New systems for managing natural and artificial wetland flooding in the Murrumbidgee Valley

C Mackay[1], T van Kalken[2]
[1]DHI Water and Environment, Sydney, NSW
[2]DHI Water and Environment, Brisbane, QLD

Recently federal and state government programs by have set aside significant volumes of environmental water in the southern valleys of New South Wales. River managers now have to decide how to best utilise this water for the environment, but also consider what impact environmental watering might have on the wider floodplain. Newly developed river management tools in the Murrumbidgee Valley are helping river managers in these decisions.

The State Water Murrumbidgee Computer Aided River Management system (CARM) has been developed primarily to provide better control of water deliveries in the Murrumbidgee Valley. However it also has a role in helping to manage flooding, whether this is artificially generated environmental wetland flooding, or larger naturally generated events.

Environmental water releases are made from Burrinjuck and Blowering into the rivers to "piggy-back" smaller natural flood events in the tributaries between the dams and Wagga Wagga. These releases are made to boost natural run-off and increase the volume flooding riverbank wetlands, however they also have to be carefully planned and managed to avoid unexpected flooding of croplands.

As part of the CARM system development a hydraulic model of the length of the Murrumbidgee and the Yanco / Billabong Creek system has been developed. Furthermore, this hydraulic model is continually updated with real-time river water-levels and observed and forecast rainfalls. This allows it to be used to simulate potential environmental piggy-backing releases "on-demand" as suitable weather conditions develop. This facility is expected to greatly improve our future ability to carry out environmental releases within the constraints of broader floodplain interests.

Introduction

There are significant volumes of water set aside in the Murrumbidgee Valley for managed environmental watering. This has created a challenge for river operations, as delivery of water to environmental assets is very different to delivery of water to regulated users such as irrigators. Augmentation of small and medium sized natural floods to reach river bank wetlands is one potential use of this water. However river operators in much of the Murray Darling Basin do not currently have tools such as rainfall runoff models or hydrodynamic models that would allow them to confidently plan small managed flood releases. This paper outlines systems being developed in the Murrumbidgee Valley that are able to be used for this purpose. It also highlights some of the uncertainty in environmental outcomes if suitable forecasting tools are not available.

Environmental water availability in the Murrumbidgee

The Murrumbidgee Regulated River Water Sharing Plan is the document that specifies the rules for management of the Murrumbidgee Valley water resource. It includes three specific Environmental Water Allowances (EWAs) that accumulate water on an annual basis. The amount available under these allowances at any given time varies depending on the overall availability of water in the valley (the licence allocations), the time of year, and some unused volumes accumulated from past years.

These Water Sharing Plan EWAs are managed by the NSW Office of Environment and Heritage, in partnership with the Murrumbidgee Environmental Water Allowance Reference Group. The Reference Group includes a range of state and valley level stakeholders, who have an interest in the management of the environment and water use in the valley in general. The Murray Darling Basin Authority and the Commonwealth Environmental Water Office are observers to the group.

In addition to the environmental allowances specified in the Water Sharing Plan, the Commonwealth Environmental Water Office has a portfolio of irrigation licences it has acquired to increase environmental water availability in the Murrumbidgee and Murray valleys. The portfolio includes a range of different types of licences, with the long-term average annual amount of water they provide expected to be approximately 148 GL per year (CEWO, 2014). This will vary greatly from year to year, as much of the volume available from the licences is tied to the amount of water stored in the dams and the catchment runoff conditions.

Environmental water management objectives

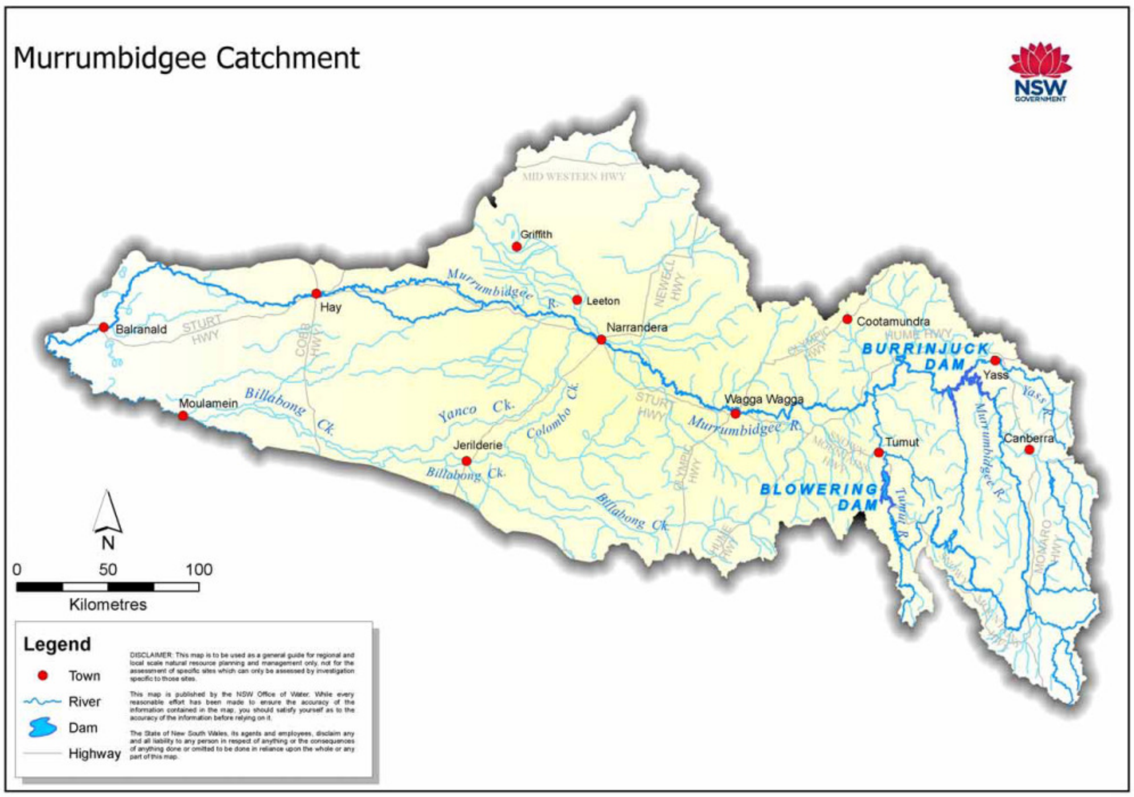
The Murrumbidgee Water Sharing Plan has a range of different water management objectives. However with regard to the environment it specifically aims to (NSW Office of Water, 2014):

- protect and restore in-river and riparian habitats and ecological processes
- provide for appropriate watering regimes for wetlands

• sustain and enhance population numbers and diversity of indigenous species

Providing water to wetlands depends on the characteristics of the wetland and the level of water availability. Some wetland features can receive water through regulated system infrastructure, or through structures developed to supply water into specific areas. Examples of this include Barren Box Swamp in the Murrumbidgee Irrigation Area near Griffith (Figure 1), which receives flow through the Murrumbidgee Irrigation regulated irrigation supply and drainage system. Another example is Yanga National Park near Balranald which can receive flows in some lower-lying floodplain areas through river bank gate structures.

Figure 1 Murrumbidgee Catchment (NSW Office of Water, 2011)



However most wetlands along the river corridor can only receive water from direct river flooding and can't access water through infrastructure. This limits the range of opportunities environmental managers have to deliver stored environmental water (EWA or CEWO licences) to these wetlands.

The sole means of delivering water to such wetlands is by augmenting natural flooding in the river. This increases benefits of small natural floods by releasing water from Burrinjuck and Blowering dams. These dams regulate and store natural floodwaters arriving from the upper Murrumbidgee and Tumut river catchments, reducing the frequency of small to medium sized floods in the downstream Murrumbidgee. However tributaries on the Tumut and Murrumbidgee rivers between the dams and Wagga Wagga still generate small short duration floods in the lower river valley, particularly in late winter and spring. Prior to the construction of the dams flows in these smaller tributaries may have coincided with a larger hydrograph moving down the Murrumbidgee catchment, producing a longer duration and higher peak magnitude event.

These tributary events can be augmented with dam water to produce larger or longer duration flood events, by releasing environmental water from the dams to coincide with the arrival of the tributary flows at the river corridor wetlands. This “piggy-backing” of environmental water volumes on tributary flow aims to achieve an outcome similar to a small river flood, increasing the volume of water spilling over the river banks into corridor wetlands through increased river water levels or maintaining the tributary flood recession level for longer.

Piggy-backing is most effectively done by waiting for large storms to occur over tributary streams between the dams and Wagga Wagga, and then releasing water from the dams to coincide with flood flows coming down tributary streams. In practice this leaves a very short window for environmental water managers to decide whether to release water, and what form and size the release should be. The topography of the major tributary catchments in the Murrumbidgee mean that if a dam release is to coincide with a tributary peak flow reaching the river, then the dam release has to be made in advance of the tributary flow magnitude being known. This means planning relies on rainfall forecasts to determine the likelihood of significant tributary runoff.

This use of environmental water dam releases to augment natural tributary events has been successfully carried out several times in the past, including a release of 38.5 GL in August 2000 (SKM, 2008) and 160 GL in 2011 (James Maguire, pers. comm.).

Constraints on tributary augmentation releases

Planning for these piggy-backing releases has to consider the impact of the flooding on communities and property owners along the river. While the objective of the releases is to increase and extend river bank flooding, this cannot not be done without consultation of potentially affected stakeholders. Furthermore, planning also has to take into account environmental and infrastructure constraints that affect rates at which water can released into the system. Key constraints are summarised in Table 1 (Paul Doyle, pers. comm., 2014).

Level constraints in the table are indications of where river flows are likely to start to cause flooding issues such as crop damage, property inundation, loss of drainage capacity or road blockage. These levels are exceeded in larger floods, however environmental releases that increase a smaller flood to be above these constraints are unlikely to be acceptable to the community without consultation.

These constraints and the need to use scarce environmental water effectively mean that environmental releases have to be planned with care. The Environmental Water Allowance Reference Group has on-going knowledge of the volume of environmental water available in the dams, and plans for potential releases months in advance. However the decision making for an actual release event has to be carried out very quickly as it relies on developing rainfall and tributary flow forecasts.

Table 1 Flooding constraints in the Murrumbidgee Valley downstream of Burrinjuck and Blowering dams

Feature	Constraint
Tumut River channel capacity	9,000ML/d at Oddys Bridge; 9,300ML/d at Tumut town
Mundarlo Bridge deck level	Deck level equivalent to a river flow of 29,500ML/d
Gundagai Minor Flood Level	6.1 metres local gauge (43,900ML/d)
Wagga Wagga Minor Flood Level	7.3 metres local gauge (50,100ML/d)
Land around Collingullie flooding threshold and Wagga Wagga stormwater system outlet flooding threshold	4.8 metres local gauge (approximately 26,600ML/d)
Narrandera Minor Flood Level	6.7 metres local gauge (approximately 40,300ML/d)
Darlington Point Minor Flood Level	5.5 metres local gauge (25,500ML/d)
Carrathool Minor Flood Level	7.0 metres local gauge (36,100ML/d)
Hay Minor Flood Level	7.8 metres local gauge (26,187ML/d)
Chastons Cutting river channel capacity constraint	8,900ML/d
Balranald Minor Flood Level	6.7 metres local gauge (20,800ML/d)

This means the decision makers have to balance the situation with care. They aim to achieve and sustain a peak flow close to the constraint levels identified above, in order to reach as many wetlands as possible and to increase the length of time they are inundated. However they rely on uncertain rainfall forecast data and catchment conditions in making these decisions. If they overestimate the size of the tributary hydrographs, water levels may not rise sufficiently and the additional dam release may produce limited riverbank wetland benefits. However if they underestimate the size of the tributary hydrographs then they may produce higher flood levels than the community is expecting.

In the past river operators have had no formal tools to estimate the size of tributary events, or how these will combine with dam releases to produce hydrographs in the downstream river. Prediction of flows has largely relied on rainfall forecasts, knowledge of general antecedent catchment conditions, past event tributary and river hydrographs, and river operator judgement. This has meant there is considerable uncertainty about the outcome of release, and that operators have had to take a conservative approach to be sure to stay within downstream constraints.

Form of the Murrumbidgee Computer Aided River Management system (CARM)

CARM is a Decision Support System (DSS) specifically developed for river operations. Its primary role is to help river operators decide what day to day releases to make from dams and weirs. In New South Wales operators currently do this using a spreadsheet-based system, into which they add anticipated demands, river losses, tributary inflows and other water sharing plan rules. Experienced operators can manage the river very effectively using this existing approach. However they spend considerable time each day inputting data into the system, incorporating constraints and factors not explicitly included in the system, and making judgements about how aspects of the system will respond in the future. The existing system has no formal forecasting functionality, either in terms of inflow forecasting, river hydrodynamic behaviour, or exchange of water between the river and the surrounding environment. Consequently much relies on the experienced judgement of the river operator.

The CARM DSS will streamline much of this process, and provide a much more comprehensive and interpreted set of information to the operator. Key elements include:

- Real-time linkages to river and tributary gauging stations, and to telemetered rainfall and evaporation observation stations in the catchment
- Automated import of Bureau of Meteorology rainfall forecasts for up to seven days into the future, and conversion into boundary conditions for rainfall runoff models
- Lumped conceptual rainfall runoff models (NAM) of gauged and ungauged tributaries and the much of the river corridor in the upper river
- A hydrodynamic model (MIKE11) of the Murrumbidgee and Tumut rivers, Yanco Colombo Billabong Creek, Old Man Creek, Bundidgerry Creek, and approximately 200 individual wetlands along the river corridor
- Data assimilation to adapt river levels and tributary runoff to observed conditions prior to forecasting
- Automated systems for importing water user future demands, as well as current real-time metered usage
- River corridor surface water – groundwater exchange and evapotranspiration (MIKE SHE)
- Forecast and data series archiving

CARM is now in the final stages of testing. Over the coming months the system will be gradually introduced into day to day river operations.

Elements of CARM relating to environmental water management

While much of the focus of CARM is on supporting regulated water delivery in the Murrumbidgee Valley, it has also been developed with environmental water release management in mind. A number of features in CARM will provide forecasts of the information useful in planning piggy-backing releases. These relate to both forecasting tributary runoff, and to simulating the combined flooding outcomes downstream from tributary runoff and dam releases.

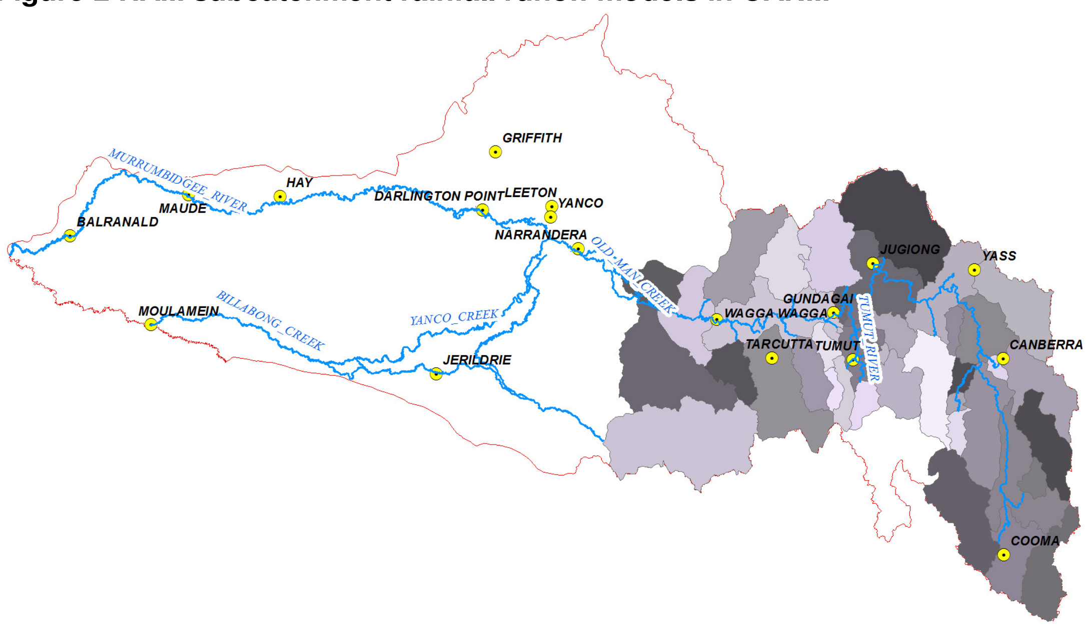
Rainfall runoff models

Lumped conceptual rainfall runoff (NAM) models have been developed and calibrated against drought and wet conditions for all tributary catchments between the dams and Wagga Wagga. The NAM model includes 10 parameters, with these representing fast and slow runoff response rates, conceptual surface and subsurface storages, and rates of exchange between different components. The models have been developed for 25 subcatchments in the upper Murrumbidgee, both upstream and downstream of the Burrinjuck and Blowering dams (see Figure 2).

The NAM models use a combination of observed and forecast rainfall data and evaporation to forecast tributary runoff up to seven days in advance. Within CARM the NAM models are run on an eight hourly cycle, with inputs with the latest data prior to simulations being carried out. The models are run in a single 14 day continuous hindcast and forecast simulation. The model uses initial conditions from model results seven days prior to the time of forecast, hindcasts the period starting seven days prior to forecast using observed rainfall data, and then continues to forecast the coming seven days using forecast rainfall data. The forecast rainfall is derived from Bureau of Meteorology gridded forecasts. These are converted into a mean area rainfall time series for each tributary catchment.

The NAM models will be an important element in planning environmental flow releases. They will provide quantitative estimates of tributary inflows into the river. This information is used in conjunction with the river hydraulic model and the environmental flow objectives as an input to deciding on dam release time series.

Figure 2 NAM subcatchment rainfall runoff models in CARM



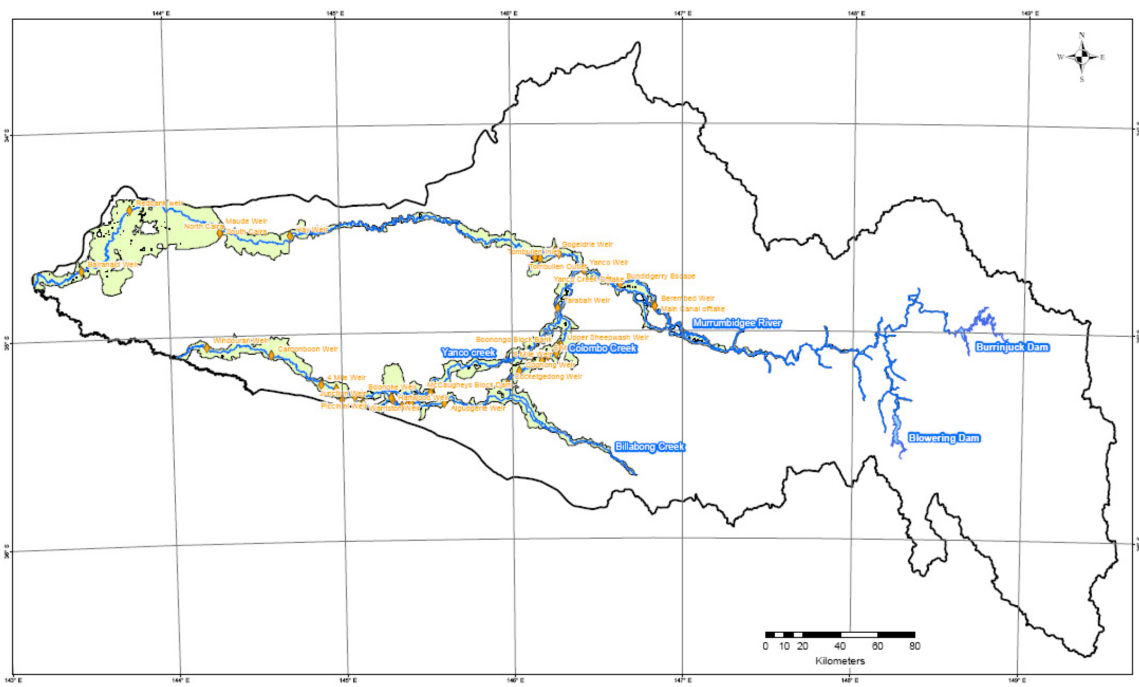
River channel and wetland hydrodynamic model

The river MIKE11 model performs a number of roles in CARM. It provides fully hydrodynamic simulation of flows in the rivers and major creek systems in the valley, exchanges flows with rainfall-runoff and groundwater models, is used in the water delivery optimisation process, and is directly updated by data assimilation to bring the model close the real state of the river prior to forecast. The model covers the regulated part of the valley (see Figure 3), as well as reaches upstream of the dams for flood forecasting purposes.

Scheduled optimisation simulations using the MIKE11 model will be the basis of day to day release planning. These will typically be carried out three times a day. However in addition to these scheduled runs, CARM includes a “river scenario” workspace used to test potential dam releases and look at their impact. This takes a recently completed optimisation run as its starting point, and then allows the river operator to simulate a hypothetical release to achieve a given outcome – e.g. achieving a minimum flow of 26,000ML/d for 3 days at Wagga Wagga. The operator can then review the outcome from the scenario run. This facility provides the operator with a model very close to the actual current state of the river due to the data assimilation facility. The operator can then quickly trial environmental release scenarios to see what the outcome will be.

The MIKE11 model also includes approximately 200 of the river corridor wetlands that receive flow duration piggy-backing events. These are modelled as individual 1D branches off the main channel, representing the wetland inlet threshold relative to the river level, and the storage volume of the wetland estimated from LiDAR data.

Figure 3 Extent of the CARM MIKE11 model



Example applications of the system

Simple dam release example

An example of an environmental release objective might be to achieve a minimum flow of 16,000ML/d at Carrathool in the downstream river for at least three days. Achieving this flow at Carrathool is likely to produce flows into a number of lower lying wetlands long the river in the river between Wagga Wagga and Hay. Continuing flows for at least

3 days at this rate is desirable both in terms of the volume flowing into the wetlands, and the length of time required for ecological responses within the wetland.

Figure 4 shows the relative position of the dam, the upstream tributaries, and the Mid-Murrumbidgee river corridor wetlands. In this simple example the entire volume is supplied from a dam release. Figure 5 shows the response of the river at Carrathool to different release profiles from the upstream dams. In order to achieve the objective a combined dam release of 30,000 ML/d is required for 72 hours, requiring a total volume of 147GL including flow recession. If the release had coincided with tributary peaks or early in a tributary event recession, then required less dam release volume would be substantially less.

Figure 4 Example environmental water target in the Murrumbidgee River

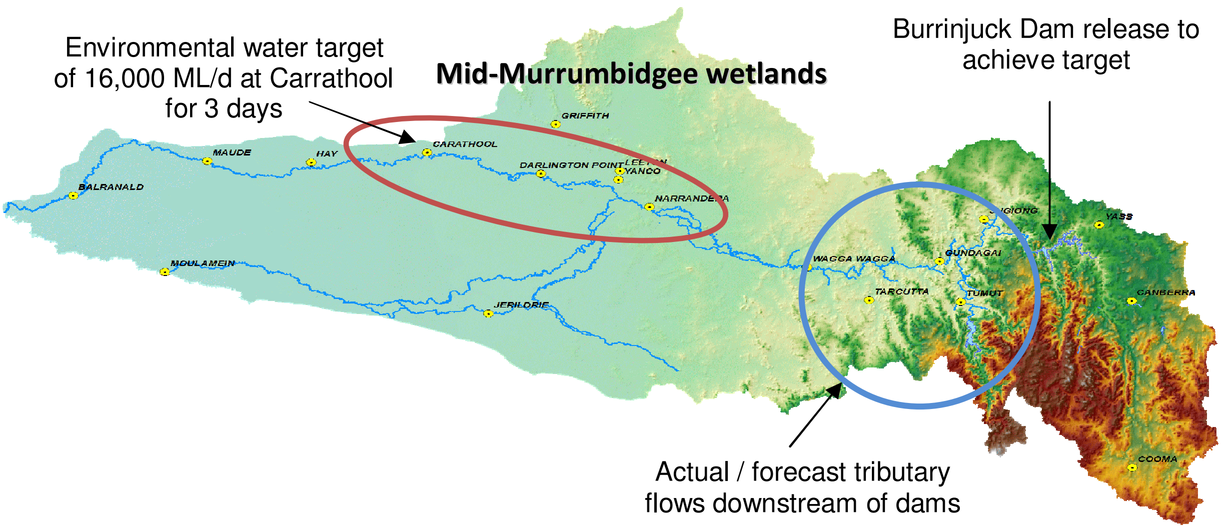
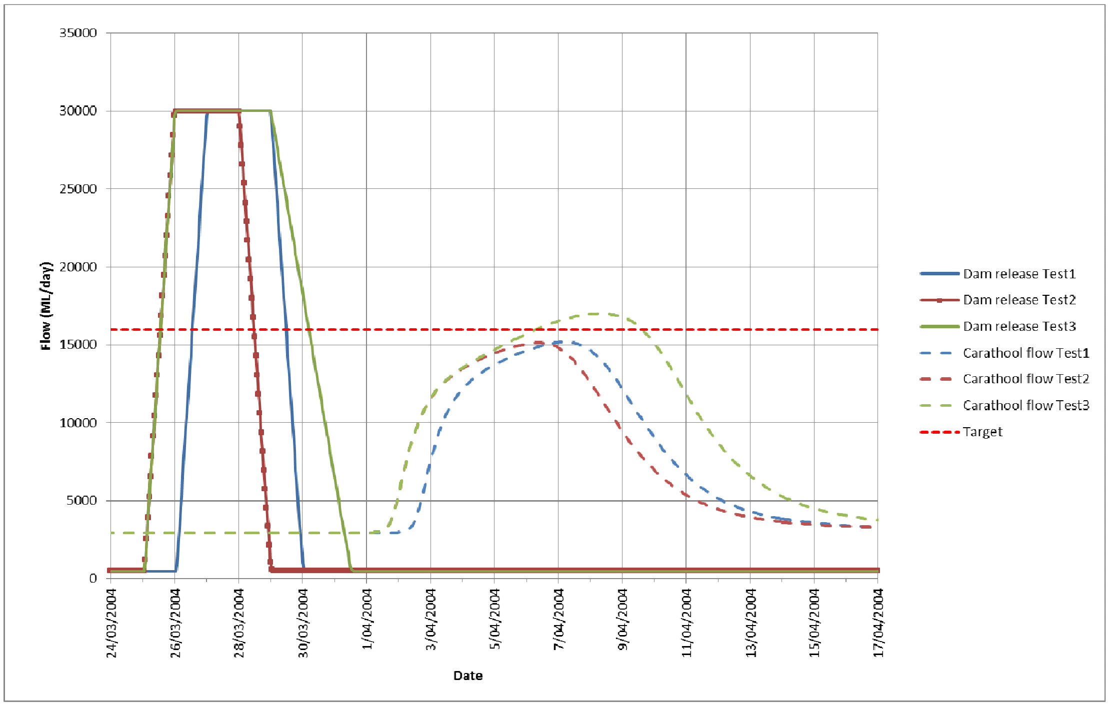


Figure 5 Dam release and Carrathool response hydrograph



Example of a dam release during tributary event

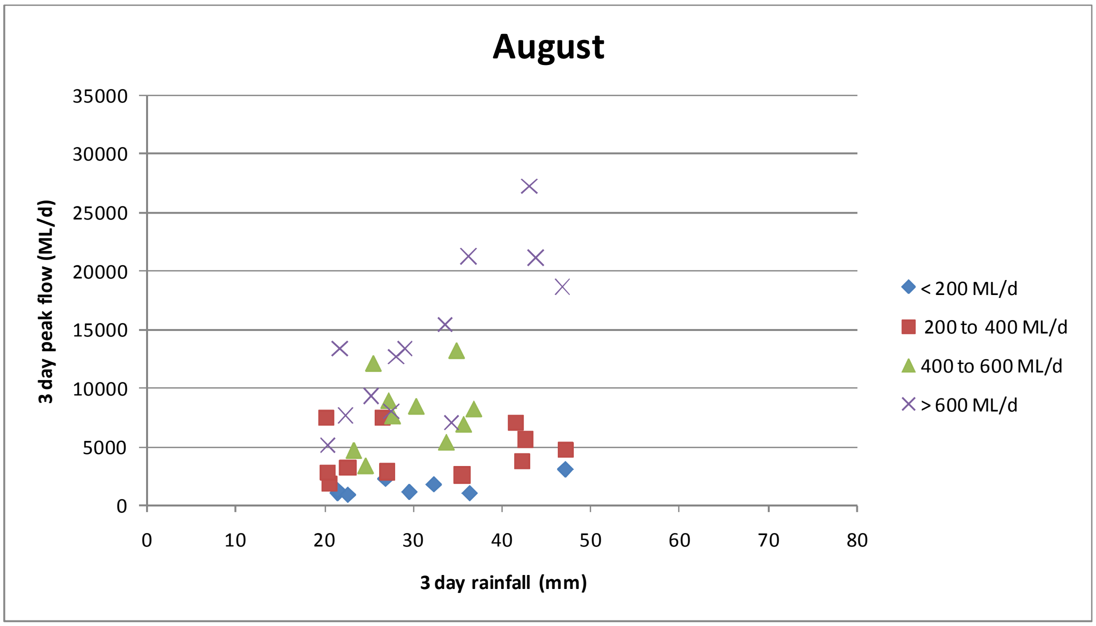
This second example illustrates the need for rainfall and runoff forecasting in determining the timing and size of piggy-backing releases. Predicting catchment runoff based on forecast rainfall is difficult with taking into account antecedent catchment conditions.

The variability in catchment response in the Murrumbidgee Valley is demonstrated in Figure 6, which shows peak runoff from a number of small flood events in Tarcutta Creek (gauging station 410047), on the southern side of the river upstream of Wagga Wagga (SKM, 2008). The figure compares the peak runoff against the 3 day rainfall total that produced the small flood. These events occurred in August over a number of years, for a range of different catchment conditions. The peak runoff values are categorised according to the average flow from the Tarcutta Creek catchment in the 3 months prior to the event. This 3 months average is chosen to give an indication of the baseflow from the catchment and the occurrence of larger events prior to the selected event.

The categories in Figure 6 show a clear difference in response to a rainfall event volume according to catchment condition. This reinforces the role tributary catchment condition plays in planning environmental flow releases. In catchments with short tributary travel times such as the Murrumbidgee, environmental dam releases often have to be made based on forecast or measured rainfall rather than based on gauging stations in the upper tributary catchments. If dam releases are based on rainfall, then the volume required to meet downstream flow objectives will strongly depend on the antecedent catchment conditions.

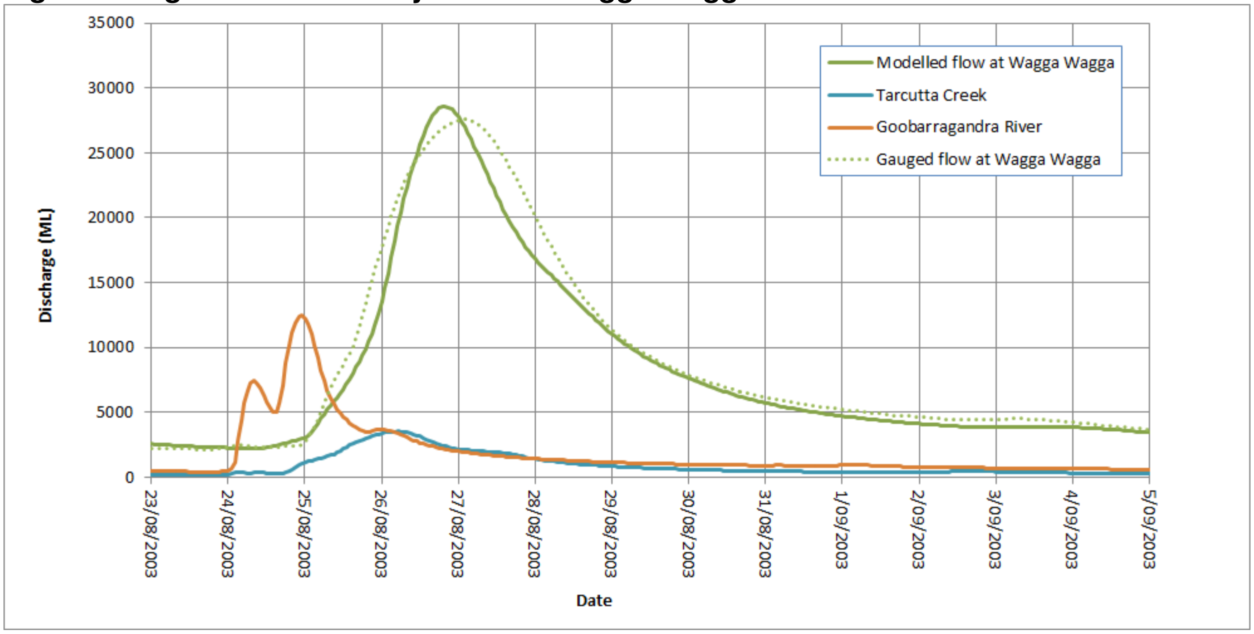
For example, in wetter catchment conditions a 3 day rainfall volume of 35 mm may produce a tributary event with a peak flow of approximately 15,000ML/d. However under drier conditions this could produce as little as 2000-3000 ML/d. This makes the use of some sort of rainfall-runoff model in planning environmental water releases necessary.

Figure 6 Peak flow response to 3 day rainfall volume for August for Tarcutta Creek (gauging station 410047)



To illustrate the sensitivity of environmental releases outcomes to knowledge of tributary conditions, model trials were carried out on a medium sized tributary event that produced a flood peaking at just under 28,000 ML/d at Wagga Wagga in August 2003. This event was produced by inflows from tributaries between the dams and Wagga Wagga. Figure 7 shows the Goobarragandra River (gauging station 410057) and Tarcutta Creek (410047) gauging station flows, along with the measured and modelled Wagga Wagga flow (410001).

Figure 7 August 2003 tributary event at Wagga Wagga

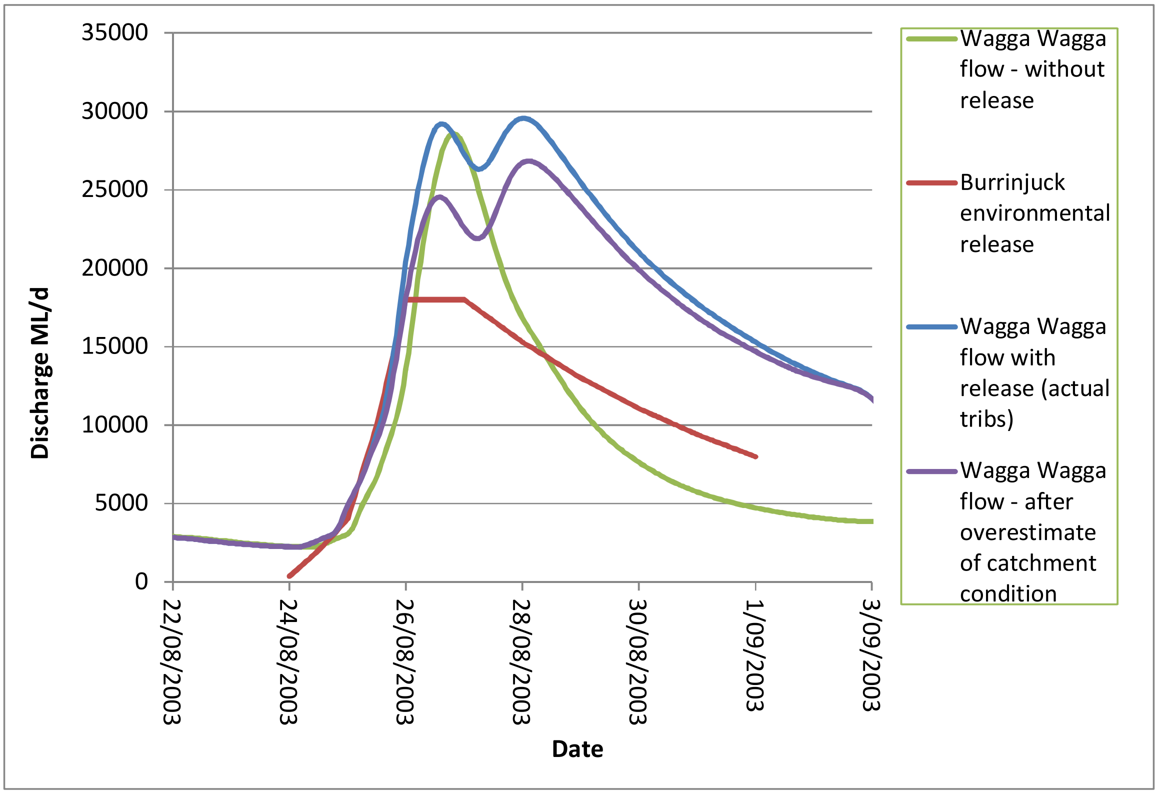


In the trial model, dam releases from Burrinjuck were increased to extend the duration of the 28,000 ML/d peak at Wagga Wagga from one day to three days. This extension of a moderately sized event is a typical environmental release objective, as it provides prolonged connection between the river corridor wetlands and the river channels. The resulting hydrograph at Wagga and Wagga and required release is shown in Figure 8 (shown in blue). This shows the combined effect of the actual recorded tributary hydrographs, calibrated residual catchment runoff and Burrinjuck Dam release (shown in red).

The impact of incorrectly forecasting the tributary runoff response can be illustrated by reducing the tributary runoff hydrographs as suggested by Figure 6. If the catchment wetness is overestimated, the tributary response will be significantly lower. As an example the actual August 2003 peak runoff from Tarcutta Creek was reduced from approximately 12,000ML/d to 8,000 ML/d in the model, reflecting the difference in runoff between a wet and medium condition catchment. All other tributaries were reduced by similar amounts to Tarcutta Creek.

Figure 8 shows the change in outcome at Wagga Wagga resulting from incorrectly forecasting the catchment state (shown in purple). While the release still produces elevated flows, the length of time the resulting hydrograph remains above 28,000 ML/d is significantly less than is seen in a wetter catchment state. In this scenario the release would fail to reach a number of river corridor wetlands with thresholds corresponding to Wagga Wagga flows above 26,000 ML/d. Furthermore, wetlands with thresholds above 23,000 ML/d would receive flows for less than the three day period objective.

Figure 8 Environmental release outcomes at Wagga Wagga for varying catchment wetness conditions



Conclusions

There are significant volumes set aside in the Murray Darling Basin for managed environmental watering. The way this water is delivered to the environment is very different to how regulated river operations have been carried out in the past. Providing water to river corridor wetlands requires the river operator to release water in conjunction with tributary events, to increase river levels above wetland inlet thresholds, and to extend inundation duration.

Planning these augmented tributary events is complicated by system constraints and hydrological uncertainty. Elevated flood levels may affect downstream property and infrastructure, especially if the community has not been consulted and warned of releases. Furthermore, tributary responses to developing storm events are uncertain due to the lack of adequate hydrological and hydraulic forecasting systems. This uncertainty results in a conservative release approach that reaches fewer river bank wetlands than expected, or alternatively unexpectedly high downstream flood levels.

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