-$600 per megalitre of permanent entitlement to annual delivery seems a reasonable estimate of the recent market price of water.

4.2 Are Market Prices Appropriate?

Given the existence of water markets, and land and water management plans to manage or tax the external impacts of irrigation, one might wonder why an economist is needed to estimate the value of water under different allocation scenarios. Perhaps it is thought necessary to factor in the elasticity of demand for produce. But isn't this what markets do?

Markets facilitate the transfer of rights between willing buyers and willing sellers. Trade occurs when willingness to pay (WTP) at least equals willingness to accept. Provided buyers and sellers are equally well informed, the equilibrium market price of water will represent the net present value (NPV) of the future stream of benefits flowing from the water entitlement in either use. Buyers and sellers will base their estimate of the value of water on the expected timing and magnitude of the additional production from irrigation using the entitlement, the expected market value of the additional produce, the magnitude and timing of additional costs and the required rate of return on marginal or core capital, whichever is appropriate.

There seems to be some underlying policy apprehension that reluctant sellers are seeking inordinately high rents from speculation. Despite the fact that the use of futures trading to manage risk in agricultural markets relies purely on speculation, some consider it inappropriate to speculate on the value of water. Yet, given the uncertainty inherent in the estimation outlined above, a non-speculative valuation is impossible. Kasper (1999, p154) argues economic agents are motivated by bounded entrepreneurial rationality and "*make their decisions within the bounds of available, but limited knowledge and take risks to overcome existing constraints*". This then leads to the question:- "If economists are better at speculating on market values, why aren't they participating in the market?" Surely, to be effective in guiding profitable investment, an economic model must reconcile its output with the reality of market prices.

4.3 Reconciling Willingness to Pay and Willingness to Accept

A large part of the perceived gap between the NPV of water in "high" and "low value" uses is due to the inappropriate use of unadjusted gross margins as a means of comparison. The annualised additional capital development costs should first be deducted from the gross margin of the expanding enterprise. This substantially reduces the annual <u>net</u> margin for the "high value" use. The relative present value of the "high value" net margin will be further reduced when discounted at the desired rate of return on marginal capital rather than the low discount rates used for sustainability of core capital advocated by Quiggin (1992).

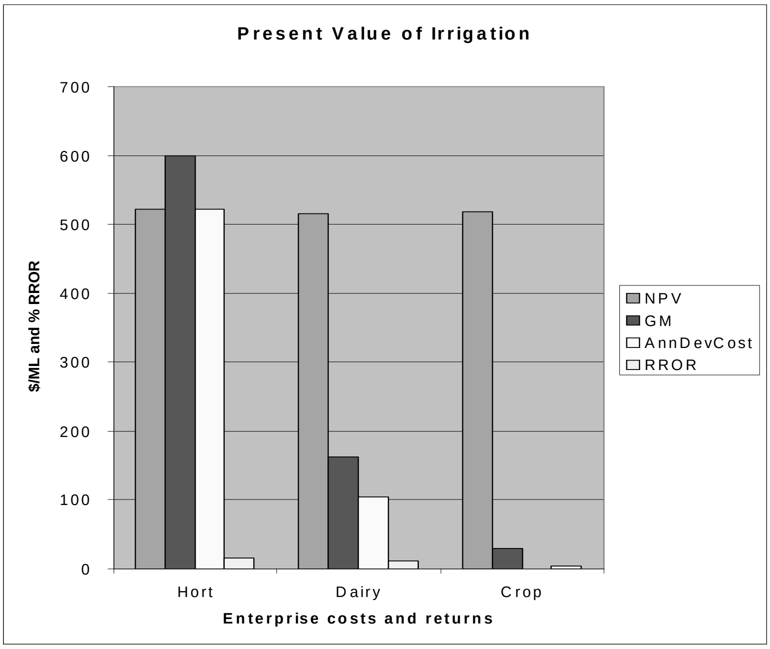

Figure 6: Present value of existing and new irrigation

Figure 6 shows how inclusion of development costs and risk adjusted discount rates reconciles a large disparity in gross margins between enterprises. In this example, the NPV of irrigated development in horticulture and dairy generating gross margins of $600/ML and $163/ML respectively is much the same as that of an existing irrigated grazing enterprise with a gross margin of $30/ML.

5. EFFICIENT EXPANSION OF IRRIGATION

Randall (1981) defines the economically efficient extent of irrigation development as that point where resource cost, social cost and opportunity cost for water are equal. Figure 7 shows a demand curve for consumptive use of water and a supply curve for regulation, storage and delivery. The intersection of the demand and supply curves indicates the extent of development where resource cost and opportunity cost are equal.

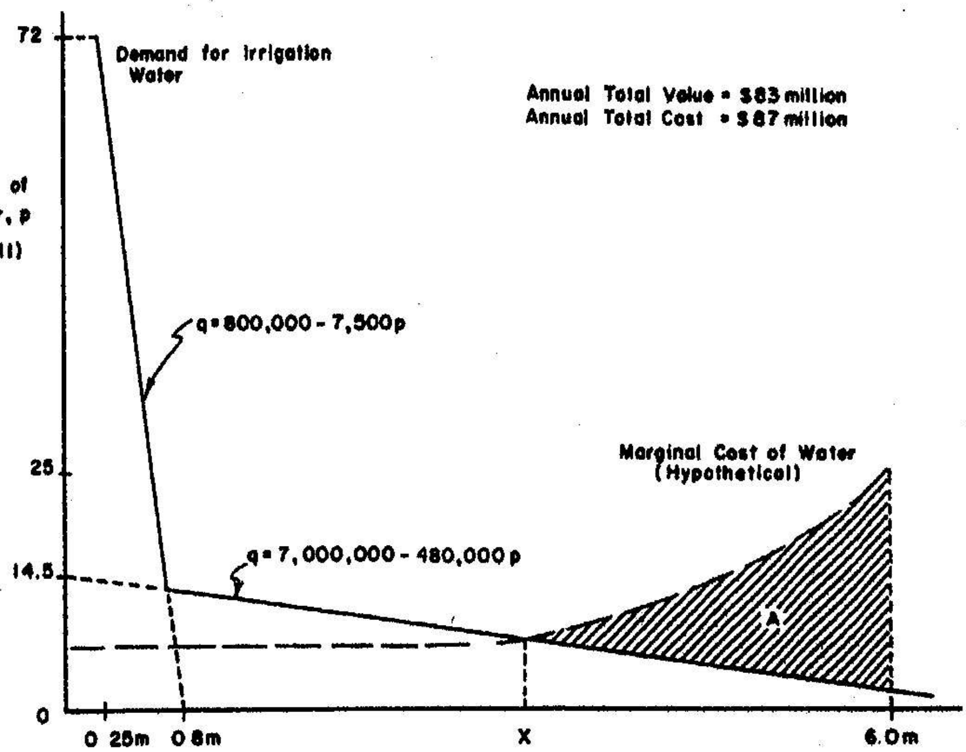

Figure 7: ***"Estimated demand for Murray-Darling irrigation water. and (hypothetical) marginal cost "*** **after Randall (1981)**

Davidson (1969) and Clark (1967) point out that for a scenario where consumptive use is expanding the demand curve should be a long run demand curve. That is development costs incurred by water users should be taken into account.

Given the subsequent preparation and implementation of LWMPs it may be assumed that the external costs of salinity and nutrients are now included in the resource cost (albeit at levels set under MDBC agreements).

Randall (1994) proposed an approach to the allocation of natural resources to the environment whereby a safe minimum standard (SMS) quantity that ensures the viability of bio-diversity is guaranteed. Beyond this minimum, economic efficiency is attained through allocation of surplus resources to competing uses, of which the environment is one. Under this approach one can envisage a demand curve (dotted line E E in Figure 8) for environmental flows which is initially extremely inelastic (SMS) but later increasingly elastic. With knowledge of the demand curves for environmental flows and consumptive use, and given the yield of a catchment, it is possible to determine the economically efficient allocation of water to these competing uses. The water resource development supply curve is not relevant in a post development analysis. The opportunity cost of environmental flows would be relevant in a pre-development appraisal.

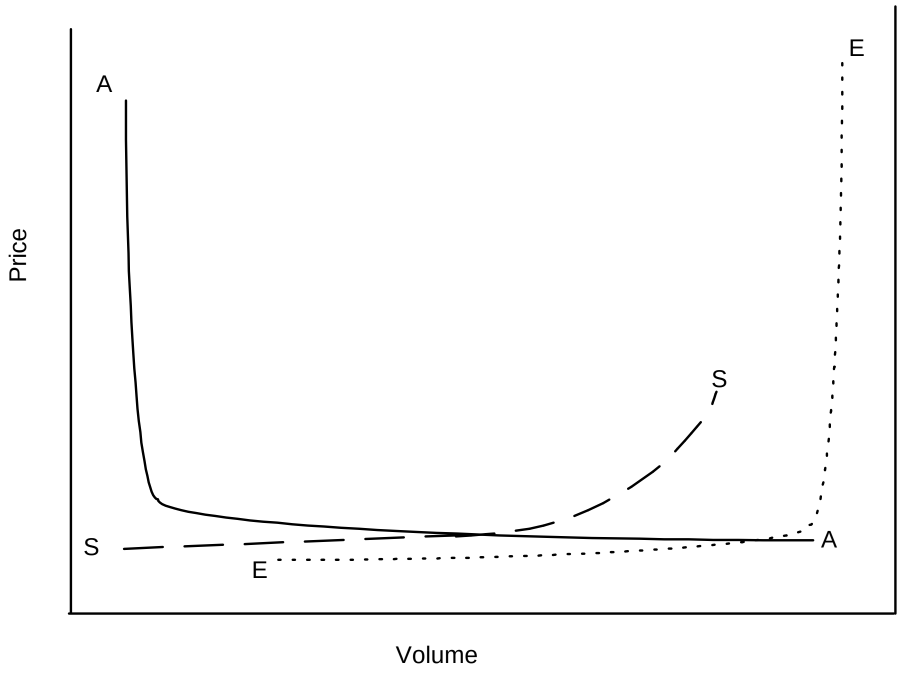

Figure 8: Intersection of hypothetical demand curves for consumptive use and environmental flows indicating optimal allocation of a limited resource to competitive uses after development.

6. EFFICIENT CONTRACTION OF IRRIGATION

If allocations for consumptive use must be reduced, the short run demand curve for consumptive use (dashed line A_2 A_2 in Figure 9) should be used to trade off agricultural and environmental demands as the long run agricultural development costs are already sunk. Using this demand curve will shift the socially optimum allocation rightward. How far rightward will depend on the shape of the demand curve for environment E_2 E_2.

6.1 Estimating impacts of reduced agricultural allocations

Using recent market prices the cumulative cost of purchasing water entitlement for the full implementation of the scenarios outlined in Young *et al* (2002) is $1.8 billion. The present value of the cost of the scheduled acquisition is $940 million. Given the demand curve for consumptive use this must be very much an under estimate. Yet this very underestimate is roughly double the estimate by Young *et al* of $450 million for a scenario where there is no adjustment through investment in increased water use efficiency. Higher environmental flow regimes may bring some benefits to downstream consumptive use through lower salinity levels. But the value of these benefits is relatively minor. And Quiggin (1988) has shown the rational national adjustment to salinity is to move salt sensitive uses upstream. However water markets may move development to areas of comparative advantage, parochial state interests and sunk capital will limit the rate and extent of adjustment.

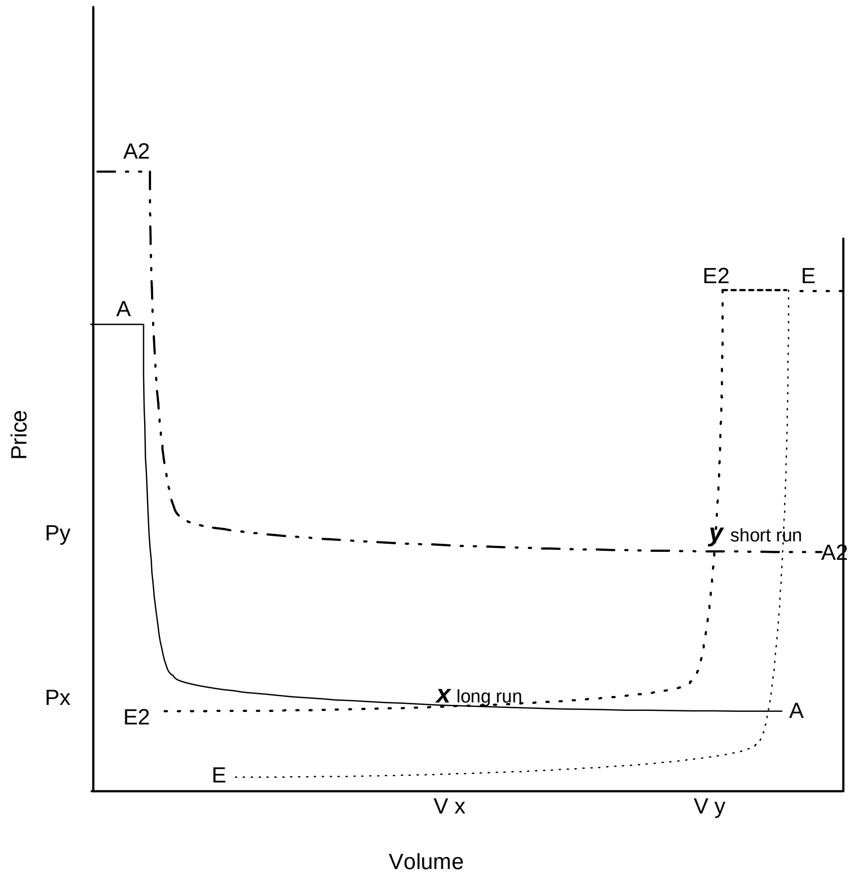

Figure 9: Intersection of hypothetical short and long run agricultural demand curves with hypothetical environmental flow demand curves

7. RATIONALE FOR INVESTMENT IN WATER USE EFFICIENCY

Private and public investment should yield increased profit and net social welfare. The corollary of this is that it is foolish to promote a state of higher technical efficiency if the benefits of being there don't exceed the costs of getting there. Thus the appropriate evaluation of proposed intervention should be based on a conventional financial or benefit: cost analysis and its implementation driven by cost sharing arrangements recognizing private and public net beneficiaries (Mishan, 1976).

While there is a growing realisation that investment in unprofitable efficiency gains is nonsensical, there is a continued clamour by vested interests for funding of unprofitable projects.

The most outlandish proposals are for the funding by government of water authorities' projects to reduce outfalls in exchange for increased environmental flows. These arrangements amount to plunder of the property rights of water entitlement holders. This is so because as the net effect on environmental flows is zero as shown in Figure 4. Hence additional water must be released from storage to keep the bargain to increase environmental flows. The additional releases mean allocations to irrigators are reduced. It can be seen as a scheme by water authorities to appropriate and sell part of irrigators' bulk water entitlements. Such fraudulent schemes promote an opposite view to that of Randall (1981) who advocated that "*The simplest solution, it seems, would be to vest ownership of all tailwaters with the original water title holder*".

7.1 *Scope for profitable investment in Water Use Efficiency*

As Adam Smith said "*It is the maxim of every prudent master of a family never to attempt to make at home what it will cost him more to make than to buy*." On this basis it would seem difficult to justify investment in water savings projects that cost more than the market price. An estimated supply curve for water savings is shown in Figure 10. A market price of $500/ML is also indicated. The fact that there are no savings identified below the market price and very limited volume is available at the market price indicates the market is well informed and operating efficiently.

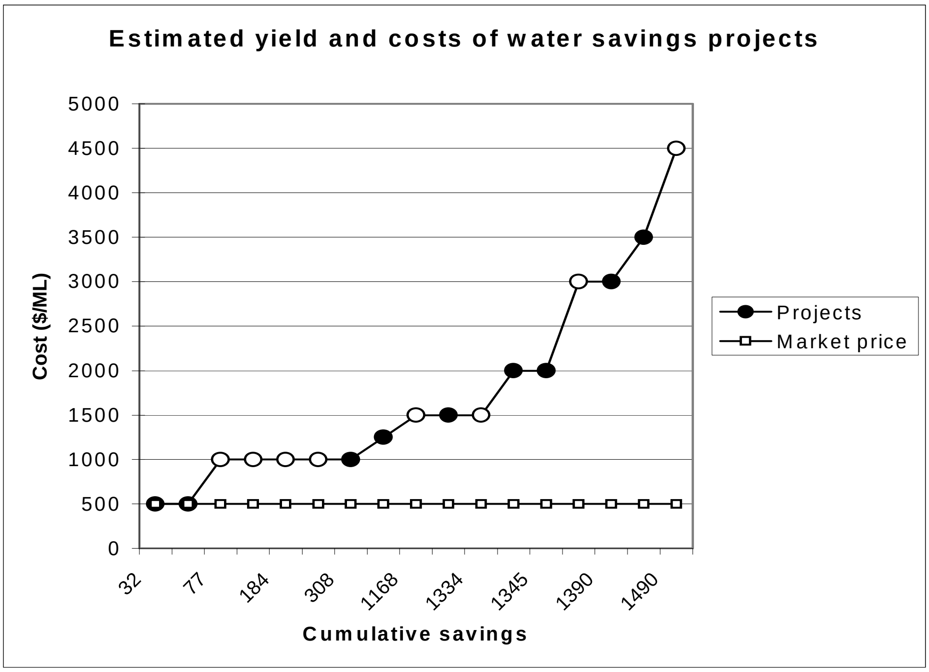

Figure 10: Estimated cost and yield of water savings projects. Note that white circles indicate projects where savings are at best dubious, illusory or non-existent.

After considering the dubious, illusory or non-existent nature of the water savings claimed for many of the proposed projects (indicated by white circles) Figure 10 shows that the prospects for obtaining high volumes of real water savings at any cost are very limited.

In comparison to the proposed increased volumes for the environment, Figure 11 shows only a couple of projects with a significant volume of potential real savings identified in the connected Murray system. These are 123 GL for on-farm options and channel sealing in the Murrumbidgee irrigation area ABARE (2001) and 800 GL for reduced evaporation losses from Lake Alexandrina and Lake Albert (Anon 2001). These savings may come at a cost of $1000/ML and $1250/ML respectively.

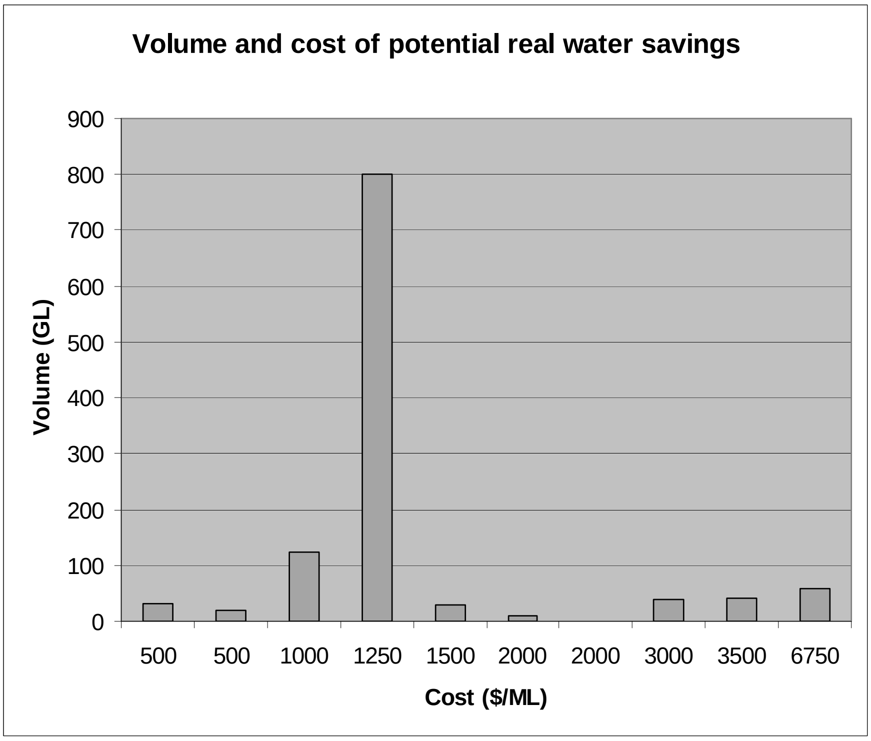

Figure 11: Volume and cost of potential real water savings identified in the connected Murray system.

7.2 Policy Options to Cope with Scarcity

Taking $500/ML as the market price for permanent entitlement to delivery of irrigation water, Figure 10 shows that there are no economical technical solutions to the problem of overuse of water resources by competing uses. Because catchment yield is limited by biophysical factors and the efficiency of use is limited by economic constraints to the adoption of technical solutions, a system of rational allocation is needed if unacceptable levels of degradation are to be avoided (Hardin, 1968). One existing possibility is the water market where *"The economist can imagine circumstances in which, for example, organised groups of recreationists and wildlife enthusiasts would purchase water entitlements and leave them unused to augment, at their own expense, in-stream flows beyond the required minima. Realistically, one would not expect such behaviour to be especially prevalent. But it is hard to conceive of any resource misallocation which would result from its occurrence"* Randall (1981). Indeed, the ACF recently indicated it would not support property rights for water for the environment while it could obtain increased environmental flows more cheaply through the political process (Moss, 2002).

8. CONCLUSION

Market prices indicate the net present value of existing and new irrigated agricultural development opportunities at the margin of regional resources. The short run demand curve for irrigation water shows that this marginal value will increase sharply as supply diminishes. That governments have indicated willingness to pay double the market price for water savings projects may indicate either a reluctance to allow an adjustment to policy decisions through the market or an anticipation that market prices will rise dramatically in response to increasing scarcity. This further underscores the prevailing gross underestimation of the agricultural impact of reduced allocations based on some economic modelling.

To the extent that LWMPs tax and manage the external impacts of irrigation, market prices indicate the social cost of moving water out of agriculture. Little is known of the demand curve for environmental flows but institutional reform allowing wider access to the water market would make the derivation of environmental demand an academic exercise.

This examination of the nature of water losses due to inefficiency has outlined basic principles and a detailed analysis should be carried out to evaluate major prospects. But notwithstanding this caveat, the majority of anticipated savings from most projects promoting increased water use efficiency are illusory due to errors in logic and the inability or reluctance of the promoters to view water flows in a systems context. A promising prospect for real increases in effective water resources from reduced evaporation is the decommissioning of Lakes Alexandrina and Albert as irrigation storages (Anon, 2001). While there are no currently economical options for greatly increasing water resources in the connected Murray system some may become so as market prices rise in response to reduced allocations for consumptive use. Some very high cost proposals such as pipelining are being promoted on the basis that water savings will be transformed into expertly marketed produce of "high value" far exceeding the cost of water savings. Yet a moment's reflection will show that, however financially successful such developments may be, the economic value of the water savings can not exceed the least cost alternative source of supply.

Well constructed markets can value and provide that source of supply.

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