River Management Decision Modelling In Iqqm

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EXTENDED ABSTRACT

The Department of Infrastructure, Planning and Natural Resources (DIPNR) is involved with the planning for the management of rivers in New South Wales. DIPNR has developed a daily time-step integrated quantity/quality river basin model (IQQM) to investigate water-sharing issues and determine river basin flow management rules. IQQM can quantify the impacts of water resource management policy changes on stakeholders, including the environment and the irrigation industry.

Recently Water Sharing Plans (WSPs) were developed for various NSW river systems. The WSPs were finalised after extensive consultation with the community and other stakeholders. During that consultative process numerous complex variations of water sharing rules were identified. IQQM was used to model those rules and quantify the likely impacts on the environment and water users under the different variations. The modelling of these complicated rules was made possible by the IQQM Decision Tree (IDT). The IDT is a device used by a subset of IQQM node types to make a decision based on defined conditions at any point in the river system. For example the releases from a dam may be dependent on:

1. The storage volume in the dam;
2. Flows at a single and/or multiple locations either upstream or downstream of the dam;
3. Time of the year;
4. Downstream demand.

The IDT combines all of these criteria into a decision network to arrive at a single governing decision at every time-step of the simulation.

The IDT is designed to avoid the need for changing and writing new and highly specific code for testing complex flow rule variations.

The mechanisms and applications of IDTs for modelling various flow rules are described in this paper with some specific examples.

1. IQQM OVERVIEW

The Department of Infrastructure, Planning and Natural Resources (DIPNR) has developed a daily-time-step integrated quantity-quality river basin simulation model (IQQM) to model various New South Wales (NSW) rivers as explained in DLWC (1995). It is designed to examine long-term river behaviour under various management regimes, which include environmental flow requirements. IQQM is based on a node-link concept. The important features of a river system such as reservoirs, irrigators, towns, etc. can be represented by one of thirteen node types. The movement and routing of water between nodes is carried out in the links. Generally the model is run on a daily time-step but for the adequate representation of certain water quality and routing processes, the model can be run on any time step down to an hourly time-step.

The water quantity module of IQQM simulates all the processes and rules associated with the movement of water through a river system. The major processes include:
(a) system inflows and flow routing;
(b) on- and off-river reservoir modelling;
(c) harmony rules for reservoir operation (operational management of multiple reservoirs ie, what and when to release from which reservoir);
(d) crop water demands, orders and diversions;
(e) town water and other demands;
(f) hydropower modelling;
(g) effluent outflow and irrigation channels;
(h) wetland demands and storage characteristics;
(i) water sharing rules for both regulated and unregulated river systems;
(j) resource assessment and water accounting; and
(k) interstate water sharing agreements.

The model applies hydrologic flow routing for the simulation of the different ranges of flow conditions. There are a variety of options available to model the different operating procedures of both on- and off-river storages. The options include Puls' routing as shown in IEAust (1987), gated storage operation and target rule curves for flood mitigation and water conservation. IQQM can be configured for systems operating single or multiple reservoirs functioning in series or parallel.

The irrigation module in IQQM includes features for soil moisture accounting, simulating decisions of farmers regarding area of crop to plant and irrigate, water ordering and usage, taking into account on-farm storage where appropriate, and accounting for uses related to water licenses and access rules conditions.

The model can also simulate fixed demands (eg, urban water supplies and power stations), riparian and minimum flow requirements, flood plain storage behaviour, wetland and environmental flow requirements, distribution of flows to effluent streams and transmission losses. It is also capable of simulating water quality processes such as salinity, temperature and other constituents. In addition, the Sacramento rainfall-runoff model as explained by Burnash et al. (1972) and climate generation model are both available as separate modules within IQQM. IQQM can also be directly linked with some of the Catchment Modelling Toolkit models such as E2 and WRAM.

2. WATER SHARING PLANS AND MODELLING

In 1994, the Commonwealth and the state governments within the Murray Darling Basin recognised that most of the river systems are either fully or over allocated and many were showing stress. Therefore, the Council of Australian Governments (COAG) adopted a Water Reform Framework as shown by MDBMC (1995) that required the states to adhere to legislative reforms that :

- cap the average annual total diversions;
- meet environmental water needs;
- separate land title and water entitlements;
- allow more water trading;
- contain a stronger regulatory framework for the delivery of water services.

In 1995, the NSW Government launched its water reform agenda and after various reforms over the years, finally the NSW Parliament adopted the new Water Act in 2000. It repealed 25 statutes and represented the biggest overhaul of water legislation for this State since early last century.

The main features of the Act are:

- the environment is recognised as a legitimate user with the highest priority given to improve environmental health of the State's waters;
- the shared government and community responsibility for water management through a community-based planning framework (Water Sharing Plans);
- the provision of greater certainty to users by clarifying and strengthening their access rights.

By recognising the environment as a legitimate user, the management and operational rules of the NSW river systems needed changing. The active participation of the community for the development of the new rules was recognised to be necessary for the successful implementation of new rules. Therefore, in each valley a River

Management Committee (RMC) was formed. RMC's are comprised of representatives from local and aboriginal communities, the irrigation industry, environmental groups and government agencies. Each RMC produced a Water Sharing Plan (WSP) for its respective river system. IQQM was used to assist with developing and analysing the flow rules contained in these WSP's. Numerous scenarios were modelled and results were analysed by DIPNR and presented to the RMC for exhaustive discussion. For example, more than 200 scenarios were modelled during the development of the Lachlan WSP as shown in Hameed (2001).

It was necessary to reproduce the complex and quite often unique valley operational rules within IQQM to ensure the robustness and representativeness of these scenarios. The rule options needed to be flexible and embedded into the daily decisions within an IQQM simulation. We developed a system called IQQM Decision Trees (IDTs) to meet these requirements. These IDTs are capable of modelling many different complex rule variations within a short period of time without the need for writing new program code. This greatly improved our response time to the RMC's requests and enabled more rapid development and analysis of WSP rules.

3. EXAMPLE OF COMPLEX OPERATIONAL RULES

Typically, WSP flow rules are very complex. This complexity is demonstrated in the translucent dam flow rules in the Lachlan River System. These rules are described in the Lachlan WSP described in DIPNR (2003) as follows:

(a) Translucent releases are to be made from Wyangala Dam. Translucency describes a process for passing inflows through a storage according to a range of criteria;

(b) The translucent release trigger is set to "on" when the inflow to Wyangala Dam since 1st January in that calendar year has exceeded 250,000 megalitres (ML);

(c) If the translucent release trigger is "on", then translucent releases are made in the period from 15th May to 15th November;

(d) If the translucent release trigger is "on" and we are within the translucent release period, then releases are made when the combination of Wyangala Dam inflows plus downstream tributary inflows would be sufficient to produce a flow downstream of Lake Brewster within a specified lower and upper flow window. This window is a function of Wyangala storage volumes (Table 1);

(e) The translucent release trigger will be switched to "off" if the sum of flows passing downstream of Lake Brewster Weir (measured at Brewster Weir) minus downstream water orders, replenishment flows, losses associated with delivery of these water orders, and replenishment flows and any flow volume resulting from airspace releases (under clause 65) in the period 1st June to 30th November, is more than 350,000 ML;

(f) Tributary inflows occurring during translucent releases are not to be used for extractive purposes or diverted to, or stored in, any weirs or water storages except to the extent that they are in excess of the flow required to satisfy the flow rate downstream of Lake Brewster that results from the calculations as described above;

(g) Releases of water from Lake Cargelligo and Lake Brewster may be substituted for all or part of the translucent release from Wyangala Dam if making the translucent releases from Wyangala Dam is likely to cause flooding;

(h) If the release capacity of Wyangala Dam is insufficient to provide the release as specified above plus the releases required to meet other access licence orders, then:

i. releases are to equal the release capacity;

ii. water can be taken in accordance with access licence water orders;

iii. the volume of the translucent release that has not been supplied is to be calculated as the total release minus the release made to satisfy access licence orders;

iv. the volumes calculated are to be accrued and released at the earliest opportunity.

Table 1: Relationship between Wyangala storage volume and the translucent window at Lake Brewster

Wyangala storage volume (%)	Lower window (ML/d)	Upper window (ML/d)
0	4,000	4,000
50	4,000	5,250
51	3,500	5,094
80	3,500	6,000
100	3,500	8,000

Some other provisions are not described here for brevity.

The Lachlan translucent dam release rules are just one example of very complex flow rules adopted by the RMC's. With each RMC, the complex river flow rules are different and configuring specific code for each valley would negate the advantages of having a generic river basin model such as IQQM. Therefore, it was imperative to develop a generic coding routine that could handle these types of flow rules and their many permutations.

4. IQQM DECISION TREE (IDT)

In general terms, a decision tree can be a visual representation of a path of dependent decisions. Each of these paths or branches of the decision tree are orientated vertically with connections to the parallel branches at the top. When assembled together, these individual branches form a tree-like structure, with a broad base at the bottom and the final decision at the top. This visual representation enables the decision-maker to identify the inter-linkages and inter-dependencies of each decision and formulate an appropriate course of action. Therefore, a decision tree illustrates both the different courses of action available as well as their possible outcomes. Finally, the decision tree combines all of the relevant factors affecting a decision and comes up with the governing factor.

Figure 1 shows an example of a simple decision tree. In this example, the final decision (Level 3) is the maximum of two values. Each of these values is determined on Level 2. The first is the minimum of two values and the second is the maximum of two values, all of which are specified on Level 1. In this example AA, BB, CC, DD could be any number of items to consider in the decision process, for example the flow at two locations or a specified flow threshold.

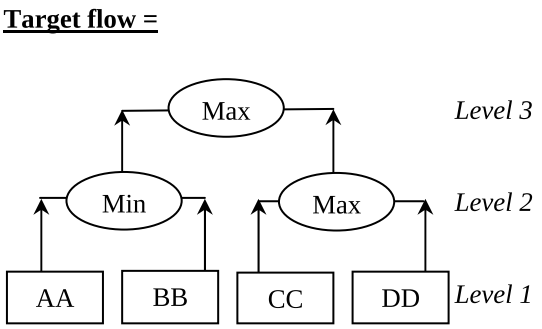

Figure 1: An example of a decision tree

The IDT capability in IQQM is embedded within the following node types:

1. Type 1: inflow nodes
2. Type 3: extraction nodes
3. Type 8: irrigation extraction nodes
4. Type 9: minimum flow nodes
5. Type 10: environmental flow nodes.

The IDTs in these nodes allow users to control:

- extractions from a river;
- releases from a reservoir;
- maintain flow at any location in a river.

The controls can be based on a combination of the following constraints:

- storage volume;
- licence conditions;
- flow at a certain location;
- concentration of a constituent in a storage;
- allocation levels;
- a sequence specified in a time series file;
- soil moisture at an irrigation node;
- time of the year.

In the example (Figure 1) the input factors were designated as AA, BB, CC and DD. In IQQM these are called Flow Control Tables (FCTs) and are the building blocks for the IDT.

The FCT is configured as a user-specified set of tabular values that relate to each other. For example, an FCT could be a relationship between dam releases and storage volume (Table 2).

Table 2: Flow Control Table relating storage volume and release rate

Storage Volume (ML)	Storage Release (ML/day)
0	0
900,000	500
1,200,000	500

The FCT in Table 2 defines that the storage releases linearly increase from 0 to 500 ML/d for a corresponding storage volume of 0 to 900 GL. Above that volume, the release is 500 ML/day.

The FCT's are linked by Branch Operations (BOs). These are either arithmetic operators (+, –, ×, or ÷) or a maximum or minimum. One or more FCTs can feed upwards via a BO to the next row in the IDT.

5. EXAMPLE OF AN IDT IN IQQM

Figure 2 shows an example river system with a wetland situated downstream of an off-river storage.

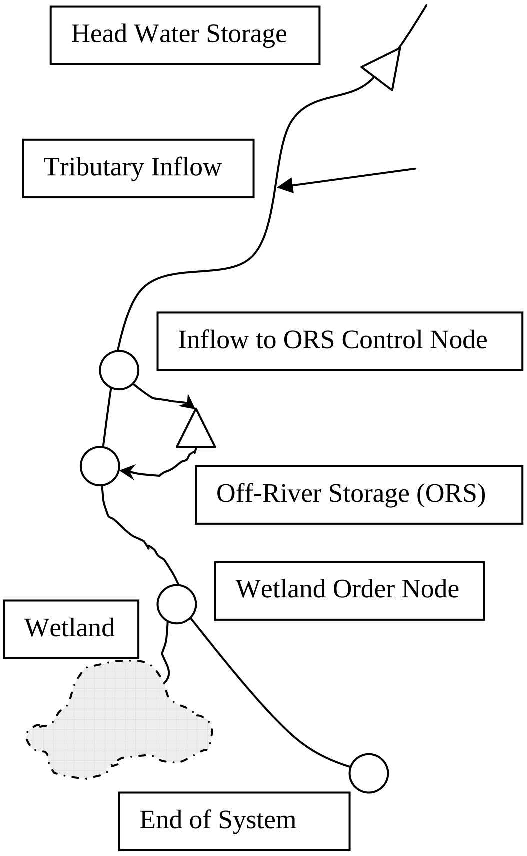

Figure 2: An example river system

We will assume that based on environmental and irrigation requirements, the RMC requires that the wetlands receive replenishment water under the following conditions:

[1] The inflow to the headwater storage will be passed based on the following headwater storage volume constraints:

Headwater Storage Volume (ML)	Inflow Passing (ML/d)
0	3,000
500,000	3,000
1,000,000	5,000
1,200,000	5,000

[2] The inflow to the headwater storage will be passed based on the following off-river storage volume constraints:

Off-river Storage Volume (ML)	Inflow Passing (ML/d)
0	3,000
40,000	3,000
80,000	5,000
160,000	5,000

[3] The period of concern is July-September.

[4] The passed inflows will be reduced by the amount of the tributary inflow.

Such a set of rules can easily be modelled within an IDT. The first step is to draw a decision tree for these conditional decisions (Figure 3).

The second step is to configure each of the conditions into a tabular FCT, as follows:

FCT 1: Headwater storage volume constraint (as specified in [1] above).

FCT 2: Off-river storage volume constraint (as specified in [2] above).

FCT 3: Critical times of year

Julian Day No.	On/Off Switch
0	0
181	0
182	1
273	1
274	0
366	0

FCT 4: Amount of tributary flow reduction

Tributary Flow (ML/d)	Passed Inflow Reduction (ML/d)
0	0
999,999	999,999

FCT 5: Minimum passed inflow is zero

Julian Day No.	Minimum Passed Inflow (ML/d)
0	0
366	0

FCT 4 and FCT 5 are combined to make sure that when the tributary inflow is deducted from the target passed inflow (Condition [4]), we do not end up with a negative number, as demonstrated in Figure 3.

Target passable headwater storage inflow =

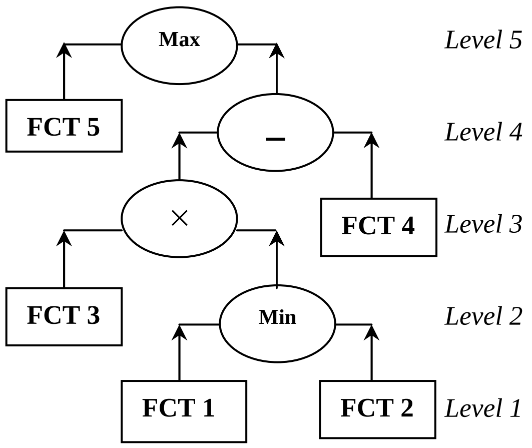

Figure 3: IDT for the example flow rules

During the simulation, the outcome of the IDT is determined at every time step (usually daily) to determine the appropriate releases from the headwater storage. To determine the outcome of the IDT, IQQM commences at Level 1 and works its way up each BO until it reaches the final level of the IDT.

In the example IDT (Figure 3), at Level 1 IQQM reads in the headwater and off-river storage volume constraint FCTs. At Level 2 IQQM will determine the minimum of the headwater and off-river storage volume constraints and also reads in the time of year FCT. At Level 3 IQQM multiplies the governing storage volume constraint from Level 2 with the time of year switch (1 or 0 depending on whether we are inside or outside the critical window). It also reads in the tributary inflow. At Level 4 IQQM subtracts the tributary inflow from the value determined at Level 3. It also reads in the zero limitation FCT. At Level 5 IQQM makes sure that if the tributary inflow is greater than the value determined in Level 4, we do not end up with a negative number. The final target passable inflow is the result of this IDT.

6. CONCLUSIONS

All of the NSW regulated and unregulated river systems have adopted new flow rules to undertake Water Sharing Plans prescribed under the new NSW Water Act. Often those new flow rules are very complex and complicated and unique to individual river systems. IQQM has been widely used for the development and assessment of the impact of new flow rules. IDTs are a facility built into IQQM to avoid the need to write new program code for each permutation of the rules, thus enabling flexibility to model a wide range of rules and a rapid response to various committees during the Water Sharing Plan development process.

7. REFERENCES

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