BENEFIT COST ANALYSIS FOR ENVIRONMENTAL FLOW OPTIONS: THOMSON AND MACALISTER RIVERS

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Abstract

Natural resource economists in URS Australia were asked by the Victorian Department of Sustainability and Environment to assess one of the most important contemporary questions in water resource management, that is, "how do we best share water resources between the three principal water users"; namely, the environment, irrigators and urban users. In late 2000, a Task Force was established to review the bulk entitlements for the Macalister and Thomson Rivers in Victoria.

Five scenarios spanning the extremes were analysed for the economic, social and environmental values of water. While most of the flow regimes assessed were economic - having positive benefit cost ratios - our assessment showed that the preferred option was one of the compromise options, where the benefits of some increase in environmental flow remained high, but relative to the 'full' recommended flows the impacts on irrigators and the urban user, Melbourne Water, were reduced.

A transparent process for sharing a resource.

Introduction

In late 2000, a Task Force was established to review the bulk entitlements for the Macalister and Thomson Rivers in Victoria. As part of this review two separate but concurrent studies were commissioned to look into the appropriateness of the bulk entitlements for environmental flows. Both studies used the FLOWS method for determining environmental water requirements.

The Thomson and Macalister Rivers are located about 160 kilometres west of Melbourne and connect the Thomson Reservoir - which presently provides around 60 per cent of Melbourne's water - and Lake Wellington, which forms part of the Ramsar-listed Gippsland Lakes. The rights to water stored in the Thomson Reservoir are held by Melbourne Water Corporation (>90%) and irrigators in the Macalister Irrigation District. The majority of irrigation water used in the Macalister Irrigation District is sourced from Lake Glenmaggie, which is an annual storage on the Macalister River.

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The FLOWS method is a method for determining environmental flow requirements in Victoria. The method is based on the philosophy of describing key flow components (such as overbank flows and freshes) as part of a recommendation for an environmental flow regime. This approach differs markedly from previous environmental flow requirements that established 'minimum flows' only.

As part of this review, URS Australia was asked to assess the benefits and costs of environmental flow options that were being developed by the Task Force based on recommendations of both environmental flows studies. In particular, the aim was to undertake a benefit cost analysis that considered economic, environmental and social benefits and costs, to investigate whether any change in bulk entitlements would be economic, and to ensure that the process for revising environmental flows remains as transparent as possible.

Environmental Flow Scenarios

An expert panel of scientists, which included people from various disciplines, including environmental science, terrestrial ecology, freshwater ecology, fish biology, engineering, catchment hydrology, geomorphology, and natural resource management, determined a flow regime that would provide for an ecologically healthy Thomson and Macalister river system; and contrasted this with the current Bulk Entitlement provisions.

In between these two extremes, three compromise environmental-flow options representing high, medium and low risk options were developed. Compromises were provided in the form of changes to the full recommendations in specific flow components.

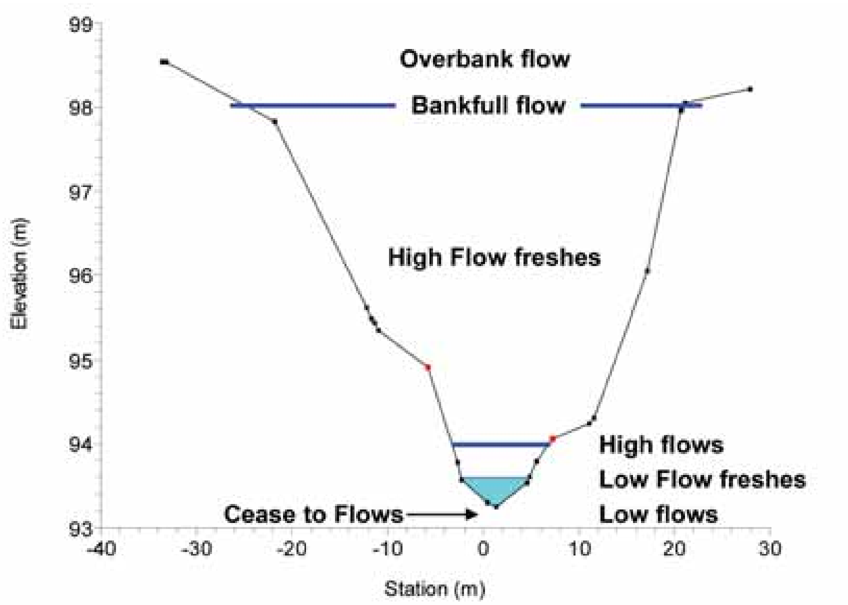

Figure 1. River flow components measured by depth.

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Flow components describe the variability in stream discharge as well as flows connecting the river to the floodplain. Seven distinct flow components were described in developing the compromise flow scenarios:

- **Cease to Flow** - periods when there is no detectable flow of water. The river bed may dry completely, or water may be retained in isolated pools.
- **Low Flows** - flows that provide a continuous flow over the bottom of the stream channel, but do not fill the channel to any great depth. The term is most often used in relation to baseflows that occur over the drier periods of the year (eg. summer) that are sustained for some period (weeks to months), even in the absence of rainfall.
- **Low Flow Freshes** - flows that produce a rise in river height for a short period (usually measured in days), due to short bursts of rain during periods of low flow.
- **High Flows** - a term used to describe the persistent increase in seasonal baseflow that generally occurs over autumn, winter and spring, but which remain confined in the stream channel.
- **High Flow Freshes** - flows that produce a rise in river height for an extended period during periods of high flow, inundating the banks of the channel to some depth.
- **Bankfull Flows** - flows that completely fill the channel to the top of the banks.
- **Overbank Flows** - flows that spill out of the channel onto the floodplain.

These different components can be visualised by the depth of water they produce in the channel (Figure 1) or from different stages in a hydrograph (Figure 2). Each flow component is assumed to have different ecological functions or consequences in a river.

For the Thomson and Macalister flow scenarios, the flow components of bankfull and overbank flows, summer and winter low flows, and summer and winter freshes were considered the least important components. If they were removed, they would still provide an improvement in the health of the two rivers. The five flow scenarios that were developed for evaluation were:

- Scenario 1 - Full environmental flow recommendations
- Scenario 2 - Low compromise
- Scenario 3 - Medium compromise
- Scenario 4 - High compromise
- Scenario 5 - Current bulk entitlement provisions

Throughout this report, these five scenarios are referred to as Options 1 to 5.

The actual change in Thomson and Macalister river flows that would have occurred under each scenario were quantified for the past 48 years using the historical flow records in Table 1.

The benefits and costs of the flow options were assessed relative to the current situation, which was modelled as Option 5.

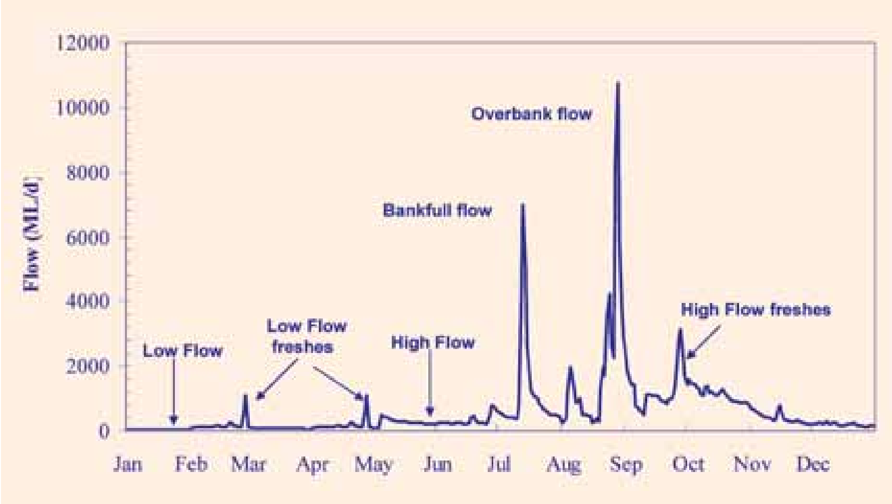

Figure 2. River flow components measured by rate of flow.

Benefits From Increased Environmental Flows

Generating primary dollar values for environmental assets and benefits was beyond the scope of this study. Bennett and Morrison (2001) and van Bueren and Bennett (2001) describe a process where the values of environmental assets assessed by detailed research at a given site can be transferred to similar environmental assets at other sites provided some minimum criteria are met. The process is termed benefit transfer. Under this process, value estimates that have been developed in other studies, and for other cases, are used to inform decision making by inference. Benefit transfer is a useful process in placing non-market values on environmental benefits where independent environmental evaluations cannot be undertaken.

Scientists, such as ecologists and fluvial geo-morphologists, think about flow regimes and their effects in many dimensions. These are seldom coincident with the set of attributes the community is concerned about when considering the effects of changing river flows or other river management variables. Therefore, a first step in valuing changes in flows is to translate the outcomes measured by scientists into the outcomes that are important to the community and can be valued by the economist. This is not an easy task and inevitably requires judgement by all involved in this process. The task was undertaken at a Workshop with approximately 20 technical experts in the various specialities. It was not possible to value all substantial outcomes, primarily because relevant valuation studies have not been conducted.

The study of Bennett and Morrison (2001) was considered to contain river attribute values most suitable for benefit transfer to the Thomson and Macalister Rivers in Victoria. Those that were considered relevant were:

- the percentage change in the length of the river with healthy native vegetation and wetlands;

Table 1. Average annual change in outflow, 1955-2003.

Option	Average increase in outflow from Thomson River* (GL/yr)	Average increase in outflow from Macalister River (GL/yr)	Average increase in outflow from Thomson and Macalister Rivers (GL/yr)	Increase in outflow from Thomson and Macalister Rivers (%)
Option 5	0	0	0	0
Option 4	12	8	20	5
Option 3	18	13	31	7
Option 2	25	16	41	10
Option 1	40	17	57	13

**Thomson River upstream of Macalister River*

- the change in the number of native fish species present; and
- the change in the number of waterbird and other faunal species present.

Whilst other values do exist for rivers and wetlands in other parts of Australia, the above values were specifically developed for the process of benefit transfer, and it was considered that extrapolation of their estimated values for 'NSW southern coastal' rivers would be most appropriate

It would be extremely difficult to determine the precise probability distribution of outcomes for each of the above three river attributes. Therefore, we used simple triangular distributions by requesting the technical experts to specify their best estimates of most likely, absolute minimum (worst) and absolute maximum (best) physical outcomes of the attributes that were valued. Even so, the technical experts emphasised that this did not capture all the uncertainty involved in predicting future outcomes for the attributes that could be valued.

In their study, Bennett and Morrison found that the values that people hold for river health varies for households inside and outside the catchment. The value estimates, expressed as willingness to pay for an improvement in river health, that were used to value the benefits of each flow regime are shown in Table 2.

The values shown in Table 2 were estimated as one-off payments made by households and as such represent respondents' "present values" (over 20 years) of the stream of benefits that they will enjoy from the attributes through time (measured as willingness to pay for an improvement in these attributes). In commenting on the robustness of the estimated values of the attributes, Bennett and Morrison note that the estimating equations explain a large proportion of the variability displayed in the data, in other words, "the models are extremely good at explaining the choice behaviour of the respondents". As well, 33 of the 35 estimated attribute values were significant at the five per cent level.

Table 2. Attribute value estimates for NSW southern coastal rivers.

Attribute	Value estimate ($ per within catchment household)	Value estimate ($ per outside catchment household)
Native Vegetation[a]	2.32	2.61
Native Fish[b]	7.37	6.72
Fauna[c]	0.92	0.87

a. Vegetation Unit = Value ($) per one per cent increase in river length with healthy vegetation and wetlands

b. Fish Unit = Value ($) per unit increase in the number of native fish species present

c. Fauna Unit = Value ($) per unit increase in the number of waterbird and other fauna species present

As discussed in URS (2003) two approaches to benefit valuation can be used. One is willingness to pay, which reflects the maximum monetary amount that an individual would pay to obtain a good. The other is willingness to accept (compensation), which reflects the minimum monetary amount required to relinquish the good. Willingness to pay, therefore, provides a purchase price, relevant for valuing the proposed gain of a good, whereas willingness to accept provides a selling price, relevant for valuing a proposed relinquishment. Conventional economic theory suggests that, in most circumstances, these two measures should yield roughly equal estimates of value. However, there is a large body of empirical evidence from observation of human behaviour that demonstrates that willingness to accept frequently exceeds by many times the willingness to pay for the same good. For example, Horowitz and McConnell (2002, Table IIIA) reviewed some 50 studies that explored empirical differences between the two concepts and summarised their results in terms of the mean ratio of 'willingness to accept' to 'willingness to pay'. They found, for example, that the mean ratio for public or non-market goods was 10.41 with a standard deviation (SD) of 2.53, the mean ratio for ordinary private goods was 2.92 (SD = 0.30), and the mean ratio for all goods was 7.17 (SD = 0.93). Horowitz and McConnell concluded that the ratio is highest for public or non-market goods, next highest for ordinary private goods and lowest for exchanges of money itself.

It is our belief (shared by others, for example, Knetsch 1990, and Brown and Gregory 1999) that this empirical evidence should not be ignored, and that the correct measure of value should be used in the analysis of environmental programs. In short, the benefits of restoration and improvement should be valued by willingness to pay for an improved environmental asset or service, while the benefit of preservation and maintenance should be valued by willingness to accept the loss of the asset or service.

If analysts use willingness to pay where willingness to accept is appropriate, a whole class of environmental goods will be under-valued and hence under-supplied. For example, willingness to pay is relevant to measure the gain in benefits of improving native vegetation and wetlands but willingness to accept is appropriate to measure the loss of benefits if there was loss of native vegetation and wetlands from its existing condition. If willingness to pay is used where willingness to accept is appropriate, there may be insufficient

PHOTO COURTESY OF MELBOURNE WATER

The Thomson Dam supplies 60% of Melbourne's water.

investment in the prevention of losses and damage (preservation and maintenance), and the associated environmental 'goods' will be under-supplied.

Estimating Willingness To Accept Compensation

Unfortunately, estimates of willingness to accept are hard to find and difficult to collect. Contingent valuation or choice modelling are perhaps the only ways to derive these estimates, but such survey methods may tend to overestimate willingness to accept. An appealing procedure is to exploit the disparity between the two measures by recognising that willingness to pay under-estimates willingness to accept and to multiply willingness to pay by a pre-determined factor, that is:

WTA = WTP x multiplier.

This approach would be suitable if we can estimate an appropriate willingness to pay and an appropriate multiplier. It is argued in URS (2003) that an appropriate multiplier for river attributes might lie between 1.0 and 5.0 and can be assessed using characteristics of the river environments. A simple, consistent and robust index has been derived to scale the characteristics of a river reach to estimate appropriate multiplier values (see URS 2003). When willingness to pay estimates are available for 'within catchment' and 'outside catchment' communities, the multipliers should be estimated for both communities. The estimated multipliers can then be applied to attribute value estimates (willingness to pay) derived from previous studies to estimate willingness to accept for the loss of those attributes.

Ideally, the scoring process to decide the multiplier should be undertaken by surveying members of the relevant communities. Where this is not possible, appropriately constituted 'representative panels' or 'focus groups' drawn from the communities would be a useful and convenient mechanism. Neither approach was possible within the resources and time-lines for this study of the Thomson and Macalister Rivers. Therefore, the following multipliers were specified:

- for households inside catchment: WTA = 5WTP
- for households outside catchment: WTA = 3WTP

Sensitivity analysis was then used to investigate the implications of different relationships between willingness to pay and willingness to accept for each community.

The distributions of benefits for the various attributes were used to calculate the mean benefit and its standard deviation for each environmental flow option. Each of the distributions of benefits was derived using the Monte Carlo risk technique, which randomly sampled 5,000 trials from the triangular distributions of benefits.

Table 3. Mean and standard deviation of benefits - perfect correlation between outcomes (WTA).

Option	Mean benefit ($m)	Standard deviation ($m)
Option 1	79	14
Option 2	53	26
Option 3	49	21
Option 4	-80	17
Option 5	-84	15

Table 4. Mean benefits relative to continuation of Option 5.

Option	Total benefit relative to Option 5 ($m)	Extra flow relative to Option 5 (GL)	Mean Value per ML of extra flow
Option 1	163	57	$2,860
Option 2	137	41	$3,341
Option 3	133	31	$4,290
Option 4	4	20	$200

Table 5. Mean benefits relative to continuation of Option 5 - all benefits at willingness to pay.

Option	Total benefit relative to Option 5 ($m)	Extra flow relative to Option 5 (GL)	Mean Value per ML of extra flow
Option 1	106	57	$1,860
Option 2	86	41	$2,098
Option 3	81	31	$2,613
Option 4	4	20	$200

Table 6. The estimated costs of increased environmental flows in the Thomson and Macalister Rivers to Urban Water Consumers.

Options	Net Present Cost @ 4% over 50 yrs ($m)	Net Present Cost @ 8% over 50 yrs ($m)
Option 1	117.70	83.25
Option 2	99.04	69.93
Option 3	89.84	64.79
Option 4	41.07	23.11

Results

Table 3 shows the results of the simulation of 5,000 trials when all outcomes are assumed perfectly correlated. The latter assumption means that when one attribute produces its worst (most likely, best) outcome all other attributes affected by the option produce their worst (most likely, best) outcome.

These results show that continuation of Option 5 (current situation) is estimated to result in a loss with a mean present value of $84m, and that in 68 per cent of cases the actual outcome would lie between a loss of $69m and a loss of $99m, that is, plus and minus one standard deviation around the mean. In 68 per cent of cases, the estimated benefits of Option 1 would lie between $65m and $93m.

Relative to continuation of the current situation, however, Option 1 would produce an overall mean benefit of $163m because it would avoid the mean loss of continuing the current flow regime ($84m) and produce an extra benefit with a mean of $79m. The overall mean benefits of each option relative to continuing the current regime (Option 5) are shown in Table 4 along with an estimate of the resultant mean value per ML of increased environmental flow.

Sensitivity analysis

Two other scenarios were evaluated to test the sensitivity of the estimated benefits to assumptions about the relationship between willingness to pay and willingness to accept. These were:

• all benefits to both communities evaluated at willingness to pay (that is, willingness to accept equal to willingness to pay; and

• willingness to accept three times greater than willingness to pay for inside catchment community, and willingness to accept equal to willingness to pay for out-of-catchment community. (Zero correlation between the attributes was also tested. Mean benefits of the Options were not altered but the standard deviations of the benefits were reduced).

In each of these scenarios the same order and signs of the benefits of the Options as shown in Table 3 were maintained and the same order and relative benefits compared to Option 5 were also maintained. In the extreme, if all benefits were evaluated by willingness to pay alone, the mean benefits relative to option 5 were those shown in Table 5.

Unvalued benefits

The assessment of benefits was unable to value changes in populations of existing species and losses of invertebrates. Because these benefits remain unvalued, the results obtained in this study, given the assumptions on which they are based, are likely to underestimate the true benefits of changing flows in the Thomson and Macalister Rivers.

Costs From Increased Environmental Flows

The costs of increased environmental flows were estimated separately for urban water customers and irrigators.

Urban Water Customers

Melbourne water consumers are using only about one half of the bulk water entitlement that is available for use. Water that is presently not being used adds to the reliability of the present urban supply system. In the future, as Melbourne's population grows and water consumption is increased, Melbourne Water will need to augment the current urban supply system. Any decision in the short-term that reduces the bulk entitlement for Melbourne will mean that these augmentations will need to occur sooner rather than later.

The impact of the flow options on Melbourne Water was assessed by assuming that water availability and reliability to urban consumers remains unchanged, and by calculating the discounted value of the capital costs of augmentations given the different timeframes for their occurrence. The costs shown in Table 6 are all relative to Option 5 - the base case.

The results showed that Option 1 - Full environmental flow - is more costly than the other options, as is to be expected. Options 2 and 3 have similar levels of costs while Option 4 is the least expensive option.

Irrigators

REALM modelling was undertaken to determine the impact of each of the options on the reliability of supply to irrigators, which in the Macalister Irrigation District are primarily dairy farmers.

Modelled results from the Department of Sustainability and the Environment (DSE) are shown in Table 7. For each of the options, information is shown for the average (1955-2003) reduction in water availability, average annual percentage of water right supplied, and the lowest annual water right supplied.

Data on average changes in water availability say little about the changes that can occur from year to year. In trying to capture these differences, the modelled data were provided as a time series. For every year between 1955 and 2003, the volume of water delivered to irrigators for each of the options was assessed relative to what would be delivered given the current bulk entitlement (Option 5).

In analysing the results, histograms were produced to show the distribution of frequencies for different variations in water delivered. For example, this analysis showed that in the majority of years (about 80 per cent), there was a negligible difference in water delivered for all of the options. The analysis also showed that the greatest differences between the options could be observed in the remaining years where water inflows are insufficient to meet irrigator demands.

Irrigators may respond to reductions in water supply using a range of strategies. Depending on the timing of the reductions, in the short-term an irrigator may:

- buy in supplementary feed;
- dry off cows earlier than anticipated;
- irrigate less pasture;
- irrigate at a reduced application rate
- buy temporary water; or
- continue milking and reduce the condition score of the herd.

Each of these strategies would involve a different set of impacts on the farm

Table 7. Average annual change in water availability and reliability to the MID, 1955-2003.

	Average reduction in water supplied (GL/yr)	Average % of water right supplied (%)	Lowest % of water right supplied (%)
Option 1	12.0	111	23
Option 2	10.5	112	37
Option 3	7.3	115	43
Option 4	4.1	117	55
Option 5	0.0	12	71

Table 8. The estimated costs of increased environmental flows in the Thomson and Macalister Rivers to Irrigators.

Options	Net Present Cost @ 4% over 50 yrs ($m)	Net Present Cost @ 8% over 50 yrs ($m)
Option 1	64.2	37.1
Option 2	58.1	33.2
Option 3	42.4	24.2
Option 4	27.4	15.6

Table 9. Comparison of the benefits and costs of increased environmental flows in the Thomson and Macalister Rivers.

Options	Environmental Benefits	Costs to urban water users	Costs to Irrigators	Net present value ($m)	BCR
Option 1	163	83.3	37.1	42.6	1.35
Option 2	137	69.9	33.2	33.9	1.33
Option 3	133	64.8	24.2	44.0	1.49
Option 4	4	23.1	15.6	-34.7	0.10

business, either by increasing business expenses or by reducing farm income. The impacts are further complicated when we consider short term and long term responses to changes in the supply of irrigation water. In the long-term, irrigators may:

- buy permanent water right, or
- improve the efficiency with which they use water on pasture.

In assessing the per unit impact of reduced water supply, it was assumed that irrigators do not shift their long-term demand for water. The actual timing of restriction (whether or not they occur in consecutive years) will ultimately determine whether demand does shift.

We have assessed the impacts of water restrictions by assuming that milk production is held constant and that the costs of production increase. It is assumed that everything else remains constant, for example, the condition score of the animal, joining rates, length of lactation and milk prices. Increases in costs of production are assumed to be due to the costs of purchased feeds that would need to be substituted for pasture, including any additional costs for feeding.

An impact of $243.00 per ML was estimated. The overall impact of each option on irrigators was quantified by multiplying this impact per ML by the reduced average volumes delivered and the likelihood of these different events occurring. The results are shown in Table 8.

The results show that the greatest impacts on irrigators are those associated with Option 1 followed by Option 2 and Option 3.

Conclusions

The benefits and costs for each of the options are summarised in Table 9 for an assumed discount rate of 8 per cent for irrigator and urban costs, and environmental benefits. The results show that the most economic option is Option 3 followed by Option 1 and Option 2. The high compromise option - Option 4 - is uneconomic.

Note that all NPVs would be negative if environmental benefits were evaluated using willingness to pay.

Where a discount rate of 4 per cent is assumed, only Option 3 remains economic, having a Net Present Value of $15.8m and BCR of 1.12. This result occurs, in part, because of a high capital expenditure ($254m) by MWC in years 30-40 (depending on the option) which is given extra weight at the lower discount rate.

Finally, it should be noted that these results are probably conservative because costs are estimated over 50 years while survey respondents were asked to value environmental benefits over 20 years. If benefits were assumed to continue to 50 years, their totals could be 20-25 per cent higher.

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