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ECONOMICS OF WATER ALLOCATION FOR THE ENVIRONMENT: A CASE STUDY IN THE GWYDIR WETLAND, NSW

By

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ABSTRACT

Determining appropriate environmental water allocations or "Environmental Flows" to maintain the natural ecosystem is a major issue among irrigators, politicians, environmentalists, ecologists and economists. As the State's water manager, the NSW Department of Land and Water Conservation (DLWC) allocates water among the major user groups. Assessing optimum volumes of environmental flow allocation is a significant problem for the Department.

Empirical economic studies on evaluating benefits of environmental flows are limited. Hence, this paper attempts to review existing economic studies on this issue, and to identify and develop a suitable methodology to evaluate costs and benefits of environmental flows. The paper will apply this methodology for optimum environmental water allocation to a case study, the Gwydir Wetlands in NSW.

KEY WORDS: *Environmental Flows, Wetlands, Environmental Benefits, Valuation*

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Introduction

Water allocation for the environment or "Environmental Flows" can be simply defined as the volumes of water allocated or released from other uses to maintain the natural ecosystem. The "natural ecosystem" includes the river environment, flora and fauna, riparian land and wetlands.

Water allocation for the environment has been a major issue among many people; politicians, irrigators, environmentalists, ecologists, economists etc. As the State's water manager, the NSW Department of Land and Water Conservation (DLWC) allocates the water among the major users. Determination of the appropriate flow levels for the environment is a significant problem. The DLWC has adopted a resource management based approach instead of a truly scientific one. This approach incorporates a risk sharing concept and operates on hydrologic data. However, environmental, economic and social information are also incorporated in the final stage.

The current process of establishing environmental flows consists of two stages. These are as follows;

Stage 1 will establish interim flow objectives, and take into account community preferences, current scientific knowledge and economic analysis.

Stage 2 involves an independent public inquiry process to help establish water quality and river flow objectives, initially for priority catchments.

The Gwydir Wetland case study is to assist in the development of interim flows. The aim of setting river flow objectives is to protect and rehabilitate riverine ecosystems through the management of river flows. In developing river flow objectives, the following principles will be adopted;

- adaptive management when the management of the flows should be flexible and staged to accommodate;
 - expanding knowledge
 - results of river health monitoring
 - changing community and river health values
- tailoring to each river system /catchment, to provide an effective and practical flow regime
- the development and implementation of river flow objectives should consider the social and economic impacts on current water users
- water flows should be based on the natural flow regime which includes variability and seasonal patterns of flow
- environmental flows should provide protection for rivers whose flow regime and riverine ecosystems have not been seriously impacted by people. There will also be programs to restore degraded river systems.

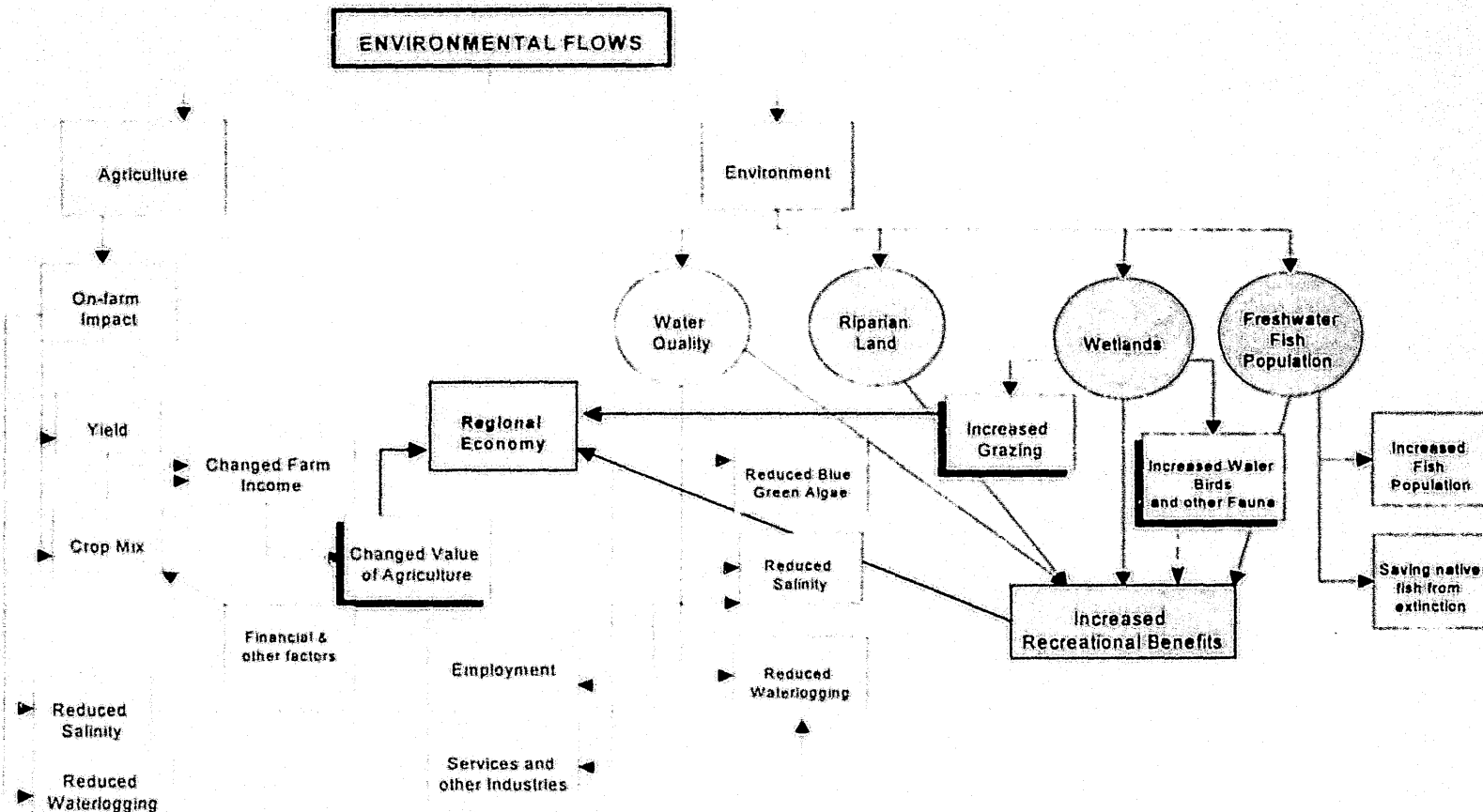
Figure 1 illustrates various impacts of environmental flows on the environment and agriculture. Diversion of water from extractive users to the environment may affect the irrigation industry adversely. Reduced water availability may encourage farmers to convert their irrigation farming to non-irrigation farming fully or partly, resulting in reduced yield and farm incomes. Further, depending on the climatic and agronomic factors they may tend to grow crops which require less water but with low values. This also leads to reductions in farm incomes.

One of the impacts of environmental flows on the environment is improved water quality by reducing the incidence of blue green algae and diluting salinity in the water, especially outside the irrigation season. Maintaining a suitable environment for fish migration and spawning is also a benefit of environmental flows. These improvements in the environment eventually increase recreational benefits in the valley. Further, environmental flows may increase grazing land by wetting wetlands and consequently increasing income from grazing.

With the current appreciation of the rights the environment has to its water, the department is faced with finding a solution that will minimize costs to current water users and maximize the benefits to the environment. The environment as a user includes flora, fauna, and fish, through rivers and wetlands, as well as estuaries. Ideally the natural regime before the building of dams and weirs could be replicated to return water flows to their original frequency. To do so would impose considerable costs to some other users. Considering methods to determine the extent of those costs is one of the objectives of this paper.

The empirical economic studies on benefits of environmental flows are limited. This paper reviews existing economic studies on allocation of water for the environment to identify a suitable methodology to evaluate the benefits of environmental flows in NSW, Australia. The paper will apply this methodology for optimum environmental water allocation to a case study, the Gwydir Wetlands in NSW.

FIGURE 1. IMPACT OF ENVIRONMENTAL FLOWS ON THE ECONOMY AND THE ENVIRONMENT



Literature Review

Although empirical studies on estimating net benefits of environmental flows seem to be limited, many researchers have attempted to estimate recreational benefits, particularly, benefits of recreational fishing of instream river flows. The impact of environmental flows on the agriculture has also been studied by few authors. An attempt was taken here to review some of these studies (see also Hill 1994).

J. Loomis (1987) reviewed several studies illustrating how both the travel cost method (TCM) and contingent valuation method (CVM) estimates of benefits could be tied to flow levels to calculate a marginal willingness to pay for alternative flow levels. The paper documented both the TCM and CVM derived demand curves based on utility maximization of instream flow users.

Ward (1985, reviewed in Loomis 1987) utilized the TCM to estimate angler and white water boating benefits on the Rio Chama River during the summer of 1982. To link recreation benefits to alternative levels of instream flow, Ward estimated seven separate demand equations, one for each of seven different seasonal flow levels. He estimated a separate equation which related combined river recreation benefits as a function of flow and then used this equation in a dynamic programming model to determine the optimal timing of releases from the dam into the Rio Chama River. In a simulation run for late summer, Ward estimated a combined worth of water in the stream to anglers and boaters.

Daubert *et al* (1979, reported in Loomis 1987) applied the CVM to valuing per-day recreation benefits of three different types of recreation on the heavily visited Poudre River in Northern Colorado. For the first time they linked alternative levels of flow and recreation benefits explicitly. In contrast to Daubert *et al*, an instream flow study by Walsh *et al* (1980, also reported in Loomis 1987) utilized CVM and encompassed both changes in values per day of existing use and changes in days per season due to variations in instream flow levels.

Unlike the Daubert *et al* (1979) approach, a study of instream flow benefits in Utah (Narayanan *et al* 1983; Amirfathi *et al* 1984) estimated the change in value of instream flow due solely to a change in use days of current anglers. They utilised a TCM demand model to estimate current angler benefits for three rivers in the Cahee Valley region of northern Utah. The authors then asked a form of CV question: change in current anglers' visitation, if flow was reduced from the peak 1982 levels (a high flow year).

The study of Bosch and Broomhall (1990) presented methods for determining how minimum instream flow (MIF) standards affected crop yields from riparian irrigation. The methods were applied to a watershed of eastern Virginia. MIF standards of 10, 20 and 30 percent of mean annual flows, 10 percent of mean monthly flows, and the minimum 7-day average flow per 10-year period (7-Q-10) were evaluated to determine their effects on irrigated corn and soybean returns.

The estimated losses reported in this study were calculated assuming that water was allocated with the riparian doctrine meaning that shortages were shared equally by all users. The losses would be different if other institutional mechanisms were used to allocate water. For example, a market system might reduce the economic losses from imposition of a MIF standard by allocating scarce supplies more efficiently than under the riparian system.

Loomis and Cooper (1990) presented a simultaneous system of demand and production equations that explicitly incorporated an instream flow variable and measured the effect on recreationists' benefits of a change in instream flow. The economic benefit of maintaining instream flow was measured as visitor's consumer surplus or net willingness to pay. To estimate the changes in stream flow in the single-site format, a single-site pooled time-series cross section travel cost model was estimated. A case study modeled this relationship between river flow and fishing trips to the North Fork of California's Feather River with results indicating a statistically significant relationship between flow and catch.

A study by Jones et al (1992) used linear programming with a hydrology simulation model developed by the DLWC to determine the average annual income and income variance of alternative irrigation water allocations and associated supply reliability in the Murrumbidgee Valley. In this study deterministic linear programming was used to calculate optimal annual net returns from irrigated agriculture for a variety of water allocation scenarios. This analysis assumed that the agricultural plans for each irrigation season were independent of the preceding season, which may not be strictly correct if rotations were considered.

As the literature survey revealed, two major analytical approaches are available for analyzing impact of environmental flows. These are focused on analyzing benefits and costs or the negative impact of environmental flows. In order to analyze the recreational benefits, travel cost and contingent valuation methods were mainly used. The impacts on agriculture or the net farm income were estimated through linear programming and statistical approaches.

Methodology

The DLWC currently uses a combination of hydrology simulation and spreadsheet models to analyze the economic impact of different environmental water flow allocations.

The hydrology data were obtained using the Integrated Water Quantity and Quality Model (IQQM) developed by the Hydrology Unit of the DLWC. This model is used in planning and evaluating water resources management policies. This is a generalized hydraulic simulation package which is capable of application to regulated and unregulated streams, and is designed to address water quality and environmental issues as well as water quantity issues.

The in-stream water quantity component of the IQQM has different processes: flow routing; reservoir operation; resource assessment; irrigation and other features. Irrigation is one of the most complex and variable process included in the IQQM and the most important component for economic evaluation.

The irrigation module in IQQM includes features for:

- assessment of available resources (soil moisture accounting);
- area planting decision (modeling a range of different crop types);
- irrigation demand (simulating decisions of farmers regarding area of crop to plant and irrigate);
- detailed modeling of on-farm storages; and
- irrigation application (accounting for water use in relation to entitlement and off-allocation access).

Because of inclusion of the irrigation module, the IQQM is able to estimate the area to be planted for each crop type based on the resource availability and the other input data: licensed volumes; maximum potential irrigable area; irrigation development factor; crop types and crop factors; pan evaporation; and expected rainfall.

The current model uses a statistical approach with hydrology data simulated over 102 years. This model can be used for estimating the direct impact of environmental flows on the farm income. The crop areas produced by the IQQM for the simulation period (102 years) for each scenario or allocation strategy are used in the economic spreadsheet model to evaluate the different scenarios. Although this approach takes farmers decisions on crop areas to plant and irrigate into consideration (in the IQQM), the market driven influences such as commodity prices and change in variable costs are not incorporated in the decision of selecting and planting different crop types. This type of problem can be solved by using linear programming, particularly a dynamic programming method.

The economic model estimates the value of each crop based on the areas planted generated by the IQQM and the gross margins of the crops for each year over the simulation period. Then the change in gross margins (difference between the base case and different scenario) is estimated. This information is used in estimating the mean and standard deviation of net farm income and present value of net income over a 30 year period.

The current model provides only possible direct effects on the agriculture under given policy scenarios. Hence, a different methodology which could incorporate the effects on the agriculture as well as benefits to the environment the DLWC is being proposed. This approach would be a combination of hydrology simulation (IQQM), linear or dynamic programming, non-market evaluation (CV) and economic spreadsheet models (figure 3.).

Currently the Department is working on this methodology. Due to lack of information, especially on the benefits of environmental flows, the current methodology was used to analyze the impact of various environmental flow policy options on the agriculture in the Gwydir Valley.

FIGURE 2. DLWC CURRENT METHODOLOGY OF EVALUATING ENVIRONMENTAL FLOWS

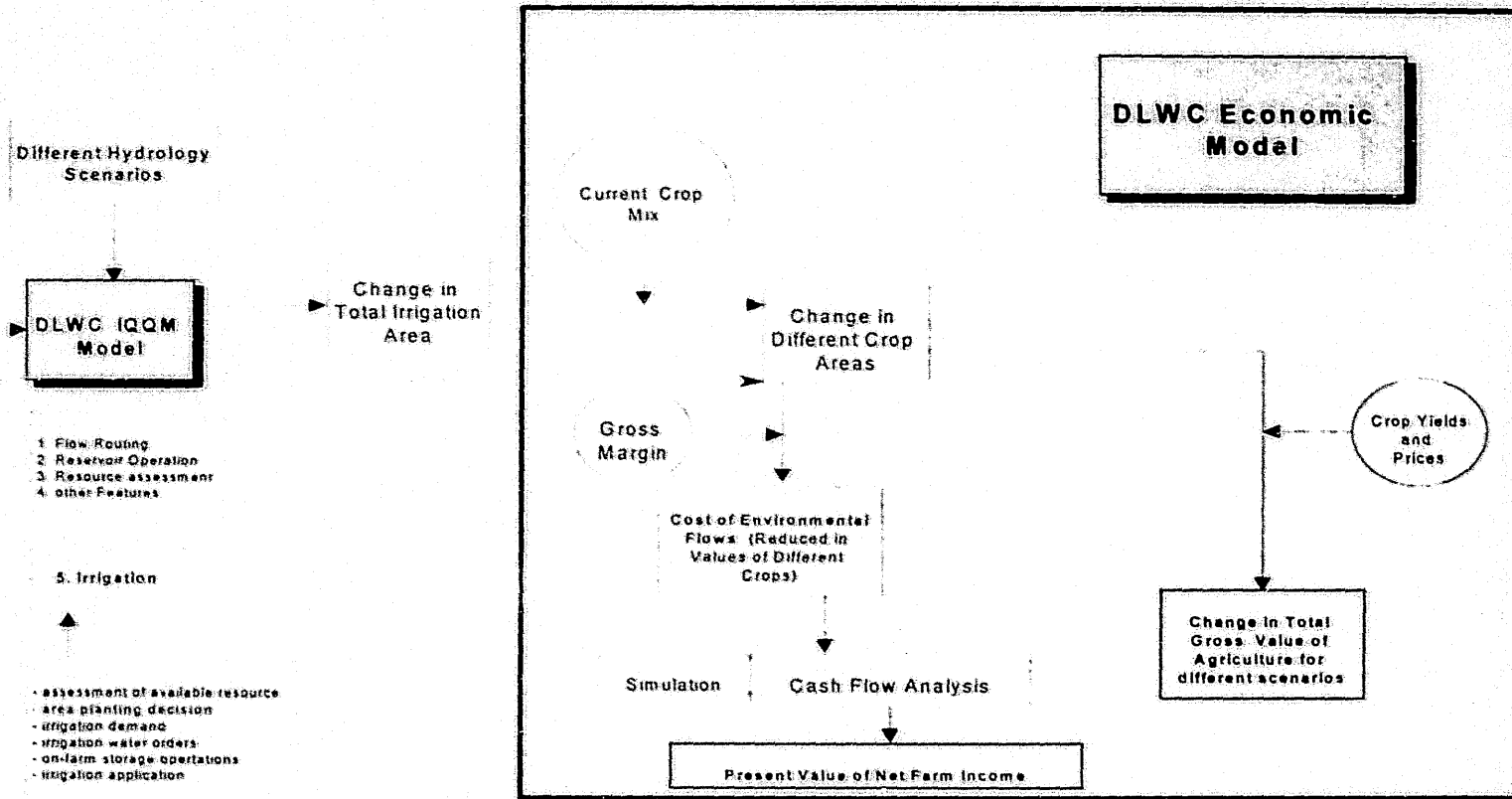
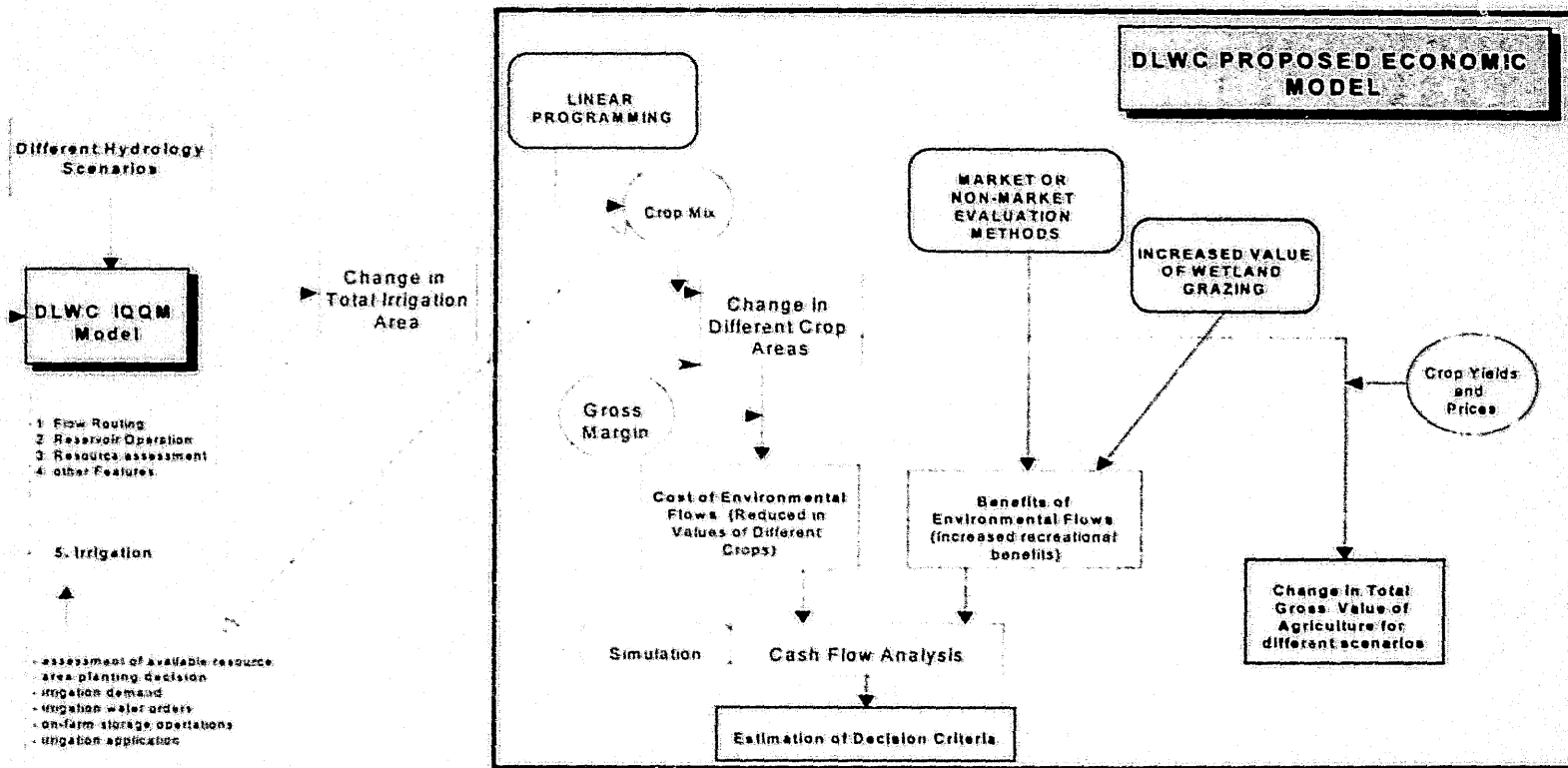


FIGURE 3. DLWC PROPOSED METHODOLOGY OF EVALUATING ENVIRONMENTAL FLOWS



Gwydir Wetland Case Study

The Gwydir wetlands are located in northern inland New South Wales west of Moree and cover an extensive area. The Gingham and Lower Gwydir Watercourses are the most valuable and unique part of the total area. The current land tenure is freehold and land use is cattle grazing. The Gwydir wetlands are of national significance and were renowned for their bird breeding habitat, which is linked to flood events. However, they have suffered from the diversion of water to irrigation. The wetland vegetation has also been altered over time, with an increase in weed invasion of peripheral areas and a reduction in the abundance of fauna. The decline in flooding frequency has contributed to the decline in the wetlands. Because of this there has been a decline in stock carrying capacity of 30-50% (Bennett and Green 1993). It is these issues which the environmental flows project addresses.

The completion of Copeton Dam in the upper catchment in 1976 enabled the establishment of an irrigation industry on the Lower Gwydir River floodplain near Moree. Before Copeton and subsequent river regulation all freshes and minor floods terminated in either the Gingham or Lower Gwydir water course wetlands. The transfer of these freshes and small floods from the Gwydir system to the irrigation industry became a major issue for the water users (McCosker and Duggin 1993).

The wetlands provide grazing, particularly when surrounding areas are dry. They are also valuable for flood mitigation, reducing flood peaks further downstream in the Barwon Darling System. Possibly they act as a water purifier and prevent the flow of nutrient rich water to the Barwon-Darling system, reducing the likelihood of algae blooms.

In order to halt the decline of wetlands the DLWC introduced new environmental flow policies, giving priority to watering of primary wetland areas. Any re-allocation of flows back to the wetland will incur some loss of production capacity for irrigation farmers. The DLWC analyzed the impact of three different policy options on the Gwydir irrigation agriculture. These options included the existing flow levels (Base Case), no access to tributary and off-allocations (option 1), no off-allocation extraction (option 2), and 50% of off-allocation extraction limit (option 3).

The base case represented flows under existing operations where the flow in the river is supplemented by releases from the dam to supply orders. As well, where the flow downstream of the dam is in excess of orders the water could be declared off allocation, and its use does not get debited against the irrigators allocations. Option 1 represents the most extreme situation for increases in environmental flows, where any water coming into the river system downstream of the dam (tributaries) can not be used for irrigation either as on allocation or off allocation water. Thus all orders are met from the dam. Under option 2 tributary flows can be used as part of the on allocation water but no tributary flows can be used for off allocation. Option 3 cuts back the use of off allocation use to 50% of off allocation (of what would have been available under the base case) for off allocation and 50% available for use.

As the water to the environment increases, from option 3 to options 2 and 1, less water is available to the other water users, especially to irrigators.

This may adversely affect the region's agricultural industry. In the Gwydir Valley the total area of crops and pastures in 1993 was 529,121 hectares which accounted for about 19.5 percent of the total area of agricultural holding in the valley. During this year, the total area irrigated was about 14.0 percent of the total area under crops and pastures. The mostly grown crop was wheat for grain (224,038 ha) which was followed by cotton (102,920 ha) and barley for grain with 83,933 ha (ABS- IRDB, 1995). In terms of gross output the Gwydir Valley based cotton industry is the most significant contributor to the local economy.

The current methodology was used in the analysis and focused on the impact on net farm income and gross value of agricultural production. No attempt was made to estimate the downstream effect such as increased salinity run off, on farm recycling costs, nor downstream benefits such as recreational benefits and wetland grazing. The results of applying this current methodology in the Gwydir Valley are presented in the following section.

Results and Discussion

The change in variability on discounted net farm income as a result of implementing the proposals was estimated by using a 30 year production period. The weather conditions were assumed to be similar to any 30 year period over the last 102 years. The average present value of the annual net farm income, median annual net income and standard deviation for the base case and the three proposals are presented in table 1. Under the base case the present value of average net farm income was \$880 million with a standard deviation of \$92 million. This implied that the annual net income should lie in the range \$788 to \$972 million, if the climatic conditions prevailed as have done over the last 102 years and prices etc remain constant over the 30 year period. The present value of reductions in net farm income range from \$132 million to \$196 million under option 1. The values for option 2 and 3 range from \$47 to \$77 million and \$4 to \$20 million respectively. According to these results option 3 (where 50% of off-allocation would be allocated) would reduce the farm net income by \$12 million, which is the least reduction of these options.

TABLE 1 PRESENT VALUE OF THE CHANGE IN NET FARM INCOME IN THE GWYDIR VALLEY

(In Gross Margins terms, over 30 years, at 7%)

(\$ million)

	Base Case	Option 1 (No tributary and off allocations)	Option 2 (No off allocations)	Option 3 (50% off allocation)
Average	880	716 (-164)	818 (-62)	868 (-12)
Median	884	712 (-165)	827 (-63)	873 (-11)
Standard Deviation	92	109 (32)	99 (15)	97 (8)

* Note: The figures in parenthesis represents the change from the base case.

The impact of the three proposals (options) on the gross value of agricultural production was also estimated in this analysis. Results in table 2 illustrate the impact of implementing different policy options on the net farm income (Base Case). As the results show, the average annual net farm income of \$154 million (in the Base Case) would be reduced by \$27 million under option 1, \$ 12 million under option 2 and \$2 million under the third option.

TABLE 2 AVERAGE ANNUAL LOSS OF GROSS VALUE OF AGRICULTURAL PRODUCTION

(\$, million)

	Base Case	CHANGE FROM THE BASE CASE		
		Option 1 (No tributary and off allocations)	Option 2 (No off allocations)	Option 3 (50% off allocation)
Gross Value of Production	154.15	-26.52	-11.80	-2.20
Change in Gross Value	-	-17%	-8%	-1%

This model has not incorporated the downstream effects such as increased salinity run-off, increased on farm recycling costs, or reduction in variable costs due to less water usage. Nor were the downstream benefits of increased wetland grazing and increased recreational benefits incorporated in this model.

As indicated earlier, the current model provides only possible direct effects on the agriculture under given policy scenarios. Hence, a methodology has been proposed which could incorporate effects on the agriculture as well as benefits to the environment.

Conclusions

This paper reveals that the existing economic studies on the impact of environmental flows mainly focused on evaluating recreational benefits of alternative instream flow levels and determining their economic effects on irrigation income. The benefits have been estimated by adopting non-market and market evaluation methods, mainly the travel cost method and contingent valuation method. The economic effect (cost) on the agriculture has been estimated using statistical and/or optimization methods.

The current model uses a statistical approach with hydrology data simulated over 102 years. This model can be used for estimating the direct impact of environmental flows on the farm income. Although this approach takes into consideration farmers' decisions on crop areas to plant and irrigate (in the IQQM), the market driven influences such as commodity prices and changes in variable costs are not incorporated in the decision of selecting and planting different crop types. This type of problem can be solved by using linear programming, particularly dynamic programming.

The proposed model which is an extension of the current model, would be a combination of hydrology simulation, dynamic programming, spreadsheet models, and a non-market evaluation. The proposed model is intended to incorporate farmers' decisions in planting and irrigating different crops (depending on water availability, commodity prices, and other financial factors) by using a linear or dynamic programming technique. The benefits of environmental flows estimated through an appropriate survey method will be incorporated into the proposed model. The proposed methodology which includes components for estimating both costs and benefits could undertake full economic analysis of environmental flow policy options.

REFERENCES

- ABS (1995) *Integrated Regional Database version 2.0*, Australian Bureau of Statistics, Canberra.
- Amirfathi, P., Narayanan, R., Bishop, B. and Larson, D. (1984) *A Methodology for Estimating Instream Flow Values for Recreation*, Logan, Utah: Utah Water Research Laboratory, Utah State University.
- Bennett M and Green J (1993) *Preliminary Assessment of Gwydir Wetlands Water Needs* Department of Water Resources Technical Services Division TS 93.085
- Bosch, D. and Broomhall, D. (1990) Estimating the Economic Costs to Irrigators of Alternative Minimum Instream Flow Standards, *Rivers*, 1(1):51-61.
- Collins, D. and Scoccimarro, M. (1995) Economic Issues in the Creation of Environmental Water Allocations, *Outlook 95: Commodity Markets and Natural Resources*, Proceedings of the National Agricultural and Resources Outlook Conference, Canberra, 241-251.
- Daubert, J., Young, R. and Gray, L. (1979) Economic Benefits from Instream Flow in a Colorado Mountain Stream, *Completion Report 91*, Fort Collins, Colorado: Colorado Water Resources Research Institute, Colorado State University.
- DWR (1995) *IQQM - Integrated Water Quantity and Quality Model*, Hydrology Unit, NSW Department of Water Resources, Parramatta, NSW.
- Hill C (1994) *Economic Environmental Evaluation for Water Resource Management; A Review* New South Wales Department of Water Resources
- Jones, R., Musgrave, W. and Bryant, M. (1992) Water Allocation and Supply Reliability in the Murrumbidgee Valley, *Review of Marketing and Agricultural Economics*, 60(2):155-172.
- Knights, P., Fitzgerald, B. and Denham, R. (1995) Environmental Flow Policy Development in New South Wales, *Outlook 95: Commodity Markets and Natural Resources*, Proceedings of the National Agricultural and Resources Outlook Conference, Canberra, 252-261.
- Loomis, J. (1987) The Economic Value of Instream Flow: Methodology and Benefit Estimates for Optimum Flows, *Journal of Environmental Management*, 24:169-179.
- Loomis, J. and Cooper, J. (1990) Economic Benefits of Instream Flow to Fisheries: A Case Study of California's Feather River, *Rivers*, 1(1):23-30.
- McCosker R and Duggin J (1993) *Gingham Watercourse Management Plan* Department of Ecosystem Management University of New England Armidale

Narayanan, R., Larson, D., Bishop, B. and Amirfathi, P. (1983) *An Economic Evaluation of Benefits and Costs of Maintaining Instream Flows*, Logan, Utah: Utah Water Research Laboratory, Utah State University.

NSW Agriculture (1993, 1994) *Crop Budget Handbook*.

Walsh, R., Ericson, R., Arosteguy, D. and Hansen, M. (1980) *An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow*, Fort Collins, Colorado: Colorado Water Resources Research Institute, Colorado State University. –

Ward, F. (1985) *Optimally Managing Wild and Scenic Rivers for Instream Flow Benefits*, In *Proceedings of the National River Recreation Symposium*, Baton Rouge Louisiana: Louisiana State University.