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BALANCING TRADE-OFFS IN THE PROVISION OF ENVIRONMENTAL FLOWS IN THE SNOWY RIVER

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Abstract

The NSW, Victorian and Commonwealth Governments are in the process of corporatising the Snowy Mountains Hydro-electric Scheme. As part of this process a water inquiry was established to assist in the determination of the environmental operating conditions of the new business, Snowy Hydro Ltd. The Inquiry's principal task was to examine the range of environmental issues arising from the current pattern of water flows caused by the Scheme and to develop a comprehensive range of costed options to address these issues.

Central to the Inquiry's deliberations is the re-allocation of water from irrigated agriculture and electricity generation to the Snowy River catchment. This paper focuses on trade-off issues associated with such a re-allocation and the difficulties involved in achieving a balance that improves net social welfare. The findings of the paper suggest that further work is required by Government and highlights a need for an on-going process to manage resource use trade-offs over time.

Keywords: environmental flows, environmental trade-offs, resource allocation.

[1] The views expressed in this paper are those of the authors, rather than those of NSW Agriculture or the NSW Government.

1. INTRODUCTION

The NSW, Commonwealth and Victorian Governments are currently in the process of corporatising the Snowy Mountains Hydro-electric Authority. The aim of corporatisation is to establish a commercially viable electricity generation business, Snowy Hydro Ltd, which can compete on the National Electricity Market (SWI, 1998). The *NSW Snowy Hydro Corporatisation Act 1997* provides for a public Water Inquiry to be held to examine and report on environmental issues arising from the current pattern of water flows in the Snowy Mountains region and to develop a range of comprehensive, fully costed options to address these issues. Corporatisation and the commencement of the operations of Snowy Hydro Ltd is expected to occur after the Governments have agreed on the implementation of the outcomes of the Water Inquiry.

The Snowy Mountains Hydro-electric Scheme is located in south-eastern NSW and was constructed for the twin purposes of hydro-electricity generation and providing water for irrigation. Construction of the Scheme was a major post war initiative in Australia which commenced in 1949 and was completed in 1974. The Scheme collects, diverts, stores and releases the waters of the various rivers and streams within the Snowy Mountains Area (comprising about 8,000 square kilometres). The Scheme captures the headwaters of the Snowy River and its tributaries above Jindabyne, including the Eucumbene River, and diverts them inland to the Murrumbidgee and Murray Rivers (see Figure 1). Water diverted across the Great Dividing Range falls up to 750 metres and generates electricity as it passes through power stations before moving into irrigation storages.

The Scheme is of considerable value to Australia. It provides benefits to the community through:

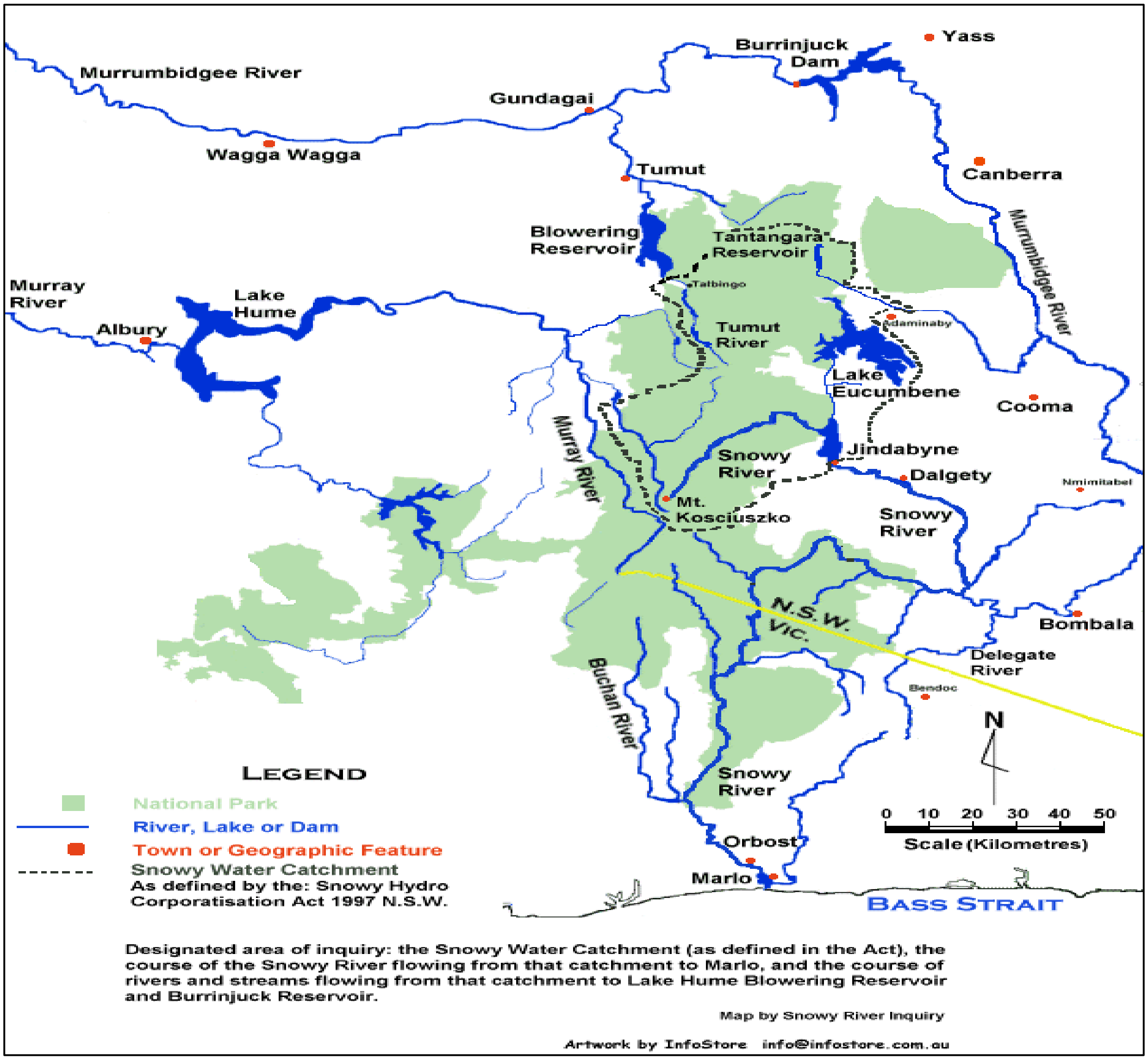
- enhancing the reliability of electricity supply. On average the Scheme provides approximately 5 per cent of south-eastern Australia's total energy requirements each year.
- reduced greenhouse gas emissions - the Scheme generates electricity from water as a clean and renewable resource, directly displacing around 5 million tonnes of carbon dioxide emissions each year;
- increased irrigation production - diverted water supports irrigated agriculture in the Murrumbidgee and Murray Valleys which in 1995-96 had an annual gross value in excess of $1,500 million.
- tourism and recreational benefits - associated with both the storages of the Scheme (eg. fishing) and stream flows within the southern portion of the Murray-Darling Basin beyond the Snowy Mountains Area; and
- mitigation of salinity in the Murray-Darling Basin.

However, the above benefits have not been costless. The Scheme has also had an adverse impact on the environmental health of many of the rivers within the Snowy Mountains catchment. The aqueducts, tunnels, weirs and dams of the Scheme have resulted in both a reduction in natural flows and the variability of these flows. This has significantly effected the aquatic and riparian habitats of rivers and streams within the area. Such river health issues are becoming more important in Australia as community awareness of environmental values increase.

The Inquiry had the task of identifying the range of benefits and costs associated with the re-allocation of water from the western to the eastern side of the Great Dividing Range. Essentially, the benefits will be in the form of potential environmental outcomes in the Snowy River catchment while the costs will be those associated with reduced water availability for electricity generation and downstream irrigated agriculture in the Murrumbidgee and Murray Valleys and any environmental costs arising from decreased flows in the Murrumbidgee and Murray Rivers.

Economic analysis provides the generally accepted decision framework for considering trade-offs inherent in the allocation of scarce resources. In the following section some of the key issues involved in the Snowy trade-off are discussed and a broad framework for their consideration is presented. Section 3 contains an overview of the approach taken by the Inquiry and some of the key results. The last Section explores the uncertainties influencing the appropriate level of environmental flows in the Snowy and discusses the need for longer term processes in resolving trade-off issues.

Figure 1: The Snowy River Catchment



2. ACCOUNTING FOR TRADE-OFFS

2.1 A Benefit-Cost Framework

Applying a clearly defined decision framework to trade-off issues provides the basis for objectivity and transparency in decision making, which are particularly important when there are a range of community views about the benefits and costs involved. The economic approach of maximising social welfare requires an awareness of relevant benefits and costs, which include environmental values such as clean water or species preservation, which may not be fully or even partially revealed in financial markets.

Environmental benefits can be broken down into explicit use benefits and implicit non-use benefits[2]. Use benefits are derived from the physical use of environmental resources (eg., agriculture, fishing, sight-seeing etc) while non-use benefits refer to the value that individuals obtain from environmental resources without directly using or visiting them (existence, option, quasi-option and bequest values).

There are a number of techniques[3] available to estimate the monetary benefits and costs from changes in environmental resources. These can generally be grouped as:

i) market value approaches (change in productivity, preventative-expenditure, replacement-cost, opportunity cost techniques etc);

ii) surrogate market approaches (travel cost, hedonic pricing, property value techniques etc); and

iii) simulated market approaches (contingent valuation, choice modelling, contingent ranking etc).

Surrogate market approaches can provide information on the non-market benefits of environmental use such as recreation. These techniques have been widely applied and accepted and have a strong theoretical basis. The valuation of non-use benefits, however, such as species diversity, is not straight-forward and relies on the use of less accepted simulated market approaches. While some progress has been made in recent years in the refinement of these techniques, there remain significant concerns about both the appropriateness of monetary valuation and the accuracy of the techniques used to evaluate non-use environmental benefits.

Concerns about the appropriateness of monetary valuation relate to the difficulty in identifying some environmental benefits (which may be due to a lack of knowledge of ecological systems), the loss in information which occurs in the process of converting diverse benefits into a single monetary valuation and the exclusion of values which future generations may place on environmental resources.

Issues associated with simulated market approaches relate to the potential for hypothetical bias due to the difficulty in obtaining meaningful responses to hypothetical questions (Perkins, 1994), potential differences between willingness to pay and willingness to accept concepts, survey design bias, the limited capacity to validate results, and the high cost of obtaining valuations.

Many of the problems associated with the monetary valuation of non-use environmental benefits are relevant to the Water Inquiry. To overcome some on-going and well documented conceptual arguments

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[2] An anthropocentric view of environmental values is taken.

[3] A useful summary of these techniques is contained in the Department of Environment, Sport and Territories and Department of Finance (1995), *Techniques to Value Environmental Resources*, AGPS, Canberra.

regarding valuation, an 'opportunity cost' approach has often be adopted in such circumstances. The Opportunity-Cost Approach (also known as the 'Threshold Value Method') avoids the need to directly place monetary values on environmental goods. The approach is based upon estimating the 'opportunity costs' which would be the consequence of a particular resource decision. The opportunity costs are then compared to the unquantified environmental outcomes which are expected from the proposal. This approach has been used in a wide range of environmental studies overseas and in Australia, including studies undertaken by the Resource Assessment Commission, ABARE and the Australian National University[4].

If the potential unquantified benefits from the proposal are considered by decision makers to exceed the quantified opportunity costs, the proposal may proceed. In benefit-cost terms, the opportunity cost approach identifies the size of environmental benefits which would be necessary to equate to the present value of the stream of opportunity costs associated with the proposal (ie., in order to achieve a benefit-cost ratio of one).

The opportunity costs of establishing environmental flows in the Snowy River catchment can be estimated in terms of the reduced revenues from irrigated agriculture and electricity generation. After allowing for estimated use-values in the Snowy, the resultant net opportunity costs can then be compared with the expected environmental outcomes which are identified and measured in physical terms, but which cannot be easily measured in monetary terms.

The opportunity cost valuation framework therefore allows for the incorporation of environmental effects into the decision making process, without the many problems involved in attempting to place monetary values on the complex range of ecological benefits which may occur from the introduction of environmental flows. When applied to proposals involving the generation of public benefits through government regulation, the approach appropriately positions Government, acting on behalf of the broader community, to make the trade-off assessment. Furthermore, the approach lends itself to reassessment (adaptive management) of the trade-off decisions as improved information becomes available.

2.2 Types of Trade-offs

There are a range of environmental, social and economic issues associated with changing the current pattern of water flows from the Snowy River catchment. Some of these trade-offs include the following:

- ***Irrigated agriculture versus the environment*** - there is a trade-off between the social benefits and revenue generated from farm businesses in the Murrumbidgee and Murray Valleys and environmental benefits which may arise from the retention of flows in the Snowy River catchment.
- ***Electricity generation versus the environment*** - there is a trade-off between the revenue generated from electricity production and environmental benefits which may arise from the retention of flows in the Snowy River catchment.
- ***Electricity versus irrigated agriculture*** - while the generation of electricity is a non-consumptive use of water from the Snowy Scheme, there are trade-offs in relation to the timing of water releases for irrigated agriculture and electricity generation.
- ***The global environment versus the environment of the Snowy catchment*** - an environmental trade-off exists between an improvement in river ecology in the Snowy River catchment, and the potential

[4] See Streeting and Hamilton (1991), Young and Mues (1993) and Saddler, Bennet, Reynolds and Smith (1980).

environmental costs associated with increased production of carbon dioxide as a result of greater reliance on electricity generated from thermal power stations.

- ***Eastern environmental flows versus environmental flows to the west*** - flows from the Snowy Scheme have a low salt content which enhances water quality in the Murrumbidgee and Murray Rivers. Increased environmental flows in the Snowy River (eastern flows) may therefore have an adverse impact on the environment of the Murray-Darling Basin (western flows)[5].

A theoretical representation of three of the key trade-offs is provided in Figure 2. The theoretical response functions for irrigated agriculture and electricity generation reflect increasing marginal costs in response to reduced water availability throughout the range of the function. That is, as environmental allocations to the Snowy River catchment increase and reduce the availability of water to industries dependent on water flows, marginal costs incurred by these sectors continue to increase.

In the case of irrigated agriculture, higher marginal costs are incurred as increasingly higher value irrigated enterprises are sacrificed from farm enterprise mixes in response to lower and lower irrigation allocations. Importantly, the shape of the response curve will be affected by longer term adjustment responses[6] including investment in water saving technologies on farm, improvements in the efficiency of regional water delivery systems and moves to higher value enterprises such as permanent horticulture[7].

Governments can also contribute to potential adjustment opportunities through institutional reform such as the introduction of more flexible trading arrangements (inter-valley and inter-state trade). These factors suggest that the slope of the response curve may be reasonably steep over the short term but is likely to flatten over the longer term in response to the adoption of adjustment measures aimed at mitigating the impacts of environmental flows.

The environmental response function indicates a theoretical relationship between environmental benefits and the provision of environmental flows. Assuming that diminishing marginal returns is as equally applicable to environmental goods as market goods, the response function reflects first increasing and then decreasing marginal benefits from successively higher allocations of environmental flows.

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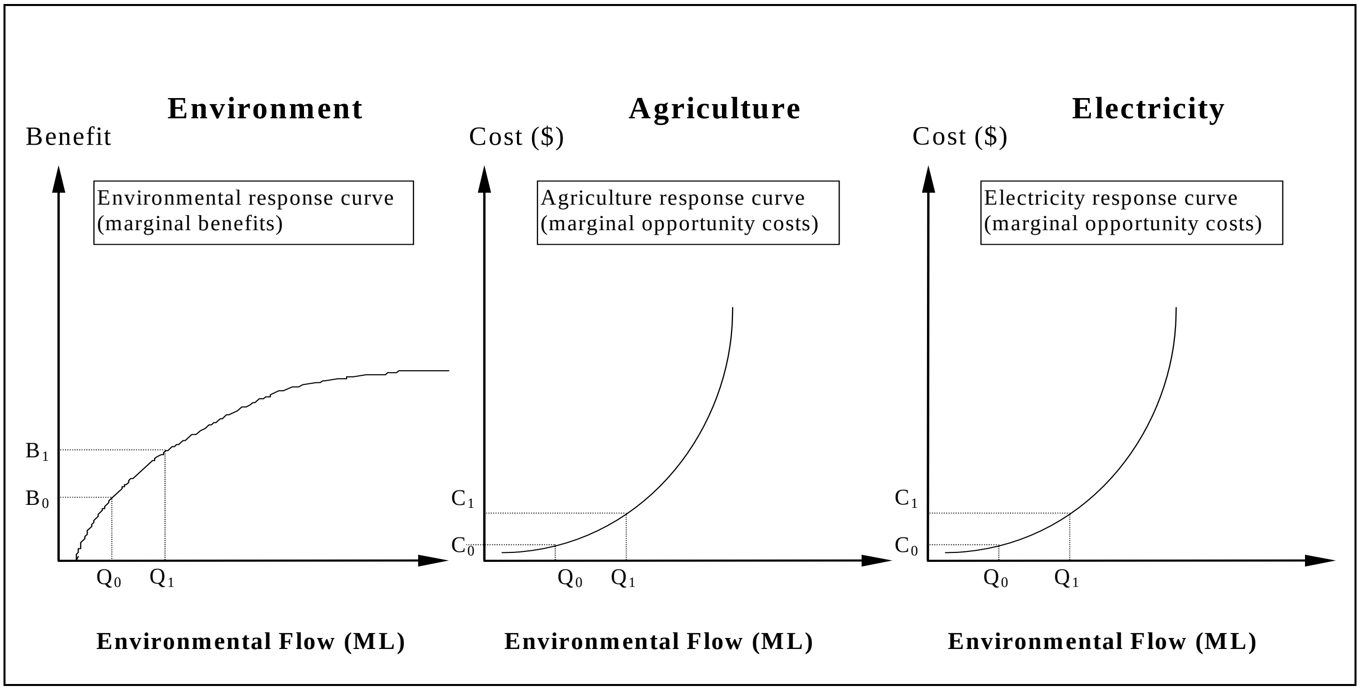
[5] This option was dismissed by one of the guiding principles endorsed by the Inquiry which stated that "existing environmental flows and functions, wherever defined on the Murray and Murrumbidgee Rivers, are protected or enhanced" (SWI, 1998). Initial indications from the Victorian Government did, however, favour meeting environmental flow targets in the Snowy through a reduction in environmental flows in the River Murray. This indicates that such a trade-off is not out of the question.

[6] Based on the assumption that shorter term adjustment responses (eg. changes to enterprise mix) are already incorporated into the trade-off curve. The analyses conducted by the Inquiry allow for these types of adjustment.

[7] This is not intended to promote permanent horticulture as a viable adjustment option. Indeed, the move from broadacre to permanent horticultural enterprises involves significant capital inputs, long development periods, product price risk and different management expertise.

Figure 2: The Response Functions for Competing Water Uses



2.3 The Environmental Response Function: Complexities and Uncertainty

The environmental response function warrants greater consideration given its central role in any decision to provide greater environmental flows in the Snowy. To provide a more detailed representation of the relationship between environmental outcomes and river flow, the environmental response function is disaggregated in Figure 3 into the three sub-components - macro-invertebrates, geomorphic attributes and riparian vegetation[8].

The diagram reflects possible outcomes whereby macro-invertebrates respond quickly to increased environmental flows, a geomorphic response which is only achieved with significant environmental flows, and the marginal response from riparian vegetation indicates some stability between particular flow ranges. While the relationships as depicted between environmental flows, macro-invertebrates, geomorphic attributes and riparian vegetation are hypothetical, they serve to highlight that not only are their trade-offs between the environment, agriculture and electricity generation, but also trade-offs

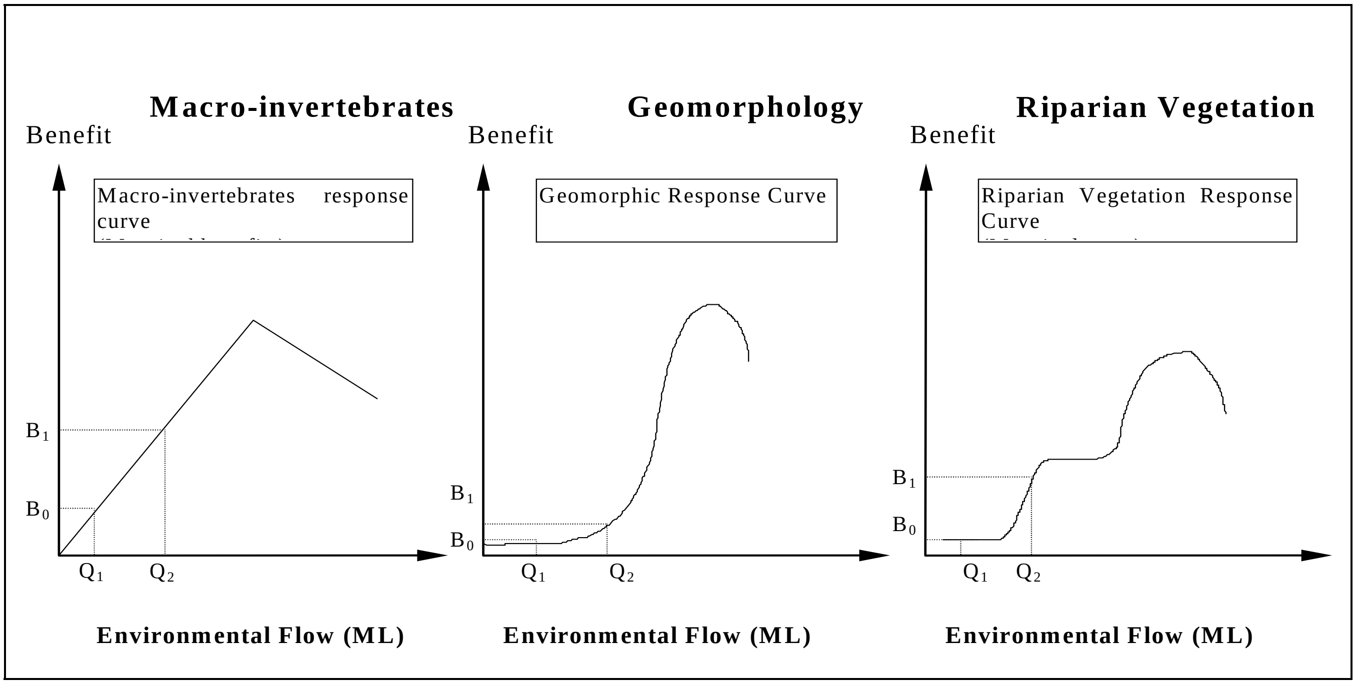
[8]Macroinvertebrates - animals without backbones including worms, insects, shrimps, snails, shellfish, and zooplankton which are large enough to be seen with the naked eye. Macroinvertebrates are a significant fauna component of rivers and streams in terms of their diversity and their importance to the ecological functioning of rivers. There are concerns about the impact of flow regulation on the diversity and population of macroinvertebrates within the Snowy River catchment.

Geomorphology - landforming processes associated with the movement of water in rivers and streams. There are concerns that rivers within the Water Inquiry area have experienced significant geomorphological change, most notably the accumulation of fine material in the bed and the loss of diverse bed structure with adverse impacts on the aquatic habitat.

Riverine vegetation - reduced stream volumes can disrupt riparian vegetation leading to loss of habitat and shelter for certain aquatic biota.

between environmental outcomes within the Snowy River catchment.

Figure 3: Components of the Environmental Response Function



The task of placing values on the various response functions outlined in Figures 2 and 3 is complex. At the outset, it needs to be recognised that parts of this valuation exercise may be relatively straight forward, while others will be sufficiently difficult to render nominal valuations of certain social benefits and costs meaningless. For example, private costs such as income forgone by irrigated agricultural and electricity businesses in response to reduced water availability will be easier to estimate than the various ‘unpriced’ benefits arising from improved environmental outcomes in the Snowy catchment.

The difficulties involved in the valuation task are compounded by knowledge gaps in relation to environmental response functions in the Snowy River catchment. Information about how river ecology may respond to alternative flow regimes is incomplete, rendering many of the environmental outcomes as highly uncertain. Part of this uncertainty may be related to only the recent emergence of ecology as a discipline. Although partially based on the ideas from earlier civilisations (e.g Plato and Aristole 4th Century BC, Bacon 1600s, Malthus late 1700s), ecology as it is now understood emerged this century and has only flourished in the past 40 years or so (Norton, 1995). The knowledge base of ecology is very incomplete and few disciplinary theories and techniques exist. Norton (1995) points out that such limitations make two things apparent:

i) “science has only limited capacity to identify and estimate the significance of impacts on ecological systems at this time – risk and uncertainty is pervasive: and

ii) only some of these limitations can be removed through new research and technological advances. Many problems appear intractable in the short to medium term, while many others may never be resolved”.

While such uncertainties exist, most ecologists question the legitimacy of a steady trend in ecological response from additional environmental flows (such as the environmental relationship depicted in Figure 2). A more favoured theory is that environmental improvements in rivers are dependent on certain threshold flow levels being reached. Defining what threshold levels are required for particular ecological functions is also, however, the subject of considerable uncertainty. At a 1998 wetlands conference hosted by the Nature Conservation Council, Dr Stuart Bunn (Associate Professor for Griffith University's Centre for Catchment and In-Stream Research) spoke on threshold levels. He said that scientists were being asked to predict what the environmental benefits would be of providing additional flows in inland rivers and commented that trying to discover where flow thresholds were was 'like walking towards a cliff in the dark'.

The intention in identifying these problems is not to devalue environmental outcomes, but rather to highlight that much of the environmental data required to undertake a rigorous and complete benefit cost assessment is not available. This tends to support a case for some flexibility to be maintained in the management of environmental flows in the Snowy to enable 'real' information on environmental responses in the catchment to be collected.

3. KEY FINDINGS OF THE INQUIRY

The purpose of this section is to provide a brief overview of the approach taken by the Inquiry and some of the key findings regarding the extent of trade-offs.

3.1 Overview of Approach[9]

The Inquiry developed a total of 23 options which outlined a proposed flow and management scenario for specific river reaches defined by the Inquiry. These options were used as the basis for the creation of subsequent composite options which address multiple river reaches. The options provide a wide range of alternative environmental condition improvements with different levels of impact and resource requirement. In developing these options a significant volume of information was taken into consideration. This included:

- the current environmental condition of the stream/river affected by the operation of the Scheme;
- the impacts of flow scenarios on the environmental condition of the streams and rivers to the west;
- hydrology and operating requirements for water releases from the Scheme;
- economic and social impacts of environmental options from a National and regional perspective;
- financial impacts of environmental release scenarios on Snowy Hydro; and
- use and non-use values in the Snowy River catchment.

To support the development of options, the Inquiry identified a large number of 'cases' based on the level of diversion into the Snowy. These cases varied in terms of the level of diversions (from their present 1 per cent level to 5, 11, 16, 20, 28 and 40 per cent of natural flows), their specific timing, how they are sourced, in associated environmental requirements in other river systems and accompanying infrastructure investments. For any given level of diversion into the Snowy, alternatives were developed for managing available flows to the west.

A Scientific Reference Panel (SRP) was established by the Inquiry to look at environmental issues associated with the operation of the Scheme. The SRP identified options which satisfied the ANZECC National Principles for the Provision of Water for Ecosystems which state that one of the goals of providing water for the environment is "to sustain and where necessary restore ecological processes and

[9] This section draws on material provided in SWI's Final Report.

biodiversity of water dependent ecosystems". An environmental assessment method was developed by the SRP which uses an Environmental Condition Index (ECI) derived from biota and habitat sub-indices. The biota index is based on an assessment of the macro-invertebrates, fish, and aquatic vegetation in each river reach, while the habitat condition index is based on an assessment of in-stream hydraulics, channel geomorphology, water quality, barriers, and riparian vegetation. The ECI is the lesser of either the biota index or the habitat condition index. Consequently, the ECI is likely to provide a conservative estimate of the health of the river environment which becomes important in considering the environmental outcomes suggested by each option.

The Panel found that when values of the Environmental Condition Index are plotted against increasing average natural flow, the plotting points generally align in a broad banded curve (similar to the environmental relationship depicted in Figure 2) increasing from zero to the environmental condition index (ranging from 0.73 to 0.92, depending on the reach). This indicates that in general the biggest increases in ECI occur for catchment measures (eg. weed control, remediation of vegetation and river banks, re-snaging of river channels etc) and initial flow increases above current levels, and that the rate of increase declines with further increments of flow and other management measures.

Consistent with the general framework outlined in the previous section, the Inquiry adopted an economic threshold approach to the assessment of trade-off issues. The approach involves:

i) Quantification of tangible benefits and costs:
- electricity generation - incremental fuel, capital and greenhouse emissions;
- agriculture - net value of lost production with an allowance for on-farm responses;
- implementation costs - catchment and outlet works, etc;
- salinity costs in Murray through to Adelaide; and
- active use values in Snowy corridor (fishing, rafting, canoeing, etc.)

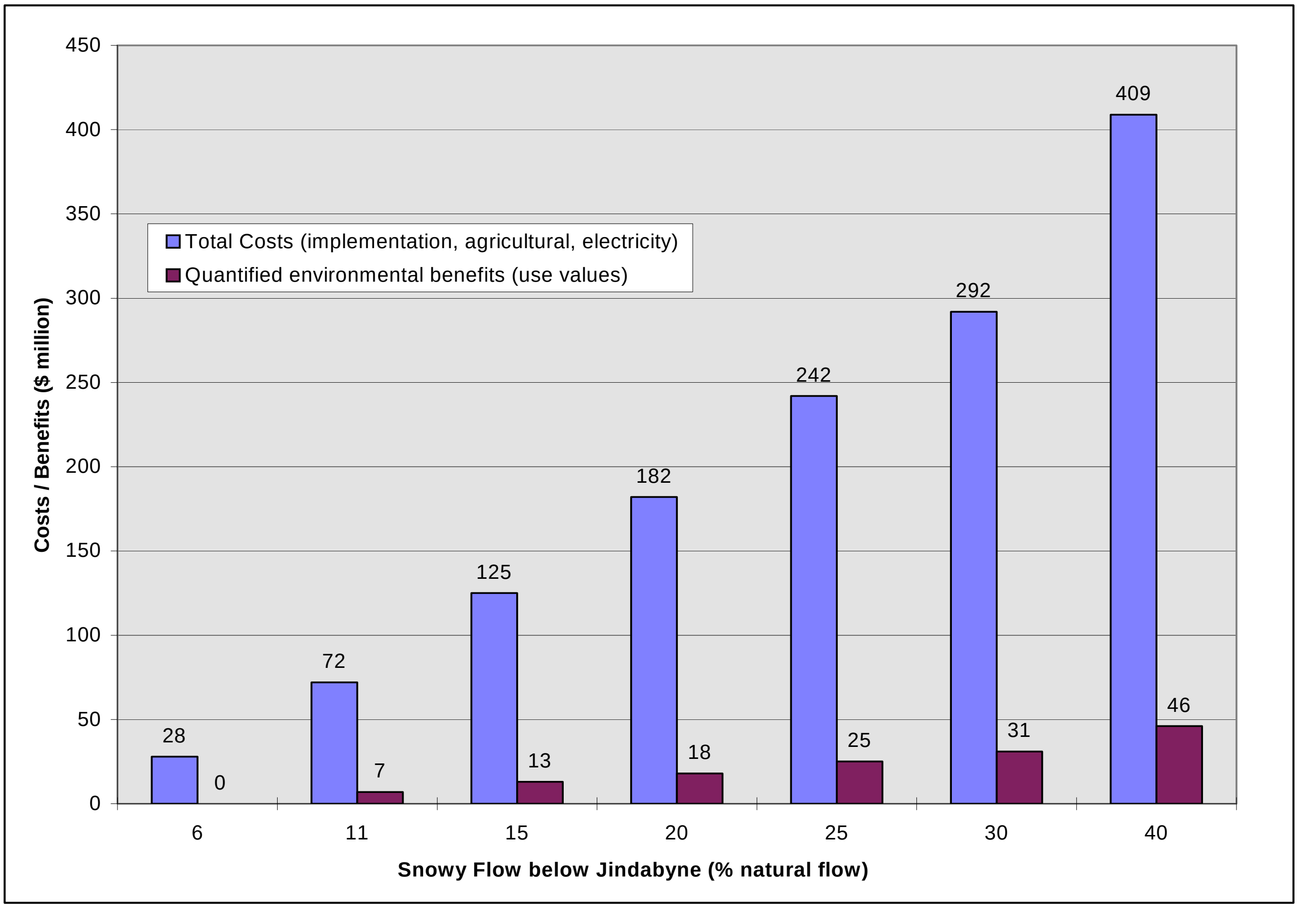
ii) Estimation of the implied 'threshold' to be offset by other changes:
- NPV over 25 years (7% ± 3%) for consistency of reporting.

iii) Identification of other impacts:
- community attitudes to and awareness of the affected river systems;
- responsiveness of these views to more information;
- attitudes to the implied trade-offs;
- distributional impacts of changed water reliability to agriculture; and
- financial implications for generation and agriculture.

3.2 Estimation of Trade-offs

The Inquiry estimated the costs and benefits of the 23 options referred to above. For simplicity the trade-offs presented in this section focus on the Snowy River below Jindabyne which is a key area of interest for the community as indicated by submissions. Figure 4 contains information on the total cost of each option and the quantified environmental benefits of returning additional flows to the Snowy. Electricity generation, agricultural and infrastructure costs are the major costs associated with enhanced environmental flows in the Snowy. The difference between the two columns provides a benchmark figure which other benefits (non-use values and other benefits not included in the analysis) would need to exceed to support a case for an increase in environmental flows in Snowy. The results indicate that the non-use values need be significant for society to benefit from a significant increase in environmental flows.

Figure 4: Economic Benefits and Costs from Environmental Flows in the Snowy River



A summary of the key trade-offs as found by the Inquiry is provided below.

- Electricity generation – most cases involve significant economic costs for generation. Essentially, any water diverted into the Snowy for environmental flows, or otherwise diverted around generation plants, is energy lost to Snowy Hydro. Economic costs to generation were proportional to the level of diversions to the Snowy, although other environmental flows which by-pass generation plants also have an impact.
- Agriculture – the economic costs to agriculture range from $0 to $143 million across the various options assessed. The effects are likely to be of greatest significance during dry periods with most options involving a substantial increase in the likelihood of significant shortfalls in these times.
- Implementation costs – implementation of most of the cases will require substantial investment in catchment management systems, water efficiency infrastructure and outlet works. The cost of these works varies from $24 to $97 million.
- Salinity costs - the diversion of water to the Snowy River is likely to have some impact on salinity levels in the rivers of the Southern Murray-Darling Basin. The salinity costs, however, are expected to be relatively small ($0 to $3 million).

- Use values of higher flows in the Snowy River – the results of previous studies have been used by the Inquiry in estimating use values (mainly canoeing and trout fishing based tourism) associated with greater levels of flow in the Snowy River. Estimates ranged from $8 to $61 million across the various options.
- Non-use values – the Inquiry conducted research into non-use values of the Snowy and community attitudes to the trade-off decision at the heart of the Inquiry's investigations. In broad terms, the results indicate that while increasing environmental flows in the Snowy River would be highly valued by many in the community, such flows should not be provided at the expense of established electricity generation and irrigation activities. The findings indicate that the community appreciates the trade-offs involved and places high values on the clean energy generation activities of Snowy Hydro and the viability of established irrigation areas within the Murrumbidgee and Murray Valleys.

Consistent with the Inquiry's terms of reference, the Final Report sets out a range of costed options which address environmental issues associated with the current operation of the Scheme. Interestingly, the Inquiry also went beyond its terms of reference by specifying a preferred outcome from the process nominating a 15% environmental flow in the Snowy (identified as Composite Option D).

4. SOME UNRESOLVED ISSUES

The Snowy Water Inquiry completed a comprehensive economic evaluation of environmental issues arising out of the operation of the Snowy Scheme. It has successfully developed and costed a large number of options to address these issues and undertaken additional studies to determine community attitudes towards the trade-offs involved. The Inquiry has be run in a professional manner and has encouraged a high degree of community participation on issues of significant complexity.

As successful as the Inquiry has been, their remains a number of unresolved issues. It is ironical that the significant uncertainty which surrounded the initial decision to construct the Scheme and divert waters westward has now been replaced by uncertainties associated with the benefits of returning a portion of the waters eastward. Some of these uncertainties are explored in the next section while the implications of these uncertainties for reaching an optimal outcome are explored in Section 4.2.

4.1 Some uncertainties

Environmental uncertainties

The uncertainty associated with environmental responses remains the major impediment in determining an optimal environmental flow outcome in the Snowy catchment. The complex, multifaceted nature of ecological systems makes predictions of environmental responses difficult. At a general level, Randall (1994) stated that:

> 'The earth's resource system is a vast, complex, dynamic, interative system. Attempts to modify individual components of that system will result in changes elsewhere in the system. Yet human understanding of this system is very, very limited, and so the consequences of manipulating components of the system are not easy to predict'.

Difficulties in foreseeing environmental impacts are illustrated by Buckley (1989) who reviewed over 1000 Environmental Impact Assessments produced in Australia and concluded that environmental impacts of development have rarely been predicted with any accuracy. Interestingly, of the EIA's reviewed, Buckley (1989) found that data was only sufficient to test the predictions of 19. While this example refers to the uncertainty associated with the environmental impacts of development, the same concerns would seem to apply to restoration initiatives such as increasing flows to the Snowy. Ultimately, the resilience of the Snowy ecosystem will determine the extent to which the existing degradation is reversible, and consequently the ecological benefits of increased environmental flows.

Community attitudes towards the environment

A major source of uncertainty relates to the attitudes of the community towards environmental values in the Snowy. There is some evidence to suggest that the value which the community places on environmental attributes is increasing due to factors such as increasing scarcity of environmental commodities, increased knowledge of degradation and increasing affluence and leisure time. Streeting and Hamilton (1991) cite a possible annual growth rate in the demand for environmental benefits of between 3.5 per cent and 5.5 per cent, representing the sum of estimates of income, population and consumer preference shift components.

Uncertainty associated with community attitudes is pervasive. It goes well beyond concerns associated with methodologies and techniques used to estimate values that the community places on environmental attributes, to intractable issues such as the preferences of future generations. It follows that the results of valuation surveys are likely to be valid for only short periods of time and will require on-going revision.

Opportunity costs to agriculture

While opportunity costs to agriculture can be calculated with relative accuracy over the short term, the longer term becomes somewhat more difficult. Agriculture operates in a dynamic environment associated with changing international commodity markets, rising input costs and a changing natural resource base. These factors ultimately influence enterprise mix and the opportunity costs of reducing the supply of water to agriculture.

Significant change in enterprise mix can occur over reasonably short periods of time. Certainly, the current enterprise mix in irrigation areas is vastly different to that originally envisaged during the planning of the Scheme. Evidence of this can be found in papers to an early symposium of the Australian Agricultural Economics Society titled – *The Agricultural Use of the Snowy Waters*. In referencing the work of the Economic Investigating Committee, which was established to examine the agricultural aspects of using Snowy waters, Duane (1960) noted that:

> "The general opinion of the Economic Investigating Committee (1947) was that the bulk of the water would be best directed towards the production of fine wool, crossbred wool, fat lambs, fat cattle and sideline cereals. Horticultural developments were thought to be strictly limited in their economic prospects".

This ordering of enterprises is fairly much the reverse of what is currently the most profitable use of water in the irrigation regions of Southern NSW and Northern Victoria.

Opportunity costs to the electricity sector

Opportunity costs to the electricity sector from increased environmental flows is dependant on the viability of Snowy Hydro. The on-going financial viability of Snowy Hydro is the subject of some debate and is strongly linked to future electricity prices and its existing debt of approximately $1 billion. The

Scheme's current financial problems may be partly related to the history of the Scheme[10] which involved the electricity generation business bearing all the costs associated with the financing and operation of the Scheme while agriculture has effectively received water free of charge.

A major commitment of funds is now required from the NSW, Victorian and Commonwealth Governments to guarantee the short term viability of Snowy Hydro. While the Inquiry was conducted on the basis that the Scheme was an on-going financial entity, in the longer term, Snowy Hydro will have to compete within a competitive National Electricity Market and so viability cannot be assured.

Greenhouse gas emissions

The economic costs of increased greenhouse emissions arising from increased environmental flows is based on a number of key assumptions. At a fundamental level, it is based on some 55 nations ratifying the Kyoto protocol of 1998, effectively constraining greenhouse gas emissions to agreed maximum levels at some date in the future. In Australia's case, this involves no more than an 8 per cent increase over 1990 emission levels by 2008 to 2012. There is no guarantee as to the effective implementation of such agreements and there is considerable uncertainty about the cost of exceeding established targets.

For the purpose of the economic analysis, the Inquiry assumed the value of tradeable permission rights to be $15 per tonne of carbon dioxide equivalent, while recognising that their value may range from $10 to $150. This level of uncertainty, in both the arrangements for the management of greenhouse gas emissions and their price, suggests that this is likely to have a significant impact on the overall Snowy trade-off.

Water efficiency savings

The guiding principles adopted by the Inquiry identified the use of water efficiency savings as the key means of offsetting potential agricultural and environmental impacts in the Murrumbidgee and Murray Rivers. There are, however, a number of uncertainties associated with water efficiency savings including their viability, availability for Snowy offsets, the absolute size of costs as well as who pays and timing issues.

Of principal concern is that some of the nominated efficiency savings are not available for Snowy offsets having been previously committed to other issues (eg. savings of losses in the NSW Murray have been committed to the Barmah/Millewa Forest watering strategy). The level of efficiency savings possible will require further research and negotiations amongst stakeholders and are likely to be phased in over time.

4.2 Implications

The previous section highlighted a number of sources of potential uncertainty and change which would directly influence the optimal level of environmental flows in the Snowy. These included environmental responses, changing community attitudes towards the environment, greenhouse gas issues, the changing magnitude of opportunity costs to the electricity generation and agricultural sectors and uncertainty about

[10] According to Duane (1960), the Scheme was ultimately recommended on the generation of hydro-electric power. This was despite its power being sacrificed to some extent by large diversions to the Murrumbidgee Valley (where better facilities for irrigation existed). 'The potential of the Snowy waters to be used for irrigation was considered to be a comparatively poor and distant relation: so poor in fact that the provision of irrigation water below the major headworks was to be completely subsidised by the sale of electricity'.

the availability of efficiency savings. These uncertainties suggest that there may be serious shortcomings in using prescriptive approaches to identify point solutions to complex and dynamic problems like environmental flows in the Snowy.

These issues highlight a need for Governments to think strategically about management processes which can be put in place to manage trade-offs and allow for the optimal allocation of scarce resources over time. An important component of this process is the concept of adaptive management which can be defined as an iterative process whereby decision makers review and modify water management strategies in light of experience and in response to new and improved information. Adaptive environmental flow regimes provide Governments with flexibility to respond to:

i) improved levels of information about ecological responses to environmental flows;

ii) improved levels of information about social and environmental impacts of environmental flows;

iii) changing community values in relation to environmental outcomes;

iv) changing environmental values in response to increasing or decreasing scarcity; and

v) adoption of new technologies in agriculture and electricity generation, and changes in agricultural and electricity markets which alter the opportunity costs of environmental flows.

The adaptive management approach to the development of flow regimes in the Snowy River catchment appear to have a much higher probability of achieving socially acceptable outcomes in relation to the trade-offs involved, than ‘one-off’ attempts based upon arbitrary, percentage estimates, of the original flow patterns in the Snowy River (prior to the Snowy Hydro-electricity Scheme being built). There are limitations, however, on the extent to which an adaptive management approach can be adopted. The most significant of these are the water licence arrangements which will apply to the corporatised body, Snowy Hydro Ltd.

The term of the Snowy Hydro’s licence is 75 years with a review after five years providing very little flexibility in pursuing an optimal outcome over time. As noted in SWI’s Final Report:

> ‘Once Governments agree on an outcome for the Snowy, flow arrangements are effectively fixed for 70 years, unless compensation is paid to Snowy Hydro for any additional flow requirements’.

Alternatives to such rigid licence conditions afforded to Snowy Hydro require consideration. One alternative which has more recently received the attention of economists is the use of market based approaches such as tradeable water entitlements (TWE’s). While transfers of water have largely been constrained to within the irrigation industry to date, there is some potential for their broader application. Extension of trading to other sectors including environmental interests, tourism and electricity generation, at least in theory, could provide a more flexible approach to the management of trade-offs between these uses over time. Many problems would of course be encountered and would require an appropriate system of property rights to be defined.

Musgrave and Kaine (1991) discuss a number of issues associated with property rights and the establishment of environmental water allocations. They suggest that defining and quantifying the appropriate right system is not easy and significant difficulties emerge because water is a multi-faceted resource that is of a flow rather than a stock nature. Nevertheless, trading between the environment, electricity and agricultural sectors could potentially play an important role in the management of trade-offs in the Snowy and could provide significant advantages to all sectors. For example, the purchase and sale of water by the environment would improve the flexibility in which environmental objectives can be pursued through access to finance rather than a given volume of water.

Environmental groups have traditionally argued that they could not afford to operate in such markets. As an alternative, they have generally pursued regulatory approaches through Government in providing environmental flows. However, with growing community concerns about environmental issues and the emergence of well organised environmental groups there appears to be some potential for more private involvement in the purchase of water for environmental purposes. Indeed, there is already some private involvement in the financing of environmental flows in the United States. While altruism in Australia may be currently inadequate for such a task, the existence of community based catchment management committees could possibly provide a vehicle by which contributions towards environmental flows from Local, State and Commonwealth Governments and the private sector could be gleaned. The operation of such a market offers a more flexible approach to the management of trade-offs in the Snowy in comparison to regulatory intervention.

As with many resource allocation policy problems, however, a solution to the Snowy trade-off is not immediately obvious. The existing process has deficiencies which may lead to poor outcomes given the dynamic nature of environmental and economic relationships. The challenge for economists is to recognise the critical role uncertainty plays in policy formulation and to identify workable management systems capable of responding to new information about resource use trade-offs, while at the same time maximising competition in the use of scarce resources.

REFERENCES

Buckley, R.C (1989). 'Precision in Environmental Impact Prediction'. Resource and Environmental Studies No. 2. Centre for Resource and Environmental Studies, The Australian National University, Canberra.

Department of Environment, Sport and Territories and Department of Finance (1995), *Techniques to Value Environmental Resources*, AGPS, Canberra.

Duane, P. (1960), 'Economics and the Use of the Snowy Waters'. Symposium: The Agricultural Use of the Snowy Waters. *Australian Journal of Agricultural Economics* 4 (1): 36-51.

Musgrave, W. and Kaine, G. (1991), 'Property Rights and Environmental Water Allocations'. *Proceedings of an International Seminar and Workshop: Water Allocation for the Environment.* University of New England, Armidale.

Norton, T. (1995), 'Ignorance and Uncertainty - Challenges to Implementing Environmental Goals for Sustainability', *Paper presented to the Ecological Economics Conference*, Coffs Harbour.

Perkins, F.C. (1994), *Practical Cost Benefit Analysis - Basic Concepts and Applications*, Australian National University.

Randall, A. (1987), *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy*, 2^{nd} Edition, John Wiley and Son.

Saddler, H., Bennett, J., Reynolds, I. And Smith, B. (1980) Public Choice in Tasmania: Aspects of the Lower Gordon River Hydro-electric Development Project, Centre for Resource and Environmental Studies, Australian National University, Canberra.

Snowy Water Inquiry (1998), *Final Report*. Submitted to the Governments of New South Wales and Victoria. Published by Snowy Water Inquiry, Sydney.

Streeting, M., and Hamilton, C. (1991), 'An Economic Analysis of the Forests of South-Eastern Australia', *Resource Assessment Commission Research Paper No. 5.* AGPS, Canberra.

Young, M. and Mues, C. (1993) 'An evaluation of water management strategies in the Barmah-Millewa forest'. *Paper presented to the 37th Agricultural Economics Society Conference*. University of Sydney. February