Development of a Decision Support System for the Namoi and Gwydir Valleys

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Abstract: This paper outlines a project currently being undertaken to develop decision support systems which are accessible to industry representatives and state government agency staff for considering the impact of various water allocation policies on water users and the environments of the Namoi and Gwydir River catchments. This work builds on a previous project (a PhD project) in which a regional scale integrated economic-hydrologic modelling framework was developed for considering water allocation in the Namoi River catchment. Feedback from State Government Agency and industry representatives at the end of this previous project indicated that there was considerable interest in further developing this prototype so that it could be used by decision makers and other catchment stakeholders for considering economic and environmental trade-offs associated with a variety of management issues in the catchment. Outcomes from the project will include delivery of decision support tools for the Namoi and Gwydir river catchments. These tools will be accessible through user-friendly interfaces. Training workshops for industry, state government agency staff and other community representatives will be held throughout the project to ensure that the tools are appropriate for the needs of these stakeholders, and so that adoption of the decision support system is ensured.

Keywords: *Decision Support System; Water allocation*

1. INTRODUCTION

Effective management of natural resource systems requires information on the nature of social, economic and environmental trade-offs resulting from implementing recommended policies. Decision support systems (DSS) are one way of providing this information in a reusable and accessible way.

Many authors have attempted to provide a definition of the term ‘decision support system’ (for example see Kersten and Micalowski, 1996; Ewing *et al.,* 1997; Rizzoli and Young, 1997), to the point where the definition is arguable. The definitions provided in the literature range from the view that any computer based system that supports decision making is considered to be a DSS, to the other extreme where a DSS is considered to be a system which has modelling capabilities and is used by decision makers to solve unstructured problems (Kersten and Micalowski, 1996). A more general definition provided by Ewing *et al.* [1997] is that DSS are ‘computer based simulation models designed to enable the user to explore the consequences of potential management options’.

Rizzoli and Young [1997] provided a review of environmental DSS and suggested that an ideal DSS should have a number of properties. It should assist in decision making for unstructured and semi-structured tasks and support and enhance managerial judgement. A DSS should be aimed at improving the effectiveness, rather than the efficiency, of decision making. It should combine the use of models or analytical techniques with data access functions whilst still focusing on the features which provide ease of use for inexperienced users. Lastly it should be flexible and adaptable to allow for changes in the decision making context.

This paper describes a project focused on the development of a DSS for considering water allocation policies in both the Namoi and Gwydir river catchments in NSW.

2. NAMOI PROTOTYPE

The DSS described in this paper has been based on a prototype model previously developed for the Namoi River Catchment in NSW, Australia. This section briefly describes this prototype model and gives a summary of feedback provided by stakeholders on the prototype model.

2.1 Overview of Prototype Model

The Namoi River Catchment covers approximately 43,000km^2 in northern NSW and is an important irrigation region. Irrigators have different access to surface and groundwater sources throughout the catchment, with different types of licences and different levels of security of access. This means that the question of where to provide access to water involves a trade-off between upstream and downstream users, and is intrinsically spatial in nature.

To address this issue a framework that accounts for the important spatial variability of this management problem was developed. This means that the catchment was mapped into a number of relatively homogenous regions based on ground water and surface water policies and production type. The regions developed for the prototype are shown in Figure 1. A set of alternative cropping activities has been developed for each region. These activities have been developed to be representative of those likely to be undertaken in each region on potentially irrigable land.

Each region also corresponds to a hydrological node (regions E and F share a hydrological node, other regions have a unique node). This structure forms the basis of the links between hydrological and economic components of the model.

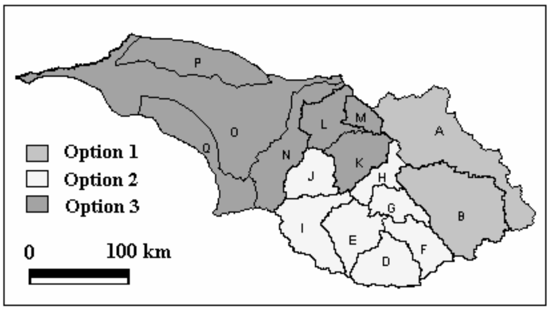


Figure 1. Land use options for Namoi Regions

Each of the regions shown in Figure 1 is linked to a flow node. The hydrological network used in the model is shown in Figure 2. These connections are detailed in Letcher [2001]. This flow network provides the limits of surface water extraction and allocation in each of the regions detailed in Figure 1 and can be considered to provide some of the constraints in the regional economic model. Additionally, any extraction decision made in each region can be fed through the hydrological network in order to determine the impacts of different allocation decisions on catchment discharge.

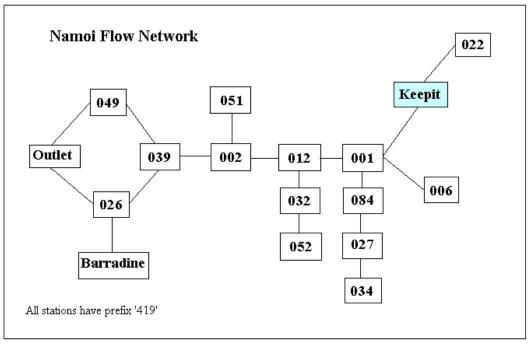


Figure 2. Hydrological Network

The economic and hydrological models are linked as shown in Figure 3.

The policy model mimics daily extraction rules which have been suggested in NSW. These extraction rules are based on a series of flow classes, with maximum extraction rules in each class for each subcatchment. This model takes daily simulated streamflow and calculates from this an annual extraction limit. The second link is through the daily extraction model. This model takes the annual extraction decision from the economic model and uses it to determine daily flows left after extraction. These extracted flows are then routed downstream. In this way, production decisions at upstream nodes impact on resource availability at downstream nodes. Further details on the prototype model are available in Letcher [2002, 2001].

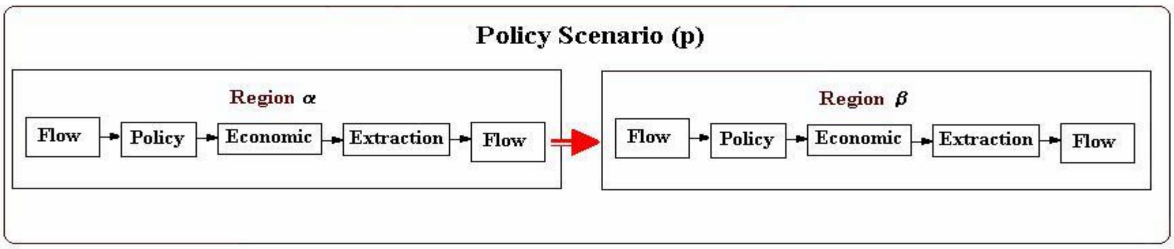


Figure 3. Conceptual framework for model

2.2. Summary of Feedback

Several feedback sessions on the prototype model were held with a variety of stakeholders. Comments on the model were recorded with stakeholders emphasising both the advantages and limitations of the prototype model. Letcher [2002] provides a detailed discussion of the response of stakeholders to the model. The main limitations that were considered by stakeholders were:

- the lack of a groundwater modelling component, and thus the lack of links between groundwater and surface water systems;
- crop yields and water use not being linked to climate;
- assumptions about pumping flood flows - some stakeholders suggested that irrigators are unlikely to pump the rising stage of a flood flow in many areas of the catchment as they risk losing their pumps. It was suggested that the model should allow for this as otherwise it overestimates the amount of water actually available to irrigators;
- assumptions about the decision making behaviour of farmers. Several stakeholders raised concerns about
  - assuming farmers are profit maximising;
  - assuming each region is controlled by a single farmer;
  - the lack of differentiation between farmers especially with respect to their levels of knowledge and expertise, and their financial ability to invest and change production.
- the simplified representation of Peel River subcatchment. Some stakeholders suggested this should be replaced with a more detailed nodal network for this region to allow investigation of trade-offs between the Peel River users and the rest of the Namoi catchment.

3. CURRENT PROJECT

The prototype described above has been developed to allow consideration of the economic and environmental trade-offs resulting from a broad range of water reform or trading options. Given the feedback on this prototype, the current project aims to complete the prototype in the Namoi river catchment and to reapply this approach in the Gwydir river catchment. This project will include:

- development of a basin scale groundwater model capable of considering links between the surface and groundwater systems - a PhD student funded through the project will be undertaking this work;
- updating the flow network for the Namoi catchment to reflect comments received during the feedback sessions - in particular, further detail of the Peel system will be provided;
- incorporation of empirical crops models which reflect the impact of rainfall variation and water availability on crop yield and water use;
- updating the policy models for the catchment to better reflect current policy options and pumping conditions experienced by irrigators;
- updating the regional scale economic models - this will include consideration of potential changes in modelling assumptions, especially relating to the representation of farmer decision making;
- inclusion of a number of representative farm models to illustrate the impacts of policy changes or trade on individual farmers - this work is an in-kind contribution to the project by NSW Agriculture;
- development of a software package and interface through which agency staff, industry representatives and other community members may access the models - this will include a number of training and development workshops which will be held to elicit feedback on interface development and provide training in model use; and
- application and testing of the modelling framework on the Gwydir river catchment.

While plans have been made for the work outlined above, the project aims to be flexible to the changing needs of stakeholders. In particular, feedback has been sought on the project and priorities expressed in the work plan. Comments that are received throughout the life of the project will be used to refine the model development process to ensure the project remains relevant to the broadest range of people.

The rest of this section outlines the individual components being developed as part of the project.

3.1. Groundwater modelling in the Namoi catchment

A simple catchment scale groundwater modelling component is being developed for the Namoi river valley. This component will link with the hydrologic and economic models in the system and will be used to simulate impacts of various management policies on the groundwater system. The large scale of modelling required (whole of basin) and the need for the model to be integrated with other models (economics, hydrology) means that a simple lumped or conceptual model is likely to be the most appropriate. A final choice of model has not yet been made. This component of the project is being undertaken by a PhD student.

3.2. Hydrological Modelling

A flow network has previously been developed for the Namoi catchment (in the prototype project described above), however, significant simplifications were made in this network (eg. Peel river treated without considering Chaffey Dam). Feedback from stakeholders on preferred options for further developing this network have been sought and are in the process of being implemented. Additional models will need to be calibrated and tested for additional streamflow nodes, particularly in the Peel system and above Keepit. Several models in the Namoi were limited in accuracy by the availability of rainfall data in the catchment. Alternatives for improving the accuracy of these models will be sought and as will estimates of the uncertainty of results provided by these models.

A flow network for the Gwydir catchment will be developed in conjunction with catchment stakeholders. Models for these flow nodes will be calibrated and testing and validation of these models will be undertaken. Details of similar calibration and model testing for hydrological models developed in the Namoi is given in Letcher [2002 and *Letcher et al.* [under review].

3.3. Crop Modelling

The Namoi prototype modelled crop yields as independent of rainfall (ie. a constant tonnes/ha yield was used for each crop). Stakeholders suggested that they wished for crops to be modelled using a simple empirical relationship with rainfall. For this project empirical crop models are being developed. These models will be based on outputs from more detailed models such as APSIM and AUSCOTT. Work on these simple models is being undertaken in conjunction with staff from ACRI.

3.4. Policy Modelling

Policy models were included in the Namoi framework. These models include a representation of commence to pump and other extraction rules. These models are in the process of being updated in collaboration with DLWC staff to ensure that the policies they represent are correct and current. Updated limits for various river reaches and rules for the operation of the Cap will also be obtained and coded into the system for the Namoi river. Rules for the Gwydir system need to be determined.

3.5. Socioeconomic Modelling

The Namoi prototype used a regional scale economic modelling approach. In this framework the catchment is divided into a number of regions, each represented by a single farmer (see Figure 1). Each of these regions corresponds to a single flow node (see Figure 2). This type of model can be used to demonstrate the catchment scale trade-offs between various types of producers (eg cotton farmers and irrigated lucerne farmers). It does not show the impact on individual producers however. For this project the aim is to integrate both regional scale economic models and representative farm models. The combination of these two types of socioeconomic modelling approaches will enable both catchment scale trade-offs and impacts on individual producers to be demonstrated for any policy scenario that is run.

3.5.1. Regional scale economic models

Regional scale economic models have already been developed for the Namoi prototype. These models are being updated, with provision for carryover of groundwater and surface water allocation being made in the model structure.

In the Gwydir catchment a definition of regions and a corresponding flow network needs to be developed through discussions with various stakeholders. Additional input data and assumptions for these Gwydir models are also required.

3.5.2. Representative farm models

Representative farm models are to be integrated with the modelling system for both the Gwydir and Namoi catchments. These models will be provided for the project by staff at NSW Agriculture. Some models currently exist for the Namoi catchment. Additional models are being developed for the Gwydir and Namoi catchments.

4. DSS DEVELOPMENT

The DSS being developed in this project is being designed in the ICMS software, which has been developed by CSIRO and the CRC for Catchment Hydrology. This software offers an object-oriented modelling environment in which rapid development and coding of models and sharing of model code is enabled. Custom built graphical user interfaces are also able to be designed to sit over the underlying 'model development' view. Figure 4 demonstrates the 'modellers view' of the prototype for the Namoi system. Note that the system is able to be divided into a 'Parent view' which represents the spatial nature of the catchment system. Objects in this view represent nodes in the river system where integration between streamflow and agricultural production models takes place. Figure 5 demonstrates the 'child layer' for one of these nodes (419012). This illustrates the individual component models being integrated at each node in the system. Table 1 provides summary information for the icons in these Figures.

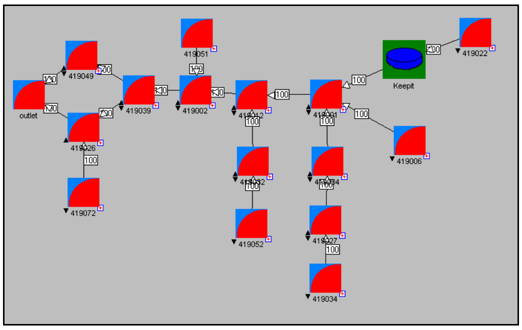


Figure 4. Parent layer of the Namoi DSS prototype

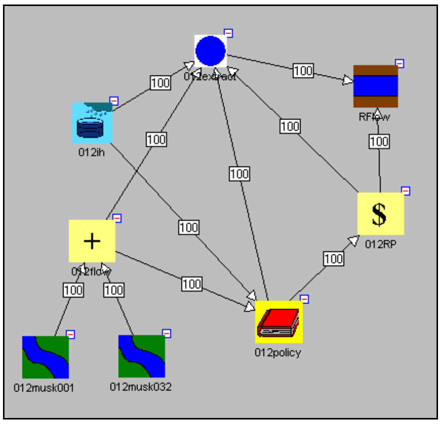
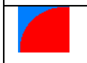
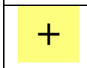
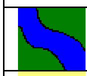
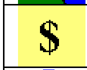
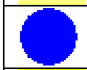
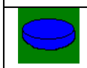
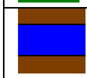


Figure 5. Child layer of the Namoi DSS prototype

Data is passed as an output from one model to an input of another model through links, as shown by the arrows in Figure 5. Post-extraction streamflow is passed between parent objects in the parent layer (Figure 4). This is then passed into the child layer, through the Muskingum routing model and fed into the policy model. Off-allocation or unregulated flow as well as regulated flows are calculated by the model.

Table 1. Summary of icons in ICMS views

Icon	Object type	Comment
	Parent	Parent object, representing nodal network
	IHACRES	Rainfall-runoff model for residual catchment area
	Sumflow	Simple model summing flow from two or more sources
	Muskingum	Flow routing model
	Agriculture production	Regional scale agricultural production model
	Extraction	Simulates unregulated extraction
	Policy	Mimics off-allocation and unregulated extraction policies
	Dam model	Representing Keepit and Split Rock Dams
	Regulated Flow	Calculates regulated system flow and extraction at the node

ICMS has several main advantages that are being utilised in this project:

- the compiled code runs rapidly. The current prototype DSS takes less than 2 minutes per run compared to a run time of over 30 minutes in MatLab.
- models are able to be developed, shared, re-used and updated easily in the system. This reduces development time and will allow other users to be trained in model development and coding during the life of the project. This will ensure that the agencies who are the recipients of the DSS are able to keep the models current after the project has been completed. It also means that component models developed in the DSS will be able to be exported and used for other purposes by DSS users.
- custom built Graphical User Interface (GUI) are able to be built to complement the Model Builder. These GUI are relatively cheap to construct, requiring only weeks rather than years of programmer time. Programmers are able to build the GUI without any knowledge of the working of the underlying models. A design document which details data templates to be accessed as inputs and outputs is sufficient to allow the programmers to develop the GUI. Additionally modellers are able to write and debug their own model code, rather than relying on iteratively testing code

written for them by programmers who may not understand the way in which the model works.

- the system contains a number of in-built visualisation tools and functions which will be used to develop the DSS. These include a range of charting tools, a raster view and a simplex algorithm function capable of solving linear programming problems.

At the time of writing this paper the prototype DSS had been coded into the platform and data imported into the system. A design document for the interface was also under development. Figure 6 demonstrates a GUI which was previously developed for the Namoi prototype.

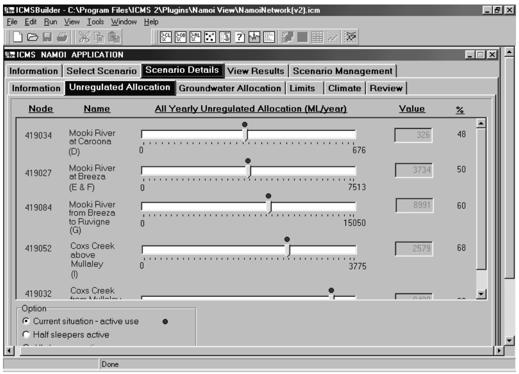


Figure 6. Namoi Prototype GUI - controls for unregulated allocation

This GUI was developed very rapidly and is able to access all the graphics and visualisation tools available in the underlying ICMS software. This is particularly useful in this project as work is able to centre around development of the models and communication with various stakeholders groups, rather than on development of the software package, as is generally the case with DSS development projects. It also means that stakeholder feedback on the interface is more readily incorporated in the final design, hopefully leading to a more useful software tool and better adoption of the technology.

5. CONCLUSIONS AND FUTURE WORK

This paper describes the development of a pair of DSS for considering water allocation options in the Namoi and Gwydir catchment in NSW. These DSS build on a prototype model previously developed for the Namoi River catchment. This project is expected to be completed in August 2005, in time to assist with the five year review of water sharing plans in NSW.

6. ACKNOWLEDGMENTS

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