DISCLAIMER:

This is a preliminary business case, used to inform decision-making by the Murray-Darling Basin Ministerial Council and Basin Officials' Committee on sustainable diversion limit adjustment mechanism projects.

The document represents the *Business case for Computer Aided River Management system for the Murrumbidgee River* at October 2015.

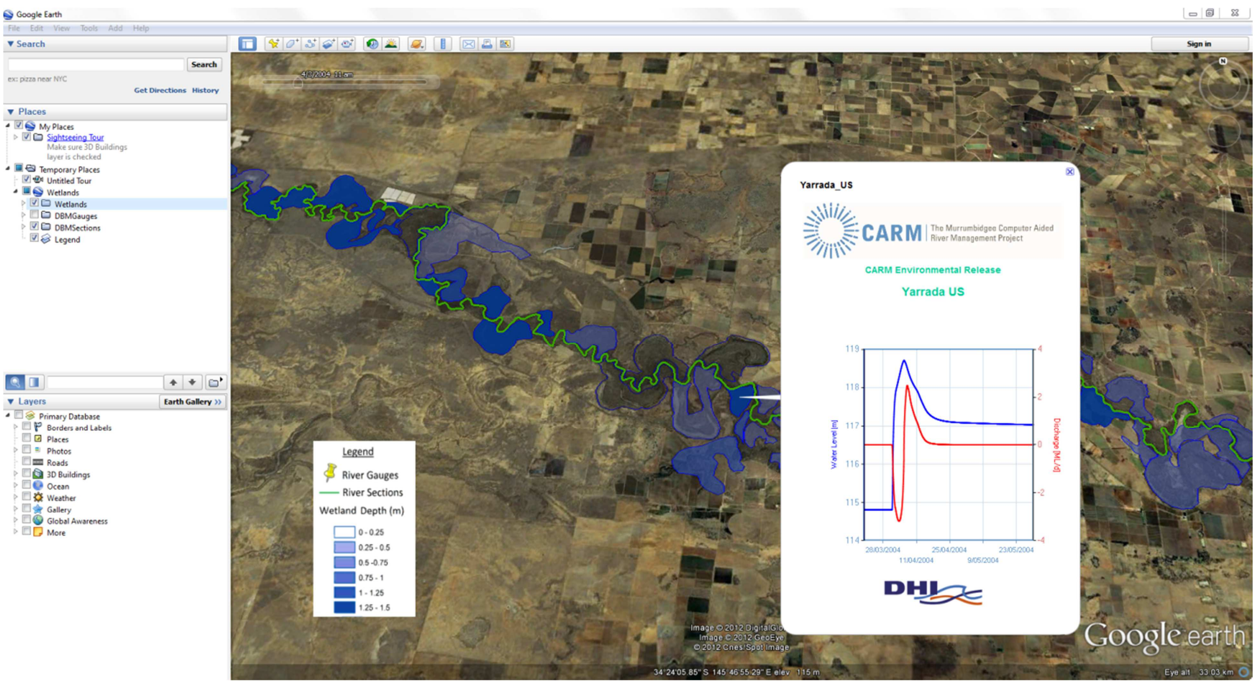
The NSW Department of Industry is currently developing project summary documents that will summarise project details, and will be progressively published on the Department of Industry website.

Detailed costings and personal information has been redacted from the original business case to protect privacy and future tenders that will be undertaken to deliver these projects.

Department of Primary Industries Water

BUSINESS CASE

Computer Aided River Management system for the Murrumbidgee River



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Version	Prepared	Date
1.	[redacted]	Friday, 25 May 2015
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3.	GHD approved for issue	Monday 10 August 2015
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WaterNSW primary contact details

[redacted]

Cover Image: Computer screen shot of Mid Murrumbidgee wetland inundation

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List of Acronyms and Abbreviations

CAIRO	Computer Aided River Operation – the current system used to manage daily river flows.
CEWH	Commonwealth Environmental Water Holder
CARM	Computer Aided River Management system
CSC	Customer Service Committee
CMS	Constraints Management Strategy
DSS	Decision Support System
EUD	Estimated Unaccounted Difference
IGA	Intergovernmental Agreement on Implementing Water Reform in the Murray–Darling Basin
IVT	Inter-Valley Transfer
Guidelines	Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases
MI	Murrumbidgee Irrigation
MDBA	Murray-Darling Basin Authority
OS	Operational Surplus
SCADA	Supervisory Control and Data Acquisition system
SDL	Sustainable Diversion Limit
SFIs	Site-specific Flow Indicators
WAL	Water Access Licence

Executive Summary

Introduction

This business case is one of three related, but independent initiatives being progressed for the Murrumbidgee River system.

The Computer Aided River Management (CARM) proposal for the Murrumbidgee River is a Supply Measure that also involves *operational and management constraint measure* benefits by enhancing the ability to deliver environmental flows.

This project has been completed by WaterNSW and it is now being phased into production and use by river operators, and will be fully operational by April 2016.

Murrumbidgee CARM

The complexity of river operations to supply water demand for towns, irrigation, and the growing environmental sectors often results in excess water being released from major dams (Burrinjuck and Blowering) which is surplus to the actual water demands in the Murrumbidgee catchment and end of system flow targets.

This supply measure is called Computer Aided River Management (CARM) - an expert Decision Support System (DSS) specifically created for river operations, based on the application of an internationally recognised hydrodynamic modelling system. This system is improving the daily operation of the Murrumbidgee River, and will reduce the current level of operational surplus flows. This, in turn, allows water to be released at other times to provide better outcomes for the environment.

The fully integrated hydrodynamic model incorporates hydraulic, hydrologic and forecasting models to manage catchment inflows, releases and deliveries and uses water resources more efficiently and transparently.

In addition to its role in daily operations, CARM can be used to inform strategic operational, resource management and investment decisions for future planned environmental watering events.

This water supply measure will allow the creation of an additional entitlement without affecting the reliability of current users in the valley[1].

Outcomes

The long term effects of CARM on the Murrumbidgee system have been modelled using the Murrumbidgee IQQM and, for the Murray system, the Murray Simulation Model (MSM).

This modelling indicates that control of up to 200 GL/year of operational surplus can be achieved. However, a significant proportion of this surplus needs to be re-released at times to ensure existing allocation reliability in the Murrumbidgee or Murray Valleys is not affected. Initial modelling has been undertaken to assess the share of the stored operational surplus required to fulfil prior commitments and ensure existing allocation reliability, although model enhancements in MSM are required to complete the assessment.

The remaining stored operational surplus can be used directly to create an SDL adjustment. This water can be released in a similar manner as other held environmental water. There is the

[1] NOW (2013) Murrumbidgee Efficiency Project – water savings and operational surplus pg 6.

potential to simultaneously mitigate some third-party impacts and align controlled releases to also simultaneously meet specific flow indicator targets with improved frequency by retiming the release of this water.

It is proposed that, when completed, a new entitlement will be established that can be called upon to enhance environmental outcomes. It is anticipated that the account created for environmental purposes would be in the form of a Murrumbidgee general security account, that will be incremented with Murrumbidgee Available Water Determinations, and will have all the same use, carryover, account limit and trade attributes of other Murrumbidgee general security licences. It is expected that the bulk of this account will be ordered at Balranald for environmental flow events in the Murray, and the Business Case modelling has been undertaken on this basis.

It is also proposed that a rules–based account would be established that would be used to ensure that Murray water users' reliability of supply is not diminished. This account could act similarly to the existing Inter-Valley Trade account used to manage the trade of water between the Murrumbidgee Valley and the wider Murray system.

A forward process to model the environmental entitlement has been developed with the MDBA. The initial steps in this process have already been completed to size a general security entitlement. However, the entitlement ultimately created is dependent on modelling of the combined package of Murrumbidgee SDL Adjustment proposals.

The remaining modelling steps will assess the portion of the created entitlement that would be available for environmental purposes, and the limits of its use to protect the reliability of supply for existing water users. This work will require modelling issues in MSM to be addressed, and this will need to be undertaken by the MDBA in close consultation with the NSW Department of Primary Industries (DPI) Water.

Governance & delivery

Development of CARM has already been undertaken by WaterNSW as part water recovery for the Snowy Initiative. The water savings from reduced transmission losses have been allocated to meet the savings targets of the Snowy Initiative, but the reduced operational surplus that CARM will provide has not yet been taken into consideration.

Creation of additional entitlement associated with reduced operational surpluses and associated changes to statutory and regulatory arrangements will be undertaken by the –DPI Water.

The Murrumbidgee CARM SDL Adjustment will come into effect in 2019 after the operation of CARM for the 2015/16, 16/17, 17/18 and 2018/19 water years. The measure will be assessed using the WaterNSW CARM evaluation framework, to quantify and verify the performance of the system.

Costs

All capital costs have already been covered by the Joint Government Enterprise (Water for Rivers) as part of the Snowy Initiative. Ongoing costs of CARM operations will be borne by water users as part of the regulated operations of the Murrumbidgee River.

The costs of CARM development, SCADA[2] extension and implementation were $7.7 million (approximately $8.2 million in $2015-16).

[2] Supervisory Control and Data Acquisition system.

The ongoing costs of the general security entitlement from water charges will be subject to the NSW Independent Pricing and Regulatory Tribunal (IPART) determinations. The current charges for general security entitlements are a combination of fixed charges (proportional to the entitlement), and variable charges (proportional to the volume of water used each year).

These charges will form part of the ongoing costs for environmental works and measures proposed through supply measures more broadly; there are likely to be benefits in considering governance and cost sharing across the SDL adjustment process on a collective basis.

Stakeholder engagement

WaterNSW has made numerous presentations of CARM to stakeholders over the last 5 years of project development. Water users and agencies receive a regular update on the project at each quarterly meeting of the Murrumbidgee Customer Service Committee. A broader engagement and communication process with water users has been developed for the next phase of the project which relates to the Evaluation Framework and the creation of the appropriate water account(s).

All agencies materially affected by this proposal have been consulted in the development of this business case. These agencies include:

- Murray-Darling Basin Authority
- DPI Water
- Office of Environment and Heritage (NSW)
- Department of Environment (Commonwealth)
- Department of Environment, Water and Natural Resources (SA)
- Murrumbidgee Local land Services
- Murrumbidgee CSC
- NSW Irrigators Council
- RAMROC (Riverina and Murray Regional Organisation of Councils)

There is a high level of support for the CARM project and its investment in best practice river operations systems. However, support for creation of further water entitlements is subject to the modelling being completed for the package of Murrumbidgee measures that demonstrates no impacts to reliability of allocations for water users, and the results of the evaluation framework following the proposed three-year verification period.

Risk management

The CARM system has already been developed, and is currently being implemented, so there are no risks involved with delivery of this proposal.

However, risk assessment, with a ranking based on the ISO methodology, was undertaken for regarding potential impacts to long-term reliability for water users. The assessment indicated that these risks can be managed and, in each case the mitigation strategy comprised two main elements:

- Appropriate analysis and modelling to confirm that the evidence showed either neutral or positive outcomes,
- On-going community engagement to ensure understanding and contributions from affected stakeholders.

The listing of the risks and the assessment of their significance is provided in summary form in Table 8 and a detailed assessment in Appendix 2.

1 Project Details

1.1 Murrumbidgee business case package

This business case is one of three related initiatives being progressed for the Murrumbidgee River system. The three business cases are closely integrated and comprise:

- Computer Aided River Management (CARM) along the Murrumbidgee River (this business case).
- Improved Flow Management Works at the Murrumbidgee River – Yanco Creek Offtake.
- Modernising supply systems for effluent creeks – Murrumbidgee River.

All three initiatives will deliver equivalent environmental outcomes as in the Basin Plan, while requiring less water to do so. Each element will generate an SDL adjustment and supply contribution.

CARM: the CARM project will provide greater control and modelling of flows through the river and creek systems. That will allow environmental flows and consumptive demands to be met with greater precision so reducing Operational Surplus.

Yanco Creek Offtake: the Yanco Creek off-take regulator will allow more efficient watering of the Mid Murrumbidgee wetlands, resulting in water savings. The proposed works and measures have been designed to increase the proportion of Murrumbidgee flows that reach the mid- Murrumbidgee and lower Murrumbidgee wetlands downstream of Yanco Weir. They also allow targeted diversion of water into the Yanco system to reinstate the freshes, bank-full and overbank flows in the Yanco Creek System.

Modernising the Yanco supply systems will reduce water losses in distribution while retaining environmental values. The water saving will be added to the held environmental water in the Murrumbidgee valley. This held water can then be targeted to meet specific environmental flow requirements where required. Reduction of irrigation supplies in the creek system will also permit creation of preferred flow regimes.

1.2 Background to SDL Adjustments

The Murray-Darling Basin Plan was prepared by the Murray-Darling Basin Authority and signed into law by the Commonwealth Minister for Water on 22 November 2012, under the Australian Government Water Act 2007. An Intergovernmental Agreement (IGA) between the Australian Government and Victorian, South Australian, New South Wales, Queensland and Australian Capital Territory governments on implementing water reform in the Basin came into effect.

The IGA subsequently outlines the commitments and responsibilities of the participating jurisdictions and the program for putting the Basin Plan into action.

The IGA on implementing Water Reform in the Murray-Darling Basin includes an agreed way of implementing the Basin Plan and details cooperative arrangements to support delivery of the Australian Government's commitment to recover water to meet the Basin Plan's sustainable diversion limits (SDL), and collaboration on the management of environmental water.

The SDLs ensure that sufficient water is available to maintain the health of the Murray Darling Basin (Basin) environment, having regard to social and economic impacts. The Murray-Darling Basin Authority (the Authority) has estimated that the Basin-wide long-term average SDL for surface water is 10,873 gigalitres (billion litres) per year. This represents a reduction of 2,750 gigalitres per year of water from the 2009 baseline diversion level[3].

Under the provision in Chapter 7 of the Basin Plan and in the IGA, it was agreed that the Plan could achieve these environmental outcomes by improved use and management of water resources, as well as by reducing current extraction levels. That would allow the SDL reduction to be adjusted or minimised, reducing impacts on regional communities.

These SDL adjustments can be achieved in two ways, through:

- Supply Measures: a measure that operates to increase the quantity of water available to be taken in a set of surface water SDL resource units compared with the quantity available under the benchmark conditions of development subject to equivalent environmental outcomes or
- Efficiency Measures: a measure that operates to decrease the quantity of water required for one or more consumptive uses in a set of surface water SDL resource units, compared with the quantity required under the benchmark conditions of development.

These measures are collectively known as 'adjustment measures'. In addition there are constraint measures.

- A Constraint Measure removes or eases physical constraint on the capacity to deliver environmental water to the environmental assets to the Murray-Darling Basin.

The Basin states and the Murray-Darling Basin Authority have established an inter-jurisdictional committee, the SDL Adjustment Assessment Committee (SDLAAC), to manage this process and to evaluate proposed projects and investments.

SDLAAC has drawn up the Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases (the guidelines) to guide the development and assessment of business cases for proposed supply and constraint measures.

The guidelines recognise the different information needs for each category of supply and constraint measure project:

- *Environmental works and measures at point locations*: These infrastructure-based measures attempt to directly achieve the Basin Plan's environmental outcomes at specific sites along the river using less environmental water than would otherwise be required.
- *Water efficiency projects*: These infrastructure-based measures achieve water savings by reducing water losses through, for example, modified wetland or storage management.
- *Operating rules changes*: Changes to policies and operating rules can lead to more efficient use of water and savings which can contribute to achieving equal environmental outcomes with less water.
- *Physical constraint measures*: These measures ease or remove physical constraints on the capacity to deliver environmental water.

[3] Murray-Darling Basin Ministerial Council (2014) The Sustainable Diversion Limit Adjustment Mechanism Joint Government Communications booklet, pg 5.

- *Operational and management constraint measures*: These measures change river management practices (e.g. policies, procedures and protocols that are outlined in legislation, intergovernmental agreements, water resource plans, river operating manuals and procedures and guidelines, as well as unwritten practices) that currently act as constraints on the capacity to deliver environmental water.

It is this last category that the Computer Aided River Management (CARM) proposal for the Murrumbidgee River (SS15) is a Supply Measure that involves *operational and management constraint measure* benefits by capturing system operational surplus and in addition collectively enabling improved management of environmental flow regimes using the hydrodynamic scenario planner. For more detailed explanation of the functionality of the supply measure see Table 1 below.

1.2.1 Business case eligibility criteria

Eligibility criteria are overarching criteria that are expected to be met to determine whether a proposed measure meets Basin Plan and IGA requirements for further assessment and consideration in the SDL adjustment mechanism:

- all supply measure projects must satisfy the requirements of criteria 3.1 and 3.3; and
- to be considered for Commonwealth Supply or Constraint Measure Funding, a supply measure must also meet criterion 3.4.1.

A statement against eligibility criteria is provided in Appendix 1.

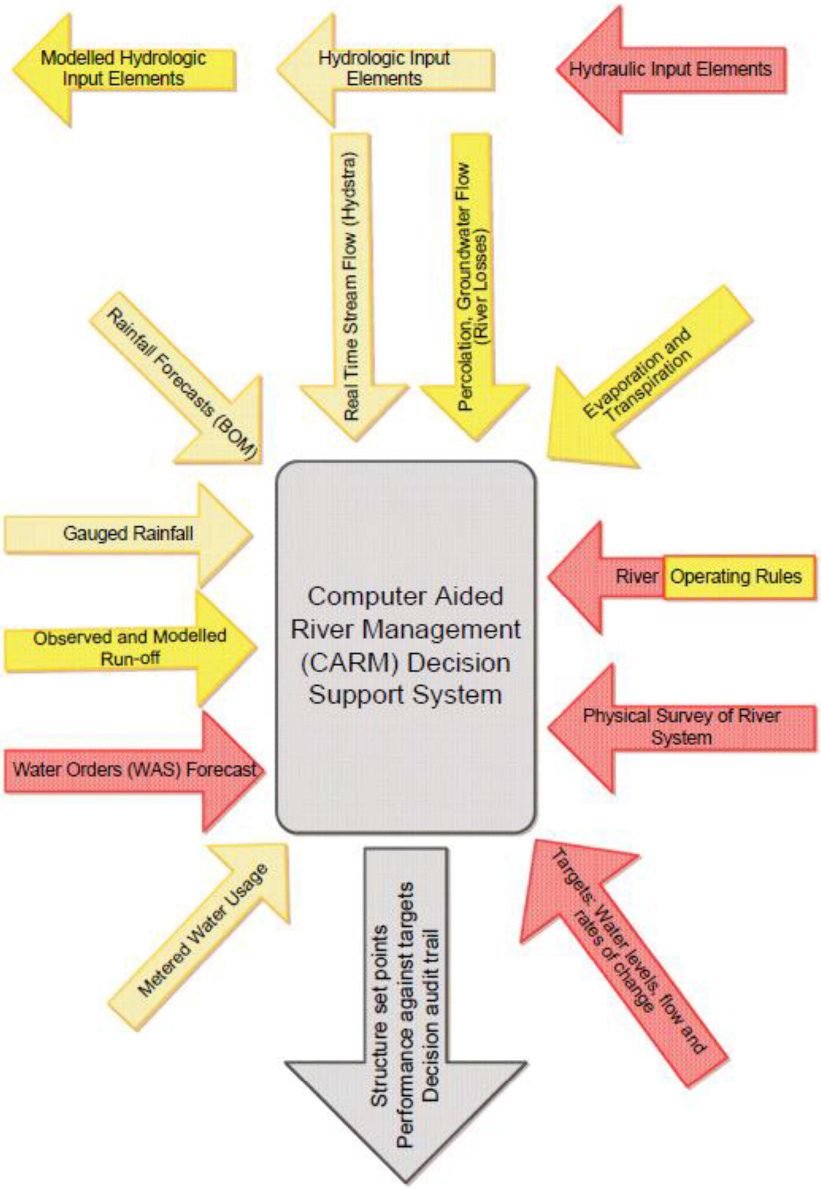
1.3 Background to the Project

1.3.1 Description of the Measure

The Computer Aided River Management (CARM) is an expert Decision Support System (DSS) specifically created for river operations. Its primary role is to integrate both real time and expert modelled flow scenarios information using a computer based hydrodynamic modelling system, to enhance the tools available to river operators, to make better informed decisions on daily releases from dams and weirs.

CARM is a fully integrated hydrodynamic model which incorporates hydraulic, hydrologic and forecasting models to manage catchment inflows, releases, deliveries and use water resources more efficiently and transparently.

Figure 1 Components of the integrated CARM system[4]



[4] Source: GHD (undated) Hydrology Versus Hydraulics: How to best model the Murray-Darling Basin, pg 3.

In a river basin context, hydraulic models are used to simulate flows in river channels and on floodplains and in wetlands, to account for the operation of regulating structures (e.g. weirs); while the hydrological processes are computed from hydrology models.

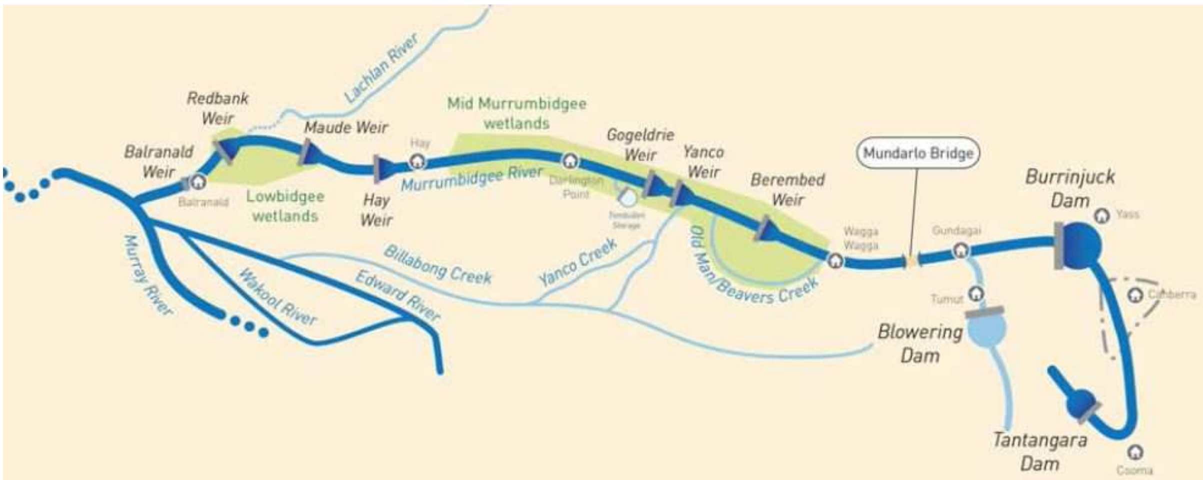
During the development of the CARM system the Danish Hydraulics Institute (DHI) was commissioned to undertake a desktop analysis highlighting the benefits of the use of hydrodynamic models for river operations. This Technical Note (Attachment 2) includes a brief background to the current work, a description of different modelling approaches applicable and concludes with some application examples highlighting the differences between the various approaches. This was not an exhaustive analysis at the time but aimed to present the main benefits of hydraulic modelling approaches for real time river operations.

In addition to its role in daily operations CARM can be used to inform strategic operational, resource management and investment decisions, for future planned environmental watering events. These decisions are becoming increasingly complex as large volumes of environmental water are managed to optimise outcomes in both the Murrumbidgee and Murray systems.

The Murrumbidgee River (Figure 2) is a very complex regulated river basin which provides bulk water supplies to major irrigation areas (Coleambally and Murrumbidgee), other private diverters, important Ramsar wetlands and key towns in the Riverina region.

The Murrumbidgee CARM is currently being made operational in 2015 and will be in full production by April 2016, after 5 years of development.

Figure 2 Map of Murrumbidgee River and Key Features[5]



Currently river operators use a spreadsheet-based system (CAIRO), into which they add anticipated demands (water orders), forecast river transmission losses, forecast tributary inflows and flow targets.

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 to the possible weather forecast.

[5] Source: MDBA (2014) Murrumbidgee Reach Report Constraints Management Strategy. pg 16.

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 and their experience and knowledge of the system.

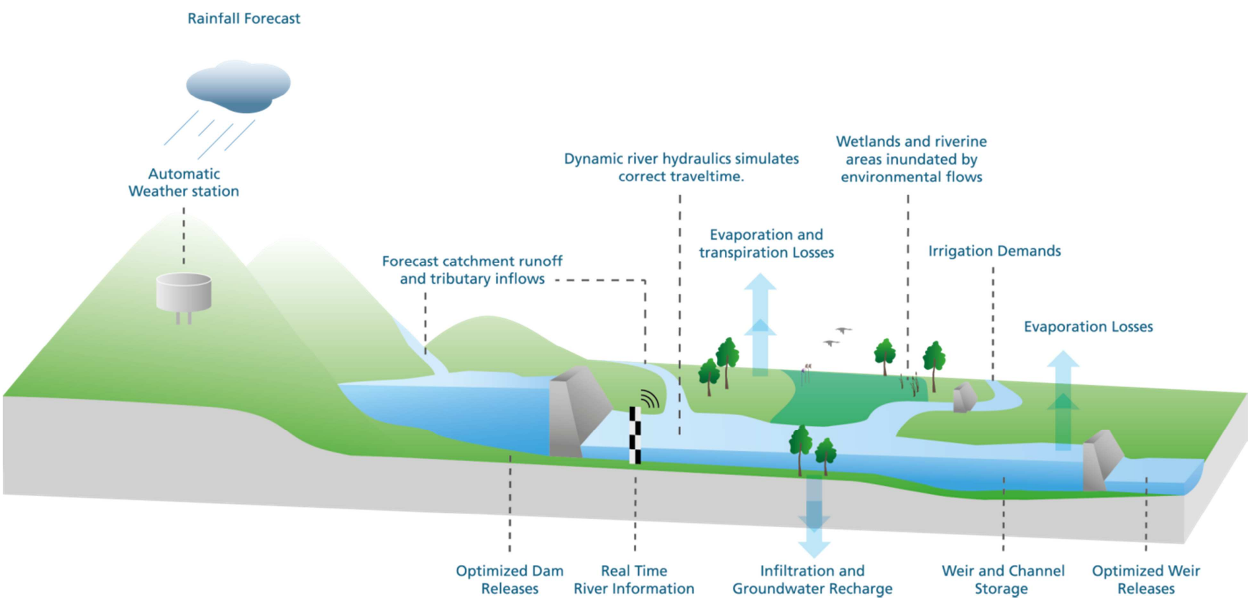
The complexity of river operations often results in excess water being released from major dams (Burrinjuck and Blowering) which is surplus to the actual water demands in the Murrumbidgee catchment and End of System targets.

The CARM system now provides operators with a much more comprehensive and interpreted set of information. 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 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 of modelled 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); and
- Forecast and data series archiving.

CARM is a fully integrated hydrodynamic model which incorporates hydraulic engineering in terms of fluid dynamics, hydrologic and forecasting models to manage catchment inflows, releases, deliveries and use water resources more efficiently and transparently.

Figure 3 Computer Aided River Management



CARM is making control of water flows and dam releases more precise and efficient through linking the physical upgrades to river infrastructure and accurate measurement/metering with hydrodynamic operational modelling and flow information systems.

Operational improvements are achieved through the integration of real time river monitoring, extraction metering, hydrodynamic river models and optimisation software systems. These improvements in operator tools and optimisation result in less regulated 'operational surplus' water being released from storages to downstream customers. This enables the stored surplus now under the river operator's control, to be retimed to meet desired environmental flow targets.

The water supply measure will result in the creation of an additional entitlement that can be created in the headwater dams without affecting the reliability of current users in the valley[6].

The savings in Operational Surplus are a result of improvements in:

1. Tributary utilisation from better forecasting;
2. Rainfall rejection forecasting;
3. More efficient Yanco offtake management; and
4. Optimised use of the water efficiency measures introduced into the Murrumbidgee System.

1.3.2 The benefits of CARM

CARM will have a number of direct effects on river operations. The additional data collection from new river flow and rainfall measurement, telemetry and metering will allow future operators to better know how much water is in the river and where and by whom it is being extracted. This will significantly increase the operator's awareness of the real state of the river. Furthermore CARM's hydraulic flow model, transmission loss model and tributary inflow models will allow operators to better anticipate the changing state of the river before they arise, and to optimise dam releases to more closely match water user demand.

An overview of the direct effects of CARM on day-to-day operations is given in Table 1 and are discussed in more detail in the NOW Water Savings Report (Attachment 1).

[6] NOW (2014) Murrumbidgee Efficiency Project – water savings and operational surplus pg 6..

Table 1 Potential direct impacts of CARM on river operations

CARM element	Effect on river operations
Hydrodynamic channel model– river flow forecasting	The length of the Murrumbidgee River means it has a large capacity to store water within the channel. This greatly affects the rate at which flows travel down the river and Yanco Creek. Operators previously had no way to calculate this prior to deciding how much water to release from the dams. The CARM hydrodynamic model will provide operators with more accurate forecasts of how their releases will move down the river. This should reduce the operational surplus produced by operators having to judge how much water is needed to "set up" the river to deliver ordered volumetric flows at the right time and duration.
Hydrodynamic channel model – weir pool management	The hydrodynamic model will include river weirs and the operational ranges and targets on the weir pools. The optimising/forecasting ability of the model will allow for more precise operation of the weirs and reduction of surpluses created by unnecessary weir pool spills.
Hydrodynamic channel model – release optimisation	CARM will be able to optimise flow delivery in the Murrumbidgee River and Yanco Creek. In practice this means it can trial different ways of delivering required orders to downstream water users, and select an efficient way which reduces unnecessary surpluses.
Transmission loss modelling	River operators have to predict future river channel losses and gains (AUD) when deciding on dam releases. To do this they have to estimate how losses will affect their releases as they flow down the river. They currently do this based on judgement and by looking at what the river has recently lost or gained. The CARM MIKE SHE component will forecast some elements of channel losses. It will predict river losses into the river banks and bed and how these will change with flow and the seasons. It is unlikely to account for the full variation in AUD from day-to-day, however it will reduce the uncertainty about how different processes are affecting river losses, and therefore increase the accuracy of flow forecasts.
Tributary catchment rainfall runoff models	River operators try to use tributary inflows to satisfy downstream orders where they can. This allows them to reduce dam releases and leads to less surplus flow at the end of the system. Currently river operators have to judge how rainfall will affect tributary inflows. Catchment models will allow operators to better predict future tributary inflows and reduce dam outflows with more confidence in the future.
Additional streamflow recorder sites, and	Greater awareness of the state of the river system means operators are more likely to foresee problems and to avoid

CARM element	Effect on river operations
telemetry to streamflow recorder sites, MI operations, rainfall gauges, meters	unnecessary surplus flows. The automated intake of monitoring data by CARM, and the in-built ability of the software to recognise where things are deviating from the required situation, means that operators will be able to respond much more quickly than in the past.
Irrigation offtake meters	Operators previously couldn't tell when each irrigator is taking water from the river, and had to assume that irrigators were taking it exactly when they had ordered it. When irrigators deviate from their order timing this causes problems downstream, as it produces shortfalls (which may affect other irrigators) and surpluses (which unnecessarily reduce the overall resource for the system). Telemetered meters allow operators to know why these shortfalls and surpluses have appeared in the river, and how to change operations to deal with them. Exceptions in water orders and usage are reported to staff and customers, which improves future water order performance.

In addition to these direct benefits, the data capture and audit capabilities of CARM will also provide long-term water management and water resource(s) planning benefits. CARM will provide a consistent record of input variables (orders, inflows, unaccounted difference), calculations prior to releases (e.g. estimated tributary inflows, estimated unaccounted difference, evapotranspiration, channels seepage, river flow rates, etc.), and general operator decisions and assumptions. While CAIRO can record some of this information, forward estimates are overwritten day by day, and there has not been consistent recording of this data by river operators in the past.

This record of past inputs and decisions is very important. River operations can't be reviewed in detail without this information. Past studies trying to determine what causes unaccounted difference in the river (such as SKM, 2010b) and looking for potential water savings projects have had to piece together incomplete archived datasets. These usually do not include a record of the operator's reasoning in deciding to take particular actions. CARM will provide a much more transparent and comprehensive record of the river management process, providing justification for further efficiency improvements in the future.

The overall benefits of the project can be grouped and summarised into:

- Operational surplus reductions by creating a robust platform for daily river management efficiency[7]
- Improved precision in the delivery of environmental water and maximisation/optimisation of environmental benefits;
- Streamlined WaterNSW business and information flow to customers;
- Greater transparency of accounting and reporting of water, when and where it matters;
- Improved community communication of flow forecasts and river state;

[7] GHD (2012) Water for Rivers Benefits of the Computer Aided River Management (CARM) System

- Improved future daily management of Murrumbidgee river constraints and improved risk management for operators with more predictive scenario modelling to better manage timed flows; and
- Underpinning the NSW Prerequisite Policy Measures requirements for 'piggy backing' and environmental re-use in the Murrumbidgee system.

1.3.3 CARM as a supply measure

CARM meets the definition of a supply measure as assessed during the Phase 1 review of this measure. CARM increases the quantity of water available to be used in a set of surface water SDL resource units, compared with the quantity available under the benchmark conditions of development subject to equivalent environmental outcomes. CARM allows the efficient watering of environmental assets to achieve outcomes with a lower volume of held environmental water than would otherwise be required.

Modelling indicates that there are no detrimental impacts on reliability of supply of water to holders of water access rights that are not offset or negated.

CARM has not been included in the Basin Plan benchmark conditions of development.

NSW river system modelling of the project using the Murrumbidgee IQQM model indicates that improved river operator performance via CARM could provide up to 200 GL/year of captured operational surplus in storage. (Attachment 1) Operational surplus for the Murrumbidgee River can also be estimated at the end of the system at Balranald and Darlot after adjusting for non-controllable inflows so that the surplus is dam related, ie. excess flows don't count if they were not released from the dam. Targeted delivery and retiming of this water (after firstly adjusting to compensate for third party impacts) can improve environmental watering outcomes for key sites and other environmental assets in the Murrumbidgee and Murray systems, and improve the frequency of Murrumbidgee and Murray Specific Flow Indicator targets. The modelling approach to this assessment is outlined in Section 3.4.

1.3.4 Measure Proponent and Implementing Entity

CARM is being proposed as Supply Measure and implemented in the Murrumbidgee Valley by WaterNSW. DPI Water will ensure changes to the Murrumbidgee Regulated River Water Sharing Plan and appropriate water access licences are created for the stored operational surplus.

WaterNSW was formed by bringing together the Sydney Catchment Authority and State Water (at 1 January 2015) to deliver the most efficient service to customers and community. The WaterNSW is a statutory State-owned corporation.

Following testing and commissioning CARM has been progressively implemented. Initially it was used for tributary forecasting and flow routing modules.

The measure is now operational and by 30th June 2019 it will have undergone three water years of operation and its performance will be assessed based on the UTS Institute for Sustainable Futures evaluation framework 2014 (refer section 5.2)

1.3.5 Interaction with other Measures

Please refer to section 6.2

2 Environmental Assessment

2.1 Environmental values and assets

2.1.1 Murrumbidgee – Environmental Assessment

The Murrumbidgee catchment not only supports a valuable irrigation industry but also provides habitat for a number of important ecological assets that include:

- a diverse range of flora and fauna species, including River Red Gum (*Eucalyptus camaldulensis*) forests and woodlands, Black Box (*Eucalyptus largiflorens*) and Tangled Lignum (*Muehlenbeckia florulenta*).
- species listed as threatened under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), including the vulnerable Southern Bell Frog (*Litoria raniformis*) and Superb Parrot (*Polytelis swainsonii*);
- wetlands of international significance listed under the Ramsar Convention; and
- colonial waterbird breeding sites (Department of the Environment).

Remnant river red gum (*Eucalyptus camaldulensis*) communities have recently been protected by new national parks at Yanga on the Lowbidgee floodplain and on the mid-Murrumbidgee floodplain.

The Lowbidgee floodplain was once the largest area of lignum (*Muehlenbeckia cunninghamii*) in Australia, small remnants of which survive. Oolambeyan National Park and the nearby Coleambally area protect the endangered weeping myall (*Acacia pendula*) ecological community and the plains wanderer (*Pedionomus torquatus*).

The Lowbidgee floodplain was once the largest area of lignum (Muehlenbeckia cunninghamii) in Australia, small remnants of which survive. Oolambeyan National Park and the nearby Coleambally area protect the endangered weeping myall (Acacia pendula) ecological community and the plains wanderer (Pedionomus torquatus).

Of importance are two large scale ecological assets within the Murrumbidgee system being the Mid-Murrumbidgee Wetlands and the Lower Murrumbidgee Floodplain that are watered by releases from Blowering and Burrinjuck Dams. Wetlands comprise approximately 4% of the Murrumbidgee catchment spanning over 1,000 wetlands with the nationally important wetlands of the Mid-Murrumbidgee and Lower Murrumbidgee River Floodplain accounting for 2.5% of the catchment area. Both these wetlands are listed under the Directory of Important Wetlands in Australia.

The Mid-Murrumbidgee Wetlands between Wagga Wagga and Carrathool are a collection of lagoons and billabongs located on the floodplain of the Murrumbidgee River. These wetlands are inundated by flood events, with the frequency of inundation dependent upon the elevation of the wetland and distance from the river. Historically billabongs and wetlands located close to the river in low lying areas would flood annually, while those wetlands located at slightly higher elevations and further from the river channel would be inundated less frequently, every three to five years; however the frequency of inundation for these wetlands has reduced due to river regulation (SKM 2011). These wetlands once inundated can take from six months to two years to dry out following a flooding event (MDBA 2010). Several of the wetlands located within this zone do not generally dry out completely, providing an important drought refuge for a range of water dependent fauna and flora species.

The Lower Murrumbidgee Floodplain (including the Nimmie-Caira) covering approximately 200,000 hectares is a mosaic of wetlands that fill and dry over various periods. In order to supply the water required to inundate and to achieve the desired ecological objectives from the environmental watering regimes, a high base flow in the Murray River and upstream releases from Murrumbidgee storages are required in addition to high river heights (SKM 2011). This floodplain contains some of the largest and most important breeding sites for colonially-nesting waterbird species (e.g. cormorants, ibis, egrets) within the Murray-Darling Basin and which are listed under bilateral migratory bird agreements that Australia has with Japan (JAMBA), China (CAMBA) and the republic of Korea (ROCAMBA)[8].

The threatened Southern Bell Frog is an iconic wetland species within this floodplain. The Lower Murrumbidgee Floodplain was adversely impacted by the 'millennium drought' and is slowly being rehabilitated via managed environmental flows to meet the water requirements of the habitats and species of the system.

The Murrumbidgee River Main Channel provides a range of habitats for faunal groups such as fish, aquatic vertebrates and macroinvertebrates, including pools, runs/ riffles, backwaters/ billabongs, snags and aquatic plants. Reduced flows (or more accurately, the prevalence of more frequent higher flow events) and modified timing and seasonality of the flow regime outside of that preferred by numerous species and communities is the greatest ecological threat (MDBA 2012). The Murrumbidgee River channel provides critical habitats for a number of threatened species listed under state[9], territory or federal legislation[10] including nine of the 23 native freshwater fish species thought to have originally occurred in this system prior to river regulation (e.g. Murray Cod *Maccullochella peelii*).

2.1.2 Recognition under international agreements or area of conservation significance

Table 2 provides an overview of the significant environmental assets within the Murrumbidgee catchment.

Table 2 Significant conservation - Murrumbidgee NSW

	Instrument	Comment
Mid-Murrumbidgee	Directory of Important Wetlands in Australia	Between Wagga Wagga and Carrathool
Lower Murrumbidgee Floodplain	Directory of Important Wetlands in Australia	Also bilateral migratory bird agreements
Fivebough- Tuckerbil wetland	Ramsar listed	East of Leeton
Murray cod (*Maccullochella peelii peelii*), the trout cod (*Maccullochella macquariensis*) and the Macquarie perch (*Macquaria australasica*).	Threatened species	Under Federal legislation

[8] Commonwealth of Australia (2014)

[9] NSW *Threatened Species Conservation Act 1995* and *Fisheries Management Act 1994.*

[10] Federal *Environment Protection and Biodiversity Conservation Act 1999.*

2.2 Environmental objectives and targets

2.2.1 Objectives and Targets

The Murrumbidgee Selected Area Monitoring and Evaluation Plan identifies three key themes related to ecosystem functions, the maintenance and improvement in vegetation communities (Flora) and supporting habitat requirements, and providing recruitment opportunities for native fauna (Fauna)[11].

The MDBA are investigating making regulated releases from storages to achieve a range of flows around 40,000 ML/day at Wagga Wagga. The bottom of this range has been delivered before and is just below the level at which Mundarlo Bridge (a low-lying bridge near Gundagai) is inundated.

The flow levels would generally be achieved by delivering water when tributaries below the dams were responding to rainfall. This would take advantage of natural triggers for native species to breed and grow, and reduce the volume of water needed to be delivered from Burrinjuck and Blowering dams[12], a key feature and benefit of the CARM operating system.

The CARM hydrodynamic model is continually updated with real-time river water-levels and observed and forecast rainfalls which allow it to be used to simulate (scenario planning & simulation model in CARM) 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.[13]

2.2.2 Relevance to Basin Plan Targets

The complexity of river operations coupled with high water demand for towns, irrigation and environmental sectors result in excess water being released from major dams (Burrinjuck and Blowering) which is surplus to the actual water demands in the Murrumbidgee catchment and End of System targets as stipulated in the Murrumbidgee Water Sharing Plan. Consequently there is an opportunity to better manage this water to enhance the overall river system.

Targeted delivery of this water has the potential to provide for existing beneficiaries of surplus flows (Lowbidgee and Murray water users) as well as improving on environmental water efficiency in the Murrumbidgee and Murray systems measured by changes in Site Specific Flow Indicators for key sites and other environmental assets in the Murrumbidgee and Murray valleys.

2.2.3 Description of Anticipated Benefits from CARM

Reconnecting the river to the lower floodplain, anabranch creeks and lagoons has multiple environmental benefits, including supporting the recovery, growth and reproduction of vegetation communities. The vegetation communities provide habitat and food for native

[11] Commonwealth of Australia (2014)

[12] MDBA (2014) Murrumbidgee Reach Report Constraints Management Strategy. pg 3.

[13] The Benefits of Hydrodynamic Models for River Operations - DHI

animals, including fish, frogs, turtles, waterbirds and woodland birds. Higher flows also provide cues for animals such as fish to move and reproduce.

The flows would flush out organic matter from inundated areas. This is an important process to reduce the severity of future blackwater events. If the period between events is prolonged, the volume of leaf litter and other organic matter can build up to a point where the next flood will cause a damaging low-oxygen blackwater event.

The flows would direct organic matter to the river. In moderate amounts, the contribution of organic matter to rivers is beneficial and important in driving the food web of river systems, and is particularly important for providing food for fish larvae and juvenile fish.

In addition, downstream of Hay, inundation of floodplains is generally seen as beneficial, wetting the soil to support the growth of native pasture. Higher up the river, inundation tends to disrupt agricultural operations, as it can damage improved pastures and lucerne crops.

Flows from the Murrumbidgee also provide significant benefits to the Murray and Lower Murray, particularly in helping build higher flows that inundate adjacent billabongs, creeks and floodplains. The contribution to Murray flows from the Murrumbidgee is, however, limited by channel capacity in the Lowbidgee (as previously discussed). This factor, in conjunction with the high level of attenuation of flows (as they move down the Murrumbidgee), means the main driver of peak flows at Balranald is the total volume of an event, not the size of the peak in the upper Murrumbidgee. The objective of higher peak flows in the Murrumbidgee is, therefore, to drive connectivity with Mid-Murrumbidgee River Wetlands, not to achieve higher peaks at the end of system. High flows at the end of the system can be achieved by longer duration within channel flows.

2.2.4 Monitoring and Evaluation Plan

The Monitoring & Evaluation of the measure (technical feasibility) will be undertaken as outlined in section 5.2The delivery of environmental outcomes will be monitored and evaluated according to existing requirements and arrangements for the Murrumbidgee system. This applies to specific environmental events and the broader Basin Plan implementation and evaluation.

This measure is expected to contribute to the achievement of outcomes under three key Chapters of the Plan, namely: under Chapter 7 Adjustment of SDL's, under Chapter 8, the delivery of ecological outcomes and under Chapter 10 for the entire Murrumbidgee and parts of the Murray system, meeting the relevant sustainable diversion limit/s (SDLs), which must be complied with under the state's relevant water resource plan/s (WRPs) from 1 July 2019.

2.3 Potential Adverse Ecological Impacts

2.3.1 Salinity and water quality outcomes

In summary, the overall trend experienced in NSW is that environmental watering from the Murrumbidgee system provides a net dilution effect from water making its way through the system and this considerably outweighs salt mobilisation risk.

Any future changes in flow requirements based on monthly regulated-flow characteristics defined by environmental watering plans using the Murrumbidgee Inter-Valley Transfer (IVT) account (together with any retimed water from CARM captured operational surplus) would offset potential NSW Murray impacts, from better regulated Murrumbidgee flows and to support environmental watering in the Lower Murray.

Given the scale of this change in timing, and the likely better use of CARM water for lower system environmental watering, it is most likely the CARM SDL project would create a situation not dissimilar from the overall assessment of a net salinity benefit from environmental watering in general. Providing Hume releases and 'called-out' of Murrumbidgee regulated water interchanged at times to meet NSW Murray demands, is unlikely to change dilution outcomes.

2.3.2 Other potential adverse effects

There are no identifiable adverse impacts that result from the measure.

3 Hydrologic Assessment of CARM

3.1 Current Hydrology and Proposed Changes

CARM integrates internationally utilised modelling software with real time metering, Bureau of Meteorology data and WaterNSW's online and data control systems to provide forecasts of future river inflows, and automatically updates the model so that it continuously emulates the real time behaviour of the river (GHD).

Operational improvements are achieved through the integration of real time river monitoring, extraction metering, hydrodynamic river models and optimisation software systems. These improvements in operator tools and optimisation result in less operational surplus water being released from storages to downstream customers. This enables the stored surplus now under the river operator's control, to be released to meet desired environmental flow targets, subject to addressing any impacts to water users.

Operational surplus for the Murrumbidgee Regulated River system can be estimated at the end of system measurement points (the Murrumbidgee River at Balranald (Station 410130) and Billabong Creek at Darlot (Station 410134). The raw system surplus is the difference between actual flow and target flow at each end of system point. The operational surplus is calculated from the raw surplus by removing those tributary inflows which could not have been re-regulated, and restricting the operational surplus to be at most the dam release volume (i.e. water doesn't count as surplus if it wasn't released from the dam). The advantage of using this end of system operational surplus is that it takes into account the re-regulation within the Murrumbidgee system that already occurs.

In the Murrumbidgee River surpluses generated in the upper river are caught by on-river weirs and Tombullen as they move downstream. This means the size of surplus reduces as it flows downstream, as demonstrated in SKM, 2010.

The water supply measure is defined as the additional entitlement that can be created in the headwater dams without affecting the reliability of current users in the valley[14].

3.2 Analysing the effects of CARM

The long term effects of CARM on the Murrumbidgee system have been modelled using the DPI Water's IQQM models. The subsequent impacts on the Murray system are then modelled using the MDBA's models.

[14] NOW (2014) Murrumbidgee Efficiency Project – water savings and operational surplus pg 6..

This measure was initially modelled for the Murrumbidgee Water for Rivers suite of projects for the Snowy Initiative. This was a very extensive process outlined in the attached NOW report 'NSW Office of Water Murrumbidgee Efficiency Project – water savings and operational surplus Volume 1 Report April 2013'

3.2.1 SDL modelling steps

The original modelling of the Murrumbidgee CARM project was completed using the Murrumbidgee IQQM water sharing plan model. This model for the purpose of this business case is referred to as the 'NSW baseline' model.

The **Murrumbidgee Computer Aided River Management** (CARM) project will produce a supply contribution through four supply measure components. These are:

- Better tributary forecasting and utilisation
- Improved rainfall rejection forecasting
- Management of Yanco Creek offtake inflows
- Better management of end of system flows

These measures and modelling assumptions are summarised in the following section and in more detail in the 'Murrumbidgee Efficiency Project – water savings and operational surplus' report (Attachment 3).

The operational efficiency benefits produced by CARM have to be assessed over the long-term to determine the size of equivalent water savings licences. Some aspects of CARM can be modelled in IQQM while other aspects of CARM can't be modelled because they affect operations indirectly, or are too complex to be represented in a long-term model. These are outlined below in Table 3.

Table 3 CARM – expected water management outcomes

Long term outcome able to be assessed	Long term outcome not able to be assessed
• Tributary utilisation from better forecasting • Rainfall rejection forecasting • More efficient Yanco Offtake management from more data and hydraulic modelling • Better management of end of system flows to achieve benefits in the Murray system	• Hydrodynamic routing • Optimisation • Broader range of inputs for operator decision making • Automated data input and management • Availability of real time diversion data • Reduction in number of processes lumped into the unaccounted difference series • Decision tracking and auditing • Detailed data archive • Accurate and telemetered metering data

3.3 Location and nature of the measures

3.3.1 Better tributary forecasting and utilisation

Each day WaterNSW Murrumbidgee river operators estimate the amount of water to be released from Blowering and Burrinjuck Dams to satisfy downstream orders. When making this calculation the operators try to take into account how much water is flowing into the river from the unregulated tributaries downstream of the dams. This tributary water can be used to satisfy orders, reducing the amount that needs to be released from the dams.

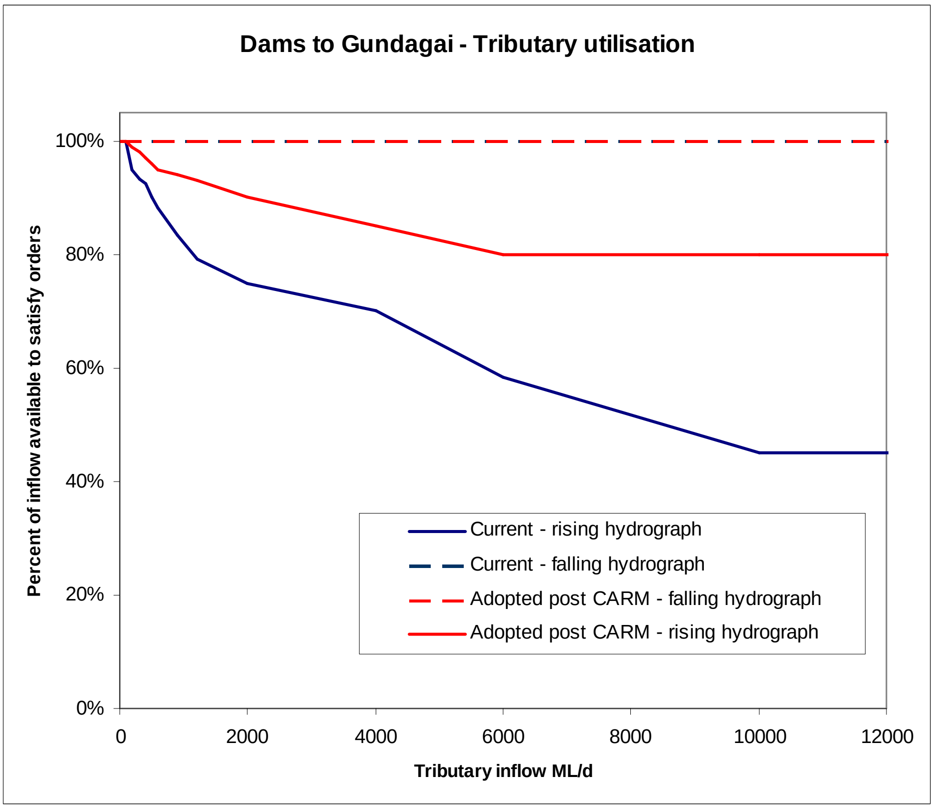
The Murrumbidgee tributaries used to reduce dam outflows are up to 4 days downstream of the dams. So the operator must predict what the tributary inflows will be up to 4 days into the future to know how much dam releases can be reduced by. Such predictions are relatively straight forward for gauged tributary catchments in dry weather, however they are often very difficult to make accurately for ungauged catchments or when it is raining.

Over time the ability to predict tributary flows affects the amount released from the dams, and the size of the resource remaining in the dams. The CARM project includes development of rainfall-runoff models of all significant tributary catchments in the Murrumbidgee Valley downstream of the dams, and increased rainfall monitoring. Provision of more reliable forecasts of tributary inflows and actual real time daily river flows through CARM means operators will be able to reduce dam releases with more confidence, generating stored operational surplus that can contribute to supply contributions under the SDL adjustment framework.

Discussions with river operators suggest that the accuracy of tributary forecasts depends on whether the hydrograph is rising or falling, and the size of the tributary flow. A review of historical dam operations confirmed this is the case, and that the proportion of tributary inflow the river operator uses to satisfy orders strongly depends on the size of the inflow and on whether the tributary hydrograph is rising or falling.

In the past operators have been able to predict and use a high proportion of inflow from the falling limb of the hydrograph, typically between 90% and 100% of the water in gauged tributaries. However on the rising limb of hydrographs the operator has to be more conservative, especially at higher flows. On the rising limb of larger inflows the operator typically only utilised 30-50% of the inflow in the past.

Figure 4 Dams to Gundagai Tributary Utilisation – rising and falling hydrograph

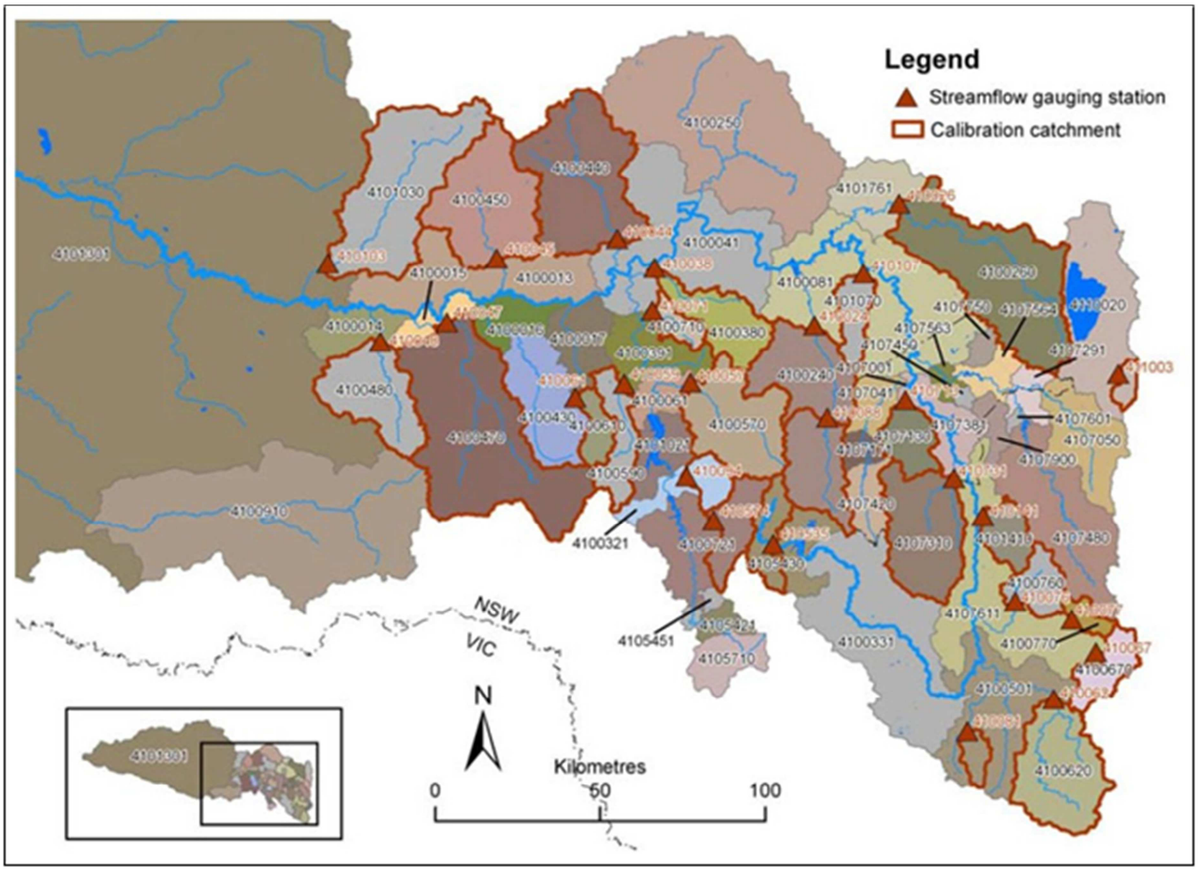


Tributary catchment rainfall runoff models will allow CARM to increase the amount of tributary flow used to fill downstream orders, particularly on the rising limb of hydrographs. In both cases IQQM assumes 100% utilisation on the falling limb. Depending on the calibration accuracy of the rainfall runoff forecast models, CARM IQQM predicts and utilises up to 80% of rising limb flows to allow for a more realistic forecasting improvement.

These levels of utilisation of tributary inflows were put into the IQQM model to estimate water operational surplus. Past operator utilisation rates were used in the baseline model (IQQM made to behave the same as historical operator rising and falling 'utilisation curves' – pre CARM), while the expected CARM rates were used in the water savings model.

A water surplus estimate has been made assuming the forecasting system is moderately successful. The estimate does not assume the system can perfectly forecast tributary inflows, but that it is a significant improvement on what an operator can do without any tools to guide them.

Figure 5 Murrumbidgee tributary catchments



Source: CSIRO 2008

3.3.2 Improved rainfall rejection forecasting

Rainfall rejections of ordered water by irrigators can produce significant volumes of surplus flow in the river. Unless this water can be re-regulated in downstream storages or used to supply orders elsewhere, it becomes operational surplus flow running into the Murray system.

Rainfall rejections occur when an irrigator orders water and operators release these orders from the dam, but it rains in the period between the dam release and the water reaching the irrigator's offtake. The rainfall may reduce the irrigator's need for water, and they may choose not to take the full amount of water they ordered. This dam release water not taken up by the irrigator becomes surplus flow in the river.

Operators try to avoid rainfall rejections by reducing dam releases if they believe significant rainfall is likely. However they have to be confident the rainfall forecast is right, and confident that irrigators will take less water than they originally ordered. Otherwise this can produce a shortfall in the river and inconvenience many irrigators.

CARM will improve the operator's access to extended rainfall forecasts from the Bureau of Meteorology (BoM). This will mean that river operators will be able to reduce dam releases with more confidence than is the past during times when rainfall rejection is likely. This improved operational practice will generate a stored operational surplus that can contribute to a supply contribution under the SDL adjustment framework. In order to determine the surplus created by this action the original IQQM has been updated to better reflect ‘actual operator behaviour’ before the measure is introduced.

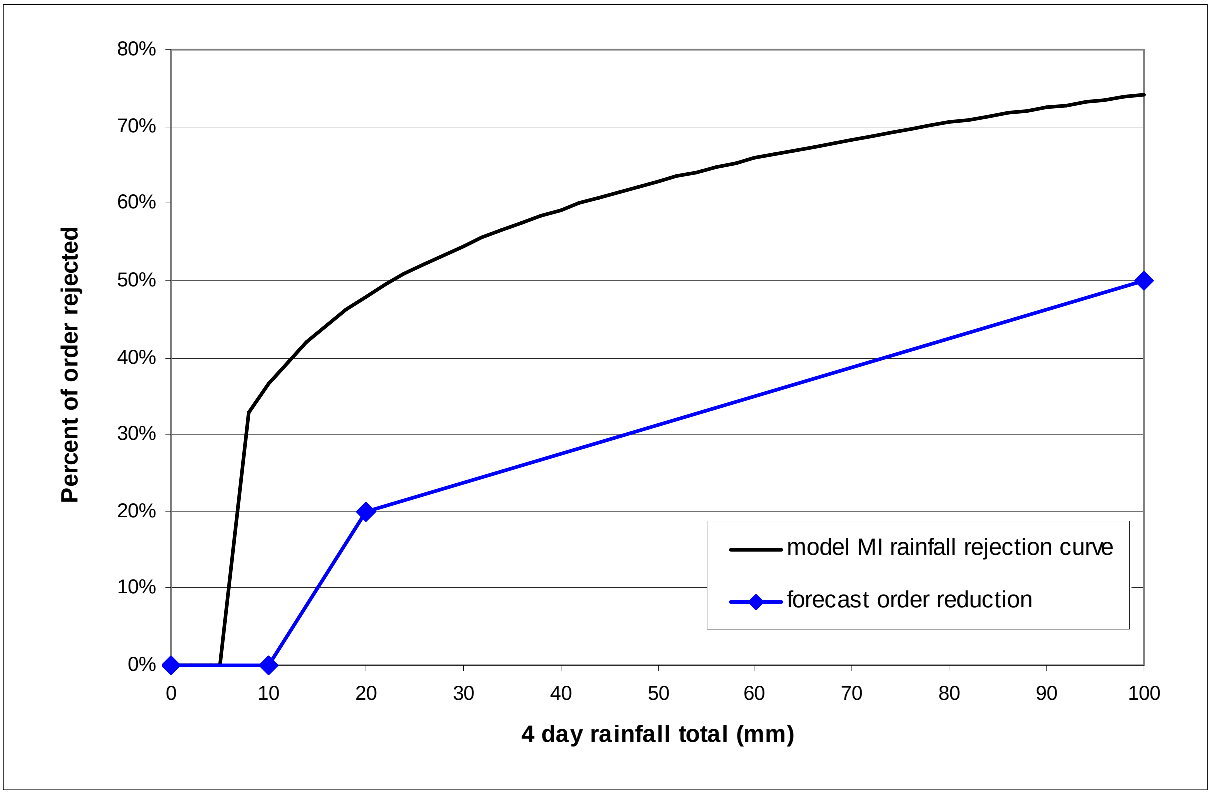
A review of BoM rainfall forecasts concluded that they are generally reliable out to 7 days, especially for events that yield more than 10mm. Although rainfall rejection was considered for both Murrumbidgee Irrigation and Coleambally Irrigation, only the Murrumbidgee irrigation main canal was included 4 days downstream of the dams. The other offtakes were rejected at this stage due to the level of confidence in the forecasting 6-7 days downstream of the dams.

The Murrumbidgee IQQM model does simulate rainfall rejection. When deciding how much ordered water to take out of the river, IQQM checks the rainfall on that day to see if the simulated irrigator actually needs its full ordered volume. If it doesn’t IQQM will leave part of the ordered water in the river, producing surplus flows downstream.

The baseline (existing case) IQQM model doesn’t reduce dam releases if rainfall is expected. In this way, it acts like an operator reluctant to risk shortfalls if the rainfall doesn’t eventuate. In reality, rainfall forecasting for a location further than 5 days travel time is highly unreliable.

In comparison, in the IQQM model simulating CARM, IQQM looks ahead at the rainfall for the next four days and may reduce dam outflows for MI orders based on this. The reduction in dam outflows IQQM makes is tied to the amount of forecast rainfall and the size of the MI order assuming a conservative forecast reduction (Figure 6).

Figure 6 Model MI rainfall rejection curve & forecast reduction



As the rainfall increases, the percentage reduction in the dam releases IQQM makes increases. This is meant to reflect both that more rainfall means less ordered water will be taken, but also that heavier rainfall forecasts mean greater certainty that at least some rain will fall. The rainfall rejection system in CARM operates using similar principles.

3.3.3 Management of Yanco Creek Offtake Inflows

The Yanco Billabong Creek system is operated in a separate CAIRO system (the current spreadsheet based river operating system) to the main Murrumbidgee River. The Yanco CAIRO system estimates orders at the Yanco Offtake (and through the Coleambally and Murray irrigation supply system), and then the river operator transfers the Yanco Offtake order from the Yanco CAIRO system to the Murrumbidgee CAIRO system.

The Yanco CAIRO system is intended to accumulate the net of all irrigation orders, transmission losses, Billabong inflow, the end of system flow requirement at Darlot, and irrigation corporation inflows. The intention when the CAIRO system was set up was that these be accumulated upwards in CAIRO, to calculate a total order at the offtake as the output of the process.

However, current operators have reported that they actually use the CAIRO system in a different way, and iterate the inflow at the top of the sheet until all flow and order commitments downstream are met.

The order at the Yanco Offtake includes provision for the expected future losses in the creek system through the assumed Estimated Unaccounted Difference(EUD) values. Typically in late spring and summer operators also include some provision for higher diversions than those ordered, to make a provision for particularly hot weather occurring, for pumping by irrigators at short notice in extreme situations.

Due to the long travel times in the Yanco System the provision has to be met from water already in the creek system, rather than waiting for additional dam releases to travel down the river and along the creek. As a result operators tend to increase the offtake order being passed to the Murrumbidgee from the Yanco System to avoid potential shortfalls. (The proposed upgrade of the Yanco regulator and offtake outlined in section 6.2 will greatly assist in reducing the associated operational surplus)

CARM will provide more certainty in calculating the total Yanco system demand and the impacts of channel routing on water availability down the creek. Telemetered meters will also allow operators to see when water is being taken from the creek and identify potential downstream shortfalls sooner. It is expected that this will result in tighter operation of the Yanco Offtake and reduced releases by river operators. This will lead to a supply contribution under the SDL adjustment framework.

Comparison of offtake flows against offtake orders for October – March periods between 2001 and 2005 indicates that on average flows through the offtake are an additional 25% above orders. To represent this, the baseline (existing situation) IQQM model adds a 25% “operator risk provision” on accumulated orders at Yanco Offtake in the October – March period of each year. This is a simple way to include the additional offtake flow operators provide above actual orders.

The reduced uncertainty provided by CARM and meter telemetry is expected to reduce this operator risk provision to be less than 25%. The actual reduction in risk provision cannot be determined until CARM has operated for several seasons. This risk provision is a product of many operational factors and operator decisions. The ways in which these factors will change the amount of water used in the river cannot be known in advance. For this reason, IQQM modelling is unable to predict the water savings benefits for this aspect of CARM.

However, river operators have indicated that an improvement in the risk provision of 5-10% is expected to be achievable with CARM. This judgement reflects potentially greater confidence given that operators will have more information about the real state of the Yanco Creek System at any given time.

On this basis, the water savings has been assessed in IQQM using an assumed future risk provision of 20%, instead of the historical provision of 25%.

3.3.4 Better management of end of system flows

The replacement of the existing spreadsheet system used to manage daily releases from storage with a hydrodynamic model of the Murrumbidgee River that can utilise the real time monitoring of water meters is expected to provide an improvement in forecasting river flow behaviour.

This more detailed river model, together with the three key areas of improved operation discussed above, is anticipated to achieve a more efficient overall operation of the river system. This is expected to be observed through a reduction in operational surplus flows. The reduction, or capture, of operation surplus flows has the potential to reduce inflows to the Murray and for water users such a Lowbidgee that rely on unregulated flow access. In order to ensure that no third party impacts occur, some of these captured flows will have to be reinstated through planned storage releases.

The advantage being sought from the planned storage releases is the potential to manage these releases in a way that improves environmental outcomes both within the Murrumbidgee and Murray. This will lead to a potential supply contribution under the SDL adjustment framework.

3.4 CARM modelling assessment

The key areas of improved river operations anticipated from CARM that are described in Section 3.3 have been previously modelled using the Murrumbidgee Valley IQQM model.

This initial Stage 1 modelling indicated that:

- reduced operational surpluses, without any explicit management of the additional “captured” water, will mean that dam storage volumes will be higher on average than in the past, and
- a small volume of transmission loss savings is expected to occur..

A number of enhancements had to be made to the Murrumbidgee IQQM to include more detailed representation of tributary utilisation, rainfall rejections and the Yanco Creek system, as described in Section 3.3.

The work undertaken as part of this business case, referred to as Stage 2 modelling, investigated the potential to manage additional planned releases of stored operational surplus to contribute (along with other supply measures) to the improvement of the frequency of achievement of the Specific Flow Indicator (SFI) targets in the Murray.

Stage 2 modelling also includes updating of the MDBA’s Benchmark modelling of the Murrumbidgee Valley to include representation of CARM and other water savings projects that had been developed by Water for Rivers and completed as part of the Snowy Initiative.

3.4.1 Stage 1 - Adjusting for Murrumbidgee Third Party Impacts

Previous modelling was undertaken using the Murrumbidgee Valley IQQM model to represent CARM and other water recovery projects developed by Water for Rivers. This included a number of enhancements to the Murrumbidgee IQQM to allow more detailed representation of the aspects of river operation that CARM was expected to improve. These key areas of river operation are tributary utilisation, rainfall rejections and the Yanco Creek system, as described in Section 3.3.

When the modelling of CARM was initially undertaken, operational surpluses reduce and the reductions in water releases from the main storages were removed from the model. The outcomes of this modelling indicated there are numerous changes in outcomes (increases and decreases) for other elements in the model, and was used to indicate who was impacted by “capture” of operational surpluses. Impacts generally included reductions in water availability to other users such as supplementary access to Murrumbidgee irrigators, inflows to the Murray system or the Lowbidgee system. These results were then used to guide the release of the captured operational surpluses so that reduced access was made up by either dam releases or, in the case of Lowbidgee, increased access to water.

These “offset” releases were specifically to ensure each water user received, on average, the same amount of water that they did before CARM was implemented. This distributes the water kept in the dams by CARM back to these third party water users, and to the water savings licence created for the Snowy Initiative. In effect the modelling releases stored operational surplus to ensure third parties receive the same average amount of water as they did before the projects.

These offsets are pictorially represented in Figure 7 and Figure 8 and are described in more detail in the NSW baseline model report (Attachment 1). Note that the approach for representing offsets in the attached NSW baseline model report and that subsequently used in Stage 2 for the benchmark model used in the current analysis are identical.

Figure 7 Estimated impact of all projects on the Murrumbidgee water balance (average annual quantities in GL/yr)

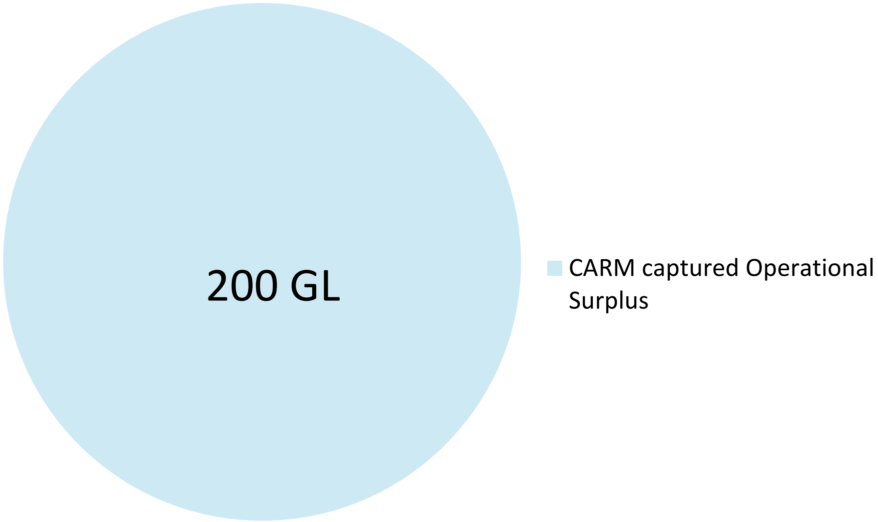
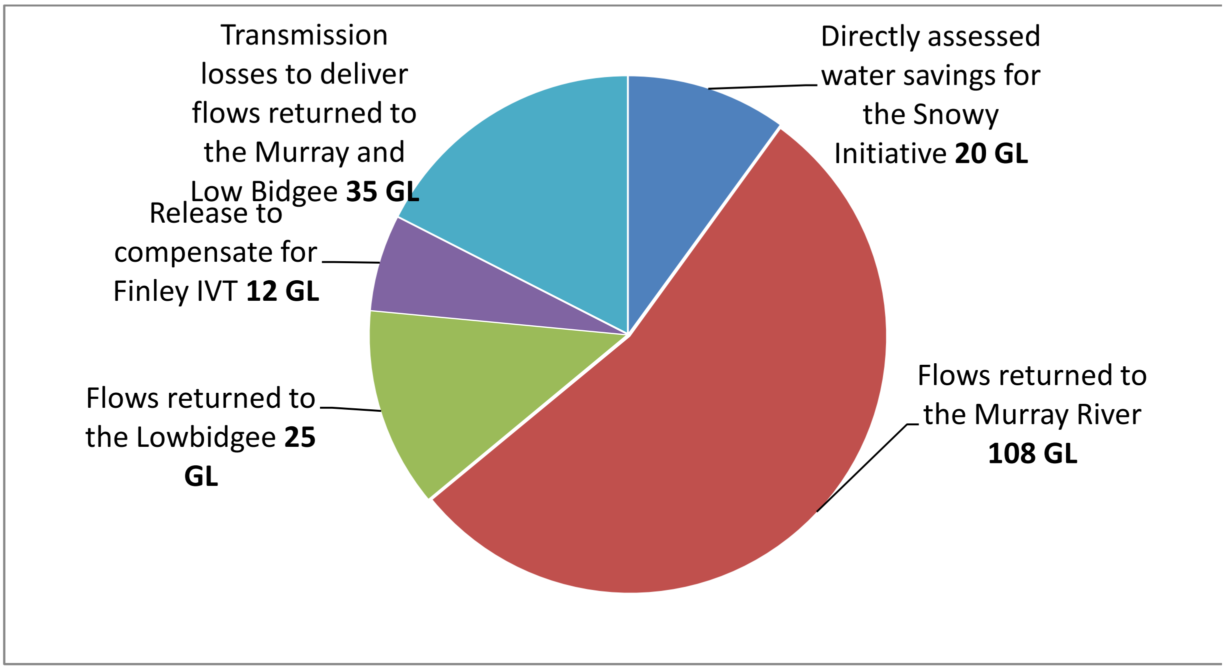


Figure 8 Use of retained dam water to offset third party impacts and provide a water savings



In addition to the directly assessed water savings high security entitlement of 20 GL in Figure 8, an additional 13 GL of general security entitlement will be created as a final step for the Snowy Initiative. This represents a share of the additional benefits of re-timing stored operational surpluses from CARM that has been committed to the Snowy Initiative.

3.4.2 Stage 2 - Determining the SDL Adjustment

The Benchmark model developed by the MDBA was based on the version of the Murrumbidgee IQQM that represented the Murrumbidgee Water Sharing Plan. At that time, not all the projects ultimately developed by Water for Rivers for the Snowy Initiative were known, or modelled.

NSW has held a number of meetings with the MDBA to develop a modelling methodology and process, outlined in Table 4, to enable the potential for an SDL adjustment from CARM to be assessed.

Table 4 Summary of Modelling methodology

Step	Actions
Step 1	REVISE BASIN PLAN BENCHMARK MODEL TO INCLUDE SNOWY INITIATIVE PROJECTS The Benchmark model was updated to include all water savings projects developed by Water for Rivers for the Snowy Initiative. Adjustment was also made to the model to include more detailed representation of tributary utilisation, rainfall rejections and the Yanco offtake. The revised benchmark model was then configured to represent CARM as per the Stage 1 work carried out in 2012. These changes were confirmed with the MDBA prior to the assessment of the CARM measure and are contained in a modelling report for review and assessment (DHI 2015). [NB adjustment was made to reduce the water available from Snowy Hydro by increasing entitlements (20,000 high security units and 13,000 general security units) for the water recovery associated with the final package of Water for Rivers works.]
Step 2	SIZE AN ADDITIONAL MURRUMBIDGEE (CARM) ENTITLEMENT, AFTER ADDRESING IMPACTS IN THE MURRUMBIDGEE VALLEY Iteratively, the modified benchmark model was adjusted to include an additional general security licence to determine the size of licence that could be added to the Murrumbidgee system without 3rd party impacts on existing Murrumbidgee licence holders. (See section 3.4.1) This was done by ordering increasing volumes of water to the end of the Murrumbidgee system at Balranald (that is, the stored operational surplus), and then extracting the ordered water. 3rd party impacts in the Murrumbidgee were prevented by sizing the entitlements at Balranald and maintaining allocations in the Murrumbidgee at benchmark levels. This step produces an estimate of an additional Murrumbidgee CARM entitlement constrained to ordering at the end of the system.
Step 3	IDENTIFY AND ADDRESS POTENTIAL IMPACTS IN MURRAY Replace the original Murrumbidgee inflows in the Murray MSM Benchmark model with inflows derived from Step 2. This produces an MSM model that identifies potential impacts in the Murray associated with reduced tributary contributions from the Murrumbidgee. Increase outflows from the Murrumbidgee Valley to determine the water required to be delivered to maintain reliability of supply in the Murray Valley.
Step 4	FINAL SDL ASSESSMENT Reduce the Murrumbidgee (CARM) entitlement estimated at Step 2 to reflect the water required by the Murray system in Step 3. The remaining entitlement represents the additional water that can be called out of the Murrumbidgee Valley without third party impacts. From this point modelling can proceed to assess the SDL adjustment by: • adding the remaining Murrumbidgee (CARM) entitlement to the held environmental water, and determining the resultant alteration in SFI achievement in the Murray and Murrumbidgee; • determine the ecological elements score; and • potential final SDL adjustment.

Steps 1 and 2

These steps have been completed and are included in this business case. These steps identified an initial general security licence at Balranald of between 42 GL and 105 GL. The 42 GL licence size was determined by iterative model runs to assess the licence that could be added to the system without 3rd party impacts for the 1st October water availability (representing the summer planting allocation decision point). A similar exercise was undertaken for the 1st January which sized the water at 87 GL and 1st June water availability, at the end of the water year, which yielded a 105 GL general security licence.

The range in this licence size is based on a conservative modelling response and will be subject to further sensitivity testing using the Murrumbidgee Benchmark model with MSM-BIGMOD. It is possible that the potential for Murrumbidgee 3rd party impacts will be sensitive to the pattern of use of the Balranald entitlement in the Murray, and this will be further investigated in the subsequent modelling steps.

Table 5 Murrumbidgee system outcomes under the benchmark and proposed supply measure (GL/year)

GL/yr	Benchmark	Adjusted Benchmark	Step 1	Step 2 42 GL licence	Step 2 87GL licence	Step 2 105 GL licence
Supplementary diversion	72	77	73	72	72	73
On allocation diversion	1260	1190	1198	1187	1176	1169
Total diversion	1333	1268	1271	1259	1248	1241
Effective Allocation reliability 1 June	94.6	90.4	92.9	91.9	91.2	90.4
Effective Allocation reliability 1 Jan	89.1	83.6	86.7	85.1	83.6	82.9
Effective Allocation reliability 1 Oct	79.1	74.2	76.1	74.2	72.4	71.6
Darlot Flow	301	289	283	283	282	282
Balranald flow (including licence to restore EOS)	1713	1702	1695	1715	1730	1737
Balranald flow (without licence to restore EOS)	1713	1702	1696	1674	1652	1647
Lowbidgee net inflow	348	348	342	339	338	338

The potential for impact is not only associated with the volume of the licence, but also the likely pattern of demands. A fixed, flat demand has been used for the simulation of additional Murrumbidgee (CARM) entitlement that represents the initial estimate of the potential to create an additional licence without impacting on existing Murrumbidgee entitlement holders. In the absence of better information on how the environment would call this water, a flat demand pattern represents a neutral assumption between the extreme cases of aggressive ordering of water as soon as it is allocated, and passive ownership characterised by late season orders and extensive carryover/forfeit.

The modelling has assumed that the water allocated to the new entitlement would be extracted and a revised end of system flow sequence should be taken from below the ordering node for use as a Murray inflow sequence..

The results in Table 5 indicate that the sizing of entitlement is lower than the long-term average volume required to be "returned" to the Murray in stage 1 modelling in Figure 8. Analysis has indicated that this is largely the result of the large amounts of water recovery that are included in the Benchmark modelling. This assumed water recovery, particularly in the Yanco Creek system, reduces the apparent effect of CARM, and less stored operational surplus flows. The interaction between this measure and the assumptions in the benchmark modelling require further consideration.

The remaining two steps require further development (coding) of MSM-Bigmod.

Step 3

The Murray Benchmark model can be used with, and without, the changed Murrumbidgee inflow sequence. This will allow the potential for impacts to water users and the environment in the Murray to be understood.

The increase in Murrumbidgee outflows required to reinstate reliability of supply to Murray water users can then be established by progressively modifying the diversion of water by the additional Murrumbidgee (CARM) entitlement modelled in Step 2.

Various modelling trials were undertaken to establish a modified Murrumbidgee CARM entitlement, but further development (coding) is required within MSM-Bigmod to complete this work.

Step 4

Once the portion of the Murrumbidgee CARM entitlement required to ensure reliability of supply in the Murray Valley has been identified, it should be made available within the Benchmark models to contribute to environmental demands, and the normal process should be followed to determine environmental equivalence under the SDL adjustment process..

3.5 Water Account and Licence Creation

It is proposed that two additional water accounts will be established in the Murrumbidgee Water Sharing Plan after the modelling assessment and review outlined above:

- a Murrumbidgee (CARM) entitlement will be established that can be used for environmental purposes within any limits identified by the proposed modelling, and
- a rules-based account that will ensure reliability of supply in the Murray Valley is maintained.

The Murrumbidgee (CARM) entitlement is likely to be in the form of a Murrumbidgee general security access licence account, would be incremented with Murrumbidgee Available Water Determinations, and would have all the same use, carryover, account limit and trade attributes of other Murrumbidgee general security licences. It is anticipated that the bulk of this account would be ordered at Balranald for environmental flow events in the Murray, and the Business Case modelling has been undertaken on this basis.

As this project will need to be assessed together with the combined package of Murrumbidgee SDL Adjustment proposals, the final entitlement that can be created will be subject to modelling assessment of the combined Murrumbidgee package of SDL measures.

The total amount of entitlement that can be created has been conservatively estimated on the basis of no third party impacts on existing Murrumbidgee licence holder's access security. That is, existing holders can be confident that the combination of the CARM measure and the creation of the new accounts do not have any detrimental impacts on their access regime.

The rules-based account will act in a similar way to the existing Inter-Valley Transfer (IVT) account, and would ensure water availability for NSW, Victoria and South Australia in the Murray River is unaffected by the reduction in operational surplus flows.

The rules-based account would likely be in the form of a Water Sharing Plan rule that incrementally receives credits of water at the same time as Murrumbidgee Valley general security Available Water Determinations are made.

4 Operation of the Measure

4.1 Ecological justification for the operating regime

The primary objective of CARM is to provide better control of water deliveries in the Murrumbidgee Valley. This enables CARM to play a significant role in assisting in improved river operations and more accurate management of daily flows instream, over bank and in the management of higher flows, whether this is a lower, artificially generated, environmental wetland watering, or larger naturally generated events.

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

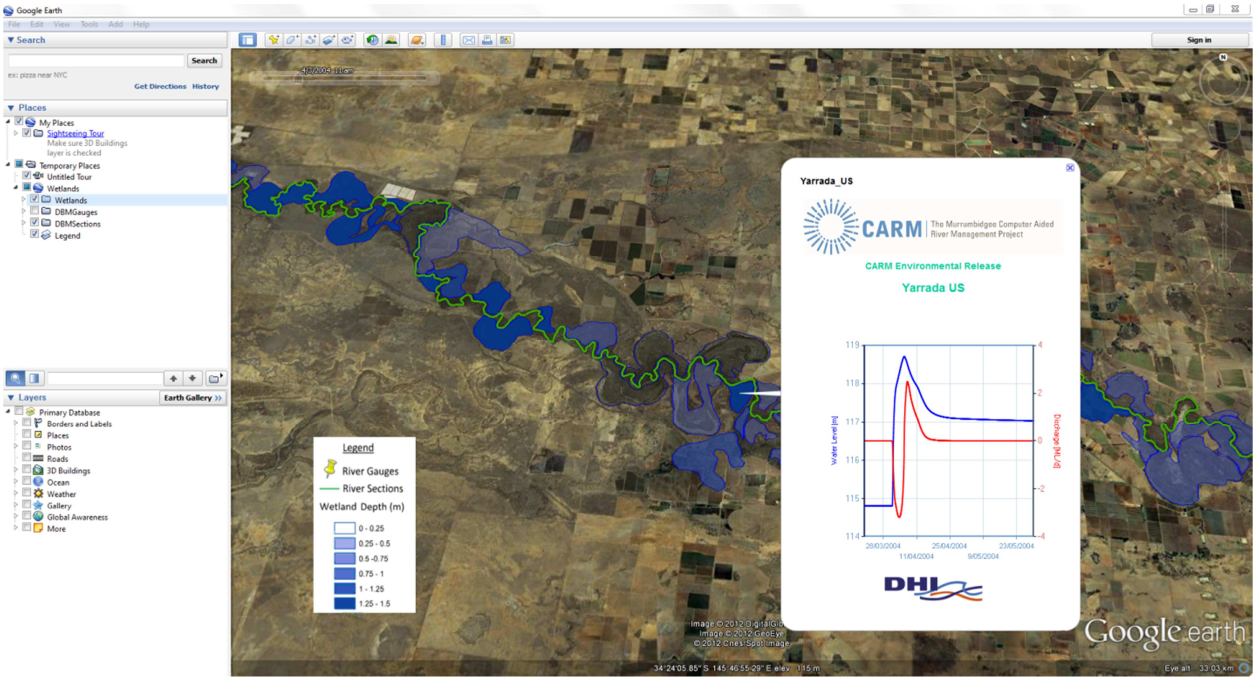
The implementation of CARM has already opened up the opportunity for clearly defined inundation mapping and assessment for the various flow regimes as described in section 2.2.1 above.

In some upper reaches of major rivers, we don't know tributary inflows in advance and correctly forecasting tributary inflows and river dynamics is very important to:

- ensure enough water is released to reach the wetlands we want to
- release doesn't affect infrastructure and property where stakeholders haven't been consulted

CARM provides a real-time continually operating system that forecasts expected and higher than expected rainfall tributary inflows, tests release scenarios, simulates river hydrodynamics, and predicts water levels along the river.

Figure 9 Objective forecasting simulation of wetland inundation



The 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 flow events 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. The CARM system(s), being implemented in the Murrumbidgee Valley, are able to be used for this purpose.

4.1 Operating Scenarios

The CARM river operation system collates data from multiple sources, and the hydrodynamic model uses the data to present the information to enable River operators to make informed daily flow management decisions as well as running future river planning scenarios to optimise resource availability and meet customer orders. These are outlined in Appendix 3.

5 Technical Feasibility and Fitness for Purpose

5.1 Sensitivity analysis of preferred option

CARM is now implemented, and there are no options for a different approach to the system.

5.2 Ongoing operational monitoring

5.2.1 CARM Evaluation Framework Implementation

WaterNSW commissioned the UTS Institute for Sustainable Futures to prepare a framework for evaluation of the Murrumbidgee CARM project performance. UTS completed its final report in late 2014, identifying a number of different outcomes for CARM evaluation. These outcomes are listed in more detail in Appendix A of the UTS report.

The Evaluation Framework draws on the evaluation guidelines as proposed by the Centre for Program Evaluation located in the NSW Treasury (NSW Government, 2013) and incorporates the inputs from consultation with relevant WaterNSW staff.

WaterNSW is currently in the process of implementing this framework.

5.2.2 The Purpose of the Evaluation

The evaluation framework has been developed to guide the assessment of CARM in terms of its effectiveness in addressing the high level objectives and delivering on agreed performance parameters for the operating system and as a risk management tool to ensure system performance is maintained when assessed against modelling assumptions used for this SDL measure, and to actively report back to key stakeholders and customers.

Four direct goals have been defined as a means to achieve the high level objectives. The evaluation framework provides a set of indicators that can inform the progress towards achieving these goals.

1. Demonstrated environmental equivalence: The improved data -collation and storage of CARM, together with its high levels of hydrological analysis will enable the testing for environmental equivalence with smaller volumes of environmental water. Water savings may in the future be used to increase the allocation for the environment and/or irrigation customers through changes to entitlements, licences or rules.

2. Flood mitigation: The improved modelling and forecasting of flows from tributaries will ensure mitigating downstream floods whilst meeting dam safety requirements.

3. Improved performance of the operating system: Improved knowledge of the system, together with the increased amount of analysis undertaken by the operators, will lead to an improved performance of the operating system, and therefore potentially lower surplus flows.

4. Customers make informed water management decisions: Access to reliable flow information, will empower customers to make informed decisions about the orders that they put in and the amounts of water they use.

For each of the four goals a number of measureable outcomes were identified to allow objective assessment to be undertaken by WaterNSW for internal and external evaluation purposes as part of the CARM Monitoring Evaluation and Reporting (MER) framework.

These outcomes are briefly described below to provide the reader with an outline of the comprehensive nature of the measures and there use in terms of monitoring future system performance.

5.2.3 Indicators

Outcome 1**:** Reduced operational surplus:

The objective of this outcome is to set up processes to calculate future operational surplus in the river and Yanco Billabong Colombo Creek system.

Outcome 2: Greater use of tributary flows:

The objective of this outcome is to establish how much tributary runoff is utilised to supply orders downstream. This would be done by assessing the reduction in orders being passed to the dams for releases due to forecast tributary flows providing the water instead.

Outcome 3: Improved demand forecasting:

This outcome will assess customer response to future forecasts and the model behavioural forecasts for irrigation demand particularly the larger irrigation customers and comparing actual use.

Outcome 4: Environmental delivery:

This outcome aims to establish the impact of CARM on piggy-back delivery of environmental flows to river corridor wetlands. It aims to evaluate the performance of past piggy-back flows against "perfect hindsight" scenarios and then procedure to evaluate delivery performance in the future.

Outcome 5: Reduced flood peaks during flood events:

This flood management outcome is similar to Outcome 4, in that it evaluates performance against perfect hindsight conditions. This is proposed to be done firstly for historical flood events, and then a procedure developed to evaluate CARM performance in the future.

Outcome 6: Knowledge of the hydraulic system is enhanced:

This outcome assesses whether the implementation of CARM improves the forecasting of river flows over time. This outcome is focussed on the benefits of the hydraulic modelling, better usage monitoring, and improved AUD estimates.

Outcome 7: Operator time is efficiently utilised:

This will monitor delivery of reports to stakeholders and hours spent on data collection for evaluation and response.

Outcome 8: Improved performance of the operating system:

This outcome will monitor and evaluate ease of use, confidence in CARM forecasts, use of tributary inflows and confidence in daily river operations using enhanced information and real time data.

Outcome 9: Security of water supply and enhanced service to customers:

This outcome will monitor and evaluate system shortfalls both at the end of system flow demands and for critical demand points along the system, both to compare CAIRO and under the CARM operating regime.

6 Complementary Actions and Interdependencies

6.1 SDL resource units that are affected by the measure

The SDL Water Source affected by the measure is the Murrumbidgee – SS15, proposed for adjustment according to section 7.13 of the Water Act 2007.

The Murrumbidgee Regulated River Water Sharing Plan (WSP) is the document that specifies the rules for management of the Murrumbidgee Valley water resource.

Other resource units affected by the measure are SS2 Vic Murray, SS11 SA Murray and SS14 NSW Murray. These resource units would be beneficiaries of the measure with the proposed callable water entitlement ordered at Balranald for environmental flow events in the Murray. Three accounts are proposed: one to complete commitments to the Snowy Initiative, one for this measure, and the third to maintain reliability of supply for the Murray Valley (see section 3.5).

6.2 Other supply and/or constraint measures, and/or complementary actions relevant to the measure

Improved targeted delivery of held environmental water can enhance the effectiveness of environmental watering outcomes for key sites and other environmental assets in the Murrumbidgee and Murray system. This operational step change will optimise the amount of held environmental water needed to be released to achieve water targets and reduces the risks of over releasing with consequent adverse flooding impacts.

There are ongoing benefits of more efficient environmental watering. There are a number of other supply measures that are proposed that may have benefits from more efficient watering through improved system uses and optimisation. However, these are not conditional on the CARM project but have a high level of complementarity to improve future management of the Murrumbidgee system.

Table 6 provides listing of current SDL adjustment proposals in the Murrumbidgee.

Table 6 Current SDL adjustment proposals in the Murrumbidgee

Measure	Description	Type of measure
Improved Flow Management Works at the Murrumbidgee River - Yanco Creek Offtake	Increase weir pool capacity and operational control of Yanco regulator and weir pool to the benefit of the environment providing a potential SDL adjustment	Supply measure
Modernising supply systems for effluent creeks Murrumbidgee River	A series of alternative supply arrangements and controls that provide higher levels of service with lower losses.	Supply measure
Nimmie Caira Project	This Proposal provides for the re-configuration of the Nimmie-Caira water delivery system and landscape to service the ecological	Supply measure

	requirements of the area more effectively and efficiently.	
Water Management Works Millewa and Yanga National Parks	A suite of works aimed at delivering a more appropriate watering regime to core wetland communities within these national parks.	Supply measure
Murrumbidgee key focus area	Investigation of opportunities to address physical and policy constraints to the delivery of higher regulated flows	Constraint / supply measure

7 Risks and Impacts of Operation CARM SDL offset Processes

7.1 Risk Assessment

The SDL Stage 2 Guidelines cover three risk categories:

- Adverse ecological effects (clause 4.4.2: If relevant, business cases need to include an assessment of potential adverse ecological impacts resulting from the operation of the proposed measure)
- Impacts from the operation of the measure (clause 4.7: All business cases need to include a risk assessment and risk management strategy for the proposed operating regimes or proposed operating rules changes)
- Project development and delivery risks (clause 4.11.4: The business case needs to include a risk assessment and risk management strategy for risks to project development and delivery)

The guidelines confirm that the business case will be assessed on the basis that:

- All significant project development and delivery risks and impacts have been identified, adequately described and analysed and robust treatments and mitigations proposed;
- The risk management strategy complies with the AS/NZS ISO 31000:2009 Risk management— Principles and Guidelines; and
- All residual risks are negligible or can be adequately mitigated.

This section of the business case sets out a generic risk management framework that has been applied across all impacts. The section covers the issues related to potential adverse ecological effects and impacts from the operation of the measure. The risks associated with project development and delivery are dealt with below in Section 7.2

Table 7 ISO Risk prioritisation matrix

		Consequence			
Likelihood	Negligible	Minor	Moderate	Major	Extreme
Rare	Low	Low	Low	Moderate	High
Unlikely	Low	Low	Moderate	High	High
Possible	Low	Moderate	Moderate	High	Very High
Likely	Low	Moderate	High	Very High	Very High
Almost Certain	Moderate	Moderate	High	Very High	Very High

7.2 Identified project delivery and operating risks

The risk assessment process comprised two main elements:

- A series of commissioned reports that have examined various risks of the project from a hydrological view

- Professional judgement: Members of the project team then made judgments on the range of risks and their likely characteristics in-line with ISO 31000, informed by experience of working on very similar projects.

The outcome was a listing of possible risks with a ranking based on the ISO methodology.

In each case the mitigation strategy comprised two main elements:

- Appropriate analysis and modelling to confirm that the evidence showed either neutral or positive outcomes,
- On-going community engagement to ensure understanding and contributions from affected stakeholders.

The listing of the risks and the assessment of their significance is provided in summary form in Table 8 and a detailed assessment in Appendix 2. The risk level refers to the severity of the risk prior to the application of any mitigation actions. With these controls in place, the business case advises that any residual risk is insignificant.

Table 8 Murrumbidgee CARM Project – Summary of Risk Assessment

Risk category & Item	Potential Issue	Residual Risk Rating	Target Risk Rating
Project Delivery			
1. CARM system doesn't deliver modelled operational assumptions by 2019	The CARM system design does not deliver Murrumbidgee river valley (modelled) operational assumptions, Operational Surplus (OS)	Medium"	Low
Legal & Stakeholder			
2. Murrumbidgee Valley support for CARM system	Murrumbidgee valley landholders don't support CARM nor recognise the project can reduce the operational surplus	High	Medium
Cumulative impacts			
4. CARM system design failure	The CARM operating system and project design does not deliver demonstrable improved river environmental management outcomes	High	Low
Environment Ecological			
5. Protection and recognition of existing river services	Plans to develop an optimal river control system fail to recognise existing river operating arrangements which exist to mitigate third party impacts, both in stream and end of system	Low	Low
Operation and maintenance			

Risk category & Item	Potential Issue	Residual Risk Rating	Target Risk Rating
6. CARM training systems are in place	Adequate training and skill(s) development of staff isn't provided to ensure 'in house' expertise and confidence to successfully operate the CARM system	Low	Low

7.3 Risk Assessment and Proposed Controls

7.3.1 CARM system doesn't deliver modelled operational assumptions by 2019

The CARM system design does not deliver Murrumbidgee river valley (modelled) operational assumptions, Operational Surplus (OS) and river operators do not use with confidence the CARM operating tools.

Treatment procedures include:

- Rigorous system operating protocols in place;
- Continued testing and model QA assessment;
- Verification and evaluation;
- Operation reflects design specification;
- Continued River operator training;
- the CARM model runs have assumed a conservative increase in operator skill in: Forecasting tribs; Forecasting demands and rainfall rejections and Operation of the Yanco Creek system; and
- set UTS MER targets higher than modelled assumptions demonstrating exceedance of assumptions by 2019

7.3.2 Murrumbidgee Valley support for CARM system

- Successful implementation of Murrumbidgee CARM computing technology with demonstrated achievements; Implementation of UTS (Institute for Sustainable Futures) MER Framework.
- Continued reporting to key stakeholders (internal & external) through stakeholder engagement strategy since 2015/16 water year.

7.3.3 CARM system design failure

- Murrumbidgee CARM operating system (hydraulic system, data management and modelling requirements) QA system implemented, verified and performance review carried out.
- Maximise use of scenario planning and forecasting linked to improved catchment measurement and monitoring.

7.3.4 Protection and recognition of existing river services

- Continued compliance with WSP's and river environmental flow requirements, and evaluation of OS benefits, including clear operating protocols for all structures, coded into the CARM operating system

7.3.5 CARM training systems are in place

- Ensure current management arrangements in place, executed and evaluated using the Evaluation Framework.
- CARM modelling runs do not assume improved operator skill is required for:
    - Improved hydraulic routing;
    - Optimisation of re-regulating storages;
    - Groundwater flux forecasting;

8 Costs, Benefits and Funding Arrangements

8.1 Total cost of the project

The Murrumbidgee CARM project is a component of a larger suite of works undertaken in the valley which included a range of water savings projects which could be classed as works and measures.

All capital costs have already been funded by the Joint Government Enterprise (Water for Rivers) as part of the Snowy Initiative.

[redacted]

These costs are estimated to be approximately $8.2 million in 2015-16 dollars.

8.2 Co-contributions

No further funding contributions are required.

8.3 Ongoing operation and maintenance costs

Annual on-going operational and maintenance costs for the system are assessed as part of WaterNSW's on-going pricing and tariff review for the operation of the Murrumbidgee system. These costs are paid for annually by all licenced water users.

The ongoing costs of the general security entitlement from water charges will be subject to NSW Independent Pricing And Regulatory Tribunal(IPART) determinations. The current charges for general security entitlements are a combination of fixed charges (proportional to the entitlement), and variable charges (proportional to the volume of water used each year).

These charges will form part of the ongoing costs for environmental works and measures proposed through supply measures more broadly and there are likely to be benefits in considering governance and cost sharing across the SDL adjustment process on a collective basis.

8.4 Expected environmental, social and economic costs and benefits

8.4.1 Methodology

Benefit cost analysis is a technique commonly used to appraise public investments to determine whether they represent an efficient use of resources from society's point of view. It requires inclusion of both the private and public costs and benefits (e.g. environmental costs and benefits) of a project.

The BCA methodology applied in this study follows the standard approach to BCA set out in the Commonwealth Government's *Handbook of Cost Benefit Analysis*[15]

A critical element of any BCA is measuring the difference between the base case (i.e. the 'without project' scenario) and the 'with project' scenario. The difference between the base case and the 'with project' scenario represents the net benefit of the project.

The net benefit of a project is the difference between the base case and the 'with project' scenario. It can be expressed as a net present value (NPV) or a benefit cost ratio (BCR).

The NPV is defined as the present value of the benefits (PV Benefits) of a project minus the present value of the costs (PV Costs). It can be expressed algebraically as follows:

$$NPV = PV\ (Benefits) - PV\ (Costs)$$

In a BCA a project is deemed economically justified if the NPV is positive.

The BCR is defined as the present value of the benefits divided by the present value of the costs. It can be expressed algebraically as follows:

$$BCR = PV\ (Benefits)/PV\ (Costs)$$

Under the BCR decision rule a project is economically justified if the BCR is greater than one.

8.4.2 Quantifiable Benefits

There are three broad benefits that are quantifiable,

- A reduction in operating surplus
- Improved flood mitigation
- Maximisation of environmental benefits

An approach to estimating the value of the benefits is to examine the alternative strategy without the measure. This involves assessing similar outcome by entitlement purchase. The steps involved ae:

- Assessment of equivalent volume of water in terms of SDLs
- Estimation of entitlements purchased

[15] Commonwealth of Australia (2006). *Handbook of Cost Benefit Analysis*, Canberra, January.

- Quantification of costs of purchase

A 'market value' is commonly defined as the price that would be negotiated between a knowledgeable and willing but not anxious buyer and a knowledgeable and willing but not anxious seller acting at arms-length within a reasonable time frame. In general and all other things being equal:

- prices will be higher in regions where the entitlement holders expect a greater return on invested capital compared to those regions with a lesser return on invested capital;
- prices for entitlements with higher reliability will be higher than those for entitlements with a lower reliability;
- prices for entitlements that are allowed to carry-over will be higher than entitlements that cannot defer or defer less use from year to year; and
- prices for entitlements that are legally secure will be higher than entitlements without that legal security.

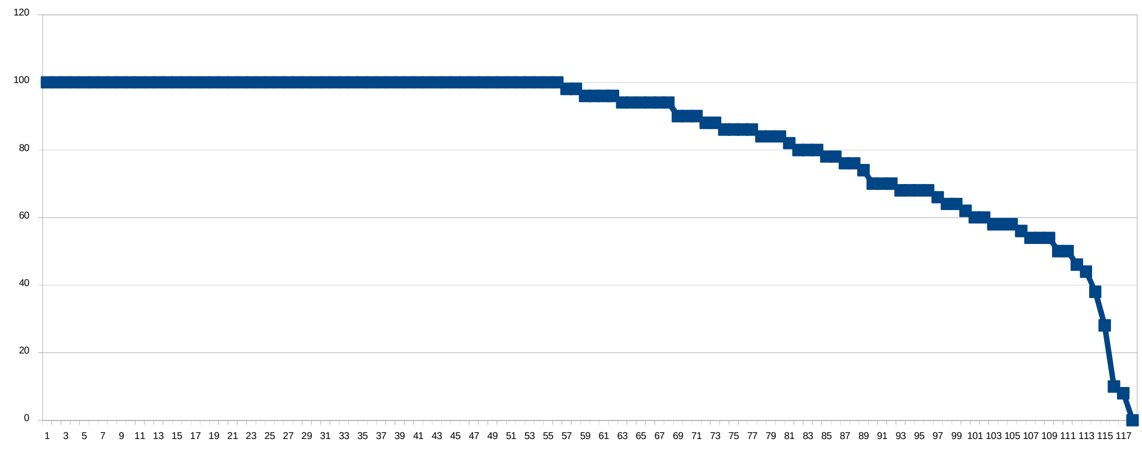
When considering value, the entitlements that are most relevant are Murrumbidgee general security entitlements. The expected reliability of a licence is the critical driver of value.

Water source: Murrumbidgee Regulated River Water Source

Entitlement Description: Murrumbidgee General security entitlement

In the Murrumbidgee valley, at the commencement of the water sharing plan, 2,043,432 shares of General Security Water Access Licence were issued to general security licence holders. This accounted for approximately 69% of all extractive shares in the water source.

Figure 10 Reliability of Murrumbidgee General security entitlement



Note: Effective allocation at end of Water Year (1 June)

In the past few years the value of general security water access entitlements has been between $960 per ML to $1,280 per ML.

The valuation is dependent on the creation of a general security WAL. The key assumptions are a ratio of WAL yields of approximately 57.62%. The estimates market value of the water savings is $40.3 million.

Table 10 Murrumbidgee NPV and BCR

	Estimate	Comment
Costs	$8.2 million	Based on project costs provided by WaterNSW.
Benefit	$40.3 million	Based on 42,000 ML of GS entitlement. The final benefit will depend on the SDL Adjustment using a value of $1,900 / ML of adjustment
BCR	4.93	

It should be noted that this does not include the benefits of more efficient environmental watering and other benefits regards transparency and communication with customers including the utility benefits of improved constraints management and optimisation of any future Commonwealth measures for the Murrumbidgee using the hydrodynamic model.

9 Project Governance and Project Management Arrangements

9.1 Stakeholder Management Strategy

9.1.1 Stakeholders

All agencies materially affected by the proposal have been consulted in the development of this business case. These agencies include:

- Murray-Darling Basin Authority
- DPI Water (formerly NSW Office of Water)
- Office of Environment and Heritage (NSW)
- Department of Environment (Commonwealth)
- Department of Environment, Water and Natural Resources (SA)
- Murrumbidgee Local land Services
- Murrumbidgee CSC
- NSW Irrigators Council
- RAMROC (Riverina and Murray Regional Organisation of Councils)

The Murrumbidgee Customer Service Committee:

- is made up of a number of representatives nominated by organisations or other customers in their valley;
- exchanges information with WaterNSW so that a positive, constructive and efficient service provider/customer relationship can be maintained; and
- meet quarterly at Leeton to discuss operational and asset management issues including water pricing

Membership includes representation of: Irrigation schemes/corporations; Industry; NSW Office of Environment and Heritage; Regulated, unregulated, groundwater and stock & domestic customers; Commonwealth Environmental Water Holder; and Local Government.

The Murrumbidgee Customer Service Committee (CSC) is the peak body representing the interests of the range of water users and agencies along the Murrumbidgee (Table 11). The individual members often represent not only their own Individual interests but also the concerns of peak bodies.

[redacted]

Presentations have been provided to numerous meetings within the Customer Service Committee over 5 years.

- environmental users.

9.1.2 Engagement and communication strategy

An engagement and communication strategy has been developed for the next phase of the project which relates primarily to the creation of an appropriate water account(s) and presentation of this project through continuing direct engagement with key stakeholders and technical presentation of the modelling review to some key parties.

The CARM program has been developed and implemented over the last five years using the following engagement strategy consistent with the technical roll out of the project:

1. Initial consultation with project sponsors to determine key project components.
    - Interviews with key project stakeholders
    - Workshops (Leadership Contexting)
    - Project briefings
    - Review background documentation
    - Review other water projects in Victoria and NSW
2. Confirm the communications strategy and an engagement strategy for the project and confirm with project partners.
    - Identify key stakeholders and stakeholder groups
    - Develop and confirm key project messages
    - Identify how we launch the project
    - Develop project schedule across each river valley
    - Define links if any with each river valley for the project
    - Identify potential sources of resistance (issues management plan)

- Confirm what materials will work best with each audience
- Identify project champions
- Identify and allocate resources needed to deliver this plan
- Confirm 'delivery' strategy and reporting lines
- Determine project milestones
- Develop monitoring and evaluation plan and confirm. What information needs to be collected progressively
- Develop case studies to aid engagement

3. Develop communications materials and install on-the-ground engagement resources.
   - Design materials
   - Employ, train and resource on ground campaign/liaison staff
   - Workshop and 'embrace' State Water Corporation's Customer Field Officers
   - Produce and distribute materials
4. Begin implementation of communications plan
   - Implement media plan (preconditioning)
   - Officially launch project in each valley
   - Monitor delivery of project milestones across the project schedule and valleys
5. Monitor and report on project delivery to key project stakeholders via agreed project reporting mechanism.
   - Implement the monitoring and evaluation plan and commence data collection
   - Periodic reporting as agreed
   - Project debriefing and monitoring and evaluation review
   - Review overall project outcomes, what worked and what did not
   - Review monitoring and evaluation data
   - Summary overview.

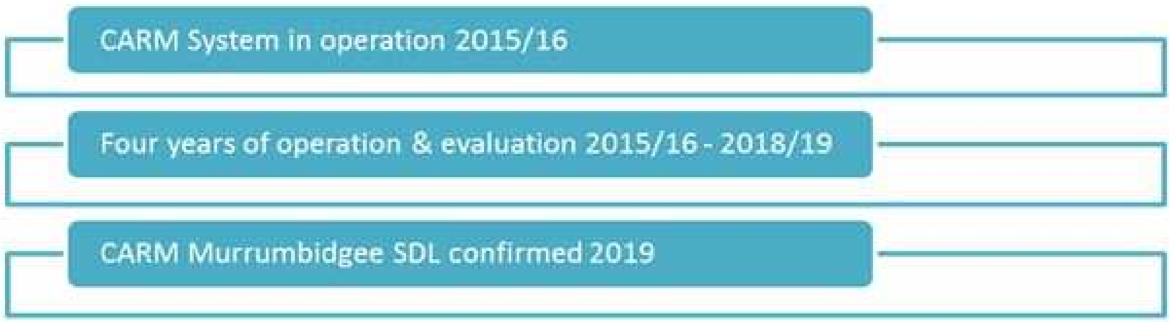
9.2 Legal and Regulatory Requirements

9.2.1 Legislative and policy amendments required

The Murrumbidgee CARM SDL Adjustment will come into effect in 2019 after the operation of CARM for the 2015/16, 16/17, 17/18 and 2018/19 water years, with evaluation of the measure using the WaterNSW CARM evaluation framework, to measure and verify for performance of the system.

The accounts to be created will be established through issue of appropriate shares of entitlement in the regulated Murrumbidgee Valley, and through amendment of the Water Sharing Plan for the Murrumbidgee Regulated River Water Source.

Figure 11 Timeline of CARM implementation



The MDBA will undertake a reconciliation of adjustments prior to 2024 to determine whether CARM has achieved a different result to that determined at 2016. If the model assumptions used in 2016 are found to have been too conservative (as expected) then the SDL Adjustment will be increased, or conversely reduced if CARM has not achieved the estimated improvements in River Operator performance.

9.2.2 Cultural heritage assessment

No cultural heritage assessment was required.

9.2.3 Required inter-jurisdictional agreements

No agreements are required

9.3 Governance and Project Management

9.3.1 Project management structure and team

This introduction of CARM was managed and implemented by WaterNSW.

9.3.2 Procurement strategy

The procurement strategy has been completed and there is no further major procurement required.

9.3.3 Monitoring and reporting during implementation

See section 5.4 above.

9.3.4 Design and implementation plan and timelines

Not applicable

9.4 Risk Assessment of Project Development and Delivery

9.4.1 Design risks

Not applicable

9.4.2 Risks to project completion on time

Not applicable

9.4.3 Risk of project failure

Not applicable

9.4.4 Delivery of the project within budget

Not applicable

10 References

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Appendix 1 - Summary of response to the Phase 2 Assessment Guidelines

This section confirms how this business case delivers against each of the relevant requirements of the SDLAAC Stage 2 Guidelines. The following table lists the requirements and then records where the issue is dealt with in this business case.

Table 12 Concordance - Stage 2 Guidelines and Business Case

Guidelines Section	Heading	Requirement	Business Case Section
3.1	Supply measure definition	Defines the requirements for supply measures to: • operate to increase the quantity of water • achieve equivalent environmental outcomes with a lower volume of water • have no detrimental impacts	1.2
3.3	Operational by June 2024	The measure must be capable of entering into operation by 30 June 2024	9.3
4.1	Project details	Key project details and overview	1
4.2	Ecological values of the site	Description of the ecological values of the site	2.1
4.3	Ecological objectives and targets	Confirm objectives and targets	2.2
4.4.1	Anticipated ecological benefits	proposed outcomes from the investment	2.4
4.4.2	Potential adverse ecological impacts	Assessment of potential adverse impacts	2.5
4.5.1	Current hydrology and proposed changes	Clear articulation of current and proposed hydrology	3.1
4.5.2	Environmental water requirements	Water requirements of new inundated areas	3.2
4.6	Operating regime	Explanation of the role of each operating scenario	4
4.7	Risks and impacts from operation	Assessment of risks and mitigation options	5
4.8	Technical feasibility	Evidence that the project infrastructure is technically feasible	6
4.9	Interdependencies	Confirm interaction with other initiatives	7
4.10.1	Costs and benefits	detailed costing and listing of benefits	8
4.11.1	Stakeholder management strategy	Stakeholder management strategy	9.1

4.11.2	Legal and regulatory requirements	Legal and regulatory requirements	9.2
4.11.3	Governance and project management	Governance and project management	9.3
4.11.4	Risks from project development and delivery	Risks from project development and delivery	9.4

Appendix 2 - Murrumbidgee CARM Project - Risk Assessment

Item #	Risk Category	Risk Description (Aspect)	The situation or sequence of events that causes the risk to crystallise, AND the associated consequence resulting in the risk event having occurred Risk Event (Impact)	Inherent Consequence	Inherent Likelihood	Inherent Risk Rating	Current Controls		Residual Consequence	Residual Likelihood	Residual Risk Rating	Proposed Controls	Target Consequence	Target Likelihood	Target Risk Rating
1	**Project Delivery**	*CARM system doesn't deliver modelled operational assumptions by 2019*	The CARM system design does not deliver Murrumbidgee river valley (modelled) operational assumptions, Operational Surplus (OS) and river operators do not use with confidence the CARM operating tools	Major	Unlikely	Medium	Conservative assumptions used to assess benefits of CARM system models; Vendor capability and procurement process; Use of established world wide commercial products; MER framework developed for 2015/16 water year implementation	4	Major	Unlikely	Medium	Rigorous system operating protocols, continued testing and model QA assessment, verification and evaluation; Operation reflects design specification; Continued River operator training; the CARM model runs have NOT assumed that the CARM operator has perfect skill; the CARM model runs have assumed a conservative increase in operator skill in: Forcasting tribs; Forecasting demands and rainfall rejections and Operation of the Yanco Ck system; set UTS MER targets higher than modelled assumptions demonstrating exceedance of assumptions by 2019	Moderate	Rare	Low
2	**Legal and Landholder**	*Murrumbidgee Valley support for CARM system*	Murrumbidgee valley landholders don't support CARM nor recognise the project can produce (an operational surplus) an approved SDL offset under the MDBA Plan and the Water Act 2007	Major	Possible	High	Review and conservative assessment of river operations and modelling analysis to demonstrate benefits of daily CARM river operations, active engagement of key stakeholders/Customer Service Committee, Developed the Institute for Sustainable Futures CARM Evaluation Framework key performance outcomes to report/demonstrate system benefits and improved operation	4	Major	Possible	High	Successful implementation of Murrumbidgee CARM computing technology with demonstrated achievements; Implementation of UTS (Institute for Sustainable Futures) MER Framework; Continued reporting to key stakeholders (internal & external) through stakeholder engagement strategy since 2015/16 water year;	Moderate	Possible	Medium
3	**Legal and Landholder**	*Irrigator current WSP rights not protected*	Irrigator reliability and current accepted river operating rules are compromised and impacted	Major	Possible	High	Review of IQQM modelling undertaken based on entitlement rights protected under State Act and Water Sharing Plan	3	Moderate	Possible	Medium	Implement recommended changes (conservative assumptions) to the IQQM modelling; External peer review; Ongoing engagement of Water Operations personnel; NOW and external SDL modelling Peer Review of assumptions; CARM system coding of all structure operating requirements fully implemented	Negligible	Unlikely	Low
4	**Cumulative impacts**	*CARM system design failure*	The CARM operating system and project design does not deliver demonstrable improved river environmental management outcomes	Major	Possible	High	CARM Murrumbidgee in full production and demonstrating effective hydraulic routing with improved flow management	4	Major	Possible	High	Murrumbidgee CARM operating system (hydraulic system, data management and modelling requirements) QA system implemented, verified and performance review; Maximise use of scenario planning and forecasting linked to improved catchment measurement and monitoring	Minor	Unlikely	Low
5	**Environment Ecological**	*Protection and recognition of existing river services*	Plans to develop an optimal river control system fail to recognise existing river operating arrangements which exist to mitigate third party impacts, both in stream and end of system	Moderate	Possible	Medium	Compliance with NSW Water Sharing Plans, environmental and Basin flow requirements	3	Moderate	Rare	Low	Continued compliance with WSP's and river environmental flow requirements, and evaluation of OS benefits, including clear operating protocols for all structures, coded into the CARM operating system	Minor	Rare	Low
6	**Operation and maintenance**	*CARM HR training systems are in place*	Adequate training and skill(s) development of staff isnt provided to ensure 'in house' expertise and confidence to successfully operate the CARM system	Moderate	Possible	Medium	Project management requires CARM river operations training with the transition to the CARM system; HR resourcing reviewed to ensure adequate skilled staff resources transitioning from CAIRO to CARM;	2	Minor	Unlikely	Low	Ensure current management arrangments in place, executed and evaluated using the Evaluation Framework; CARM modelling runs do not assume improved operator skill is required for: Improved hydraulic routing; Optimisation of re-reg storages; Accurate metering; Metering telemetry; Groundwater flux forecasting; 24/7 operations rather than once per day; Precise delivery of challenging Env orders (piggy-back etc) achieving targets with minimum release; minimising overbank flooding	Negligible	Rare	Low

Appendix 3: Operating Scenarios

CARM Dashboard

The CARM river operation system collates data from multiple sources, and the hydrodynamic model uses the data to present the information to enable River operators to make informed daily flow management decisions as well as running future river planning scenarios to optimise resource availability and meet customer orders.

CARM, linked to SCADA system inputs, can provide optimised flow and level information for automation of gates, valves and regulators.

CARM gathers, collates and processes many data sets – weather, water orders, actual extraction, real time catchment rainfall, river hydraulic and converts this data into real time and modelled information.

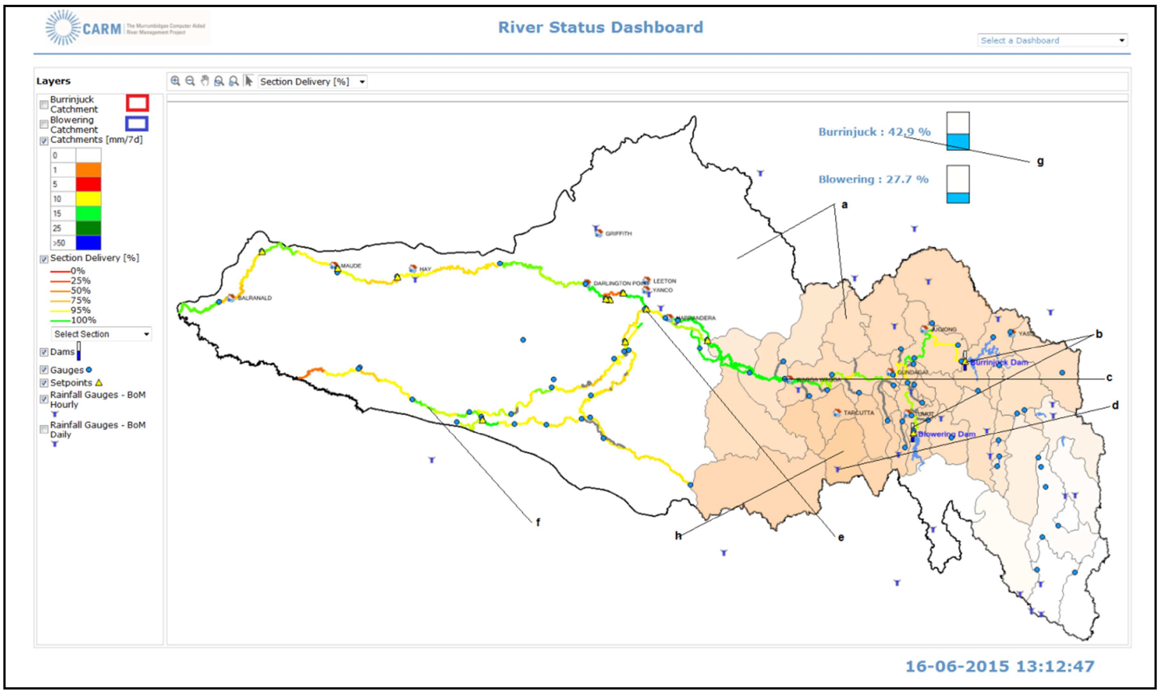
This information is in graphical and tabular form previously not readily available to the river operator using the CAIRO manual spreadsheet system.

The CARM information is made available to the river operator through a series of dashboards.

Using the “dashboard manager” CARM provides an easy, fast and flexible way of creating customised web pages for advanced presentation of scientific, water resource data and allows the setup and maintenance of web pages showing live data feeds of the entire river system as well as modelling results for forward planning of storage releases, active management of river constraints and meeting Basin Plan prerequisite policy measure requirements i.e. shepherding of water.

The following are examples of the dashboards and data displays presented by the Murrumbidgee CARM system

This dashboard is GIS (Geographical Information System) based and provides a real time schematic overview of the river system and also on a river reach basis.

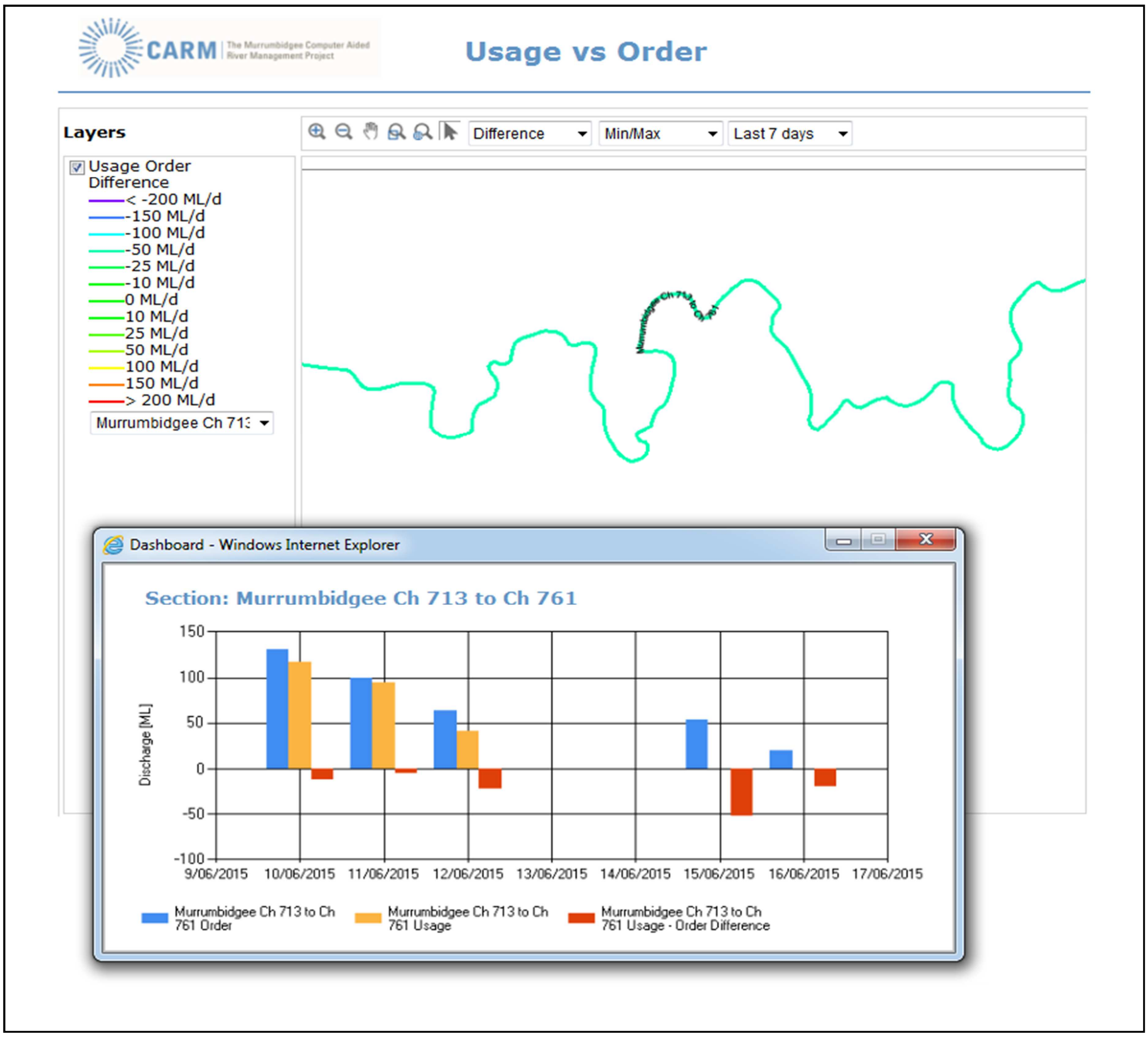


Ordering

Water is released from dams to meet customer orders. The time of travel (lag time) from dam to the customer extraction point can be many days – in excess of days lag time at the lower end of the system. Based on the weather conditions and accuracy of the original order release, there is often an imbalance between demand and water available in transit. This can result in an 'excess or deficit' of available water to meet customer demand.

This dashboard compares the orders and usage at any given section of the river. By selecting a section, the river operator can view the orders, usage and the differences between the orders and the usage for that particular river section.

An important part of the CARM Murrumbidgee implementation was the installation of meters – compliant to national standards, with telemetry, that report extraction in near real time.

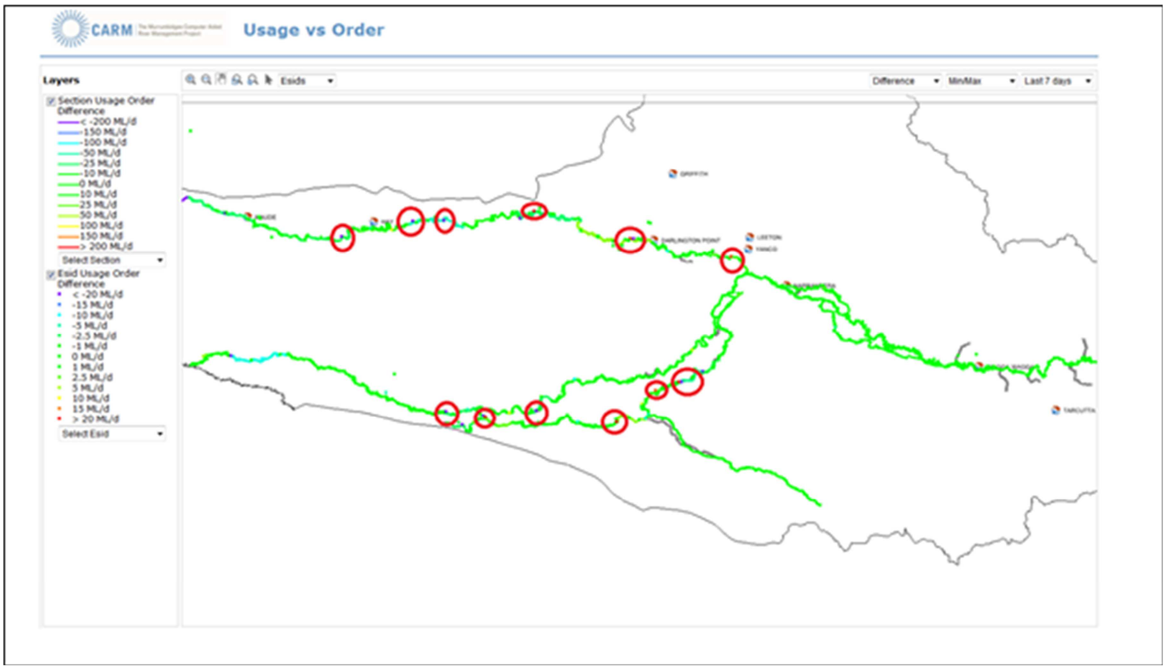


This dashboard plot indicates the orders and usage difference (negative) in the section Murrumbidgee Ch 713 to Ch 761, ie. more water has been pre-ordered than extracted. This could be due to a rainfall event, or a poor ordering regime in this section.

Information on order versus extraction can show that more water was ordered than actually extracted. It would appear that a 'bulk order' was made by a customer -5 ML per day, and the customer extracted water as and when needed. Over a long period the volume ordered and the amount extracted may match reasonably well, but this non-compliance with expected orders makes river operation very difficult. Showing customers these plots helps to educate them as to the impact of their ordering behaviour and the opportunities to improve system efficiency.

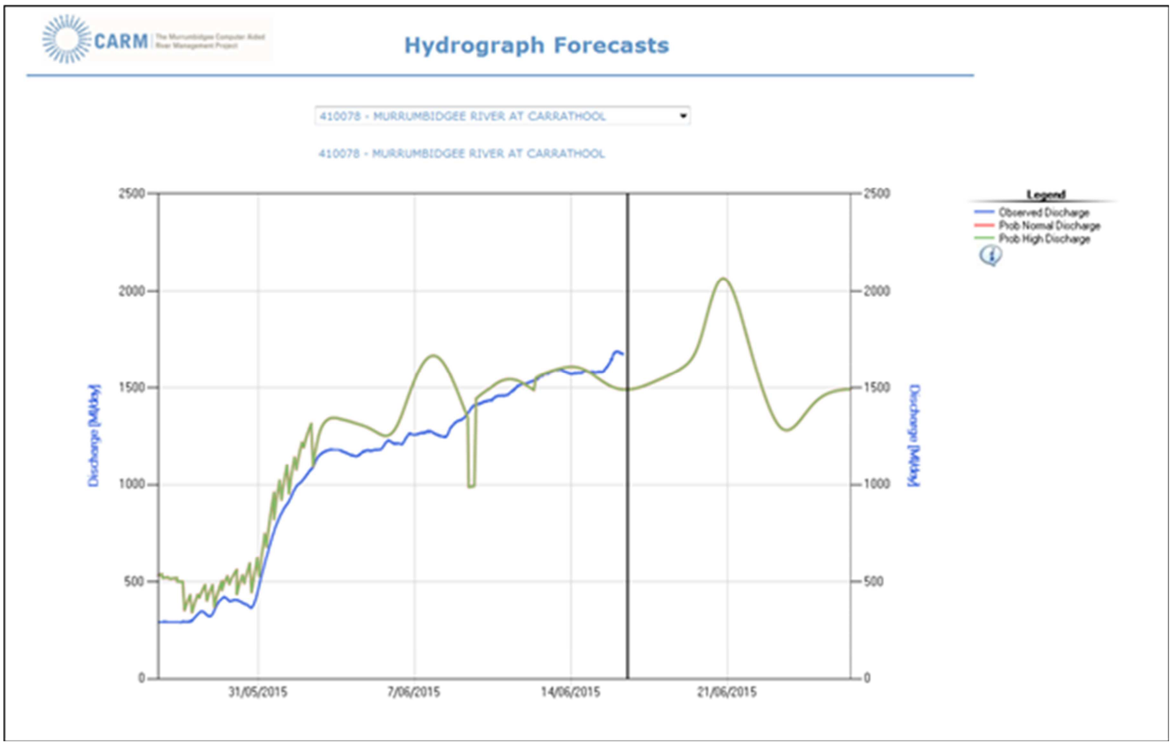
Usage Vs Orders – Individual Extractor Level

The River operator is also able to examine extraction versus order behaviour at the individual level. The extraction points are colour coded to easily identify the extractor non-compliant with orders.



Hydrograph Forecast

An important function of CARM is to be able to forecast downstream river flows. The forecast takes into account, future extraction (orders), tributary inflows (based on Rainfall forecast), time of travel and river hydrodynamics. The hydrodynamic forecast tools will also enable proactive river reach management for improved channel capacity management and to manage (minimise) over bank flows when not required.


CARM
Hydrograph Forecasts
410078 - MURRUMBIDGEE RIVER AT CARRATHOOL
410078 - MURRUMBIDGEE RIVER AT CARRATHOOL
Discharge [Ml/day]
2500
2000
1500
1000
500
0
31/05/2015
7/06/2015
14/06/2015
21/06/2015
Legend
Observed Discharge
Prob Normal Discharge
Prob High Discharge

Murrumbidgee SDLA – Update of Benchmark model

1 Benchmark model revisions

This report describes:

- additional work to update the Benchmark model to include more detailed representation of hydrological and operational processes for the Yanco Creek system that are necessary to assess the Yanco modernisation proposal, and
- a final summary of the model enhancements to represent all of the Water for Rivers projects in the Murrumbidgee Valley previously described in *Murrumbidgee CARM Sustainable Diversion Limit Adjustment Modelling – Business Case* (DHI 2015) report prepared during development of the business case.

This work includes some minor additional enhancements to the representation of the Water for Rivers projects.

Some amendments to the MDBA Benchmark model are necessary to allow detailed assessment of proposed Murrumbidgee supply measure proposals. The MDBA Benchmark model took account of Water for Rivers pre-2009 projects by post-processing results, and it is proposed to adapt the Benchmark model to represent these projects directly. Furthermore, some hydrological and operational processes have been updated or extended in the Murrumbidgee IQQM to provide a robust assessment of the post-2009 Water for Rivers projects, and it is proposed that these model enhancements be included in the Benchmark model, together with representation of these later projects.. This work is described in more detail in “Murrumbidgee CARM Sustainable Diversion Limit Adjustment Modelling – Business Case” report prepared during development of the business case.

The changes to the models are summarised in the sections below. They are also show in flowchart form in Figure 1. This figure shows the relationship between the various models, and what information or alterations are used to produce each model.

2 Water for Rivers projects prior to 2009

The Water for Rivers projects carried out prior to 2009 not included in the MDBA Benchmark IQQM model include:

- Purchase of general security licence from the valley of 40,400 unit shares (prior to 2009)
- On-farm reconfiguration projects yielding 21,500 general security unit shares
- Coleambally Irrigation Area works, yielding 3,500 unit shares of Coleambally Irrigation Area conveyance licence
- Barren Box Swamp works, yielding 20,000 unit shares of Murrumbidgee Irrigation Area conveyance licence
- Hay PID works, yielding 1,000 ML/yr of conveyance licence
- Forest Creek removal of Warriston Weir minimum flow requirement of 100 ML/d, yielding 34,700 general security unit shares

The licences associated with these projects were redistributed in the model, from the irrigation corporation bulk offtake or the reach scale irrigation nodes to a water savings node (dummy irrigator) just downstream of Blowering Dam.

General Security licences
Of the total 61,900 general security unit shares (40,400 unit shares purchase and 21,500 unit shares on-farm reconfiguration), 32,000 unit shares was taken from the Coleambally Irrigation Area bulk licence, 7,500 unit shares from Forest Creek irrigators, and the remainder of 22,400 unit shares was taken uniformly from all other river pumpers (excluding the Murrumbidgee Irrigation bulk licence). The total of 61,900 unit share general security licence was then added as a dummy irrigator node immediately downstream of Blowering Dam, to avoid re-allocation of this water.

Murrumbidgee Irrigation and Coleambally Irrigation conveyance
This was removed from the allocation – additional volume table in the bulk irrigator (3.4) node. The volume provided by the conveyance licence to be removed was calculated for each row in the table, and the table volume decreased accordingly. A new dummy irrigator node with equivalent allocation – volume was then added immediately downstream of Blowering Dam to avoid re-allocation of this water.

Hay PID conveyance
This conveyance of 1,000 ML/yr was removed from the bulk irrigator node allocation – volume table, across all entries (i.e. constant allocation). This water was added to the dummy re-allocation node downstream of Blowering Dam used for the MI and CI conveyance licences.

Forest Creek – Warriston Weir
The MDBA Benchmark model has the 100 ML/d Warriston Weir minimum flow requirement already removed. For this reason the 34,700 general security unit shares produced by this measure are not included in the revised Benchmark model.

The redistribution of licences is outlined fully in Appendix A. The tables in Appendix A include:

- The calculation of the licence to be removed from the irrigation or bulk supply nodes, for general security and conveyance licence types
- The revised licences after the WFR licence is removed
- The revised irrigation areas (reduced using a similar approach used by the MDBA when decreasing licensed entitlement to represent water recovery from the Water Sharing Plan scenario to the Benchmark scenario)

3 Adjustments to support representation of Murrumbidgee supply measure proposals

This section outlines the changes required to the Benchmark model to allow a robust evaluation of the effect of the Murrumbidgee supply measure proposals.

3.1 Water for Rivers projects post 2009 (tripartite projects)

The post 2009 WFR projects are referred to here as the tripartite projects, as they were developed under an agreement between the NSW Office of Water, State Water and Water for Rivers.

Modelling the changes due to the tripartite projects requires improving the model's representation of some physical processes that have previously been lumped together, such as transmission losses across several smaller river reaches. For example, the Wilson Anabranch project involves construction of a regulator on the Wilson Anabranch on lower Yanco Creek, in order to reduce losses during regulated flow periods. In the

MDBA Benchmark model (and the Water Sharing Plan model), the losses caused by the pre-project Wilson Anabranch are not separately represented in the model. If this unadjusted model was used as the benchmark, the post-project model would show no reduction in losses compared to this benchmark. To more accurately calculate the change from the project, losses in the anabranch first have to be represented.

The tripartite projects requiring adjustments to the MDBA Benchmark to allow more accurate representation of their impact are:

- Wilson Anabranch and associated losses
- Beavers Creek existing offtake structure, and losses and return flows on the Beavers / Old Man Creek system
- Augmented supply via Irrigation Corporations:
    - Coleambally Irrigation Area escape drain operation and historical loss provision, and
    - Murray Irrigation Finley Escape drain operation,
- Oak and Gras Innes Wetland losses on Bundidgerry Creek
- Tributary utilisation for regulated orders (for CARM)
- Yanco Offtake operation (for CARM)
- Rainfall rejection from Murrumbidgee Irrigation (for CARM)

The changes to the Benchmark model are summarised in Table 1. These changes are described in more detail in DHI 2015.

Some further work has also been undertaken to implement associated changes to key parameters (relating to irrigated crop areas) at irrigation nodes where entitlement has been recovered through (pre and post 2009) Water for Rivers projects. An approach similar to that used to “recover” entitlement from irrigation nodes in the Benchmark model (representing implementation of the Basin Plan) has been adopted.

3.2 Yanco Colombo Billabong modernisation project

Projects that produce water savings due to reduced transmission losses are sensitive to the loss functions in IQQM. They are sensitive to both the magnitude of the loss, but also the change in loss resulting from a change in flow.

The calibration in the 2005 and 2007 versions of the Water Sharing Plan models uses very flat flow – loss curves to simulate transmission losses in Yanco Colombo Billabong Creeks (i.e. the loss is the same even if the flow doubles). This means any long term reduction in flow through the creek system through efficiency or using irrigation corporation escapes produces little simulated benefit.

DPI Water have recalibrated the loss functions in the Yanco Colombo Billabong system to produce updated functions and new residual catchment inflow time series. The updated loss functions provide a better representation of observed behaviour and are more sensitive to change in flow. This, in turn, produces a more realistic transmission loss assessment.

3.3 Yanco Offtake

No changes to the Benchmark model are understood to be required for the Yanco Regulator supply measure proposal.

3.4 Nimmie Caira and Yanga National Park projects

No changes to the Benchmark model are understood to be required for the Nimmie Caira and Yanga National Park supply measure proposals.

Table 1 Summary of Benchmark model changes to support SDLA project assessment

Project	Key changes
Beavers Creek regulator and high-river anabranch control structures	• Prevent model ordering extra water just to supply head at offtake if river is too low • New spill from river into "Old" Old Man Creek anabranch • New spill from Old Man Creek through Dog Fall Creek anabranch back to river • Split loss function Berembed to Yanco into Berembed – OMC return, OMC return to Yanco • Removal of variable Beavers offtake relationship (low level culvert was jammed) • Add Berry Jerry Forest floodplains • Update Old Man Creek transmission loss function • Add flow-dependent evaporation loss
Coleambally Irrigation Escape Drains	• Refinement of modelling prior to new agreement between State Water and CI that puts more orders through CI drains • Redistribution of orders to drains done on Yanco Creek near Morundah, rather than up at Offtake (avoids redistribution based on Colombo orders) • Added 10% loss provision through CI (State Water working agreement) • Review of historical redistribution patterns • Addition of CI winter shutdown into redistribution calculation
Wilson Anabranch	• Placement of regulator to prevent anabranch inflows during regulated flow periods • Opened during winter • Addition of: • Existing anabranch offtake relationship based on pipe rating • Anabranch pond into model: • Existing composite outflow based on spillway and outlet pipe capacity

Project	Key changes
	• Applied combined evaporation and seepage (1mm/day)

Bundidgerry Creek wetlands	• New regulators on small wetlands to exclude regulated flows during supply periods
	• Gras Innes wetland (just north of storage) and Oak Creek (south of Bundidgerry Creek, several km upstream of storage)
	• Open water evaporation loss modelling
	  • Based on Bundidgerry Storage level for Gras Innes
	  • Based on water level and creek flow rate for Oak Creek

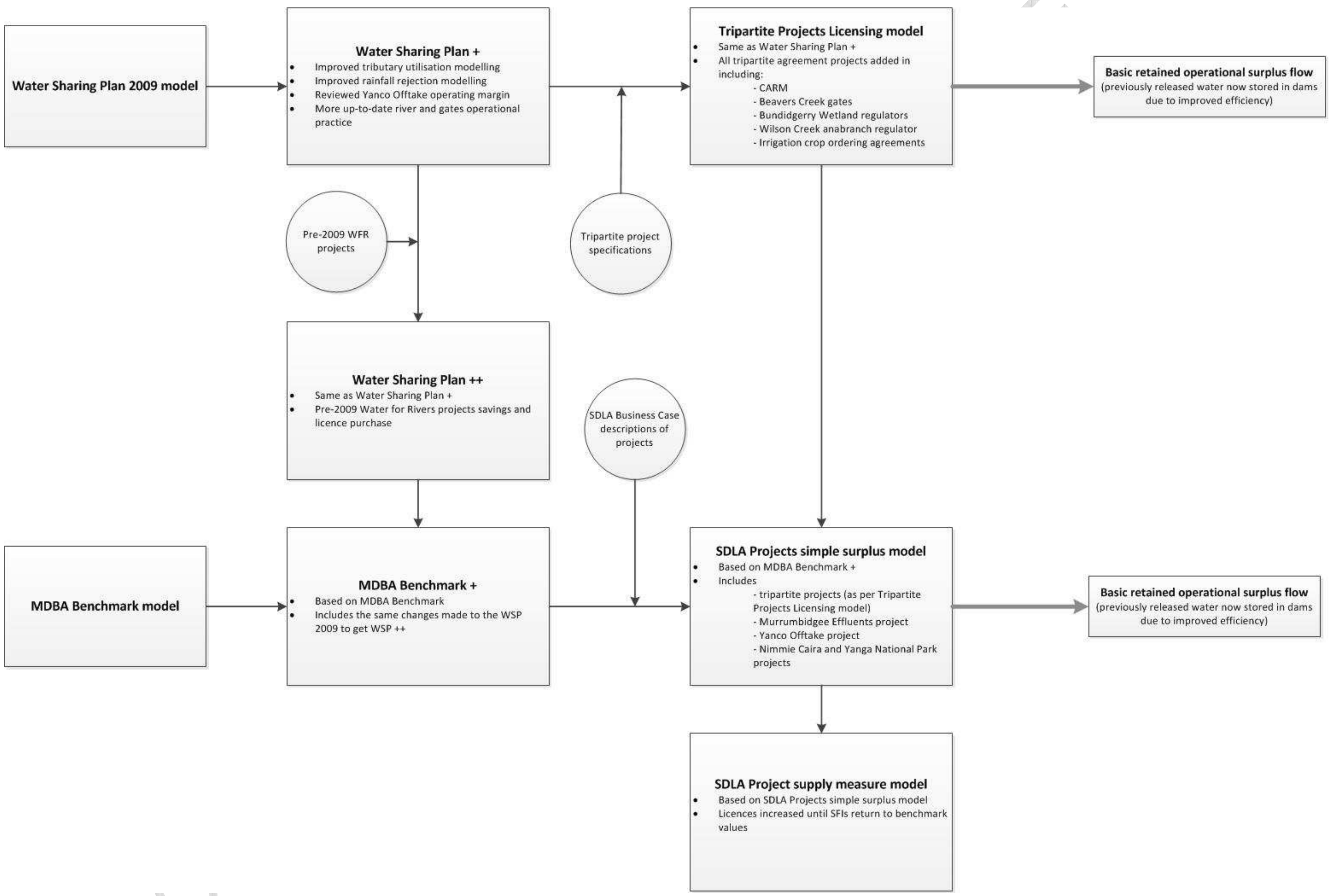
Finley Escape	• Refinement of modelling prior to new agreement between State Water and MIL • WSP model – average of 25GL/yr, repeating annual pattern • WFR project increases utilisation to an average 37GL/yr, depending on orders in lower Billabong (saving is ~2.6GL/yr) • Benchmark model updated with MSM-Bigmod flows from MI – average of ~50GL/yr • *Not adjusted from MDBA Benchmark model*

CARM	• Benchmark adjusted to allow modelling of the impact of three processes (see Appendix 2 for more information on these changes):
	  • Tributary utilisation
	  • Rainfall rejection
	  • Yanco Offtake order margin
	• Potential other changes such as improved monitoring and hydraulic routing too difficult to include directly

Yanco Colombo Billabong transmission losses	• Update of loss functions • Addition of residual catchment inflow series

Project	Key changes
Yanco Offtake	• No changes required
Nimmie Caira and Yanga National Park	• No changes required

Figure 1 Flowchart showing model versions for Benchmark and Project models



4 Effect of Benchmark changes

After the changes to the benchmark model were made, long-term average diversions were calculated for each licence category. These are summarised in Table 2 for the Benchmark (BIDG) and the Adjusted Benchmark (GNX7).

The table gives the average annual volume diverted under each licence type, the total number of unit shares of that licence type, and the proportion of the 1 ML/unit share diverted.

Table 2 Average annual diversions for water years 1895 – 2008

Licence category	**Benchmark (BIDG)**	**Adjusted Benchmark (GNX7)**
	Volume (ML)	**Volume (ML)**
General security (**total**)	599910 (57.1% of 1051100 us)	602291 (57.4% of 1051100 us)
High security (irrigation)	349916 (98.0% of 356846 us)	349646 (98.0% of 356846 us)
Hay PID to be transferred to WFR	983 (98.3% of 1000 ML)	984 (98.4% of 1000 ML)
MI and CI Conveyance (irrigation)	367223 (98.5% of 373000 us)	342677 (98.0% of 349500)
MI and CI Conveyance (WFR projects)	-	23121 (98.4% of 23500)
MI and CI Conveyance (**total**)	367223 (98.5% of 373000)	365799 (98.1% of 373000)
Supplementary	72463 (36.5% of 198780)	72516 (36.5% of 198780 us)

Announced allocations on the 1st October (summer crop planting decision date) and 1st June (effectively end of water year allocation) are shown in Figure 2 and Figure 3 for the Benchmark and Adjusted Benchmark models. Effective allocations, which include carryover, are shown in Figure 4 and 5 for these dates.

The changes to the Adjusted Benchmark model have the apparent impact of reducing annual licence allocations, as shown in Figure 2 – Figure 5 below. This is despite average annual irrigation diversions staying the same. The primary reason for the change in allocation is the change in how tributary utilisations are modelled.

In the Benchmark model, utilisations are modelled using a fixed tributary recession factor – i.e. when working out how much tributary water will be available in 1-4 days to use to supply orders, the model takes todays flow and multiplies it by the factor to get the potential future reduction in order. In the Benchmark model a factor of 1.0 is applied in the tributary catchments between the dams and Gundagai, and value of 0.85 – 0.90 are applied between Gundagai and Wagga Wagga.

In the Benchmark this factor is applied irrespective of the tributary discharge magnitude or whether the tributary is rising or falling. As part of the evaluation of CARM for the Water for Rivers tripartite licence evaluation, past river operations worksheets were reviewed to understand what the level of utilisation had been in the past. This found that operators utilised a higher proportion of the tributary inflow at lower discharges and on the falling limb of the hydrograph. They used less of the inflow on the rising limb of the hydrograph, particularly for larger discharges. This information was used to derive relationships between potential tributary utilisation, discharge magnitude and whether the tributary was rising or falling (see Appendix A for these relationships).

These utilisation relationships are applied in the Adapted Benchmark model, instead of the constant tributary utilisation factors in the Benchmark model. As previous fixed utilisations were very high (1.0 upstream of Gundagai, 0.85-0.90 between Gundagai and Wagga Wagga), running the model with the new variable utilisations has reduced the use of tributaries to fill orders in the Adapted Benchmark model. This has led to the reduction in the apparent reduction in reliability in the model, as shown in Figure 2 – Figure 5.

Table 3 Average allocations on 1st October and 1st June

		Benchmark (BIDG)	**Adjusted Benchmark (GNX7)**
Announced allocation	1 October	56.8	54.9
	1 June	86.9	84.0
Effective allocation	1 October	79.1	74.5
	1 June	94.6	90.4

Figure 2 Announced allocation exceedance – 1st October

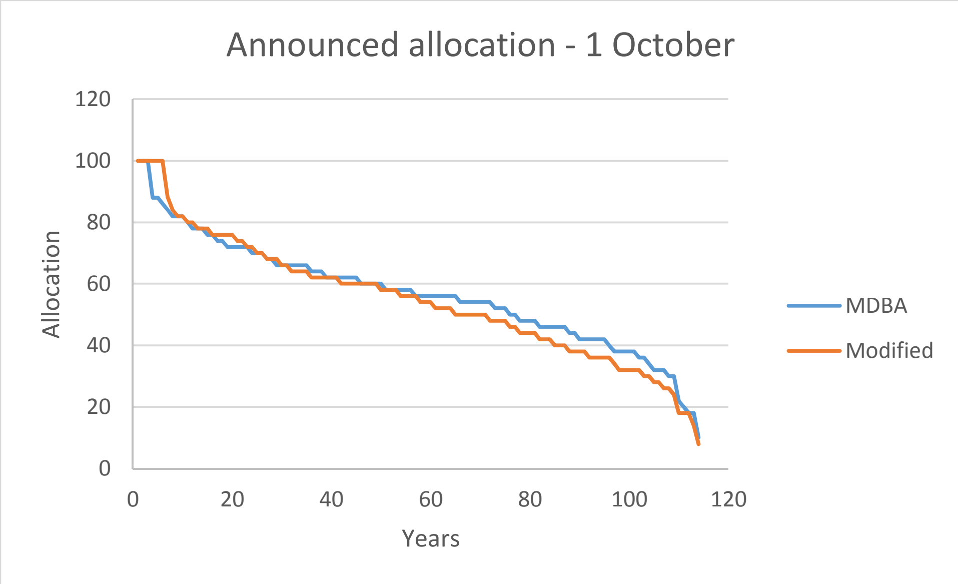


Figure 3 Announced allocation exceedance – 1st June

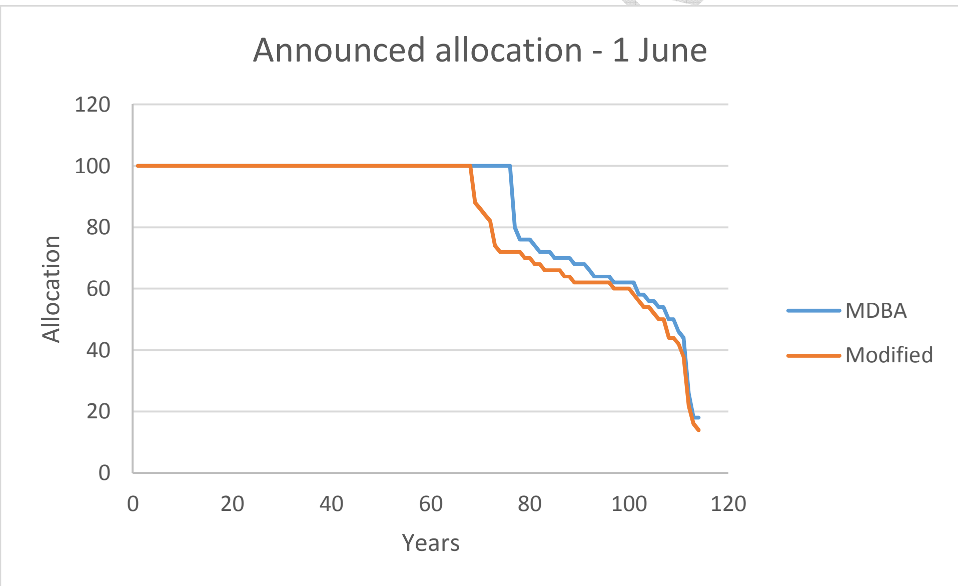


Figure 4 Effective allocation exceedance – 1st October

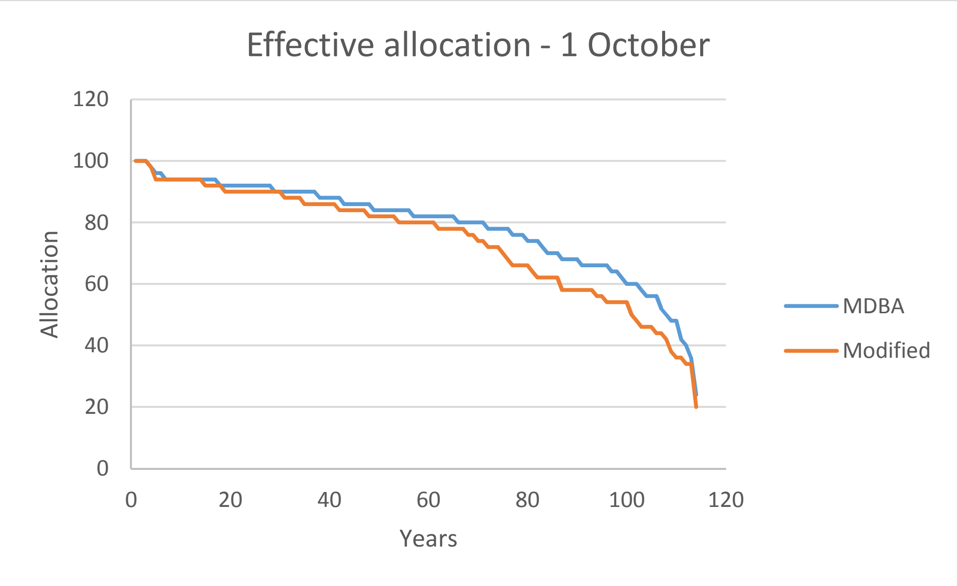
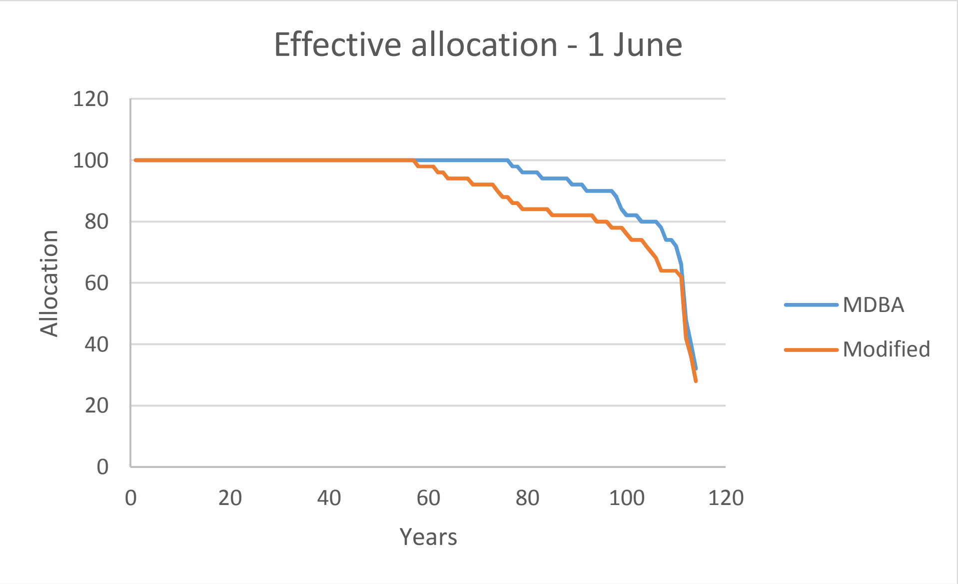
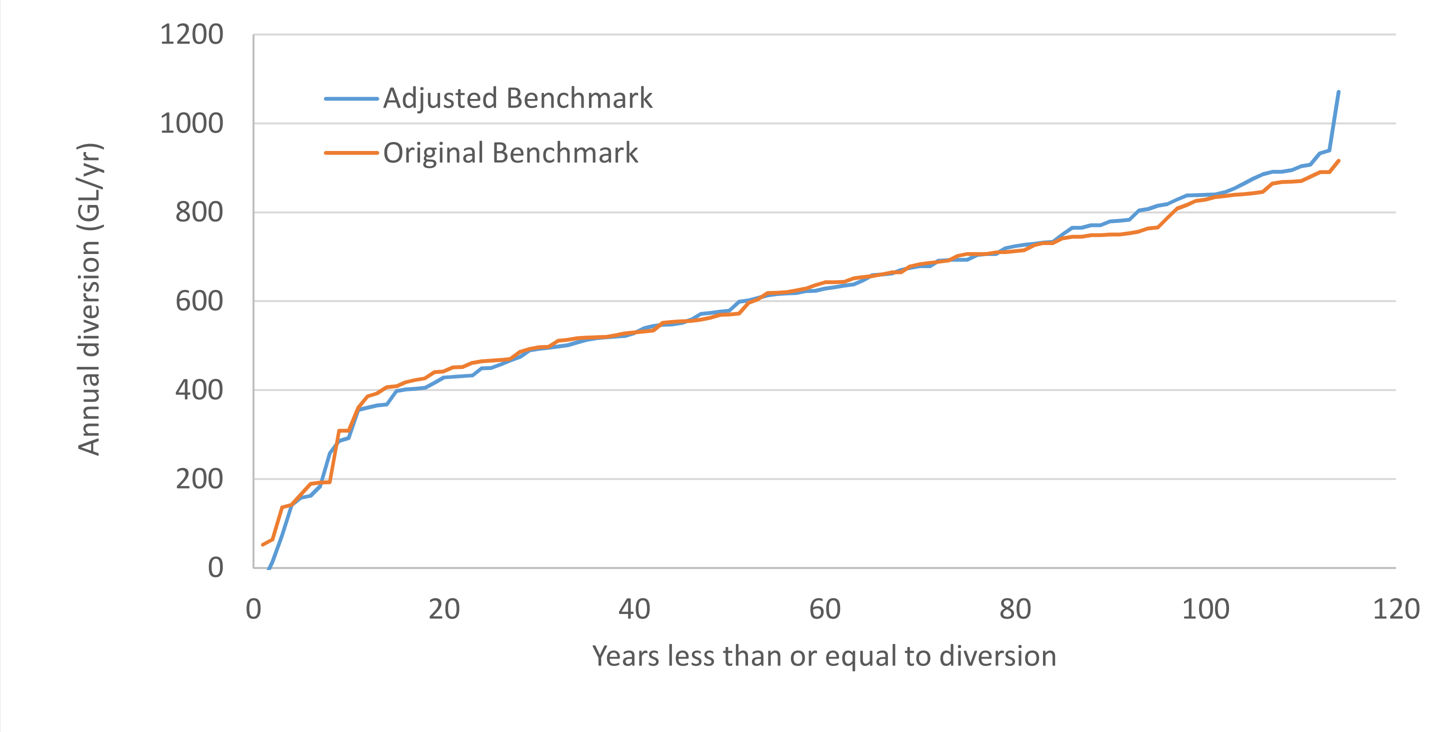


Figure 5 Effective allocation exceedance – 1st June



The effect on annual total diversions of general security diversions is shown in Figure 6. This plots the Benchmark annual GS for each year against its corresponding Adjusted Benchmark value.

Figure 6 Comparison of annual general security diversion volume in Benchmark and Adjusted Benchmark models



Appendix A – Pre-2009 licence redistribution

Table A1 Summary of pre-2009 Water for Rivers licence purchases (General Security)

GENERAL SECURITY

Licences to WFR pre-2009		
River Pumpers - purchase	40400	GS unit shares
On-farm reconfiguration	21500	GS unit shares
TOTAL GS CHANGE	61900	GS unit shares
Distribution of GS licence purchased / from reconfig		
Coleambally	32000	GS unit shares
Yanco Billabong and Forest Creek	7500	GS unit shares
Remainder to distribute to river pumpers (excl. MI)	22400	GS unit shares
Murrumbidgee River redistribution		
Licence to be removed across river pumpers	22400	GS unit shares
Total river pumpers excl YCB, Forest, CI and MI	411588.6	GS unit shares
Licence to be removed per unit share	0.054423	Per existing GS unit share
Yanco Billabong redistribution		
Licence to be removed across YCB	7500	GS unit shares
Total YCB licence	116052.2	GS unit shares
Licence to be removed per unit share	0.064626	Per existing GS unit share

Table A2 Summary of change to IQQM node licences for Water for Rivers pre-2009 licence redistribution (General Security)

Node (bulk 3.4 or non-bulk 8.0)	Upstream extent	Downstream extent	Original GS licence on bulk or non-bulk node	Updated GS licence on bulk or non-bulk node	Change in GS licence	Original area	Change in area	Updated area
328	Dams	Gundagai	14970.4	14155.7	-814.7	1261	-77.2	1183.8
525	Gundagai	Wagga	21626	20449.0	-1177.0	722	-111.5	610.5
340	Wagga	Beavers Off	8049	7610.9	-438.1	635	-41.5	593.5
344	MI Main Canal		341259.4656	341259.5	0.0			
342	Beavers Offtake	Berembed	12490	11810.3	-679.7	1063	-64.4	998.6
347	Berembed	OMC return	1419	1341.8	-77.2	416	-7.3	408.7
351	Beavers OMC		27161	25682.8	-1478.2	5093	-140.0	4953.0
356	OMC	Narrandera	6502	6148.1	-353.9	1072	-33.5	1038.5
359	Narrandera	Yanco Weir	6372.6	6025.8	-346.8	81		81.0
365	CI Main Canal		182199.8311	150199.8	-32000.0	38964	-3030.3	35933.7
366	MI Sturt Canal							
367	Yanco Weir	Gogeldrie	4367.5	4129.8	-237.7	242	-22.5	219.5
513	Gogeldrie	Darlington Point	30040	28405.1	-1634.9	3256	-154.8	3101.2
501	Darlington Point	Carrathool	75050	70965.5	-4084.5	12243	-386.8	11856.2
290	Carrathool	Hay	147420	139396.9	-8023.1	19357	-759.8	18597.2
294	Hay	Maude	25144.901	23776.4	-1368.5	13155.784	-129.6	13026.2
517	Maude	Redbank	15260	14429.5	-830.5	1002	-78.6	923.4
521	Redbank	Balranald	6398.225	6050.0	-348.2	1041.78	-33.0	1008.8
505	Balranald	Murray	9318	8810.9	-507.1	1270	-48.0	1222.0
154	Yanco Offtake	Morundah	8672	8111.6	-560.4	2163.036	-53.1	2110.0
529	Morundah	DC800	7705.997	7208.0	-498.0	2043.464	-47.2	1996.3
533	DC800	Billabong Confluence	11144.693	10424.5	-720.2	3105.292	-68.2	3037.1
509	Colombo Creek		5686.489	5319.0	-367.5	1633.196	-34.8	1598.4
179	Cocketdegong	Jerilderie	13866.9	12970.7	-896.2	1535.82	-84.9	1451.0
183	Jerilderie	Warriston	34059.1	31858.0	-2201.1	3089.54	-208.4	2881.1
436	Puckawidgee	Darlot	30028	28087.4	-1940.6	1823.652	-183.8	1639.9

Node (bulk 3.4 or non-bulk 8.0)	Upstream extent	Downstream extent	Original GS licence on bulk or non-bulk node	Updated GS licence on bulk or non-bulk node	Change in GS licence	Original area	Change in area	Updated area
438	Darlot	Moulamein	4889	4573.0	-316.0	1911.72	-29.9	1881.8

Table 3 Summary of pre-2009 Water for Rivers licence redistribution (Coleambally Irrigation Conveyance)

3.4 node allocation table (Node 365)				
	MDBA BIDG model		Updated WFR Benchmark model	
GS allocation	CI extra allocation	Conveyance part	Conveyance part	CI extra allocation
0	123400	111600	108595	120395
0.35	123400	111600	108595	120395
0.36	*123813*	112360	109335	120788
0.4	*125467*	115400	112293	122360
0.5	129600	117833	114661	126428
0.75	135700	123916	120580	132364
1	141800	130000	126500	138300

Table 4 Summary of pre-2009 Water for Rivers licence purchase (Murrumbidgee Irrigation Conveyance)

3.4 node allocation table (Node 344)				
	MDBA BIDG model		Updated WFR Benchmark model	
GS allocation	MI extra allocation	Conveyance part	Conveyance part	MI extra allocation
0	380000	150250	137884	367634
0.1	435077	155750	142931	422258
0.2	435648	161250	147978	422376
0.25	435933	169500	155549	421982
0.3	436219	177750	163120	421589
0.4	443210	194250	178262	427222
0.5	437361	210750	193404	420015

3.4 node allocation table (Node 344)				
	MDBA BIDG model		Updated WFR Benchmark model	
GS allocation	MI extra allocation	Conveyance part	Conveyance part	MI extra allocation
0.5999	437946	242750	222771	417967
0.6	490932	243000	223021	470953
0.7	476503	243000	223000	456503
0.8	462074	243000	223000	442074
0.9	447645	243000	223000	427645
1	433216	243000	223000	413216

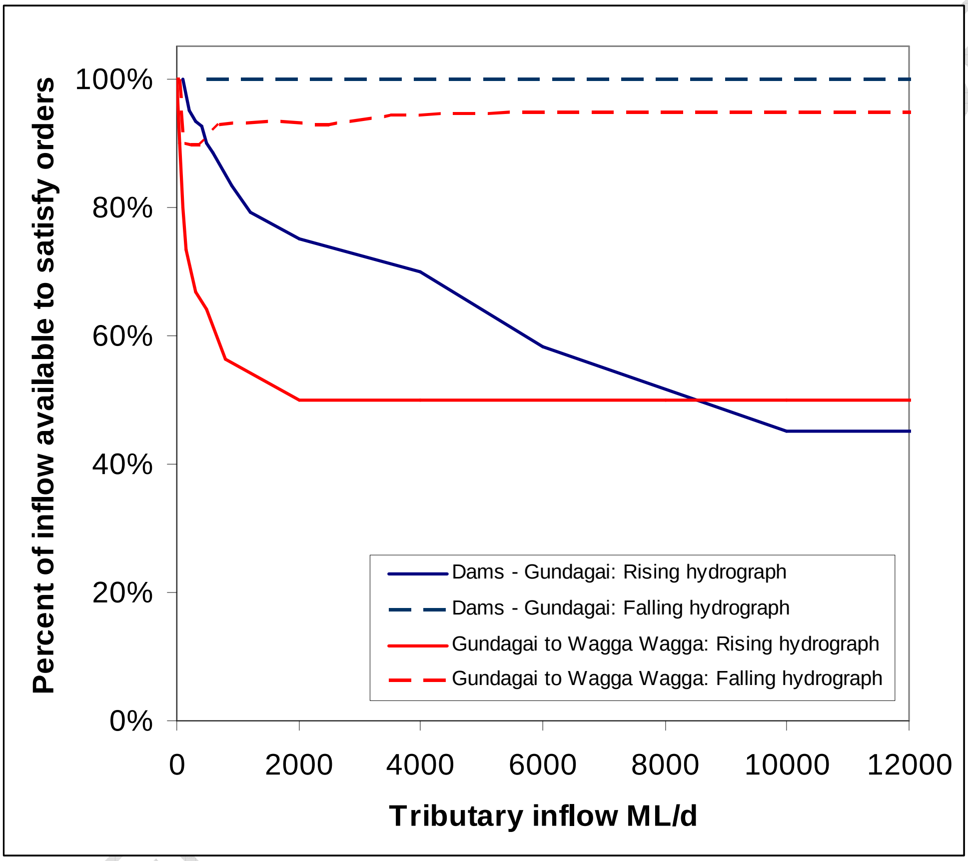
Table 5 Summary of pre-2009 Water for Rivers licence purchase (Hay PID Conveyance)

3.4 node allocation table (Node 290)				
	MDBA BIDG model		Updated WFR Benchmark model	
GS allocation	Hay extra allocation	Conveyance part	Conveyance part	Hay extra allocation
0	6142	1000	0	5142
0.1	-6143.1	1000	0	-7143
0.2	-1672.2	1000	0	-2672
0.3	2798.7	1000	0	1799
0.4	7269.6	1000	0	6270
0.5	11740.5	1000	0	10741
0.6	16211.4	1000	0	15211
0.7	20682.3	1000	0	19682
0.8	25153.2	1000	0	24153
0.9	29624.1	1000	0	28624
1	34095	1000	0	33095

Appendix B – CARM measure background

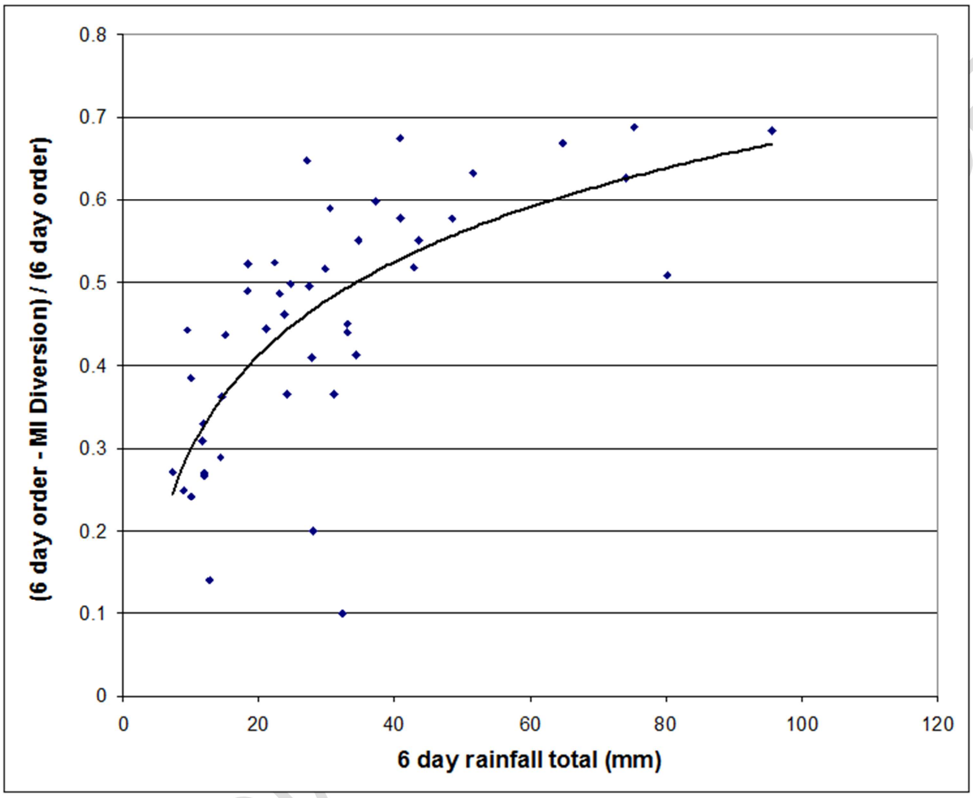
Tributary utilisation

- Change in approach from fixed utilisation values to time varying
- Vary based on rising / falling limb, size of tributary flow
- Biggest variation in rising limb



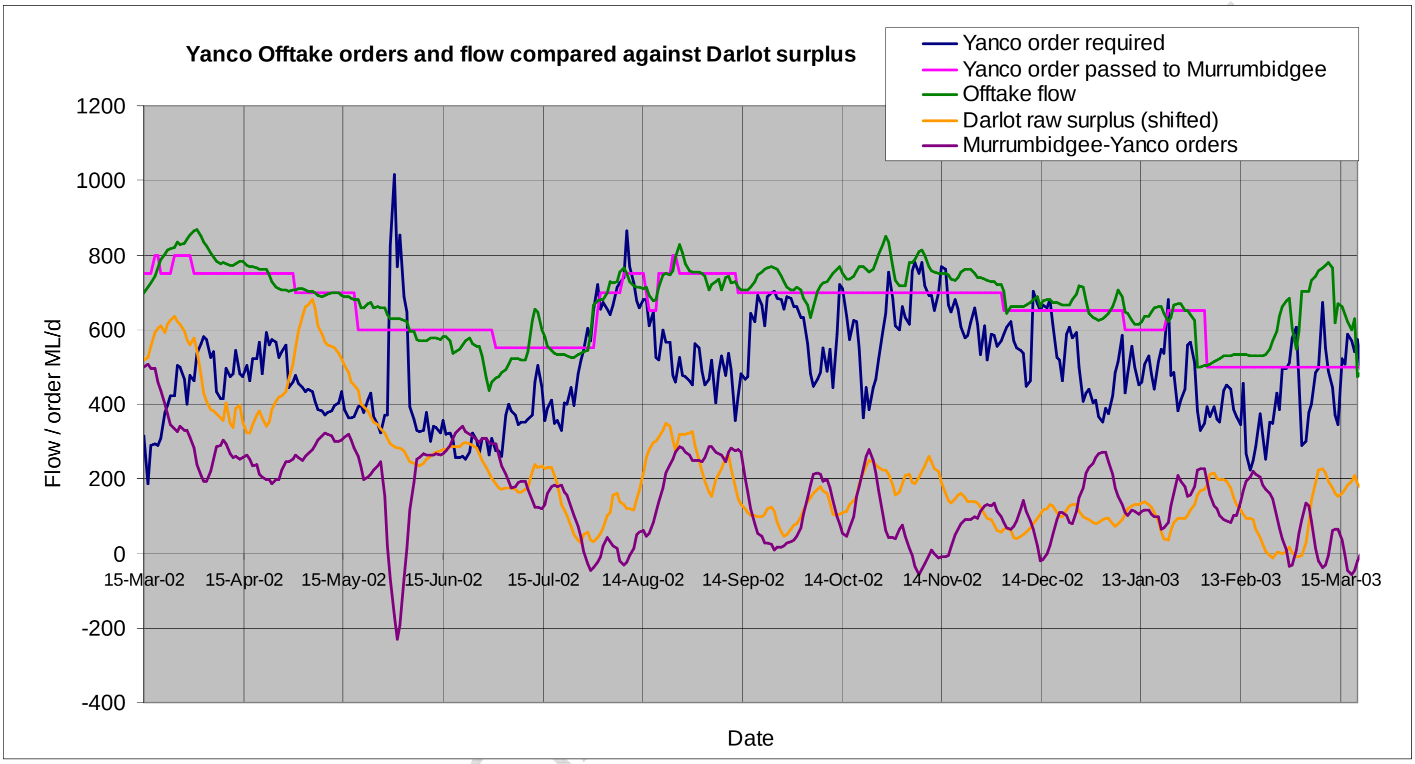
Rainfall rejection

- Review of current relationship used to reject flows from MI at Berembed Weir
- Previously reduces orders to 70% when 5 day average 4mm/d or greater
- Extended to larger reduction at higher rainfalls



Yanco Offtake operation

- CAIRO operations show smoothing, scaling of orders passed from Yanco Offtake to Bidgee
- Can produce surplus flow at Darlot
- October – February inclusive typically 25%
- Applied as a scaling factor to the order at Yanco Offtake



Appendix C – Revision of Yanco Creek Loss Relationships and Residual Inflows

Hemal Hemakura, DPI Water; Shahadat Chowdhury, DPI Water; Donna Hughes, Watermation; Daren Barma, Barmawater

The calibration in the 2005 and 2007 versions of the Water Sharing Plan models uses very flat flow – loss curves to simulate transmission losses in Yanco Colombo Billabong Creeks (i.e. the loss is the same even if the flow doubles). This means any long term reduction in flow through the creek system through efficiency or using irrigation corporation escapes produces little simulated benefit.

DPI Water have recalibrated the loss functions in the Yanco Colombo Billabong system to produce updated functions and new residual catchment inflow time series. The updated loss functions are more sensitive to change in flow and are expected to produce a more realistic transmission loss assessment.

Derivation of Loss Relationships

Re-derived loss relationships have been based upon four Yanco Reach IQQM sub models. These are:

1. Reach 2: Yanco Creek from Morundah to Yanco Bridge (d/s DC800) - YancR2_19.sqq, run period 01/07/1995-30/06/2006
2. Reach 3: Yanco Creek from Yanco Bridge to Conargo/Puckawidgee - YancR3_7.sqq, run period 01/07/1995-30/06/2006
3. Reach 6: Billabong Creek from Jerilderie to Hartwood Weir - BillR2_6.sqq, run period 01/10/1984-30/06/2006
4. Reach 7: Billabong Creek from Conargo to Darlot - BillR3_7.sqq, run period 01/9/1994 -30/06/2006

Loss functions from the models are presented below in Tables 1 to 4.

Table 1 - River Losses in YancR2_19.sqq

Loss 1			Loss 2	
River (ML/d)	Loss (ML/d)		River (ML/d)	Loss (ML/d)
0	0		0	0
60	2		60	9
100	3		100	13
130	4		130	17
200	9		200	35
350	14		350	56
700	28		700	112
900	37		900	147
1100	43		1100	173
2000	65		2000	259
5000	86		5000	346

Table 2 - River Losses in YancR3_7

River (ML/d)	Loss (ML/d)
0	0
100	15
200	25
400	40
600	45
700	50
800	55
1000	60
1200	65
1400	100
2000	200
5000	300

Table 3 - River Losses in BillR2_6.sqq

River (ML/d)	Loss in reckoner
0	0
60	9
100	13
300	30
600	70
2000	180
10000	300

Table 4 - River Losses in BillR3_7.sqq

River (ML/d)	Loss (ML/d)
0	0
100	35
200	50
400	70
1000	150

River (ML/d)	Loss (ML/d)
2500	500
5000	600

Residual Inflow Estimation

Re-derivation of losses has required the derivation of residual inflows along four reaches of the Yanco system. Sacramento rainfall runoff models were developed to estimate residual flows for:

1. Reach 2: Yanco Creek from Morundah to Yanco Bridge (d/s DC800)
2. Reach 3: Yanco Creek from Yanco Bridge to Conargo/Puckawidgee
3. Reach 6: Billabong Creek from Jerilderie to Hartwood Weir
4. Reach 7: Billabong Creek from Conargo to Darlot

The main steps undertaken to derive residual inflows have consisted of:

Step 1 – extracting rainfall and evaporation from the Murrumbidgee IQQM Benchmark model.
Step 2 - deriving a time series of flow at each downstream gauge without residual inflows using the reach IQQM models provided by DPI Water.
Step 3 – Calibrating Sacramento models for residual catchments with output from Step 2 and observed flows.
Step 4 – checking results and potentially modifying rainfall stations used.

Data Compilation

Rainfall and evaporation from the Murrumbidgee IQQM Benchmark model

Rainfall data for Leeton (74062), Coleambally (74249), Deniliquin (74128), Hay (75031) and Balranald (49002) were extracted from BIDG_R.idx (rainfall input file from the Murrumbidgee benchmark model. Similarly evaporation for Deniliquin (74128) was extracted from BIDG_E.idx (evaporation input file from the Murrumbidgee benchmark model).

Residual catchment areas

Areas for relevant residual catchments are noted below. Appendix C1 presents a figure showing sub-catchment areas.

- Reach 2: Yanco Creek from Morundah gauge 410015 to Yanco Bridge gauge 410169 - Residual area 752km2
- Reach 3: Yanco Creek from Yanco Bridge (410169) and Billabong Creek at Hartwood (410168) to Billabong Creek at Conargo/Puckawidgee (410017) - Residual area total of subcatchment areas for 410017 and 410018 - 1414km2

- Reach 6: Billabong Creek from Jerilderie (gauge 410016) to Hartwood Weir (gauge 410168) – The residual area for this reach was not clear from mapping. In the interim, an initial calibration was done using an approximate area.

- Reach 7: Billabong Creek from Conargo (gauge 410017) to Darlot (gauge 410134) - Residual area is 6570km^2 and is shown to include a large area north of Yanco River which may drain as part of Coleambally drainage system and thus already considered in the IQQM. An initial calibration was done using an approximate area.

Sacramento Modelling

Sacramento models were developed to represent residual flows for each Reach noted above. Calibration periods were limited to the concurrent period of available IQQM reach model results and gauged flows unless noted otherwise. The period varied for reaches but generally covered a period from 1995 to 2006.

Areas used for Sacramento models were chosen to reflect the actual residual catchments between gauges but was limited to information available from DPI Water. All Sacramento models used evaporation for Deniliquin (74128) from the Benchmark Murrumbidgee IQQM. Different combinations of rainfall stations were tested as noted for each reach.

The approach for calibrating the models was to use the estimate of simulated flows at the downstream gauge with the re-derived loss estimates as inflows to the Sacramento model. The model was then calibrated to observed flows at the downstream gauge. Results from a calibration run were visually checked against gauged flows and using standard statistics in SOURCE.

Each reach calibration trial had three runs – “a” was a preliminary run to get initial parameters values, output from this run are not provided; “b” was the reported calibration run with initial parameters from run “a” and “c” simulation of residual time series over the available period of rainfall, this run used calibrated parameters from run “b”. Run c is provided for the preferred trial for each reach.

Results

Reach 2 residual catchment from Morundah (410015) to Yanco Bridge (410169)

Three trials were done in the Sacramento model using different rainfall stations. The calculated contributions from each rainfall station in the trials are presented in Table 5. Sacramento parameters are presented in Appendix C2. Statistics (from Source) for simulated flows at gauge 410169 verses observed flows are presented in Table 6. DPI Water advised to adopt Trial 2 to simulate 114 years of flow. Results for Trials 1 and 3 are presented in the previous draft memo for comparison with results from Trial 2.

Figure 2 present the time series of observed flow (410169_obs) and simulated flow from model calibration for Trial 2. Appendix C3 presents shorter duration plots for observed data, estimated flow at 410169 from YancR2_reckoner.sqq and the simulated flow from the model calibration. Time series plots show times when Sacramento generated residuals result in better representation of flows than 410169_IQQM in April 1999, Oct 1999, May 2003, Dec 2004 and July 2005. For reference the calculated and simulated residual catchment flows are presented in Appendix C.

Figure 3 presents the flow duration curve for simulated flow without residual flow and simulated flows with residual from Trial 2, Figure 4 includes observed data.

Table 5 – Trials for various rainfall contributions in FORS, Reach 2

Rainfall Station		Trial 1	Trial 2	Trial 3
	Rfsum	2.89	1.31	1.64
		Contribution		
Leeton	74062	2.25		
Coleambally	74249	0.63	1.31	0.78
Deniliquin	74128			0.85
Hay	75031	0.01		

Table 6 - Statistics of simulated flows at 410169 compared with observed flow (Statistics from Source) Period 18/9/1995 to 30/6/2006

	r	Volume	Efficiency
Review YancR2_IQQM	0.857	0.056	0.716
FORS Trial 1	0.894	0.696	0.785
FORS Trial 2	0.89	0.815	0.781
FORS Trial 3	0.891	0.906	0.78

Figure 2 410169 - Observed verses simulated flow, Simulated with residual flow from Sacramento model Trial 2

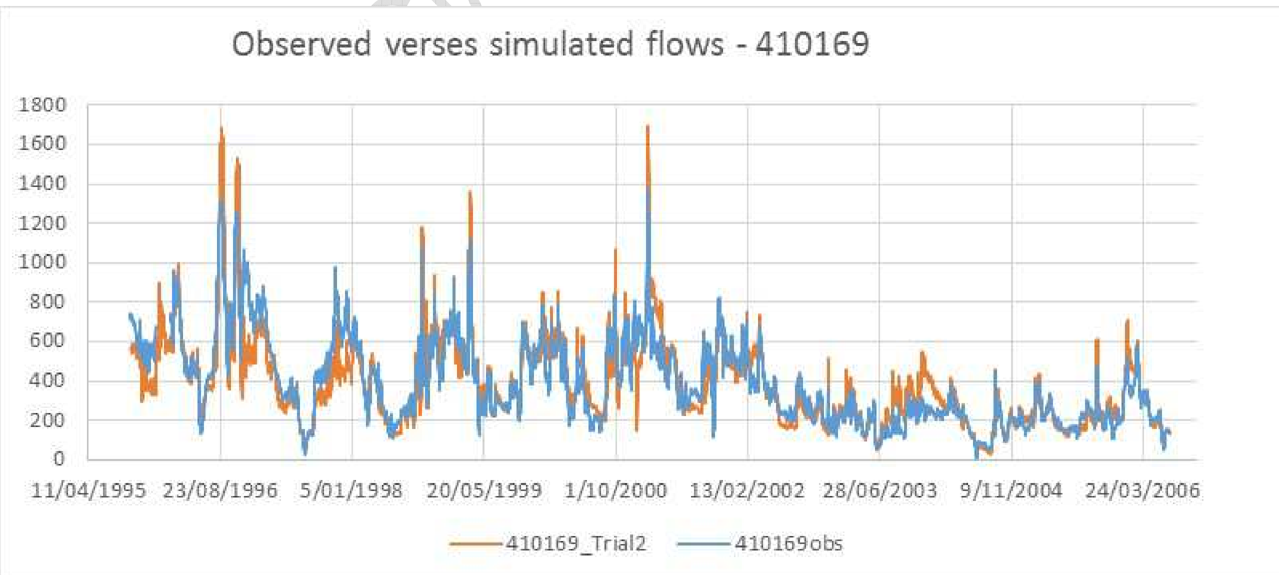


Figure 3 410169 – Flow duration curve, Simulated without residual flow and simulated with residual from Sacramento model Trial 2

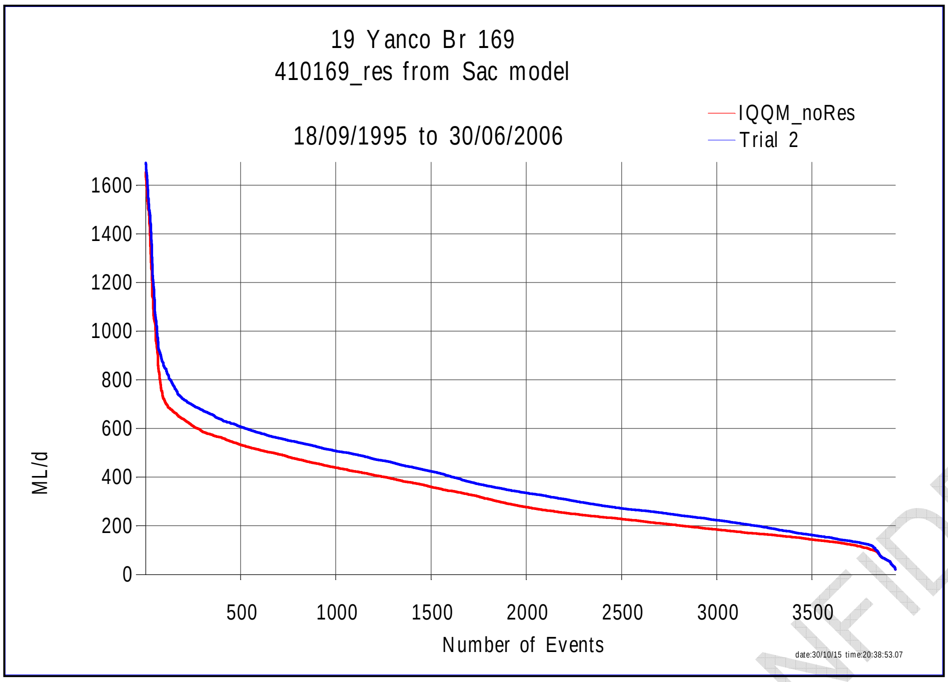
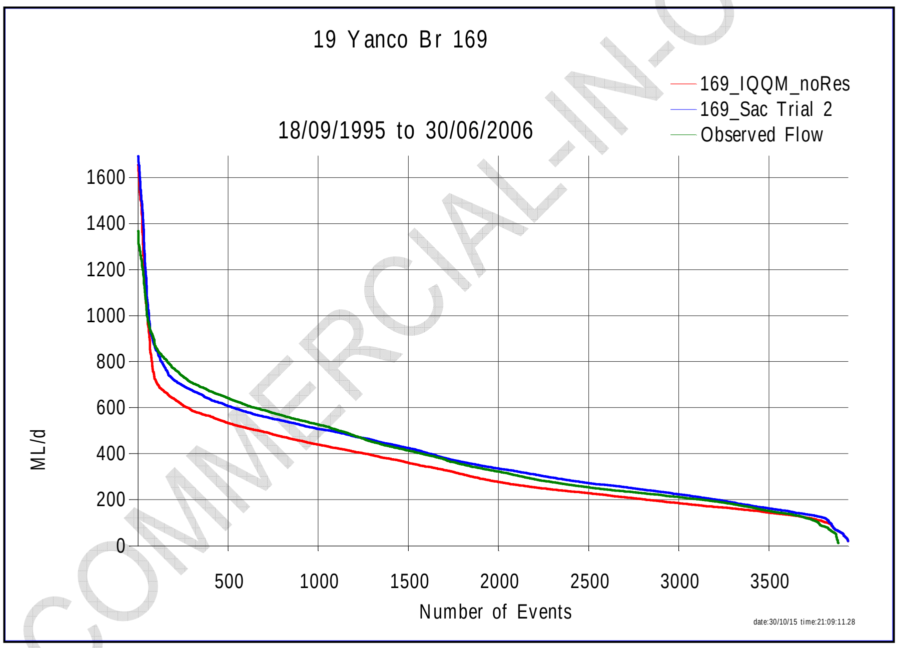


Figure 4 410169 – Flow duration curve, Observed data, Simulated without residual flow and simulated with residual from Sacramento model Trial 2



Reach 3 residual catchment from Yanco Bridge (410169) and Hartwood to Billabong Creek at Conargo (410017)

Residual flows were estimated using the Sacramento model calibrated with an inflow node for “410017_R3_7_noRes.csv”. The model was calibrated to observed flow at 410017 from 1/10/1995 to 30/6/2006. Catchment area used for the Sacramento model was 1400 km2. Four trials were done using different rainfall stations. The calculated contributions from the trials are presented in Table 7. Results indicate that rainfall at Coleambally and Deniliquin best represent the residual flows, therefore Trial 4 calibrated parameters was used simulate 114 years of residual flows.

The simulated time series of flow at 410017 over the calibration period was compared to observed flows. Statistics (from Source) are presented in Table 8. Figure 7 show flows over the whole calibration period for Trial 4 against the gauged. Appendix C3 presents shorter duration graphs of simulated flow at 410017 for Trial 4, results and observed flow. For reference the calculated and simulated residual catchment flows are presented in Appendix C.

Figure 8 presents the flow duration curve for simulated without residual flow and simulated with residual from Sacramento model Trial 4; Figure 9 is the flow duration curve with observed data.

Table 7 – Trials for various rainfall contributions, Reach 3

Rainfall Station		Trial 1	Trial 2	Trial 3	Trial 4
	Rfsum	2.25	2.24	2.26	2.27
Leeton	74062	0.00			
Coleambally	74249	0.26	0.34	0.30	0.28
Deniliquin	74128	1.99	1.90	1.96	1.98
Hay	75031	0.00	0.00	0.00	
Balranald	49002		0.00		

Table 8 - Statistics of simulated flows at 410017 verses observed flow (Statistics from Source from 1 Oct 1995 to 30 June 2006)

	r	Volume	Efficiency
Review YancR3_7	0.944	1.201	0.86
YancR3_7_noRes			
FORS Trial 1	0.945	0.623	0.866
FORS Trial 2	0.945	0.609	0.867
FORS Trial 3	0.945	0.562	0.867
FORS Trial 4	0.945	0.567	0.867

Figure 7 410017 - Observed versus simulated flow, Simulated with residual flow from Sacramento model Trial 4

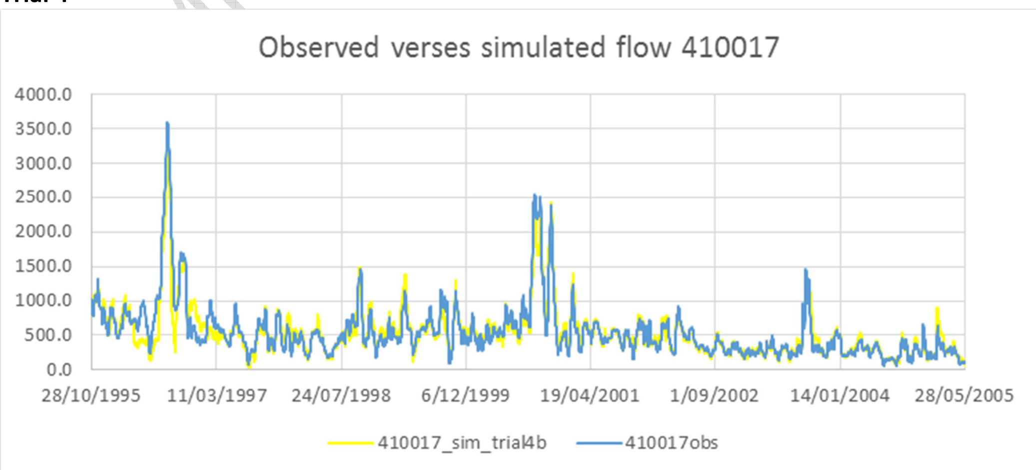


Figure 8 410017 – Flow duration curve, Simulated without residual flow and simulated with residual from Sacramento model Trial 4 (all flow, high flows, low flows)

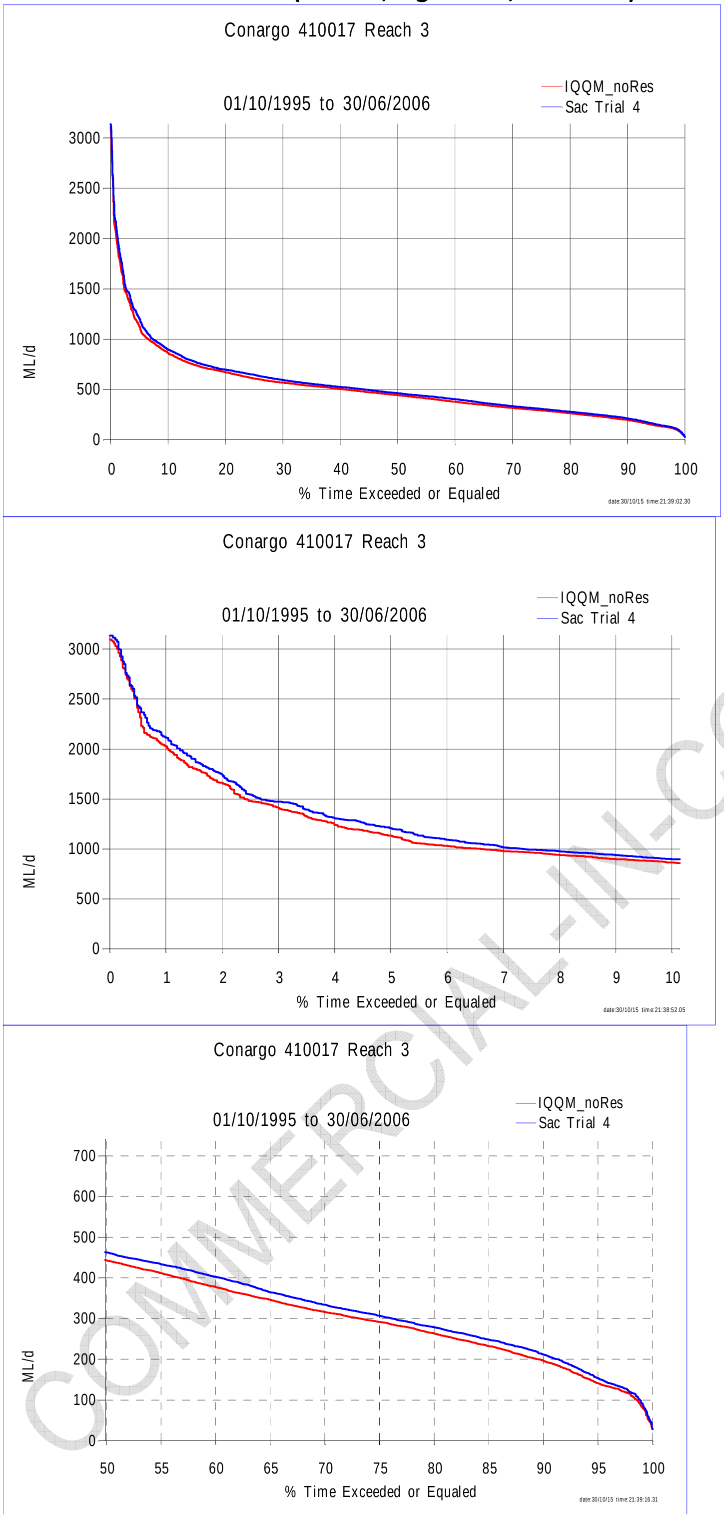
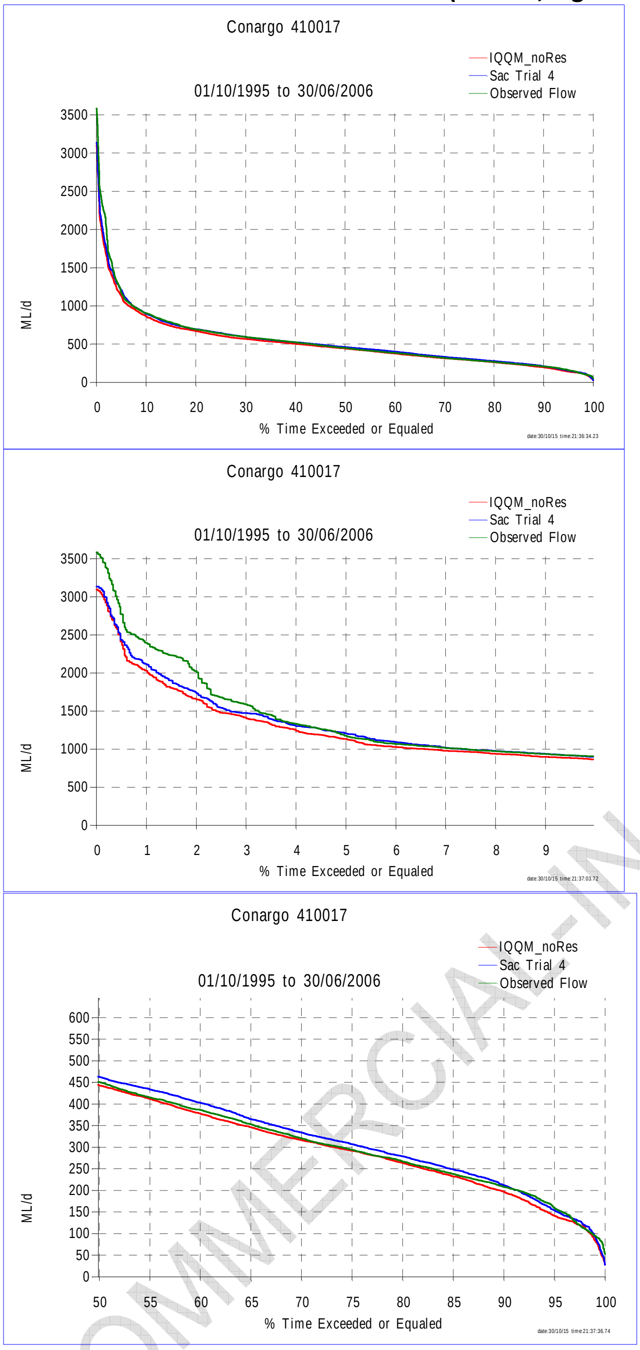


Figure 9 410017 – Flow duration curve, Observed data, Simulated without residual flow and simulated with residual from Sacramento model Trial 4 (all flow, high flows, low lows)



Reach 6 residual catchment from Billabong Creek at Jerilderie (410016) to Billabong Creek at Hartwood (410168)

Residual flows were estimated using the Sacramento model calibrated with FORS. The contributing catchment area from available mapping was not clear, so an estimate of 500km2 was used which was based on length of the reach in IQQM (approximately 50km) and a nominal catchment width of 10km. The calibration was based on the period from 1/7/1999 to 30/6/2006.

Rainfall stations at Deniliquin, Leeton and Coleambally were trialled in the calibration process. Rainfall for Balranald was tested as this rainfall station is used in the Benchmark IQQM for irrigation nodes in this reach, however the automatic calibration method used in the Sacramento model resulted in a small contribution from this station and thus this station was not used. The combinations tested are noted in Table 9.

Sacramento parameters for Trials are presented in Appendix C2. Statistics (from Source) for simulated flows at gauge 410186 verses observed flows are presented in Table 10. Plots of results for Trials 1 and 2 against observed is shown in Figure 12. Appendix C3 presents shorter duration graphs of simulated flow at 410186 for Trials 1 and 2, results from the IQQM reach model and observed flow.

Figure 13 presents the flow duration curve for simulated without residual flow and simulated with residual from Sacramento model Trial 1, Fiure 14 is the flow duration curve with observed data.

At the conclusion of this work a preference for Trial 1 or 2 was not agreed upon with DPI Water, therefore parameters for both trials were used to simulate flows for 114 years. DPI Water has subsequently adopted Trial 2 for analysis.

Table 9 Trials for various rainfall contributions in FORS, Reach 6

Rainfall Station		Trial 1	Trial 2	Trial 3	Trial 4
	RFsum	2.05	1.72	2.12	2.85
Leeton	74062	0.55			
Coleambally	74249	0.22	0.64	2.12	
Deniliquin	74128	1.28	1.08		2.85

Table 10 Statistics of simulated flows at 410168 verses observed flow (Statistics from Source), 1/7/1999 to 30/6/2006

	r	Volume	Efficiency
Review BillR2_reckoner	0.962	6.33	0.92
Method 1			
FORS Trial 1	0.962	1.224	0.917
FORS Trial 2	0.959	1.394	0.91
FORS Trial 3	0.962	1.74	0.91
FORS Trial 4	0.958	1.467	0.908

Figure 12 410168, Observed and simulated flow using Trials 1 and 2

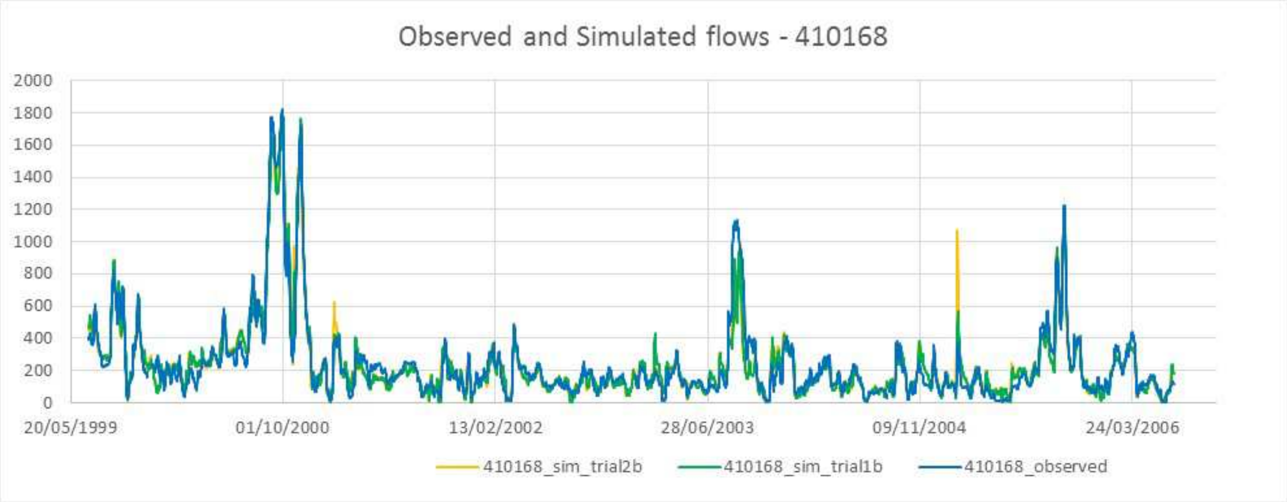


Figure 13 410168 – Flow duration curve. Simulated without residual flow and simulated with residual from Sacramento Trial 1

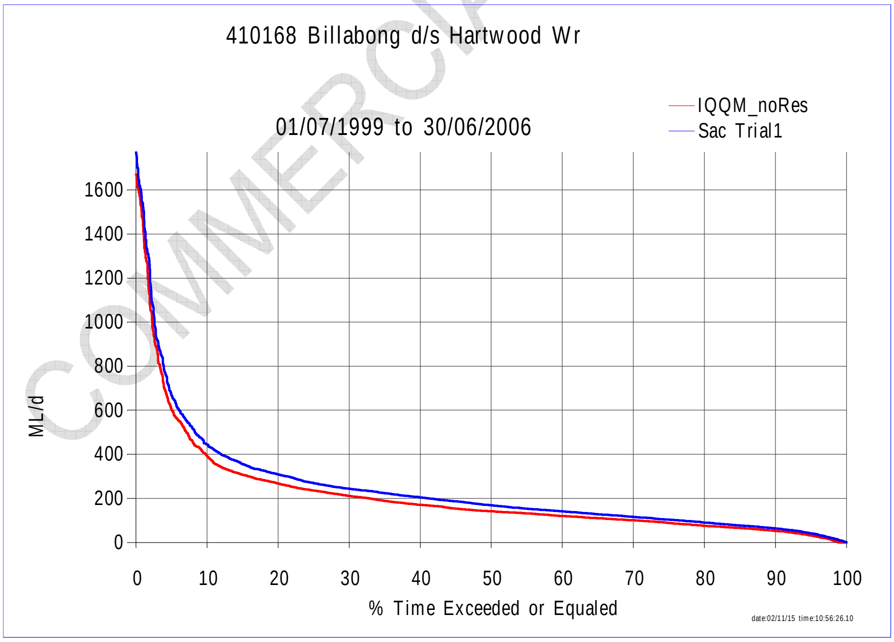
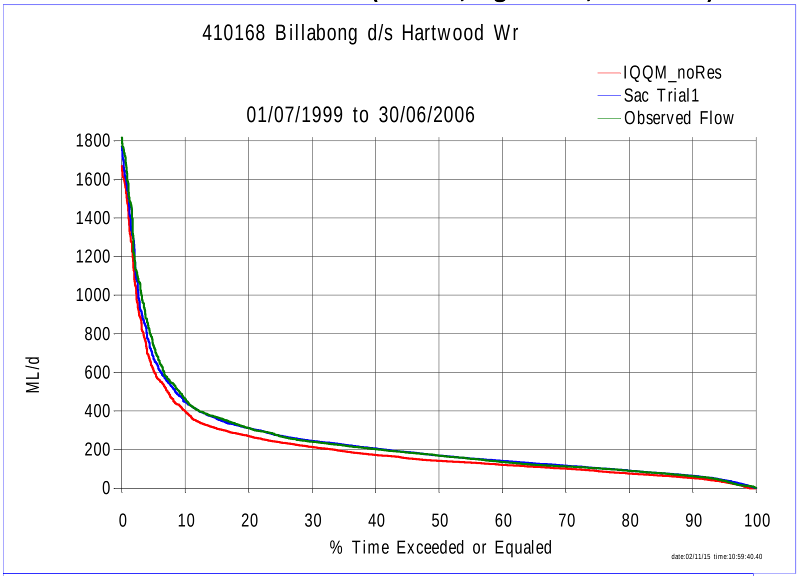
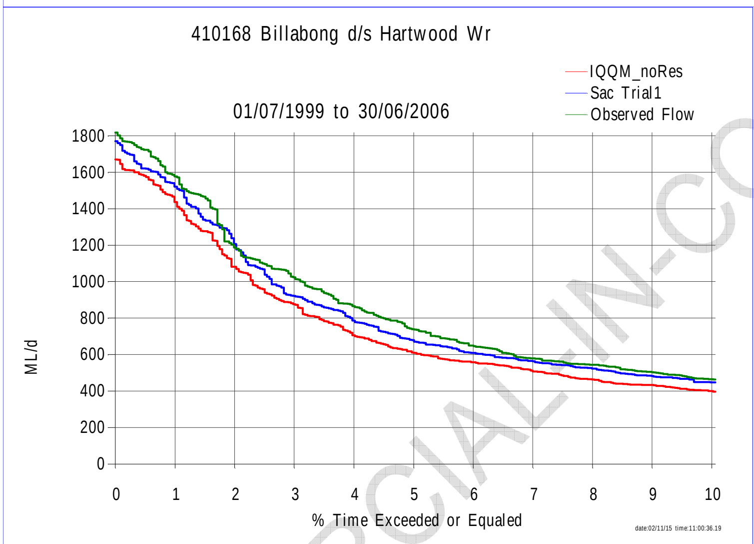
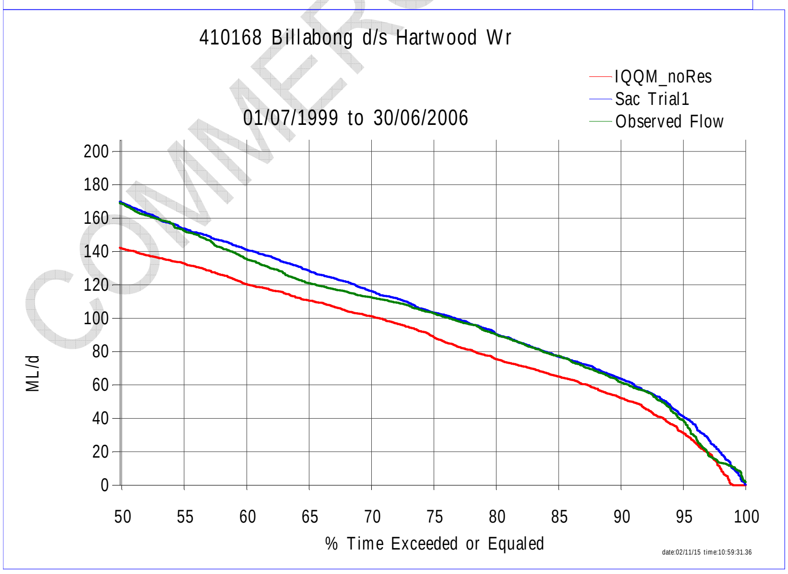


Figure 14 410168 – Flow duration curve. Observed flow, Simulated without residual flow and simulated with residual from Sacramento Trial 1 (all flow, high flows, low flows)







Reach 7 residual catchment from Billabong Creek at Puckawidgee (410017) to Billabong Creek at Darlot (410134)

Residual flows were estimated using the Sacramento model calibrated with an inflow from "410134_R3_7_noRes.csv" and calibrated to observed flow at gauge 410134. The contributing catchment area from available mapping was not clear so an approximate area of 840km^2 was used in modelling which is based on length of reach in IQQM (approximately 84km) by a nominal width of 10km. Four trials were done in the model using different rainfall stations. The calculated contributions from the trials are presented in Table 11. Sacramento parameters for Trials are presented in Appendix C2.

Statistics (from Source) for simulated flows for gauge 410134 verses observed flows are presented in Table 12. Based on these results Trial 2 was selected as resulting in more favourable representation of flow at 410134 and was used to present further results. Plot of time series of flow for Trial 2 against observed flows for the whole calibration period is shown in Figure 16. Appendix C3 presents shorter duration graphs within the calibration period for observed flow, generated flow from the IQQM reach model ("410134_R3_7.csv") and simulated flow from the Sacramento model run.

Figure 17 presents the flow duration curve for simulated without residual flow and simulated with residual from Sacramento model Trial 2, Figure 18 is the flow duration curve with observed data.

Table 11 Trials for various rainfall contributions in FORS, Reach 7

Rainfall Station		Trial 1	Trial 2	Trial 3	Trial 4
	RFsum	1.24	2.93	1.24	2.86
		Contribution			
Coleambally	74249	0.47	1.55	0.62	1.80
Deniliquin	74128	0.61	1.38	0.62	0.97
Hay	75031	0.16			0.10
Balranald	49002	0.00		0.00	

Table 12 Statistics of simulated flows at 410134 verses observed flow for period 01/09/1994 to 30/06/2006 (Statistics from Source)

	r	Volume	Efficiency
Review BillR3_7	0.98	-3.466	0.958
FORS Trial 1	0.977	2.62	0.936
FORS Trial 2	0.982	1.829	0.949
FORS Trial 3	0.976	2.791	0.933
FORS Trial 4	0.98	2.003	0.945

Figure 16 Observed and simulated flow at 410134 Trial 2

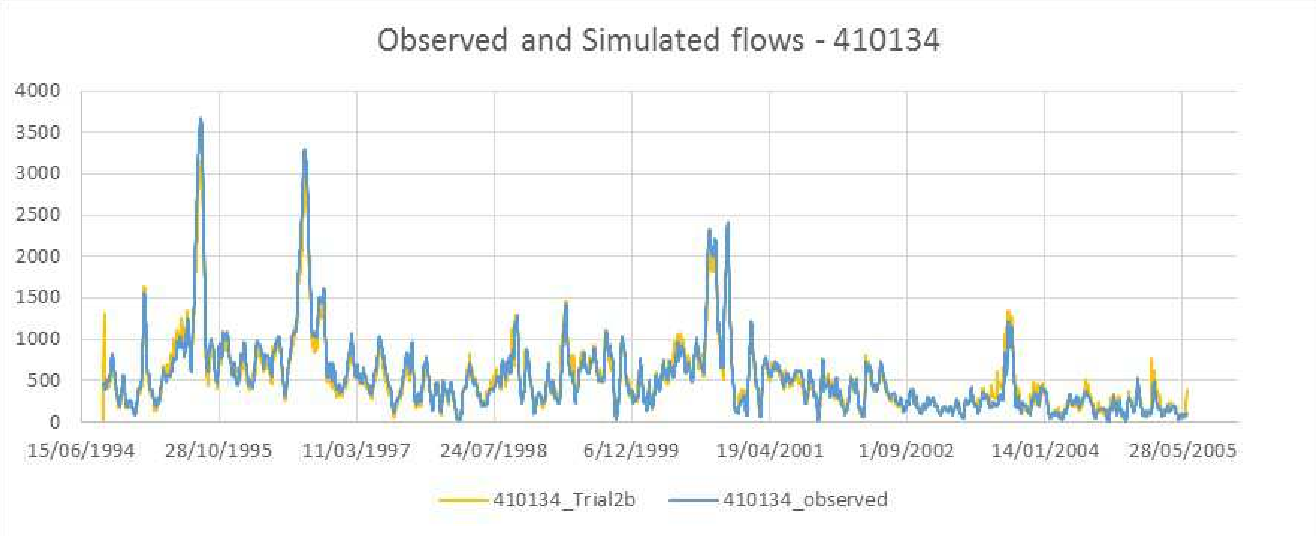


Figure 17 410134 – Flow duration curve. Simulated without residual flow and simulated with residual from Sacramento Trial 2

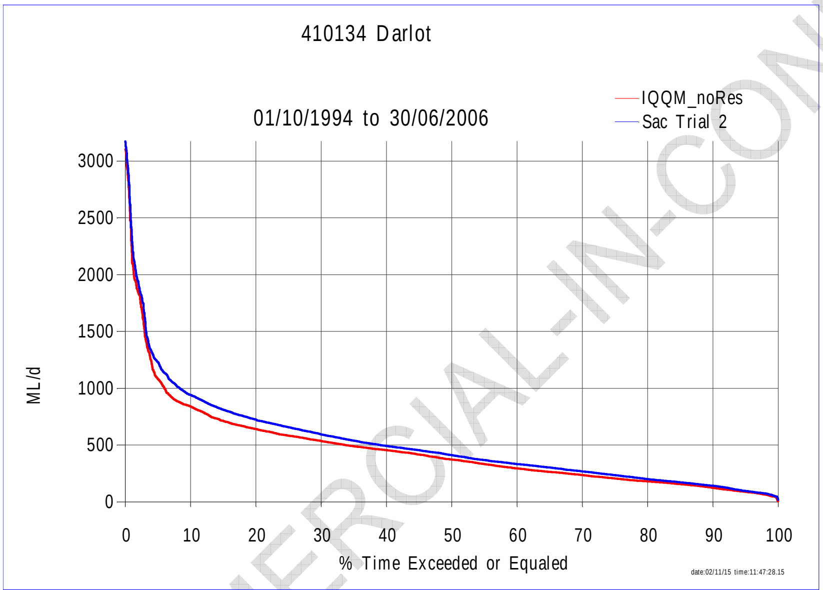
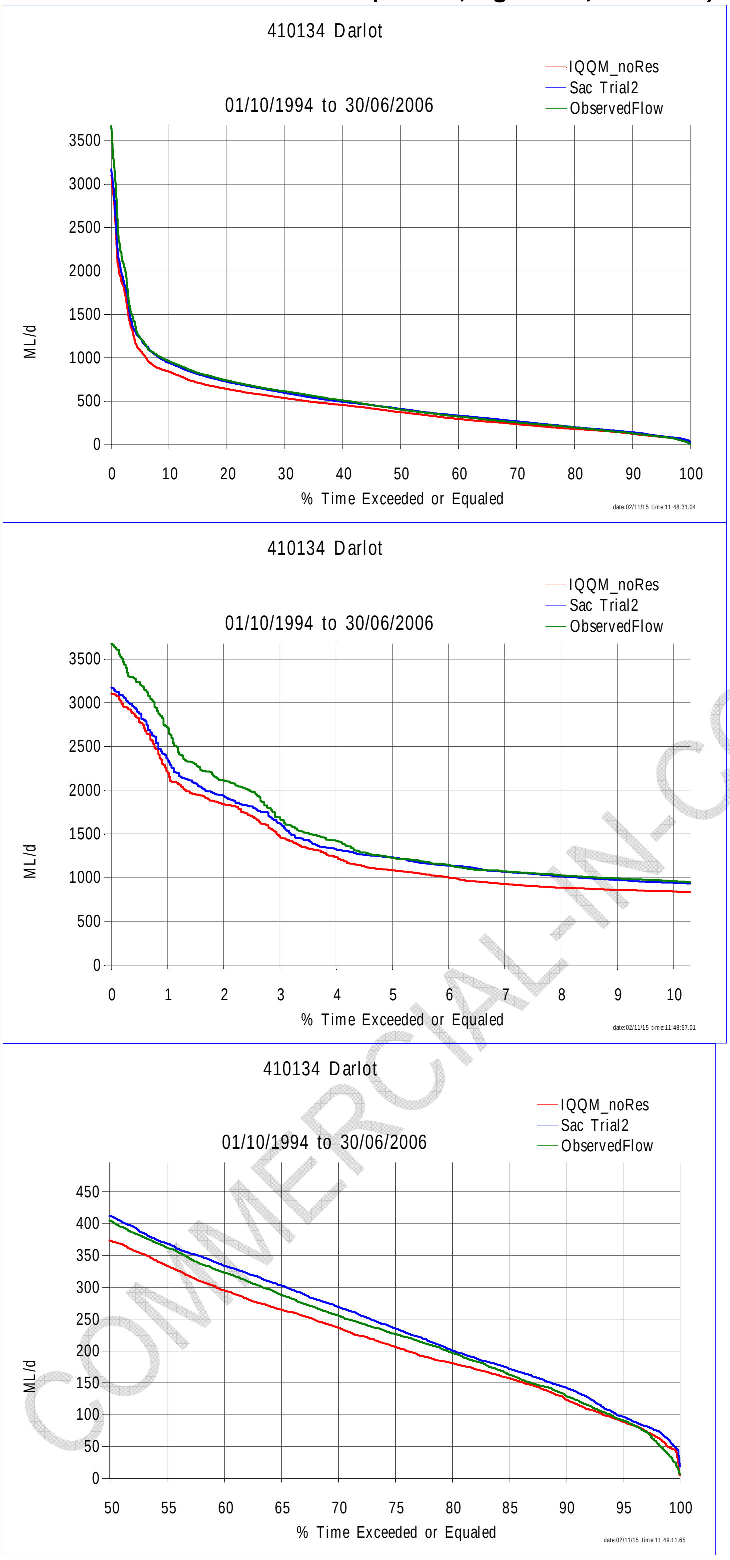
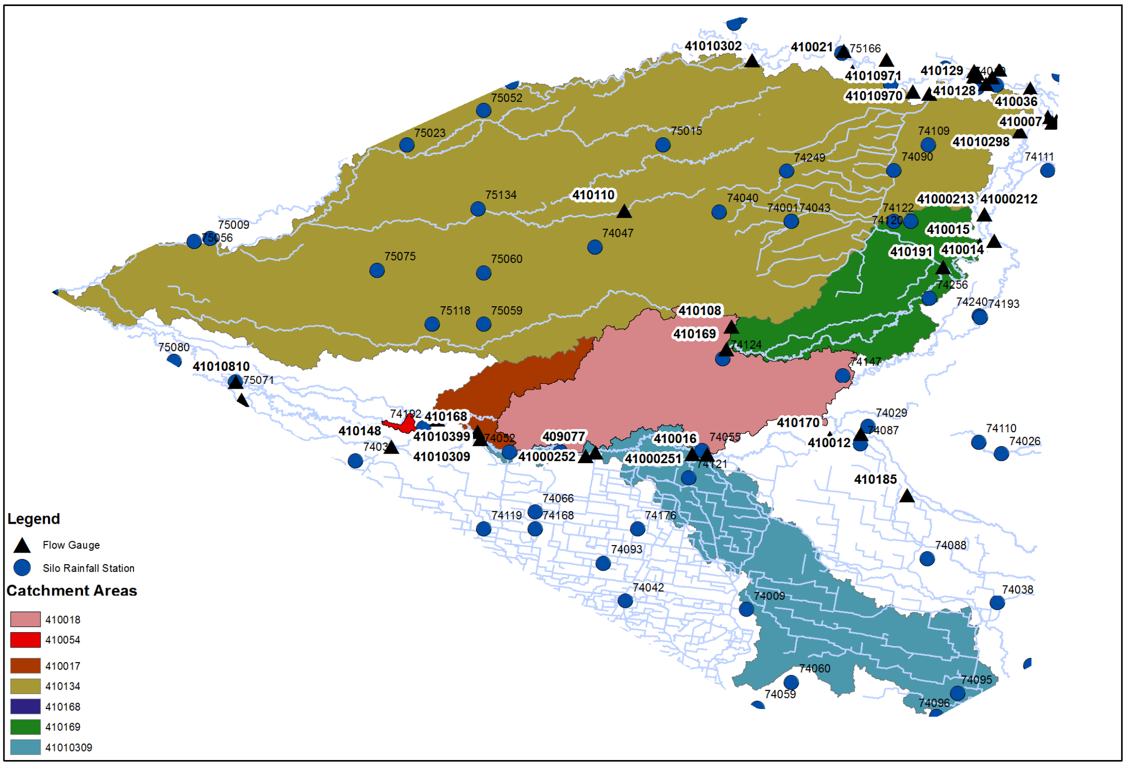


Figure 18 410134 – Flow duration curve. Observed flow, Simulated without residual flow and simulated with residual from Sacramento Trial 2 (all flow, high flows, low flows)



Appendix C1 – Catchment Area map



Appendix C2 Sacramento model parameters

Reach 2 Residual catchment

		Trial 1	Trial 2	Trial 3
Catchment area modelled		752	752	752
Rain				
	Rfsum	2.89	1.31	1.64
Leeton	74062	2.25		
Coleambally	74249	0.63	1.31	0.78
Deniliquin	74128			0.85
Hay	75031	0.01		
	adimp	0.002	0.000	0.003
	lzfpm	2.5	1.0	4.3
	lzfsm	249.3	349.9	97.8
	lzpk	0.002	0.006	0.016
	lzsk	0.084	0.013	0.019
	lztwm	322.6	71.1	401.7
	pctim	0.000	0.000	0.000
	pfree	0.045	0.412	0.265
	rexp	2.025	2.968	1.522
	sarva	0.000	0.000	0.000
	side	0.000	0.011	0.000
	ssout	0.000	0.100	0.068
	uzfwm	7.9	5.0	5.0
	uzk	0.146	0.401	0.545
	uztwm	12.0	12.0	12.0
	zperc	170.5	171.1	48.7
	uh0	0.000	0.000	0.000
	uh1	0.415	0.000	0.000
	uh2	0.585	0.352	0.638
	uh3		0.648	0.362

Reach 3 residual catchment – Sacramento model parameters

		Trial 1	Trial 2	Trial 3	*Trial 4*
	Rfsum	2.25	2.24	2.26	2.27
	Contribution				
Leeton	74062	0.00			
Coleambally	74249	0.26	0.34	0.30	0.28
Deniliquin	74128	1.99	1.90	1.96	1.98
Hay	75031	0.00	0.00	0.00	
Balranald	49002		0.00		
	adimp	0.001	0.000	0.000	0.000
	lzfpm	1.2	1.0	10.8	1.4
	lzfsm	310.1	242.0	336.6	333.8
	lzpk	0.000	0.016	0.006	0.006
	lzsk	0.039	0.039	0.039	0.038
	lztwm	147.0	137.0	260.2	314.8
	pctim	0.001	0.001	0.001	0.001
	pfree	0.047	0.049	0.051	0.050
	rexp	3.339	1.952	5.997	2.322
	sarva	0.001	0.001	0.001	0.001
	side	0.000	0.000	0.000	0.000
	ssout	0.000	0.000	0.000	0.000
	uzfwm	7.4	15.5	26.3	26.7
	uzk	0.260	0.304	0.389	0.179
	uztwm	12.0	12.0	12.0	12.0
	zperc	544.0	600.0	295.0	390.0
	uh0	0.000	0.000	0.000	0.000
	uh1	0.000	0.000	0.000	0.000
	uh2	0.322	0.081	0.454	0.370
	uh3	0.678	0.919	0.546	0.630

Reach 6 residual catchment – Sacramento model parameters

		Trial 1	Trial 2	Trial 3	Trial 4
Catchment area modelled		500	500	500	500
Rain					
	Rfsum	2.05	1.72	2.12	2.85
Leeton	74062	0.55			
Coleambally	74249	0.22	0.64	2.12	
Deniliquin	74128	1.28	1.08		2.85
	adimp	0.000	0.000	0.029	0.150
	lzfpm	3.7	8.9	300.0	3.7
	lzfsm	262.0	16.1	34.8	112.3
	lzpk	0.005	0.036	0.012	0.029
	lzsk	0.080	0.097	0.121	0.102
	lztwm	76.6	197.9	593.0	585.0
	pctim	0.003	0.002	0.002	0.001
	pfree	0.075	0.116	0.129	0.046
	rexp	2.016	3.028	4.548	2.789
	sarva	0.000	0.000	0.001	0.000
	side	0.002	0.000	0.043	0.000
	ssout	0.000	0.000	0.031	0.000
	uzfwm	7.0	31.9	8.9	5.0
	uzk	0.325	0.515	0.777	0.546
	uztwm	12.7	13.5	12.0	12.0
	zperc	590.3	309.4	47.7	587.2
	uh0	0.000	0.000	0.000	0.000
	uh1	0.000	0.000	0.000	0.000
	uh2	0.434	0.477	0.474	0.317
	uh3	0.566	0.523	0.526	0.683

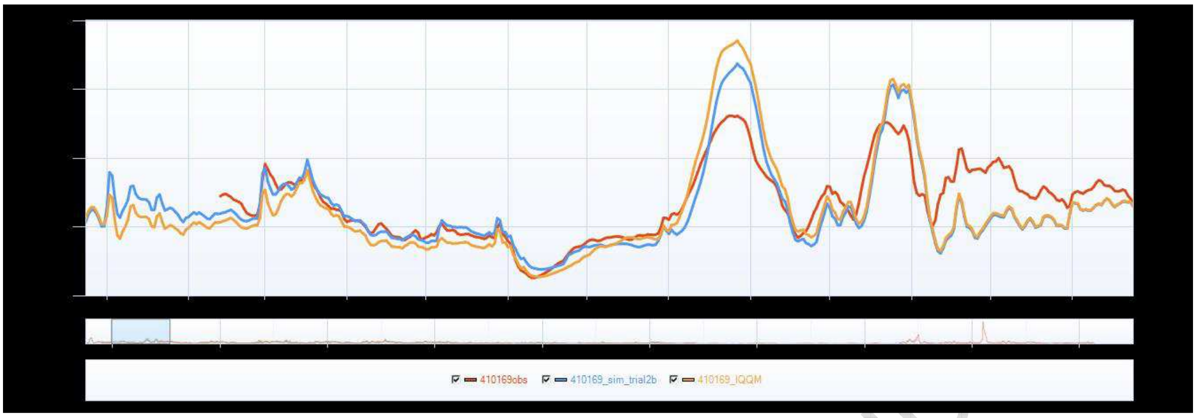
Reach 7 residual catchment

catchment	trial 1	trial 2	trial 3	Trial 4
840km2				
Rfsum	1.24	2.93	1.24	2.86
74062				
74249	0.47	1.55	0.62	1.80
74128	0.61	1.38	0.62	0.97
75031	0.16			0.10
49002	0.00		0.00	
adimp	0.000	0.005	0.001	0.000
lzfpm	1.8	1.4	10.2	2.1
lzfsm	324.4	97.7	196.5	350.0
lzpk	0.002	0.019	0.024	0.014
lzsk	0.024	0.019	0.027	0.014
lztwm	49.0	599.8	292.5	238.1
pctim	0.004	0.005	0.002	0.005
pfree	0.500	0.143	0.500	0.249
rexp	5.830	2.820	2.890	3.082
sarva	0.002	0.005	0.002	0.005
side	0.010	0.000	0.000	0.000
ssout	0.000	0.000	0.000	0.000
uzfwm	32.7	21.8	19.2	32.3
uzk	0.231	0.677	0.248	0.232
uztwm	12.3	12.0	13.4	25.6
zperc	277.4	587.3	56.7	540.4
uh0	0.000	0.000	0.000	0.000
uh1	0.000	0.000	0.000	0.000
uh2	0.150	0.414	0.549	0.455
uh3	0.850	0.586	0.451	0.545

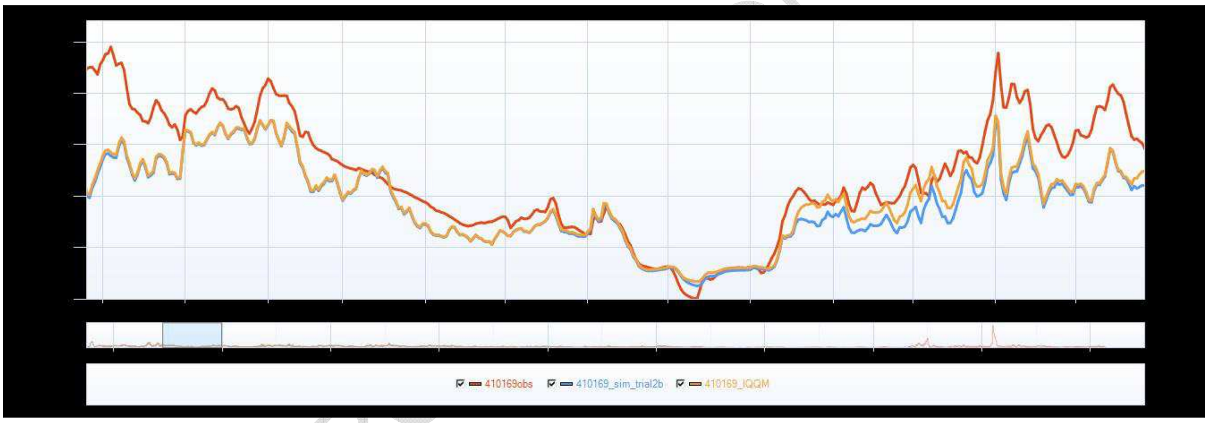
Appendix C3 Time Series Plots in calibration periods

Reach 2 Time series plots of observed flows at 410169 (red line), 410169_IQQM.csv (simulated flows from IQQM reach model, orange line) and Sacramento simulated flows at 410169 for Trial 2 (blue line)

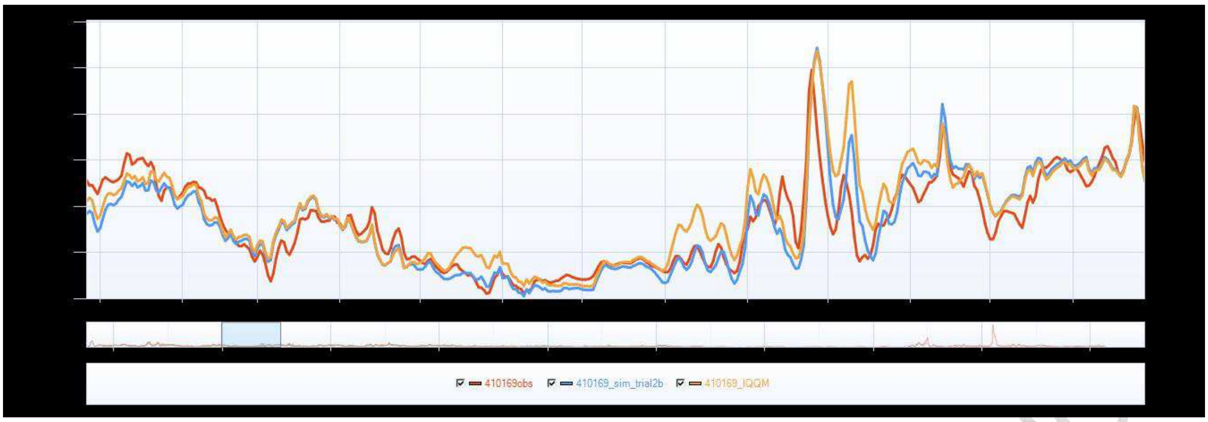
Observed and simulated flow – 1996



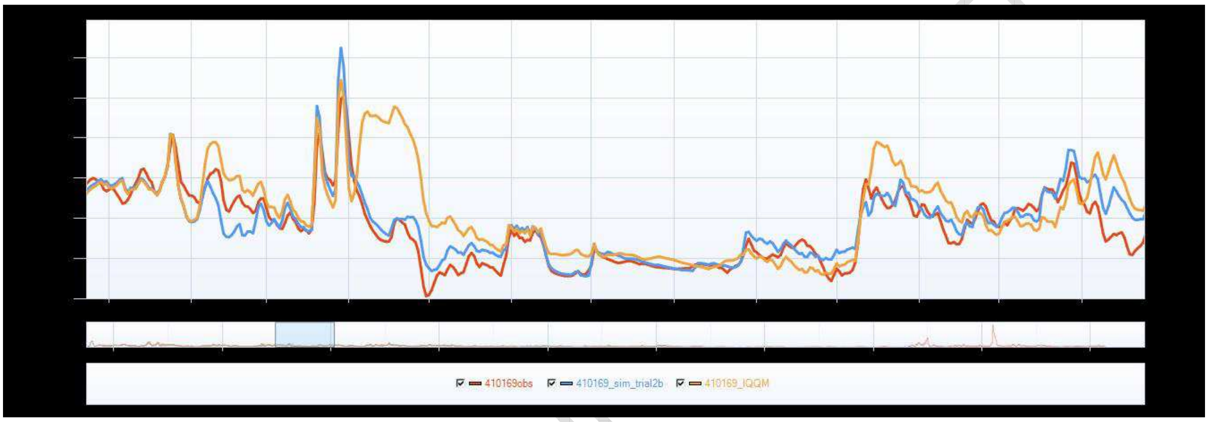
Observed and simulated flow – 1997



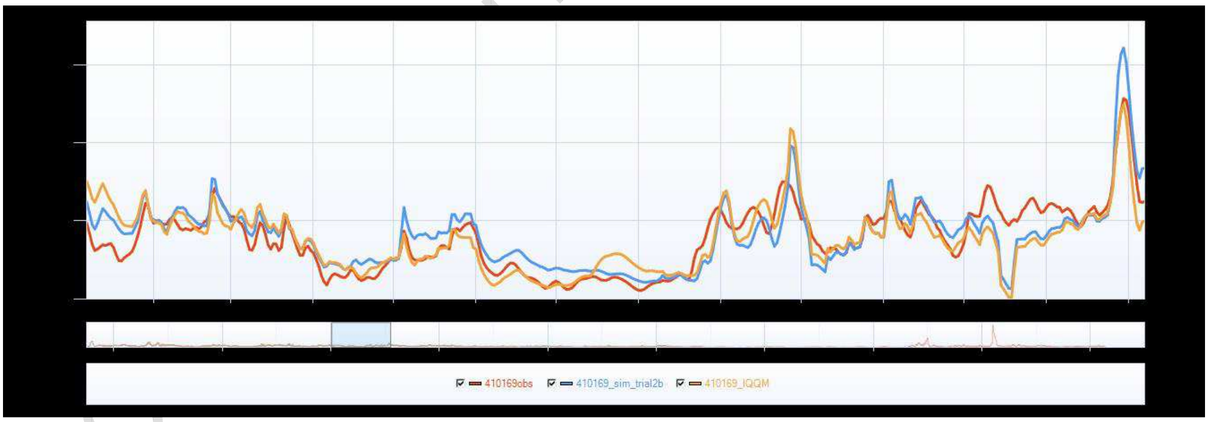
Observed and simulated flow – 1998



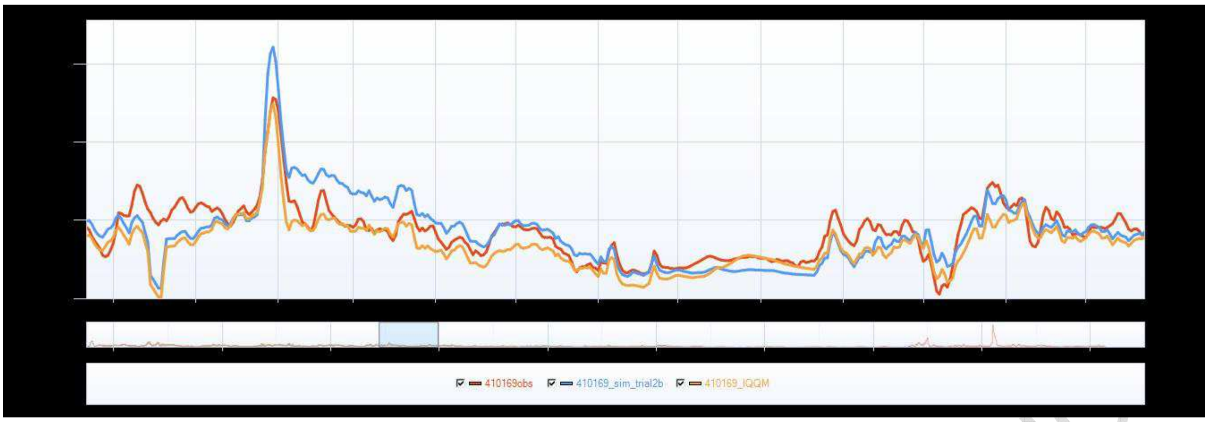
Observed and simulated flow – 1999



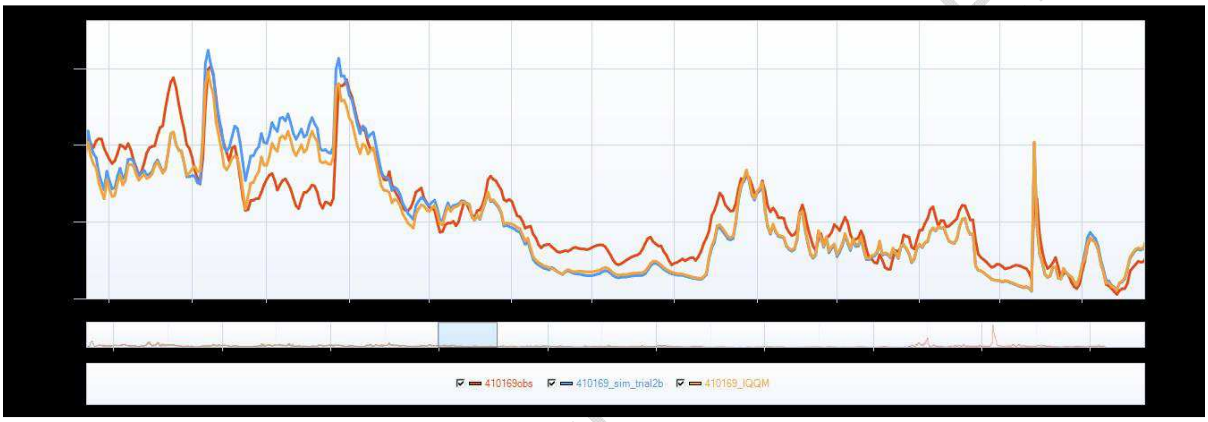
Observed and simulated flow – 2000



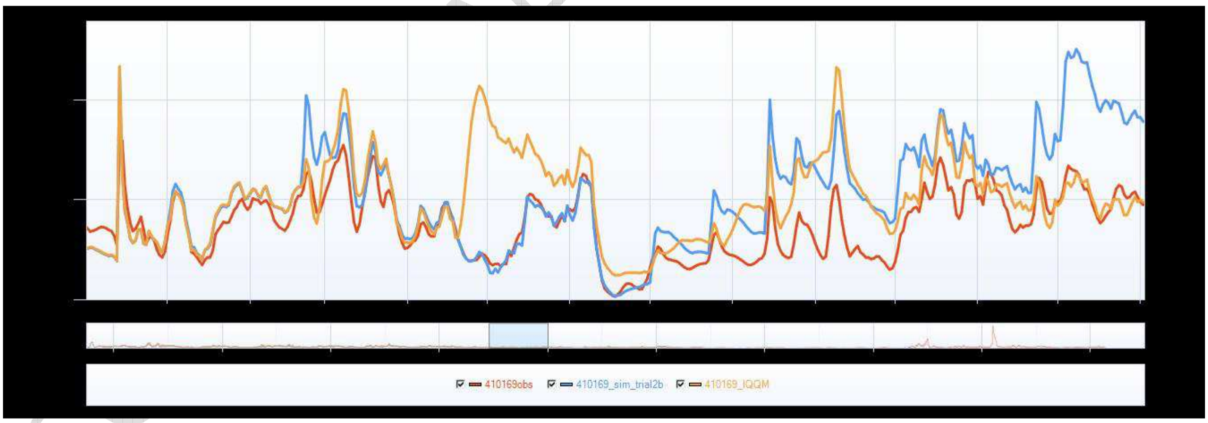
Observed and simulated flow – 2001



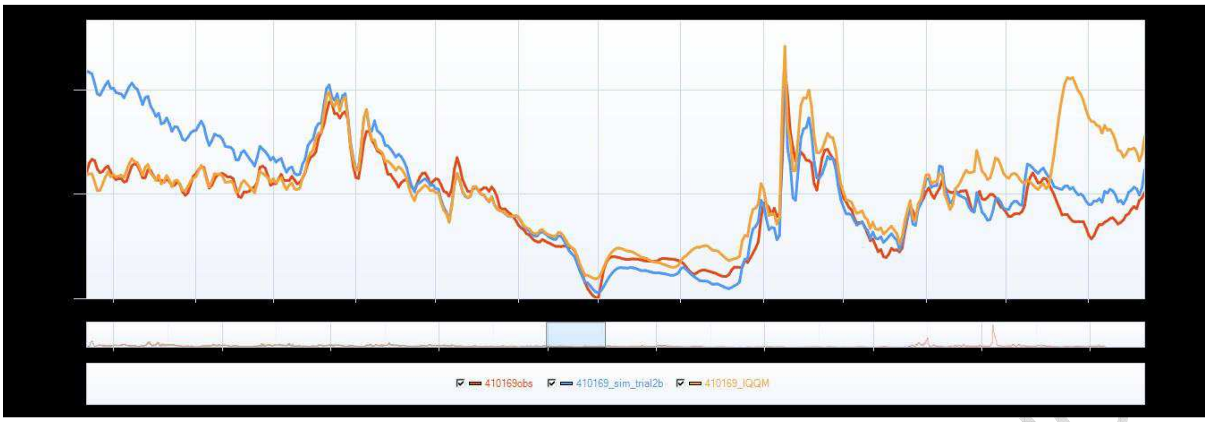
Observed and simulated flow – 2002



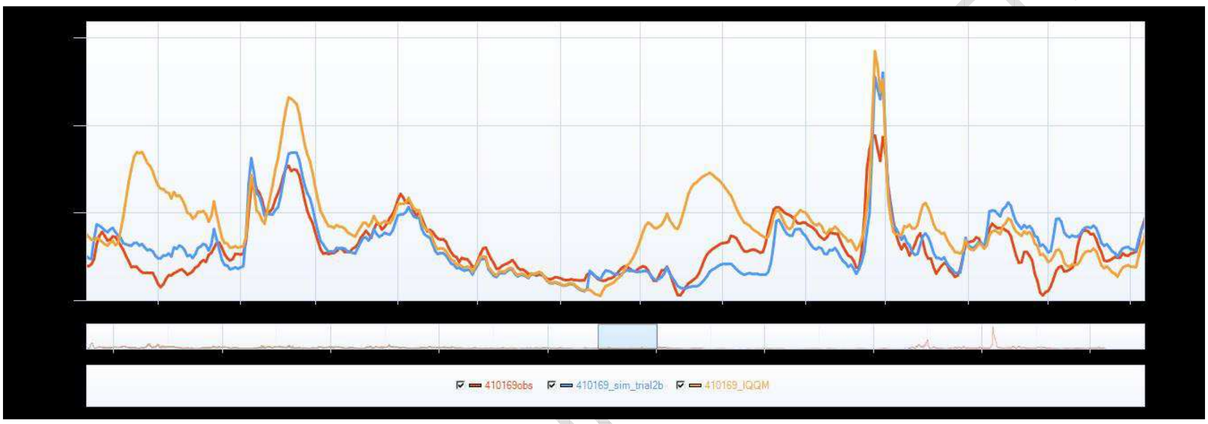
Observed and simulated flow – 2003



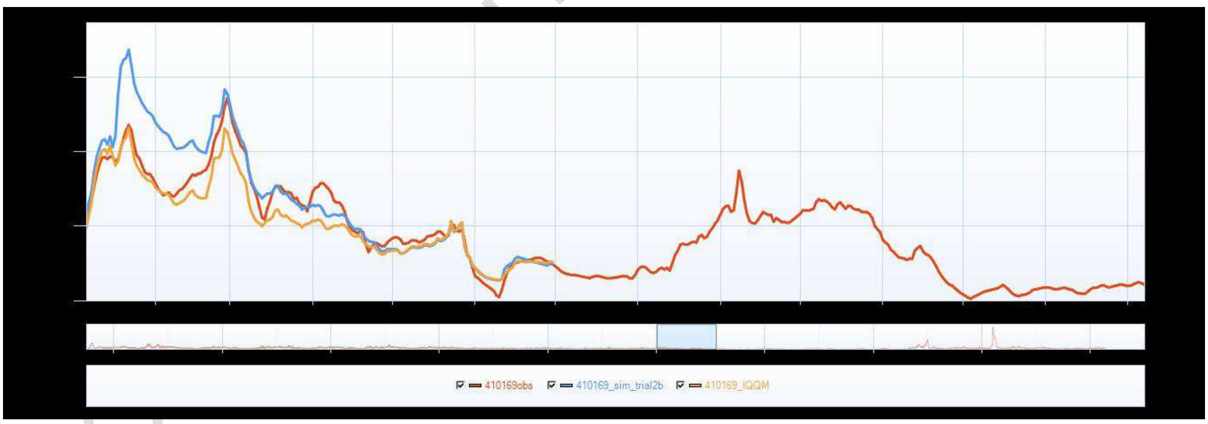
Observed and simulated flow – 2004



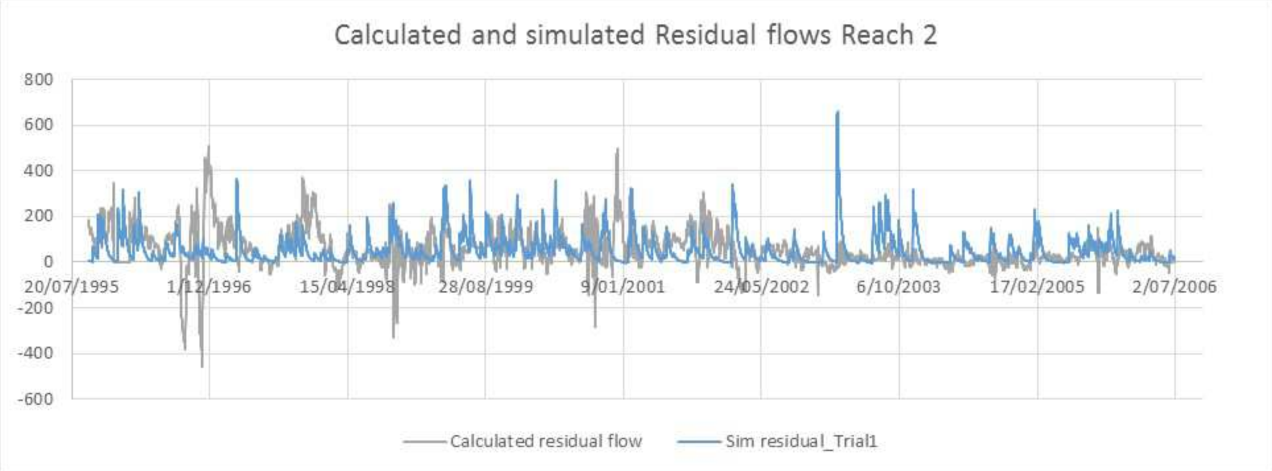
Observed and simulated flow – 2005



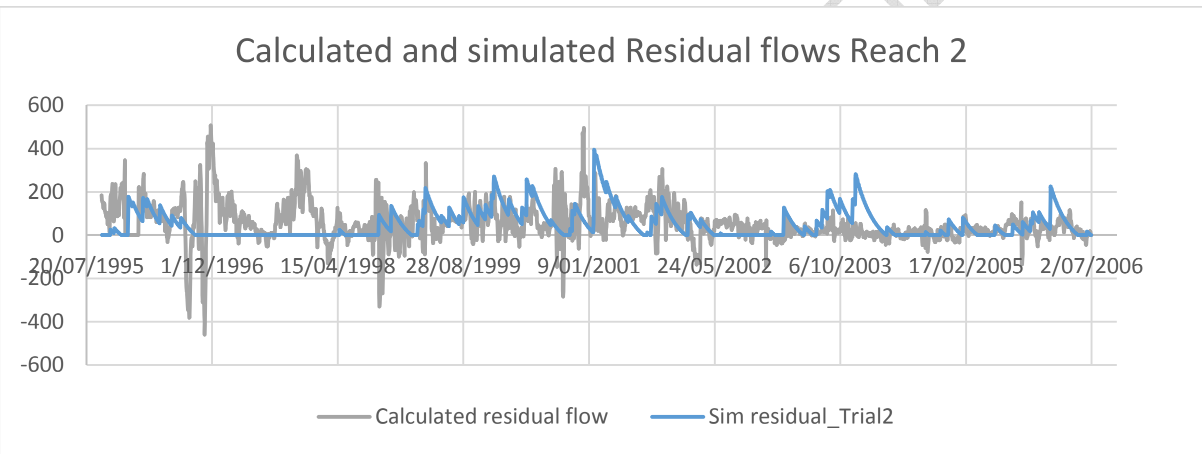
Observed and simulated flow – 2006



Residual flows Reach 2 – Calculated and simulated from Sacramento model Trial 1

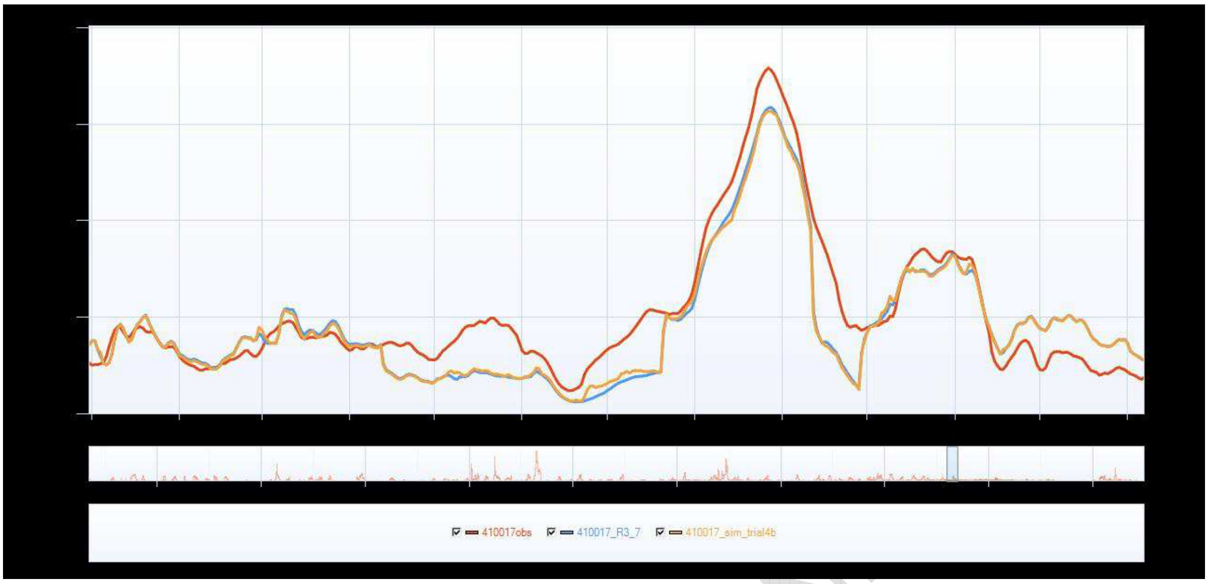


Residual flows Reach 2 – Calculated and simulated from Sacramento model Trial 2

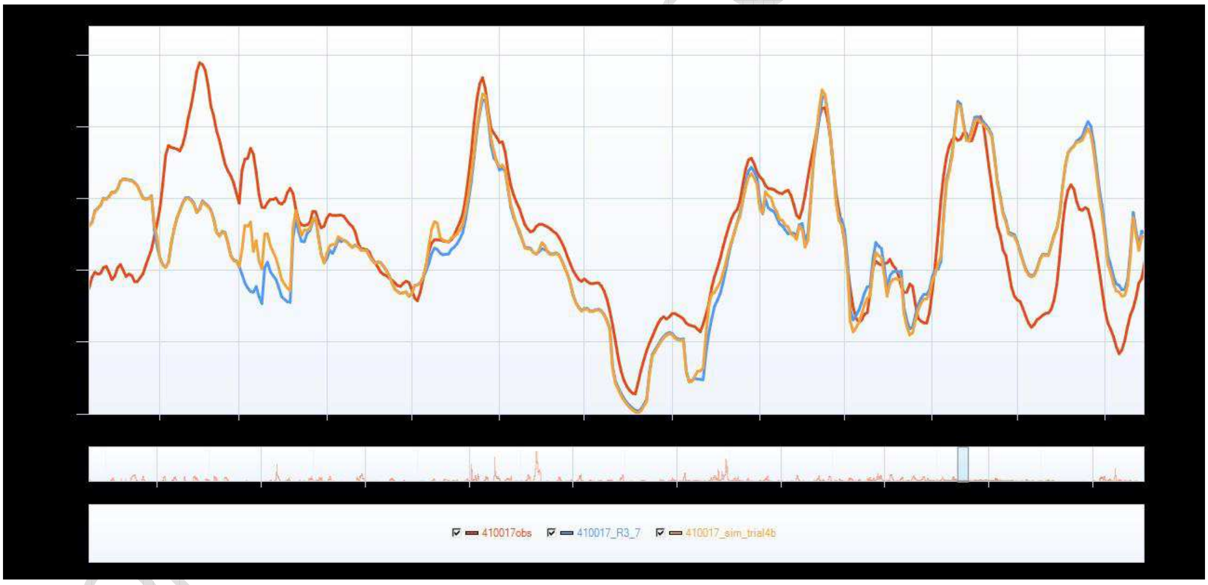


Reach 3 Time series plots of observed flows at 410017 (red line), 410017_R3_7 (blue line, simulated flows from IQQM reach model) and Trial 4 (orange line)

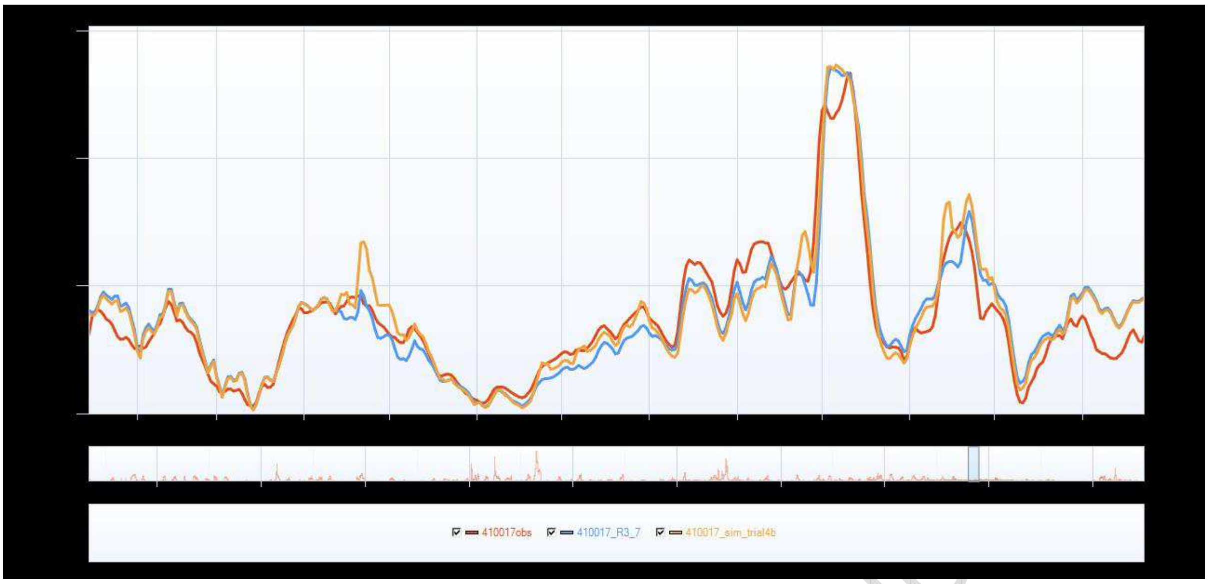
Observed and simulated flow – 1996



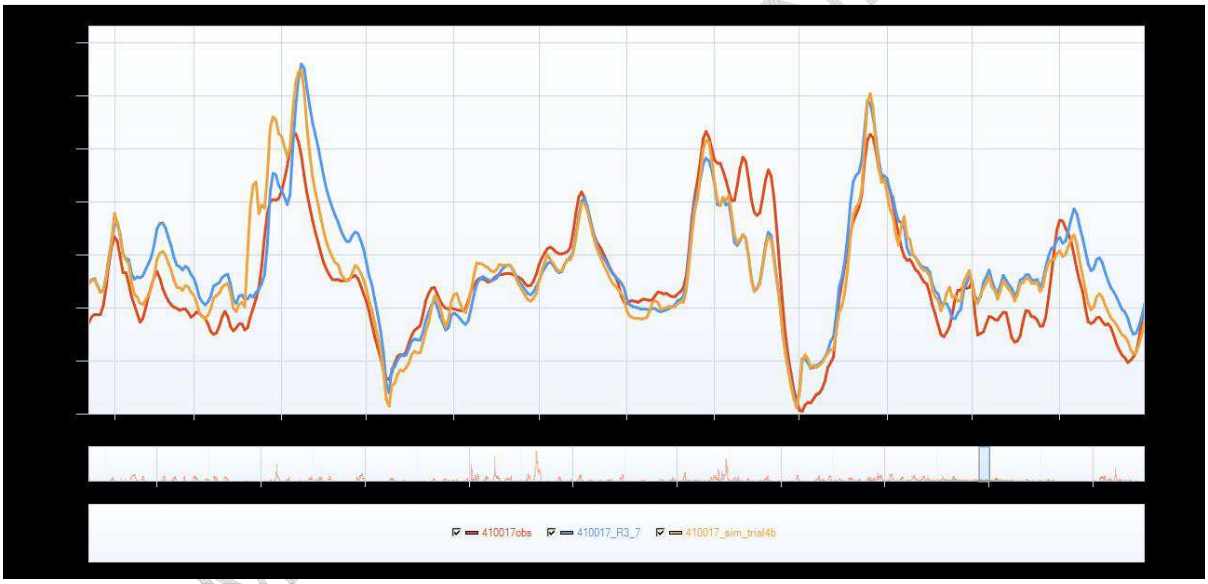
Observed and simulated flow – 1997



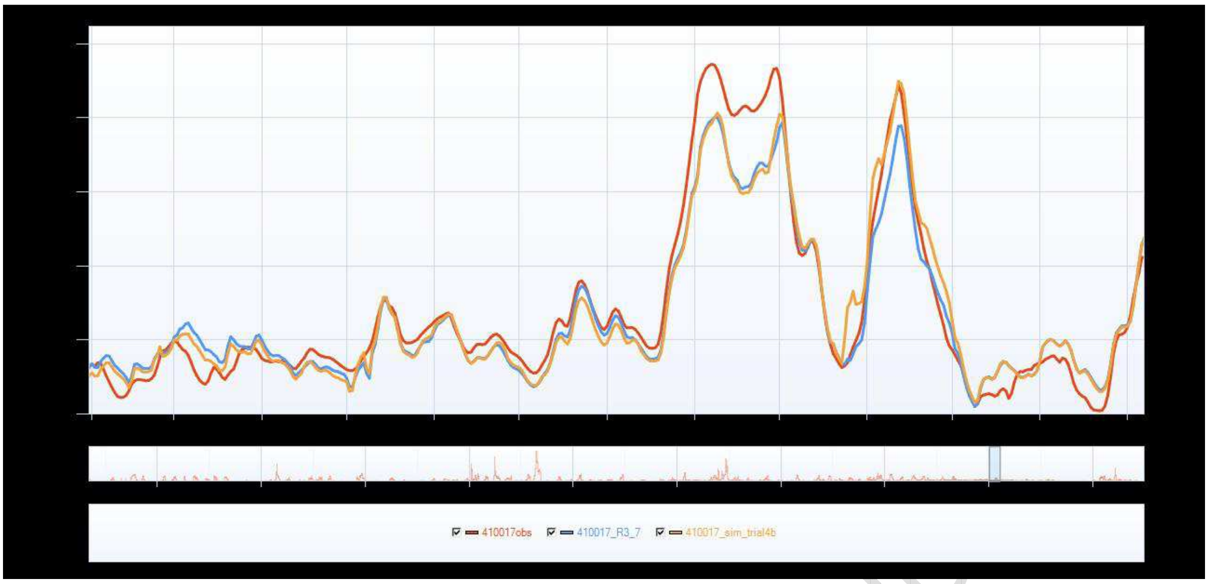
Observed and simulated flow – 1998



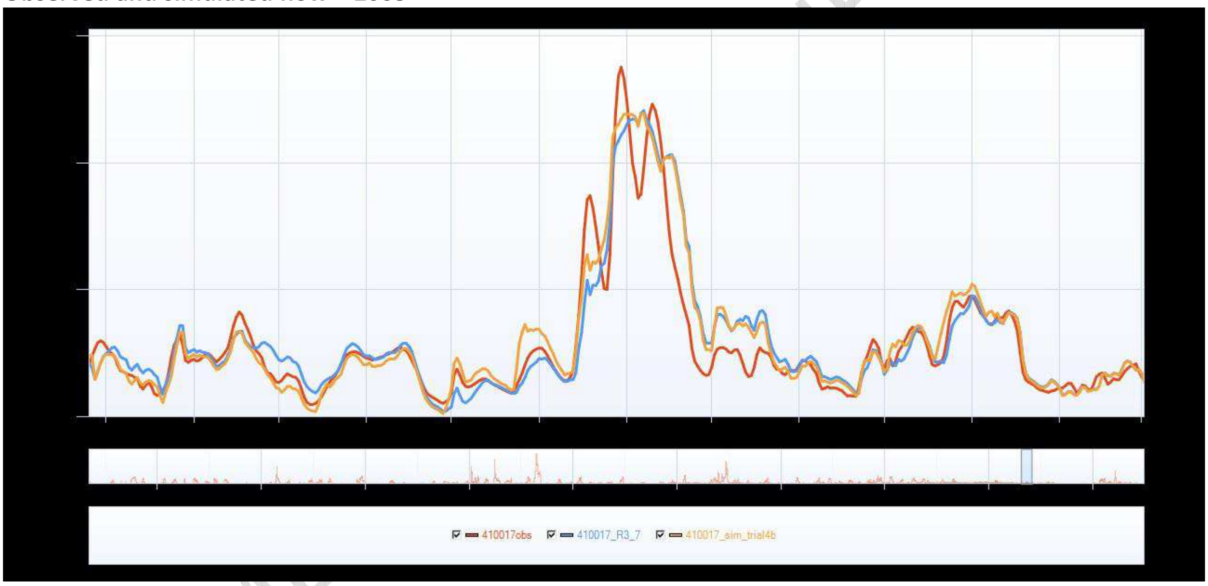
Observed and simulated flow – 1999



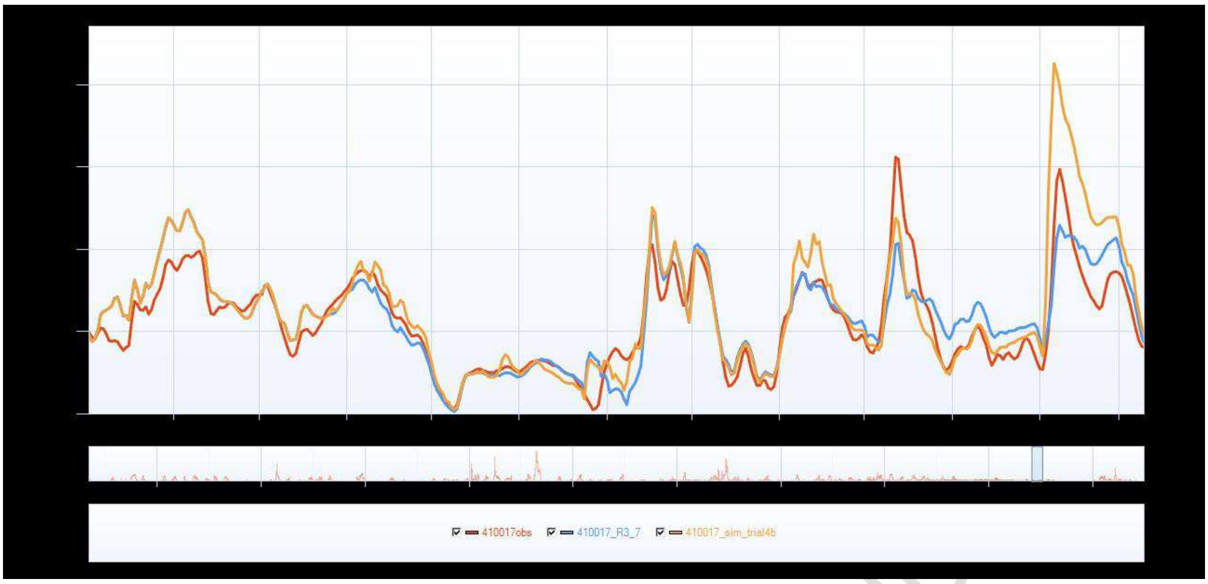
Observed and simulated flow – 2000



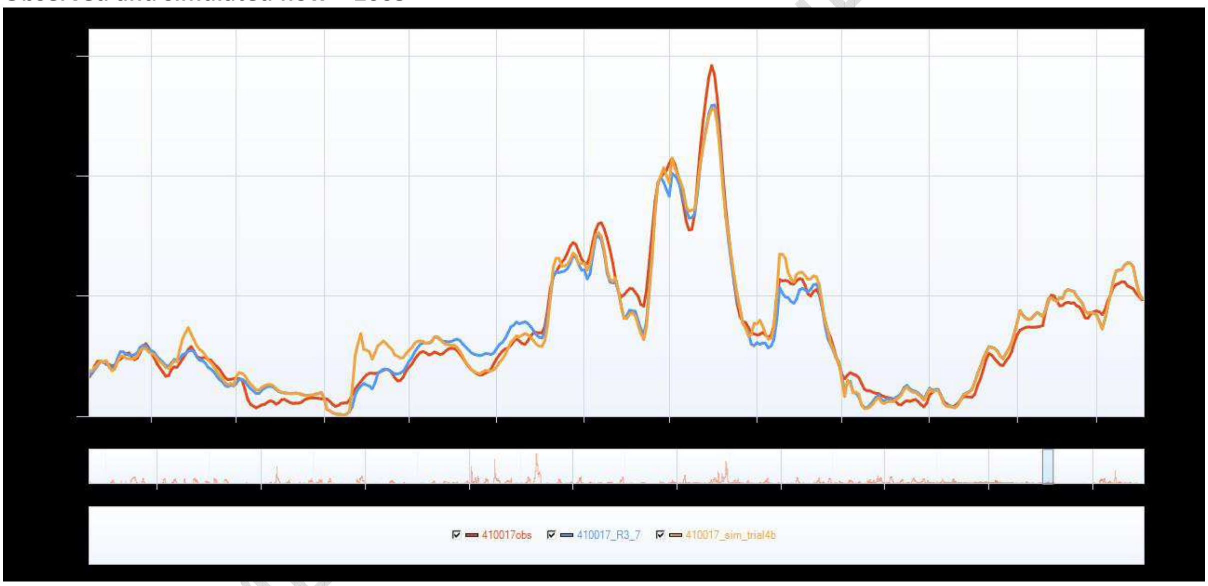
Observed and simulated flow – 2003



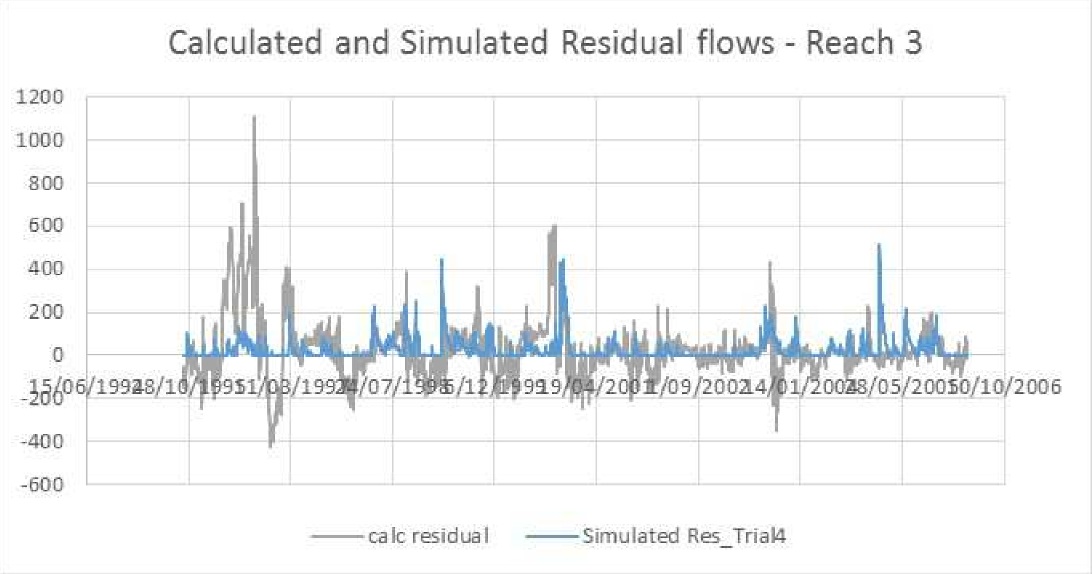
Observed and simulated flow – 2004



Observed and simulated flow – 2005



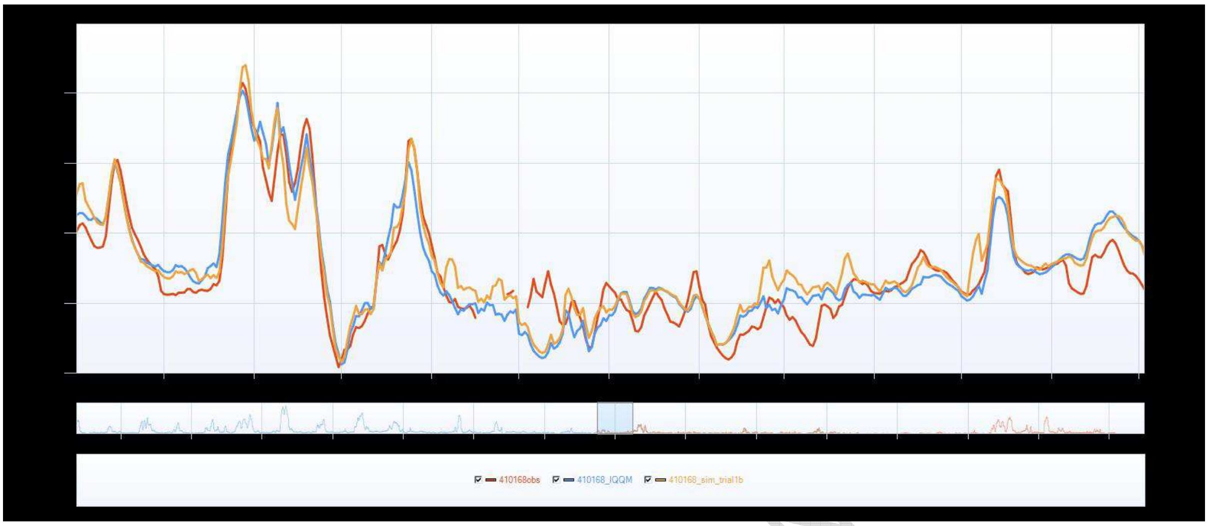
Residual flows Reach 3 – Calculated and simulated from Sacramento model Trial 4



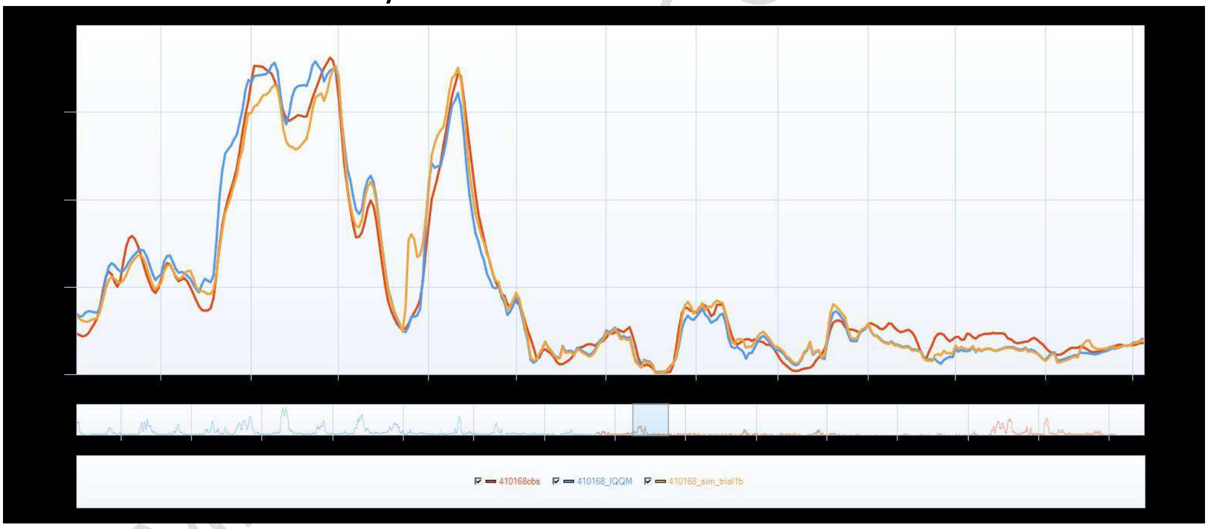
Reach 6

Time series plots of observed flows at 410186 (red line), 410186_IQQM (blue line, simulated flows from IQQM reach model) and resultant flows using Sacramento models Trial 1 (orange line)

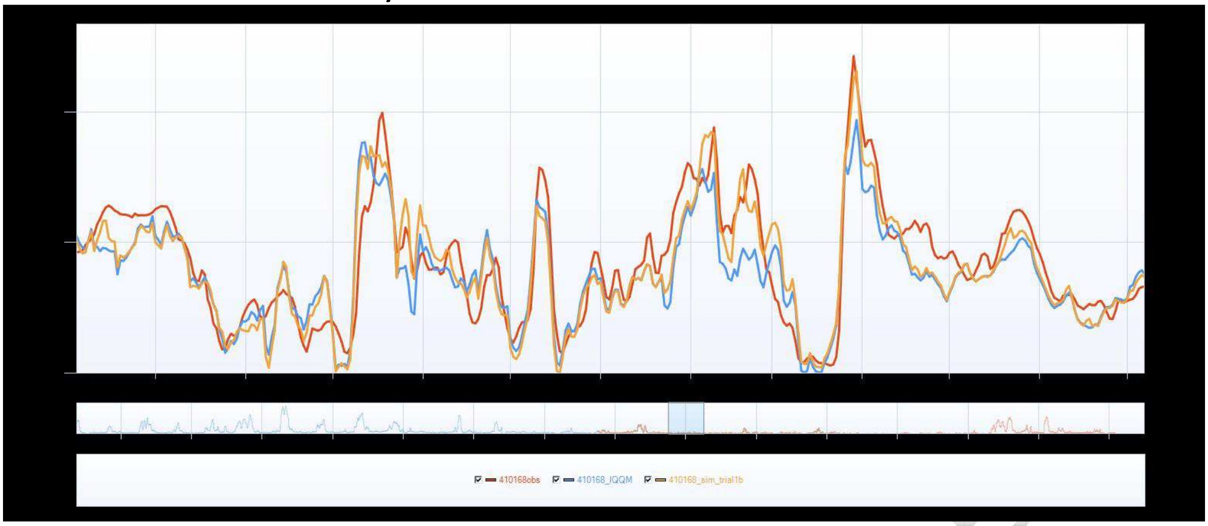
Observed and simulated flow – 1999 to 2000



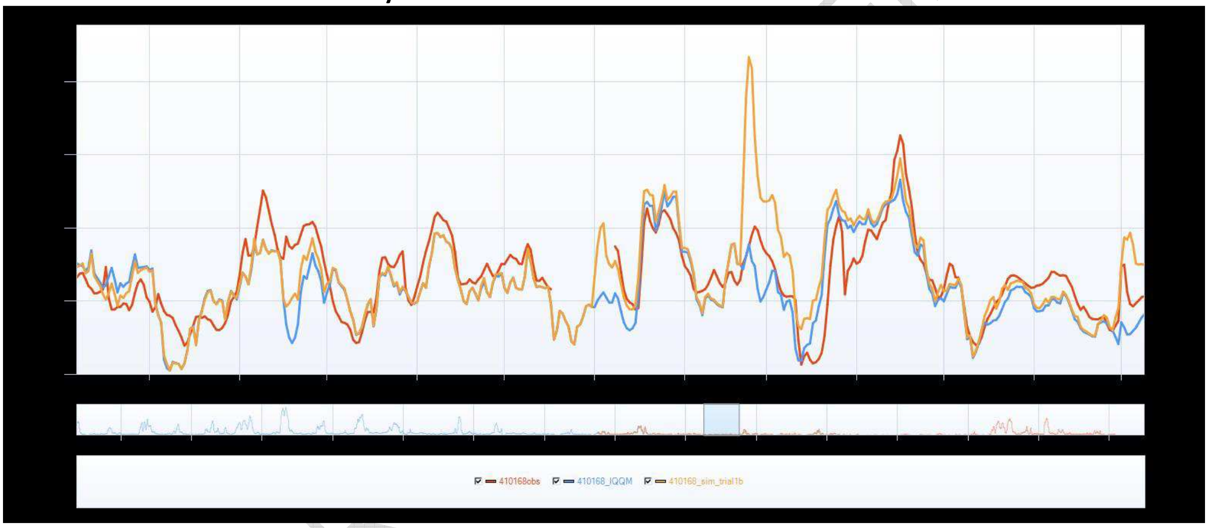
Observed and simulated flow – July 2000 to June 2001



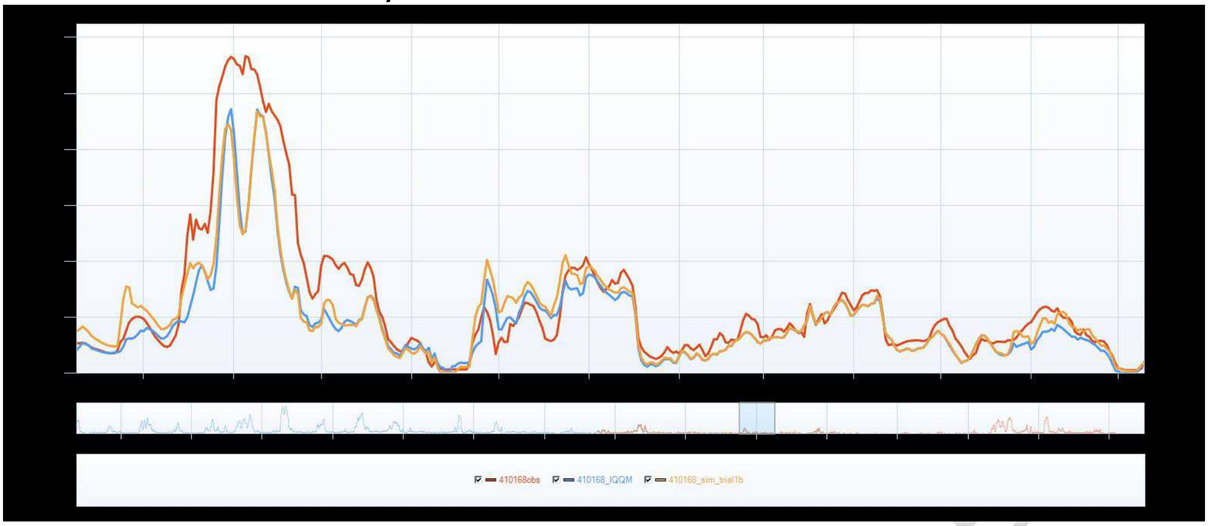
Observed and simulated flow – July 2001 to June 2002



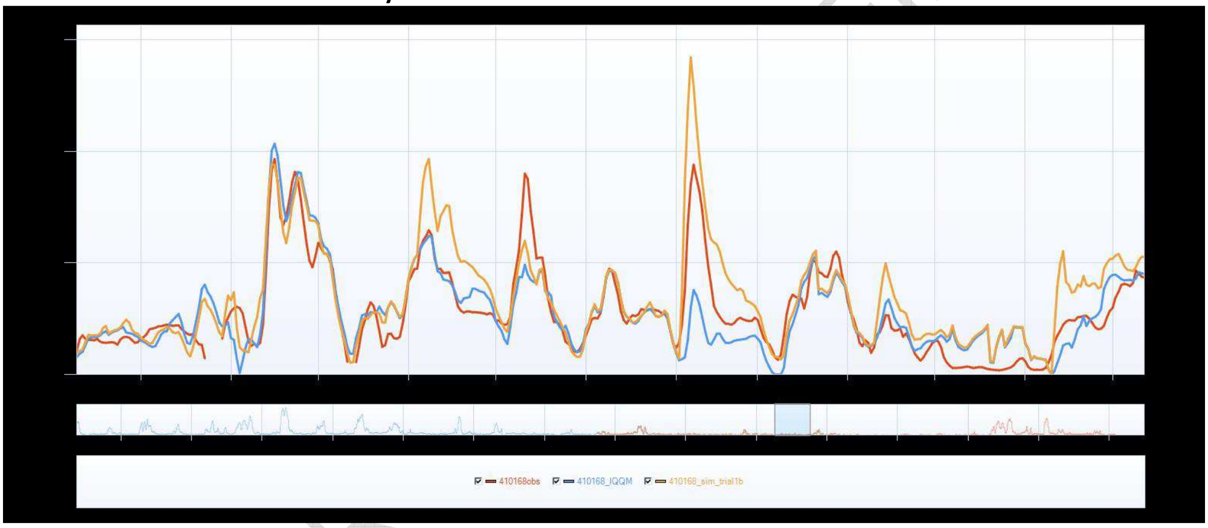
Observed and simulated flow – July 2002 to June 2003



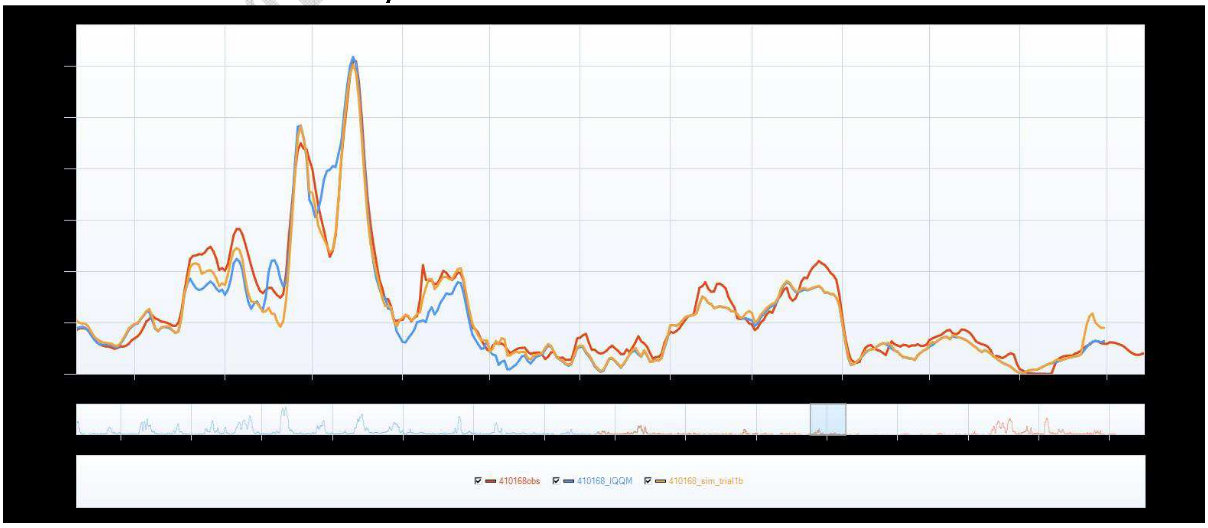
Observed and simulated flow – July 2003 to June 2004



Observed and simulated flow – July 2004 to June 2005

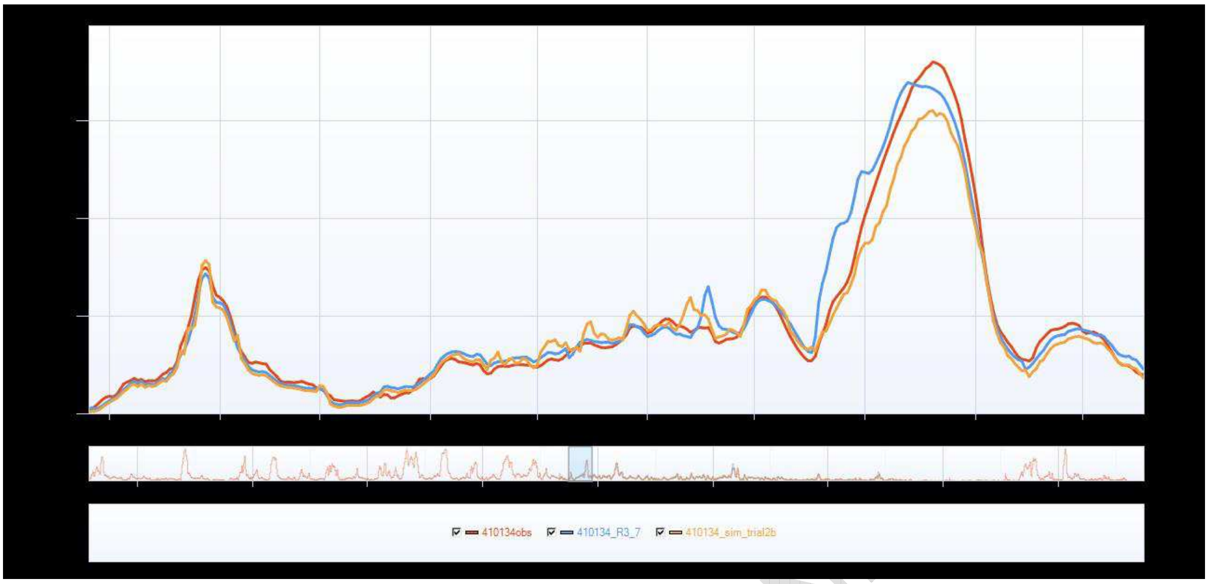


Observed and simulated flow – July 2005 to June 2006

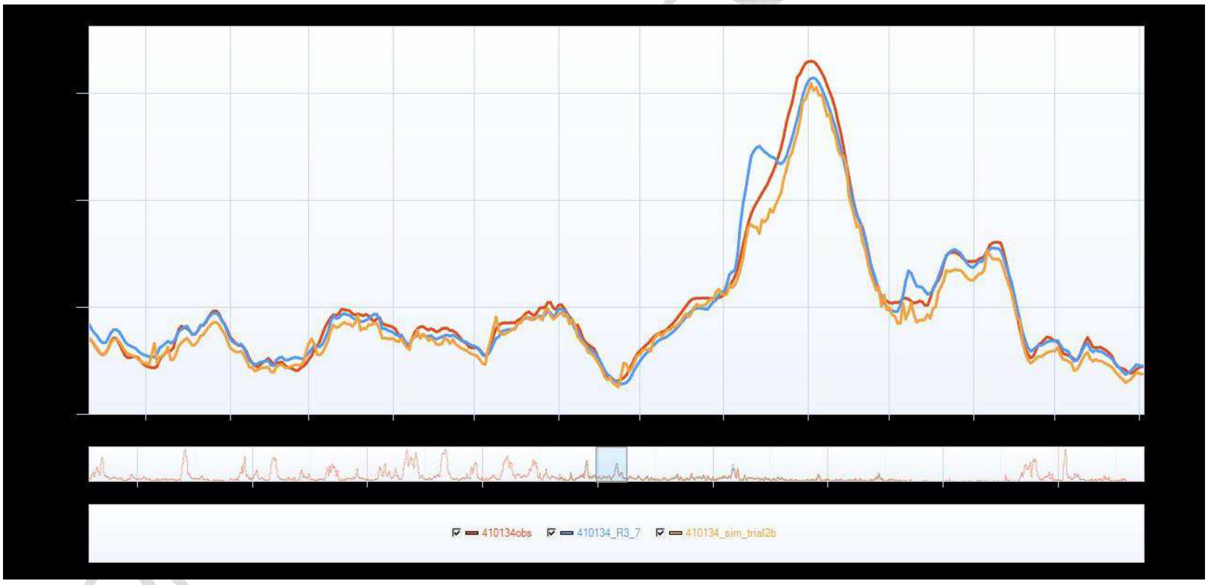


Reach 7 Time series plots of observed flows at 410134 (red line), 410134_R3_7 (blue line, simulated flows from IQQM reach model) and Trial 2 (orange line)

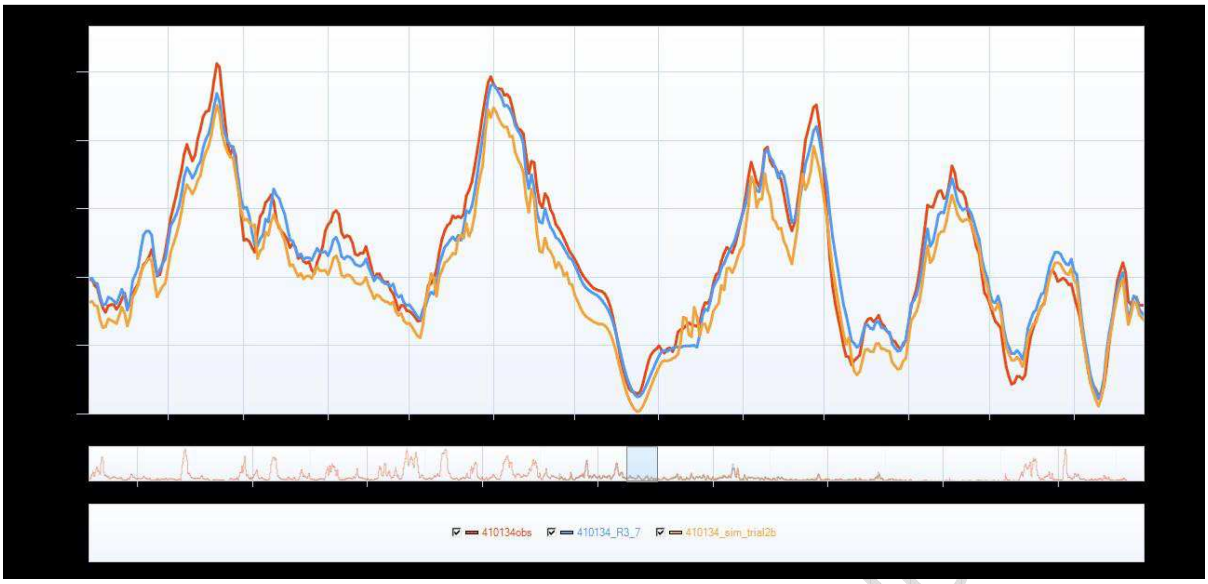
Observed and simulated flow – 1995



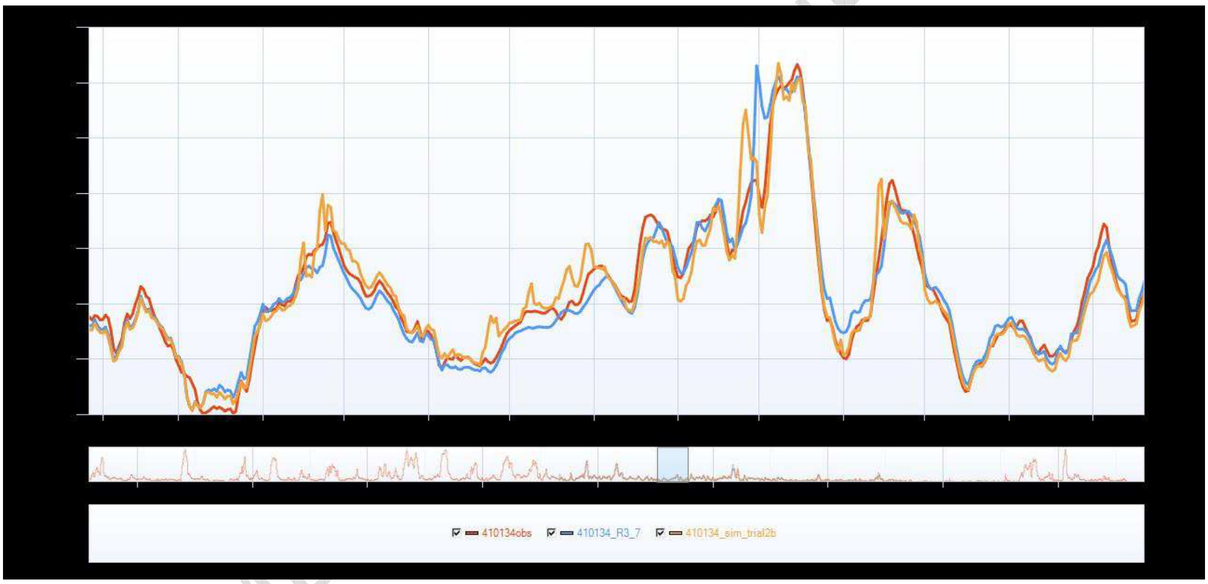
Observed and simulated flow – 1996



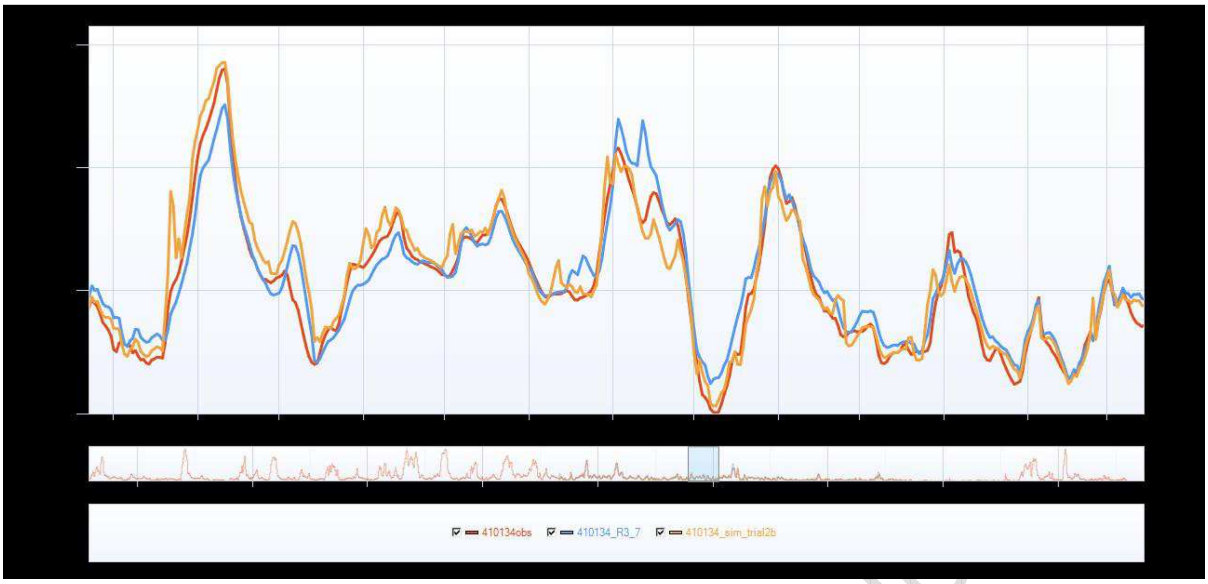
Observed and simulated flow – 1997



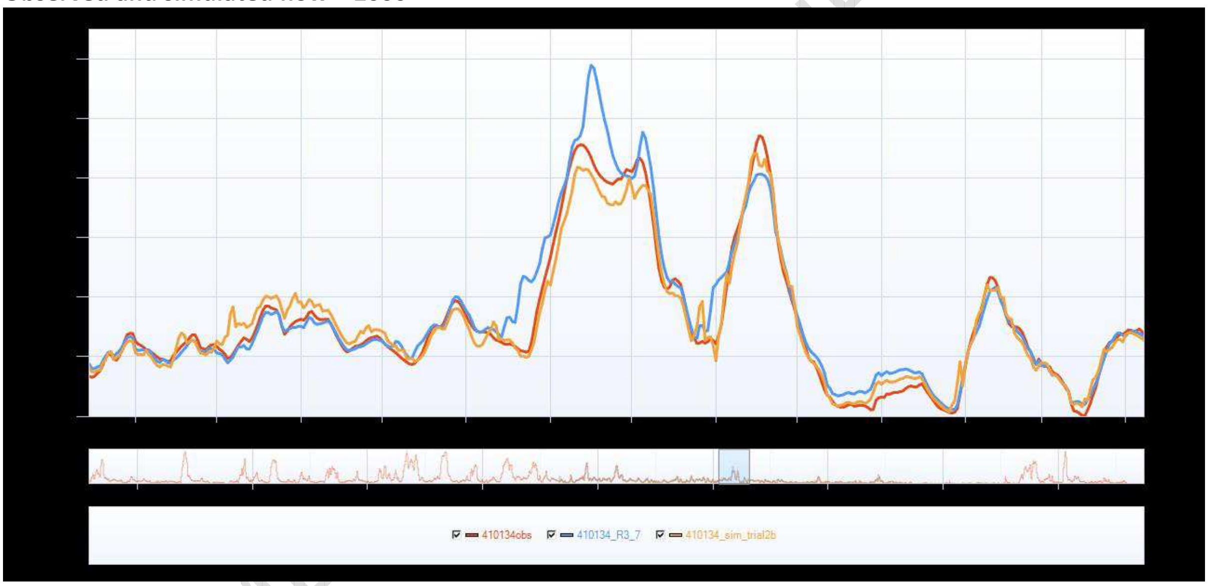
Observed and simulated flow – 1998



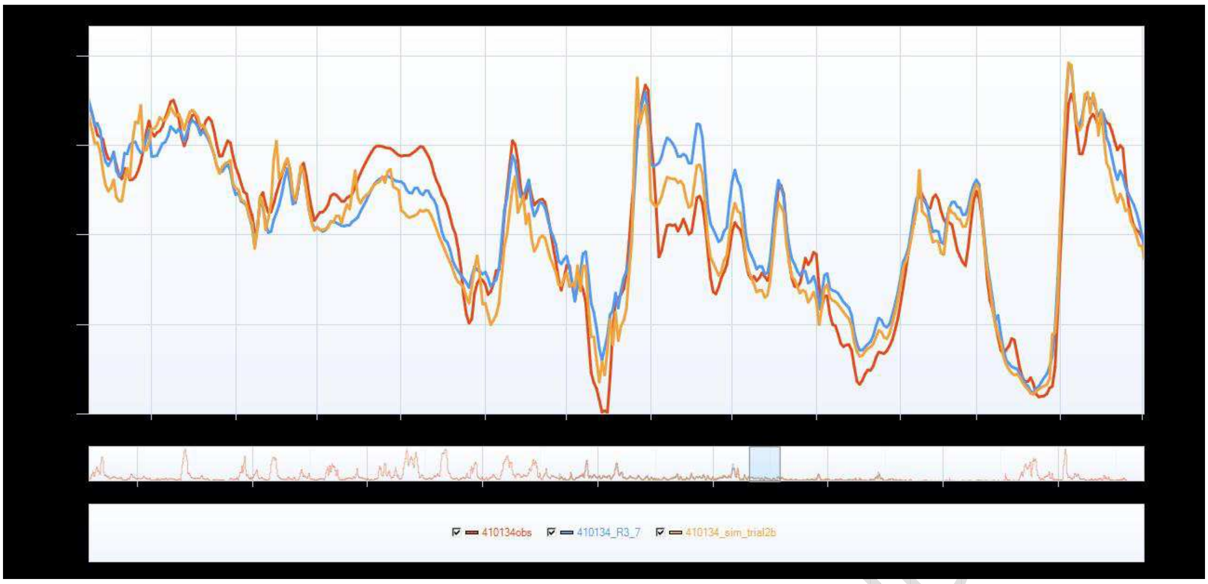
Observed and simulated flow – 1999



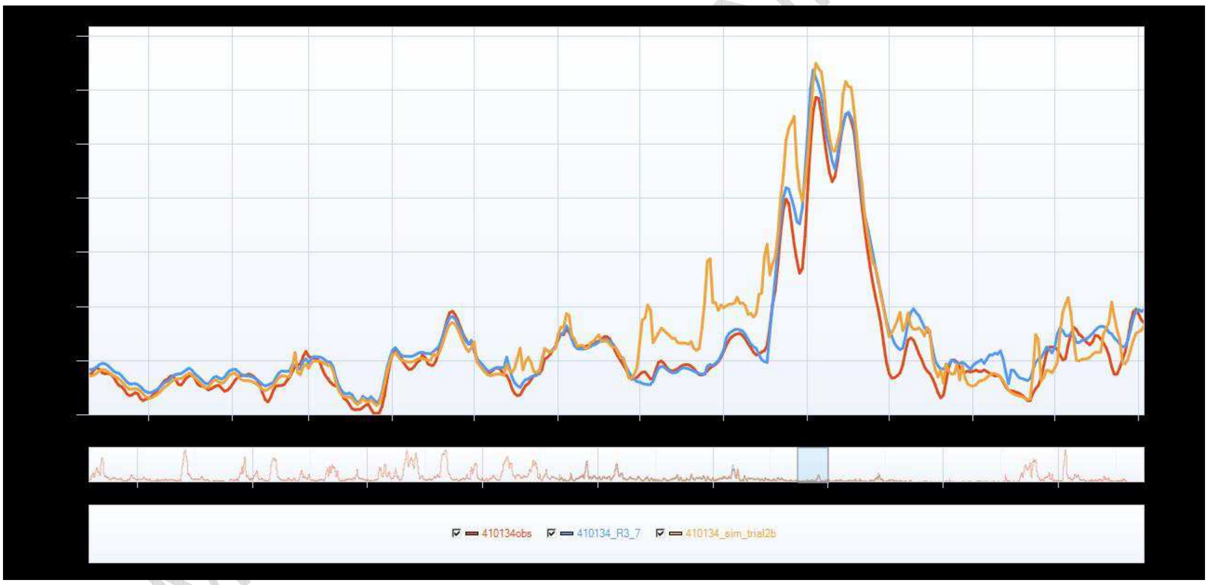
Observed and simulated flow – 2000



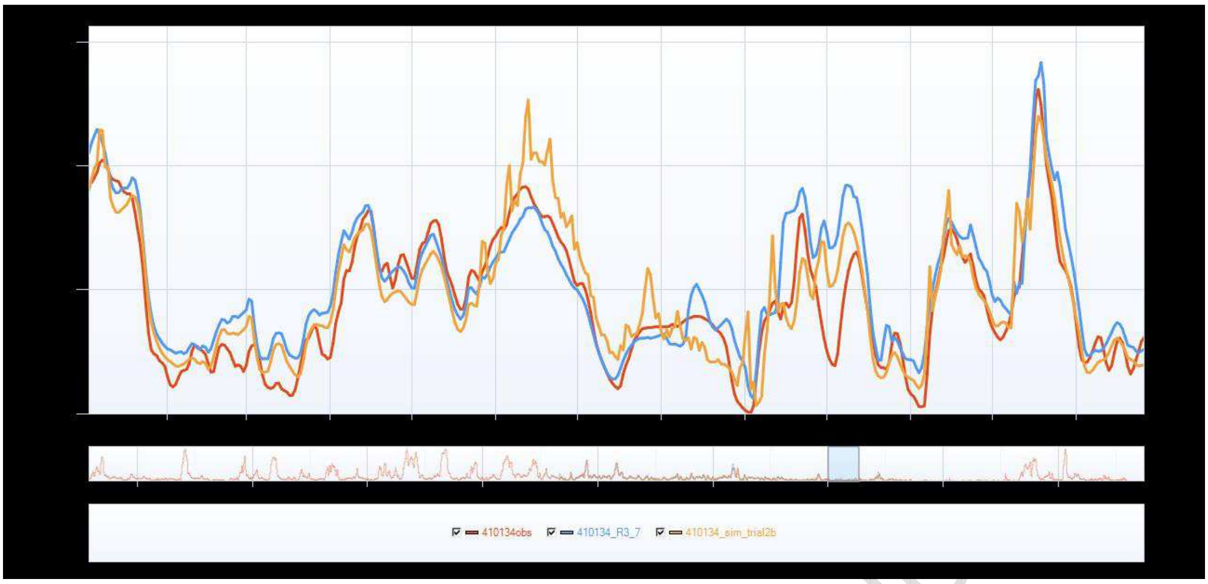
Observed and simulated flow – 2001



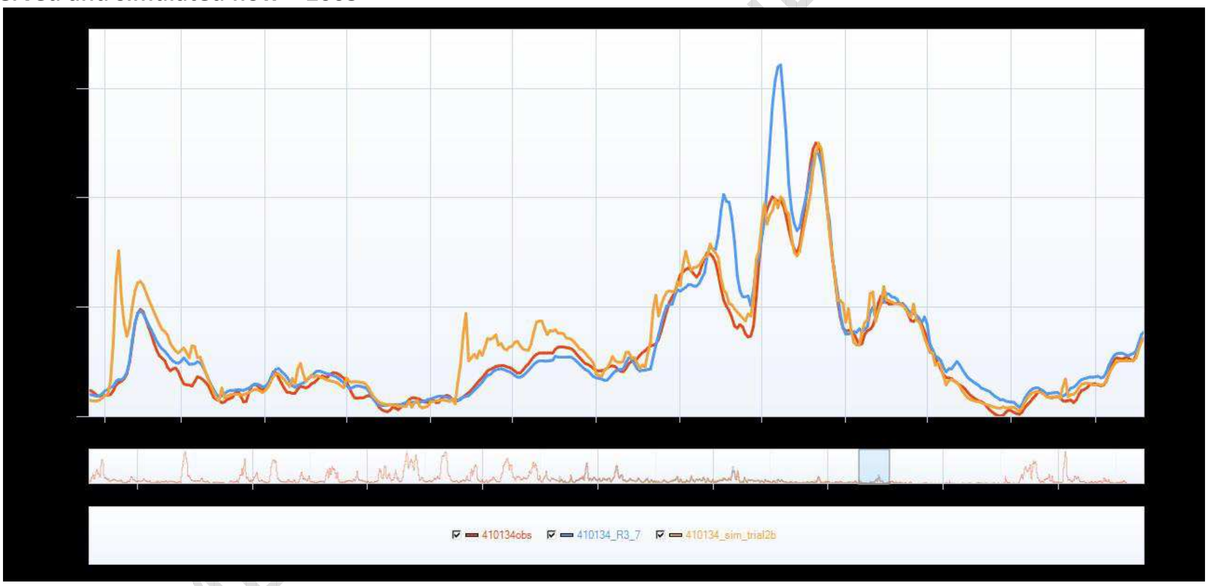
Observed and simulated flow – 2003



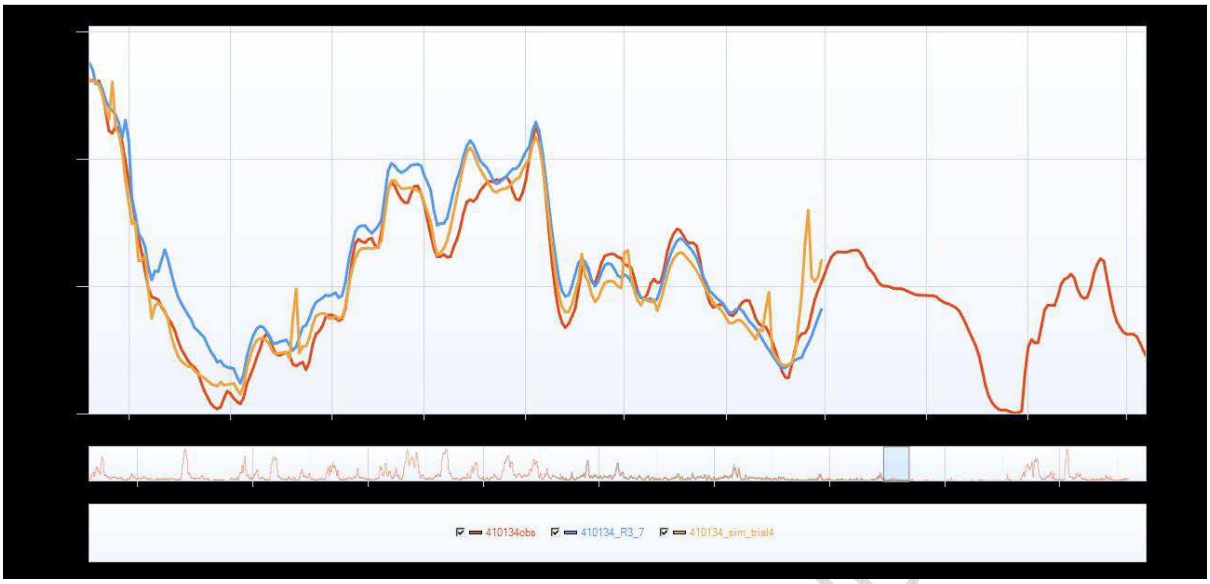
Observed and simulated flow – 2004



Observed and simulated flow – 2005



Observed and simulated flow – 2006



Murrumbidgee SDLA – Project models

22 March 2016

1 Project model overview

This report describes:

- The project model cases that have been developed
- How the models were developed from the Adjusted Benchmark model
- Key assumptions

The MDBA's Benchmark model was altered to produce an Adjusted Benchmark model (see note *Murrumbidgee SDLA – Update of Benchmark Model*, DHI, 2016). The Adjusted Benchmark was then changed to include the proposed SDLA projects for the Murrumbidgee. These include:

- Water for Rivers projects post 2009 (tripartite projects including CARM)
- Yanco Colombo Billabong modernisation project
- Yanco Offtake project
- Nimmie Caira project
- Yanga National Park project

Individual project models were produced for each of the above, as well as a combined overall model including all projects.

2 Project model development

2.1 Water for Rivers projects post 2009 (tripartite works)

This project includes a number of sub-projects which were carried out under the tripartite agreement between NSW Office of Water, Water for Rivers and State Water. These include:

- Wilson Anabranch and associated losses
- Beavers Creek existing offtake structure, and losses and return flows on the Beavers / Old Man Creek system
- Augmented supply via Irrigation Corporations:
    - Coleambally Irrigation Area escape drain operation and historical loss provision, and
    - Murray Irrigation Finley Escape drain operation,
- Oak and Gras Innes Wetland losses on Bundidgerry Creek
- Tributary utilisation for regulated orders (for CARM)
- Yanco Offtake operation (for CARM)
- Rainfall rejection from Murrumbidgee Irrigation (for CARM)

Prior to adding these tripartite projects, the Adjusted Benchmark model had been produced to allow better representation of these changes between the Benchmark and the post-project case. These changes are outlined in *Murrumbidgee SDLA – Update of Benchmark Model* (DHI, 2016).

The tripartite projects were added to the Adjusted Benchmark model to produce the post-project Tripartite works model. The significant changes to the model included:

- Wilson anabranch: adding a regulator that opens and closes the anabranch inlet on a seasonal basis, and change of the outlet relationship to reflect the outlet gate being left permanently open
- Beavers Creek / Old Man Creek: Replacement of the old weir structure with new gates, with these operated on a seasonal basis, and including some supplementary flow sharing; addition of the Dog Fall and Old Old Man Creek anabranch structures;; addition of the seasonal minimum flow target at the end of Old Man Creek
- Coleambally Irrigation Area Drains: Change of the ordering priority through Yanco Offtake, to provide a minimum 50 Ml/d through offtake, then to supply all additional Yanco Creek orders through the CI drains until they are at full capacity
- Murray Irrigation Finley Escape: Change of operation to alter drains flows in respond to orders at Puckawidgee, with this reducing orders being passed up Billabong Creek to the Yanco Offtake
- Oak Creek and Gras Innes Regulators (Bundidgerry): Removal of these wetland areas from the creek, to represent supply from environmental water volumes as required
- CARM tributary utilisation: change of the “available flow to use for orders” time series, with more flow now available then in the Adjusted Benchmark, to reflect better tributary forecasting
- CARM Yanco Offtake Operation: Reduction of the seasonal oversupply factor through Yanco Offtake from 1.25 to 1.20, to reflect improved operational information on Yanco Billabong under CARM
- CARM rainfall rejection: Reduction of orders into MI Main Canal at Berembed in response to rainfall to represent improved river forecasting capacity under CARM (Benchmark only reduces extractions, not orders)

These changes are implemented in the model BIDGDA3.sqq.

As part of the tripartite agreement, licences were granted to Water for Rivers for the water savings produced by these projects. These included a 20,000 unit share High Security licence and a 13,000 unit share General Security licence. These licences have been added into the post-project model, and are placed in the model at two dummy irrigation nodes immediately downstream of Blowering Dam (one for General Security and one for High Security licences). These are the same nodes used to represent the pre-2009 Water for Rivers projects in the Adjusted Benchmark, with the licence volumes increased to include the additional tripartite projects licence.

The increased utilisation of Finley Escape also increases the volume coming through into the Murrumbidgee Valley from the Murray. This additional volume has to be returned to the Murray to ensure there is no net change in the intervalley trade balance. This is done in the model by adding a dummy irrigation node downstream of Balranald. This node orders and diverts a long-term average amount that is the same as the increase in Finley Escape outflow. This dummy node effectively sets aside water from the allocation to restore the IVT balance.

The addition of the projects also reduces the surplus flows within the system, including reducing end of system flows at Balranald and Moulamein. In the model, this reduction in surplus flow is linked to a reduction in dam releases, as unnecessary releases are reduced. This produces an increase in storage in the model, and an associated increase in allocations occurs. In the version of the post-project model provided, the allocation is allowed to increase, and there are no specific nodes calling this retained surplus out of the dams.

The projects also reduces the long-term average inflow to Lowbidgee by approximately 2,800 ML/yr compared to the Adjusted Benchmark case. This reduction has not been restored in the post-CARM case, as the combined model includes diversion into Nimmie Caira and Yanga to satisfy environmental inundation targets.

2.2 Yanco Colombo Billabong modernisation project

This project includes a number of modifications to the Yanco Colombo Billabong system, as outlined in the Effluents Business Case. These include:

- DC800: Increase of the capacity of the Coleambally Irrigation drain DC800 from 50 ML/d to 100 ML/d
- Lower Yanco Weir: A new weir to re-regulate flows
- Colombo Weirs: Addition of re-regulation structures on Colombo Creek, at 8 Mile, Chesneys Weir, Cocketdegong and Coonong Weir (these are modelled as one combined weir in the model)
- Murray Irrigation Berrigan Escape: Supply of up to 100 ML/d through Berrigan Escape in response to orders. This is done in the model based on the remaining order upstream of Finley Escape, though maintaining a minimum 60ML/d in the creek upstream of Berrigan Escape
- Hartwood Weir: Reconstruction of the weir to include re-regulation storage
- Downstream of Yanco and Billabong confluence: A new weir to re-regulate flows
- Wanganella: A new weir to re-regulate flows
- Piccanniny diversion: Extraction of surplus flows at the end of Forest Creek, and diversion of these through Piccanniny Creek back into Billabong Creek
- Existing structures on Billabong Creek at Algudgerie and on Mid Yanco Creek: Lowering of these fixed crest structures to reduce losses

These changes are implemented in the model BIDGEA9.sqq.

The utilisation of Berrigan Escape increases the volume coming through into the Murrumbidgee Valley from the Murray, as was noted for the tripartite works projects for Finley Escape. This additional Berrigan Escape volume also has to be returned to the Murray to ensure there is no net change in the intervalley trade balance. The dummy irrigation node downstream of Balranald created to balance the tripartite Finley Escape additional flow is adjusted in the model to balance the combined increase in both Finley and Berrigan Escapes.

The re-regulation structures in the model are represented using in-line storages. These storages accumulate excess discharge. When the weir has reached a threshold stored volume, it reduces the order being passed upstream by the amount it has stored. It subsequently releases this on the appropriate day to supply the downstream order.

Existing fixed crest structures on the Mid-Yanco and at Algudgerie on Billabong Creek are modelled as time series of evaporation losses. Different time series are used for the Adjusted Benchmark and post-project models.

2.3 Yanco Offtake project

This project involves construction of a regulator on Yanco Offtake, as described in the *Business Case: Yanco Offtake SDL Adjustment Supply Measure* (Alluvium, XXX). The changes to the Adjusted Benchmark model are in the model BIDGMFE6.sqq

The offtake itself is implemented in the model by adding a control structure in the model, with an assumed maximum diversion capacity for the structure.

The approach in the Benchmark model to surplus flow sharing between the Murrumbidgee River and Yanco Creek is changed in the post-project model. The surplus flow diversion is determined by a new time series that specifies large diversions into Yanco Creek, in order to achieve bankfull and overbank flows within the creek system. This is specified in the Yanco Offtake Business Case.

The post-project model also includes a minimum flow time series downstream of the Yanco Offtake. This minimum flow aims to preserve the flow regime in the creek when river flows are less than 15,000 ML/d. It does this by extracting the Benchmark time series of discharges through the offtake for river flows < 15,000 ML/d, and adding this as minimum flow node referring to the extracted time series.

2.4 Yanga National Park 1AS regulator project

This project is described in the *Business Case: Murray and Murrumbidgee Valley National Parks SDL Adjustment Supply Measure* (Alluvium, October 2015). One of the measures proposed by this project is reconstruction of the Yanga 1AS regulator. The Business Case estimates this leaks water from the river into Yanga National Park at an average rate of approximately 5,400 ML/yr.

To model this the river loss between Maude Weir and Redbank Weir was changed. The loss rate in the benchmark model is a constant 55 ML/d for all flows greater than 55ML/d. This was reduced to 40 ML/d in the post-project model (which is equivalent to an annual volume of 5,400 ML as flows do not fall below the 55 Ml/d threshold).

The changes to the Adjusted Benchmark model are in model BIDGFA2.sqq.

2.5 Nimmie Caira – Yanga National Park project

This project is described in the *Business Case: Nimmie-Caira SDL Adjustment Supply Measure* (Alluvium, XXX). The Business Case identifies target environmental water volumes inside Nimmie – Caira and Yanga National Park, which should be achieved on a target inter-annual frequency.

The project is modelled by diverting additional volumes out of the river to try and achieve these target volumes. Targets differ for different cases - the four cases considered were:

- Nimmie Caira with no rehabilitation: Target environmental volumes based on Nimmie Caira requirements, without any rehabilitation works of the floodplain inside Nimmie Caira having been carried out (i.e. current configuration)
- Nimmie Caira with rehabilitation: Target environmental volumes based on Nimmie Caira requirements, with rehabilitation works of the floodplain inside Nimmie Caira having been carried out
- Nimmie Caira and Yanga National Park with no rehabilitation: Target environmental volumes based on both Nimmie Caira and Yanga National Park requirements, without any rehabilitation works of the floodplain inside Nimmie Caira having been carried out (i.e. current configuration)
- Nimmie Caira and Yanga National Park with rehabilitation: Target environmental volumes based on both Nimmie Caira and Yanga National Park requirements, with rehabilitation works of the floodplain inside Nimmie Caira having been carried out

The targets specified in the business case were simplified in order to make them assessable in the model. The set of targets applied in the model were:

Table 1 Nimmie Caira and Yanga environmental water volume targets

Case	Model Name	Supply Measure (GL) achieved in percentile of years			
		95% tile	50% tile	40% tile	14% tile
Nimmie Caira (no Rehab)	BIDGA02	3	46	192	302
Nimmie Caira (with Rehab)	BIDGA03	3	46	290	414
Yanga and Nimmie Caira (no rehab)	BIDGA04	26	46	248	664
Yanga and Nimmie Caira (with Rehab)	BIDGA05	26	46	346	774

In order to apply these targets in the model, the following approach was used:

- Years in which SFI targets at Maude Weir are met in the model are identified – this is taken as an indicator that sufficient flow may be available to divert water into Nimmie Caira / Yanga to reach a watering target event
- The volume of environmental water already diverted into Lowbidgee is calculated from the Benchmark model run
- The additional volume required to reach the target is then worked out in a spreadsheet; this is done for each of the four target columns in Table 1
- The additional volume required for the four targets is disaggregated into a daily diversion series, based on the time series of surplus flows available according to the Benchmark run results
- The resulting time series is set as a diversion series in the project model
- The project model is run, and it is checked whether the target volumes are achieved, and whether the frequency of reaching these volumes is within the range specified in the business case

The project model is modified from the Adjusted Benchmark model. It includes an additional Lowbidgee floodplain storage that is separate to the “bucket” storages in the benchmark model. All additional discharge to meet the target event volume is diverted into the separate floodplain bucket.

Furthermore, it is assumed that none of the additional diverted flow to meet the environmental targets returns to the Murrumbidgee River. It is assumed that the entire volume is retained within Lowbidgee and eventually lost to the system.

3 Combined project model

The combined model includes all of the individual SDLA project model changes. As there four different Nimmie-Caira and Yanga National Park cases, there are four different versions of the combined project model file, as outlined in Table 2.

Table 2 Combined project model files

Case	Model Name
Nimmie Caira (no Rehab)	BIDGCA2
Nimmie Caira (with Rehab)	BIDGCA3
Yanga and Nimmie Caira (no rehab)	BIDGCA4
Yanga and Nimmie Caira (with Rehab)	BIDGCA5

The key issues and assumptions regarding the combined model are summarised here:

- The models do not include nodes to utilise any water “produced” by the projects, instead any gain will result in an increased long-term allocation in the model
- Changes to Finley and Berrigan escapes increase the amount of water diverted from the Murray into Billabong Creek, and a dummy irrigation node downstream of Balranald is used to balance the IVT
- The water savings licences associated with the tripartite projects (including CARM) are included in the model, and are added to dummy irrigation nodes situated immediately downstream of Blowering Dam (these nodes also include the pre-2009 Water for Rivers project licences)
- There is a small decrease in Lowbidgee diversions in the post-CARM model (2.8 GL/yr), however the combined model includes the Nimmie-Caira environmental targets which override this
- Yanco Offtake is modelled with a fixed low flow regime, which is based on the MDBA Benchmark model discharge time series through the offtake (instead of specific low flow targets at the offtake)

Attachment D: Amendment 1 – Murrumbidgee proposals

This amendment applies to the following proposals:

1. Nimmie-Caira Infrastructure Modifications Proposal
2. Improved flow management works at Murrumbidgee Rivers - Yanco Creek offtake
3. Modernising supply systems for effluent creeks
4. Computer Aided River Management (CARM)
5. Murray and Murrumbidgee Valley National Parks

Note: this amendment applies to the Murrumbidgee component of the Murray and Murrumbidgee Valley National Parks proposal. The Murray component, though retained in the notification, will not be modelled under the SDL adjustment mechanism and as such will not form part of the M D BA's adjustment determination.

The proposals are all incorporated in the NSW IQQM model of the Murrumbidgee River. This model has been developed by NSW DPI and subsequently reviewed by MDBA modellers. The model is linked to the MDBA MSM Bigmod as part of the overall modelling framework for the Southern Connected Basin.

The NSW projects Effluent Creeks and CARM have entitlements associated with them. NSW has confirmed that the entitlements will be provided as a single unencumbered NSW General Security entitlement. An Inter Valley Trade account will either be established or an existing account modified to mitigate any third party issues in terms of reliability impacts for Murray downstream users.

MDBA has conducted modelling assessment to determine the volume of general security entitlements and IVT account from the CARM and Modernising supply system for Effulent Creeks projects. The modelling assessment is presented at Appendix E.

Appendix A: Murrumbidgee model updated by NSW

The original Murrumbidgee Basin Plan Benchmark model for the SDL adjustment had a number of deficiencies preventing the Murrumbidgee supply measures from being assessed in a sensible technical manner. MDBA received the Murrumbidgee models from NSW which addressed deficiencies. The latest models (MDBA Trim No: D17/20418) have been incorporated into the MDBA's modelling framework (Rev No: 4625) to form a basis of modelling assessment for SDL adjustment. The changes made to the model by NSW are well documented in the NSW DPI Water reports.

MDBA has subsequently merged each of the Murrumbidgee SDLA project models into one combined model and incorporated it into the modelling framework (Rev No: 4626).

The reports from NSW that describe these changes are set out in Attachment E.

Appendix B: Further changes made by MDBA

There are two specific changes made by the MDBA to improve model fitness, as follows:

Representing Water for Rivers

To model a reduction in the required annual release from the Snowy, extraction nodes from Blowering Dam have been included by NSW. MDBA has adjusted Murrumbidgee entitlements and irrigation area so that the long term average extracts are equal to the LTCE numbers of 96 GL for the Benchmark (ie prior to 2009) and 123.3 GL for the SLDA model (post 2009) as shown in Table 1.

Table 1: Water recovered through the Water for Rivers initiatives

	Measures	HS	Conveyance	GS	LTCE
Prior to 2009	Water Purchase			40.4	25.7
	On-farm reconfig			21.5	13.7
	Coleambally conveyance		3.5		3.4
	Mbidgee irrig (Barren Box Swamp)		20.0		19.3
	Hay PID		1.0		1.0
	Forest Ck	34.7			33.0
	Total	34.7	24.5	61.9	**96.0**
Post 2009	Tripartite works	20.0			19.0
				13.0	8.3
	Total	20.0	0.0	13.0	**27.3**

Tributary utilisation

In consultation with NSW, MDBA has applied redeveloped tributary utilisation time-series from modelled tributary inflows. Table 2 presents annual averages before and after the MDBA's update.

Table 2: Annual average of tributary utilisation

Benchmark	**As provided by NSW (GL/yr)**	**Updated by MDBA (GL/yr)**
Gundagai - Wagga	319	288
Muttama upstream	32	32
Jugiong	197	197
Tumut downstream	207	207
Tumut upstream	290	290
Post CARM		
Gundagai - Wagga	411	390
Muttama upstream	38	38
Jugiong	255	255
Tumut downstream	261	261
Tumut upstream	290	318

Appendix C: Spatial data describing the inundation extent associated with the Improved Flow Management Works (Yanco Creek) proposal

To represent the impact of the Yanco Creek proposal on inundations areas, it is assumed that the area of the floodplain affected by the Improved Flow Management Works (i.e. upstream of Yanco Creek) would reach the inundation area associated with the Specific Flow Indictors (SFI) at a 10% lower flow threshold.

To illustrate, without Improved Flow Management works SFI 1 is associated with a flow of 26,850 ML/d for 45 days.

For the part of the floodplain affected by the works, SFI 1 would be considered successful if a flow of 24,621 ML/d for an appropriate number of days is achieved.

The inundation areas associated which each SFI flow band have been split into that part affected by the works and that part unaffected. This provides separate hydrological assessment units (HAUs) for the assessment of Ecological Outcome scores. Total floodplain area affected and unaffected by the works is presented in Table 3.

Table 3: Total area (Ha) of the floodplain targeted by the Specific Flow Indicators, split in an area not affected by the works, and an area affected by the work.

Mid Murrumbidgee Floodplain	Inundation area (ha)
Floodplain area not affected by works	66942
Floodplain area affected by works	26234
Total floodplain area	93176

The areas for the separate hydrological assessment units (HAU) are provided in Tables 4 and 5. The areas for the specific flow thresholds represent the inundation area *additional* to the area already inundated by a lower flow threshold.

Table 4: Inundation area (hectares) additional to the area already inundated by a lower flow threshold for hydrologic assessment units outside the area impacted by the works.

	SFI Bands ML/day			
Ecological Element	**26,850**	**34,650**	**44,000**	**63,250**
General health and abundance - all Waterbirds	6715.4	3770.8	15151.0	41305.3
Bitterns, crakes and rails	1538.2	290.4	551.3	41.3
Breeding - Colonial-nesting waterbirds	6715.4	3770.8	15151.0	41305.3
Breeding - other waterbirds	1538.2	290.4	551.3	41.3
Redgum Forest	2681.7	1211.3	4359.9	402.7
Redgum Woodlands	12.3	11.6	81.4	12.4
Forests and Woodlands: Black Box	166.3	112.1	305.6	48.4
Lignum (Shrublands)	0.0	0.0	0.0	0.0
Tall Grasslands, Sedgelands and Rushlands	1525.6	285.9	507.4	40.6
Benthic Herblands	0.0	0.0	0.0	0.0
Short lived fish	1538.2	290.4	551.3	41.3
Long lived fish	6715.4	3770.8	15151.0	41305.3

Table 5: Inundation area (hectares) additional to the area already inundated by a lower flow threshold for hydrologic assessment unit impacted by the works

	SFI Bands ML/day			
Ecological Element	**24,621**	**31,522**	**39,912**	**56,700***
General health and abundance - all Waterbirds	15337.7	3864.6	7031.3	0.0
Bitterns, crakes and rails	2411.2	211.9	227.3	0.0
Breeding - Colonial-nesting waterbirds	15337.7	3864.6	7031.3	0.0
Breeding - other waterbirds	2411.2	211.9	227.3	0.0
Redgum Forest	10824.4	2386.4	3958.3	0.0
Redgum Woodlands	319.7	141.4	186.2	0.0
Forests and Woodlands: Black Box	1732.4	539.9	871.9	0.0
Lignum (Shrublands)	0.0	0.0	0.0	0.0
Tall Grasslands, Sedgelands and Rushlands	2410.1	211.9	227.3	0.0
Benthic Herblands	0.0	0.0	0.0	0.0
Short lived fish	2411.2	211.9	227.3	0.0
Long lived fish	15337.7	3864.6	7031.3	0.0

*The flow rate is beyond regulating capacity of the proposed works and therefore no additional benefits counted.

Appendix D: Spatial data describing the inundation extent for the Lower-Murrumbidgee reach

The figures below represent the inundated areas of the separate hydrological assessment units (HAU) for the Nimmie Caira without rehabilitation scenario. The areas for the specific flow thresholds represent the inundation area *additional* to the area already inundated by a lower threshold.

Table 6 Inundation areas in hectares for hydrologic assessment unis in the without rehabilitation scenario

	SFI Bands GL					
Ecological Element	**175**	**270**	**400**	**800**	**1700**	**2700**
General health and abundance - all Waterbirds	34,362.9	968.2	4,777.0	26,705.4	28,624.4	16,561.3
Bitterns, crakes and rails	7,291.5	97.8	376.6	1,120.7	1,065.5	543.6
Breeding - Colonial-nesting waterbirds	34,362.9	968.2	4,777.0	26,705.4	28,624.4	16,561.3
Breeding - other waterbirds	7,291.5	97.8	376.6	1,120.7	1,065.5	543.6
Redgum Forest	10,964.0	157.6	673.8	5,832.0	4,022.7	1,188.5
Redgum Woodlands	801.7	31.6	188.4	1,049.9	830.0	311.1
Forests and Woodlands: Black Box	6,338.7	196.7	917.8	7,387.7	7,646.3	3,289.0
Lignum (Shrublands)	5,446.9	299.3	1,111.4	4,388.8	7,945.2	6,446.8
Tall Grasslands, Sedgelands and Rushlands	6,623.8	96.8	373.9	1,063.9	1,021.3	532.7
Benthic Herblands	667.7	1.0	2.7	56.8	44.2	10.9
Short lived fish	7,291.5	97.8	376.6	1,120.7	1,065.5	543.6
Long lived fish	34,362.9	968.2	4,777.0	26,705.4	28,624.4	16,561.3

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Assessment of the CARM and Modernisation projects for entitlement creation

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Contents

Tables

1 Introduction

Chapter 7 of the Basin Plan allows SDLs to be adjusted if equivalent environmental outcomes can be achieved through works and measures with less environmental water recovery. For assessing potential SDL adjustments possible, MDBA in consultation with the states has been incorporating a number of SDL offset proposals developed by the states.

As SDL offset proposals, NSW has put forward multiple business cases with operational and structural changes for the Murrumbidgee system. Among those, there are two projects that have specifications to issue environmental entitlements. These two projects are:

- Computed Aided River Management (CARM) system for the Murrumbidgee River (NSW DPI Water, 2015a) and
- Modernising supply systems for effluent creeks – Murrumbidgee River (NSW DPI Water, 2015b).

The CARM is an expert Decision Support System (DSS) specifically for river operations so that operators can make better informed decisions on daily releases from dams and weirs. This project will improve system operations by capturing operational surplus.

The modernisation project improves operational efficiency by multiple measures within the Yanco creek system including re-regulating flows, use of neighbouring irrigation corporations to supply demands and other operational changes.

These projects are developed to save water which can be called out to meet environmental needs. At the same time, however, harvesting surplus flows at the head storage leads to less inflows to the Murray system. Therefore Murray users including environment can be affected by the reduced inflows.

This report describes modelling undertaken to determine the callout volume from the two projects and Murrumbidgee IVT account to mitigate third party impacts to Murray users.

2 Agreed approach

In consultation with NSW, an assessment approach has been determined. It involves two steps including:

- Determination of the total available water from the two projects
- Breaking up the total volume into two accounts – one for callable entitlement within the Murrumbidgee system and another for Murrumbidgee IVT account to mitigate third party impacts in the Murray system.

3 Application of the agreed approach

3.1 First step

There are 4 scenarios modelled by changing the size of general security unit shares that can be extracted at the end of the system. For the modelling purpose, a fictitious license holder is created at the end of the system and 4 different unit shares are assigned, that are 0 GL, 30 GL, 40 GL and 100 GL. Table 1 presents the changes of system outcomes due to the different entitlement sizes. At the table, the GS extraction is a long term averaged annual volume that is extracted from the fictitious license holder. The extracted volume is considered to be the best indication of the long term average yield from the two projects. When there is no extract (i.e. 0 GL unit share), water saved at major storages is socialised thereby improving irrigation diversions and reliability at expense of reduced flow at the end of the system. As the unit shares increased, the third party benefits are reduced. When 100 GL is assigned, system indicators are worse than the Benchmark outcomes, indicating that the size of entitlements should be lower than 100 GL. The two intermediate runs show that some third party benefits exist with 30 GL entitlement but quite close outcomes to the benchmark are expected with 40 GL entitlement.

Table 1: Comparison of water balance and allocations against the Benchmark for the 4 different entitlement sizes

	Benchmark	0 GS extracted	24 GS extracted	32 GS extracted	76 GS extracted
Water Balance (GL/yr)					
MIA diversions	751.5	753.8	750.9	750.2	744.0
CIA diversions	230.8	233.03	231.1	230.6	228.0
NIA diversions	377.6	383.54	379.8	378.2	369.4
Township water supply	12.9	12.9	12.9	12.9	12.9
WfR extraction	97.0	122.6	122.4	122.1	121.5
Darlot flows	258.9	245.78	245.6	245.6	245.8
Forest Creek flows	9.8	7.35	7.3	7.3	123.7
Balranald flows before GS extraction	1,575.8	1,564.1	1,574.3	1,578.2	1,597.7
EOS GS unit modelled	-	-	30.0	40.0	100.0
Balranald flows after GS extraction	1,575.8	1,564.1	1,550.2	1,546.3	1,521.8
Allocation (%)					
Announced allocation (Jun)	77	79	78	77	76
Announced allocation (Jan)	65	67	66	65	63
Announced allocation (Oct)	49	51	50	50	48
Effective allocation (Jun)	85	86	86	85	84
Effective allocation (Jan)	78	79	79	78	76
Effective allocation (Oct)	67	69	68	67	65

By comparing flows at Balranald before and after GS extraction at Table 1, it indicates that flows are increased as the size of entitlements increased to supply their demands but flows arriving Murray after the extraction point are reduced.

Table 2 shows achievements of environmental outcomes at Murrumbidgee. Due to reduced surplus flows along the system, all indicators are met less frequently than the benchmark outcomes. In summary,

- At Mid-Bidgee, the highest flow indicator that is actively managed (i.e. indicator 3) is mostly affected.
  - Environmental outcomes are decreased as the extraction is increased.
  - However, the Limits of Change (LoC) are maintained for most indicators except one failure for the 100 GL scenario.
- At Lower-Bidgee, flow indicators are measured as volumetric requirements.
  - Medium events (i.e. indicators 2 and 3) are improved as the extraction is increased.
  - For the all cases, changes in environmental outcomes are not significant.

Based on this, general security entitlements of 40 GL (or a long term annual yield of 32 GL) would be an appropriate size which can maintain irrigation and system outcomes at the Benchmark level without significantly compromising environmental outcomes.

Table 2: Achievement of environmental indicators depending on extracted volumes at the end of the system

Mid-Bidgee Floodplain	Target	WOD	Baseline	Benchmark	LoC	0 GL	24 GL	32 GL	76 GL
26,850 ML/d for a total duration of 45 days (with min duration of 1 day) between Jul & Nov									
26,850 ML/d for 5 consecutive days between Jun & Nov									
34,650 ML/d for 5 consecutive days between Jun & Nov									
44,000 ML/d for 3 consecutive days between Jun & Nov									
63,250 ML/d for 3 consecutive days between Jun & Nov									
Lower-Bidgee Floodplain									
Total volume of 175 GL (flow > 5,000 ML/d) between Jul & Sep	70 - 75 %	94%	68%	94%	85%	93%	93%	93%	93%
Total volume of 270 GL (flow > 5,000 ML/d) between Jul & Sep	60 - 70 %	92%	57%	86%	77%	86%	86%	86%	89%
Total volume of 400 GL (flow > 5,000 ML/d) between Jul & Oct	55 - 60 %	92%	52%	83%	75%	79%	80%	80%	84%
Total volume of 800 GL (flow > 5,000 ML/d) between Jul & Oct	40 - 50 %	78%	39%	60%	54%	58%	58%	58%	58%
Total volume of 1,700 GL (flow > 5,000 ML/d) between Jul & Nov	20 - 25 %	56%	18%	30%	27%	29%	29%	29%	29%
Total volume of 2,700 GL (flow > 5,000 ML/d) between May & Feb	10 - 15 %	44%	9%	18%	16%	18%	18%	18%	18%

3.2 Second step

At the second step, the long term average extract of 32 GL is reviewed to determine a volume of IVT account required to neutralise any third party impacts to Murray users. For this modelling, it is assumed that the IVT account will be created with Murrumbidgee general security licenses.

As presented at Table 3, when there is no IVT account assigned, NSW Murray users are affected (i.e. less allocations leading to smaller diversions than Benchmark). This is because NSW available resources is reduced as a result of reduced flows from Murrumbidgee by around 30 GL/yr at Balranald. It should be noted that there is no significant changes in environmental outcomes even though some are improved slightly and others are a bit worse off (Table 4 and Table 5). Some improvements especially for the low flow targets at the Upper Murray are mostly due to increased Hume releases to count balance the reduced flows at Balranald. However, when a long term average of 16 GL is assigned to the IVT account, the Murray third party impacts are reduced and return back to Benchmark level without affecting overall environmental outcomes.

Table 3: Comparison of water balance and allocations for different volumes assigned to the Murrumbidgee IVT account

Water Balance (GL/yr)	**Benchmark**	**0 GL**	**16 GL**
NSW Murray Diversions	1,226	1,218	1,226
Lower Darling Diversions	39	39	39
Vic Murray Diversions	1,196	1,196	1,196
SA Murray Diversions	481	481	481
Barrage flows	7,092	7,061	7,069
NSW Murray allocation			
Long term average of %-age allocation at the start of year (HS)	95.6	95.8	96.0
Long term average of %-age allocation in February (HS)	99.4	99.3	99.4
Long term average of %-age allocation at the end of year (HS)	99.4	99.4	99.4
Minimum %-age allocation at the end of year (HS)	97.0	97.0	97.0
1999-2009 average of %-age allocation at the end of year (HS)	97.8	97.8	97.8
Long term average of %-age allocation at the start of year (GS)	53.3	52.8	54.7
Long term average of %-age allocation in September (GS)	71.0	69.8	71.6
Long term average of %-age allocation at the end of year (GS)	90.6	89.7	90.6
Minimum %-age allocation at the end of year (GS)	-	-	-
1999-2009 average of %-age allocation at the end of year (GS)	61.4	60.7	61.6
Vic Murray allocation			
Percentage of years with full HRWS allocation in February	98.2	98.2	98.2
Percentage of years with full LRWS allocation in February	93.0	93.9	93.0
Percentage of years with LRWS allocation in February > 0	98.2	98.2	98.2
Minimum February allocation	42.0	42.0	41.0
Long term average HRWS February allocation	99.3	99.3	99.3
Long term average LRWS February allocation	96.5	96.4	96.3
1999-2009 average HRWS February allocation	93.0	93.1	92.7
1999-2009 average LRWS February allocation	77.4	77.1	77.1
SA Murray allocation			
Percentage years with full entitlement in June	85.1	85.1	85.1
Percentage years with full entitlement in May	88.6	87.7	86.8

Long term average % entitlement in June	96.3	96.2	96.2
Long term average % entitlement in May	98.8	98.7	98.7
Minimum % entitlement in May	51.0	50.8	50.3
1999-2009 average % entitlement in June	79.4	79.3	78.7
1999-2009 average % entitlement in May	91.3	91.3	91.2
Percentage of years with spill at Dartmouth Dam	39.5	37.7	39.5
Percentage of years with spill at Hume Dam	57.9	57.9	57.9
% years of SA entitlement allocation < 90%	3.5	3.5	3.5
Long term average of SA entitlement allocation	98.9	98.7	98.9
Lower Darling allocation			
Long term average of Lower Darling General Security November Allocation	93.6	92.8	93.9
Long term average of Lower Darling LWU End of year Allocation	100.0	100.0	100.0

Table 4: Comparison of environmental outcomes for different volumes assigned to the Murrumbidgee IVT account

Upper Murray	Target	WoD	Base-line	Bench-mark	LoC	0 GL	16 GL
12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	87%	50%	78%	70%	78%	78%
16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	52%	47%	54%	52%
25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	47%	42%	48%	48%
35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33 - 40 %	53%	24%	35%	33%	34%	34%
50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25 - 30 %	39%	18%	18%	18%	18%	18%
60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20 - 25 %	33%	14%	15%	14%	15%	15%
15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	44%	11%	34%	31%	33%	34%
Mid-Upper Murray							
16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	86%	31%	68%	61%	68%	67%
20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60 - 70 %	87%	34%	64%	60%	64%	64%
30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33 - 50 %	60%	25%	39%	35%	39%	39%
40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25 - 33 %	39%	11%	25%	25%	25%	25%
20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	43%	7%	25%	23%	25%	25%
Mid Murray							
40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40 - 50 %	67%	30%	46%	41%	45%	45%

50,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	30 - 40 %	47%	19%	30%	30%	30%	30%
70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20 - 33 %	38%	11%	18%	16%	18%	18%
85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20 - 30 %	33%	10%	11%	10%	11%	11%
120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14 - 20 %	23%	8%	8%	8%	8%	8%
150,000 ML/d for a total duration of 7 days (with min duration of 7 consecutive days) between Jun & May	10 - 13 %	17%	5%	6%	5%	6%	6%
Lower Murray							
20,000 ML/d for 60 consecutive days between Aug & Dec	71 - 80 %	89%	43%	68%	68%	68%	68%
40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50 - 70 %	80%	37%	54%	50%	54%	53%
40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33 - 50 %	58%	22%	38%	34%	38%	38%
60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25 - 33 %	41%	12%	25%	25%	25%	25%
80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17 - 25 %	34%	10%	13%	11%	14%	14%
100,000 ML/d for a total duration of 21 days (with min duration of 1 day) between Jun & May	13 - 17 %	19%	6%	8%	7%	8%	8%
125,000 ML/d for a total duration of 7 days (with min duration of 1 day) between Jun & May	10 - 13 %	17%	4%	5%	4%	5%	5%
Edward-Wakool							
1 500 ML/d for a total duration of 180 days (with							
5,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	60 - 70 %	82%	39%	65%	60%	65%	65%
5,000 ML/d for a total duration of 120 days (with min duration of 7 consecutive days) between Jun & Dec	35 - 40 %	52%	22%	33%	30%	34%	33%
18,000 ML/d for a total duration of 28 days (with min duration of 5 consecutive days) between Jun & Dec	25 - 30 %	39%	15%	17%	15%	16%	16%
30,000 ML/d for a total duration of 21 days (with min duration of 6 consecutive days) between Jun & Dec	17 - 20 %	28%	12%	14%	12%	14%	14%
Lower Darling							
7 000 ML/d for 10 consecutive days between Jun							
17,000 ML/d for 18 consecutive days between Jun & May	20 - 40 %	47%	18%	21%	20%	21%	21%
20,000 ML/d for 30 consecutive days between Jun & May	14 - 20 %	27%	10%	11%	10%	11%	11%
25,000 ML/d for 45 consecutive days between Jun & May	8 - 10 %	14%	8%	8%	8%	8%	8%
45,000 ML/d for 2 consecutive days between Jun & May	7 - 10 %	10%	7%	7%	7%	7%	7%
Coorong , Lower Lakes and Murray Mouth							
Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,500 EC		87%	96%	100%	100%	100%	100%
Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,000 EC		85%	89%	99%	95%	99%	99%

Barrage flows: Percentage of years that barrage flows are greater than 2,000 GL/yr (measured on a three year rolling average) with a minimum of 650 GL/yr	97%	77%	98%	95%	98%	98%
Barrage flows: Percentage of years that barrage flows are greater than 600 GL for any two year period	100%	97%	100%	100%	100%	100%
Coorong Salinity: Percentage of days South Lagoon average daily salinity is less than 100 grams per litre.	100%	93%	100%	96%	100%	100%
Mouth Openness: Percentage of years mouth open to an average annual depth of 1.0 meters (-1.0 m AHD) or more	100%	76%	93%	90%	93%	93%
Mouth Openness: Percentage of years mouth open to an average annual depth of 0.7 metres (-0.7 m AHD) or more	100%	84%	96%	95%	96%	96%

Table 5: Comparison of outcomes for CLLMM ESLT indicators with different volumes assigned to Murrumbidgee IVT account

CLLMM ESLT indicator	Benchmark	0 GL	16 GL
% of days when Salinity in Lake Albert > 2000 EC	-	-	0.2
% of days when Salinity in Lake Alexandrina > 1000 EC	0.8	0.9	0.9
% of time when Lake Alexandrina level < 0.4 m	6.9	6.1	6.5
Maximum salinity in south Coorong (g/L)	113.6	111.0	114.5
Maximum Salinity in south Coorong: % of years < 100 g/L	97.4	98.2	97.4
Maximum period south Coorong salinity: > 130 g/L (days)	-	-	-
Average salinity in south Coorong (g/L)	43.0	43.1	
	43.1		
Maximum salinity in north Coorong (g/L)	63.8	63.4	63.4
Maximum period north Coorong salinity: > 50 g/L (days)	95.0	95.0	108.0
Average salinity in North Coorong (g/L)	22.0	22.0	22.0

4 Conclusion

A modelling study has been conducted to inform a long term yield that can be created from the CARM and effluent creek modernisation projects. In order to identify a right amount, a two staged approach is adopted. At the first step, the total amount is assessed. Out of the total, the size of Murrumbidgee IVT account is tested at the second step so that impacts to the Murray users are neutralised.

It is found that the two projects can yield a long term average of 16 GL/yr for Murrumbidgee environmental water and another 16 GL/yr for the Murrumbidgee IVT account.

Reference

NSW DPI Water (2015a). Business Case: Computer Aided River Management system for the Murrumbidgee River.

NSW DPI Water (2015b). Business Case: Modernising supply systems for effluent creeks – Murrumbidgee River

Department of Primary Industries Water

Technical Notes on Updating the Murrumbidgee SDLA Benchmark Model 2017

Introduction

In order to be able to simulate a number of Sustainable Diversion Limit adjustment (SDLA) proposals it was necessary to increase the model resolution at various points in the Murrumbidgee. This resulted in a number of different benchmarks and an inconsistency between the relative differences when the results were compared. It was agreed with MDBA that NSW would build a single common SDLA benchmark model for the Murrumbidgee so that the proposals can be assessed from a common starting point.

In addition, the original Murrumbidgee Basin Plan Benchmark (SDL) model had a number of known deficiencies so the opportunity was taken to fix these and add a number of improvements that were material to the proposed SDLA projects. The deficiencies were primarily the quantum of water recovery assumed from Nimmie-Caira and the double counting of water that was intended to go to Lowbidgee but remained in the river and was also counted as flow past Balranald.

Changes Made

The changes that were made to the Murrumbidgee SDLA Benchmark IQQM are described below.

Baseline

The starting point for these changes was BIDGNX7 and BIDGDA3 which were created by DHI Water and Environment (2016) from BIDG (The MDBA SDL). BIDG itself was based on DPI Water's WSP model wsp05cue. As these files had previously been used by the MDBA we assumed that the changes made were acceptable and no further checks were made.

BIDGNX7 and BIDGDA3 are designed to represent the Tripartite Projects[1]; BIDGNX7 represents the before case and BIDGDA3 the after.

Reconfiguring the Nimmie-Caira High Flow Relationship

The Nimmie-Caira environmental watering requirements prepared by Alluvium were developed based on estimates of volumes required to fill discrete areas and are hence expressed as an absolute volume and do not consider if the water was part of a regulated delivery or overbank flow. Previously the representation of Lowbidgee in the Murrumbidgee IQQM model was focused on representing the diversions made into Nimmie-Caira, and overbank or high flow effluents were generally treated as a loss for flow calibration purposes for the entire reach between Maude and Balranald. In order to make a reasonable estimate of the amount of controlled delivery to Nimmie-Caira, there was a need to better represent the overbank behaviour around Lowbidgee.

The original work on this was done by DHI Water and Environment and involved reanalysing historic data from the 1956, 1976 and 1984 flood events in the Murrumbidgee. From this an additional high flow effluent relationship was derived as shown in Figure 1.

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[1] Wilson Anabranch and associated losses, Beavers Creek existing offtake structure, losses and return flows on the Beavers / Old Man Creek system, augmented supply via Irrigation Corporations (Coleambally Irrigation Area escape drain operation and Murray Irrigation Finley Escape operation), Oak and Gras Innes Wetland losses on Bundidgerry Creek, and CARMS.

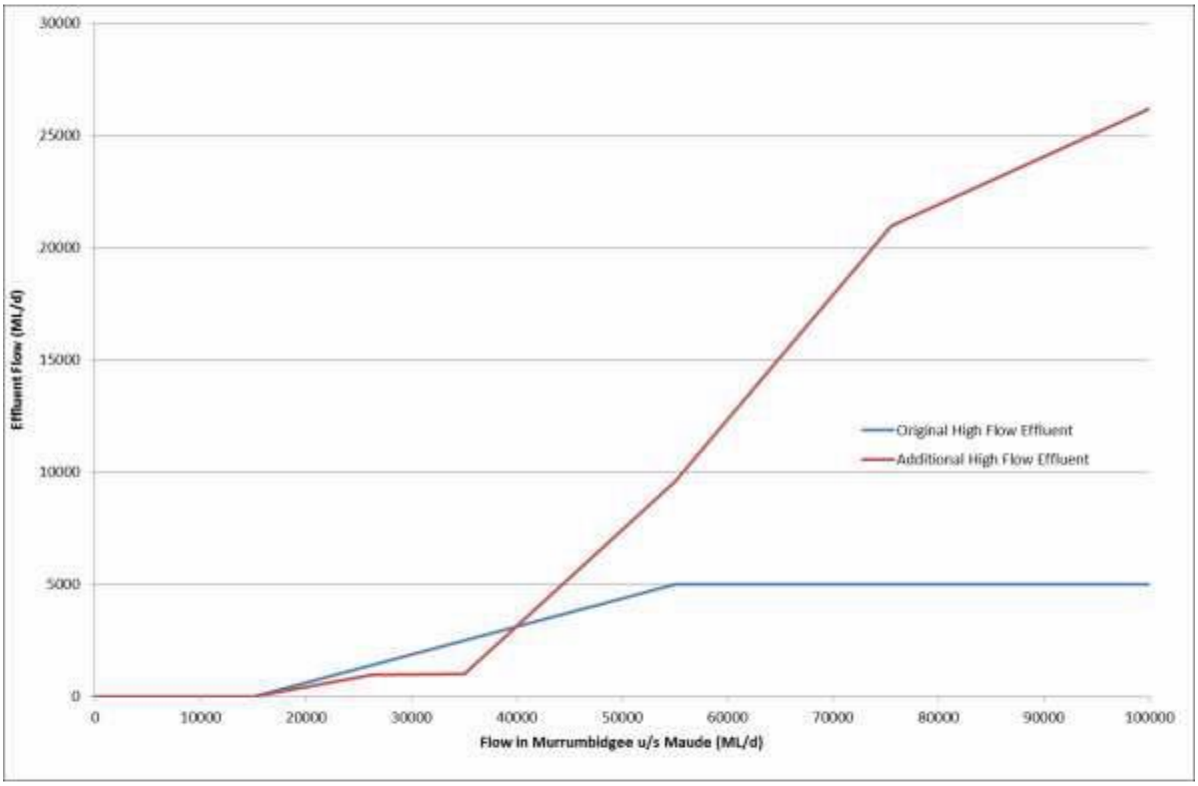

Figure 1 New Lowbidgee High Flow Effluent

The flow from this additional high flow effluent is put into a storage representing the Lowbidgee high floodplain. The return behaviour was based on the information in the 2012 business case for the purchase of Nimmie-Caira that approximately 3000 ML/d can drain back from the floodplain through Yanga to the river.

This new configuration was included in the SDLA benchmark and scenarios in a three-step process:

1. The configuration and parameters were copied from the DHI IQQM model (BIDGGA02) to the DPI WSP model (WSP05CUE).
2. The parameters were tweaked so that the annual mean flow at Balranald was not changed by adding the new configuration (WSP05CT).
3. The tweaked parameters and configuration was then copied into the SDLA benchmark family of models.

The matching of annual mean flow at Balranald ensures that the water return behaviour of Lowbidgee was not changed during efforts to describe at a higher resolution how flows behave between the known flow points at Maude and Balranald

Increasing the Order Capacity at Old Man Creek Effluent to 60 000 ML/d

This change was made by WaterNSW as part of the Yanco Creek Regulator proposal modelling.

The original Benchmark model did not include a limit on demands in the Murrumbidgee River at the Beavers Creek offtake. A limit of 30,000 ML/day was introduced at this point in the Murrumbidgee as part of the Tripartite modelling (DHI). Under recent changes this has been increased to 60,000 Ml/d in all models to allow environmental flow requirements downstream to be achieved.

Fixing Non-mass-balancing KEA Nodes.

In the original MDBA SDL model the accounting for the Key Environmental Assets (KEA) was simulated by using a combination of:

1. Water removed from the river using a bulk-access licence node (3.4), driven by a time series, and returned to the model below Balranald at a pumped return node (1.2).
2. A very large volume of water (1 TL/d) added back immediately below the 3.4 node using a tributary node (1.0).
3. The water not required to return the flow back to what it was above the 3.4 node was removed using a demand node (3.1).

It was discovered that this arrangement can cause a mass balance error due to the numerical problem of subtracting one large floating point number from another large floating point number. What happens is that the net effect is "lumpy" as IQQM uses floating point numbers with about 7 significant digits and it was found that the node arrangement could add up to 40 GL/a to the river.

To fix this problem additional functionality was add to the IQQM to allow the flow going from a 3.4 node to a 1.2 node to be "intercepted" by a 1.0 node. This allowed us to remove the very large inflow and extraction arrangement and removed the mass-balance problem.

Adjust Nimmie-Caira Diversions to Represent SFIs

One of the key deficiencies of the original SDL model was that despite there being water ordered with the intent to inundate parts of the Lowbidgee floodplain, there was no additional water being diverted into Nimmie-Caira.

To compound the problem the inclusion of a pair of KEA nodes ordering to below the Nimmie-Caira offtake resulted in a reduction of both the surplus flow available to be diverted and the diversions into Nimmie-Caira by previously surplus flow now being accounted as regulated flow to meet the KEA order.

The flow that was not diverted into Nimmie-Caira remained in the river and later flow past the gauge at Balranald and was counted as meeting some or all of the environmental requirements there and was double counted by an external process as achieving inundation outcomes in Nimmie-Caira.

Returning Nimmie-Caira and Redbank Diversions to WSP Level

The first step in adjusting the Nimmie-Caira diversions to represent the SFIs was to recalibrate the offtake control functions such that the diversions into Nimmie-Caira and Redbank were returned to the level prior to the introduction of the KEA nodes into the model. This was necessary as the introduction of the KEA nodes had reduced the availability of surplus flow for use by Lowbidgee and represented a third-party impact.

Moving the Maude and Balranald KEA Nodes

It was found during the re-calibration that there was not enough surplus available at Maude to meet the SFI requirements (and enhanced Nimmie-Caira watering requirements) and the KEA nodes had to be moved upstream of the Nimmie-Caira offtake so that flows are seen as surplus (and therefore accessible) by the Nimmie-Caira offtake node rather than as a regulated delivery for some other water user.

Initially only the Maude KEA was moved but it was found that this didn't result in enough surplus so the Balranald KEA was also moved. This required creating a new time series of requirements offset from the original to account for the travel time between Maude Weir and Balranald. As there is negligible irrigator development between Maude and Balranald it is expected that any water that was originally ordered to pass Balranald and not required to meet the Nimmie-Caira SFI will still pass Balranald.

The changes preserve the intent of the KEA nodes to order volumes to the end of system in a way that builds on existing flow events to achieve SFI flow targets.

Adjusting the Volume of Storage in Lowbidgee to Represent Removing the Irrigators.

The storage volume in Nimmie-Caira system is represented in the IQQM by:

1. A 50 GL “Stock and Domestic” storage that represents the initial “loss” of the Nimmie-Caira system. That is, there has to be an inflow of at least 50 GL before water will return to the river.
2. The Pendlebury Buckets: two storages in series with a capacity of 325 GL each that represent the rest of the storage of the system.
3. A by-pass function around the Pendlebury Buckets. This function represents the progressively higher return of water to the river as there is more water stored in the Nimmie-Caira system. This is a linear function that by-passes 0% when the buckets are empty up to 20% when the buckets have a combined storage of 325 GL. Above 325 GL combined storage all of the water will by-pass the buckets.

As irrigation in Nimmie-Caira has ceased in the SDLA benchmark it is necessary to adjust the storage representing Nimmie-Caira to reflect that water will no longer be directed into bunded paddocks. This is required as there is a fundamental shift in the way water will behave in Nimmie-Caira; previously water was managed by moving it from irrigation bay to irrigation bay in such a way as to maximize the infiltration of water into the soil profile, whereas now water will be directed to areas in the floodways where it can do the most benefit for the environment.

To estimate the current storage capacity of Nimmie-Caira the various watering options in the Alluvium were reviewed and based on the largest scenario, which covered all of the floodways with an inflow of 297 GL, it was decided to use a total storage of 250 GL. The 250 GL was divided up into a 50 GL initial loss storage (the Alluvium report also estimated the initial loss at 50 GL) and two storages of 100 GL. The surface areas were adjusted to represent the area of the floodways. The by- pass function was also adjusted to pass 20% at 200 GL storage in the Pendlebury Buckets and 100% above that level.

Meeting SFIs

The Nimmie-Caira access functions were then re-calibrated to represent the Nimmie-Caira diversions that would be required to achieve the inundation extent that was intended by Basin Plan, and assuming that diversions to Nimmie-Caira would now occur during the periods that the SFI conditions at Maude were being met. The re-calibration was done on the understanding that:

1. The SFI diversion targets (Table 1) were defined as the minimum required.
2. The SFI diversions were the sum of the diversions made through the Nimmie-Caira offtake and the flow entering Lowbidgee through the original high-flow effluent and the new high- flow effluent added as part of the high floodplain representation.

Table 1 MDBA SFIs for Nimmie-Caira

SFI	SFI Volume - Total inflow volume past Maude Weir (GL) over SFI period	SFI period	Total inflow volume (GL) into Nimmie-Caira over SFI period
1	175	Jul - Sep	21
2	270	Jul - Sep	33
3	400	Jul - Oct	43
4	800	Jul - Oct	80
5	1700	Jul - Nov	147
6	2700	May - Feb	241

The diversions into Redbank were kept at Water Sharing Plan levels while the re-calibration was carried out.

As discussed, the original MDBA Basin Plan scenario double counted water diverted into Nimmie- Caira as also achieving Balranald flow targets. NSW & MDBA agreed that the best reflection of the intent of the plan was to actually divert the water required to achieve the nominated inundation extent, and that this would consequently reduce apparent Balranald flow outcomes.

Adjust Water Recovery from Nimmie-Caira

The water recovery in the original SDL modelling used a uniform 27% reduction in irrigation diversions from all of the regulated and an assumed 27% reduction in the diversions by the Nimmie- Caira irrigators. NSW & MDBA agreed that since the Nimmie-Caira purchase is well known, the entire Nimmie-Caira irrigation demand should be removed, and the remaining irrigation nodes be adjusted higher to maintain the overall 27% reduction.

Quantum of Water Recovery from Nimmie-Caira

In the original MDBA SDL modelling the water recovery assumed to have been made from Nimmie- Caira was reduced by 41 GL/a to represent existing environmental outcomes within the Nimmie- Caira system based on MDBA's interpretation of the Basin Plan requirement that protects existing planned environmental water. NSW disputes this interpretation as it causes the Basin Plan to assert an uncompensated property right over environmental outcomes occurring on privately held land and through the actions of a privately held water entitlement, and that this is not permissible under the protects against 3rd party impacts. No agreement was able to be reached between NSW and MDBA officers, however NSW modellers identified that in the *HEADS OF AGREEMENT: AN AGREEMENT SUPPORTING THE NIMMIE-CAIRA SYSTEM ENHANCED ENVIRONMENTAL WATER DELIVERY PROJECT* it was agreed:

> "to jointly seek a review by the MDBA of the Murrumbidgee SDL, taking into account the Nimmie-Caira Entitlement, in the context of the next available opportunity for review of SDLs. Until that review, the Commonwealth will treat the 'gap bridging' volume of the Nimmie-Caira entitlement as 132.6 GL [/a]".

No such review has been conducted, and in the absence of an overriding agreement, this agreement has been assumed to represent the status quo and as a result is was necessary to increase the long- term mean diversions of the irrigators by 91.6 GL/a.[2]

DPI Water, April 2017

Adjusting the Water Recovery

As there was little time available to do the water recovery adjustment it was decided to speed up the process by only adjusting the Coleambally Irrigation Corporation's and the largest group of river irrigators' (Hay to Maude--RP13) licences and areas. The resulting changes made are summarised in Table 2.

[2] NSW is continuing to pursue this issue with the MDBA

Table 2 Changes Made for Water Recovery

	Before			After			Change		
	Entitlement (GL)	Area (Ha)	(ML/Ha)	Entitlement (GL)	Area (Ha)	(ML/Ha)	Entitlement (GL)	Area (Ha)	(ML/Ha)
CIA	150.2	35900	4.2	379	85000	4.5	+228.8	+49100	+0.3
RP13	23.7	13000	1.8	45	18000	2.5	+21.3	+5000	+0.8
KEA	908.1	-	-	658.1	-	-	-250	-	-

Subsequent discussions with MDBA officers identified that MDBA has automated tools to carry out the required adjustments more broadly and it is expected that MDBA will use their own system when constructing the SDLA package.

Adjust the Yanco Creek Calibration

In 2012 there was a re-calibration of the Yanco-Colombo-Billabong Creeks system carried out by DPI Water. The aim of this re-calibration was to derive a set of loss functions that would produce loss estimates that were similar in terms of rate per unit length between reaches. The re-calibration also created a set of residual inflows that didn't cover the full historic time span (1890-)

These loss parameters were adopted by DHI Water and Environment and a set of residual inflows that would cover the time span required (1895-2009) were derived by Watermation. However during this model update process there were a number of problems with this recalibrated parameter set:

1. Not all of the re-configuration arising from the 2012 re-calibration were carried over to the SDLA models.
2. The time-series residuals for the second reach of the Yanco Creek did not look plausible.

A desktop review of the calibrations was undertaken by Watermation and the changes adopted by DPI water are described below.

Adding in Missing Effluent Running from Colombo to Yanco Creek

There is an effluent that leaves the Colombo Creek just upstream of the Morundah gauge and enters the Yanco Creek downstream of the Morundah gauge. As a result there is flow in the upper Yanco system that doesn't pass by a gauge until Yanco Bridge and the apparent residual inflow in the second reach (Morundah to Yanco Bridge) is not related to rainfall and is not possible to reproduce with a rainfall runoff model.

To fix this an effluent was added between Colombo and Yanco Creek; the offtake relationship (Figure 2) was based on the HECRAS work done by Tim Morrison. With the addition of this effluent it was found that the second reach could be modelled without the use of a residual inflow. The losses in the second reach were tweaked to work with the new effluent and were found to be more consistent with the pre-2012 loss functions.

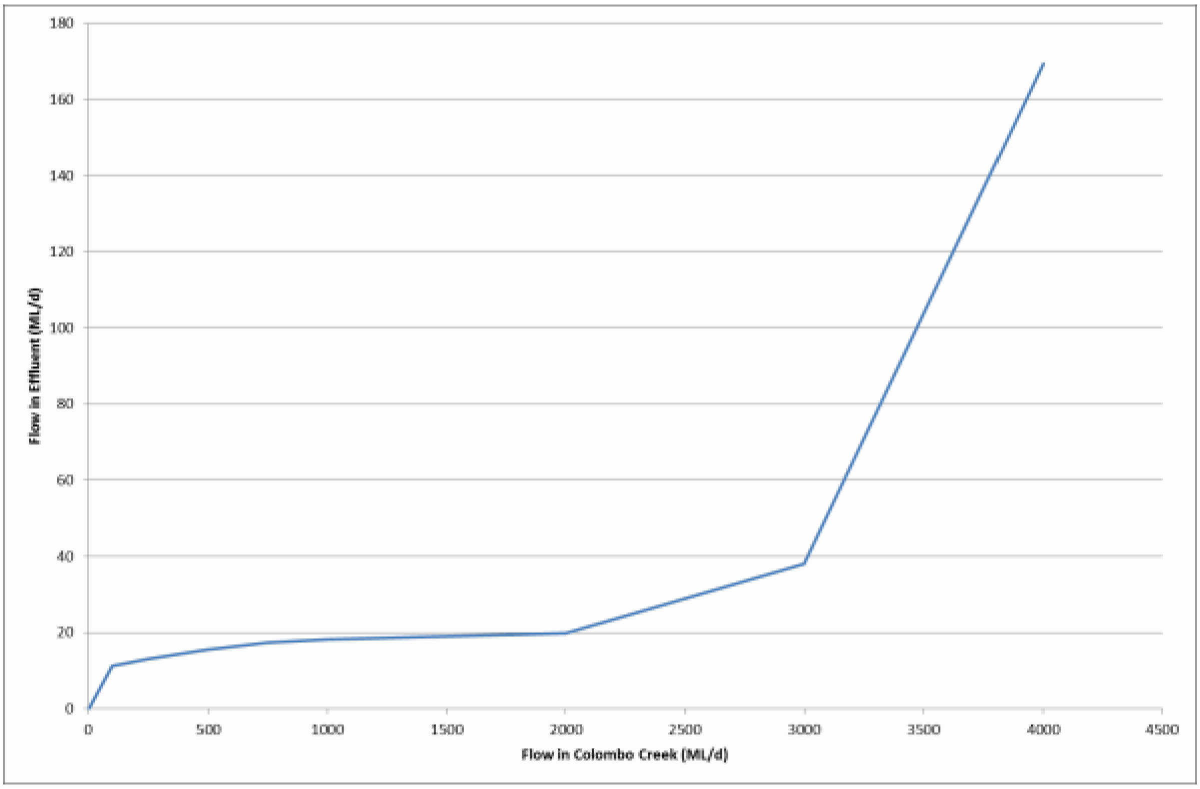

Figure 2 Morundah Effluent

Adding in Missing Components in the Yanco Reach to Morundah.

As part of the 2012 re-calibration there were a number of additional model components added that subsequently were not brought into the previous SDLA model:

1. Flow routing and a 25% loss on the flow passing down the Washpen Effluent.
2. Two overbank storage nodes representing surface water groundwater interaction.

As the loss functions adopted in the SDLA models were calibrated on the basis of the presence of these two components, they were added to the model to reinstate a coherent set of parameters. A code change was made to allow the flow from a 3.1 node to be returned to a 5.0 node (effluent return) so that its functionality could be used to model the loss and routing. There is an issue with the structure of the Murrumbidgee IQQM model that results in an additional 24 hours of lag in the Washpen Effluent but it was decided that this was acceptable in light of being able to represent the 25% loss and the impacts would not be material to the proposed SDLA scenarios.

Adjusting Snowy Inflows for the Water for Rivers Entitlements

The previous SDLA scenario used a fictional demand point to represent the reduction in water availability resulting from the Water for Rivers project. It was identified that the effects on water allocations was representative of a reduction in Snowy inflows, however the artificial demand continued to compete for release capacity from Blowering Dam and that this was distorting the results. It was originally intended to adjust the time series of Snowy inflows to Blowering Dam to represent the water owned by Water for Rivers that will be used elsewhere. Given the short time frame available for this and the fact that the entitlement remained tied to the Murrumbidgee resource assessment it was decided to take an alternative approach. The IQQM was modified to add the facility to allow regulated irrigators (8.0) and bulk-access licence nodes (3.4) to pump directly from a storage. The SDLA models were then modified to have the two WfR nodes pump directly from Blowering and free up the access to the outlet capacity of that dam for other water users.

Enhanced Nimmie-Caira Watering Proposal

A scenario for the enhanced Nimmie-Caira watering proposal was prepared. The without rehabilitation option was modelled as the rehabilitation will be dealt with as a separate activity.

Creating the scenario for the enhance watering proposal require re-calibrating the access functions at the Nimmie-Caira and Redbank offtakes such that the water diverted in to Lowbidgee would be sufficient to meet the Alluvium targets.

Representing Yanga in the IQQM Setup

The Murrumbidgee IQQM represents the Redbank area as a single overbank storage. Based on the inundation extent it was estimated that the Yanga (southern bank of the Murrumbidgee) component is half of this based on the relative area of Redbank and Yanga. In the revised SDLA benchmark model the Redbank diversions are 109 GL/a so the Yanga component was estimated as 55 GL/a.

1. Based on an estimate of the increase in diversions required to meet the Alluvium enhanced watering it was initially estimated that the Yanga component would become 75% of the total Redbank diversion and the flow requirements were judged on this basis. After calibration it was found that the Yanga component was 65% which was close enough to the initial estimate that it was decided to not adjust this. The overall take figure for both sites is consistent with the previous estimate of joint consumption added to the additional alluvium Yanga demands.

A more detailed representation of water balances between Redbank and Yanga requires a full hydraulic model of the area between Maude and Balranald and this is outside the scope of the SDLA projects

Interpreting the Alluvium Watering Requirements

While attempting to configure the offtakes into Nimmie-Caira and Redbank it was found that meeting more of the highest flow class targets resulted in a reduction in the number of lower flow class targets being met. As a result it was decided to use a configuration that resulted in missing 4 high flow events but meeting 6 more medium flow class events.

No attempt was made to determine the relative environmental value of the events and the highest event count was chosen for consistency with the SDLA ecological elements equivalence scoring mechanism.

Net Effect of Changes

Table 4 shows a summary of the statistics obtained from the original BDL and SDL, and the revised benchmark and project proposals.

Caveats

As there is a large change in the flows going into Lowbidgee and the purpose of those flows there is a high degree of uncertainty in the prediction of return flows from Lowbidgee.

The fundamental difficulty of modelling Lowbidgee is that the only reliable flow data available is at Hay and Balranald Weirs; the intermediate stream gauges do not necessarily measure all of the flow and only the regulated flow into Nimmie-Caira is directly measured. As a result of the distance between the measuring points and the flat topography in the area there is little constraint on the paths that water takes from Hay to Balranald as it could be passing through Nimmie-Caira or passing down the Murrumbidgee but overbank. The Lowbidgee model was calibrated so as to replicate the observed regulated diversions into Lowbidgee and the flow passing Balranald.

The cessation of irrigation in the Nimmie-Caira area will result in a major change in the behaviour of the water once it is inside Lowbidgee. Previously the water would be deliberately managed to maximise infiltration but this may not be the long term management aim for future environmental managers. The storage characteristics adopted for this Nimmie-Caira representation represent the best available understanding of the future environmental operations for Nimmie-Caira but these should be reconsidered as long term environmental watering plans are developed and experience is gained in how best to manage an environmental Nimmie-Caira.

Ongoing monitoring of the water behaviour within Lowbidgee will be an essential requirement to improve the understanding of where the water will go.

Table 3 Enhance Nimmie-Caira Watering Requirements

Event occurrence (proportion of successful years)	Event duration months	Min Flow	Max Flow	Event Timing	Volume required from offtakes (GL)				
					Maude Weir	Waugorah creek	1AS/ 1ES	Overbank flows	TOTAL
95%	1	0	15,000	July to Sep	3		23		26
50%	1	0	15,000	July to October	46				46
40%	3	0	15,000	July to October	180	12	56		248
14%	3	15,000		May to February	230	72	72	290	664

Table 4 Summary Statistics

Mean Annual (GL/a)	MDBA BDL	MDBA SDL	Revised SDLA Benchmark	SDLA Proposals		
				Tripartite	Yanco Regulator	Enhanced NC Watering
Regulated Diversions (excluding TWS &IVT)	1841	1331	1423	1469	1432	1422
Lowbidgee Diversion	292	204	290	284	286	400
Supplementary Diversions	243	156	153	148	155	155
Balranald Flow	1233	1718	1590	1578	1634	1567
Darlot Flow	324	301	283	265	248	283
Redbank Diversion	105	58	109	107	106	155
Total Inflow to Nimmie-Caira (Diversion + Flood)	230	195	265	262	269	330
Outflow from Nimmie-Caira	34	29	93	92	96	150
Nimmie-Caira Return	15%	15%	35%	35%	36%	46%