Submission on the Draft Report of the Independent Panel assessment of the management of the Northern Basin First Flush event

August 2020

Contents

1. Introduction

WaterNSW welcomes the Independent Panel's Draft Report and with it the NSW Government's continued commitment to identify and address opportunities for improvement in the management of the State's water resource.

We are pleased that the Draft Report identifies and recognises the positive aspects of the Northern Basin First Flush Event (**the event**) including the outcomes achieved with connectivity and the collaborative and well- intended approach of the Department of Planning, Industry and Environment – Water (**the Department**) and WaterNSW in managing the event.

However, we note the perception that many stakeholders have shared of the management of the event and its outcomes. WaterNSW is committed to playing our role in addressing the issues raised.

In that context, WaterNSW accepts and supports the intention of the Draft Report's recommendations and is of the view that considered implementation of the recommendations will improve the outcomes from the management of future extreme events.

In this supplementary submission we provide brief commentary on the relevant recommendations for WaterNSW.

Separately, an observation that was identified in the Draft Report was a perception that the approach used by WaterNSW to inform the management of the event was *overly* conservative. We provide some commentary on that observation in this submission.

Appendix B also includes some additional information on inflows and river behaviour as requested by the Panel following the consideration of public submissions.

We look forward to continuing to engage with the Panel in its preparation of the Final Report and to work collaboratively with the Department on the development and implementation of the action plan to deliver the Panel's final recommendations.

2. Recommendations of the Draft Report for WaterNSW

Recommendation 1. Water management must provide for and promote connectivity between water sources.

WaterNSW agrees connectivity between the Barwon Darling and tributaries needs to be considered and defined within the rules that govern the operation of these systems. Greater clarity around the management of connectivity between systems is an important step in improving the transparency of intended policy objectives and operations.

However, connectivity can mean different things to different people. To preserve the integrity of the current water management framework it is important that connectivity is defined with reference to natural conditions. While storages modify downstream conditions in the regulated rivers, they are not intended, nor operated under the rules within the water sharing plans, to ensure connectivity between river sections. Many of the northern rivers are ephemeral and naturally run dry for periods.

Over the period from late 2016 to early 2020 the northern New South Wales (**NSW**) tributaries natural inflows would not have provided connectivity to Menindee Lakes. The main rivers continued to flow for an extended period with regulated flows releases from water captured during inflows during the second half of 2016.

The environmental water holders also used licensed water held in the northern storages to create connectivity during 2018 and 2019 in some sections of the Barwon Darling. However, any rule-based changes to connectivity must be made to promote and protect connectivity with reference to the catchment's natural inflows.

Recommendation 4. Incorporate learnings from the 2020 Northern Basin First Flush event into systems that will be used to manage any further first flush event that arise in the short term, including by undertaking community consultation on the objectives, principles and targets.

Following the event WaterNSW engaged an experienced hydrologist, Barma Water Resources Pty Ltd, to review WaterNSW's models and their application during the event. A copy of this report has been attached to this submission (Appendix A). While the report identified the application of our model for forecasting the event is sound and appropriate, it did identify areas for improvement in relation to data and information, specifically;

- The single biggest improvement to any future NSW forecast would be through the capture of additional real time rainfall information for large local ungauged contributory sub catchments.
- Linking of information on real time extractions, future orders, and installed or authorised pump capacities to the forecast model would allow for a better assessment of the impact of pumping on the forecast estimate.
- At the beginning of the forecast a lack of information on cross border flows hampered the forecast estimate. A more formal collaboration process between WaterNSW and the Queensland Department of Environment and Science (DES) in forecasting cross Border flows would allow for improved future forecasts.

WaterNSW is using this report to supplement the initiatives outlined in our initial submission in relation to data and modelling. This is also considered below at Recommendation 8.

In relation to stakeholder consultation, WaterNSW has committed together with the Department, to engaging with customers and communities on the event through the next round of our River Operations Stakeholder Consultation Committees (ROSCOs) for northern and southern basins in November. This engagement will focus on continuing to build understanding of the event and how it was managed and provide a useful forum going forward on reporting progress of the action plan arising from the Panel's Final Report.

Recommendation 6. Review and update incident management systems for managing first flush events

WaterNSW supports the need to develop good incident management practices for extreme events that have the potential to impact on regional NSW.

As the operator of the State's groundwater and surface water systems, WaterNSW has an incident management capability founded in the need to manage risk across our assets for flood and water quality. This capability includes communication arrangements, event escalation/de-escalation frameworks, operational procedures and roles and responsibilities protocols with other key agencies including the Bureau of Meteorology (**BoM**), the NSW State Emergency Service (**SES**), Sydney Water and NSW Health.

WaterNSW believes that this capability could be expanded, in collaboration with the Department, to support an improved and integrated incident management framework for extreme events in regional NSW. Guided by the Final Report, WaterNSW will work with the Department to develop this capability for future extreme events.

Recommendation 8. Improve flow forecasting modelling and real-time monitoring capability, including measurement of extractions and the hydrometric system for inflows and monitoring end of system flows.

Over recent years, WaterNSW has invested significantly in the continual improvement of our modelling capacity to support our real- time resource management capability. This program of work has included greater access to real- time information, enhanced reporting of current and forecast conditions and the development and application of our Computed Aided River Management (**CARM**). The CARM system benefits from having a centralised framework and capabilities to manage data from a range of sources, including:

- standard hydrometric and meteorological data through WaterNSW and Queensland Hydstra services,
- links to the Murray Darling Basin Authority (**MDBA**) for Murray, Victoria and South Australia information;
- water order information through Water Allocation System (**WAS**);
- real time metering information; and
- a range of BoM hydrometric and meteorological observations, forecasts, and modelled products, covering rainfall, evaporation, river levels, soil moisture spatial data sets, and enhancing its use in the modelling and decision-making process

Combined with its ability to utilise water resources models in real time operations, CARM provides a solid foundation to continually improve our forecasting and water operations capability over time.

Our initial submission outlined the initiatives underway to improve our ability to understand river behaviour and the true nature of gains and losses in the Barwon Darling river system.

WaterNSW is developing an eWater source model for the Barwon Darling with a specific focus on low flows and using the latest topographic data. Once developed, this model will be incorporated into the existing CARM system.

Further improvement will be gained through developing similar models for the regulated and unregulated upstream tributaries, ungauged tributaries and the sections coming from Queensland. These models will be complemented with the use of forecast and observed estimates of rainfall, evaporation and soil moisture from BoM gridded data sets.

Recommendation 10. Improve and resource communication coordination and capability

In response to the Matthew's Inquiry (in relation to transparency of information) WaterNSW, in partnership with the Department, has developed *Water Insights*, a single portal to make it easier for customers, communities and stakeholders to find information on water management in the State.

Water Insights has been developed by WaterNSW reflecting our engagement with regional customers and communities to get a sound understanding of the information that they consider useful to help understand water management and assist in making informed decisions. For example, the portal has recently been updated to include information on water availability, water holding in accounts and the ability to compare water availability over previous years for each regulated valley and the Barwon Darling.

In relation to the Barwon Darling, the *Water Insights* portal will play an important role in supporting the implementation of NSW Government's active management framework. Through the portal, WaterNSW will announce when water in individual flows classes can be extracted, avoiding the need for customers to monitor river gauges. Through *Water Insights*, WaterNSW has developed flow indication maps and communication tools to enable customer notification of access arrangements and to improve transparency of those access arrangements. This will also ensure the same information is being made available to all stakeholders at the same time.

WaterNSW will continue to develop the portal over the coming years both as a passive source of information but also as an active communication tool with WaterNSW looking to add additional functionality to allow for registration for notifications on water availability, changes in river flows and announcements.

Reflecting this, as outlined in our initial submission, WaterNSW is of the view that the *Water Insights* portal will play a significant role in a multi-channel approach to materially improving communication capability for future extreme events.

3. The conservative nature of forecasts

WaterNSW notes that that an observation of the Draft Report was a stakeholder perception that WaterNSW was *overly* conservative in its approach to forecasting inflows during the event.

Generally, it is a well-recognised principle that water managers must tend to a conservative rather than speculative approach in making resources assessments in recognition of the consequences of over allocation compared to under allocation. While it is accepted that an element of conservativism may result in foregone opportunity to some, it mitigates the risk to many that water that should be available, is not. Decisions made by the water system managers reflect the information available at any point in time. So, while after an event it may be viewed by some that operations were very conservative, the information at the time of making decisions was not sufficient to take a different approach.

As indicated in our submission between the 6 February when water first started flowing onto the Barwon Darling and the 21 February when temporary water restrictions were lifted in the northern tributaries, most of the rainfall fell across the Border River, Gwydir and Namoi flood plain. WaterNSW were only able to forecast flows to Menindee Lakes based on water that had fallen as there was no forecast for additional rainfall across the northern valleys. The additional flow that provided the above target flows to Menindee occurred as rainfall events continued through until early April. Appendix B provides more information on the timing of the rainfall and flows.

In relation to the event, WaterNSW applied the same approach as is standard to modelling forecast flows. However, there were additional uncertainties that needed to be factored in the flow forecasts, primarily due to the possibility of very high losses from the unprecedented dry condition of the riverbed that had developed in the months and years leading up to this first flush

The unfavourable conditions also extended into the tributaries (regulated and unregulated) that were also in unprecedented dry conditions. These dry conditions in the tributaries also meant it was likely that there could be unprecedented losses between the gauges on the tributaries and their confluences with Barwon-Darling. These factors meant that field observations did not necessarily translate into flow forecasts as some stakeholders may have expected.

Additionally, the forecasting of flows from Queensland tributaries is very difficult with large variation of flows past St George reaching the Barwon due to river conditions, extractions and diversion of water between the minor Balonne and the Culgoa. WaterNSW relied on advice from the Queensland Department of Natural Resources, Mines and Energy.

As noted above, following the event WaterNSW engaged Barma Water Resources Pty Ltd to undertake a desktop review of the fitness for purpose of WaterNSW models and the modelling undertaken to forecast inflows during the event. The review found that "*The application of the spreadsheet models in forecasting the first flush event is sound and appropriate. All available data was used in the assessment with the main limitations in forecasting accuracy predominantly due to insufficient information on local inflow events and cross border flow from Queensland.*"

A copy of the report is included at Appendix A.

Appendix A: First Flush Modelling Review

FINAL REPORT

First Flush Modelling Review Report

July 2020

Barma Water Resources Pty Ltd

BWR Barma Water Resources

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Executive Summary

WaterNSW engaged Barma Water Resources Pty Ltd to undertake a desktop review of the fitness for purpose of the models and the modelling undertaken to forecast inflows in the Northern NSW tributaries and into the Barwon Darling to Menindee during the first flush event during February to April 2020. As part of this review the Department of Primary Industry and Environment (Water) also requested that an assessment be made of the impacts that pumping may have had on event volumes. In particular the Mooki and Cox's unregulated tributaries of the Namoi River.

Review Findings

As a result of the review the following conclusions have been made:

Input Data

- The single biggest improvement to any future NSW forecast would be through the capture of additional real time rainfall information for large local ungauged contributory sub catchments. In particular those in the Namoi and Gwydir catchments such as Thalaba Creek or the Pilliga Region in the Lower Namoi. WaterNSW have advised that it is possible to install Tipping Bucket rain gauges at existing stream gauging stations to deliver real time rainfall data.

- Linking of information on real time extractions, future orders, and installed or authorised pump capacities to the forecast model would allow for a better assessment of the impact of pumping on the forecast estimate.

- The forecast was subject to considerable uncertainty with respect to end of system flows. WaterNSW hydrographers have advised that potential improved methods could include:

    1. Acoustic Doppler current profilers noting that any slight interference from debris such as logs and weeds can affect results. Additionally, they can be expensive and require quite a deal of maintenance and calibration.

    2. Deployment of remote cameras to calculate surface velocities using either Large-Scale Particle Image Velocimetry (LSPIV) or Space Time Image Velocimetry (STIV).

- At the beginning of the forecast a lack of information on cross border flows hampered the forecast estimate. A more formal collaboration process between WaterNSW and the Queensland Department of Environment and Science (DES) in forecasting cross Border flows would allow for improved future forecasts.

- Similar past historic event can assist in predicting current event behaviour. Development and categorisation of a suite past Menindee inflow events would contribute to better forecasts.

Modelling Platform

- The application of the spreadsheet models in forecasting the first flush event is sound and appropriate. All available data was used in the assessment with the main limitations in forecasting accuracy predominantly due to insufficient information on local inflow events and cross border flow from Queensland.

- Notwithstanding the above point, the need for improved forecasting is becoming more apparent with recent initiatives such as active management of NSW unregulated flows requiring this. There exists a significant opportunity to develop a more sophisticated forecasting model for use in the North Western Rivers of New South Wales by WaterNSW. The spine of such a model already exists in the form of the WaterNSW river system valley Source models. These individual models could be joined together to form the basis of an improved forecasting model. A suitable user interface through utlisation of the existing Computer Aided River Management (CARM) system could also be developed.

Namoi Unregulated Tributary River Pumping

1. At the Namoi end of system, pumping from the Mooki and Cox's Creek the reduced event volume in the order of 21%.
2. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not occurred, the impact upon Namoi end of system event volume from additional pumping would have been small and in the order of as extra 2%.
3. In the Barwon Darling at Wilcannia, extractions from the Mooki and Cox's Creek reduced the NSW portion of the flushing event volume by approximately 5.3% and the total event volume by 3.8%.
4. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not of occurred, the impact upon event volumes at Wilcannia from additional pumping would have been less than 1% for both the NSW portion and the total.
5. The volume reductions at Wilcannia are also indicative of the likely reductions at Menindee.

1 Introduction

1.1 Background

WaterNSW engaged Barma Water Resources Pty Ltd to undertake a desktop review of the fitness for purpose of the models and the modelling undertaken to forecast inflows in the Northern NSW tributaries and into the Barwon Darling to Menindee during the first flush event during February to April 2020. As part of this review the Department of Primary Industry and Environment (Water) also requested that an assessment be made of the impacts that pumping may have had on event volumes. In particular the Mooki and Cox's unregulated tributaries of the Namoi River.

1.2 Review Methodology

In summary the review has consisted of the tasks as presented in Table 1:

Table 1: Tasks and Methodology

Purpose	Undertake a review of the fitness for purpose of the models and the modelling undertaken to forecast inflows in the Northern NSW tributaries and into the Barwon Darling to Menindee during the first flush event during February to April 2020
Inputs	WaterNSW 1. Descriptions of Operational Tools, assumptions and limitations 2. Forecasting Spreadsheet 3. Forecasting Results DPIE 1. Authorised and Installed Pump Capacities for larger tributaries of the upper Namoi, such as Mooki and Cox's Creek.
WaterNSW Tasks	1. Review of models for NSW northern tributaries and the Barwon Darling for fitness for purpose as a forecasting tool with the objective to identify potential improvement in the operational models including: a. Climatic Input Data b. Representation of Physical Processes c. Representation of management rules and operational practices 2. Review the application of the operational models in modelling undertaken by WaterNSW as part of advising on water flows in the Northern NSW Tributaries and the Barwon Darling during the February – April event. The review should evaluate:

	a. The accuracy of the forecast. b. The timing and adjustment of flows in the modelling. c. The timing and impact on the inclusion of flows from QLD. 3. Assess whether the improvements identified in Task 1 would have led to improvements in outcomes from Task 2.
DPIE Tasks	1. Using information on authorised and installed pump capacities, determine the volume of water that could have been extracted in the major unregulated rivers of the main tributaries, particularly those larger tributaries of the upper Namoi, such as Mooki and Cox's Creek. 2. Broadly assess how this would have impacted upon inflow volumes at Menindee, particularly in the context of the contribution from northern tributaries, prior to the predicted inflows from Qld. 3. Develop the methodology required to determine: a. the total volume of water that was protected from extraction as a result of the temporary water restriction in each tributary valley and the Barwon Darling. b. the resulting inflow ~~hydrographs to~~ the Barwon Darling from NSW tributaries and at Menindee.

1.3 Review Report Structure

Chapter 2 of this report describes and reviews the tools used to forecast the flushing event, together with the data inputs and their limitations. Chapter 3 reviews how the forecasting tools were applied in undertaking the forecast, and Chapter 4 details the assessment of how pumping may have influenced flushing event volumes.

2 Tools used for Forecast the Flushing Event

2.1 Overview

Forecasting of the flushing event has been based upon the WaterNSW *"Computer Aided* Improvement in River Operation" CAIRO model. This model resides within tresides within the WaterNSW Computer Aided River Management (CARM) system, which uses the DHI's Mike Operations software. The model platform is spreadsheet based and has been developed over the past 25 years using operator input to aid in refinement. The CAIRO software includes components to address:

- Input Data Management
- Tributary Inflow Assessment
- Demand Assessment
- Transmission Loss Assessment
- Capacity Constraint Assessment
- Output Data Management

A separate spreadsheet model exists for each of the NSW Barwon Darling tributaries and the Barwon Darling. Flow forecasting outputs from the tributary models formed inputs to the Barwon Darling model to allow estimates of forecasted inflow volumes at Menindee to be made.

2.2 Data Inputs

The model is primarily driven by streamflow inputs using observed daily streamflows. A separate uncounted difference value is also used in the model on a reach by reach basis to take into account

- channel bed losses and gains,
- channel storage filling and emptying, including weirs and billabongs,
- river channel direct rainfall and evaporation,
- spilling and return flows from the floodplain.
- ungauged inflows,
- unknown extraction, especially after long and extended dry sequences,
- floodplain harvesting volumes, and
- gauging station error.

The model also has the facility for known demands to be included if required. Extractions were not required to be included during forecasting of the flushing event due to embargos being placed on extractions.

2.3 Review Findings with Respect to Models Used to Forecast the Flushing Event

The following findings have been made with respect to the input data and models used to forecast the flushing event as part of this review.

Climatic Data

Any model used to forecast the first flush event will only be as good as the input data that underpins it. During the flushing event large volumes of inflows occurred from parts of ungauged catchments, most notably from Thalaba Creek in the Gwydir system, and from ungauged tributaries in the Namoi system.

These were not captured in the forecast due to insufficient real time representative rainfall data estimates. The single biggest improvement to any forecast would be through the capture of additional real time rainfall information for large local ungauged contributory sub catchments such as Thalaba Creek or the Pilliga Region at in the Lower Namoi. WaterNSW have advised that it is possible to install Tipping Bucket rain gauges at existing stream gauging stations to deliver real time rainfall data.

Extraction Data

The effect of upstream extractions upon forecast event volumes is required to be assessed in order to inform decisions in relation to whether pumping embargoes should be put in place. Linking of information on real time extractions, future orders, and installed or authorised pump capacities to the forecast model would allow for a better assessment of the impact of pumping on the forecast estimate.

Streamflow Measurement

Observed end of system flow estimates for the tributaries of the Barwon Darling are often subject to considerable uncertainty due streamflow gauging stations with poor rating curves. This uncertainty is usually a result of very shallow channel gradients and small capacities leading to influence by downstream flow behaviour (backwater). Often observed end of system flows can be underestimated as a result of this uncertainty. There are potentially a range of measures that could be implemented to improve end of system flow estimates, but it is important to recognise that to date there is no method that can reliable predict flows affected by backwater. WaterNSW hydrographers have advised that potential improved methods could include:

- Acoustic Doppler current profilers noting that any slight interference from debris such as logs and weeds can affect results. Additionally, they can be expensive and require quite a deal of maintenance and calibration.

- Deployment of remote cameras to calculate surface velocities using either Large-Scale Particle Image Velocimetry (LSPIV) or Space Time Image Velocimetry (STIV).

The choice of most appropriate method would vary from site to site.

Cross Border Flows

At the beginning of the forecast a lack of information on cross border flows hampered the forecast estimate. The delay in receiving information on cross border flows in Queensland led to underestimation of the flushing event forecast volume in tributaries and at Menindee early in the event. This was rectified to some extent by the end of February. A more formal communication protocol between WaterNSW and the Queensland Department of Environment and Science in the area of forecasting cross Border flows would allow for improved forecasts of Queensland inflows.

Incorporation of Historical Past Event Behaviour in Forecasting

One of the many challenges in forecasting flow events in Northern Basin is that events rarely behave in the same manner. Consequently, information on historic events can be used as a guide to inform the forecast of a current event. Development and categorisation of a suite past Menindee inflow events would contribute to better forecasts.

Model Architecture

The spreadsheet model used in forecasting the first flush event represents a simplified representation of the river system. This is deliberate and lends itself to ease of use by river operators. Importantly, it also reflects the lack of detail available in terms of input data required to produce an accurate forecast. It is this reviewers opinion that there is no value in developing a more sophisticated forecasting tool until such time as there is a willingness to gather improved input data to underpin its use.

In the event that improved input data sets become available, there is significant scope for developing a more sophisticated forecasting model for use in the North Western Rivers of New South Wales by WaterNSW. The spine of such a model already exists in the form of the WaterNSW river system valley Source models. These individual models could be joined together to form the basis of an improved forecasting model. Such a model would have the ability to generate local ungauged inflows through rainfall runoff models, route flows along reaches, and incorporate more sophisticated transmission loss relationships. It also would have extraction locations and access rules already identified and incorporated.

During a forecast there will be a need to import new observed information and overwrite old forecast information to allow for an updated forecast. Input and output data management will likely become cumbersome without the development a suitable user interface. Such an interface (decision support tool) could be developed through the WaterNSW existing CARM platform.

WaterNSW have advised that as part of the CARM System, they have commenced development of a framework which to date includes:

- Ad hoc and automatic routine data collection from a range of sources, including:
    - hydrometric and meteorological data through WaterNSW and Queensland Hydstra services, and links to the Murray Darling Basin Authority (MDBA) for Murray, Victoria and South Australia information.
    - Order information through WAS, (noting that at the moment this is mainly for regulated systems with plans to include the unregulated Barwon Darling.
    - Any water metering information that is available. Currently capturing metering information from NSW Murray, Lower Darling and Murrumbidgee, where it is available, with future capture of any information that becomes available through the Natural Resources Access Regulator (NRAR) metering program.
    - A suite of BOM rainfall, flow and level observation and forecasts
- Workflow management process that assists operators to not only undertake daily operations but also provides opportunities
    - to undertake scenario or uncertainty analysis,
    - archiving capability for each of their decisions, to enable auditing and review of historical events
    - provide a 'duty officer' role to ensure decisions can be attributed to that position
- Capabilities to run external models, such as eWater Source model with a range of differing inputs and read in results for use in the decision making process
- Reporting and email capabilities

Alternatively, the necessary architecture in a simpler form may be developed using a package such as Veneer. Veneer is designed to make the creation of new front ends for Source faster and easier. These front ends can be generic and work with any Source model Decision Support Tool for an important catchment (Ref https://www.flowmatters.com.au/articles/introducing_veneer.html).

3 Model Application in Forecasting the Flushing Event

3.1 Application of the Models in Flushing Event Forecasting

The broad process for using the model described in Chapter 2 for forecasting the flushing event is presented in Figure 1. The forecast commenced with upstream tributary forecasting spreadsheet models being run with a combination of observed tributary inflows and forecasted flows for the remainder of the event. These flows were then translated to the end of each tributary system with flows being adjusted for losses and gains as required. The final end of system forecasted event was then fed into the Barwon Darling forecasting spread sheet to determine an event volume at Menindee.

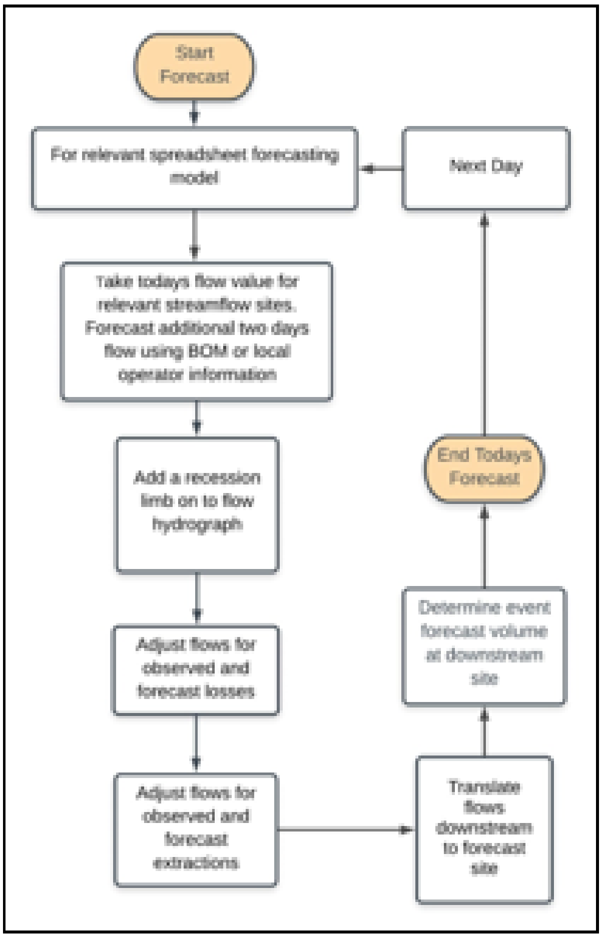


Figure 1 – Process of Event Forecasting

3.2 Flushing Event Forecasting Results

Event Description

The progression of the flushing event in terms of cumulative volume through the tributaries of the Barwon Darling and then along its length is presented in Figure 2. The flushing event was produced by rainfall over NSW and Qld during February 2020. As can be seen from Figure 2, the runoff response and contribution to Barwon Darling inflows from NSW tributaries occurred more rapidly than for Qld tributaries. NSW tributaries primarily produced the first Menindee inflow event (with the Namoi being the biggest contributor), whilst Qld tributaries produced the second. Peaks of the two events were separated by approximately one month with NSW tributary contribution to Barwon Darling inflows being slightly greater than that of the Qld tributaries. The event was also characterised by substantial local inflows between stream gauging stations.

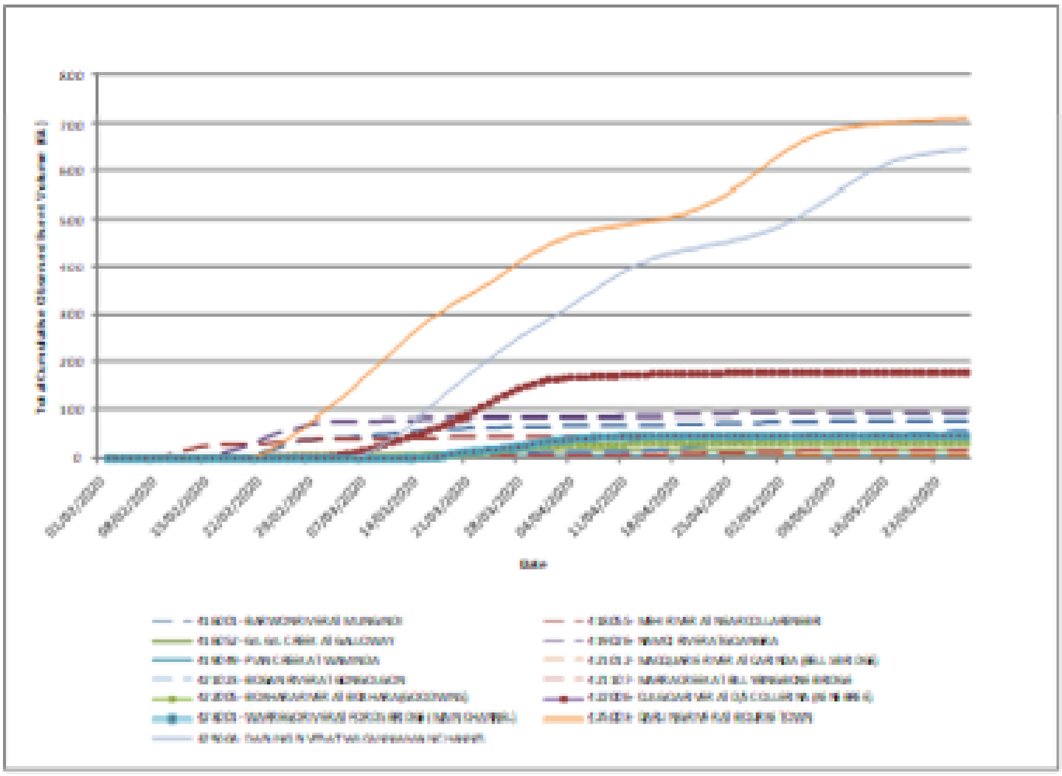


Figure 2 – Cumulative Event Volume (GL) (Data sourced from WaterNSW)

Event Forecasting

An illustration of how WaterNSW flushing event volume forecast estimates using the spreadsheet models compared to actual observed event volumes is presented in Figure 3 to Figure 5. NSW and Qld Tributary inflow event volume forecasts and observed volumes are shown in Figure 3 and Figure 4. The blue squares represent forecasts when rainfall was still occurring whilst the black square represent forecasted event totals when rainfall had ceased. The blue line represents the actual observed inflow cumulative event total.

In both the NSW and Qld forecasting cases, final event volume was overestimated by the forecast. However, as expected forecast estimates stabilised and did not increase at the same rate once rainfall had ceased. Reasons for forecasting overestimation are largely due to the uncertainties described in the proceeding chapter. It is expected that forecasting estimates for tributary flows would improve if these uncertainties were addressed.

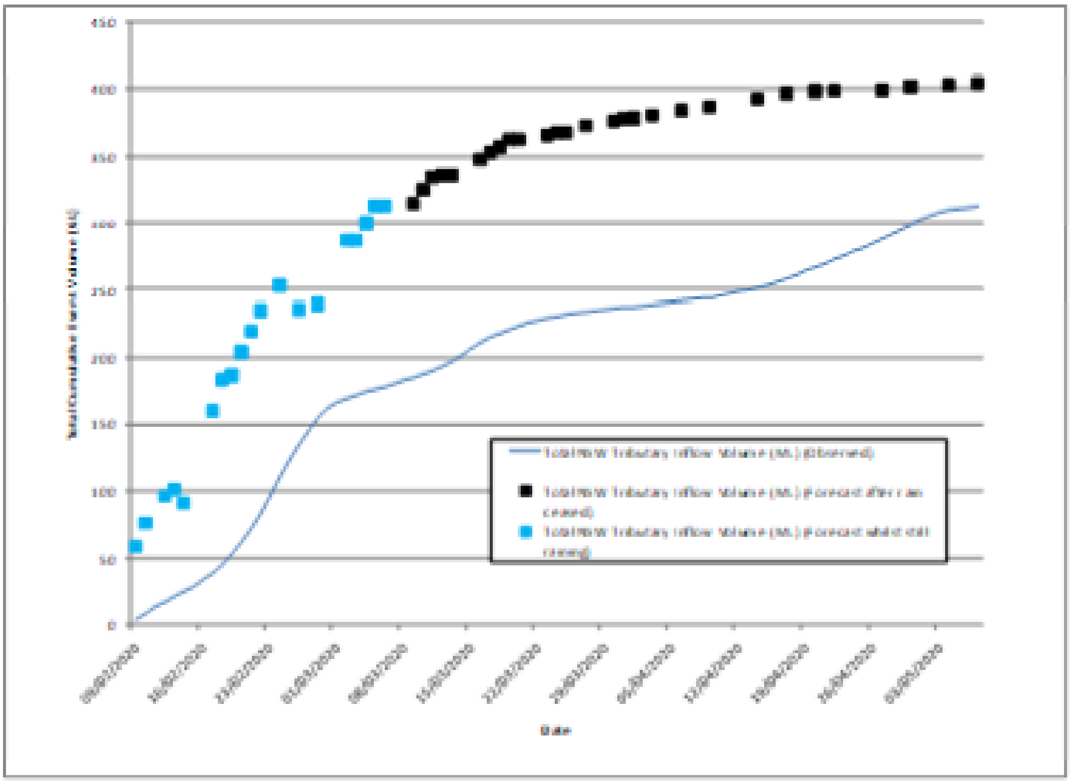


Figure 3 – NSW Tributary Event Volume Forecast and Actual Cumulative Event Volume (Data sourced from WaterNSW)

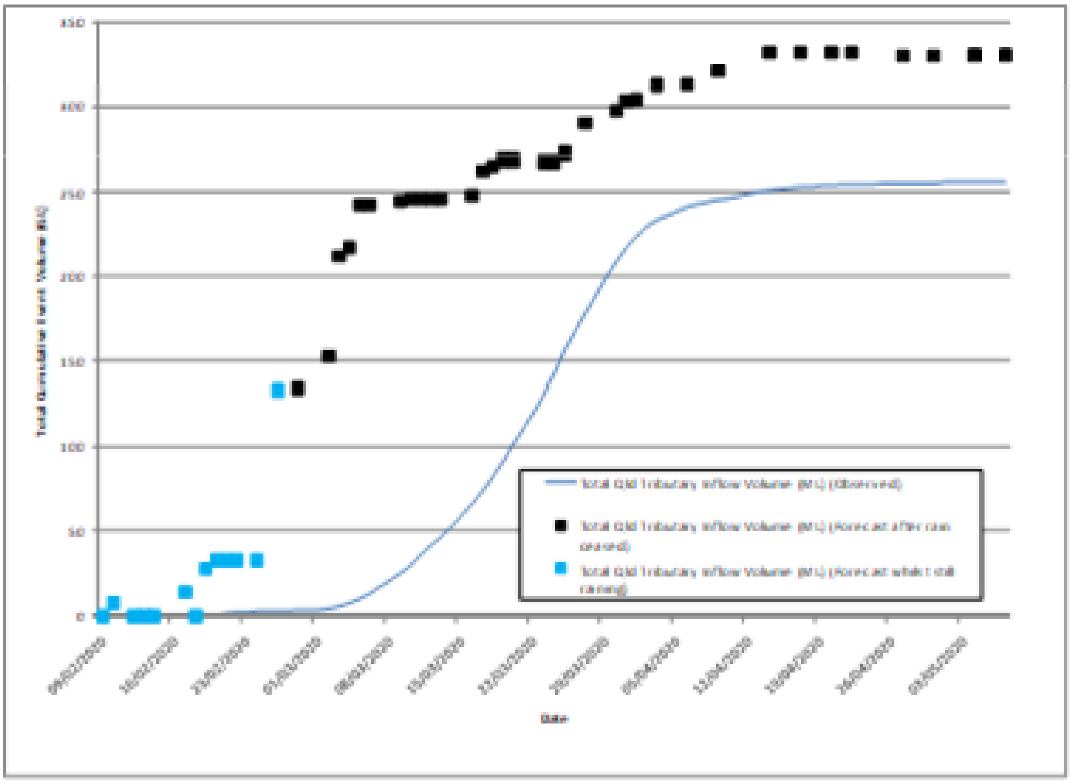


Figure 4 – Queensland Tributary Event Volume Forecast and Actual Cumulative Event Volume (Data sourced from WaterNSW)

Event forecasted and observed volumes for the Barwon Darling at Wilcannia are presented in Figure 5. As shown in the Figure, event forecasts still change by a considerable amount on a day to day basis even after rainfall has ceased. Indicating the long travel times and uncertainties associated with flows in transit to Wilcannia.

The extent to which the final forecasted event volume is over estimated is less than for the tributary end of system inflows. This is due to most of the event volume being contained within the riverbanks once it enters the Barwon Darling, meaning that flow estimates are more accurate than for end of system tributary inflow locations where flows are made up of in channel and overbank components.

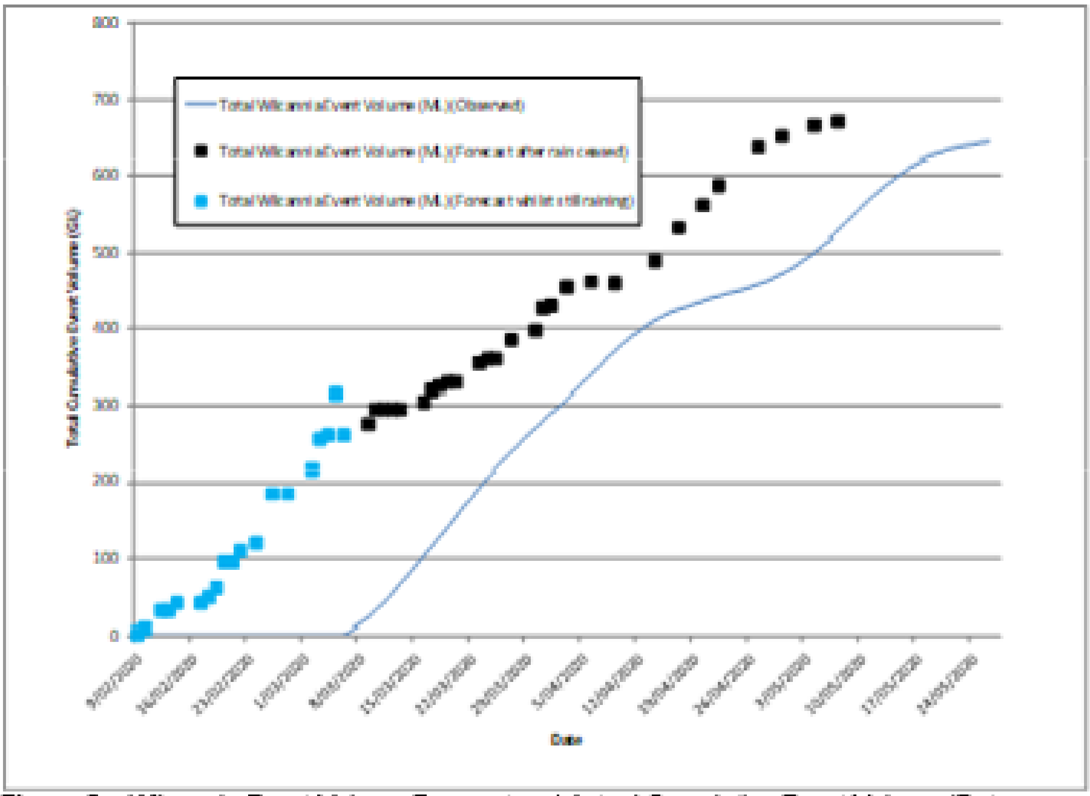


Figure 5 – Wilcannia Event Volume Forecast and Actual Cumulative Event Volume (Data sourced from WaterNSW)

3.3 Review Findings with Respect to Models Used and Their Application to Forecasting the Event

The application of the spreadsheet models in forecasting the flushing event appear sound and appropriate. All available data was used in the assessment with the main limitations in forecasting accuracy predominantly due to insufficient information on local inflow events and cross border flows from Queensland. Uncertainties in the forecast estimates were also built into the assessment in an effort to try and capture many of the unknowns that can cause forecasted volumes to be incorrect.

Application of the existing spreadsheet models used to forecast the flushing event in the future would be improved through incorporation of additional data as discussed in Chapter 1 of this review. Adoption of new model architecture would also improve application of the forecasting tools.

4 Potential Impacts of Extraction on the Flushing Event

4.1 Introduction

One of the terms of reference of this review was to make an assessment of the potential impact of extractions volume upon downstream flushing event volumes. This assessment was broken into a number of components.

1. Using information on authorised and installed pump capacities, determine the volume of water that could have been extracted in the unregulated Mooki River and Cox's Creek systems. These are major unregulated rivers of the main Namoi regulated river.

2. Pumping from the Mooki and Cox's Creek was embargoed from the 17th to 20th of February. Using information on authorised and installed pump capacities, assess how extractions in the Mooki and Cox's Creek if allowed during the period from the 17th to the 20th of February would have impacted upon inflow volumes at Menindee, particularly in the context of the contribution from northern tributaries, prior to the predicted inflows from Queensland.

3. Develop the methodology required to determine:

    - the total volume of water that was protected from extraction as a result of the temporary water restriction in each tributary valley and the Barwon Darling.

    - the resulting inflow hydrographs to the Barwon Darling from NSW tributaries and at Menindee if extraction was allowed.

Each of these components is discussed in the following sections.

4.2 Impacts of Pumping In Unregulated Tributaries of Namoi Regulated System

An assessment of the potential impact of pumping in the Mooki River and Cox's Creek has been made with results presented in Table 1, Table 2 and Figure 6. Estimates have been based on the pump and on farm storage capacities presented in Table 1. Storages were assumed to be empty at the start of the event.

A number of observations can be made from these results.

1. The Mooki contributed around 17% of volume to Namoi flows at Gunnedah.
2. Both the Mooki and Cox's Creek contributed around 40% of flows at Boggabri.
3. At the Namoi end of system, pumping from the Mooki and Cox's Creek reduced event volume in the order of 21%.

4. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not occurred, the impact upon Namoi end of system event volume from additional pumping would have been small and in the order of as extra 2%.
5. In the Barwon Darling at Wilcannia, extractions from the Mooki and Cox's Creek reduced the NSW portion of the flushing event volume by approximately 5.3% and the total event volume by 3.8%.
6. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not of occurred, the impact upon event volumes at Wilcannia from additional pumping would have been less than 1% for both the NSW portion and the total.
7. The volume reductions at Wilcannia are also indicative of the likely reductions at Menindee.

Changes in hydrograph shape as a result of pumping have not been considered as part of this review. Such an analysis would entail the use of a daily time step river system model. This has been beyond the scope of this review but it is discussed further in the following section.

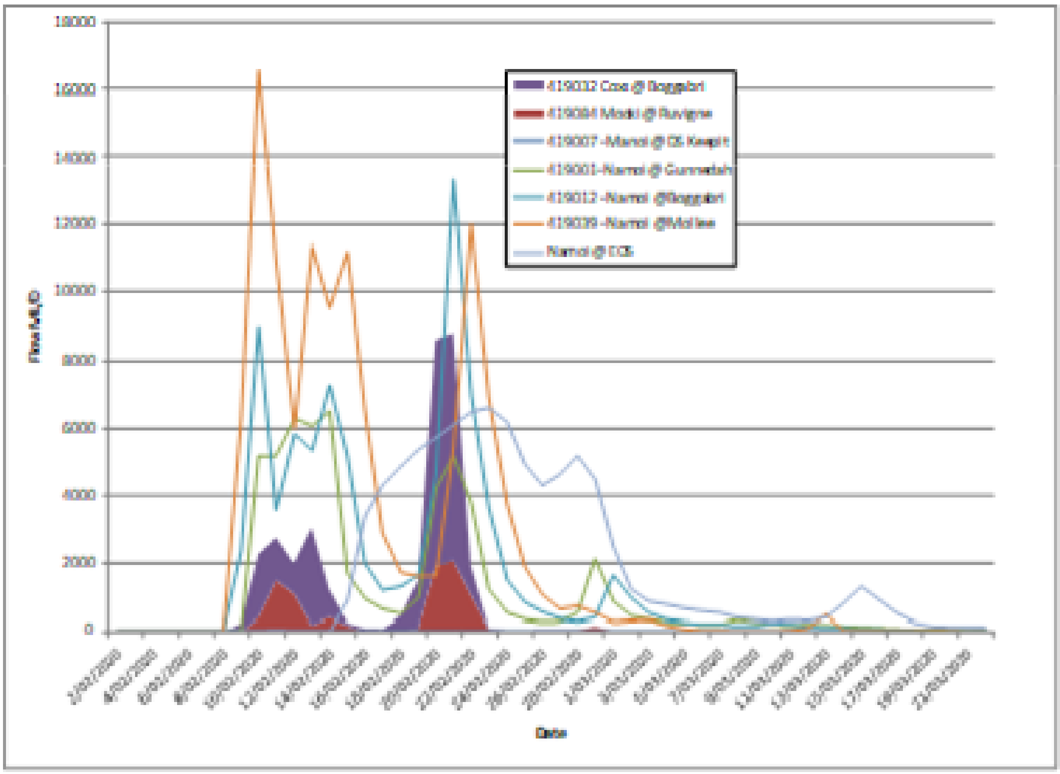


Figure 6 - Tributary Inflow and Regulated Section Event Hydrographs (Data sourced from WaterNSW)

Table 1 – Analysis of Mooki and Cox's Ck Pumping on Flushing Event Volumes in the Namoi (Data sourced from WaterNSW and NSW DPIE)

Mooki and Cox's Creek Event Details	
Mooki Event Contribution to Gunnedah Flow	16.7%
Cox's Ck and Mooki Event Contribution to Boggabri Flow	41.0%
Mooki (Pump Capacity ML/d)	2571
Cox's (Pump Capacity ML/d)	1539
Mooki OFS Capacity (GL)	18.35
Cox's Ck OFS Capacity (GL)	7.61
Mooki Extraction Totals	
Mooki Extraction Totals Assuming Unconstrained by OFS	
Estimated Mooki Pumped Volume up to 16th Feb (GL)	10.3
Potential Foregone Mooki Pumped Volume (GL) 17th to 20th of Feb (GL)	2.1
Estimated Mooki Pumped Volume from 21st Feb Onwards (GL)	5.1
Mooki Extraction Totals With 18.3GL Mooki OFS Capacity Constraint	
Estimated Mooki Pumped Volume up to 16th Feb (GL)	10.3
Potential Foregone Mooki Pumped Volume (GL) 17th to 20th of Feb (GL)	2.1
Estimated Mooki Pumped Volume from 21st Feb Onwards (GL)	5.1
Cox's Creek Extraction Totals	
Cox's Creek Extraction Totals Unconstrained by OFS	
Estimated Cox's Creek Pumped Volume up to 16th Feb (GL)	9.2
Potential Cox's Creek Forgone Pumped Volume 17th to 20th Feb (GL)	4.7
Estimated Cox's Creek Pumped Volume from 21st Feb Onwards (GL)	3.1
Cox's Creek Extraction Totals With 7.61GL Cox's Creek OFS Capacity Constraint	
Estimated Cox's Creek Pumped Volume up to 17th Feb (GL)	7.6
Potential Cox's Creek Forgone Pumped Volume 18th to 20th Feb (GL)	0.0
Estimated Cox's Creek Pumped Volume from 21st Feb Onwards (GL)	0.0
Total Unrestricted Mooki and Cox's Extraction Volume	
Estimated Total Potential Mooki Pumped Volume (GL)	17.5
Estimated Total Potential Cox's Ck Pumped Volume (GL)	7.6
Effect of Potential Mooki and Cox's Pumping on Namoi Event Volumes	
Gunnedah Event Volume without any Pumping (GL)	72.8
Gunnedah Event Volume with Mooki Pumping (GL) up to the 16th and from the 21st Feb Onwards	57.3
Gunnedah Event Volume with no access restrictions to Mooki Pumping (GL)	55.3
Boggabri Event Volume without any Pumping (GL)	106.3
Boggabri Event Volume with Mooki and Cox's Ck Pumping up to the 16th and from the 21st Feb Onwards(GL)	83.2
Boggabri Event Volume with no access restrictions to Mooki and Cox's Pumping (GL)	81.2
Mollee Event Volume without any Pumping (GL)	154.8
Mollee Event Volume with Mooki and Cox's Ck Pumping up to the 16th and from the 21st Feb Onwards(GL)	121.2
Mollee Event Volume with no access restrictions to Mooki and Cox's Pumping (GL)	118.3
Namoi EOS Event Volume without any Pumping (GL)	112.4
Namoi EOS Event Volume with Mooki and Cox's Ck Pumping up to the 16th and from the 21st Feb Onwards(GL)	88.0
Namoi EOS Event Volume with no access restrictions to Mooki and Cox's Pumping (GL)	85.8
Estimated % Reduction in Namoi EOS Total Volume through Mooki and Cox's Pumping up to the 16th and from the 21st Feb Onwards (GL)	**21.7%**
Estimated % Reduction in Namoi EOS Total Volume through Mooki and Cox's Pumping with no access restrictions (GL)	**23.6%**
Difference	**1.9%**

Table 2 – Analysis of Mooki and Cox's Ck Pumping on Flushing Event Volumes in the Barwon Darling (Data sourced from WaterNSW and NSW DPIE)

Effect of Potential Mooki and Cox's Pumping on Barwon-Darling Flows	
Wilcannia NSW Event Volume without any pumping (GL)	471.9
Wilcannia NSW Event Volume Mooki and Cox's Pumping up to the 16th and from the 21st Feb Onwards (GL)	448.9
Wilcannia NSW Event Volume with no access restrictions to Mooki and Cox's Ck Pumping (GL)	446.8
Estimated % Reduction in Wilcannia NSW Event Volume through Mooki and Cox's Pumping up to the 16th and from the 21st Feb Onwards (GL)	4.9%
Estimated % Reduction in Wilcannia NSW Event Volume through Mooki and Cox's Pumping with no access restrictions (GL)	5.3%
Wilcannia Total Event Volume without any pumping (GL)	666.8
Wilcannia Total Event Volume Mooki and Cox's Pumping up to the 16th and from the 21st Feb Onwards (GL)	643.8
Wilcannia Total Event Volume with no access restrictions to Mooki and Cox's Ck Pumping (GL)	641.7
Estimated % Reduction in Wilcannia Total Event Volume through Mooki and Cox's Pumping up to the 16th and from the 21st Feb Onwards (GL)	**3.5%**
Estimated % Reduction in Wilcannia Total Event Volume through Mooki and Cox's Pumping with no access restrictions (GL)	**3.8%**

4.3 Impacts of Pumping In Both Unregulated and Regulated Systems

Determining the impacts that widespread pumping across the Northern Basin would have had on flushing event hydrograph shapes and volumes requires a more detailed analysis than can be conducted in the time allotted for this review. If a forecasting model was developed in the Source rivers platform, as discussed in Chapter 2, such an assessment would be possible in a relatively straight forward manner. However, at present, any assessment requires the use of the Department of Industry and Environment (Water) river system models. Therefore this review only recommends a suggested methodology to allow this to occur.

Ideally each river NSW tributary river system model would be run from the commencement of the flushing event, with:

1. system gauged inflows and any storage releases set to observed values.
2. residual inflows set to observed values.
3. general security diversions set to zero.
4. on farm and instream weir storage volumes set to an initial start of event value. In most instances this is most likely to be zero.
5. modelled transmission loss relationships adjusted to reflect observed values.

Simulated outflows from each tributary model would then be entered in the Barwon Darling River system model with:

1. on farm and instream weir storage volumes set to an initial start of event value. In most instances this is most likely to be zero.
2. Barwon Darling licence account allocation volumes set to the maximum.
3. modelled transmission losses adjusted to observed values if possible.

The resulting end of system hydrograph will show the effects of upstream pumping on event shape and volume.

5 Review Overall Conclusions

This review has considered the input data, tools used and their application in forecasting the February to April Barwon flushing event. It has also assessed the potential impact of pumping on event volumes in the main unregulated tributaries of the Namoi River. The following conclusions are made:

Input Data

- The single biggest improvement to any future NSW forecast would be through the capture of additional real time rainfall information for large local ungauged contributory sub catchments. In particular those in the Namoi and Gwydir catchments, such as Thalaba Creek or the Pilliga Region in the Lower Namoi. WaterNSW have advised that it is possible to install Tipping Bucket rain gauges at existing stream gauging stations to deliver real time rainfall data.

- Linking of information on real time extractions, future orders, and installed or authorised pump capacities to the forecast model would allow for a better assessment of the impact of pumping on the forecast estimate.

- The forecast was subject to considerable uncertainty with respect to end of system flows. WaterNSW hydrographers have advised that potential improved methods could include:

  1. Acoustic Doppler current profilers noting that any slight interference from debris such as logs and weeds can affect results. Additionally, they can be expensive and require quite a deal of maintenance and calibration.

  2. Deployment of remote cameras to calculate surface velocities using either Large-Scale Particle Image Velocimetry (LSPIV) or Space Time Image Velocimetry (STIV).

- At the beginning of the forecast a lack of information on cross border flows hampered the forecast estimate. A more formal collaboration process between WaterNSW and the Queensland Department of Environment and Science (DES) in forecasting cross Border flows would allow for improved future forecasts.

- Similar past historic event can assist in predicting current event behaviour. Development and categorisation of a suite past Menindee inflow events would contribute to better forecasts.

Modelling Platform

- The application of the spreadsheet models in forecasting the first flush event is sound and appropriate. All available data was used in the assessment with the main limitations in forecasting accuracy predominantly due to insufficient information on local inflow events and cross border flow from Queensland.

- Notwithstanding the above point, the need for improved forecasting is becoming more apparent with recent initiatives such as active management of NSW unregulated flows requiring this. There exists a significant opportunity to develop a more sophisticated forecasting model for use in the North Western Rivers of New South Wales by WaterNSW. The spine of such a model already exists in the form of the WaterNSW river system valley Source models. These individual models could be joined together to form the basis of an improved forecasting model. A suitable user interface through utlisation of the existing Computer Aided River Management (CARM) system could also be developed.

Namoi Unregulated Tributary River Pumping

1. At the Namoi end of system, pumping from the Mooki and Cox's Creek the reduced event volume in the order of 21%.
2. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not occurred, the impact upon Namoi end of system event volume from additional pumping would have been small and in the order of as extra 2%.
3. In the Barwon Darling at Wilcannia, extractions from the Mooki and Cox's Creek reduced the NSW portion of the flushing event volume by approximately 5.3% and the total event volume by 3.8%.
4. If the embargo on Mooki and Cox's Creek pumping from the 17th to the 20th of February had not of occurred, the impact upon event volumes at Wilcannia from additional pumping would have been less than 1% for both the NSW portion and the total.
5. The volume reductions at Wilcannia are also indicative of the likely reductions at Menindee.

Appendix B: Additional Resource Information: timing of inflows into the system

The Panel identified several submissions raised questions in relation to the impact the restrictions had on flows arriving at Menindee. The additional information below is provided at the request of the Panel to better understand the timing of inflows into the system during the event.

The rainfall events commenced on the weekend of the 9-10 February, with heavy rainfall over the lower Gwydir and Namoi systems. During this weekend and in the days after the rainfall the river systems were managed to meet localised targets with the aim to get water into critical weir pools both along the Namoi, and also the upper Barwon to support the towns of Walgett, Collarenebri, Brewarrina and potentially Bourke.

Early in the week after the event (around 12 February) with good flows in the Barwon, flows were forecast to reach Wilcannia and potentially connect to Menindee lakes.

By the end of the week (around 14 February) higher flows were observed in the Barwon, most notably from the Namoi. This shifted the focus towards the potential to achieve further downstream benefits including the need for a volume in Menindee Lakes. A target of 60-70 GL was set to allow for 20-30 GL to be available to recommence flows in the Lower-Darling. To ensure that the rate of release was high enough to minimise fish deaths a minimum of 60 GL was required in the Menindee storages to provide sufficient head to allow for a release in the order of 1,500-2,000 ML/day.

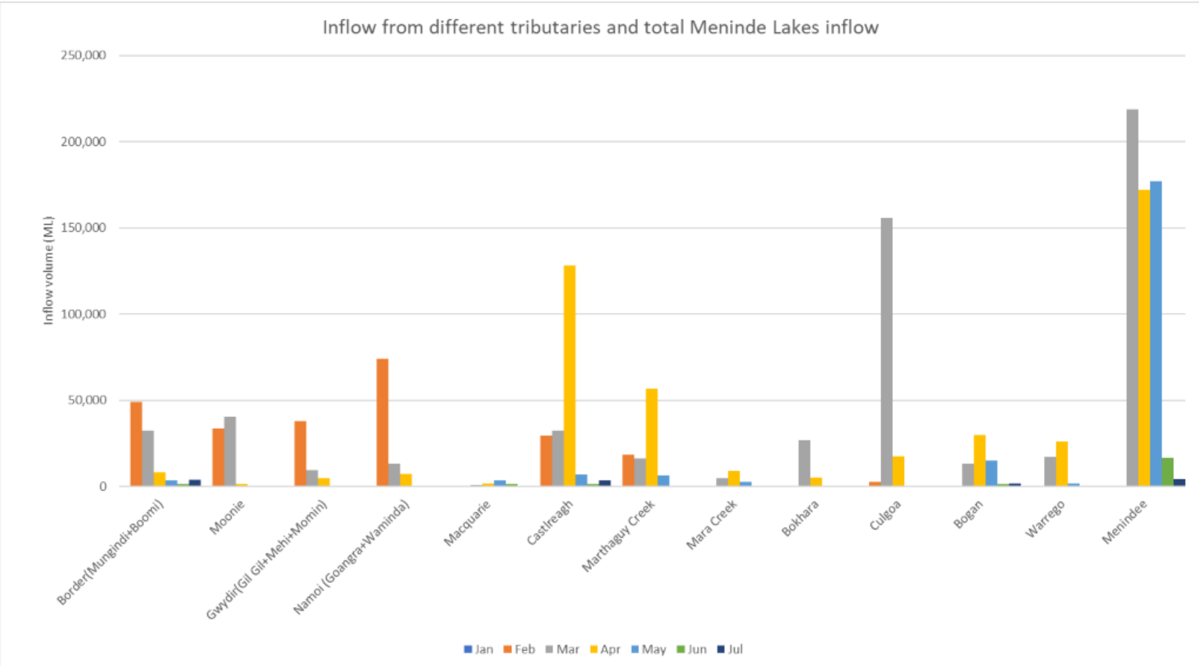
While conditions stabilised over the weekend of the 15-16 February, further rainfall in the early parts of the following week resulted in increased flows across the northern NSW tributaries. Increased flows from the Border and Namoi resulted in increased inflow forecasts for Menindee of 15-35 GL on 17February to 60-80 GL on 21 February. This triggered the lifting of temporary restrictions in the north tributaries as a significant portion of the flows were now in the lower sections of the rivers and analysis of extractions based on pump capacity determined that it would not impact meeting the target of 60 GL at Menindee.

Heavy rainfall in the order of 150-200mm over the western parts of the Queensland catchments over the 23 and 24 of February resulted in significant flooding in the Balonne and Warrego rivers. Initial forecasts indicated that these systems would provide in the order of 150 GL of inflows to the Barwon Darling. This unexpected change in circumstances prompted a revision of the requirements for the Lower Darling. The revised requirements were to provide enough water to enable the Lower Darling to run for a minimum of 12 – 18 months. This also included the removal of the block banks in the Lower Darling to improve environmental outcomes and secure water for stock and domestic users.

The forecast of flows from the Queensland tributaries increased over the week as the flood peaks arrived at St George enabling the restrictions in the Barwon Darling to be lifted by the first week of March.

Rainfall continued over the central NSW catchments during March and April with an additional 350 GL of flows coming out of the unregulated river systems of the Castlereagh, Marthaguy and Bogan rivers during these months resulting in higher inflows to the Menindee Lakes.

The graph below shows the timing of the inflows from the different north tributaries. This graph shows that the NSW northern tributaries of the Border, Gwydir and Namoi combined with the Moonie provided most of the flow into the system during February while the central valleys (Castlereagh, Marthaguy and Bogan) along with the Culgoa and Warrego provided inflows during March and April.



Border River

System inflows began around the 12 February with flows commencing at Boggabilla and these peaked around the 16-22 February and then started to recede. Most of the inflows at Boggabilla were recorded between the 12 - 24 of February (119 GL) with the total flow for February being 129 GL. After February the flows dropped off with only 22 GL of flows past Boggabilla in March, 10GL in April, 3GL in May and 6GL in June.

Flows at Terrewah arrived on the 14 February with 89 GL being recorded during February past the gauge. Initial flows were lower than at Boggabilla as water was lost to replenishing the river and as a result of water breaking out of the channel. Flows were slightly higher than Boggabilla during March with 28 GL recorded but reduced from here similar to Boggabilla with 9 GL in April, 1.5 GL May and 3.3 GL in June.

A similar situation can be seen at Boomi with the flows beginning around the 16 February and flows of 31GL recorded past the gauge for the month. Similar with the above gauges the system started to recede from late February with 22 GL recorded in March, 8 GL in April, 1.5 GL in May and 2.8 in June.

Flows reached Mungindi on the 16 February with over 40 GL recorded past the gauge during February. Most of this flow would have been from local runoff and from the Weir River which commenced to flow into the Macintyre on the 17 February providing 24 GL of flow in the month. Flows again reduced in March to 29 GL and then 8 GL in April, 3 GL in May and 1.3 in June.

The flows past Terrewah, Boggabilla and Mungindi show that significant losses, in the order of 120- 130 GL, occurred along the river. These losses do not take into account local runoff that would have added to the flow at these gauges.

The Border Rivers are part of the Murray-Darling Basin and the major river systems in NSW are the Dumaresq, Severn, Macintyre and Mole Rivers. The western half of the catchment comprises flat alluvial plains drained by intermittent water courses. At the lower end of the catchment the Macintyre River is characterised by a complex series of anabranch channels. The Weir River in Queensland is the Macintyre River's largest tributary (570 Km^2), flowing into the Macintyre River around 25 kilometres upstream of Mungindi.

The river channel of the Macintyre river decreases as it flows from the escarpment to the flood plain. The river channel at Goondiwindi can contain 160,000 ML/d but due to constraints at Terrewah the channel capacity is reduced to around 9,300ML/day and then further reduces at Boomi to 3,200 ML/d. As a result of this as the water flows down the system and reaches these constraints the river cannot pass the flows and the water is pushed out on the flood plain.

During the February rainfall event, flows of well above the 3,200ML/day were recorded at Boomi for 11 consecutive days (16-26 February inclusive, average daily flow 7,493ML/day). This resulted in significant volumes breaking out of the channel between Terrewah and Boomi.

In NSW, a significant proportion of supplementary extractions are located upstream of Terrewah. Supplementary access targets the peak of the hydrograph and therefore reduces the volume of water breaking out onto the flood plain. As access was not allowed during the February event a larger volume of water broke out onto the flood plain. Therefore, the restriction on supplementary access resulted in higher system losses with more water breaking out of the system. The breakout of water on the Border river flood plain would have allowed flood plain harvesting on both the NSW and Queensland side of the river. While NSW had restriction on flood plain harvesting Queensland did not so the implementation of restriction on supplementary access provided greater opportunity for Queensland landowners in the region to access water through flood plain harvesting.

Gwydir River

Approximately 53 GL of water flowed out of the Gwydir through the Mehi, Grawan Creek or the Gil Gil. Flows from the Gwydir into the Barwon Darling commenced in early February from the rainfall event on 8-10 February.

The upper reaches of the Gwydir did not commence to flow until 11 February with significant flows at Pallamallawa recorded between the 11-29 February (49 GL). However, most of this flow continued down the Gwydir with only approximately 15 GL being diverted down the Mehi. While there was 15-16 GL of flow recorded in the Mehi at Moore for February only 11 GL of flow was recorded downstream of Gundare. Downstream of Gundare flows for February increased both between Gundare and Ballin Boora and between Ballin Boora and Bronte. These increases can be attributed to water flowing in off the Gwydir floodplain from the event around the 8-10 February.

In relation to the Gwydir River, approximately 60 GL was directed into the Gwydir downstream of Tareelaroi weir (offtake for the Mehi) during the first half of the year. Most of this flow occurred in February (31 GL), March (12 GL) and April (10 GL). Even at Boollooroo most of the flow continued down the Gwydir (48 GL) while only 16 GL was directed to the Carole. From the flow data at Tareelaroi and Boolooroo the river seemed to have gained water off the flood plain with flow volumes in the Gwydir and Carole slightly higher than the flow recorded in February downstream of Tareelaroi.

However, as the water continued to flow down the Gwydir below Boolooroo system losses were observed between Boolooroo and Yarraman Bridge. The flow from the Gwydir was split as evenly as possible over February and April between the Gwydir wetlands (16GL) and the Gingham (20 GL)

During the event as much water as possible upstream of Tareelaroi weir was directed into the Mehi and Carole systems to provide maximum opportunity to get flows to the Barwon Darling. The only supplementary access provided in the early stages of the event occurred in the Gwydir River downstream of Boolooroo (downstream of the Carole offtake). This water could not be directed to the Barwon due to physical constraints. Access in the lower Gwydir did not impact flows to the Barwon Darling as it feeds the Gingham/Gwydir wetlands.

Like the Border River, the Gwydir River channel capacity decreases below Boolooroo resulting in water breakout of the channel and flooding private property. Under the water sharing plan the first 500ML/day from the 3 main upstream tributaries is protected from extraction, and then only 50 percent of flow above this rate is available for supplementary access. With the advantage of hindsight, greater supplementary access could have occurred on the Gwydir River (between Copeton and Boolaroo) if restrictions had not been applied without impacting flows to Barwon.

Namoi River

There were two major inflows events to the Namoi during February. The first event occurred on the weekend of 9-10 February with widespread rainfall across the catchment. The Namoi commenced flowing from the top end of the system with good inflows from the Peel River, and the Moki and Cox's sub-catchments and heavy rainfall in the middle sections of the catchment around Narrabri over the weekend. This event resulted in approximately 85 GL inflows to the Namoi, measured at Mollee.

The second event occurred on 20 -21 February which was a smaller event resulting in approximately 34 GL at Mollee. Between these two events, approximately 119 GL of flow was recorded at Mollee during the month of February. This compared to 2 GL in March 7.3GL in April and less than 0.1 GL in May and June.

Total flows recorded in the mid-section Namoi were128 GL for the first 6 months of the year with flows in February accounting for 93 per cent of the flow. Total flows in the Namoi decreased downstream of Mollee with a portion of the flow being directed into the Pian Creek system (14 GL) to meet stock and domestic demands. However, further losses occurred in the lower reaches especially between Gunidgera and Bugilbone during February with loses in the order of 30 GL and again between Bugilbone and Goangra with losses in the order of 7 GL.

Macquarie River

The Macquarie River system has channel capacity constraints restricting flows further down the system with flows being restricted to 5,000ML/d at Warren and to 3,500 ML/d at Marebone.

Supplementary access in the Macquarie aims to protect the 5,000 ML/d at Warren to provide for flows to the Macquarie marshes, by allowing access to flows at the top of the hydrograph above this level. While some of the water breaking out of the Macquarie above this level will find is way to the Bogan and Marthaguy systems and potentially flow into the Barwon Darling, significant losses are experienced from the break outs as can be seen this year with over 188 GL lost to system replenishment.