SINCLAIR KNIGHT MERZ
SKM

Scoping Study
Commonwealth Use of Private Water Storages in the Northern Murray-Darling Basin

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

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Scoping Study

Report prepared for The Environmental Water Branch (Water Governance Division) within the Department of Environment, Water, Population and Communities by Sinclair Knight Merz [EN03137]

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1 Introduction

Commonwealth Environmental Water (CEW) was established under the *Water Act* 2007 (the Act) to manage environmental water and water holdings acquired by the Commonwealth. Under the Act, Commonwealth environmental water and water holdings are managed to protect or restore the environmental assets of the Murray-Darling Basin (MDB), and other areas outside the Basin where the Commonwealth holds water and water holdings.

The Commonwealth Environmental Water Office uses a number of mechanisms to ensure the Commonwealth's environmental water portfolio can best meet environmental needs. These mechanisms include the use of water trade and carryover. However, much of the flexibility to delivery water is derived from the Commonwealth's ability to store water within headwater dams and call the required volumes to specific locations at a time which best meets environmental need. In the largely unregulated northern catchments of the MDB this option is more limited or not available at all. This is because water rights and water infrastructure in these catchments are based on opportunistic access to water when certain flow conditions are met. These conditions are often linked to flow rates specified at certain points on a river system. Irrigators in these areas typically have high capacity off-takes and large on-farm dams (called 'ring tanks' or 'turkey nest' dams) to harvest and store both river and overland flows. These features of unregulated catchments influence how, and when, environmental watering is undertaken.

The Commonwealth Environmental Water Office has identified some opportunities where it may be advantageous for the Commonwealth to use private storages and other water infrastructure to store and deliver Commonwealth environmental water. The use of private storages and water infrastructure may provide flexibility when watering assets that are located far from the main river channel, or where there is no public infrastructure or delivery arrangement in place.

This scoping report explores the potential for use of private storages and water infrastructure in the northern MDB. The objectives of the study were to:

- discuss how the Commonwealth could use private storage and water infrastructure to assist in delivering Commonwealth environmental water, and the potential benefits and risks associated with this use, and
- provide a preliminary assessment of the environmental utility and operational flexibility that private storage and delivery of Commonwealth environmental water might provide.

The study focused on three pilot catchments in Queensland and New South Wales – the Condamine-Balonne, Border Rivers and Namoi. The scoping report is structured such that opportunities to use private storages and water infrastructure are discussed in separate chapters for each pilot catchment.

2 Approach for Determining Usefulness of Private Water Storages

The primary focus of the approach to determining the usefulness of private water storages was to assess the feasibility of using private storages and infrastructure to meet selected environmental water targets, and compare this to alternative means of meeting the targets. Hence, the project involved the following key tasks:

- Identification of environmental water assets, their water regime requirements and a set of indicative environmental watering (flow/volume) targets.
- Collation of available baseline information on locations and capacities of on-farm storages, water entitlements, current use of private storages and current achievement of the environmental flow targets.
- Identification and assessment of how private storages and infrastructure might be used to achieve the watering targets, as well as alternative mechanisms.
- Comparative evaluation of available mechanisms.

The comparative evaluation considered:

- Effectiveness – To what extent is the mechanism likely to be able to meet the flow targets?
- Workability – How feasible and practical is the mechanism to implement? What impediments would need to be addressed?
- Risks and uncertainties – What factors could derail the mechanism being implemented or achieving the expected results?

The following assumptions and limitations are acknowledged:

- The environmental watering targets used in the report were sourced from the Murray-Darling Basin Authority (MDBA 2012) *Assessment of Environmental Water Requirements for the Proposed Basin Plan* for each study catchment. The particular flow targets investigated were included as directed by Commonwealth Environmental Water Office personnel.
- The information available from IQQM models was the critical limitation in describing environmental watering shortfalls and the manner in which various possible delivery mechanisms could be used. This necessitated the use of approximating assumptions about environmental asset water requirements, and the delivery of water. For example, the spatial scale of the analyses is at reach level, and was referenced to 'nodes' in the IQQM. As multiple irrigators are often grouped together in IQQM and modelled as a single entity, the storage information at individual model 'nodes' may represent a number of water licenses and storages, over a distributed area. Hence, the river systems in each catchment were divided into reaches, and the information regarding the operation of the storages has been used as an indicator for likely irrigation behaviour within each reach.
- Data on the locations and volumes of on farm storages was limited to what was available from IQQM models and available spatial imagery. Individual storage capacity information was generally not available – only the combined 'node' volumes from the IQQM models.

Inferences on individual storage volumes were drawn from total volumes and numbers of storages at IQQM nodes, and viewing of spatial representation of storages.

- No field work was undertaken to assess the physical feasibility of using storages.
- Aside from contacting the NSW Office of Water (NOW), and the Queensland Department of Environment and Resource Management (DERM), to source IQQM data, there was no direct interaction with irrigators or their representatives, or government staff in the development of this report.

These limitations are considered to be acceptable at this stage given this is a scoping study. Further work will be required to more explicitly investigate the feasibility of options identified herein.

3 Condamine-Balonne Catchment

3.1 Target Environmental Assets

Wetlands of national importance in the Condamine-Balonne catchment include Great Artesian Basin Springs, Lake Broadwater, the Gums Lagoon, and Dalrymble and Blackfellow Creeks. The Lower Balonne floodplain area is particularly significant because it supports the largest number of wetlands in the Murray-Darling Basin, including the Ramsar-listed Narran Lake Nature Reserve, and the Culgoa River floodplain (MDBA 2012a).

The Lower Balonne floodplain area is a complex floodplain channel system, heavily dissected by well-defined channels of various sizes with expansive floodplain areas (Sims & Thoms 2003). These channels carry a significant proportion of the 'overland' flow during flood events, and provide significant refuge habitat for freshwater-dependent species during extended dry periods (Thoms *et al*. 2001).

The Balonne floodplain contains the Narran Lakes system and two other significant wetlands: the Lower Balonne River Floodplain and the Culgoa River Floodplain Park (Sims & Thoms 2003). There are also two National Parks on the Balonne floodplain: the 22,430 ha Culgoa National Park managed by New South Wales National Parks and Wildlife Service, and the adjoining 42,800 ha Culgoa Floodplain National Park managed by Queensland National Parks and Wildlife Service.

The Narran Lakes are a large terminal wetland system on the Narran River in NSW. It is comprised of a series of terminal drainage lakes (Back, Clear, Long Arm and Narran/Terewah Lake) connected by a network of river channels, ephemeral wetlands and an extensive floodplain (Sims & Thoms 2003). The system is recognised as one of the most important waterbird habitats in eastern Australia, and a portion is listed under the Ramsar Agreement (Narran Lakes Nature Reserve).

The Lower Balonne River Floodplain (incorporating the Culgoa River floodplain) and the Narran Lakes are the target environmental assets in the Condamine-Balonne River catchment.

3.2 Environmental Watering Targets

The Murray-Darling Basin Authority (MDBA) has determined the environmental watering requirements of the Lower Balonne Floodplain and the Narran Lakes, as part of its preparation of the proposed Basin Plan. These are presented in Table 1.

Table 1: MDBA environmental watering requirements for the Lower Balonne Floodplain and the Narran Lakes. (Source: MDBA 2012a)

ASSET	EVENT	TARGET
Lower Balonne Floodplain	▪ 1,200 ML/d flow at Brenda gauge for minimum seven days, every 22-28 months	▪ Maintain critical habitat for endangered fish and invertebrate species in the channels of the Lower Balonne River Floodplain System
	▪ 12,000 ML/d flow at Brenda gauge for minimum 11 days, every 3-4 years	▪ Maintain current extent of Coolibah-Black Box woodlands in good condition
	▪ 18,500 ML/d flow at Brenda gauge for	

ASSET	EVENT	TARGET
	minimum nine days, every 4-5 years ▪ 126,500 ML/d flow at Brenda gauge for minimum seven days, every 7-10 years	▪ Maintain current extent of floodplain grassland communities in good condition
	▪ 38,500 ML/d flow at Brenda gauge for minimum six days, every 20 years	▪ Maintain current extent of lignum shrublands in good condition
Narran Lakes	▪ 25 GL inflow over a 2 month period measured at Wilby Wilby gauge every 1-1.1 years ▪ 50 GL inflow over a three month period measured at Wilby Wilby gauge every 1-1.33 years ▪ 250 GL inflow over a six month period measured at Wilby Wilby gauge every 7-10 years	▪ maintain the current extent of lignum shrublands in good condition ▪ maintain the current extent of riparian open forest and woodland communities in good condition
	▪ 100 GL over a 12 month period measured at Wilby Wilby gauge every 6-8 years	▪ provide conditions conducive to successful breeding of colonial nesting waterbirds

The target flow components for testing the usefulness of using private infrastructure and storages in the Condamine-Balonne catchment focus on the particular susceptibilities of each target asset to extended periods of low or no flow.

Flows in the Lower Balonne system are highly variable, with frequent ‘flashy’ (high magnitude, low duration) floods, and long periods of low and no-flow conditions common (MDBA 2012b). Refuge waterholes are a feature of the rivers in the Lower Balonne Floodplain region, providing important habitat for freshwater-dependent flora and fauna during extended low and no-flow periods (Webb 2009). Maintenance of these areas contributes to supporting food webs and ecosystem function and resilience. Low flows and freshes are critical for supporting the quality and quantity of refuge waterholes for freshwater-dependent flora and fauna, and connectivity between them (Sheldon *et al*. 2010, MDBA 2012b).

Hence, in the Lower Balonne Floodplain the target is to support an end-of-system flow event to maintain critical in-channel habitat. To ensure waterholes in the system retain at least 1 m of water, flows of approximately 1,200 ML/day for seven days at Brenda should occur every 22 months (MDBA 2012b). A flow of this magnitude and duration will connect waterholes along the length of the main rivers in the floodplain (MDBA 2012b). Hence, this is the flow target adopted for determining the usefulness of private storages and infrastructure in storing and delivering Commonwealth environmental water to the Lower Balonne Floodplain asset.

The Narran Lakes complex is part of the Lower Balonne Floodplain and as such, is subject to the same ‘flashy’ flood flows and extended periods of low or no-flow. The extent and duration of lake inundation in the system depends on the timing, magnitude and duration of multiple events of a similar threshold in close proximity (MDBA 2012c). The physical character and inundation requirements of the lakes are relatively well known, with the MDBA (2012c) documenting three water delivery regimes to maintain vegetation condition in the lakes and floodplain, and to support a waterbird breeding event (Table 2).

Table 2: Environmental flow requirements for the Narran Lakes system (Sims & Thoms 2003, MDBC 2007, MDBA 2012c).

Delivery Regime*	Duration of Inundation	Extent Inundated	Target Ecological Outcome
25,000 ML delivered over two months, every year.	Two to six months without further inflows.	▪ Inundates the northern lakes in the system, filling Back Lake and bringing Clear Lake to approximately 80 percent capacity. ▪ Inundates Lignum shrubland in the littoral zone of Back Lake, riparian open forest fringing wetland and river channels between the Narran River and Clear Lake, and between Clear and Back Lake.	▪ Maintain vegetation condition in the northern lakes. ▪ Provide open water habitat in Clear Lake.
50,000 ML delivered over three months, twice in a year, maximum every seven to ten years.	Water levels in Clear Lake would reach 1 m and remain for up to 12 months.	▪ Significantly inundates the northern lakes and areas of the channelized floodplain south of Clear Lake. ▪ Water is also pushed down the length of the system into Narran Lake.	▪ Maintain the health of rookery habitat in the northern lakes and sustain lignum and river cooba on the channelized floodplain.
250,000 ML delivered over six months, every ten years.	Water levels in Narran Lake would persist for up to 18 months.	▪ Inundates most of the Narran Lakes system, covering the broader floodplain and filling Narran Lake to approximately 60 percent capacity.	▪ Inundate the entire lake system, and sustain lignum and coolibah growing on the broader floodplain.
100,000 ML delivered over 12 months, every six to eight years.	Water levels would persist for up to 14 months depending on inundation time and evaporation rates.	▪ Inundates the northern lakes and Narran Lake.	▪ Provide conditions conducive to successful breeding of colonial-nesting waterbirds in the Narran Lakes

* *The timing is preferably summer-autumn for maximum environmental benefit, but can occur anytime during the year.*

The flow thresholds presented in Table 2 are significantly larger than the current Commonwealth environmental water holding in the Condamine-Balonne (12,500 ML un-supplemented as at February 2012[1]), and as such provision of an event solely from Commonwealth water is not feasible. However, a carefully timed delivery of 12,500 ML is sufficient to prevent nest desertion by colonial breeding waterbirds in the Narran Lakes. For example, in 2008, 10,433 ML purchased from a private storage

[1] Since this report was drafted the Commonwealth Environmental Water Holdings have increased to approximately 36 GL in the Lower Balonne, and are expected to increase in the future. For example, the Commonwealth has recently purchased a large volume of entitlement share on the Culgoa River. The provision of this additional volume will improve the Commonwealth's ability to achieve more watering targets and potentially undertake actions solely provisioned by Commonwealth environmental water. The Commonwealth will also be better able to negotiate use of the now available storage capacity.

located 10 km south-west of Dirranbandi on the floodplain adjacent to the Narran River, was released into the river to contribute to maintaining water levels at Back Lake, above the 28 cm nest desertion depth (EAA 2009). Approximately 8,124 ML reached the lake, extending the duration of inundation in the lake above the nest desertion threshold for a month, allowing 50,000 chicks to fledge.

Hence, to explore opportunities to use private storages and infrastructure to augment high flow conditions, the following flow target was analysed:

- to contribute to total flows of 100,000 ML at Wilby Wilby gauge over 12 months at least once every six years was the flow target analysed.

The following operational constraints and triggers were assumed:

- 10,000-20,000 ML available Commonwealth environmental water to use to augment events
- modelling was conducted on the July to June water year, because modelling on the calendar year would split the wet season
- 80-90 GL total flow at Wilby Wilby gauge up to the end of March if three to six years have passed since the last 12 month, 100,000 ML event
- 50-90 GL total flow at Wilby Wilby gauge up to the end of March is greater than six years have passed since the last 12 month, 100,000 ML event
- No augmentation flow after the end of April in any year.

3.3 Baseline Information

3.3.1 Data Collation, Analyses and Approach

Analysis of on-farm storage behaviour, river flow and availability of water in the Border Rivers catchment was achieved using data from two models developed and supplied by the Queensland Department of Environment and Resource Management (DERM). These were the St George ROP model, extending from Beardmore Dam to the B1 Bifurcation, and the Lower Balonne (distributory) model, extending from the B1 Bifurcation to the Barwon River. Key details of the models are presented in Table 3.

Table 3: Hydrologic model details.

Title	Model Name	Extent	Simulation period
St George ROP model	S1002AR	Beardmore Dam to the B1 Bifurcation	01/01/1922 to 31/12/1995
Lower Balonne (distributory) model	D1006C	B1 Bifurcation to the Barwon River	01/01/1895 to 30/06/2009

Data either supplied by DERM or derived from the model included:

- a description of modelled reaches
- for each modelled irrigation node that has an on-farm storage:
  - licence entitlement volume
  - on-farm storage capacity
  - airspace

  - crop type and area
- simulation results including daily time series for:
  - on-farm storage volumes
  - on allocation, off allocation and floodplain harvesting extractions for each irrigation node
  - allocation levels for regulated water entitlements
  - flow at stream gauges
  - surplus water availability at off allocation nodes.

The data and results were used to assess available volume in on-farm storages and assessment of river flows to achieve environmental flow targets.

3.3.2 Available Volume in On-farm Storages

The majority of private storages in this region are unregulated and are used for water harvesting. As the supplemented demand in this area is low and would be a poor indicator of available storage, capacity announced allocations and supplemented supply have not been used for this assessment.

Irrigators in the Lower Balonne models are represented as clustered groups, combined to match the division of the river into its major reaches (Figure 1). These irrigators are also grouped within each reach to represent their various water access rights. For the purpose of this investigation irrigators have been grouped into three regions: Region 1 from Beardmore Dam to Jack Taylor Weir; Region 2 from below Jack Taylor Weir to the B1 Bifurcation, and Region 3 below the B1 Bifurcation. Irrigator details for these reaches are provided in Table 4.

Table 4 Details of relevant irrigation groups and corresponding on-farm storage in the Lower Balonne models

Region	Upstream Boundary Location (Gauge Number)	Downstream Boundary Location (Gauge Number)	On-farm Storage Capacity (ML)	Maximum Pump Capacity (ML/day)
1	Beardmore Dam	Jack Taylor Weir	258,200	
2	Jack Taylor Weir	B1 Bifurcation	223,000	
3	B1 Bifurcation	End of system	760,000	8,545

The largest combined volume of on-farm storages (760,000 ML) occurs in the third region, below the B1 Bifurcation. The volume in this region is substantially larger than the first two. These storages are primarily used for floodplain harvesting, although some are used for overland flow capture.

In the Narran River system licence there are five licence holders with potentially large on-farm storage capacities (26, 070 ML) downstream of the B1 Bifurcation. Of these, EAA holds 45 percent of the total nominal capacity available in the system (Table 5).

Table 5 Key licence holders in the Narran River system (EAA 2009)

Licence Holder	Nominal Volume (ML)	Percentage of the Total
HC and RL Crothers	2,540	9.7
EAA	11,930	45.8
McIntyre Cotton	1,550	5.9
DT, PE, DM and LK Crothers	4,185	16.1
Pechelba	5,865	22.5

The on-farm storage is where water is stored from river pumping, floodplain harvesting and/or local rainfall run-off harvesting. A reserve volume is often maintained in storage to capture about one

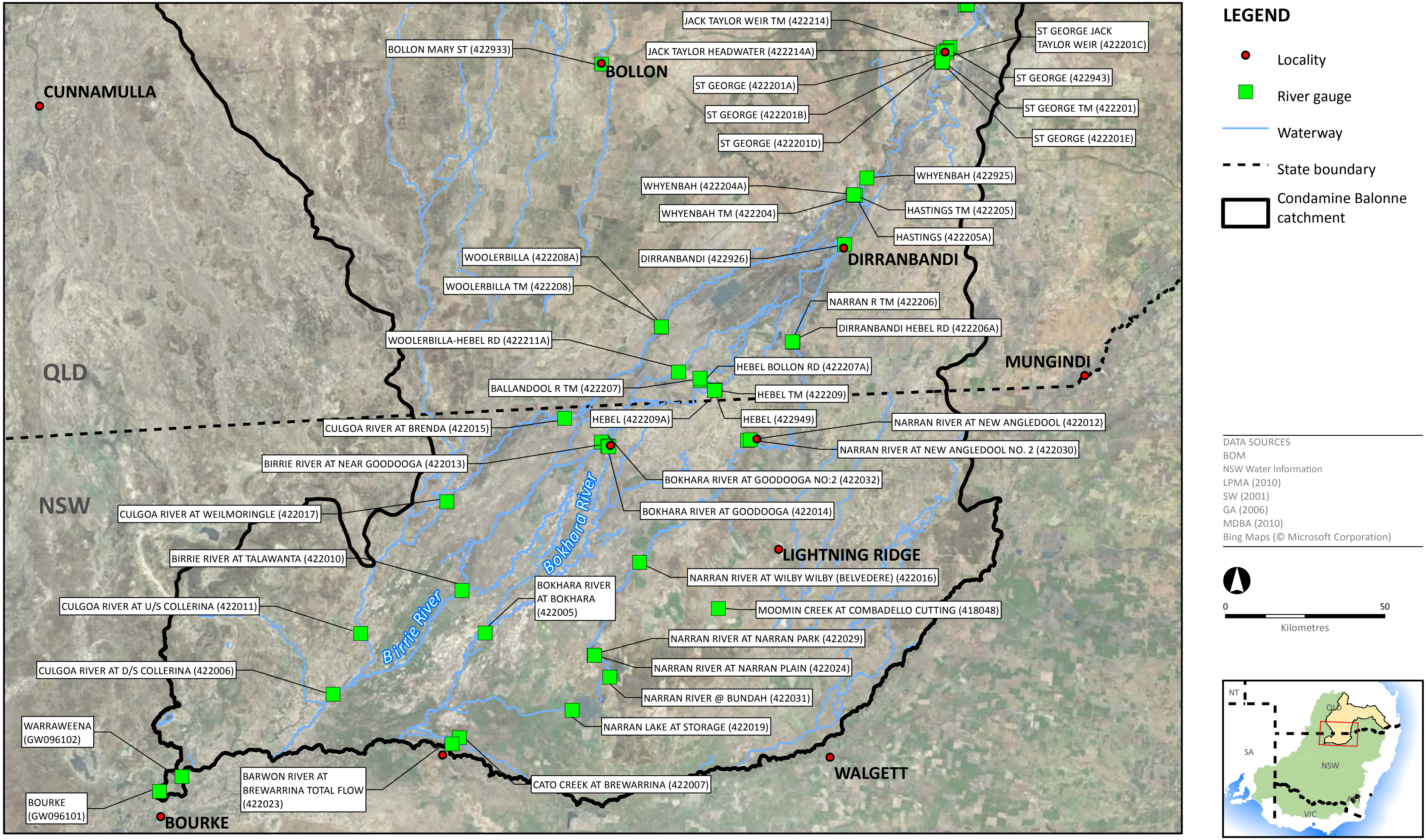

FIGURE 1 | Location of relevant irrigation nodes in the lower Condamine-Balonne catchment

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watering, with an airspace volume also maintained to allow the first flush from rainfall run-off to be kept within the property, due to water quality issues. There were no details specified within the modelling for the operation of storage reserves and airspace volumes. Therefore, for this study, the use of airspace or reserve volumes for storage of environmental water (as a separate volume to the total on-farm storage) was not considered, in recognition that use of these volumes may conflict with standard farm practices in the catchment.

Figure 3 and Figure 4 depict the location of key on-farm storages in the Lower Balonne Floodplain and the Narran Lakes system.

On-farm Storage Availability

An assessment has been made of the potential available storage capacity in each region. The results are presented in terms of:

- volume in storage for the combined on-farm storages of the system;
- overall distribution curve of daily available volume in storages;
- summer and winter distribution curve of daily available volume in total, and
- average space available in storages for each month.

Volumes Held in Storage

Figure 2 presents the combined storage volume for on-farm storages from the St George Water Supply Scheme (SGWSS), upstream and downstream of Jack Taylor Weir (derived from the St George ROP model). This shows that there is considerable variation in the storage volume on an annual basis, with storages staying less than half full for most years.

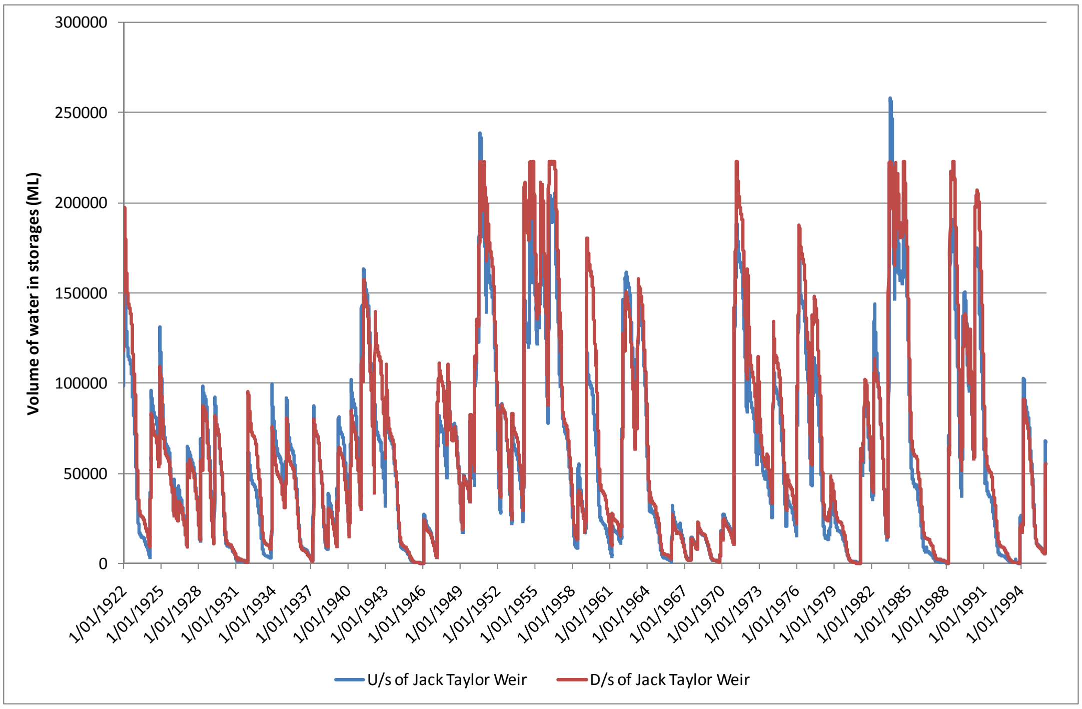

Figure 2: Modelled storage traces of on-farm storages upstream and downstream of Jack Taylor Weir.

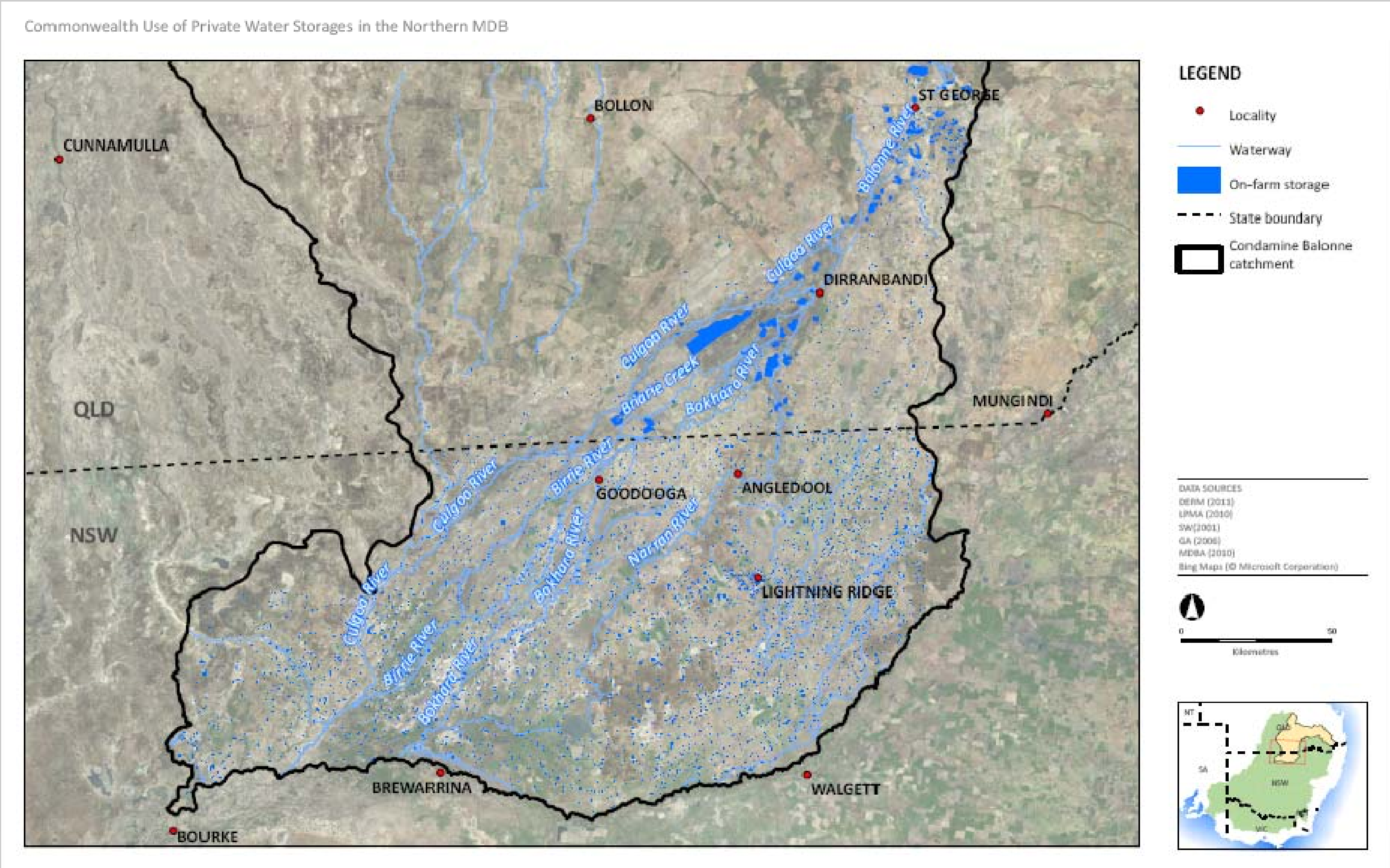

Figure 3: On-farm storages in the Lower Balonne Floodplain

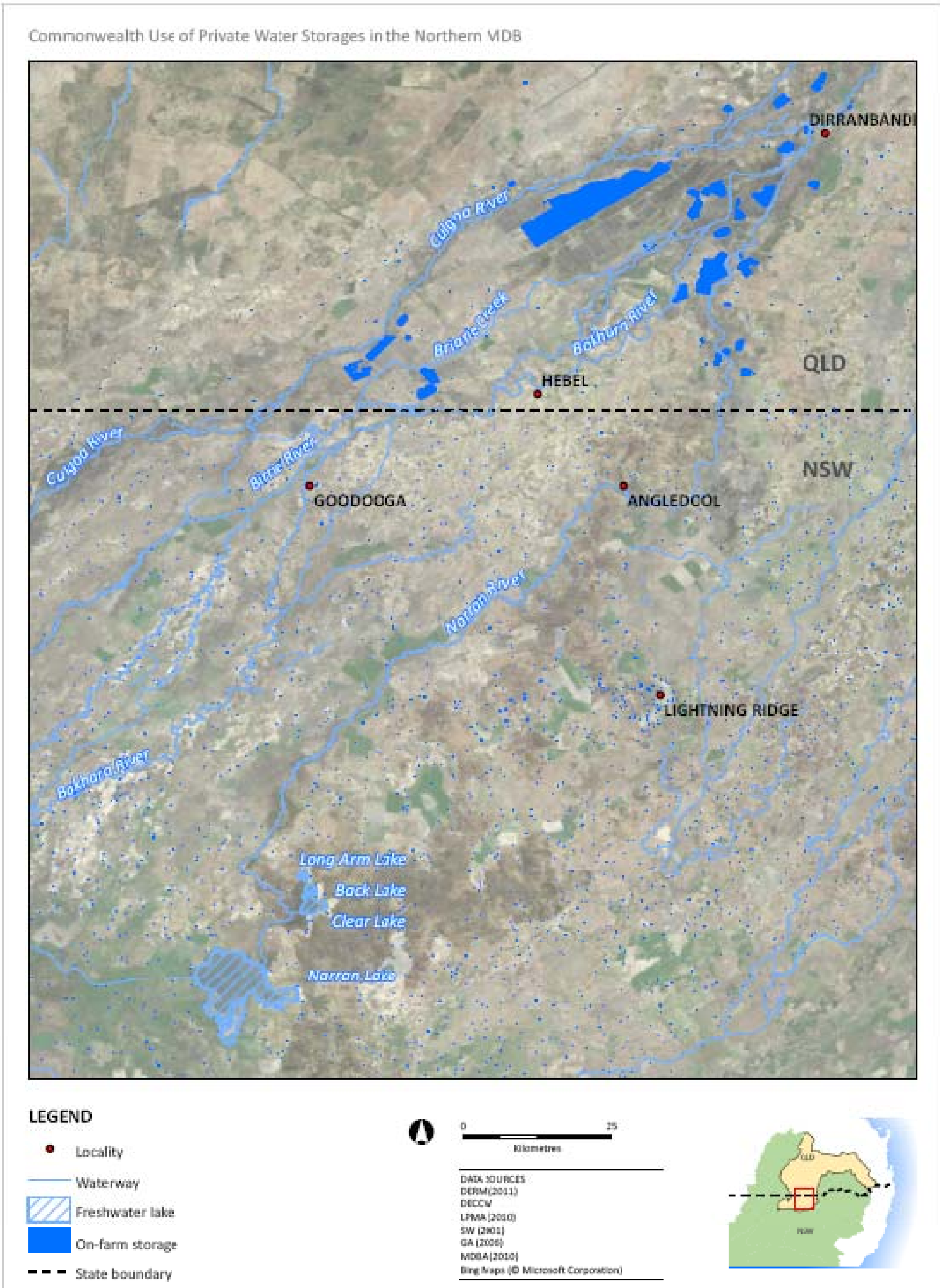

Figure 4: On-farm storages near the Narran Lakes complex

Figure 5 presents the combined storage volume for on-farm storages from the Lower Balonne (distributory) model, downstream of the B1 Bifurcation (Region 3). This shows a similar pattern of storage volume, again with storages remaining less than half full during most years.

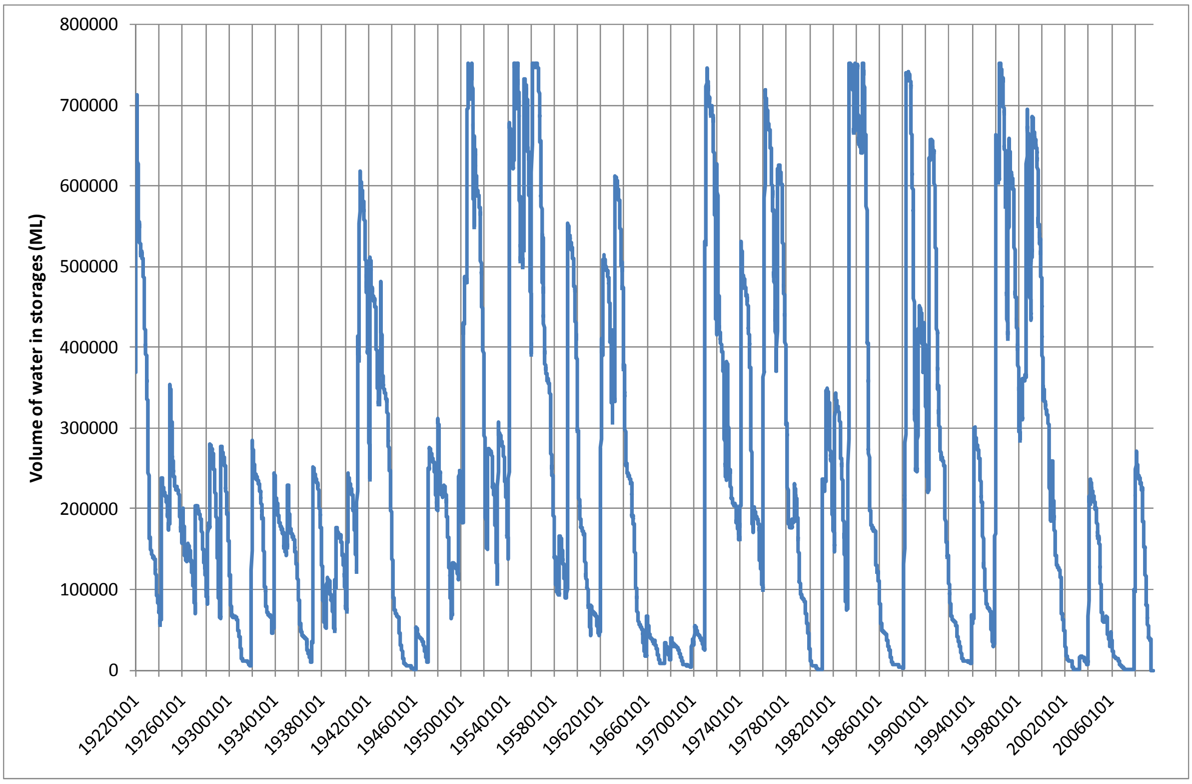

Figure 5: Modelled storage traces of on-farm storages in Lower Condamine (shown over period 1922 – 2008).

Distribution Curve of Daily Available Volume in Storages

Figure 6 presents the distribution curve of daily volume available in the storages in Regions 1 and 2 (upstream and downstream of Jack Taylor Weir). This shows that there are generally large volumes available, with over 400,000 ML available for approximately 45 percent of days and over 100,000 ML available over 96 percent of days. More storage is available in the storages located upstream of the Weir, although these are less practical for supplying water to the Narran Lakes and Lower Balonne floodplain.

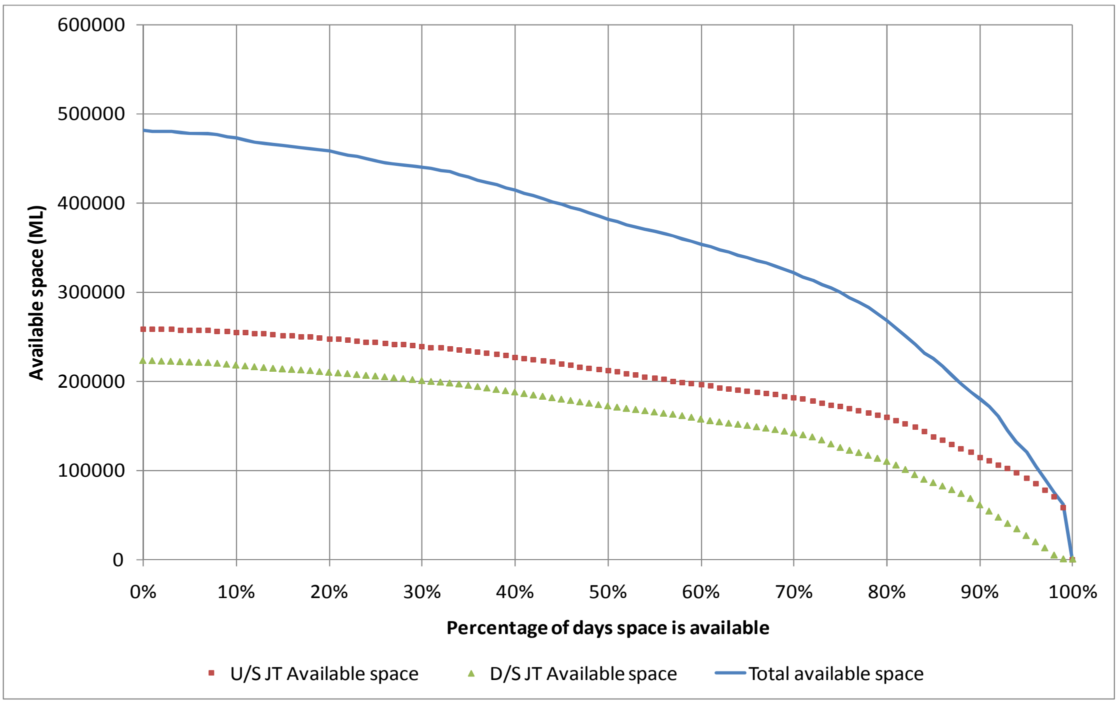

Figure 6: Distribution curve of daily available volume in storages upstream and downstream of Jack Taylor Weir.

Figure 7 presents the distribution curve of daily volume available in the storages in the Lower Balonne (Region 3). This shows that there is generally a large volume available, with over 600,000 ML available for approximately 45 percent of days, and over 100,000 ML available 97 percent of days.

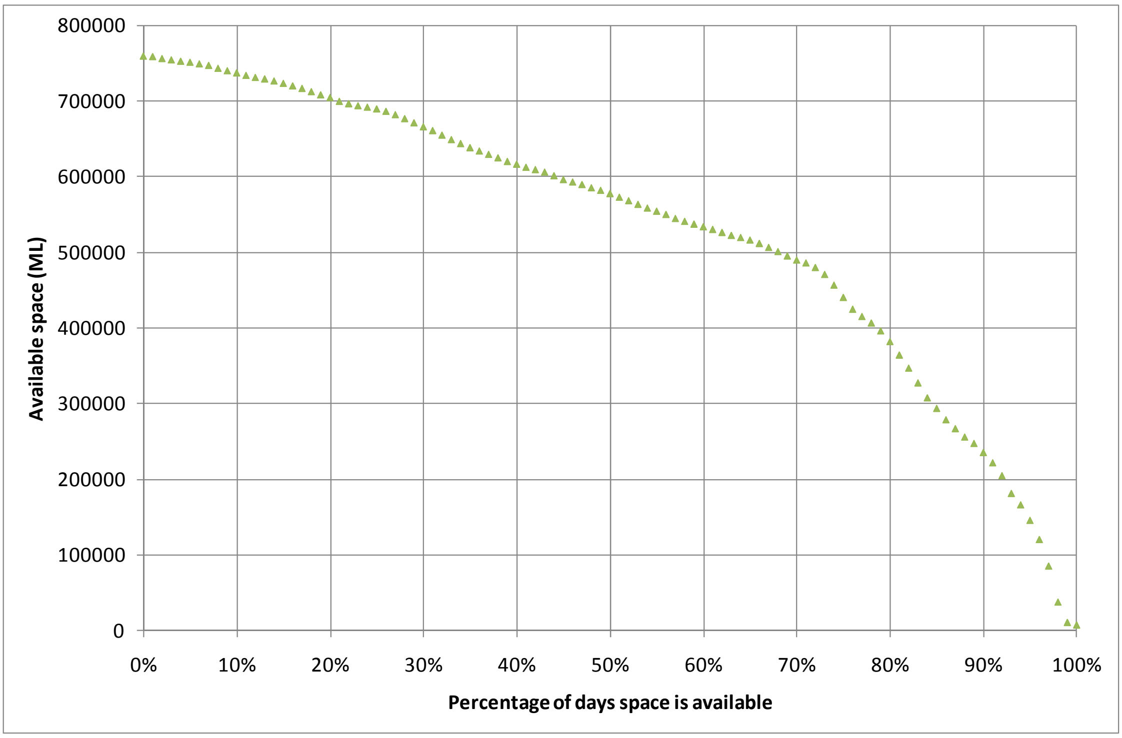

Figure 7: Distribution curve of daily available space in storages of the Lower Balonne

Summer and Winter Distribution Curve of Daily Available Volume

Figure 8 presents the seasonal distribution curve of daily volume available in the storages upstream and downstream of Jack Taylor Weir (Regions 1 and 2). This shows that more volume is usually available during summer. This is also true in the Lower Balonne (Region 3), as depicted in Figure 9.

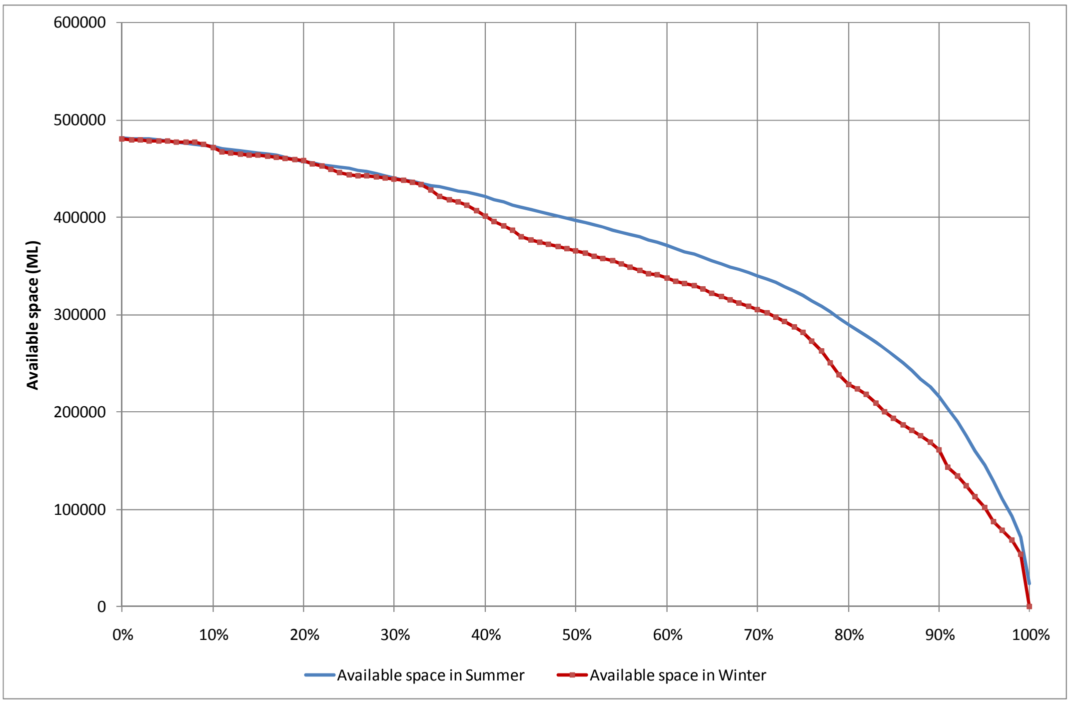

Figure 8: Summer and winter distribution curve of daily available volume in total – Regions 1 and 2.

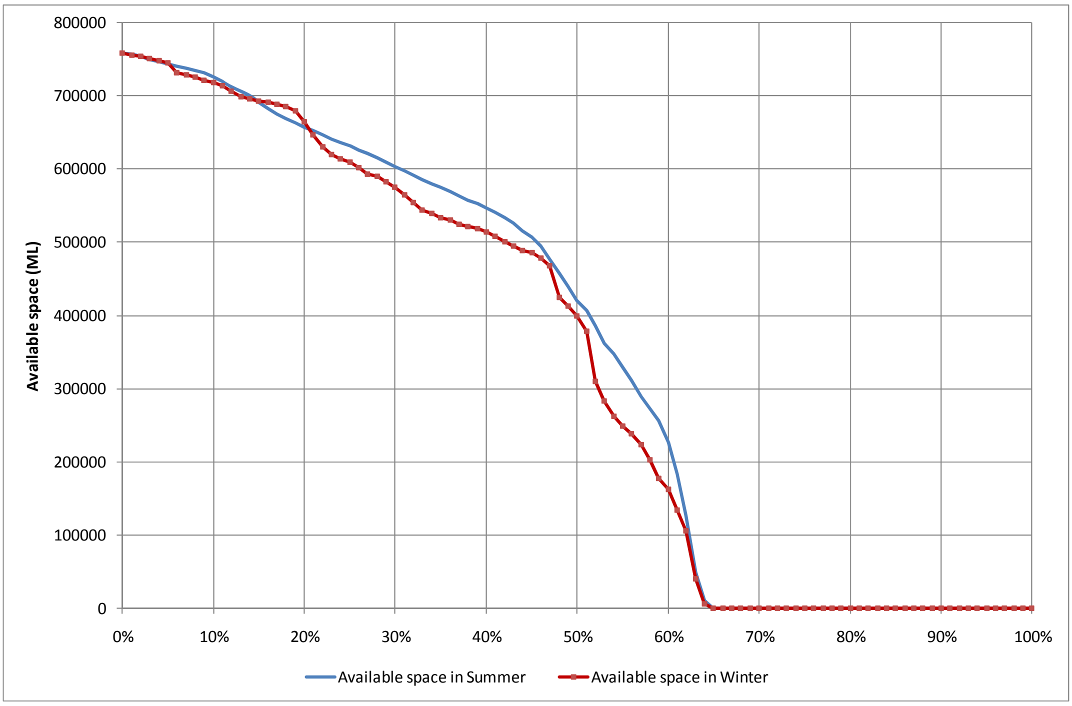

Figure 9: Summer and winter distribution curve of daily available volume in total – Region 3.

Average Space Available in Storages for Each Month

On a monthly basis, the greatest storage space is available during the months October to March in each of the regions (Figure 10 and Figure 11).

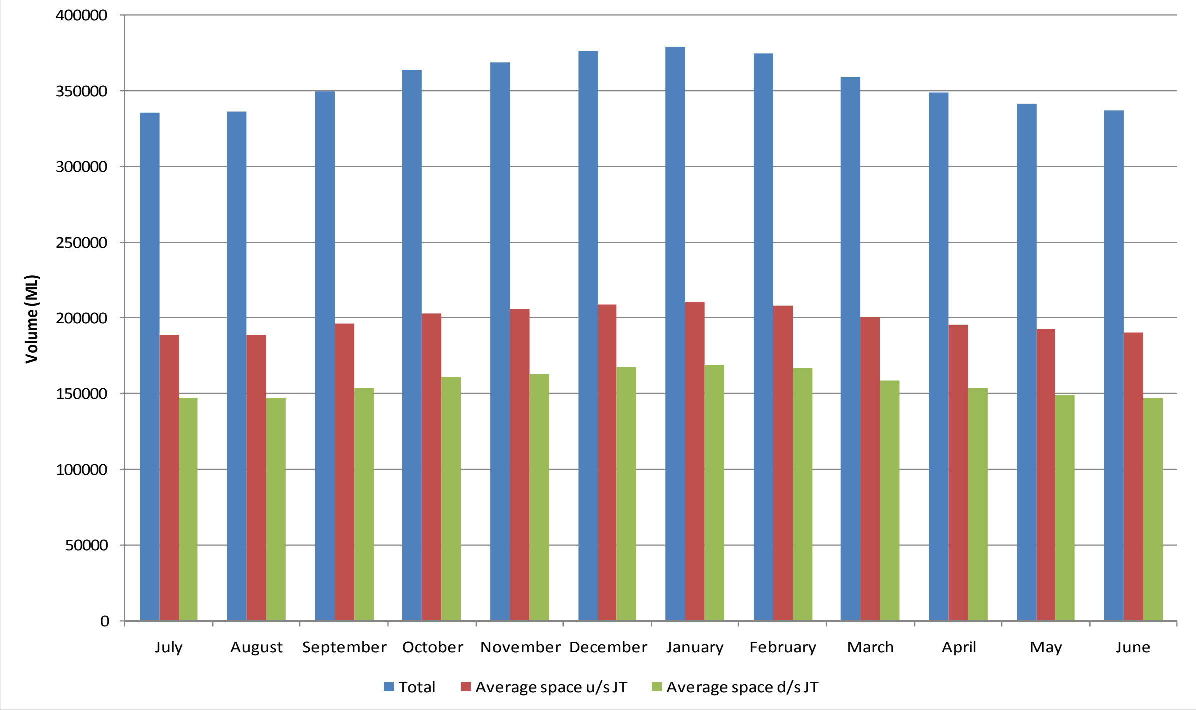

Figure 10: Average space available in storage for each month in Regions 1 and 2.

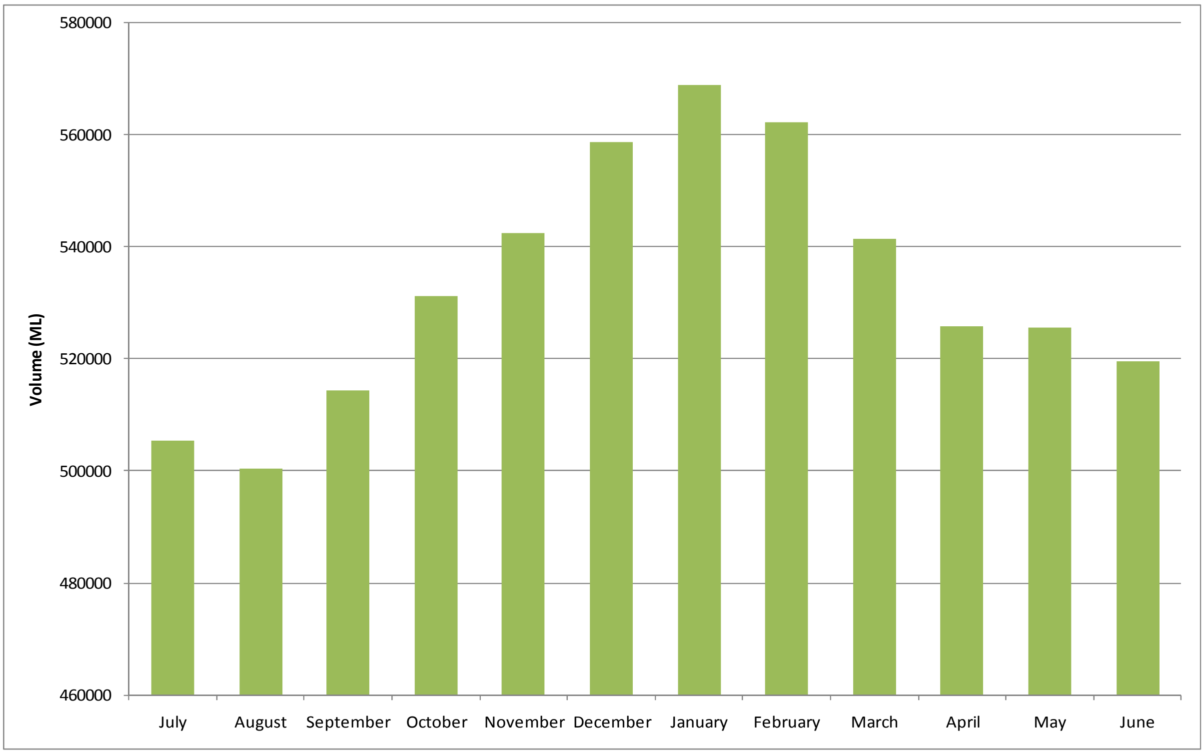

Figure 11: Average space available in storages for each month – Region 3.

3.3.3 Options for Meeting the Target Flow Components

End-of-system Flows in the Lower Balonne System

Environmental flow requirements for the Condamine-Balonne have been recommended as follows:

- *At Brenda* – provide a flow of 1,200 ML/d for seven days every 22 months, in order to inundate in-channel refuge waterholes
- *At Wilby Wilby* – provide a total flow volume of 100,000 ML over 12 months at least once every six years, assuming the following operational triggers and constraints:
  - Triggers for augmenting a primary or follow-up inflow event are:
    - 80-90 GL total flows at Wilby Wilby up to end March if three to six years since last 12 month 100 GL event
    - 50-90 GL total flow at Wilby Wilby up end March if ≥ six years since last 100 GL event
    - 10-20 GL augmentation volume; and
    - No augmentation flow after end April in any year.

Modelled flows under baseline conditions were extracted from the model run for Brenda and Wilby Wilby and assessed for compliance with requirements. A June to July water year has been used for this assessment.

Brenda

Over the 114 yr modelling period (1895–2009), the required event occurred 176 times (i.e. at an average frequency of 1 in 1.5 yrs, or every eight months). The target frequency of an event every 22 months is met for all but 14 events. The target frequency is not achieved when there is an extended drought period, and during these periods flows suitable for augmentation rarely occur. Of the 14 intervals which did not achieve the target flow event, three contained flows suitable for augmenting. While the average interval between events was eight months, the longest interval was 43 months (3.5 years). This interval occurred between 1984 and 1988, with the flow during that period presented in Figure 12.

There are opportunities for the Commonwealth to extend existing flow events. The majority of events have a reasonably long period of recession flow and Commonwealth environmental water could be released to augment these flows, extending the number of days above the critical flow level. The Commonwealth could also shorten the period between events. Providing an event at 12 or 15 months (since the last event) is achievable with further investigation.

The target flow events have an average duration of 20 days. Approximately one third of the events have a duration of 7-20 days and these are the events which could be targeted for augmentation, however, further investigation is required to identify the ideal event duration.

Hence targeting the 1,200 ML flow at Brenda for augmentation is very achievable and represents a good opportunity for further investigation.

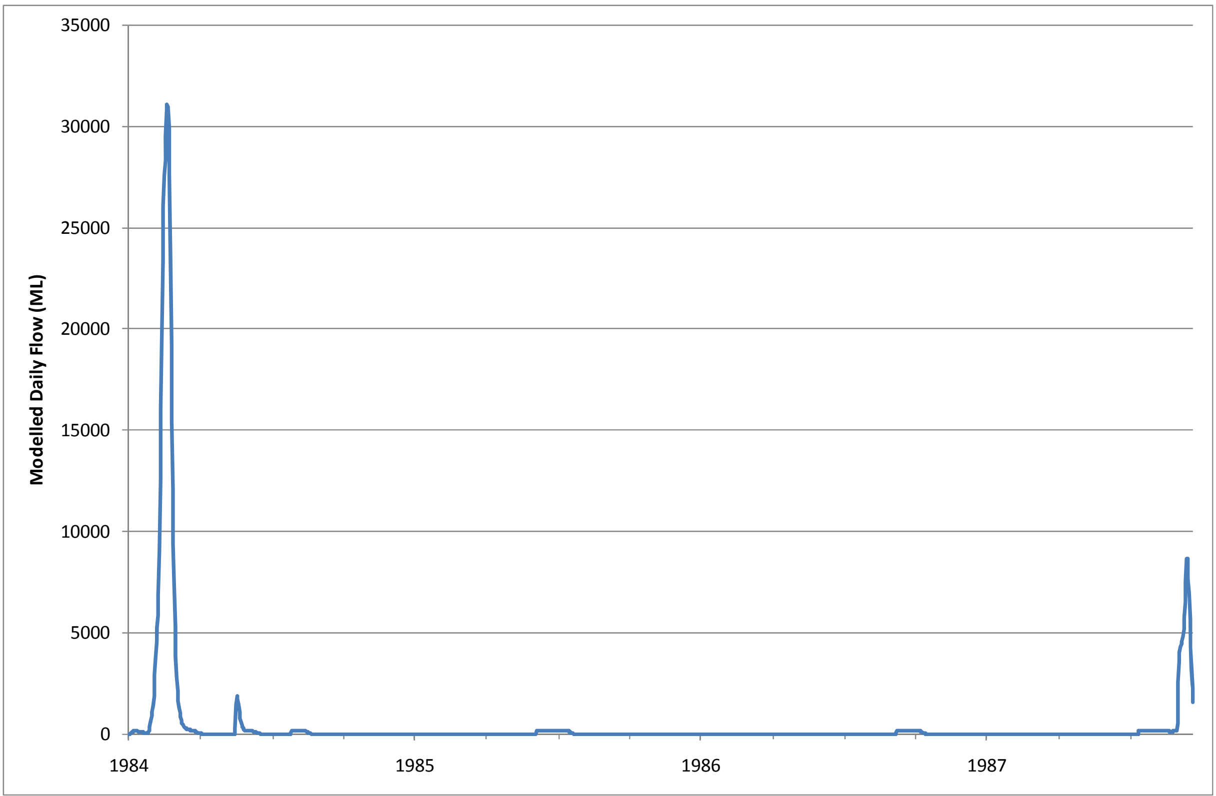

Figure 12: Modelled flow at Brenda during 1984-1988.

Wilby Wilby

The achievement of the specified flow requirement at Wilby Wilby (total flow volume of 100,000 ML over 12 months at least once every six years), and the specified trigger events, is provided in Table 6.

Table 6: Frequency of achievement of recommended flow conditions for the Narran Lakes system.

Flow Condition	Occurrence Frequency	Comment
▪ Annual flow > 100,000 ML	▪ Occurs 26 times in 114 years; once every 4.4 years. ▪ The largest gap between events is 19 years, between 1921 and 1940.	These events combine to prevent need for supplementary releases over 55 yrs. This leaves 59 yrs (114-55) where extra flows could be supplied.
▪ 80-90 GL total flows at Wilby Wilby up to end March if 3-6 years since last 12 month 100 GL event	▪ 1 (1905)	This event had a shortfall of 8,500 ML and covered an additional three yrs. This leaves 56 yrs where extra flows could be supplied.
▪ 50-90 GL total flow at Wilby Wilby up end March if ≥ 6 years since last 12 month 100 GL event	▪ 4 (1897, 1931, 1946, 2007)	These events had an average shortfall of 33 GL.

The annual flow and the total flow to the end March at Wilby Wilby are presented in Figure 13. Combining the natural availability of flows and proposed triggers, the achieved frequency of total annual flows of 100 GL would be 31 /114 yrs, that is, at least once every 3.7 yrs, with the largest gap between events occurring between 1921 and 1931 (10 yrs). There are five events with intervals greater than six years, one event with an interval of 12 years and one event with an interval greater than 12 years (the 18 year event). Supplementing the events identified in Figure 13 drops one of these events to below six years and reduces the duration of three others, in particular, the longest event is reduced from 18 years to nine years (Table 7).

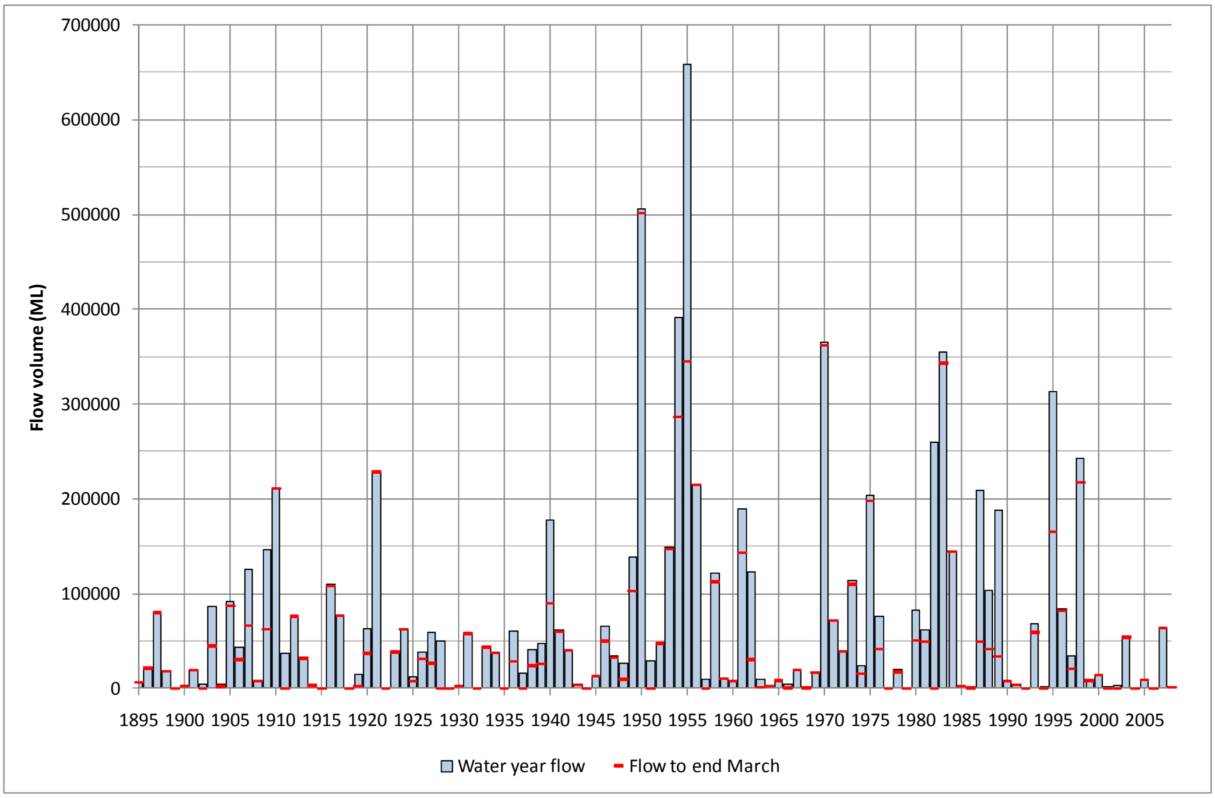

Figure 13: Modelled annual flow, and flow to the end of March at Wilby Wilby during 1895-2008.

Table 7: Effect of supplementing identified years on achievement of target.

Event with > 6 years between 100GL years	Duration without supplemented flows	Duration with supplemented flow events
1895 – 1906	12	7
1922 – 1939	18	9
1941 – 1948	8	5
1963 – 1969	7	7
1999 – 2009	11	8

In terms of the influence of extraction on these flows, of the 88 years where the flow is <100,000ML, there are 53 with total diversions of >50,000 ML, 37 years with total diversions of > 100,000 ML, and 24 years with total diversions of >200,000 ML (note that these are the total diversions across the catchment, not just diversions from the Narran River). Of the 26 years, which achieve the target flow of 100,000 ML flow at Wilby Wilby, 24 of these also achieve total diversions of >200,000 ML.

3.4 Mechanisms to Achieve Environmental Watering Targets

3.4.1 Possible Mechanisms for Achieving the Brenda Watering Target

During periods when the target flow event does not naturally occur smaller flow events are generally not available for augmentation. If a flow event was desired, it would have to be created purely from environmental water holdings or purchases and would require in the order of 8,500 ML to 10,000 ML, depending on the method of delivery and potential transmission losses. Instead of trying to create entirely new flow events there may be some benefit to extending existing flow events.

The Lower Balonne system has many interconnecting anabranches and channel breakout regions, as well as relatively high transmission losses. This means that environmental water delivery will have to be considered in terms of delivery method and location, as well as flow rates (i.e. to stay below breakout levels).

In delivering environmental water to augment the Brenda flow requirement (1,200 ML/d for seven days every 22 months), the flow rate is such that only minor losses would be incurred along the Culgoa River. These would be in the order of 80 ML/d, for a total flow of 1,200 ML/d. However, if the water was being delivered via the river system from a location above the B1 Bifurcation weir (the junction of the Culgoa River and Balonne Minor), substantial losses could be incurred at B1, with water being split between the two rivers.

The following mechanisms could be used to achieve this environmental watering target:

- Water release from Beardmore Dam
- Water release from private storages.

3.4.2 Possible Mechanisms for Achieving the Wilby Wilby Watering Target

In delivering environmental water to augment the Wilby Wilby flow requirement (total flow volume of 100,000 ML over 12 months at least once every 6 years), the window for augmentation is only one month, from the end of March to the beginning of April. Flow rates would therefore need to be in the order of 670 ML/d, assuming a total volume of 20,000 ML of environmental water, or 1,100 ML/d assuming the average shortfall described in Table 6 will be met. If the environmental water was delivered via the Narran River, only minor losses (approximately 60 ML/d) would be incurred at both of these flow rates. If the water was being delivered via the river system from a location above the B1 Bifurcation weir (the junction of the Culgoa River and Balonne Minor), substantial losses could be incurred at B1, with water being split between the two rivers. The same is true of subsequent bifurcations.

The following mechanisms could be used to achieve this environmental watering target:

- Release of water from Beardmore dam
- Reduce extraction under unsupplemented water licences
- Release of water from private storages.

3.4.3 Supply from Beardmore Dam

Beardmore Dam lies approximately 100 river kilometres upstream of the B1 Bifurcation, and about 300 km upstream of Brenda. It has a capacity of 81,700 ML. The Dam supports a supplemented water supply scheme with 3,000 ML (nominal volume) of high priority allocations and 81,575 ML (nominal volume) medium priority allocations. Medium priority allocations have a cap equivalence rating of

0.92. Supplemented water is delivered as far as the B1 Bifurcation, which is the end of the scheme operations area.

The CEWH does not currently hold any supplemented allocations, though they could be obtained as part of the projected further recovery of water under the draft Basin Plan.

In theory, water under allocations could be released from the Dam and allowed to flow out of the end of the scheme past the B1 Bifurcation, to contribute to either of the water targets. While the water resource plan and resource operation plan make no provision for this, it is achievable. However, the water delivered would split at each bifurcation and thus be substantially reduced in effect as it moved downstream.

3.4.4 Reduce Extraction under Unsupplemented Licences

Unsupplemented licences are capable of extracting large volumes of water. This access to water is governed by rules stipulated on the licences regarding commence-to-pump river heights and maximum rates of take and volumes of take. In theory, water extraction during events could be reduced by not taking water under licences held by the Commonwealth and by entering into arrangements whereby other licence holders agree not to take water in specified events in return for financial compensation.

However, reducing extraction is unlikely to be of benefit in achieving the targeted flows, since surplus flow events are not likely to be occurring when the water is needed. This option is therefore not considered further.

3.4.5 Release Water Capture in Private Storages

As discussed in Section 3.3.2, private storages are large and there is likely to be both water available in storage and airspace available to store Commonwealth water. In particular, storages in Region 3 are well-placed to be used to meet environmental watering targets. There are several very large storages, so agreements with one or two farmers would be sufficient to meet any need. Use of water from storages in Regions 1 and 2 (upstream of the B1 Bifurcation) is possible also, but is discounted because of the much larger volumes available below the bifurcation; the lower transmission losses, and losses associated with splitting of flows at bifurcations.

To access water in private storages individual contractual arrangements are needed with each farm owner to access their water held in their storages. The following options are possible:

a) *Purchase water at the time of need*. This was done successfully by the MDBA in 2008. At the time when a need for water is flagged under an environmental watering target, the Commonwealth identifies farmers with water in storage and enters into contractual agreements to purchase the water and have it released into the river.
b) *Purchase water ahead of time*. Enter into contracts with farmers at the start of each year to purchase some of the water they hold in storage, retain it there until needed, and deliver it back to the river when requested by the Commonwealth. Consideration would be needed as to how evaporation and seepage losses are shared, as well as what happens should the storage be filled (i.e. where landholders are prevented from capturing water that they otherwise could have captured).
c) *Purchase an option to have water supplied within an agreed window of time*. Enter into arrangements with landholders at the start of each year to retain some of the water they hold in storage to be called out by the Commonwealth by a certain date (e.g. during April) after which the call option would lapse and the water could be used by the landholder. This is fundamentally similar to the previous option, but perhaps more straightforward. The

contract could split payment into an initial payment for the option and a second payment when (and if) the water is called on.

d) *Pay for water under Commonwealth licences to be captured and stored and released on call*. As the Commonwealth already holds licences, this is the only option whereby water under these licences could be stored and called on when it is needed. It requires entering into an arrangement with a farmer to capture the water, store it, and return it to the river when called upon. Consideration would be needed as to how evaporation and seepage losses are shared, as well as what happens should the storage be filled (i.e. where the farmer is prevented from capturing water that they otherwise could have captured). Additionally appropriate licence location transfers would need to be executed to allow the Commonwealth licences to be used to take water through the particular works. As the exact nature of the Commonwealth licences is not known, the legal/administrative issues in doing this are not known. Lastly the effect of taking Commonwealth water on the farmer's ability to take water under their own licences would have to be factored into the financial arrangements.

Considering the data on volumes held in storage presented earlier, not surprisingly the volume held in private storages is low or zero in most critical years identified for environmental watering at Brenda and Wilby Wilby. This means that while the first option is workable some times (as shown by the MDBA), there is a significant risk that the desired water will simply not be there to be purchased at times when it is most needed. Further, Option (c) is considered to be preferable to Option (b) as it would deliver the same result more efficiently. For this reason either Options (c) or (d) are preferable as a long term strategy. Further detailed modelling analysis is needed to increase understanding of the risk.

In all cases shepherding of flows down the River would need to be addressed. Additionally, local investigations would be needed to determine which storages are suitable, and whether works are capable of returning water to the River, as desired.

3.5 Comparative Evaluation of Mechanisms

The mechanisms available for both environmental watering targets are essentially the same and so will be considered together (Table 8).

Table 8: Comparison of mechanisms for achieving environmental watering targets

Criterion	Supply of Water from Beardmore Dam	Supply of Privately Owned Water from Private Storages	Supply of Commonwealth Owned Water from Private Storages
Effectiveness	Volumes available may not be sufficient to achieve the target. Transmission losses larger than other options due to longer distance and bifurcations.	Volumes are available in storages relatively close to where the water is needed, so transmission losses are low. There are large storages available so only a few contracts likely to be needed.	More than adequate airspace available in storages close to where the water is needed, so transmission losses are low. Could be achieved using just a few storages. However, evaporative loss from storages is substantial.

Criterion	Supply of Water from Beardmore Dam	Supply of Privately Owned Water from Private Storages	Supply of Commonwealth Owned Water from Private Storages
Workability	Allocations or seasonal volumes would need to be purchased. Otherwise straightforward..	Has been proven to work in MDBA trial in 2008. Requires contractual arrangements with irrigators and may require modification to private works in some cases.	Requires contractual arrangements with irrigators. Could require modifications to works. Could be operational, administrative and/or legal hurdles to be addressed to enable this water to be captured using private works.
Risk and uncertainty	Water may not be available when most needed. This risk would be reduced by owning allocations and carrying over volumes rather than purchasing on demand.	In the majority of occasions when it is needed water available in these storages is low and may not be available. This risk can be reduced by purchasing options to water ahead of time so it is held and not used.	If water is held in storage for an extended period, evaporative losses could be substantial.

3.6 Key Conclusions and Recommendations

The following environmental watering targets were selected for assessment:

- *At Brenda* – provide a flow of 1,200 ML/d for seven days every 22 months, in order to inundate in-channel refuge waterholes.
- *At Wilby Wilby* - provide a total flow volume of 100,000 ML over 12 months at least once every six years to maintain Narran Lakes ecosystems.

Supply of water from Beardmore Dam is likely to be least effective because of the large transmission losses at bifurcations. The option of using private storages to hold Commonwealth water and deliver it on demand appears to provide the greatest likelihood of achieving the environmental watering targets, as there are large storages with plenty of airspace in most years that are conveniently located, and the water is most likely to be there when needed (Table 9).

Table 9: Comparison of mechanisms for delivery of Commonwealth environmental water.

Mechanism	Effectiveness	Workability	Low Risk & Uncertainty	Further Information
Supply of water from Beardmore Dam	✓	✓✓✓	✓	Requires purchase of allocations.
Supply of privately owned water from private storages	✓✓✓	✓✓✓	✓	Water may not be available when needed.
Supply of Commonwealth owned water from private storages	✓✓✓	✓✓	✓✓✓	Evaporative losses may be large

Further Investigations

The previous analysis relied on available statistics and spatial information of storages. To further assess the viability of options and identify which combination of options is likely to be the most cost-effective, the following would be required:

- Identify candidate storages in consultation with DERM (now Department of Natural Resources and Mines) and undertake local assessments to determine the physical viability and cost of using particular on-farm water storages.
- Undertake more detailed simulations to further assess which options or combinations of options would be best for achieving the targeted enhancements.
- Develop estimated costing for each option based on market values of water in average, dry and very dry years.
- Evaluate the ecological benefit of extending the Brenda target flow event duration and identify a suitable target duration which could be achieved with Commonwealth environmental water holdings.

4 Border Rivers Catchment

4.1 Target Environmental Assets

There is one listed wetland of national significance in the Border Rivers catchment - the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex. The complex is part of a remnant channel of the Macintyre River, and has been identified as an Aboriginal site of significance. It is located southeast of Goondiwindi.

Other freshwater assets in the catchment are associated with the Macintyre River channel, and the numerous anabranches and billabongs located downstream of Goondiwindi. Extensive floodplains up to 20 km wide with a network of anabranch channels characterise this part of the catchment (Thoms *et al*. 2005). These channels are typically disconnected from the main channel for most of the year, and commence to flow at a range of discharges in the main river (Thoms *et al*. 2005). After inundation many retain refuge pools for several months.

The Macintyre River channel, and its main anabranches, and the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex are included in the NSW *Fisheries Management Act* 1994 '*aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River'* endangered ecological community. The Dumaresq River to the confluence with the Mole River, and the NSW Severn River below Pindari Dam, are also included in the listing.

The Morella Watercourse/Pungbougal Lagoon/Boobera Lagoon complex, and a 40 km reach of high conservation value anabranches and billabongs on the Macintyre River floodplain between Goondiwindi and Boomi, were the target environmental assets used in the assessment of opportunities to use private storages and infrastructure for environmental watering actions in the Border Rivers catchment.

4.2 Environmental Watering Targets

Of the various changes to the natural flow regime, in-channel flow variability and channel-floodplain connectivity are the most affected in the Border Rivers catchment (Thoms *et al*. 2005, DWE 2009, MDBA 2012). These flows are important for nutrient cycling and provision of habitat and food resources for fish communities in the system, and contribute to sustaining key ecological features in the floodplain. Hence, options to use private storages to contribute to re-introducing a more natural flow regime for billabongs and anabranches downstream of Goondiwindi, and a more natural inundation pattern for the Morella Watercourse/Pungbougal Lagoon/Boobera Lagoon complex near Boggabri were the focus for this scoping study.

The MDBA (2012) has determined the environmental watering requirements of the Border Rivers catchment as part of its preparation of the proposed Basin Plan (Table 10). These flow targets were used to test options for contributing to re-introducing a more natural flow regime for billabongs and anabranches downstream of Goondiwindi.

Table 10: MDBA environmental watering requirements for the Border Rivers catchment. (Source: MDBA 2012b)

EVENT	TARGET
▪ 4,000 ML/d flow at Mungindi gauge for five days in October-December every 1:2.5 years	▪ Improve nutrient cycling an provide greater availability to key feeding and foraging habitats by wetting benches,

EVENT	TARGET
▪ 4,000 ML/d flow at Mungindi gauge for five days in October-March every 1:1.4 years	banks, in-stream habitat and facilitate migration and recruitment of native fish species
▪ 4,000 ML/d flow at Mungindi gauge for 11 days twice per year in summer/autumn and winter/spring	

Previous work in the catchment on billabongs and anabranches downstream of Goondiwindi identified a preferred environmental release regime for connecting these floodplain assets with the Macintyre River (Butcher *et al*. 2008). The recommended release regime relies on piggybacking natural high flow events to commence filling floodplain billabongs in late spring and through summer, especially when there has been a connecting event in the previous three to five months. Hence, the environmental flow targets for the Macintyre River were to achieve the MDBA streamflow thresholds presented in Table 10 (using piggybacking) annually between October and March.

Data on inflows and water requirements for the Morella Watercourse/Pungbougal Lagoon/Boobera Lagoon complex are patchy, with estimates for area, depth and volume available for some and not other lagoons in the complex. Reasonable estimates exist for the volumes of Maynes Lagoon, Morella Watercourse and Pungbougal Lagoon (Table 11). Data on the dominant vegetation community, and the prevailing management regimes at each wetland is similarly patchy. Table 11 provides a brief summary of the relevant descriptive data for each wetland in the target complex. These data were used to determine a target volume to meet the environmental water needs for the complex, and for testing the feasibility of delivering water to each using nearby private infrastructure and storages.

Table 11: Site and flow summary statistics, and character description for the Morella Watercourse/Pungbougal Lagoon/Boobera Lagoon complex. (Source: Medeiros 2004, pers. comm. Jane Humphries 2010, Reid *et al*. 2011).

Waterbody	Distance to River (m)	Length (m)	Depth (m)	Area (m^2)	Volume (ML)
Maynes Lagoon	4,000	2,400	3.8	289,258	136-371
Morella Watercourse	5,600	6,000	1.0-3.0	589,509	400
Poopoopirby Lagoon	10,000	1,000			
Pungbougal Lagoon	11,500	3,600	8.4	498,578	880-1,031
Gooroo Lagoon	11,600*	2,300	0.5		
Boobera Lagoon	22,000*	11,500		807,480	

* *Approximate distance only, calculated using a straight line to the next nearest upstream flow point on the Macintyre River.*

A target of 3,000 ML to maintain wetland inundation levels was assumed for subsequent analyses of opportunities to use private infrastructure and storages for delivery of environmental water in the Morella Watercourse complex. Note that the target is to *maintain* wetland inundation levels, not inundate the wetlands, or any riparian vegetation, or the floodplain. Also, the 3,000 ML target is not subject to further detailed hydrologic assessment because the water can be provided from existing Commonwealth regulated holdings and the action only requires resolution of practical arrangements to divert and deliver water using private infrastructure.

4.3 Baseline Information

4.3.1 Data Collation, Analyses and Approach

Analysis of on-farm storage behaviour, river flow and availability of water in the Border Rivers catchment was achieved using results from the Border Rivers IQQM Intergovernmental Agreement model, supplied by the Queensland Department of Environment and Resource Management (DERM). The model referenced is "Bor0703A.sys", with a simulation period of 1/1/1890 to 30/9/2000. Data either supplied by DERM or derived from the model included:

- description of modelled reaches
- for each modelled irrigation node that has an on-farm storage:
  - licence entitlement volume
  - on-farm storage capacity
  - airspace
  - crop type and area
- Simulation results including daily time series for
  - on-farm storage volumes
  - on allocation, off allocation and floodplain harvesting extractions for each irrigation node
  - allocation levels for regulated water entitlements
  - flow at stream gauges
  - surplus water availability at off allocation nodes.

The data and results were used to assess available volume in on-farm storages, availability of water from regulated water entitlements, likelihood of water being available in on-farm storages when general security water is low, and assessment of river flows to achieve environmental flow targets.

4.3.2 Commonwealth Environmental Water Holdings

The Commonwealth's water holdings in the Border Rivers catchment are 10,403 ML medium security (Qld), and 269 ML general security B (NSW). The Commonwealth also holds 1,000 ML un-supplemented (QLD), but this is in the Severn River and is not likely to be useful for the Macintyre River. The draft Basin Plan proposes an additional 8,000 ML/year long term cap equivalent be added to this to meet local environmental water needs, largely from NSW. This translates to approximately an additional 12,260 unit shares of general security B (NSW) and 3,300 ML medium security (Qld)[2] (in total approximately 11,600 ML/year long term cap equivalent available to the Macintyre River).

4.3.3 Availability of Regulated Water

As Queensland and New South Wales share water along the river, there are two water accounting schemes to consider. Water accounts record the water made available to the water entitlement holder over time. Irrigators for each reach have been split by state for some sections of the analysis.

[2] Based on assuming 7,000 ML of the long term cap equivalent comes from NSW, and 1,000 from QLD, and factors of 0.571 for NSW general security B and 0.33 for QLD medium priority water entitlements.

Announced allocation levels are the percentage of the nominal entitlement volume (for NSW this is assumed to be 1 ML per unit share) that accrues to entitlement water accounts in a year as a result of inflows to dams. Table 12 and Figure 14 present the frequency of announced annual allocations during the simulation period. These indicate that for 50 percent of the simulation period NSW receives a 38 percent allocation level and Queensland receives a 22 percent allocation level. Note that the high levels in a small proportion of years (very wet years) for NSW do not mean that that volume is available to the water user, as water account rules that apply in the 2009 water sharing plan limit the water that can be accrued in a year to a licence to 100 percent of nominal entitlement volume.

Table 12: Frequency of allocation levels to regulated water entitlements in the Border Rivers catchment – NSW and Qld

Frequency (%)	NSW Allocation Level (%)	Qld Allocation Level (%)
1	300	67
5	200	57
25	52	32
50	38	22
60	32	18
70	26	13
80	20	9
85	18	8

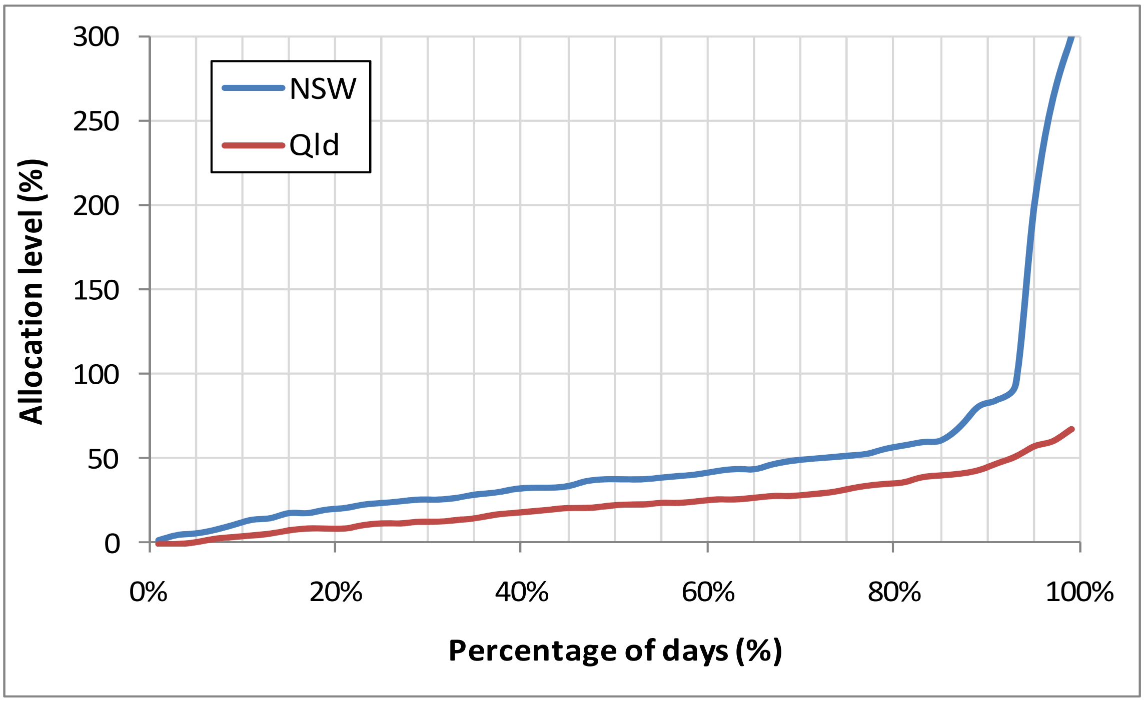

Figure 14: Frequency of regulated water allocation levels in the Border Rivers catchment – NSW and Qld.

4.3.4 Available Volume in On-farm Storages

Irrigators in the Border Rivers IQQM are represented as clustered groups, combined to match the division of the river into its major reaches. These irrigators are also grouped within each reach to represent their various water access rights. Three reaches on the Macintyre River are of interest for this analysis; Boggabilla Weir to Goondiwindi GS, Goondiwindi GS to Terrewah GS, and Terrewah GS to Boomi Weir GS (Reaches 25, 26 and 27 respectively in Figure 15). Irrigator details for these reaches are provided in Table 13. (Note that on-farm storages on the Weir River and associated anabranches were not considered due to the distance from the environmental assets under consideration and the low likelihood of the Commonwealth acquiring holdings in this catchment in the short to medium term).

Table 13: Location of relevant irrigation nodes, and corresponding on-farm storage in the Border Rivers IQQM.

River Reach	Irrigation Model Node Label	IQQM Node	Upstream Boundary Location (Gauge Number)	Downstream Boundary Location (Gauge Number)	Irrigator Licence Volume (ML)	On-farm Storage Capacity (ML)	Pump Capacity (ML/day)
25	NSW 7b	72	Boggabilla Weir	Goondiwindi (416201)	31,467	12,300	485
26	Qld 6b, 6c & 7, and NSW 8	421 to 286	Goondiwindi (GS 416201)	Terrewah (416047)	104,063	152,562	4,505
27	Qld 8 and NSW 9	085 & 086	Terrewah (GS 416047)	Boomi Weir (416043)	22,823	38,800	2,016

The largest volume of on-farm storages (152,562 ML) occurs in the second reach, between the Goondiwindi and Terrewah gauging stations. This volume is substantially larger than is found in the other two reaches, although it also likely represents a larger number of on-farm storages. The first reach (Boggabilla Weir to Goondiwindi) contains a combined on-farm storage capacity of 12,300 ML, while the third reach (Terrewah GS to Boomi Weir GS) contains 38,800 ML of on-farm storage capacity.

The on-farm storage is the location where water is stored from river pumping, floodplain harvesting and/or local rainfall run-off harvesting. A reserve volume is often maintained in a storage to capture about one watering, with an airspace volume also often maintained to allow the first flush from rainfall run-off to be kept within the property, due to water quality issues. There were no details specified within the modelling for the operation of storage reserves and airspace volumes. Therefore, for this study, the use of airspace or reserve volumes for storage of environmental water (as a separate volume to the total on-farm storage) was not considered, in recognition that use of these volumes may conflict with standard farm practices in the catchment.

FIGURE 15 | Location of relevant irrigation nodes on the Macintyre River downstream of Goondiwindi

SKM

Table 14 presents the frequency of on-farm storage volumes during the simulation period for the target irrigation reaches along the Macintyre River, between Boggabilla Weir and Boomi Weir. Irrigator groups are presented by State for each reach. The largest combined storage volume occurs in the second reach (Goondiwindi to Terrewah) (Figure 16 and Figure 17). The NSW storages in the three reaches are generally maintained at a high level, with much greater volumes of capacity available in the Queensland storages. For 50 percent of the simulation period, the NSW storages in Reaches one, two and three are maintained at 68 percent, 63 percent and 57 percent of capacity, respectively. Comparatively, the Queensland storages in reaches two and three are maintained at 41 percent and 49 percent of capacity, respectively.

Table 14: Border Rivers: on-farm storage volumes (ML) and their relative frequency.

Irrigator group	Max OFS Volume (ML)	Frequency (%)							
		5	10	20	30	40	50	70	90
Boggabilla Weir to Goondiwindi (GS 416201)									
NSW 7b	12,300	12,300	12,300	11,941	11,063	9,762	8,308	5,817	1,023
Goondiwindi (GS 416201)to Terrewah (GS 416047)									
NSW 8	47,860	47,860	47,648	45,413	40,898	34,812	30,275	22,197	13,952
Qld 6b, 6c & 7	104,702	102,730	93,866	75,580	63,351	52,796	42,544	26,659	6,759
Terrewah (GS 416047)to Boomi Weir (GS 416043)									
NSW 9	20,300	20,300	20,254	19,381	17,355	14,434	11,649	6,888	1,110
Qld 8	18,500	18,500	18,369	17,331	14,539	12,106	9,063	6,063	259

The average volume of water held in the on-farm storages for each month over the simulation period is presented at Figure 18. There is a general trend of higher volumes of water in storages during the months July to November. Lower volumes are generally present from December to June.

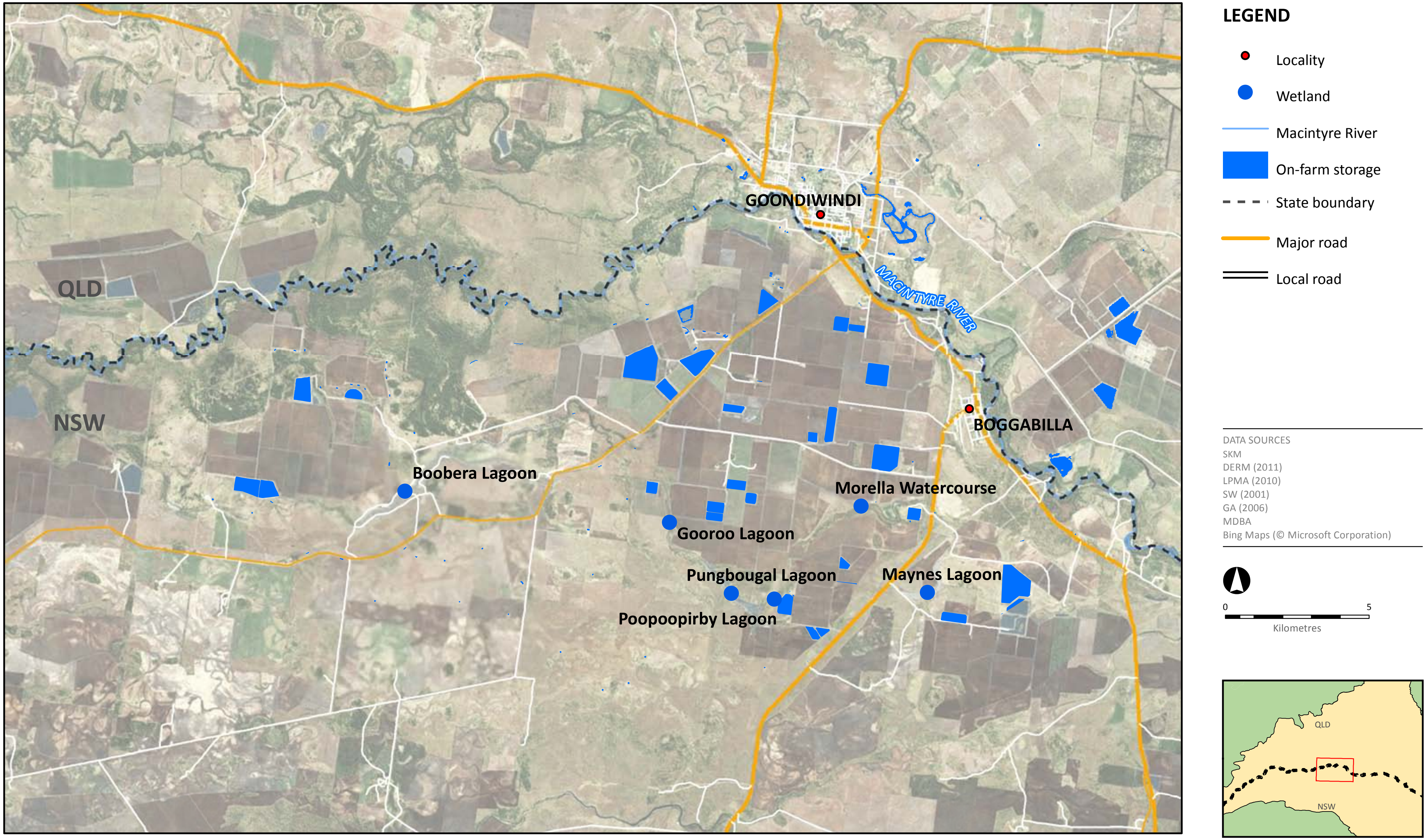

FIGURE 16 | On-farm storages in the Morella Watercourse complex

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Newcastle Spatial Team - Prepared by : AL
Checked by: DD

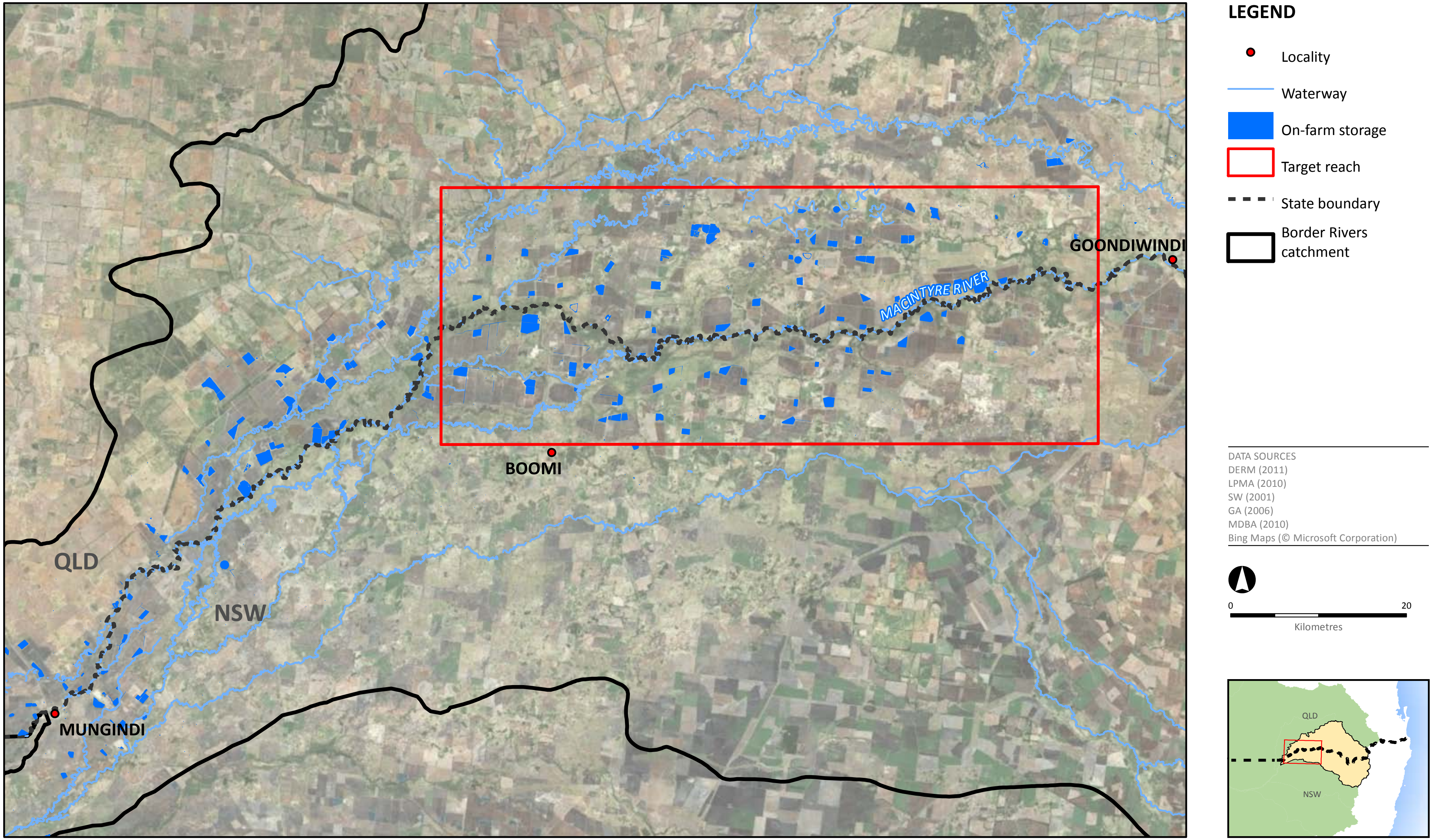

FIGURE 17 | On-farm storages downstream of Goondiwindi

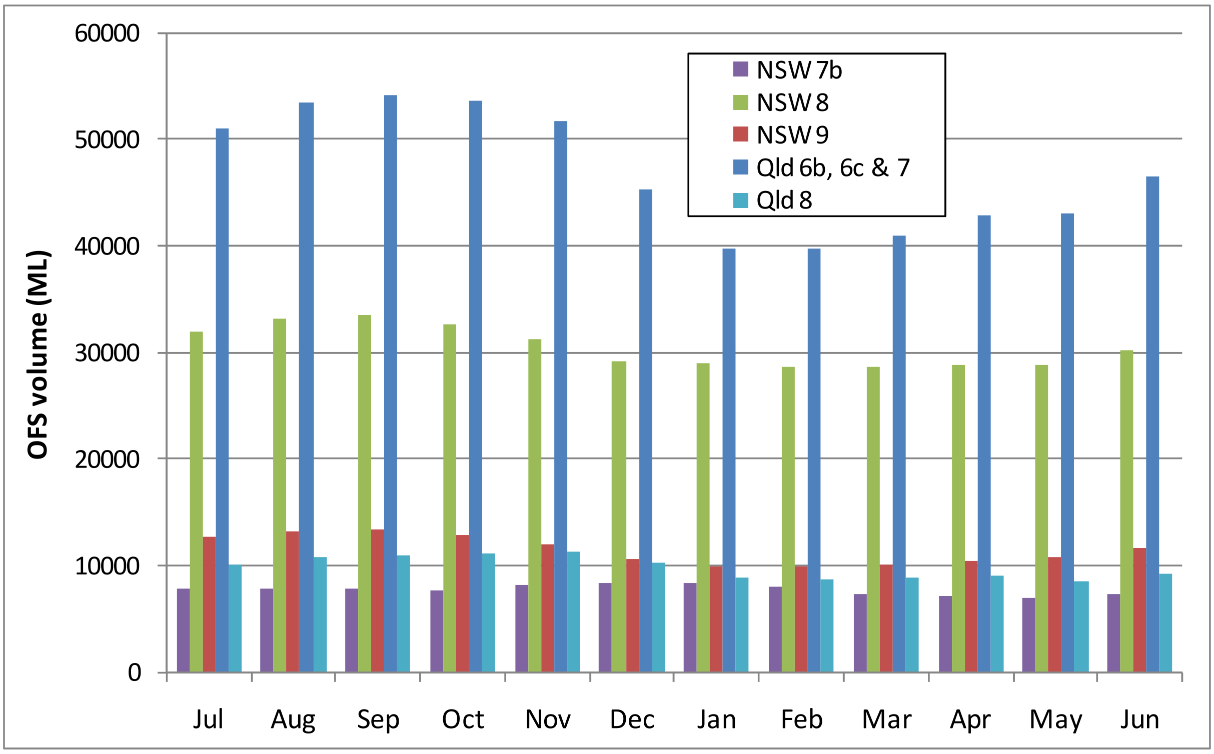

Figure 18: Average modelled farm storage per month

A preliminary assessment of the spatial data indicates that on-farm storages are numerous and well distributed along the three reaches of interest, and often have a large surface area. Furthermore, these storages are not often utilized to their full capacity. Based on the review of the irrigation nodes, this is likely due to a combination of surplus water availability, sub-maximal pump capacity, satisfying irrigation demand and annual limits on take under surplus water entitlements. Therefore, enhanced use of on-farm storages may (in some cases) require increased pump capacity, or ordering water to be temporarily stored over an extended period to utilize current pump capacity. Securing environmental water in some storages may also have an impact on the amount of area that farmers can plant. In such instances farmers would consider the trade off between foregone farm income and income received in exchange for storing and delivering Commonwealth environmental water.

An assessment was made of the on-farm storage volumes at different levels of regulated water allocations for the irrigators in the three reaches of interest. Table 15 presents the average volume in storage, over the simulation period, for a range of allocation levels. Table 16 presents the percent utilisation of the same storages in each reach at varying allocation levels. This data provides an indication of the likelihood of water availability in on-farm storage for various levels of regulated water allocations. The tables depict a general trend of increasing volumes of water in storage with increasing allocation levels. However, as the Queensland irrigators have a maximum allocation level (in the model simulation) of 67 percent, there are no results for the Queensland storages at higher allocation levels.

Table 15: Average volume (ML) in storage at varying regulated entitlement allocation levels (data: 1890-2000).

Allocation level (%)	Irrigator group				
	Boggabilla Weir to Goondiwindi GS	Goondiwindi GS to Terrewah GS		Terrewah GS to Boomi Weir GS	
	NSW 7b	NSW 8	Qld 6b, 6c & 7	NSW 9	Qld8
>100	3,693	16,695	n/a	6,191	n/a
75-100	10,640	37,741	n/a	15,973	n/a
50-75	9,749	34,952	77,381	14,172	15,034
40-50	7,504	30,054	64,018	11,029	12,077
30-40	8,197	32,943	52,742	12,409	10,845
20-30	7,915	31,970	46,259	11,626	10,138
<20	5,789	24,898	37,938	8,467	8,116
Max OFS volume (ML)	*12,300*	*47,860*	*104,702*	*20,300*	*18,500*

Table 16: Percent utilisation of on-farm storages in each reach at varying allocation levels.

Allocation level (%)	Irrigator group				
	Boggabilla Weir to Goondiwindi GS	Goondiwindi GS to Terrewah GS		Terrewah GS to Boomi Weir GS	
	NSW 7b (%)	NSW 8 (%)	Qld 6b, 6c & 7 (%)	NSW 9 (%)	Qld 8 (%)
>100	30	35	n/a	30	n/a
75-100	87	79	n/a	79	n/a
50-75	79	73	74	70	81
40-50	61	63	61	54	65
30-40	67	69	50	61	59
20-30	64	67	44	57	55
<20	47	52	36	42	44

The NSW irrigators show increasing volumes of water in storage up to 100 percent allocation, then reduced volumes of water above this allocation level. This is due to the operation of carryover rules. When the full allocation is not used within the water year, the unused volume may be carried over into the next year, giving the irrigator an allocation level above 100 percent. As this occurs after a dry period (when the irrigator could not access their full entitlement), the storage volume is likely to be low, while the allocation level is above 100 percent.

4.3.5 Achievement of Environmental Watering Targets

Average annual flow at Goondiwindi is 816 GL/year. Flows at this location generally occur in large pulses over the summer months. Zero flow occurs occasionally, although some flow is usually maintained within the channel due to the delivery of regulated water or environmental releases. Figure 19 presents the daily flow exceedance probability at Goondiwindi under current rules and development. Flows are above 670 ML/day for 50 percent of days, above 1,730 for 25 percent of days and above 7,850 for 5 percent of days.

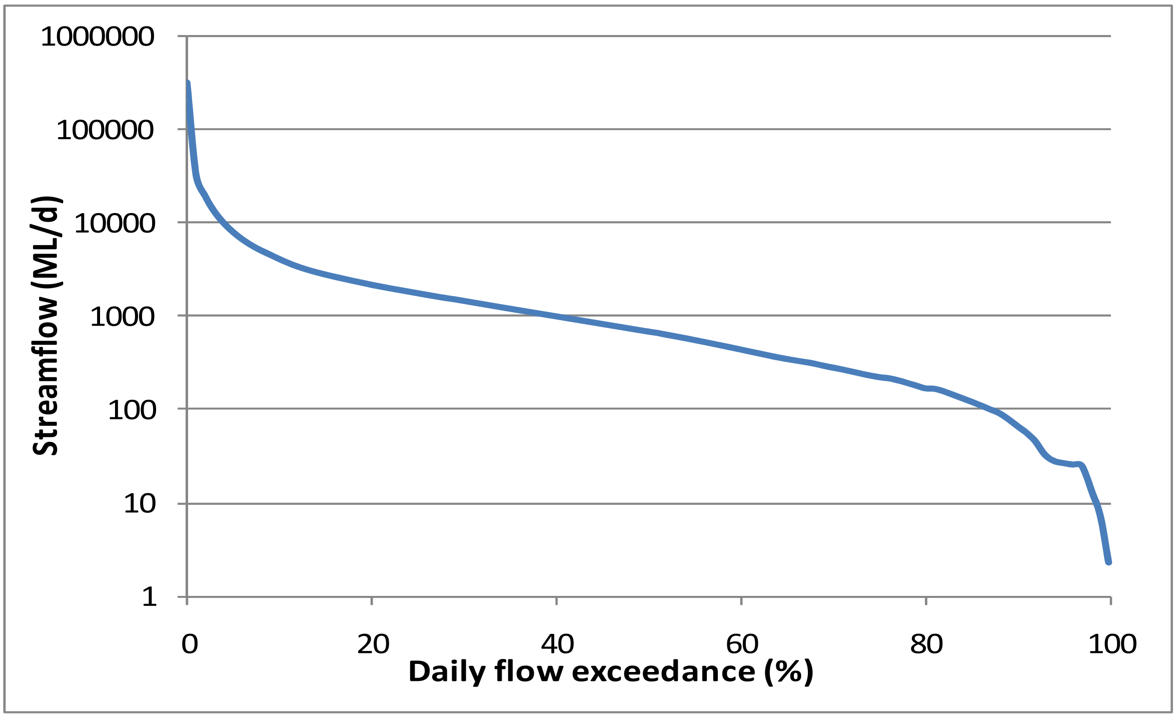

Figure 19: Daily flow exceedance at Goondiwindi GS 416201 (data: 1890-2000).

Figure 20 depicts the average daily flow at the Goondiwindi gauge per month for the 1890-2000 simulation period. These results indicate that the months of highest average flows are January and February, and these months should be considered further for the opportunity to augment existing flows to reach key environmental flow targets.

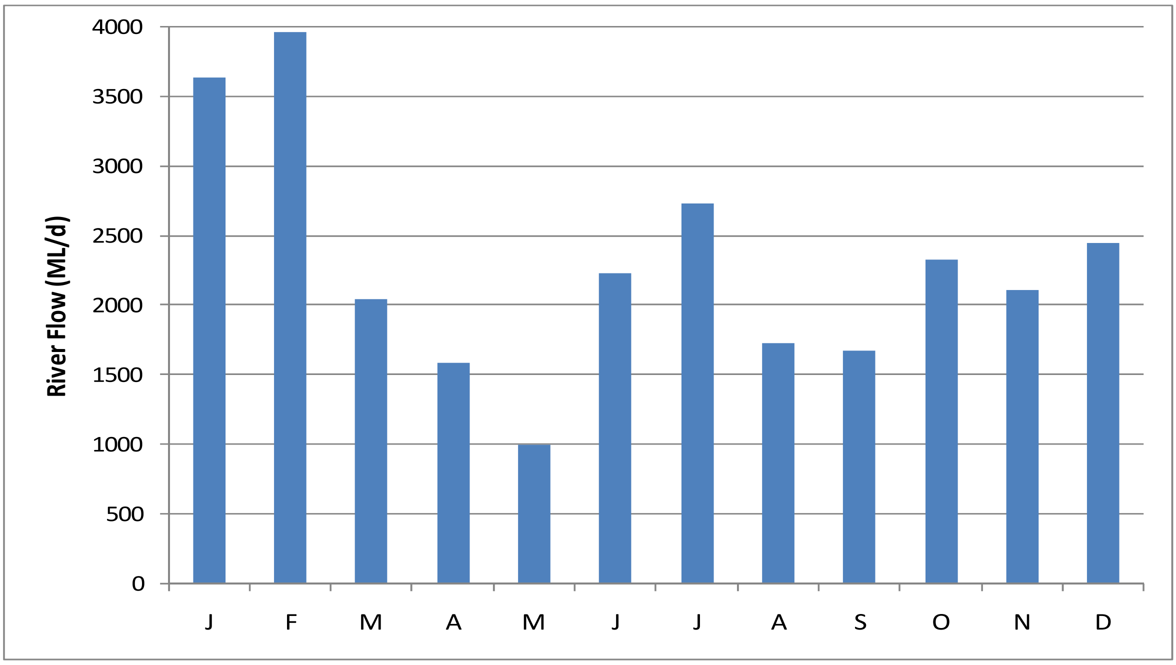

Figure 20: Average daily flow per month (ML/d) at Goondiwindi GS 416201 (data: 1890-2000).

There are two environmental flow targets for the Macintyre River; firstly to achieve streamflow downstream of Goondiwindi of 7,500 ML/day for at least seven days (to connect the four main anabranch channels of the Macintyre River), and secondly, to achieve flows exceeding 20,000

ML/day downstream of Goondiwindi for at least seven days (to connect 95 percent of the floodplain between Goondiwindi and Mungindi). Simulated streamflow at the Goondiwindi gauge was assessed to determine how many years this is achieved under the IGA model, and the number of events that occurred over the simulation period, as an indication of the frequency of opportunities to enhance naturally occurring higher-than-average events.

Table 17 presents the number of years where the first environmental flow target is met (i.e. flow events with at least seven consecutive days of flow greater than 7,500 ML/d at the Goondiwindi gauge), for all months throughout the year, as well as during the 'low' and 'high' regulated seasons. The data indicates that the flow target is met in 41 percent of years, with most of these events occurring in the high regulated season (October to March). Further analysis of the data indicates that the total number of events with at least a seven-day duration is 92; 25-day duration is six, and 45-day duration is one. An assessment of flow thresholds indicates that the months which have the most opportunity for augmenting flows to reach the target 7,500 ML/day threshold are July, January and February, although there are events which could be augmented in every month, depending on ecological requirements.

Table 17: Number of years with flow event 1 present (at least seven consecutive days of flow >7,500 ML/day at Goondiwindi).

Flow Statistic	Goondiwindi (416201)		
	All months	Low regulated season (April-Sept)	High regulated season (Oct-March)
Number of years with an event	45	30	45
Total years in simulation	110	110	110
Missing years	65	80	65
Percent of years flow does not meet target 7,500 ML	59%	73%	59%

Table 18 presents the number of years where the second environmental flow target is met (flow events with at least seven consecutive days of flow greater than 20,000 ML/d at the Goondiwindi gauge), for all months throughout the year, as well as during the 'low' and 'high' regulated seasons. The data indicates the flow target is met in approximately 15 percent years, and that the flow events are fairly evenly distributed across the low and high regulated seasons. Further analyses of the data indicated the total number of events with at least a seven-day duration is 27; 25-day duration is 1, and there are no events with a duration of 45-days or more. An assessment of flow thresholds indicates that the months which have the most opportunity for augmenting flows to reach the target thresholds are November to March, although there are events which could be augmented in every month, depending on ecological requirements.

Table 18: Number of years with flow event (at least seven consecutive days of flow >20,000 ML/day at Goondiwindi).

Flow Statistic	Goondiwindi (416201)		
	All months	Low regulated season (April to Sept)	High regulated season (Oct to March)
Number of years	17	12	14
Total years in simulation	110	110	110

Flow Statistic	Goondiwindi (416201)		
	All months	Low regulated season (April to Sept)	High regulated season (Oct to March)
Percent of years flow does meet target 20,000 ML	15%	11%	13%

4.4 Mechanisms to Achieve Environmental Watering Targets

4.4.1 Possible Mechanisms for the Macintyre River Watering Target

Under the current water management arrangements flows events which meet the environmental watering targets in the Macintyre River floodplain below Goondiwindi occur in 41 percent of years for 7,500 ML/day events, and 15 percent of years for 20,000 ML/day events. While these flow events do occur they are reduced in frequency and duration, compared to pre-development conditions.

According to the CSIRO (2007) assessment, the current regulated water rules and development have reduced the frequency of events exceeding 20,000 ML/day at the Goondiwindi gauge from an average of 5.9 months between events to an average of 7.2 months between events, although the maximum number of months between events has not changed. Average event volumes have reduced from 192 GL to 176 GL.

Creating a 7,500 ML/day event at the Goondiwindi gauge requires a minimum total volume of 52.5 GL (minimum seven days), while creating a 20,000 ML/d event would require a minimum volume of 140 GL (minimum seven days). Therefore, to achieve the flow targets it was assumed that Commonwealth environmental water would be used to supplement natural river flow events, as the Commonwealth's current and likely holdings (12 GL/year long term cap equivalent volume) are insufficient to generate stand-alone river flow events for the required duration, and the cost of purchasing large volumes of additional water during dry years is likely to be prohibitively expensive. Additionally, it was assumed significant supplementation of natural events approaching, or exceeding, the 20,000 ML/day target is also beyond reach.

Therefore, the optimum target for the Macintyre River floodplain below Goondiwindi is supplementing events that peak in the range of 2,500-10,000 ML/d so as to maintain flows above 7,500 ML/d for at least seven days. An indicative volume of 21,000 ML (i.e. 3,000 ML/d for seven days) would be required to achieve this event supplementation. As discussed previously in the report, while events that reach or approach the targeted flow and duration can occur at any time of the year, the greatest opportunity for augmentation occurs during the summer months, and the preferred timing for environmental gains is November to February.

Broadly, the following options to enhance targeted flow events in the Macintyre River below Goondiwindi are:

- release additional water from Glenlyon, Pindari or Coolmunda Dams
- reduce extraction of water from uncontrolled flows upstream of the target reach
- release water captured in private on-farm storages.

4.4.2 Possible Mechanisms for the Morella Watercourse Complex Watering Target

For the Morella Watercourse/Pungbougal/Boobera system, the target was to supply water to the system during selected dry years, to maintain inundation levels and provide a fresh, using 3,000 ML of environmental water. Options for supplying this water are:

- from the river to the system via private infrastructure, with the river water being water released from Glenlyon, Pindari or Coolmunda Dams against regulated water entitlements
- from water captured in private on-farm storages adjoining the complex.

The feasibility of each of option is discussed below.

4.4.3 Releases from Glenlyon, Pindari or Coolmunda Dams

Details of the three dams are provided in Table 19. Of the three dams, Coolmunda Dam is the closest, while Pindari Dam provides the largest storage capacity.

Table 19: Border Rivers headwater dams.

Name	Active Storage Volume (ML)	Approximate distance to Goondiwindi (km)
Glenlyon Dam	247,600	200
Pindari Dam	311,920	170
Coolmunda Dam	68,780	90

Water held in these storages is fully committed to: water entitlement holders; meeting obligations for environmental requirements; providing water to basic water rights holders, and meeting system losses. While there is a small volume of unallocated water (5,000 ML strategic reserve), this is held for irrigation, industrial use and town water supply purposes. Therefore, access to additional water from these Dams would require water held in the dam on behalf of water entitlement holders to be released down the river.

This could be achieved by the Commonwealth:

a) owning general security water licences in NSW or supplemented water allocations in Queensland (as it already does), so that water can be released on demand;

b) purchasing water from other (regulated or unregulated) water entitlement holders (‘temporary trading’) ahead of time so this can be released when ordered, or

c) entering into contractual arrangements whereby other water entitlement holders agree to order their water to be released and allowed to flow down river at a time stipulated by the Commonwealth.

Within the NSW system, the most common type of water access licences are the General security ‘B’ licences (241,000 unit shares). General security ‘A’ makes up 22,000 unit shares, while High security comprises 1,500 unit shares (supplementary licences are not considered here as they do not relate to volumes held in dams). While the water sharing plan provides for unlimited carryover, the total water held under a general security water licence at any point in time cannot exceed 1 ML per unit share plus any water purchased from other licences (i.e. through ‘temporary trade (cl 42(2)), and the maximum water allocated to a licence in a water year is 1 ML per unit share less any water carried over from the previous year (cl 36(4)).

These rules affect Option (b) if the water is purchased and carried over, since any water carried over can reduce the water allocated in the following year. Thus Option (b) carries some risk if water is purchased when it is cheap (e.g. during wet conditions). Purchasing water when it is clear it is likely to be needed within a short time because conditions are dry to very dry is likely to be much more expensive because the market value of water will be very high.

A further issue is that the NSW Water Sharing Plan links accounting of water taken to be the greater of either the volume of water extracted by the approved water supply work nominated by the access licence, or the water ordered for extraction by the approved water supply work/s nominated by the access licence (cl 41). It is not clear what happens if water is ordered but left in the river, and whether the accounting systems are able to cope with this. Additionally adjustments to clauses 45 and 46 of the Water Sharing Plan may be required to ensure water released to augment freshes is not taken under supplementary licences.

Within the Queensland system, high priority allocations total 3,654 ML nominal volume, and medium priority allocations total 109,965 ML (un-supplemented allocations are not considered here as they do not relate to volumes held in dams). Allocations in the Macintyre Brook water supply scheme (Coolmunda Dam) are largely under a continuous capacity sharing arrangement, whereby inflows are distributed to allocations as they occur, subject to the water accrued not exceeded the capacity share held. Additionally, water ordered in any one year cannot exceed the nominal volume. In the Queensland Border Rivers water supply scheme, there is no carryover of unused water from one year to the next and the maximum volume of water that can be held is 85 percent of the nominal allocation volume.

As with NSW, these rules affect Option (b) for Queensland water allocations if the water is purchased and not used in the current water year, since there is a risk that the water will be ‘spilled’ if there are subsequent inflows that fill accounts to beyond account limits. Thus Option (b) for Queensland water allocations carries the same risks as for NSW (i.e. purchasing water when it is clear it is likely to be needed within a short time because conditions are dry to very dry is likely to be much more expensive because the market value of water will be very high).

As outlined earlier, it was assumed the Commonwealth’s water holdings in the Border Rivers catchment will eventually be around 13,700 ML medium security water allocations (QLD), and 12,600 unit shares of general security (NSW), based on projections set out in the draft Basin Plan. On average the water available under these entitlements will be approximately 11,600 ML per year. The maximum volume that could be available in any one year under these entitlements is approximately 26,000 ML. However in drier years, when the water will be needed for environmental watering, the volume will be less. Table 12 showed that annual allocations are below 38 percent for NSW and 22 percent for Queensland for up to 50 percent of years (i.e. years drier than average), and below 18 percent for NSW and 8 percent for Queensland in 15 percent of years (very dry years). By carrying over water from one year to the next larger volumes can be accrued in dry periods. For example, if there were three average years in a row, in the third year a total volume of 21,300 ML could be available if no water was taken in the first two years. However, if there was an extended drier sequence of years, volumes available would be low even if carryover is maximised.

Overall it can be assumed that the volumes available under these entitlements would allow supplementing a targeted event in the Macintyre River below Goondiwindi once every two years on average, but only once during a drought extending beyond three years. They would be more than adequate to supply the targeted 3,000 ML for the Morella Watercourse/Pungbougal/Boobera system even in very dry years. Obtaining of additional water through Options (b) and (c) is also feasible, but carries significant risks if water is obtained well ahead of need when prices are low, and could be very expensive if purchased at or near the time when it is required.

A significant challenge with using water released from dams to supplement in-river events below Goondiwindi, is timing the releases. The dams are a substantial distance from the location, with travel times of the order of ten days, so coordinating the timing of releases to meet natural freshes downstream could be difficult. Advice from the river operator (State Water) is that, while it may not be possible to time releases to arrive at the same time as the commencement of an event at Goondiwindi, they could certainly be used to sustain an event. Travel times from the dams to Goondiwindi are six to seven days, whereas notice of an event may only be two to four days ahead of its arriving at Goondiwindi.

Timing would not be a problem with delivering water for the Morella Watercourse/Pungbougal/Boobera system, as this could simply be pumped when the water arrives as per normal irrigator water ordering practice. Arrangements would need to be made with landholders to use their infrastructure (e.g. pumps and channels) to get the water from the river to the system. Some modifications to works to allow this to occur, and to allow water to appropriately flow between lagoons, would most likely be required.

4.4.4 Reduce Upstream Extraction from Uncontrolled Flows

The targeted environmental flow events in the Macintyre River can coincide with surplus water events (uncontrolled flows), from which water may be taken under supplementary licences (NSW) or un-supplemented water allocations (QLD). Queensland un-supplemented water allocations have a total nominal volume of 99,188 ML. NSW supplementary licences total 120,000 unit shares. For convenience both types of entitlements are considered together as surplus flow entitlements. As shown in Table 13, there is capacity to pump around 7,000 ML/day from the river under these entitlements.

Surplus flow entitlements provide access to surplus water events in the river that occur as a result of spills from dams or substantial inflows from tributaries downstream of the dam (uncontrolled flow events). The take of water under these entitlements is constrained to times, locations and rates that are announced when uncontrolled events arise. There are complex rules for determining these announcements. According to the NSW Water Sharing Plan clause 46, access to freshes below the junction of the Macintyre River and the Dumaresq River that arise from inflows above Goondiwindi does not commence until the two day flow exceeds 10,000 ML plus water required for downstream commitments, and continues until the two day flow at Goondiwindi drops below 3,650 ML plus requirements for downstream commitments. In dry years it is likely that some of these events will be protected in order to meet downstream requirements for freshes in the Barwon-Darling River.

Take of water under these entitlements is also limited by maximum annual volumes, which is 150 percent of the nominal volume for Queensland un-supplemented allocations and 1 ML per unit share for the NSW supplementary licences. There is no carryover of unused volumes from one year to the next. These volumetric limits to extraction are called water allocations in NSW and are tradable between supplementary licence holders.

Overall it is likely that surplus flow entitlements are taking significant volumes of water from targeted flow events. Unfortunately, detailed data on the effect of surplus flow entitlements of targeted events in dry years was unable to be extracted from models for this study. Anecdotal evidence suggests surplus flow was accessed in all of the last ten years except 2006/07, meaning it was occurring through most of the drought.

The following approaches are possible for reducing extraction under surplus flow entitlements during targeted events:

a) Purchase and hold surplus flow entitlements, and leave the available share of surplus flows in the river in targeted events.
b) Purchase options not to take water in surplus events. Enter into arrangements with surplus flow entitlement holders at the start of each year whereby they agree not to take water in events nominated by the CEWH. Thus the CEWH could choose the events it wishes to enhance as they arise and call on the entitlement holders to not pump. Individuals would still be able to take water from later events, but run the risk that no further events will occur in the year.

Under the NSW Water Sharing Plan, use of water is specified as that taken through an approved work. According to advice from State Water, the current practice in NSW is to invite expressions of interest in taking surplus water, then distribute the available volume in the event based on orders and relative size of entitlements. The Queensland practice is similar, but rights to take volumes are simply distributed to entitlement holders in proportion to size of entitlement without inviting expressions of interest. In both cases, water is only debited against the entitlement account if it is actually pumped from the river. Thus volumes in events that are not taken simply remains in the river.

Option (b) has the advantage that landholders may still be able to achieve economic output in many years, though this could also be achieved by the Commonwealth selling unused volume limits under Option (a). Option (b) also relies on accessing meter readings to confirm compliance with the request not to pump. This would require establishing some administrative arrangements.

Overall, Option (a) is administratively much simpler as it does not rely on numerous, repeated private contract negotiations, and potential private contract enforcement.

Regarding supplying water to the Morella Watercourse/Pungbougal/Boobera system, surplus flow entitlements could potentially be used to access the volume needed from the river. As with using dam water, arrangements would need to be made with landholders to use their infrastructure to get the water from the river to the system. Some modifications to works to allow this to occur, and to allow water to flow appropriately between lagoons, would most likely be required.

For practical reasons the 3,000ML would be best delivered in one watering, to minimise transmission losses between the river and the lagoons, and to minimise need for use of private infrastructure. To achieve this with surplus water would require an entitlement volume much higher than 3,000 ML, because access to this volume would be split between events. Additionally, surplus water is generally much less available in dry to very dry years when it is most likely to be needed.

4.4.5 Release Water Captured in Private On-farm Storages

Once taken from a water source through legal means (e.g. under a water entitlement through approved works), water is then effectively owned by the entity who took it. Water held in private storage is thus totally under the control of the owner of the storages. No water entitlement is required to arrange to access this water.

Delivery of this water back into the river or into the Morella Watercourse/Pungbougal/Boobera system may not, however, be straightforward. It cannot be assumed that works used for taking water and delivering it into storage can be used to return the water to the river. There could easily be capital costs to install works to enable this to occur. Additionally, there may be water quality issues that could trigger obligations under the *Protection of the Environment Operations Act* 1997, particularly as many properties mix recycled water and catchment runoff water with river water in on-farm storages. The NSW Environment Protection Authority may require either compliance with practice guidelines or a discharge licence, or may not allow it to occur if the risks are too great. In each case, the feasibility and cost of returning water from storages to the river would need to be assessed (this was not considered in this study). Similar considerations apply to use of Queensland storages.

As shown in Table 14, there is an estimated 191,000 ML of on-farm storage in the Macintyre River downstream of Goondiwindi that could be used to contribute to targeted river flows. An analysis of surface areas, using an estimated average depth of 1.8 metres, suggests that 70 of these have capacity greater than 1,000 ML; 17 greater than 2,000 ML; seven greater than 3,000 ML, and the largest being over 5000 ML. The largest five storages have an estimated combined capacity of 20,000 ML.

Table 14 also shows that the volumes held in these storages are only a proportion of the total volume in drier years. So in a one-in-ten dry year the volume held is around 15 percent of capacity, meaning the top five storages would have around 3,000 ML stored. Also, in 50 percent of years, the storages would be around half full, which means the largest five storages would have around 10,000 ML stored. Additionally, it is probably unlikely that farmers will be willing to sell all of their water.

To access water in private storages individual contractual arrangements are needed with each farm owner to access their water held in their storages. The following options are proposed:

a) *Purchase water at the time of need*. As time is required to establish such arrangements, this would be challenging, since lead times to augment small to moderate uncontrolled events will probably be no more than a few days and part of that time would be needed to physically get the water from the storage to the targeted river reach. Contacts would need to be pre-arranged to such an extent that they could be quickly agreed and processed.

b) *Purchase water ahead of time*. Enter into contracts with farmers at the start of each year to purchase some of the water they hold in storage, retain it there until needed, and deliver it back to the river when requested by the Commonwealth. The landholder would probably seek a limit to the time they hold the water as otherwise it could limit their ability to irrigate indefinitely. Consideration would also be needed as to how evaporation and seepage losses are shared.

c) *Purchase an option to have water supplied within an agreed window of time*. Enter into arrangements with landholders at the start of each year to retain some of the water they hold in storage to be called out by the Commonwealth by a certain date (e.g. end of summer) after which the call option would lapse and the water could be used by the landholder. This is fundamentally similar to the previous option, but perhaps more straightforward. The contract could split payment into an initial payment for the option and a second payment when (and if) the water is called on.

Of these, Option (c) is probably the most feasible. Purchasing water solely on demand (the first option) is unlikely to be practical in the tight timeframes, so some sort of preliminary arrangements would be needed, which is effectively Option (c) anyway. Option (b) would likely have a time limit on it, meaning again it is similar to Option (c) but more complex.

A concern with any attempt to use water from private storages to augment river flows is that to have any effect it would require output from several storages to achieve enough volume, and a lot of coordination for it all to reach the river at the right time. This could be manageable if arrangements are limited to the five largest storages, but as shown above, the volume likely to be available in those storages would not be enough to provide the required flow enhancement. Additionally, the volumes held in store could be enhanced by the Commonwealth adding water from its river entitlements.

Additionally, it would have to be determined whether the works are available to get the water into the river at a sufficient rate (i.e. 3,000 ML/day). This is a significant pump capacity, and may not be possible even for the five largest storages. Case-by-case field investigations would be required to determine feasibility.

A further operational/administrative issue that would have to be addressed is that water released to enhance uncontrolled events could be extracted by holders of surplus flow entitlements. Administrative arrangements would need to be made with river operators to ensure the water is protected. This also may require adjustment to the NSW Water Sharing Plan.

With regard to use of water held in on-farm storages to supply the Morella Watercourse/Pungbougal/Boobera system, there are storages around the systems that could be used as a source of water. Indicative assessment suggests around five have capacities greater than 1,000 ML, the largest being approximately 2,000 ML. As for other storages, it is likely that the water in storage would be substantially less than this in dry years, so finding 3,000 ML would be unlikely. But there would certainly be capacity to provide a partial top up. It is possible however, that the cost of works to get the water to the system from some of these storages could be prohibitive. Further field investigation is needed to clarify this.

4.5 Comparative Evaluation of Mechanisms

4.5.1 Enhancing Flows Downstream of Goondiwindi

As discussed, the objective considered was to supplement events that peak in the range of 2,500–10,000 ML/day for the Macintyre River floodplain below Goondiwindi as so as to maintain flows above 7,500 ML/d for at least seven days. It was assumed 21,000 ML (i.e. 3,000ML/day for seven days) is required.

All of the identified options – using water from dams, from private storages and reducing extraction of surplus water – could in theory be used to enhance the targeted flow events.

Assuming the Commonwealth’s water holdings in the Border Rivers catchment will eventually be around 14,400 ML medium security water allocations (QLD), and 17,800 unit shares of general security (NSW), the volumes available under these entitlements would allow supplementing a targeted event in the Macintyre River below Goondiwindi once every two years on average, but only once during a drought extending beyond three years. Obtaining additional water through temporary trade is also feasible, but runs the risk of being spilled if purchased ahead of time when prices are low, and could be very expensive if purchased at or near the time when it is required. A significant challenge with using water released from dams to supplement in-river events below Goondiwindi is timing the releases. While it may not be possible to time releases to arrive at the same time as the commencement of an event at Goondiwindi, they could certainly be used to sustain an event.

Flows could also be supplemented by reducing extraction under surplus flow entitlements. The CEWH's current holding of 1,000 ML would not be sufficient to make a significant impact, particular as only part of it would be accessible in any particular event. The Commonwealth could choose to procure additional surplus flow entitlements rather than dam entitlements to increase this. Alternatively, the Commonwealth could enter into arrangements with surplus flow entitlement holders whereby they agree not to take water in events nominated by the Commonwealth. As the entitlement holder could still harvest the water in later events, the cost of doing this would likely be much less than purchasing water entitlements outright. Administrative arrangements would be needed to confirm water is not taken.

Flows could also be supplemented by releases from several larger private water storages. However, it is unlikely that this option alone could deliver sufficient water at a sufficient rate to achieve event enhancement. Volumes could be enhanced by arranging for the private water storage to store and release Commonwealth water. It is also likely that modifications to works would be required to allow the water to be returned to the river at rates sufficient to make an impact. Case-by-case field assessments are needed to confirm feasibility of returns from private water storages to the river considering works and potential water quality risks.

For all of these options, there are a number of operational and legal issues to be addressed, and a potential requirement to adjust the NSW Water Sharing Plan. For example, to enable accounting for volumes delivered to a point in the river but not taken through meterable works, and to ensure water released is not lawfully taken by surplus water entitlement holders. A comparison of the various options is summarised at Table 20.

Table 20: Comparison of options for delivery of Commonwealth environmental water to assets downstream of Goondiwindi.

Criterion	Supply of water from dams	Reducing extraction of surplus flows	Supply from private water storages
Effectiveness	Very likely to be able to achieve the target, though only if the event has a sufficient duration of itself to enable the releases to reach it in time.	Could achieve the target, but further investigation is needed to confirm this. Costs of paying surplus water entitlement holders to defer extraction from targeted events likely to be less than the cost of holding entitlements.	Unlikely to be able to achieve the target on its own. Additionally the total costs consisting of cost of water, costs to get the water to the river and potentially cost to pump CEWH water into storage and store it there for a time, evaporative losses
Workability	Easily done using current arrangements, subject to some possible minor adjustments.	Requires purchase of entitlements or contractual arrangements with entitlement holders, and fairly straightforward administrative adjustments.	Requires contractual arrangements with several irrigators. Likely to require modifications to works and considerable effort to coordinate timing of releases.
Risk and uncertainty	Some challenges associated with timing of releases to piggyback on events.	While costs of contractual arrangements may be cheaper, it is likely to be more challenging to administer.	Coordination of releases from multiple storages could be difficult to achieve. Sufficient volumes may not be available.

Combinations of these options are also possible. For example, to address the potential two to three day delay in delivering water from a dam to the target location, it could be combined with an initial release from private water storages to cover the gap. Also, reducing extraction could be combined with either of the other options.

Overall the likely best option is to reduce access to surplus flows, but confirmation would require further investigation. If this proves to be the case, it may be advantageous for the Commonwealth to focus future procurement on obtaining surplus water entitlements, or considering establishing a fund to enable contractual non-exercise of rights to take surplus water on an annual basis as an alternative to buying entitlements.

4.5.2 Supplying Water to the Morella Watercourse/Pungbougal/Boobera Complex

For the Morella Watercourse/Pungbougal/Boobera complex, the assumed target was to supply water into the system to maintain inundation levels and provide a fresh. It was assumed 3,000 ML would achieve this.

The Commonwealth's river water entitlements would be more than adequate to supply the targeted 3,000 ML for the system from the major dams even in very dry years. This is however, subject to feasibility of using private works, likely with some modifications, to get the water to the system and move it through. This would require field investigation with landholders. Water from surplus water entitlements could similarly be used, but would be less reliable in very dry times.

With regard to use of water held in on-farm storages, there are storages around the systems that could be potentially used as a source of water. Indicative assessment suggests around five have capacities greater than 1,000 ML, the largest being approximately 2,000 ML. As for other storages, it is likely that the water in storage would be substantially less than this in dry years, so finding 3,000 ML in storage would be unlikely. But there would certainly be capacity to provide a partial top-up, and a lesser volume might be all that is necessary if water is supplied directly to each lagoon rather than having to be moved across country and between lagoons (therefore incurring transmission losses). It is possible, however, that feasibility and cost of works to get the water to the system from some of these storages could limit this option. Further field investigation is needed to clarify the options. A comparison of the various options is summarised at Table 21.

Table 21: Comparison of options for delivery of Commonwealth environmental water to the Morella Watercourse/Pungbougal Lagoon/Boobera Lagoon complex.

Criterion	Supply of water from river	Supply from private water storages
Effectiveness	Available volumes of water adequate.	Volumes may not be adequate in dry to very dry years, but lower volumes may be enough to top up. Could be substantial costs in infrastructure modifications.
Efficiency	*Uncertain* Could be substantial costs in infrastructure modifications. Also probably some volumes lost in transmission losses through the system.	*Uncertain* Could be substantial costs in infrastructure modifications. Also entails loss of production by irrigator.

Criterion	Supply of water from river	Supply from private water storages
Workability	Requires contractual arrangements with irrigators and will probably require modifications to works. Likely to be workable based on availability of water and visual inspection of maps. However requires field investigation to confirm.	Requires contractual arrangements with irrigators and will probably require modifications to works. Likely to be workable based on visual inspection of maps, but whether volumes prove adequate is uncertain. Requires field investigation to confirm.
Equity	Impacted parties are compensated through payments for entitlements, use of infrastructure etc. Impacts on regional economy broadly the same under either option.	

It is possible both options could be used in different circumstances, for example, a fuller flow through from the river might be beneficial in moderately dry times, whereas supply from local storages might be most effective in very dry times when through flow connection is not deemed vital.

4.6 Key Conclusions and Recommendations

4.6.1 Enhancing Flows Downstream of Goondiwindi

The target considered was to supplement events that peak in the range of 2,500 – 10,000 ML/day for the Macintyre River floodplain below Goondiwindi so as to maintain flows above 7,500 ML/d for at least seven days. It was assumed 21,000 ML (i.e. 3,000ML/day for seven days) is required.

Three mechanisms could potentially be used. However, the use of private storages is least likely to be effective because of the numbers of storages that would be required to be involved, costs and coordination difficulties. Combinations of these options are also possible. For example, to address the potential two to three day delay in delivering water from a dam to the target location, it could be combined with reducing extraction under supplementary licences.

Overall, the likely best option could be to reduce access to surplus flows, but confirmation would require further investigation. If this proves to be the case, it may be advantageous for the Commonwealth to focus future procurement on obtaining surplus water entitlements, or consider establishing a fund to enable contractual non-exercise of rights to take surplus water on an annual basis as an alternative to buying entitlements (Table 22).

Table 22: Comparison of mechanisms for delivery of Commonwealth environmental water.

Mechanism	Effectiveness	Workability	Low risk and uncertainty	Further Information
Supply of water from dams	✓✓	✓✓✓	✓✓	Assumes Commonwealth purchases substantially more entitlement as suggested in draft Basin Plan.
Reducing extraction of surplus flows	✓✓✓	✓✓	✓✓✓	Supplementary water entitlement purchase needed or contracts with entitlement holders.
Supply from private water storages	✓	✓	✓	Many storages would need to be involved to hope to achieve the desired result.

Supplying Water to the Morella Watercourse/Pungbougal/Boobera Complex

For the Morella Watercourse/Pungbougal/Boobera complex, the environmental watering target was to supply water into the system to maintain inundation levels and provide a fresh. It was assumed 3,000 ML would achieve this.

The Commonwealth's river water entitlements would be more than adequate to supply the targeted 3,000 ML for the system from the major dams even in very dry years. Private water storages adjoining the lagoons also have the potential to be used to supply water, however, availability of water in these storages when it is most needed is uncertain. Both are subject to feasibility of using private works, likely with some modifications, to move the water across private land. This would require field investigation with landholders.

While the use of water from dams (i.e. river water entitlements) appears more attractive, the option of private water storages may also be preferable in order to allow the entitlement water to be used for the Macintyre River in stream environmental watering targets (Table 23).

Table 23: Comparison of mechanisms for delivery of Commonwealth environmental water.

Mechanism	Effectiveness	Workability	Low Risk & Uncertainty	Further Information
Supply of water from dams	✓✓✓	✓✓	✓✓	Works to move water across private land needed.
Supply from private water storages	✓✓	✓✓	✓	As above, plus uncertainty about water availability in dry years.

4.6.2 Further Investigations

This analysis relied on available statistics and spatial information of storages. To further assess the viability of options and identify which combination of options is likely to be the most cost-effective, the following would be required:

- Further refine the targeted water regimes to identify the particular kinds of events that should be given highest priority for enhancement, as the volumes required for enhancements are large and selection will be needed.
- Further discussions with river operators regarding constraints on such things as rates of rise and fall in the river, operation of weirs, ability to time flow events moving down the river, and management of access to surplus water that could affect the options being considered.
- Discuss with NSW Office of Water ability to deliver water to a point in a river and have it accounted properly, how transmission losses should be dealt with in doing so, how shepherding of releases from private water storages might be achieved and what if any changes to the water sharing plan might be needed to enable it.
- Undertake more detailed simulations to further assess which options or combinations of options would be best for achieving the targeted enhancements.

- Develop estimated costing for each option based on market values of water in average, dry and very dry years.
- If use of private water storages proves to be worth pursuing, identify candidate storages in consultation with State Water and undertake on the ground assessments in consultation with willing water users and the EPA to assess the physical viability and cost of using particular on-farm water storages (if using them is shown to be potentially viable option) and whether water quality issues might prove to make this unviable.

Once preferred approaches are settled upon, there are also operational/administrative issues that would need to be addressed that may require adjustments to the Water Sharing Plan, but these would not be great and could be done under the Act with little risk. Discussion with the NSW Office of Water would be needed to make necessary arrangements.

5 Namoi Catchment

5.1 Target Environmental Assets

There is one wetland of national importance in the Namoi region (Lake Goran). Lake Goran is located in the mountainous eastern region of the catchment, adjacent to the Liverpool Plains. The Lake is at the end of an internal drainage basin that does not connect to the Namoi River (Environment Australia 2001). It is a seasonal/intermittent freshwater lake, which when full provides approximately 6,385 ha of wetland habitat (Environment Australia 2001). However, only 10 per cent of the lake is regularly waterlogged, and because it is privately owned, the remaining 90 per cent of the lakebed is used for intensive agriculture.

Other freshwater assets in the catchment are associated with the Namoi River, its anabranches and tributaries. The Namoi River and tributaries downstream of the major storages are included in the NSW *Fisheries Management Act* 1994 '*aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River'* endangered ecological community. The lowlands portion of the catchment (downstream of Narrabri) is especially significant because it provides a wide range of aquatic habitats in an extensive and well-developed floodplain (MDBA 2012c). Bifurcating channels, anabranches, high channel sinuosity, deep refuge pools, flood-runners, and a range of in-channel bench habitats are common and provide habitat at a range of scales for freshwater-dependent flora and fauna. Inundation of these areas also contributes to maintaining riverine, riparian and floodplain function (MDBA 2012c).

These lowland habitats below Narrabri were the focus for this scoping study.

5.2 Target Flow Components

Independent studies on the hydrology and ecosystem condition of the Namoi River catchment concluded that of the various changes to the natural flow regime, low to medium flows are the most impacted in the lower Namoi River (Foster 1999, Thoms *et al*. 1999, Lambert & Short 2004), and that these flows support significant riverine and floodplain ecosystem function. Hence, options to use private storages to contribute to re-introducing a more natural low to medium flow regime in the lower Namoi River was the focus of this scoping study.

The MDBA (2012) has determined the environmental watering requirements of the Border Rivers catchment as part of its preparation of the proposed Basin Plan (Table 24). These flow targets were used to test options for contributing to re-introducing a more natural flow regime for in-channel assets upstream of Bugilbone.

Table 24: MDBA (2012c) environmental watering requirements for the Namoi catchment.

EVENT	TARGET
▪ 4,000 ML/d at Bugilbone for 45 days every 1:3 years ▪ 1,800 ML/d at Bugilbone for 60 days 1:2 years ▪ 500 ML/d at Bugilbone for 75 days every year	▪ Provide a flow regime which ensures the current extent of native vegetation of the anabranch communities is sustained in a healthy, dynamic and resilient condition ▪ Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates) ▪ Provide a flow regime which supports key ecosystem

EVENT	TARGET
	functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon

Previous work to determine the commence-to-flow heights for lowland habitats (such as in-stream benches, anabranches and billabongs) estimated the flow requirements for in-channel and floodplain habitats at several locations downstream of Narrabri (Table 25). Of these, the anabranches between Duncan's Junction and Bugilbone have been the most affected in terms of frequency and duration of inundation (MDBA 2012). Commence-to-fill heights for flood-runners and billabongs in this reach are consistently between 3,300 and 4,500 ML/d. Flows at this height at Duncan's Junction gauge are known to inundate approximately 1,000 km of billabongs and wetlands along the river system (CSIRO 2007). Subsequent hydrological analyses in this report use Duncan's Junction gauge as the test sites for delivery of Commonwealth environmental water via private storages.

Table 25: Flow thresholds for in-channel and floodplain habitats in the lower Namoi River (Foster 1999, MDBA 2012).

Reach	Gauge	Asset	Flow Target (ML/d)
Downstream of Duncan's Junction	Namoi River upstream of Duncan's Junction (419082)	In-channel benches	1,740
		Low-floodplain habitats (e.g. floodrunners, billabongs)	3,300
Bugilbone	Namoi River at Bugilbone (419021)	In-channel benches	1,780
			3724
			3921
		Anabranch linkage	4,500
Goangara	Namoi River at Goangara (419026)	In-channel benches	1,865
			6,277
			13,766
Downstream of Goangara	Namoi River at Goangara (419026)	In-channel benches	2,148

5.3 Baseline Information

5.3.1 Model Data Used

Analysis of on-farm storage behaviour, river flow and availability of water in the Namoi valley was conducted using results from the Namoi IQQM current planning model used by NOW. The model referenced by NOW is "Namo_A0_01.sqq", which represents 1999/2000 development conditions for the 2003 Water Sharing Plan. Results were provided for the simulation period from 1/6/1895 to 30/6/2009. Data and results provided by NOW included:

- description of modelled reaches

- for each modelled irrigation node that has an on-farm storage
  - licence entitlement volume
  - on-farm storage capacity
  - airspace
  - crop type and area
- Simulation results including daily time series for
  - on-farm storage volumes
  - on allocation, off allocation and floodplain harvesting extractions for each irrigation node
  - general security allocation levels
  - flow at stream gauges downstream of Gunnedah
  - surplus water availability at off allocation nodes.

The data and results were used to assess available volume in on-farm storages, availability of general security water, likelihood of having water available in on-farm storages when general security water is low, and assessment of river flows to achieve environmental flow targets.

5.3.2 Commonwealth Environmental Water Holdings

The Commonwealth's water holdings in the Lower Namoi Regulated River System comprises 6203 unit shares in general security water access licences[3]. Therefore, to achieve the flow target it is assumed that Commonwealth environmental water would be used to supplement natural river flow events, as the Commonwealth's current holdings are insufficient to generate stand-alone river flow events.

5.3.3 Availability of Regulated Water

The resource assessment system for the Namoi is a continuous accounting system. The allocation level can be up to 200 percent in a year, however, general security licence holders are restricted to taking 125 percent of their licence volume in any one year. Allocations levels are the percentage of the licensed entitlement volume that general security irrigators can divert. Table 26 presents the frequency of allocations over the simulation period. These indicate general security water availability is relatively good with just less than 50 percent of the simulation period having a 100 percent allocation level.

Table 26: Frequency of general security allocation levels in the Namoi catchment.

Frequency (%)	Allocation Level (%)
1	196
10	185
25	149
50	96
60	68
70	48

[3] As at 29 Feb 2012. See http://www.environment.gov.au/ewater/northern/namoi/index.html, accessed 3 March 2012

Frequency (%)	Allocation Level (%)
80	28
85	20

5.3.4 Available Volume in On-farm Storages

Irrigators in the Namoi IQQM are represented as clustered groups, broken up to match the division of the river into the 17 gauged reaches (Department of Infrastructure, Planning and Natural Resources, 2005). On-farm storages are included in 13 of these reaches (between IRR05 and IRR17) (Table 27). Upstream of Duncan's Junction, the greatest capacity for on-farm storage occurs between Mollee Gauge and Gunidgera Weir (IQQM node IRR08), at 41,000 ML. This volume is significantly larger than the capacity for on-farm storage in other reaches, but it is spread across 38 farms. The reach immediately upstream of Duncan's Junction (Weeta Weir to Duncan's Junction Gauge – IQQM node IRR10) has the next nearest capacity for on-farm storage at 5,675 ML, distributed across eight farms. The Gunnedah to Boggabri reaches (IQQM nodes IRR05 and IRR06) represent the least opportunity for storing Commonwealth water because their relative storage capacities are low, and spread across a relatively large number of farms (i.e. 69 properties for a total 5,475 ML stored).

The IQQM Cap Implementation Summary Report (Department of Infrastructure, Planning and Natural Resources, 2005) notes that on-farm storages were modelled to include a reserve and airspace. The on-farm storage is the location where water is stored from floodplain harvesting and local rainfall run-off harvesting. A reserve volume is generally maintained in a storage to capture about one watering. Airspace in on-farm storages is generally maintained to allow the first flush from rainfall run-off to be kept within the property because of water quality issues. There was no specific information for the actual on-farm storage operation to use for establishing the Namoi IQQM. Therefore, parameters of reserve and airspace volumes were arbitrarily defined during calibration of the IQQM. In this study, the use of airspace or reserve volumes for storage of environmental water (as a separate volume to the total on-farm storage) was not considered, in recognition that use of these volumes may conflict with standard farm practices in the catchment.

Table 27: Location of each modelled irrigation node, and corresponding on-farm storage in the Namoi IQQM.

River Reach	Irrigation Model Node Label	IQQM Node	Number of Farms Represented by Node	Upstream Boundary Location (Gauge Number)	Downstream Boundary Location (Gauge Number)	Irrigator Lic Vol (ML)	On-farm Storage Capacity (ML)	Pump Capacity (ML/d)
5	IRR 05	261	24	Gunnedah (419001)	Boggabri gauge (419012)	1,920	1,000	177
6	IRR 06	75	45	Boggabri gauge (419012)	Narrabi gauge (419003)	4,131	4,475	82.5
7	IRR 07	177	15	Narrabi gauge (419003)	Mollee gauge (419039)	5,094	2,600	121
8	IRR 08	178	38	Mollee gauge (419039)	Gunidgera weir (419059)	83,780	41,000	2,620
9	IRR 09	180	11	Gunidgera weir (419059)	Weeta weir (419068)	20,224	3,740	617
10	IRR 10	182	8	Weeta weir (419068)	Duncan's Junction gauge (419094)	7,912	5,675	146
14	IRR 14	190	12	Gunidgera Creek d/s of reg (419061)	Gunidgera Creek - Pian cutting	22,454	11,440	580
15	IRR 15	192	6	Gunidgera Creek - Pian cutting	junction with Namoi	6,432	1,850	229
11	IRR 11	184	13	Duncan's Junction gauge (419094)	Bugilbone (419021)	13,107	16,380	240
12	IRR 12	186	8	Bugilbone (419021)	Goangra (419026)	8,370	11,350	94.5
13	IRR 13	188	13	Goangra (419026)	Upstream of Walgett (419091)	6,900	4,700	112
16	IRR 16	194	24	Pian Creek - Pian cutting	Pian Creek Rosemore gauge (419064)	38,795	59,755	1,870
17	IRR 17	196	10	Pian Creek Rosemore gauge (419064)	Upstream of Walgett (419091)	5,763	14,850	565

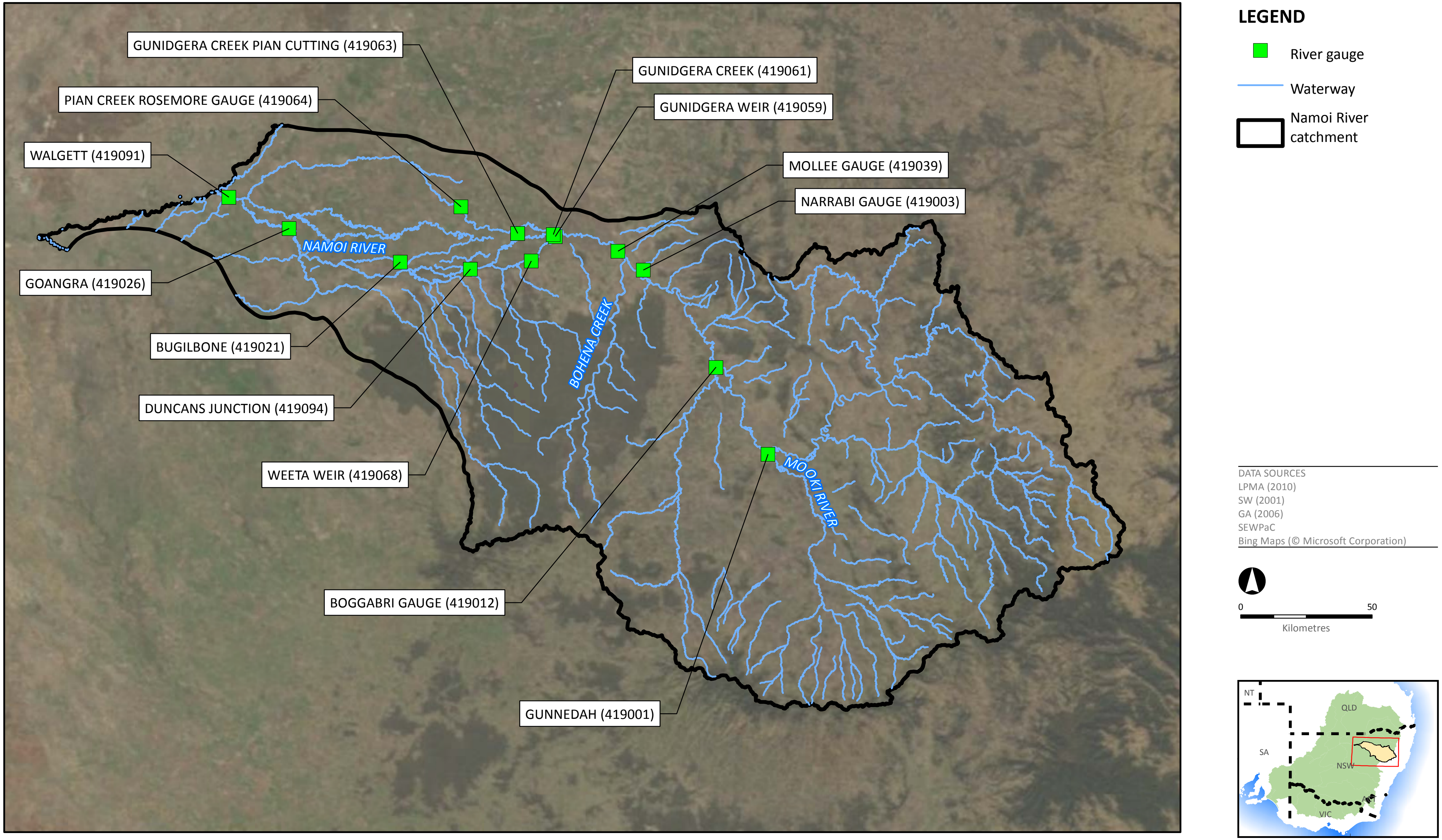

FIGURE 21 | Location of each Namoi IQQM node in the catchment

SKM

Table 28 presents the frequency of on-farm storage volumes during the simulation period for irrigation reaches along the Namoi River from Gunnedah to Walgett (i.e. IRR05 to IRR17). Farms in the Narrabri to Mollee node (IRR 07) have the greatest on-farm storage volumes, with water stored in them most of the time. The remaining farms routinely have smaller volumes in on-farm storages. Note that on-farm storages on the Pian system were not considered due to the unknown delivery potential, and anticipation that any available water would not significantly benefit the entire reach between Duncan's Junction gauge and Bugilbone.

The average volume of water held in on-farm storages for each month over the simulation period is presented at Figure 22 and for nodes IRR07, IRR09 to IRR11, and Figure 23 for IRR08 (these reaches were scrutinised owing to their position immediately upstream and adjacent to of Duncan's Junction and therefore their capacity to contribute to a release to target assets downstream of Duncan's Junction gauge). These indicate the storages are fullest during winter and emptiest in late-summer/early autumn. A preliminary assessment of the Lands and Property Information 'waterbodies' spatial data indicated storages in these reaches are numerous and well-spaced in the landscape, rather than there being a few primary storages holding most of the water.

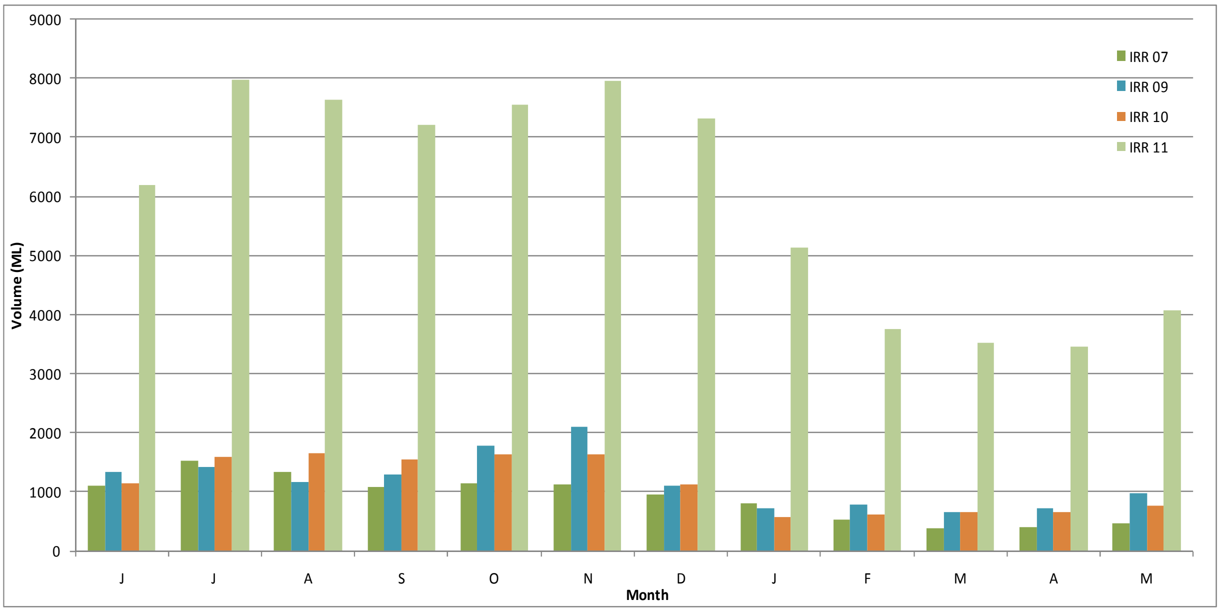

Figure 22: Average modelled on-farm storage per month for irrigation nodes five to ten.

Table 28: On-farm storage volumes (ML) at each irrigation node in the Namoi catchment, and their relative frequency.

Model Node	Max OFS Volume (ML)	Frequency (%)							
		5	10	20	30	40	50	70	90
IRR 05 (Gunnedah-Boggabri)	1,000	940	729	392	253	113	26	0	0
IRR 06 (Boggabri-Narrabri)	4,475	4,187	3,558	1,933	1,135	626	223	0	0
IRR 07 (Narrabri-Mollee)	2,600	2,396	2,188	1,729	1,345	994	746	251	0
IRR 08 (Mollee-Gunidgera)	41,000	40,435	38,589	34,739	30,837	26,200	21,443	10,988	244
IRR 09 (Gunidgera-Weeta)	3,740	3,714	3,523	2,956	1,888	1,041	367	0	0
IRR 10 (Weeta-Duncan's Junction)	5,675	5,108	4,201	2,260	1,221	608	257	0	0
IRR 11 (Duncan's Junction-Bugilbone)	11,440	15,061	14,441	12,126	9,399	6,704	4,714	1,510	0
IRR 12 (Bugilbone-Goangra)	1,850	10,648	10,224	9,978	7,923	4,977	2,142	0	0
IRR 13 (Goangra-Upstream of Walgett)	16,380	4,354	4,230	3,553	2,622	1,483	724	0	0
IRR 14 (Gunidgera Creek d/s of reg-Gunidgera Creek Pian Cutting)	11,350	8,790	6,794	4,593	2,904	1,386	416	0	0
IRR 15 (Gunidgera Creek Pian Cutting-junction with Namoi)	4,700	1,814	1,680	14,71	1,067	731	424	18	0
IRR 16 (Pian Creek Pian Cutting-Pian Creek Rosemore gauge)	59,755	33,109	27,443	18,452	13,824	11,475	8,655	3,204	0
IRR 17 (Pian Creek Rosemore gauge-upstream of Walgett)	14,850	390	64	0	0	0	0	0	0

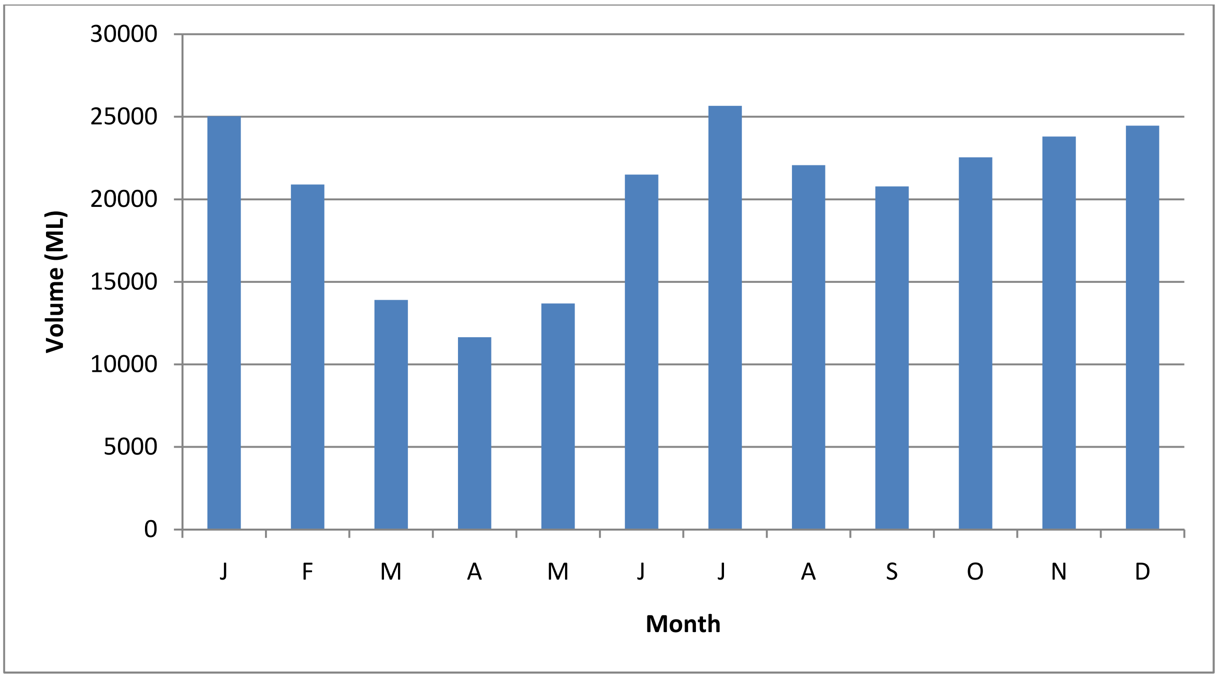

Figure 23: Average modelled farm storage per month for irrigation node eight.

These results indicate that on-farm storages are not often utilized to their full capacity. Based on review of some irrigation nodes this is likely due to a combination of off-allocation water availability, pump capacity, satisfying irrigation demand and potential supplementary cap. Therefore, enhanced use of on-farm storages may in some reaches require increasing pump capacity, or ordering water to be temporarily stored over an extended period to utilize current pump capacity. Securing water within some storages may also have an impact on the amount of area that farmers can plant, as on-farm water management potentially influences crop planting.

An assessment of on-farm storage volume at different levels of general security allocations was undertaken for irrigation model reaches from Gunnedah to Duncan's Junction Gauge (reaches 5 to 10). Table 29 presents the average volume in storage, over the simulation period, for a range of allocation levels. Table 30 presents the percent utilisation of the same storages in each reach at varying allocation levels. This data provides an indication of the likelihood of water availability in on-farm storage for various levels of general security allocations. There could be opportunities in medium to dry years (assuming low allocation is representative of climatic conditions) that water potentially is available from Reach 8.

Table 29: Average volume (ML) in storage at varying general security allocation levels (data: 1895-2009).

Allocation level (%)	Model Node						
	IRR 05 (Gunnedah-Boggabri)	IRR 06 (Boggabri-Narrabri)	IRR 07 (Narrabri-Mollee)	IRR 08 (Mollee-Gunidgera)	IRR 09 (Gunidgera -Weeta)	IRR 10 (Weeta-Duncan's Junction)	IRR 11 Duncan's Junction-Bugilbone)
>125	294	1,449	1,283	26,611	1,515	1,838	8,927
100-125	210	782	933	21,870	1,217	1,096	6,497
75-100	176	992	971	19,449	1,138	1,134	5,284
50-75	163	656	876	18,218	986	748	5,004

Allocation level (%)	Model Node						
	IRR 05 (Gunnedah-Boggabri)	IRR 06 (Boggabri-Narrabri)	IRR 07 (Narrabri-Mollee)	IRR 08 (Mollee-Gunidgera)	IRR 09 (Gunidgera -Weeta)	IRR 10 (Weeta-Duncan's Junction)	IRR 11 Duncan's Junction-Bugilbone)
40-50	202	710	761	20,850	1,287	795	4,231
30-40	140	721	655	17,036	1,152	647	3,488
20-30	147	758	643	17,855	1,138	654	3,381
<20	64	415	232	9,191	461	232	2,236
Max OFS volume (ML)	*1,000*	*4,475*	*2,600*	*41,000*	*3,740*	*5,675*	*16,380*

Table 30: Percent utilisation of on-farm storages in each reach at varying allocation levels.

Allocation Level (%)	Model Node						
	IRR 05 (Gunnedah -Boggabri)	IRR 06 (Boggabri-Narrabri)	IRR 07 (Narrabri-Mollee)	IRR 08 (Mollee-Gunidgera)	IRR 09 (Gunidgera -Weeta)	IRR 10 (Weeta-Duncan's Junction)	IRR 11 Duncan's Junction-Bugilbone)
>125	29	32	49	65	40	32	55
100-125	21	17	36	53	33	19	40
75-100	18	22	37	47	30	20	32
50-75	16	15	34	44	26	13	31
40-50	20	16	29	51	34	14	26
30-40	14	16	25	42	31	11	21
20-30	15	17	25	44	30	12	21
<20	6	9	9	22	12	4	14

5.3.5 The Current Scenario for Meeting Environmental Watering Targets

The environmental flow target is 4,000 ML/d for at least seven consecutive days (optimum 45 days) between Duncan's Junction gauge and Bugilbone. Simulated river flow at Duncan's Junction gauge was assessed to determine how many years this is achieved under the water planning model, and the number of events that occurred over the simulation period, as an indication of the frequency of opportunities to enhance naturally occurring higher-than-average events.

Table 31 presents the number of events with consecutive days of flow greater than 4,000 ML/day at Duncan's Junction gauge, for anytime during the year, and during the 'low' and 'high' regulated seasons. The data indicates there is a flow of 4,000 ML/day over several consecutive days at Duncan's Junction gauge in most years, and most of these events occur in the high regulated season (October to March). Further analyses of the data indicated the number of events per year with seven-day duration is 129; 25-day duration is 26, and 45-day duration is nine. This means in most years there are opportunities to augment naturally occurring higher flows at Duncan's Junction, typically in autumn and winter.

Table 31: Number of events with consecutive days of flow >4,000 ML/day at Duncan's Junction gauge.

Flow Statistic	Duncan's Junction (419094)		
	Anytime within a year	Low regulated season (April to Sept)	High regulated season (Oct to March)
Number of years	103	18	94
Total years in simulation	113	113	113
Percent of years flow does meet target	91	16	83

Modelled river flow and surplus water availability were obtained from NoW for three gauges along the Namoi River. These were Boggabri (419012), Mollee (419039) and Duncan's Junction (419094) gauges. Surplus water occurs in uncontrolled flow events that typically arise out of tributaries flowing into the river below Keepit Dam. Surplus water availability in these events is the river flow less volumes that satisfy orders, less the environmental requirements. Overall extraction may not exceed 10 per cent of the supplementary event volume for events occurring between 1 July and 31 October, and 50 per cent of the supplementary event volume for events between 1 November and 30 June. Irrigators holding supplementary water access licences are able to access the allowed portion of surplus flow events. The total volume they can take in a year is, however, limited by their annual allocation under those licences.

Table 32 presents flow frequency of daily river flows and surplus available water. Figure 24 shows the average daily flow at Duncan's Junction gauge per month during the 1895-2009 data simulation period. These results indicate that the optimum time to supplement river flows is late summer or winter (July). This corresponds to the optimum time for watering assets.

Table 32: River and surplus flows on the Namoi River.

River Flow Statistic	Gauge		
	Boggabri (419012)	Mollee (419039)	Duncan's Junction (419094)
Average Annual River Flow (GL/yr)	741.7	770.3	550.7
Number of surplus water events:			
- over full simulation period	544	510	949
- average per year	4.8	4.5	8.4
Average length of surplus water events (days)	9.2	10.6	7.2
River flow during surplus water events:			
- average annual volume (ML/yr)	441,529	475,265	452,312
Volume of surplus water events:			
- average volume per event (ML)	571	8,478	1,962
- average annual volume (ML/yr)	2,749	38,264	16,480
- percent of annual river flow during events	0.6	8.1	3.6
	Reach		
	Gunnedah to Narrabri	Gunnedah to Gundigera	Gunnedah to Bugilbone
Extractions under supplementary water licences:			

- average annual volume (ML/yr)	543	10,564	20,853
- percent of annual river flow during events	0.1	2.2	4.6
	River flow threshold at Duncan's Junction		
	3000	4000	5000
Number of surplus water events within threshold			
- over full simulation period	951	1,065	1,089
- average events per year	8.4	9.4	9.6
Average length of surplus water events (days)	3.5	3.7	4.1
River flow during surplus water events:			
- average daily volume for events (ML/d)	1,492	1,803	2,090
- average volume per event (ML)	5,246	6,714	8,518
- average annual volume (ML/yr)	44,150	63,276	82,090
Volume of surplus water in events			
- average volume per event (ML)	746	842	948
- average annual volume (ML/yr)	6,274	7,933	9,135
- percent of total event volume	14.2	12.5	11.1

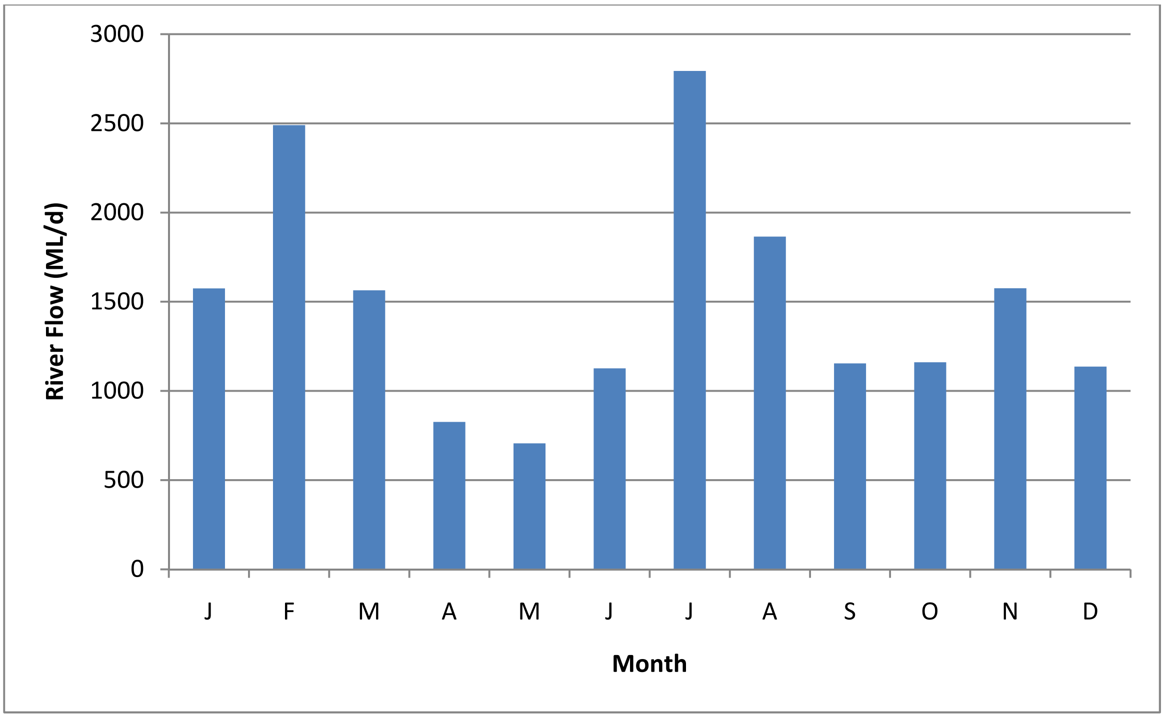

Figure 24: Average daily flow per month (ML/day) at Duncan's Junction gauge (data: 1895-2009).

5.4 Mechanisms to Achieve Watering Targets

5.4.1 Possible Mechanisms

Under current arrangements, flows that meet the 4,000 ML/day for 45 days (minimum of seven days) target at Duncan's Junction, typically occur as a result of either flood spills from Keepit Dam and/or uncontrolled inflows from tributaries below Keepit Dam. An increased frequency and duration is desired approaching pre-development conditions.

According to the CSIRO (2007) assessment, the current regulated water rules and development have reduced the frequency of events exceeding 4,000 ML/day at Duncan's gauge from an average of three months between events to an average of 3.8 months between events, and from a maximum of 25.2 months between events to a maximum of 37.2 months between events. Average event volumes have reduced from 154 GL to 140 GL.

Creating a 4,000 ML/day event at Duncan's Junction requires a minimum total volume of approximately 28 GL (minimum seven days) to 180 GL (45 days). Given the volume of environmental water licences currently held by the Commonwealth, this is not feasible. Much lower volumes would be needed, however, to augment an existing uncontrolled event to increase its height and duration, so this is a possible approach. As demonstrated previously in the report, while events that reach or approach the targeted flow and duration can occur at any time of the year, they are most likely to occur in February and July.

Broadly, the following options are available to enhance targeted flow events:

- release additional water from Keepit Dam
- reduce extraction of water from uncontrolled flows upstream of the target reach
- release water captured in private off-river on-farm storages.

The feasibility of using each of these options is discussed below.

5.4.2 Supply from Keepit Dam

Water released from Keepit Dam arrives at Duncan's Junction approximately ten days later. Keepit Dam has a regulated release capacity of 4,000 ML/day, and an operational storage capacity of 419 GL[4]. Water could be released from the dam to reach the targeted reach, and there is the potential to coordinate such releases with uncontrolled tributary inflows downstream of the dam. Discussions with river operators suggest this to be feasible, but trials would be required to confirm it.

Water held in Keepit Dam is fully committed to water licence holders, and to meeting obligations for minimum end-of-system flows, providing water to basic water rights holders and meeting system losses. Thus to access additional water from Keepit Dam would require water allocations held in the dam on behalf of water licence holders to be released down the river.

This could be achieved in the following ways:

a) By the Commonwealth owning general security water licences (as it already does), so that water allocations can be released on demand.

b) By the Commonwealth purchasing water allocations from other general or high security water licence holders ('temporary trading') ahead of time so this can be released when ordered.

c) By the Commonwealth entering into contractual arrangements whereby other general or high security water licence holders agree to order their water allocations to be allowed to flow down river at a time stipulated by the Commonwealth.

[4] As stated on Statement of Approval 90WA811444 to State Water to operate infrastructure in the Namoi Regulated River system.

General security water access licences are the most common type in the Namoi Regulated River System. General security licences with a total of 246,692 unit shares are on issue in the Lower Namoi Regulated River water source. High security licences with a total of 3,418 unit shares are also on issue, but are not likely to be considered because of the small quantity and inability to carry over water allocations.

The Commonwealth already holds general security licences comprising 6203 unit shares[5], and can accrue water allocations for release on demand from Keepit Dam. Water allocations accrue whenever significant inflows to the dam occur. Water allocations are tradeable.

For general security water licences, there are rules that govern how these allocations may be held and used. General security licences can carry over unused water allocations without limit, subject to the volume in the account at any time not exceeding 2 ML/unit share. The maximum water allocations that can be taken under a water licence in a water year is 1.25 ML times the number of unit shares (plus any water allocation volume temporary traded to the licence). Thus there is a direct link between the capacity to retain and use water allocations and the number of unit shares (i.e. ongoing entitlements) held. The effect of this is to make Option (a) very flexible, but to significantly constrain Option (b). The Commonwealth can only purchase water allocations (temporary trade) to the extent that it holds general security unit shares and then only up to the point where the total allocation held does not exceed 2 ML/unit share. So the Commonwealth must hold water licences and would need to exercise care in purchasing allocations (temporary trade) to ensure they are not lost due to account limits being exceeded. Option (c) avoids this problem by leaving water allocations with their original water licences, but is reliant on private contractual arrangements.

A further issue is that the Water Sharing Plan links accounting of water use under water allocations to *'approved water supply works nominated on the access licence'* (clause 43). It is not clear what happens if water is ordered but left in the river, and whether the accounting systems are able to cope with this. For example, if the water was taken through a pump at Duncan's Junction gauge, the water allocations taken would be the volume pumped or the water ordered, whichever was greater. Losses accrued in getting the water to the point are accounted against system operating losses. Thus the volume of water allocations ordered and taken is not the same as the volume of water released from the dam. So presumably operators would have to set the amount of releases as if the water was to be taken from a pump at Duncan's Junction gauge, allowing for whatever losses would occur in getting it there. Water allocations 'taken' would have to be assumed to be the volume ordered.

A further operational/administrative issue that would have to be addressed is that if care is not taken, water released from the dam to enhance uncontrolled events could be extracted by holders of supplementary water licences, because the targeted flow events are also typically events where supplementary water access is allowed. This could be addressed by ensuring the volume allowed to be taken under supplementary licences is adjusted down for volumes released from the dam that are part of the flow event. This may require adjustment to clause 49 of the Water Sharing Plan.

As shown in Table 26, substantial general security water allocations are likely to be available in most years. Given that 100 percent allocation in the table corresponds to approximately 247 GL in storage, this volume of water would be available in more than half of years, going down to approximately 50 GL or more in 85 percent of years. In very dry years though, volumes are likely to drop away to very

[5] As at 29 Feb 2012. See: http://www.environment.gov.au/ewater/northern/namoi/index.html, accessed 3 March 2012

low levels. In these years, the Commonwealth may still be able to call on water allocations from its own entitlements carried forward from previous years, but would be unlikely to be able to purchase allocations from other licence holders, or if it did so the cost would be very high.

5.4.3 Reduce Upstream Extraction from Uncontrolled Flows

Generally the targeted environmental flow events will coincide with surplus water events (uncontrolled flows) in the Namoi River below Keepit Dam. Under the Water Sharing Plan, water can be taken from these events under supplementary licences, subject to a range of constraints set out in clause 49 of the Water Sharing Plan.

Supplementary water access licences provide access to surplus water events in the river that occur as a result of spills from Keepit Dam or substantial inflows from tributaries downstream of the dam (uncontrolled flow events). Water allocations under the licences define the limit to water that can be taken during a year, and are tradable. However, accessing the notional water allocated is subject to uncontrolled flow events occurring, and rules that limit the quantities of water that can be taken from those events. Supplementary licences with a total of 115,503 unit shares are on issue.

Under the provisions of clause 49, access to uncontrolled flows is only permitted when various downstream flow targets will be reached. Subject to these, access starts when flows at Narrabri exceed 5,000 ML/day (Aug-Dec), 4,000 ML/day (Jan), and 2,000 ML/day (Feb-July), with lower flow triggers at points in the river downstream. These flow targets drop to a uniform 500 ML/day if total water allocations in general security licences is less than 90 GL. Access to events is further restricted to 10 percent of the total volume between July and October, and 50 percent of the volume at other times. Thus the probability of events being substantially diminished by supplementary water extraction is highest in drier years (when general security allocations are also low), and in any year from November to June.

Table 31 gives some indication of the number of events currently occurring that achieve the targeted level and duration. These same events would most likely be surplus water events when supplementary water licence holders are able to take water. There are a large number of events that achieve the minimum seven-day target, but the number that achieve 25 day duration drops back markedly. It is likely that reducing extraction above Duncan's Junction gauge from these uncontrolled events could increase the duration of targeted environmental flow events.

Table 32 provides some statistics on surplus flows derived from the IQQM model for the river system. The model data suggests that on average about 4.6 percent of the flow in surplus flow events is extracted from surplus water events. The data on low threshold events at Duncan's Junction gauge suggests that the volume of surplus water available per event is around 12 percent of the flow at the gauge for a threshold of 4,000 ML/d. However, the effect of supplementary water extraction upstream must be added to this, so the total effect of extraction under supplementary licences would be higher. More complex analysis is needed to assess the effect of extraction on events as they pass down the river system.

As shown in Table 27, the reach Mollee to Gunidgera has by far the highest pump capacity (2,620 ML/d) and on-farm storage. These pumps alone could significantly draw down and reduce the duration of smaller targeted flow events (e.g. in the range of 3000 to 5000 ML/d) to levels that are below the target, particularly in drier years in the period November to June.

Clause 49(2) of the Water Sharing Plan indicates that rights to the calculated volume available in each uncontrolled water event are given to each supplementary licence holder in proportion to the number of unit shares they have on their licence. Thus in theory if they do not take the water it should flow down the river untouched by other water users (discussions with the river operator is need to check that this is not done on a reach by reach basis, so water flowing out of one reach might be available to supplementary licence holders in the next reach).

Supplementary licences receive water allocations at the start of each year. This is effectively a fixed 1 ML per unit share (it can be adjusted downwards if needed to achieve CAP compliance on a long term basis, but this has not yet happened). However, unlike general security licences, these allocations are a right to take water should it become available (or in other words a maximum volume that can be taken subject to availability), and are not a guarantee that the volume will be made available. For example, in a very dry year there might be no uncontrolled flow events and supplementary licence holders would therefore not be able to access any water, despite holding a substantial water allocation.

Supplementary licence water allocations cannot be carried over from one year to the next, so if no events occur in a year, double the volume cannot be taken in the next year. Supplementary licence water allocations can be assigned (transferred) between supplementary licences without limit. But the available share of event take is tied to unit shares on the supplementary licence, so assigning water allocations does not increase opportunities to access water during a particular event, but rather means water can be accessed from more events over a longer period should they occur.

The following approaches are possible for reducing extraction/consumptive use under supplementary water licences during targeted events:

a) Purchase and hold supplementary water licences above Duncan's Junction gauge, and order the water but leave it in the river in targeted events. In years when targeted events are being achieved anyway, water allocations could be sold to other supplementary licence holders.
b) Purchase supplementary water allocations from other supplementary licence holders. However unless all of an individual holder's water allocations for a year are purchased, this will not prevent them taking water from the earlier events in a year and may have no effect on their total volume of take if there are few supplementary events during the year (since they would not have been able to access all of their allocation anyway).
c) Purchase options not to take water in supplementary events. Enter into arrangements with supplementary licence holders at the start of each year whereby they agree not to take water in supplementary events on days nominated by the Commonwealth. Thus the Commonwealth could choose the events it wishes to enhance as they arise and call on the supplementary licence holders to not pump. Individuals would still be able to take water from later events, but run the risk that no further events will occur in the year.

Considering these options, Option (b) is not worth pursuing because it is unlikely to achieve the desired result of enhancing targeted events. Both of the other options are possible and could be used to contribute to enhancing targeted events. Option (c) has the advantage that landholders may still be able to achieve economic output in many years, though this could also be achieved by the Commonwealth selling water allocations under Option (a). Option (c) also relies on accessing meter readings to confirm compliance with the request not to pump. This would require establishing some administrative arrangements.

Overall, Option (a) is administratively much simpler as it does not rely on numerous, repeated private contract negotiations and where needed private contract enforcement. In the end it becomes more a financial and administrative feasibility decision. Supplementary licences associated with the river immediately upstream of the target reach (i.e. between Weeta Weir and Duncans Gauge) are likely to most effective.

5.4.4 Release Water Captured in Private On-farm Storages

Once taken from a water source through legal means (e.g. under a water licence through approved works), water is then effectively owned by the entity who took it. Water held in private storage is thus totally under the control of the owner of the storages. No water licence is required to arrange to access this water.

Delivery of this water back into the river may not, however, be straightforward. It cannot be assumed that works used for taking water and delivering it into storage can be used to return the water to the river. There could easily be capital costs to install works to enable this to occur. Additionally there may be water quality issues that could trigger obligations under the *Protection of the Environment Operations Act 1997*, particularly as many properties mix recycled water and catchment runoff water with river water in on-farm storages. The NSW Environment Protection Authority may require either compliance with practice guidelines or a discharge licence, or may not allow it to occur if the risks are too great. In each case the feasibility and cost of returning water from storages to the river would need to be assessed (this has not been attempted in this study).

As discussed in Section 5.3.2, there is 58,480 ML of capacity in 141 farms on the Namoi upstream of Duncan's Junction gauge that could be used to contribute to targeted flows. Of these the most likely to be useful would be the 41,000 ML of on-farm storages in the Mollee to Gunidgera reach of the river. These are relatively large individual storages, are most likely to have water most of the time, and are relative close to the target reach.

It is assumed that private on-farm storages will not be used to hold water taken from the river under water access licences held by the Commonwealth. This is because for general security entitlements, it is clearly more efficient that the water be left in Keepit Dam. If the Commonwealth chooses to own supplementary water access licences, then the likely scenario is to want this water left in the river to achieve targeted flow events which are associated with the uncontrolled flows where supplementary water can be taken.

To access water in private storages individual contractual arrangements are needed with each farm owner to access their water held in their storages. The following options are proposed:

a) *Purchase water at the time of need*. As time is required to establish such arrangements, this would be challenging, since lead times to augment small to moderate uncontrolled events will probably be no more than 20 days and part of that time would be needed to physically get the water from the storage to the targeted river reach. Contacts would need to be pre-arranged to such an extent that they could be quickly agreed and processed.
b) *Purchase water ahead of time*. Enter into contracts with farmers at the start of each year to purchase some of the water they hold in storage, retain it there until needed, and deliver it back to the river when requested by the Commonwealth. The landholder would probably seek a limit to the time they hold the water as otherwise it could limit their ability to irrigate indefinitely. Consideration would also be needed as to how evaporation and seepage losses are shared.
c) *Purchase an option to have water supplied within an agreed window of time*. Enter into arrangements with landholders at the start of each year to retain some of the water they hold in storage to be called out by the Commonwealth by a certain date (e.g. end of summer) after which the call option would lapse and the water could be used by the landholder. This is fundamentally similar to the previous option, but perhaps a more straightforward option.

The contract could split payment into an initial payment for the option and a second payment when (and if) the water is called on.

Of these, Option (c) is probably the most feasible. Purchasing water solely on demand (the first option) is unlikely to be practical in the tight timeframes, so some sort of preliminary arrangements would be needed, which is effectively Option (c) anyway. Option (b) would likely have a time limit on it, meaning again it is similar to Option (c) but more complex.

A concern with any attempts to use water from private storages is that to have any effect it would most likely require output from several storages to get a substantial enough volume and a lot of coordination for it all to reach the river at the right time so as to cumulatively enhance a targeted event. This would be a major exercise, with a high risk of failure.

As with using water from Keepit Dam, a further operational/administrative issue that would have to be addressed is that water released to enhance uncontrolled events could be extracted by holders of supplementary water licences. This may require adjustment to clause 49 of the Water Sharing Plan.

5.5 Comparative Evaluation of Mechanisms

All of the identified options – using water from Keepit Dam, from private storages and reducing extraction of supplementary water – could in theory be used to enhance targeted flow events. However, initial qualitative assessment suggests use of private on farm storages is probably the least viable.

Water from Keepit Dam could be used to enhance targeted flows by supplementing uncontrolled inflows from downstream tributaries. The Commonwealth would most likely need to hold a substantial quantity of unit shares of general security water entitlement to make this viable. With the current holding of 6,203 unit shares of general security, the best that could be hoped would be to extend one event every two years by maybe a week. Based on the Draft Basin Plan proposing a total of 10GL per year to be Cap equivalent to be re-allocated to the environment[6], and a unit share to cap conversion rate of 0.77, it appears the Commonwealth's holding could increase to approximately 13,000 unit shares. With carryover, this could be used to extend an event every two years by around two weeks.

Additions to the current holding could be warranted. Temporary trading could be used to some extent to enhance the benefit of held water entitlements, but is limited by accounting rules, and would be prohibitively expensive in very dry years. Alternatively, private contractual arrangements could be entered into with water licence holders to commit them to release their water allocations when the Commonwealth desires it, however, this would likely be cumbersome and not much cheaper than owning entitlements. Further detailed investigation would be needed to assess this.

Increasing targeted flow events by cutting back on extraction under supplementary licences is a potentially viable option. This can be achieved by either purchasing supplementary licences or entering into private contractual arrangements with supplementary licence holders whereby they agree not to take water in events nominated by the Commonwealth as they arise. The choice of which would require further assessment of cost and administrative feasibility of the second option. An advantage of this compared to other options is that timing would not be such a risk, as it

[6] see http://www.mdba.gov.au/draft-basin-plan/draft-basin-plan-for-consultation/schedule02.

essentially leaves freshes intact rather than trying to time releases from other sources to supplement them.

Accessing water in private on-farm storages is also potentially viable. However, it would require entering into numerous arrangements with farmers to cumulatively achieve the sort of volumes of releases that would be needed, and a substantial, high risk, operational arrangement to coordinate those releases so as to achieve the desired flow enhancement. The best hope for this option would be to identify a number of properties with large storages where water can readily be returned to the river and seek to enter into arrangement whereby options on water held in storage are purchased at the start of each water year. The storages in the Mollee to Gunidgera reach of the river are most likely to fit this specification, and additionally it appears they are also more likely to have water in storage when it would be needed, though even in this case it would still require coordination of releases from multiple storages. Case by case assessments would be needed to determine whether accessing water from particular storages is physically possible and if so at what cost, and whether water quality risks might limit ability to return water to the river.

It is assumed that private on-farm storages will not be used to hold water taken from the river under water access licences held by the Commonwealth. The reason for this is that for general security entitlements, it is clearly more efficient that the water be left in Keepit Dam. If the Commonwealth chose to own supplementary water access licences, then it will be more efficient for this water to be left in the river to achieve targeted flow events, which coincide with the uncontrolled flows where supplementary water can be taken.

For all of these options, there are a number of operational and legal issues to be addressed, and a potential requirement to adjustment the Water Sharing Plan. For example, to enable accounting for volumes delivered to a point in the river but not taken through meterable works, and to ensure water released is not lawfully taken by supplementary water licence holders.

It should be noted though that the volumes required to enhance these flow events repeatedly are very large. Extending an event by just a week could require 14 GL. Volumes likely to be available under general security entitlements currently held by the Commonwealth could only extend a single event by a week every two years at best. If the entitlement holdings are doubled, as is suggested by the draft Basin Plan, this could be extended to two weeks every two years. Volumes available in private storages could potentially also be used. Indicative statistics suggest that around 15 GL maximum could be accessed in average to moderately dry years. The alternative of reducing supplementary water extraction should be considered as a viable alternative option.

In very dry years the value of water to irrigators would most likely drive up the cost of procuring private water or purchasing water allocations to very high levels, making it very expensive to do, and in any case the volume required to create a minimal event rather than enhancing a naturally occurring event would be around 30 GL – a volume unlikely to be available. In those years, the best option might be to pump smaller volumes of water into critical refuge wetlands rather than attempting to restore overbank flow events.

The viability of different options could also be significantly affected if accounting rules or rules for accessing supplementary water are changed when the Water Sharing Plan is re-worked in 2014. Table 33 shows a comparison of mechanisms for achieving environmental water targets.

Table 33: Comparison of mechanisms for achieving environmental watering target

Criterion	Supply of water from Keepit Dam	Reducing extraction of surplus flows	Supply from private water storages
Effectiveness	Volumes could be adequate if further entitlements purchased	Directly and positively achieves targeted flows.	Would be challenging to involve sufficient storages to achieve the needed volumes and release rates.
Workability	Generally workable, but would require administrative changes and possibly minor changes to water sharing plan.	Straightforward. Would require purchase of entitlements or contractual arrangements with entitlement holders.	Coordination of releases from multiple storages would be difficult. Likely to be a need for considerable adjustments to private infrastructure – subject to field inspections.
Risk and uncertainty	Available volumes may be inadequate in very dry years.	The volume of entitlements involved to achieve the targets could be large.	Risk of operational failure is high.

5.6 Key Conclusions and Recommendations

AN environmental flow target of 4,000 ML/d for at least seven consecutive days (optimum 45 days) each year between Duncan's Junction gauge and Bugilbone was selected for assessment.

All of the identified options – using water from Keepit Dam, from private storages and reducing extraction of supplementary water – could in theory be used to enhance targeted flow events. However, initial qualitative assessment suggests use of private on farm storages is probably the least viable.

Increasing targeted flow events by cutting back on extraction under supplementary licences at first cut appears to be potentially most viable option. This can be achieved by either purchasing supplementary licences or entering into private contractual arrangements with supplementary licence holders whereby they agree not to take water in events nominated by the Commonwealth as they arise (Table 34).

Table 34: Summary of mechanisms for delivery of Commonwealth environmental water.

Mechanism	Effectiveness	Workability	Low Risk and Uncertainty	Further Information
Supply of water from Keepit Dam	✓✓	✓✓	✓✓	Requires purchase of additional entitlements
Reducing extraction of surplus flows	✓✓✓	✓✓✓	✓✓	Would require either purchase of further entitlements or finances for contracts with entitlement holders
Supply from private water storages	✓	✓	✓	Would involve lots of storages to make up the necessary volumes.

5.6.1 Further Investigations

The previous analysis relied on available statistics and spatial information of storages. To further assess the viability of options and identify which combination of options is likely to be the most cost effective, the following would be required:

- Gain a clearer picture of the likely limitations on Commonwealth future holdings of water entitlements and potential to purchase options or privately owned water on an ongoing basis.
- Further refine the targeted water regime to identify the particular kinds of events that should be given highest priority for enhancement, as the volumes required for enhancements are large and selection will be needed. (Given the limits to Commonwealth holdings this might lead to changing the target to critical habitat preservation in dry periods).
- Discuss with river operators constraints on such things as rates of rise and fall in the river, operation of weirs, ability to time flow events moving down the river, and management of access to supplementary water that could affect the options being considered.
- Discuss with NOW the ability to deliver water to a point in the river and have it accounted properly, how transmission losses should be dealt with in doing so, how shepherding of releases from private water storages might be achieved, and what if any changes to the Water Sharing Plan might be needed to enable it.
- Undertake more detailed simulations to further assess which options or combinations of options would be best for achieving the targeted enhancements.
- Develop cost estimates for each option based on market values of water in average, dry and very dry years.
- If use of private water storages proves to be worth pursuing, identify candidate storages in consultation with State Water and undertake on the ground assessments in consultation with willing water users and the EPA to assess the physical viability and cost of using particular on-farm water storages (if using them is shown to be potentially viable option) and whether water quality issues might prove to make this unviable.

Once preferred approaches are settled upon, there are also operational/administrative issues that would need to be addressed that may require adjustments to the Water Sharing Plan, but these would not be great and could be done under the Act with little risk. Discussion with the NSW Office of Water would be needed to make necessary arrangements.

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