Ecological Assessment of Flow Management Scenarios for the Lower Balonne

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Report to Queensland Department Natural Resources and Mines

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Cooperative Research Centre for Freshwater Ecology

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The Cooperative Research Centre for Freshwater Ecology is a national research centre specialising in river and wetland science. In particular, the CRC for Freshwater Ecology provides the ecological knowledge needed to help manage the rivers in a sustainable way. The CRC was established in 1993 under the Australian Government's Cooperative Research Centre Program and is a joint venture between:

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Department of Land and Water Conservation, NSW
Department of Natural Resources and Environment, Victoria
Environment ACT
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Executive Summary

1. The Queensland Department of Natural Resources and Mines (NR&M) has explored five potential water resource management scenarios for the Lower Balonne River and its floodplain. A working group from the Cooperative Research Centre for Freshwater Ecology was established to provided an objective relative assessment of the likely ecological outcomes of these scenarios.

2. The five flow management scenarios presented to the CRC were:

   A. Hold extraction capacity and river flows at around current levels;

   B. As per A, but generally reduce Lower Balonne water harvesting extractions to improve river flows by about 10% over current levels;

   C. As per A, but "switch off" all water extractions along the Narran River.

   D. As per A, but minimise water extractions from the Culgoa and redirect some of the water savings down the Narran to achieve improved Narran River and Narran Lake outcomes, with the remainder of water savings remaining in the Culgoa River system.

   E. As per A, but modify the Narran Lakes to make the Reserve area fill first.

3. The water resource management scenarios were assessed as to whether they could deliver one or more of three target ecological outcomes identified by NR&M:

   Target 1: Arrest the decline in and improve the ecological condition of the Narran Lakes

   Target 2: Arrest the decline in and improve the ecological condition of the broader Lower Balonne floodplain.

   Target 3: Reduce the risk of long-term, irreversible and widespread ecological degradation and risk to the sustainability of agriculture in the Lower Balonne region posed by increased salinity.

4. The assessment was based on an evaluation of the likely ecological benefit of changes to the hydrology based on IQQM derived flow statistics provided by NR&M. The CRC recognised that there is limited ecological knowledge about the impacts of water resource development on ecosystem health in the specific assessment region, including the Narran Lakes system and the broader Balonne floodplain. However, recommendations were based on the considerable collective experience and expertise of the CRC in similar floodplain rivers, as well as

information derived from the literature on the ecological consequences of similar kinds of development. Validating assumed relationships between flow scenarios and ecological condition in the Lower Balonne will require considerable scientific investigation. However, this is unlikely to alter the relative ecological merit of the 5 scenarios.

5. The following assessments relate to the flow management scenarios developed by NR&M.

6. *Scenario A: Hold extraction capacity and river flows at around current levels.*

   The CRC noted the considerable change that has already occurred to flow regime across most flow variables. It is the considered opinion of the CRC that such changes in flow volume and temporal pattern will impact on the river system and its floodplain. Given this, the ecological condition of the Narran Lakes system and the Lower Balonne Floodplain system is at risk and likely to further decline under Scenario A. Also, we argue that the full ecological impact of recently constructed infrastructure for floodplain harvesting has yet to be realised, particularly as current infrastructure has yet to be utilised to the full extent because flows have not been high enough. Therefore, we predict there will be considerable time-lag effects in the ecological response to the current level of development. Accordingly, the long-term ecological outcomes of current development are not yet fully apparent.

7. *Scenario B*: *As per A, but generally reduce Lower Balonne water harvesting extractions to improve river flows by about 10% over current levels.*

   The CRC noted that this was the only scenario specifically directed at desired ecological Target 2. While this Scenario provides a small improvement in key flow statistics across both the Lower Balonne floodplain system and Narran Lake system, the overall effect on flow regime is insufficient to indicate a measurable improvement in ecological condition. Given the predicted time-lag effects in ecological condition (outlined above), this scenario is unlikely to even arrest decline.

8. *Scenario C: As per A, but "switch off" all water extractions along the Narran River.*

   While there is some improvement in key hydrological indicators in the Narran Lake system (though not much more than Scenario B), the overall effect on flow regime is insufficient to indicate a measurable improvement in ecological condition. Scenario C provides no improvement to flow regime in the broader Lower Balonne Floodplain system, therefore it is likely that ecological condition of the Lower Balonne floodplain will decline as the long term ecological consequences of current management are realised (see Scenario A).

9. *Scenario D: As per A, but minimise water extractions from the Culgoa and redirect some of the water savings down the Narran to achieve improved Narran River and Narran lake outcomes, with the remainder of water savings remaining in the Culgoa River system.*

   This Scenario provides a considerable improvement in the flow statistics to the Narran Lakes system and is likely to provide a significant ecological benefit there. Scenario D provides only a very slight improvement in key hydrological indicators in the broader Balonne floodplain. Given the predicted time-lag effects in ecological condition (outlined above), this scenario is unlikely to even arrest decline of the broader Balonne floodplain. The engineering works required to deliver Scenario D may further impact the broader Balonne floodplain. Consequently, and engineering works on the floodplain or in the river would need an independent ecological investigation.

10. *Scenario E: As per A, but modify the Narran Lakes to make the Reserve area fill first.*

    It is the considered opinion of the CRC that Scenario E will not provide a system-wide ecological benefit to the Narran Lakes, nor does it arrest the decline in the ecological condition of the broader Lower Balonne Floodplain. The danger of this type of proposal is that Narran Lake may be sacrificed to provide water for the remaining two lakes with no understanding about the interdependence and connectivity of the lakes for overall ecosystem condition. Given our limited knowledge of the ecology of the Narran Lakes system, the CRC recommends that the Narran Lakes be viewed and managed as an integrated ecosystem comprising all three lakes and the connecting Narran floodplain and wetlands.

11. Only Scenario D is likely to achieve NR&M's target ecological objective (1) of arresting the decline and improving the ecological condition of the Narran Lakes. It should be noted that the full benefits of this scenario will only be realised if other non-flow issues are addressed. These include: potential contamination of the lake food web with pesticides; increased sedimentation and salinity; lake bed cropping; floodplain vegetation protection and engineering works on the floodplain.

12. None of the proposed scenarios appear capable of achieving the second ecological target of arresting the decline and improving the ecological condition of the broader Lower Balonne floodplain. Further declines in ecological health in this region (which includes 2 National Parks) may also have long-term consequences for viability of populations of aquatic biota in the upper Condamine-Balonne system which historically have been well connected with other catchments in the Murray-Darling Basin.

13. There is very little information available to the CRC on the relative impact of the five flow scenarios on the threat that increasing salinity poses to the long-term sustainability of agriculture, or to the risk of wide spread ecological degradation in the Lower Balonne System. We speculate that scenarios that reduce the storage of large volumes of water on the floodplain may reduce the risk of increasing water tables and salinity, however we stress that we have no evidence to support this and further investigations would be required to confirm this. Nevertheless, it is our opinion that increases in river salinity will threaten the ecological integrity of floodplain wetlands and the Narran Lakes system. Therefore, the salinity risk needs to be managed through appropriate land and water management in both the irrigation regions and the broader catchment.

Introduction

Background to Study

The Queensland Department of Natural Resources and Mines (NR&M) has explored five potential water resource management scenarios for the Lower Balonne River and its floodplain. A working group from the Cooperative Research Centre for Freshwater Ecology was established to provided an objective relative assessment of the likely ecological outcomes of these scenarios.

Modelled hydrological outcomes using Integrated Quantity Quality Model (IQQM) of the five water resource management scenarios were presented to the CRC by NR&M at a Workshop held on 21st January 2002 at the Virginia Palms International Hotel, Brisbane. The CRC requested additional IQQM modelling which was provided over the following three weeks.

The Workshop was attended by Professor Peter Cullen, Professor Gary Jones, Professor Stuart Bunn, Associate Professor Keith Walker, Associate Professor Gerry Quinn, Associate Professor Martin Thoms and Dr John Whittington from the CRC for Freshwater Ecology. NR&M were represented by Tom Vanderbyl, Grant Crabbe, Gary Burgess and Seamus Parker. NR&M (Bruce Pearce) provided a brief progress report on the outcomes of the ‘Salinity Hazard Mapping Project’ for the Queensland portion of the Condamine Balonne catchment.

This document reports the CRC’s scientific opinion on the likely ecological outcomes of the five flow management Scenarios presented by NR&M. This opinion is based on an evaluation and synthesis of IQQM hydrological data and expert opinion. However, recommendations were based on considerable collective experience and expertise of the CRC in similar floodplain rivers, as well as information derived from the literature on the ecological consequences of similar kinds of development.

The CRC was not asked to, nor did it consider the social or economic implications of the Scenarios presented, nor did the workshop consider any other flow management Scenarios.

The CRC was not asked to recommend any course of action, rather it was asked to provide scientific opinion on the likely ecological outcomes of the five flow management scenarios.

Terms of Reference – Target Ecological Outcomes

NR&M requested that the CRCFE consider the following three target ecological outcomes when assessing the flow management scenarios:

1. Arrest[1] the decline in, and improve the ecological condition of the Narran Lakes;

2. Arrest the decline in and improve the ecological condition of the broader Lower Balonne floodplain; and

3. Reduce the risk of long-term, irreversible and widespread ecological degradation and risk to the sustainability of agriculture in the Lower Balonne region posed by increased salinity;

Terms of Reference – Assessed Flow Scenarios

The five flow management scenarios presented to the CRC Freshwater Ecology by NR&M were:

A. Hold extraction capacity and river flows at around current levels;

B. As per A, but generally reduce Lower Balonne water harvesting extractions to improve river flows by about 10% over current levels;

C. As per A, but "switch off" all water extractions along the Narran River.

D1. As per A, but minimise water extractions from the Culgoa and redirect some of the water savings down the Narran to achieve improved Narran River and Narran lake outcomes, with the remainder of water savings remaining in the Culgoa River system.

E. As per A, but modify the Narran Lakes to make the Reserve area fill first.

Assumptions

In undertaking this assessment, the following assumptions were made by the CRC:

1. NR&M's hydrological data used to develop hydrological indicators provides suitably accurate information to underpin this assessment.

2. Current provisions for water harvesting have not been fully exploited to date, largely because flow conditions have not been appropriate since the construction of some significant water harvesting infrastructure. This means that the river is

[1] The target ecological outcomes identified by NR&M recognise that current ecological condition is likely to continue to decline as the full ecological impact of recent increases in water harvesting occur.

yet to experience the full impact of current water resource development. This together with likely time-lag effects in ecological response, contributes to the view that the ecological health of the system is likely to further decline.

3. Scenario D would require significant engineering works (levees or channels) either on the floodplain or at the bifurcation to direct sufficient flow into the Narran River.

4. Expansion of abstraction upstream of Beardmore Dam (Node 1) will have additional impact on the ecological condition of the Lower Balonne floodplain.

5. River flows allocated for environmental purposes in QLD will not be abstracted from the Lower Balonne system, including Narran River by water users in NSW. Increased abstraction in the NSW part of the Lower Balonne would undermine the ecological outcomes of the Scenarios discussed in this report.

Ecological Attributes of the Assessment Regions

Narran Lakes

The Narran Lakes system comprises a series of interconnecting terminal drainage lakes of the Narran River – Back, Clear and Narran. The Narran River is the eastern most anabranch of the Balonne River and historically carried about 25% of the discharge. Under current levels of water abstraction, median and mean flows reaching Narran Lakes have been reduced to approximately 24% and 43% respectively.

The Narran Lakes system receives water at lower flow levels than the lake beds further north along the Narran River and hence fills more often and holds water for longer periods than many of the regional wetlands. At moderate flows, water fills Clear Lake and then back-floods into Narran Lake. The water level in Clear Lake can drop very quickly if flows are not sufficient to keep water levels up in both Narran and Clear Lakes (http://environment.gov.au/ramsar/wet_report.html?listitem=53&mapimage=").

The Narran Lakes system is recognised as one of the most important waterbird habitats in Eastern Australia. Thoms et al (2001) report that 65 species of water birds have been recorded in the Narran Lakes, 46 of which breed in the system. Five species are listed under the NSW Threatened species Act (1995) and a further 8 species are of conservation concern. The triggers for successful bird breeding events in the Narran Lakes system are unclear but the following are considered important:

- area flooded;
- rate at which water arrives;
- time of year;
- depth, and;
- overall period of inundation at the local and regional scale.

Preliminary studies by Mike Maher (New South Wales NPWS) indicate that bird breeding in the Narran Lakes occurs when the system is 86% of capacity (Thoms et al 2001). Recruitment must occur sufficiently often to match the birds' life cycle.

The vegetation of the Narran Lakes Nature Reserve is dominated by arid and semi-arid adapted species. Species richness is relatively high compared to other western reserves. Associated with the wetlands are a number of vegetation communities considered to be ecologically significant including: sedges and ephemeral herbfields, lignum, Phragmites and open riparian forests of Redgum, Coolibah, Black Box, and River Cooba. These communities are sensitive to frequency of inundation and other hydrological parameters. The Lignum shrublands in the Narran Lakes Complex are some of the largest undisturbed communities of their type in NSW.

There is limited information on the fish community of the Narran Lake System. A single study reports 5 native species, including high abundance of juvenile golden perch (Thoms et al 2001 pg36).

Narran Lake System Ecosystem Model
An ecosystem model has been developed for the Narran Lakes System (Thoms et al 2001) with the following features:

- Water, nutrients, carbon and biota are transported to the Narran Lakes via the Narran River and floodplain
- The amount and type of material transported is changed by interactions with the floodplain
- Many biota colonise wetlands from the river or elsewhere (eg birds) once the water arrives
- A major component of the biota are permanently associated with the wetlands and are adapted to inundation and drying (either in seedbank or as terrestrial)
- A key characteristic is its spatial and temporal variability.

The model indicates that important habitats include:

- Deep holes in the Narran River as refugia
- Snags in channels from fallen riparian vegetation
- Lake bed as a seedbank for plants and invertebrates
- Riparian vegetation for nesting and roosting and habitat complexity for aquatic organisms
- Open floodplain forest and woodland provides habitat for reptiles and amphibians.
- Cracking soils as habitat for biota

Lower Balonne Floodplain

The Lower Balonne is a complex floodplain channel system. The floodplain is heavily dissected by well-defined channels of various sizes. During flood events these channels carry a significant proportion of the 'overland' flow (Thoms et al 2001).

Vegetation across the Balonne Floodplain forms a complex mosaic; a result of spatially complex geomorphology and hydrology. Recent mapping of floodplain vegetation assemblages and extent of flood water inundation in the Lower Balonne has been undertaken by Sims and Thoms (submitted) using ground truthed satellite imagery. These data allow the calculation of flood thresholds for inundation of significant vegetation types (see Table 1).

Geomorphological studies of the main river channels in the Lower Balonne have been undertaken (Thoms et al., 2001). These studies indicate the channels of Briarie Creek, Ballandool River and Bokhara River are inherently unstable, as defined by the relationship defined by Schum (1979) of mean annual flows and bed slope. Consequently, small changes to the mean annual flow of these systems are likely to lead to significant changes in channel morphology.

Thoms et al (2001) suggest that sedimentation rates on parts of the Balonne Floodplain have increased by an order of magnitude since European settlement. This is in large part due to increases in sediment supply from the upper catchment.

The Salinity Hazard Map for the Condamine Balonne Catchment presented by NR&M indicates that considerable sections of the catchment have a potential for high salinity risk. The salinity hazard map was developed using several weighted geomorphic and hydrographic criteria including: excess water, topography, relative elevation, soil characteristics, depth of weathering, depth of impermeable layer and groundwater flow systems.

A study of the floodplain vegetation of the Culgoa, Birrie and Narran Rivers identified 175 species, of which only 8.5% were exotics which is one of the lowest records of introduced species in the MDB (Dick 1990). The Coolibah woodlands in the Lower Balonne are some of the most extensive and contiguous communities remaining, as are the grasslands of the Narran, Birrie and Culgoa floodplains (Thoms et al. 2001).

There are two National Parks on the Balonne Floodplain; the 22,430 ha Culgoa National Park managed by NSW National Parks and Wildlife Service and the adjoining 42,800 ha Culgoa Floodplain National Park managed by Queensland National Parks and Wildlife Service.

The Lower Balonne floodplain contains two listings in the 3rd edition of the Directory of Important Wetlands in Australia:

- The Culgoa River Floodplain (NSW170) within the Culgoa National Park (NSW); and;
- An aggregate of wetlands on the Balonne River Floodplain (QLD084) in QLD.

Culgoa River Floodplain

The Culgoa River Floodplain located within the Culgoa National Park (NSW) is listed for the significance of its terrestrial floodplain vegetation, in particular the large area of undisturbed Coolibah woodlands. The Culgoa National Park has a high plant diversity with a low percentage of exotic species. Flows from the Culgoa River, particularly the period of inundation appears to be the most significant factor affecting the distribution of vegetation communities in the Culgoa National Park (www.ea.gov.au/cgi-bin/wetlands/reportwets.pl). A Draft management plan for the Culgoa National Park has been prepared, which "recognizes that natural levels and timing of flooding and protection of water quality are vital for maintenance of the high habitat values of the national park and floodplain" (http://www.npws.nsw.gov.au/news/exhibition/POM/draft/Culgoa_draft.pdf).

Balonne River Floodplain
The Balonne River Floodplain wetlands (QLD) represent a significant aggregation of permanent and ephemeral billabongs and swamps on the floodplain. The listing includes: Lake Munya, Parachute Lagoons, Birch Lagoon, Mooramanna Lake and the swamp at Brookdale. These systems range from ephemeral wetlands to permanent billabongs. The actual area of the wetlands is in the order of several hundred hectares spread over approximately 24,000 ha of floodplain. Water resource development in the Balonne floodplain is recognised as a threat to the ecological integrity of these wetlands (www.ea.gov.au/cgi-bin/wetlands/reportwets.pl).

Hydrology

IQQM Model Hydrological Data

NR&M generally uses the water resource flow model Integrated Quantity Quality Model (IQQM) for water planning purposes. This model allows an analysis of simulated flow data for the Condamine-Balonne catchment and has been used to derive the data to develop hydrological indicators used in this analysis.

To apply IQQM to a river system it is necessary to configure the model to represent the physical features and the water management system. This includes configuring for storages, inflows, effluent outflows and returns, floodplain detention storages and limits of flow routing reaches as well as defining system operating rules such as license flow thresholds (Thoms et al 2001).

Implementing IQQM involves calibration and validation. NR&M has used separate hydrologic models for the St George system and the Distributary system. The St George hydrologic model was calibrated for the period from 1986 to 1996. The Distributary IQQM model was calibrated from the period 1974 to 1989. The model used to develop the pre-development case was calibrated to the period from 1966 to 1973, before construction of the bifurcation weirs.

Hydrologic models were verified for the period 1991 – 2000 using information on stream gauging and water harvesting information. Hydrologic simulations used to produce hydrological data for this analysis were run for a 73 year period (1922-1995).

There are several things that need to be considered when interpreting the IQQM output:

- IQQM is a planning tool that provides information on long-term future system performance and behavior under various management rules.
- Prediction of long-term future performance is based on historical data (rainfall, streamflow and evaporation). This approach assumes that the future will be a repeat of the past.
- There are limitations on the accuracy of input data. Streamflow gauging, particularly in geomorphically complex areas under very high and low flows can be unreliable (Thoms et al 2001). There can be inaccuracies in other data used in the calibration including water use data.

NR&M state that rated gauges in the Condamine-Balonne used to develop the IQQM perform well during most flow events, with the exceptions under high flows of the Briarie Creek gauge and the Woolerbilla gauge on the Culgoa River. NR&M acknowledge that all gauges are less reliable during high flow events.

NR&M state that despite the uncertainty about on-farm storage capacity and high flow events the models provide a reliable estimate of stream flow and water harvesting diversions. NR&M state that IQQM estimated Mean Annual Flow at St George is within 2% of recorded flow and Total Water Harvesting Diversions in the distributary system for the period were within 6% of the metered data.

We note that NR&M commissioned an independent Audit of the hydrologic models for the assessment area. The report indicates that the hydrologic models used in the Lower Balonne are acceptable for the purpose of water planning. We have not cited this report.

Hydrological Indicators

After consultation with the CRC, NR&M provided the following flow statistics for Nodes 1-12 at the Workshop:

- Mean Annual Flow (absolute and % simulated natural)
- Median Annual Flow (absolute and % simulated natural)
- Annual Proportion of Flow Deviation (APFD)
- Qmin and Qmax where:
    - Qmax = average (73 year) annual maximum daily flow
    - Qmin = average (73year) annual minimum daily flow
- Seasonal Amplitude – estimates the change from simulated natural of the difference between the highest and lowest monthly flows.
- Flow Duration Curve Difference - a measure of the overall difference between current and simulated natural flow duration curves
- Flow spell analysis at three flood event thresholds (small, medium, large flood):
    - Number (over simulation period)
    - Duration (days)

- Spells (days)

In addition NR&M provided the following statistics for Narran Lake:

- Number of events exceeding 10%, 20%, 50%, 86%[2] and 100% full over simulation period.
- Duration at each level over simulation period and as a proportion of simulated natural.

Martin Thoms and Melissa Parsons (CRCFE, University of Canberra) undertook multivariate analyses of the IQQM data. Classification (UPGMA), ordination (Semi-strong-Hybrid Multidimensional Scaling) and Principal Axis Correlation was used to determine groups of nodes with similar hydrological character and to examine the relationship between different scale flow variables and the position of nodes in ordination space.

The CRC requested the development and calculation of additional flow statistics linked to ecologically relevant flood thresholds. Ecologically relevant flood thresholds were determined by Martin Thoms and Neil Sims by analysing the distribution of various vegetation communities across the floodplain compared with the corresponding flood frequency data. These are presented in Table 1.

[2] Narran Lake reaching 86% full is considered the minimum volume to allow successful bird breeding event based on advice from NSW NPWS (Thoms et al 2001).

Table 1. Ecological Flood Thresholds[3] for Balonne Floodplain System

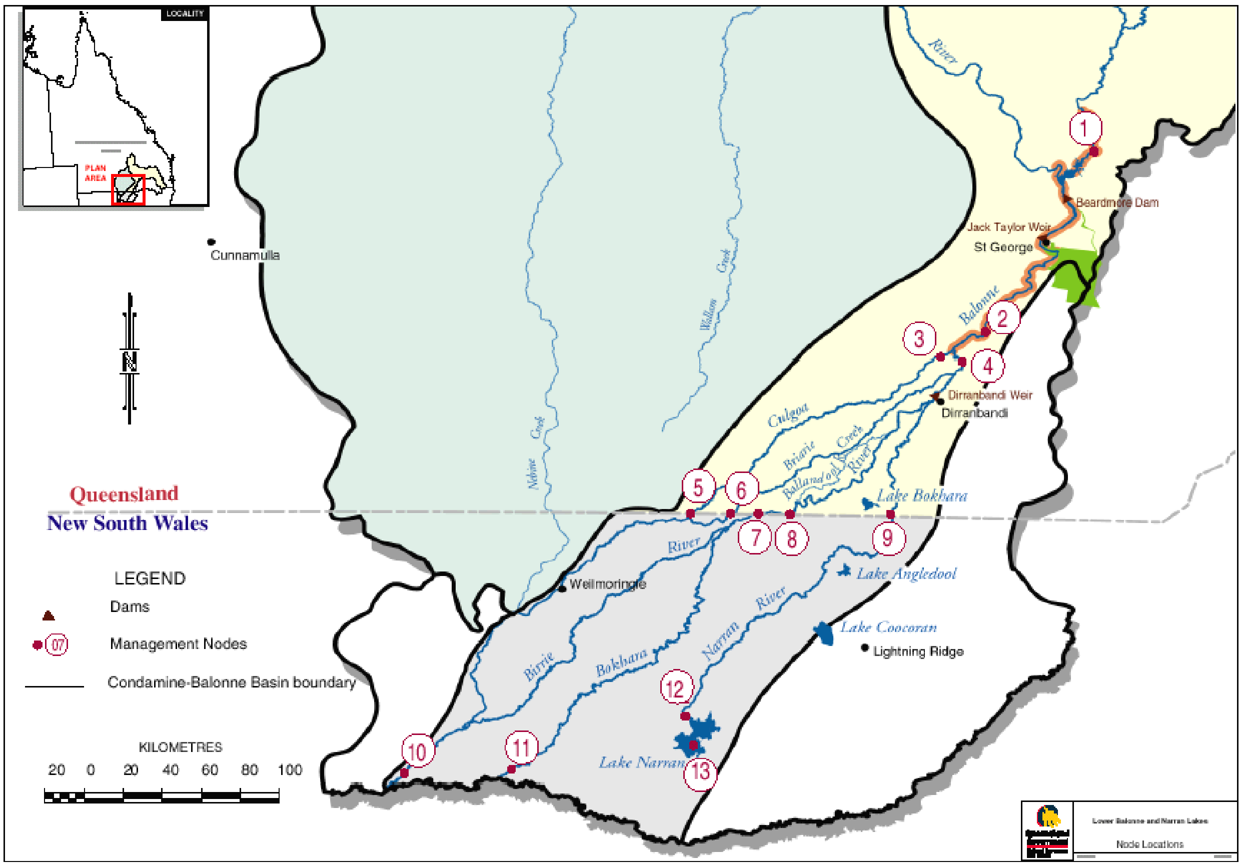
Flow Threshold	Ecological relevance
25,000 ML/D	Water begins to moves out of the main channel and into the secondary channel network of the floodplain i.e. floodplain inundation begins.
45,000 ML/D	Three of the main floodplain vegetation communities (Coolibah open woodlands, Lignum and Riparian Forests) have at least 50 percent of their total area wetted.
60,000 ML/D	The majority of the main flow paths across the floodplain are full. This area includes the large stands of Coolibah Open, Woodland, Riparian Forest and Lignum communities on the floodplain.
70,000 ML/D	There is a significant increase in the diversity of floodplain plant communities. Four of the main vegetation communities have at least 40 percent of their total area wetted plus another 3 vegetation communities have at least 15-20 percent of their total area wetted. At this flow at least 40 percent of the total floodplain is inundated.
120,000 ML/D	Approximately 70 percent of the total floodplain area between St George and the Qld/NSW border is inundated at this flow level and further increases in flow result proportionally larger increases in the depth of flow across the floodplain rather than floodplain area inundated.

[3] These flood thresholds refer to flows at St George.

Assessment Nodes

Hydrological indicators were calculated by NR&M for 13 locations (nodes) throughout the Lower Balonne system (see Figure 1).

Figure 1. Lower Balonne system showing location of IQQM nodes used for the assessment presented in this report.



Data for the 13 nodes were considered by the CRC at the workshop. Summary flow statistics for nodes 5, 8, 10, 12 and 13 (Table 2) were analyzed further to establish the likely ecological outcomes of the five scenarios.

Table 2 Description of Assessment Nodes.

Node	Site	Description
5	Culgoa R at QLD/NSW Border	Indicator of flow down the Culgoa below Queensland floodplain harvesting. Indicates the likely hydrology of the Culgoa Floodplain National Park (QLD) and the Culgoa National park (NSW).
8	Bokhara River at the border	Indicator of flows in Bokhara and Ballandool River below Queensland floodplain harvesting. Indicates likely hydrology of the central part of the Lower Balonne floodplain.
10	Culgoa River upstream of junction with Barwon River.	An indicator (in conjunction with Node 11) of the effect of water abstraction on flows to the Barwon River.
12	Narran Lakes inflow	Indicator of flows into the Lake Narran complex
13	Narran Lakes	Indicator of inundation (flood frequency & extent) in Lake Narran.

Simulated Natural Hydrology

IQQM was used to develop simulated natural flows for the Lower Balonne system. Simulated natural flows are calculated by setting flow regulating structures and water abstractions to zero and utilising long-term climatic conditions – 73 years in this case.

Analysis of IQQM simulated natural data undertaken by Thoms and Parsons for this report indicates three distinctive hydrological zones – the western Balonne Floodplain region (Culgoa R), the eastern Balonne Floodplain region (Bokhara R, Ballandool R, Briarie Cr) and the Narran River region. This represents a high spatial diversity in the hydrology of the lower Balonne region. Hydrological diversity is often associated with ecological diversity.

Simulated natural mean annual flow at St George is 1,364GL.y^{-1}, of this 68% flows to the Culgoa River, 25% flows to the Narran River and 7% flows to the remaining rivers. Due to the evaporation, seepage and infiltration into the floodplain simulated mean annual flow reduces downstream. Simulated mean annual flow into NSW is approximately 1066GL.y^{-1}, while the simulated total mean annual end of system flow under simulated natural conditions is 736 GL.y^{-1}.

Under simulated natural conditions, Narran Lake filled to greater than 86% full (160,000ML) on 37 occasions in the last 73 years, giving an average interval for 'successful bird-breeding flooding' of 2 years. Under simulated natural conditions Narran Lake was at least 86% full for 18% of the time.

Current Hydrology

The hydrology of the Balonne river upstream of Beardmore Dam (assessed at Node 1) is relatively unimpacted by diversions. Mean annual flow at Node 1 is approximately 87% of simulated natural and the frequency and duration of flood events is within 10% of simulated natural.

The following is a summary of data provided by NR&M on diversions from the Lower Balonne below Node 1:

- Regulated diversions in the St George Regulated Scheme are approximately $80GL.y^{-1}$.
- Total daily licensed diversions below Beardmore Dam are approximately $25GL.d^{-1}$.
- Floodplain harvesting of overland flows is also permitted on the Lower Balonne floodplain.
- NR&M estimate total water storage on the Lower Balonne floodplain to be 1,160GL, with 410 GL between St George and the bifurcation and 750GL between the bifurcation and the QLD border.
- These figures indicate that total water storage on the Balonne floodplain is equivalent to the current mean annual flow at St George.

Water abstraction is controlled by a complex set of diversion management rules triggered by system flows measured at St George. There are 34 flow threshold windows for flows up to $60GL.d^{-1}$ for water harvesting. NR&M argue that under current licence conditions, flows up to $20GL.d^{-1}$ are fully committed such that all floods of up to $20GL.d^{-1}$ can be completely captured by water harvesting.

IQQM output indicates that licensed water allocation has the potential to reduce total end of system (EOS) flows from the Lower Balonne System to 46% of simulated natural EOS ($340\ GL.y^{-1}$). In addition, levees and other development in the Lower Balonne have reduced the area of 'active' floodplain. The total area below St George that is either cropped or used as water storage has increased from 6,125 ha in 1988 to 58,400ha in 1999 (Thoms et al 2001). Most of this development has occurred in the last decade. Current licensed allocations have not been fully exploited to date, largely because of prevailing flow conditions. This means that the river is yet to experience the full impact of current water resource development.

IQQM output indicates that mean annual inflow to the Narran Lakes has reduced to 43% of simulated natural, reducing the average interval for 86% filling event from 2 years to 6.5 years. Narran Lake was at >=86% full for 6.3% of the time, down from 18% under simulated natural conditions.

Under current management rules, flow statistics for the main rivers of the Lower Balonne are heavily modified from simulated natural condition. All of the flow attributes that are likely to have an ecological influence such as small, medium and large floods and spells have been modified to a large extent. Changes to the Narran system for most parameters are greater than for the broader Balonne system rivers – Culgoa R, Ballandoon R, Bokhara R and Briarie Cr.

With respect to reductions in flood flows, the CRC predicts a significant impact on:

- Channel form and the distribution and composition of floodplain woody vegetation where floodplain vegetation contracts to a narrow riparian fringe.
- Other floodplain and wetland vegetation will be significantly impacted by changes in floodplain inundation frequency, duration and extent.
- Floodplain production, which would be affected, (a) by changes in flow and (b) by isolation of floodplain areas by levees and diversions.

With the possible exception of the Bokhara River, the low end of the flow regime also is markedly reduced. This may translate into:

- Reduction in permanent pool habitat (refugia)
- Reduced water quality in remaining pools – bigger temperature fluctuations (and DO), concentration of biota (aquatic and terrestrial), less frequent small 'flushes' to keep pools topped up.
- Flow duration curves (and SA and APFD), indicate that the Node 8 on the Bokhara River has increased low flows over simulated natural.

It is possible that the level of extraction and associated water resource development will affect longitudinal connectivity between the Condamine/Balonne and other systems in the Darling. For example, species of fish and crustaceans show widespread movement among the tributaries of the Darling (e.g. Ben Cook's Honours thesis on *Macrobrachium*). The current activity in the study region could impede this movement and isolate populations in the upper Condamine and Maranoa River.

The multivariate analysis undertaken by Thoms and Parsons for this study indicated that water resource development has changed the hydrological character of the Balonne system. Overall, the simulated natural hydrological character, or diversity, present within the lower Balonne system has been homogenised by water resource development. This loss of hydrological diversity may lead to a loss of ecological diversity.

Assessment of Flow Scenarios

The likely ecological outcomes of the proposed flow scenarios have been assessed against the target ecological outcomes identified by NR&M. The assessment was based on an evaluation of the likely ecological benefit of changes to the flow statistics provided by NR&M and were derived from IQQM data. The CRC recognised that there is limited ecological knowledge about the impacts of water resource development on ecosystem health in the specific assessment region, including the Narran Lakes system and the broader Balonne floodplain. However, recommendations were based on the considerable collective experience and expertise of the CRC in similar floodplain rivers, as well as information derived from the literature on the ecological consequences of similar kinds of development. Validating assumed relationships between flow scenarios and ecological condition in the Lower Balonne will require considerable scientific investigation. However, this is unlikely to alter the relative ecological merit of the 5 scenarios.

Scenario A

Hold extraction capacity and river flows at current levels.

It is the considered opinion of the CRC that under this Scenario the ecological condition of the Narran Lakes system and the Lower Balonne Floodplain system will decline. This is because the full impact of recently constructed water harvesting infrastructure has yet to be realised on the system's ecology. A significant point to make is that, given the recent nature of this development, we are yet to see the full consequences in terms of changes to populations of aquatic organisms and, more longer lived biota such as riparian and floodplain trees. Because of this likely time-lag effect, and noting that the licenses are yet to be fully utilized, we strongly suggest that ecological condition of the system will get worse. In other words, ecological outcomes will not be fully realised (perhaps for several decades) as for example, flow-dependent reproduction and growth of long lived plants and animals fails. Research in the lower River Murray suggest time-lag effects of over 70 years (Thoms and Walker, 1993).

The median annual flow in the Culgoa River and Narran River at the Border are 21% and 27% of simulated natural respectively. These, and other flow statistics indicate that the flow attributes are highly modified from simulated natural. Other Australian rivers that have similar levels of abstraction but for historically longer periods are now assessed as being in poor condition. For example, for the River Murray (1994 median annual EOS flow 27% of simulated natural) the Snapshot of the Murray-Darling Basin Condition (MDBC 2002) assessed fish populations to be in very poor to extremely poor condition throughout the River Murray and macroinvertebrate communities in generally poor condition declining towards the river mouth.

Experience from elsewhere in the MDB and other Australian rivers indicates that if no further actions are taken, the current level of diversion will ultimately result in the reduction of river health for the Narran Lakes system and broader Lower Balonne systems.

Scenario B

Reduce Lower Balonne water harvesting extractions across the board to improve (mean annual flow) river flows by 10% over current level.

The Scenario provides some improvement in key flow statistics in the Narran Lakes system, for example mean annual inflow increases from 43% to 53% of simulated natural and median annual inflow increases from 24% to 35% of simulated natural. The average interval of events greater than 86% reduces from 6.7 years to 4.9 years, though simulated natural is about 2 years. However, this scenario does not come close to the simulated natural condition for reaching the critical bird breeding thresholds for the Narran system.

There is also some improvement in key hydrological indicators across the Lower Balonne and Culgoa floodplain system. However, most statistics still would remain at or less than 50% of the simulated natural condition.

While there is a small improvement in key flow statistics across both the Lower Balonne floodplain system and Narran Lake system given the current high level of water use, a 10% increase in flow is unlikely to any measurable effect on ecological condition. Also, given the predicted time-lag effects in ecological condition (outlined above), this scenario may not even arrest decline.

The increases in flow under Scenario B do not reinstate the hydrological diversity indicated by the multivariate analysis that existed prior to water resource development.

Scenario C

Stop water extraction from the Narran River and hold extraction capacity and river flows at current levels in all other rivers.

Scenario C provides some improvement in certain flow statistics for the Narran Lakes system, for example mean annual inflow improves from 43% to 58% of simulated natural and average median annual inflow improves from 24% to 48% of simulated natural. The average interval of events greater than 86% filling reducing from 6.7 years to 4.9 years, though noting that simulated natural is about 2 years. However, the magnitude of these improvements is not sufficient for the CRC to be confident that it will provide an improvement in the ecological condition of the Narran Lakes.

Scenario C provides no improvement to hydrological indicators in the Lower Balonne Floodplain system. Therefore, as with Scenario A, it is likely that ecological condition of this part of the system will decline as the long term ecological consequences of current management are realised.

Scenario D

Minimise water extractions from the Culgoa and redirect a portion of the water savings to the Narran River to simulate natural hydrology, with the remainder of water savings remaining in the Culgoa River system.

This Scenario provides a considerable improvement in the hydrological indicators to the Narran Lakes system and is highly likely to provide a significant ecological benefit. Key flow statistics for the Narran system are restored close to simulated natural under this scenario. For example mean annual inflow improves from 43% to 77% of simulated natural and median annual inflow improves from 24% to 73% of natural. Average interval of filling events greater than 86% reduces from 6.7 years to 2.7 years which compares to a simulated natural condition of about 2 years. The CRC expects that this scenario would arrest the decline in and improve the ecological condition of the Narran Lakes.

Scenario D provides only a very slight improvement in key hydrological indicators in the broader Balonne floodplain. Given the predicted time-lag effects in ecological condition (outlined above), this scenario is unlikely to even arrest decline of the broader Balonne floodplain. It is also noted that the increases in flow do not reinstate the hydrological diversity of the broader Balonne floodplain that existed prior to water resource development.

NR&M presented two alternatives for implementing Scenario D, both of which require significant engineering work to direct flows to the Narran River. These works require either:

- A major channel to be cut from west of the Culgoa R to the Narran River through Briarie Cr, Balandoon R and Bokhara R. which may result in an unacceptable longitudinal barrier across the floodplain; or,
- Construction of levees and other weirs near the bifurcation which has the potential to alienate part of the floodplain from the river while weir construction is a potential barrier to fish passage.

The ecological and geomorphological consequences of the engineering works required to deliver Scenario D would need an independent ecological investigation.

Scenario E

Hold extraction capacity and river flows at current levels but undertake engineering works to modify the Narran Lakes complex such that the Nature Reserve area fills first. Scenario E does not provide a system-wide ecological benefit.

This scenario will not arrest the decline in the ecological condition of the broader Lower Balonne Floodplain.

The CRCFE holds the strong view that the Narran Lakes should be viewed and managed as an integrated ecosystem comprising all three lakes and the connecting floodplain and wetlands. We have no sound ecological basis to recommend that the Nature Reserve fills first. What if, for example, breeding birds in the reserve are dependent on aquatic production from Narran lake proper? This separation of roosting and feeding areas is apparent in other systems such as in Currawinya National Park. The danger of this type of proposal is that Narran Lake may be sacrificed to provide water for the remaining two lakes with no understanding about the interdependence and connectivity of the lakes for overall ecosystem condition.

Threats Not Addressed by the Flow Scenarios

The flow Scenarios presented to the workshop address the issue of water harvesting in the QLD Balonne system. The management of the Condamine Balonne system has to be considered at the catchment scale in order to optimise ecological outcomes of flow Scenarios. Without due consideration of the following matters the ecological outcomes of the flow Scenarios will be less than optimal:

- *Salinity hazard* – the salinity hazard mapping presented by NR&M indicates a significant salinity hazard in parts of the Condamine Balonne catchment. The risk maybe exacerbated by further land clearance and other inappropriate land management. Rising salinity threatens the ecological integrity of Narran Lake system and Lower Balonne floodplain wetlands.

- *Pesticide loads* –agricultural activities on the floodplain create a risk of pesticide entering the Narran Lake system and other Lower Balonne floodplain wetlands and rivers. An analysis of how the Scenarios contribute to the risk of pesticide pollution to various parts of the Lower Balonne system should be considered.

- *Engineering works on floodplain* – the ecosystem model for the Narran system as well as current major river models (River Continuum Concept, Flood Pulse Concept, and Riverine Productivity Model) recognise that connectivity of the river with its floodplain is a critical element in its functioning. Further increases in the proportion of the floodplain alienated from the river by levee's and other engineering works will reduce river and floodplain health. Scenario D and E require considerable engineering works on the floodplain. The ecological consequences of these engineering works need to thoroughly investigated

- *Lake bed cropping* – this practice compromises the integrity of Narran Lake and other floodplain lakes in several ways. The Narran ecosystem function model recognises the lakebed as critical seedbank for aquatic vegetation and invertebrates, and provides habitat for small terrestrial animals when dry. Cultivation of the lakebed compromises this valuable habitat. Agricultural activity may result in altered nutrient concentrations and ratios upon refilling. This could trigger nuisance algal blooms and other undesirable plant growth.

- *Interstate cooperation* – the ecological outcomes of the Scenarios will be severely compromised if there is not an agreement that there will be no increase in abstraction in the NSW portion of the Lower Balonne system, including the Narran River.

- *Floodplain, riparian and terrestrial vegetation protection* – each of these provides important habitat and also inputs of woody debris to the Lower Balonne system. Appropriate vegetation and grazing management are necessary. This includes clearance controls, weed management and exclusion of stock from sensitive or fragile areas (e.g. through fencing riparian corridors and aquatic refugia, providing alternative stock watering etc).

- *Increased rates of sedimentation* – recent evidence (Thoms et al 2001) indicates a significantly increased rate of sedimentation on the Balonne floodplain. Improved catchment management is required to arrest this threat.

- *Expansion of Narran Nature Reserve* – currently the Narran Nature Reserve is 5,538 ha and excludes Narran Lake and much of the Lignum channel swamps. At the Federal level, 10,000 ha have been listed on the Directory of Important Wetlands. Either through acquisition of private lands (e.g. Narran Lake) or extending conservation management partnerships with existing landowners the whole Narran Lake complex should be managed for conservation purposes.

Summary

Ecological outcome 1:
Only Scenario D is likely to achieve NR&M's target ecological objective (1) of arresting the decline and improving the ecological condition of the Narran Lakes. It should be noted that the full benefits of this management option will only be realised if other non-flow issues are addressed (see above).

Ecological outcome 2:
None of the proposed scenarios appear capable of achieving the second ecological target of arresting the decline and improving the ecological condition of the broader Lower Balonne floodplain. Scenarios B and D are the only scenarios to move in this direction but would not go far enough to even arrest the predicted current decline. Further declines in ecological health in this region (which includes 2 National Parks) may also have long-term consequences for viability of populations of aquatic biota in the upper Condamine-Balonne system which historically have been well connected with other catchments in the Murray-Darling Basin.

Ecological outcome 3:
Salinity hazard mapping undertaken by NR&M indicates a widespread salinity hazard in the Condamine-Balonne catchment and suggests the potential for rising salinity to threaten the long-term sustainability of agriculture. The five flow management scenarios presented do not specifically address the issue of rising salinity. There is very little information available to the CRC on the relative impact of the five flow scenarios on the threat that increasing salinity poses to the long-term sustainability of agriculture, or to the risk of wide spread ecological degradation in the Lower Balonne System. We speculate that scenarios that reduce the storage of large volumes of water on the floodplain may reduce the risk of increasing water tables and salinity, however we stress that we have no evidence to support this and further investigations would be required to confirm this. Nevertheless, it is our opinion that increases in river salinity will threaten the ecological integrity of floodplain wetlands and the Narran Lakes system. Therefore, the salinity risk needs to be managed through appropriate land and water management in both the irrigation regions and the broader catchment.

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