Decision Support Systems – assisting implementation of long-term environmental water planning

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Key Points

- The Basin Plan requires Long-Term Watering Plans (LTWP) to be developed by States to guide environmental water management at a catchment-scale
- The Commonwealth Environmental Water Holder is developing practical experience in environmental water delivery, which is contributing to the development of Decision Support Systems (DSS)
- These DSS are built "bottom up" based on expert practitioners' judgement. They have not yet been tested using long term eco-hydrologic modelling and require on-going adaptation, but are nonetheless useful planning and operational tools.
- Eco-hydrologic models used for development of catchment specific plans required by the Basin Plan do not currently reflect environmental water DSS. There are opportunities to improve models to better represent environmental water management, for the benefit of other plans.
- Whilst DSS will need to be refined to reflect the requirements of LTWP, operational experience is expected to continue to be a source of further adaptation. This is a good reason to avoid "locking in" DSS in LTWP, but rather to allow DSS to be developed and maintained separately.

Abstract

The Commonwealth Environmental Water Holder (CEWH) is a statutory position established under the *Water Act 2007* to manage the Commonwealth's environmental water portfolio to protect or restore environmental assets of the Murray-Darling Basin. The portfolio consists of retail water entitlements, which as at April 2016, have an average annual yield of over 1650 GL. The CEWH's decisions on water use, carryover and trade are made in line with the Basin Plan's Environmental Watering Plan and the subsidiary instrument, the Basin-wide Environmental Watering Strategy. The Basin Plan also requires Basin States to prepare Long-Term Watering Plans (LTWP) for environmental water management in each water resource plan area. These must identify priority environmental assets and functions; their ecological objectives and targets; and environmental watering requirements to meet them. LTWPs will be an important resource to guide environmental water holders' activities. However, there remains a gap in the efficient implementation of these plans which specify key objectives and targets in a static sense (such as magnitude, frequency, and gap interval for particular watering events) and as such there may be advantages in developing dynamic Decision Support Systems (DSS) to guide environmental watering activities in near real-time (events, annually, and intra-annually). Consistent with adaptive management principles, DSS can be readily updated in response to improved knowledge and lessons learned from previous interventions. This paper describes some emerging approaches to managing environmental water in the Murray-Darling Basin; and explores the potential benefits of further development of environmental watering DSS in the context of long-term environmental water planning.

Keywords

Environmental Water Holder, Basin Plan, Decision Support Systems, CEWH, Murray-Darling Basin

Introduction

The Murray-Darling Basin (MDB) covers over 1,060,000 km^2 in south-eastern Australia, and is defined by the catchment areas of the River Murray, the Darling River, and their many tributaries (Crabb 1997). It comprises 14 per cent of Australia's land area, yet produces just 6 per cent of Australia's runoff. The Basin includes more than 77,000 km of rivers, creeks and watercourses, and wetlands numbering over 30,000 (Crabb 1997, Australian Government 2012). The Basin features highly variable streamflows, within and across seasons and years, and from region to region (Australian Government 2012). At a global scale, Australia (together with Southern Africa) experiences higher runoff variability than any other continental area (Crabb 1997).

The MDB is one of the most productive agricultural regions in Australia (Hart 2015a), and irrigation within the MDB represents 75 per cent of Australia's irrigation water use (Crabb 1997). A series of water reforms aimed at arresting unsustainable growth in diversion has been implemented over the last 30 or so years, commencing under the Murray-Darling Basin Initiative (Connell and Grafton 2011). In 2007, the Australian Government introduced the *Water Act 2007* (the Water Act), and instituted a program of water reform to rectify environmental degradation and the over-allocation of water resources in the Murray-Darling Basin (Docker and Robinson 2013).

The Water Act established the Murray-Darling Basin Authority (MDBA) to develop a comprehensive plan for sustainably managing the water resources of the MDB (the Basin Plan). Refer to Hart (2015a) and (2015b) for a comprehensive description of this water reform including the MDBA's role in preparing the Basin Plan, and the challenges that remain. The Water Act also established the Commonwealth Environmental Water Holder (CEWH), a statutory position responsible for managing the Commonwealth's holdings of water for the purpose of protecting or restoring environmental assets so as to give effect to relevant international agreements, such as the Ramsar convention and bilateral migratory bird agreements. The CEWH leads and is supported by the Commonwealth Environmental Water Office (CEWO).

The Basin Plan 2012 includes an Environmental Watering Plan, which requires the MDBA to provide overall guidance on environmental water use through a Basin-wide Environmental Watering Strategy. Commonwealth environmental water must be managed consistent with both the Environmental Watering Plan and the Strategy. The Basin Plan also requires the State jurisdictions to prepare Long Term Watering Plans (LTWPs - to inform environmental water management) and Water Resource Plans (WRPs – to manage all water resources) for each of the 23 surface water resource planning areas. LTWPs provide guidance on environmental water use at a valley-scale and must identify the catchment's priority environmental assets and functions; their ecological objectives and targets; and the environmental watering requirements to achieve these targets.

However, the Basin Plan allows scope for environmental water managers to develop the most appropriate tools to guide implementation in real-time. Given uncertainty associated with hydrology even in the short to medium term (flows in the coming days, weeks and months), real-time decisions must be made in a risk management setting. Decision Support Systems (DSS) have the potential to assist implementation decisions taken in real-time to ensure that environmental water holders have the greatest chance of meeting identified objectives. DSS also have the potential to improve the accuracy of eco-hydrologic models used to develop WRPs and LTWP, by incorporating DSS into hydrologic models to better represent expected behaviour of environmental water holders.

Planning Challenges

Integration of Various Sources of Environmental Water

The Commonwealth owns “retail” water entitlements— often referred to as *held environmental water (HEW)*— that have identical characteristics to water entitlements held by irrigators, including the ability to “order” water to accounting points and trade them in the water market. The Commonwealth holds a range of entitlement types consistent with the range of retail water entitlement products available in the numerous valleys of the Basin (refer also Docker and Robinson 2013).

The Commonwealth’s portfolio is not the sole source of HEW, nor is it the only form of environmental water in the MDB. HEW is also managed by State environmental water management agencies and The Living Murray Initiative (TLM), which pre-dates the establishment of the CEWH, and is administered by the MDBA. Whilst the Commonwealth’s environmental water holdings represent the largest source of HEW in the MDB, quantities vary widely across the many valleys. In some cases, the Commonwealth’s holdings represent the majority of HEW in a valley; in other cases the Commonwealth’s holdings are small in comparison to State sources; and in some cases, whilst the Commonwealth’s share may be a majority, the quantity of HEW is small regardless. Refer to http://www.agriculture.gov.au/about/water/progress-recovery/progress-of-water-recovery.

Despite the availability of HEW, the majority volume of environmental flow falls into the category of *planned environmental water (PEW)*, which results from the operation of WRPs for each valley. WRPs are used to manage the entire water resource of each valley, and describe diversion limits and the processes and rules used to manage water entitlements and allocations of water against these entitlements throughout each season. PEW can be further categorised into two main forms: (i) “account based”, which may have some of the characteristics of HEW, such as allowing for discretionary release of flows from storage for targeted delivery to particular ecological outcomes; and (ii) passive planned environmental water, which is that component of the water resource unable to be extracted within the rules governing diversions for consumptive purposes, but not directly managed under a planned environmental water account. Much of this component of PEW occurs as unregulated flow via spills from storages or from tributaries downstream of storages and hence is not able to be discretely managed in a way that HEW or account based PEW can. However PEW is important in terms of the environmental outcomes achieved, particularly at higher floodplain elevations (larger flood flows less affected by river regulation) and as a source of streamflow variability, which has generally been lessened as a result of river regulation.

A challenge for environmental water holders is to integrate delivery of HEW with other holders’ HEW and with PEW to respond to changing water availability or environmental demands and optimise the outcomes achieved.

Pre-LTWP – Evolution of Annual and Multiple Year Portfolio Management

Since 2009, the CEWH has delivered over 5000 GL to environmental assets in partnership with relevant State Government environmental management agencies, NGO’s and communities (**Figure 1**). Annual planning processes cater for a range of water resource availability scenarios and possible environmental water delivery actions developed in collaboration with partners. In so doing, the CEWH and CEWO (and relevant partners) have developed significant practical experience in the planning and delivery of environmental flows at scales ranging from small individual wetland sites, to large wetland complexes and river systems across multiple large reaches; and under a range of seasonal and climatic conditions. The implementation of these environmental flows over the period 2009–16 has reflected contemporary ecological demands based on a combination of goals to (i) support ecological recovery from the combined effects of the Millennium Drought and a long period of river regulation (to rebuild resilience to withstand future stresses such as drought conditions) and (ii) reflect seasonally appropriate environmental flows based on natural climatic and hydrologic signals, recognising that ecological demands are not "static" but rather vary in direct relationship to hydrologic conditions (**Figure 2**). The annual planning for the CEWH's activities has also evolved to better reflect environmental water use, carryover and trade decisions over multiple years, rather than a focus on a single year. Refer to http://www.environment.gov.au/water/cewo/publications/integrated-planning-cew-planning-approach.

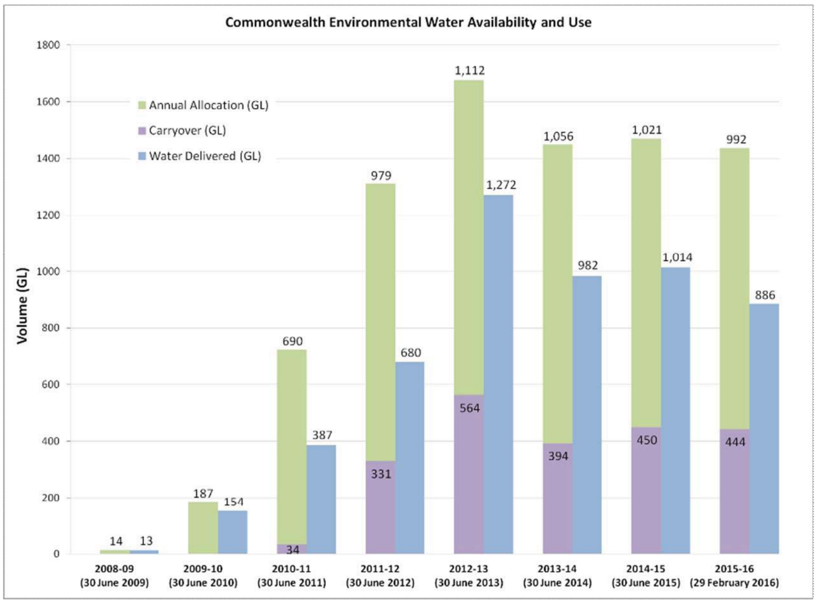

Figure 1 - History of Commonwealth Environmental Water availability and delivery in the MDB

Given the inherent variability and unpredictability of the climate and hydrology of the MDB, the planning process considers a wide range of possible hydrologic (inflow) conditions for each valley, antecedent conditions, and ecological demands consistent with each of these scenarios. Environmental watering actions are scaled accordingly, with the CEWH's commitment also adjusted to reflect other sources of PEW and or HEW.This approach enables the CEWO to adapt throughout the water year to changes in circumstances without needing to revisit objectives or administrative approvals.

In a process of continual improvement, adaptive management principles are applied to individual environmental watering actions and actions undertaken in concert over each relevant water year. Previously informed by monitoring and evaluation undertaken on a project by project basis, in 2014 the CEWH instituted a $30 million commitment (over five years) to monitor and evaluate the contribution of Commonwealth environmental water delivery to the objectives of the Basin Plan's Environmental Watering Plan and inform the adaptive management of environmental water use (the Long Term Intervention Monitoring (LTIM) Project: http://www.environment.gov.au/water/cewo/monitoring/ltim-project). This process of incremental improvement based on practical experience, informed by monitoring and evaluation, has been described as a "bottom up build".

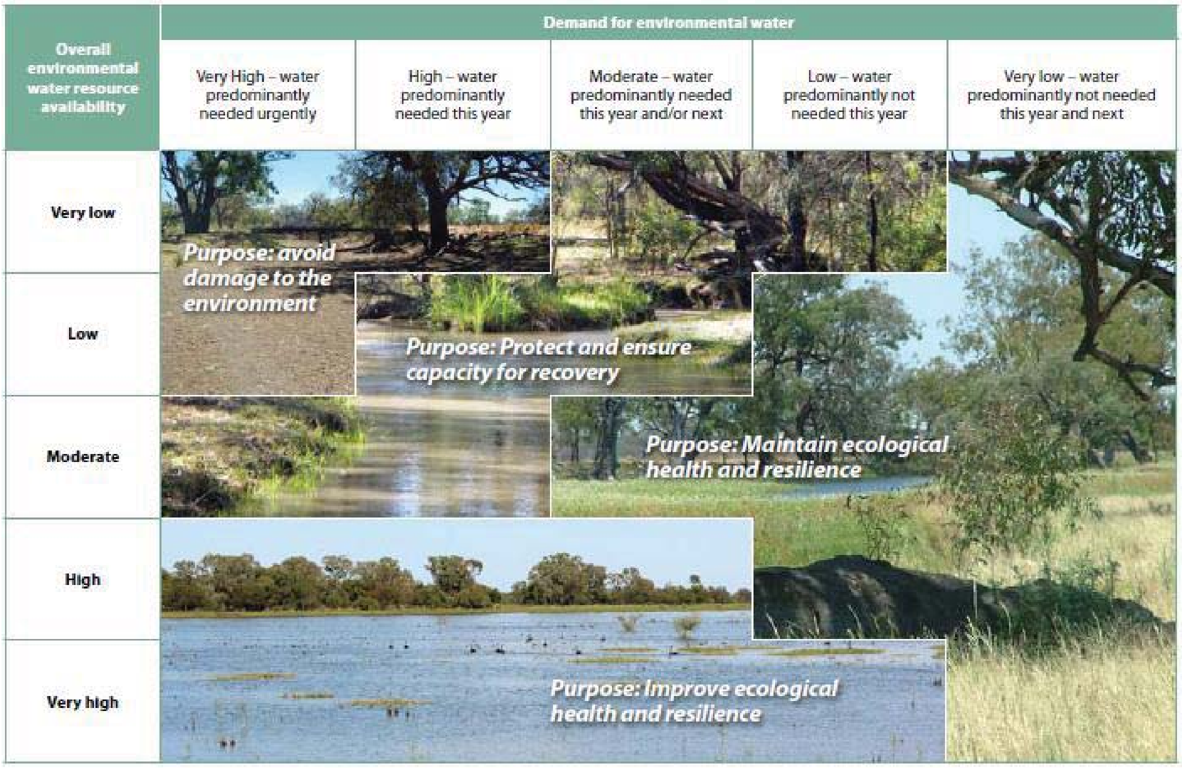

Figure 2 - Dynamic ecological demand, and environmental watering objectives, in response to varying hydrologic conditions

Emergence of DSS

As knowledge has been gained through planning and delivering environmental water, consideration has been given to improving discrete watering actions (including by addressing additional objectives hitherto not achieved), and circumstances where environmental water delivery may be repeated. In addition, as the Commonwealth's portfolio of HEW has grown, consideration has been given to developing more efficient approaches to implementation, with consideration given to "automation" as far as practicable (within the scope of the CEWH's statutory responsibilities), in response to natural hydrologic conditions. Accordingly a variety of DSS in the form of simple frameworks have emerged to guide decision-making and delivery of environmental water. These approaches have varied within and across catchments depending on the type of water entitlement and the environmental assets and functions targeted. However, in broadly similar circumstances some consistency has developed. The approaches developed so far can be categorised into:-

(i) **Flowchart or "Decision Tree"** – commonly used in circumstances where a flow event that cannot be captured by water storages occurs in response to rainfall, and a decision is required (sometimes with little notice) to distribute environmental water allocations to a particular environmental asset(s) from a field of several possible alternatives;

(ii) **"Natural Cue" In-stream Flow** – commonly used to restore or protect a component of natural flow, including flows that have been regulated within headwater water storages and/or unregulated tributary flows that would otherwise be re-regulated within mid-river water storages or extracted for consumptive use, within a pre-determined flow range (usually less than nuisance flood level) to meet a range of in-stream objectives; and

(iii) **Multiple Objective** – less commonly used to guide planning and delivery across multiple wetland, distributary effluent stream and/or instream assets and functions, in response to a range of antecedent and possible seasonal conditions.

Case study examples of each of these approaches are described in Appendices 1-3 respectively.

Each of these approaches vary in terms of the degree of “automation”. In the case of (ii), one particular example (applied to the River Murray, refer to Appendix 2) has the potential to allow daily variation of flow, following natural hydrologic cues, to be implemented by the River Operator (the MDBA) without intervention from the CEWO. In practice, River Operators have tended to consult closely on implementation, however this has the potential to be reduced as experience and confidence is gained.

A common feature of each of these DSS is the refinement and adaptation that has occurred in response to both annual planning activity and actual delivery experience – adaptive management in practice. Whilst the knowledge of experienced practitioners is drawn on in the initial development of a DSS, practical implementation often leads to the identification of refinements.

In the case of the Macquarie flowchart/decision tree approach (refer to Appendix 1), dry conditions have prevailed since the DSS was developed and hence no opportunity for an actual test has occurred. However, refinements to the DSS have been incorporated in response to the DSS being reconsidered at each annual planning cycle, and in response to new information about the watering requirements of target assets.

The Lachlan DSS example (refer to Appendix 3) has been refined based on implementation for some components, and based on annual planning reconsideration for others. However, a key additional driver for refinement was identified based on the potential to upgrade the Lachlan hydrologic model to support the development of the Lachlan WRP, and for the development of the LTWP to follow. Current versions of the Lachlan IQQM[1] do not recognise HEW explicitly, and therefore assume that the CEWH’s and NSW Office of Environment and Heritage’s (NSW OEH) HEW is used in a demand pattern consistent with irrigation demand (dominated by annual crops, including cotton, which has an unseasonal bias to summer-autumn compared to the Lachlan’s natural hydrologic pattern). The Lachlan DSS was originally developed as a tool to guide HEW use and planning, but has been refined in 2015-16 to provide advice to NSW Department of Primary Industries - Water on more representative HEW demand patterns. Despite these efforts, the Lachlan IQQM hydrologic model has not been able to be upgraded at this stage, and this issue has been effectively deferred (hopefully to be revisited, perhaps under the development of the LTWP).

The Lachlan DSS remains an interim approach as (i) it has not been refined based on LTWP objectives (which are still to be developed, including via local stakeholder consultation on possible options); and (ii) the DSS’s consistency with these objectives has not been model tested. Despite the expertise and knowledge contributed by a number of agencies so far, and the application of adaptive management to refine it, the Lachlan DSS could be further refined and improved through iterative model testing once the LTWP is established.

Future implementation of environmental watering

As described above, the Basin Plan requires planning instruments to be completed for each Water Resource Plan Area over the next several years. Both LTWPs and WRPs have important implications for environmental water holders, and will help to guide activity. However, the absence of guidance for real-time operations, and the need to take informed risks in choosing to undertake particular watering actions, leaves scope for DSS to continue to fill an implementation gap. **Figure 3** shows conceptual relationships between the WRP, LTWP and an environmental watering DSS within a water resource plan area.

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[1] Integrated Quantity Quality Model (IQQM) – developed by NSW Department of Primary Industries – Water and predecessor agencies to support water resource planning and operations in the Lachlan system.

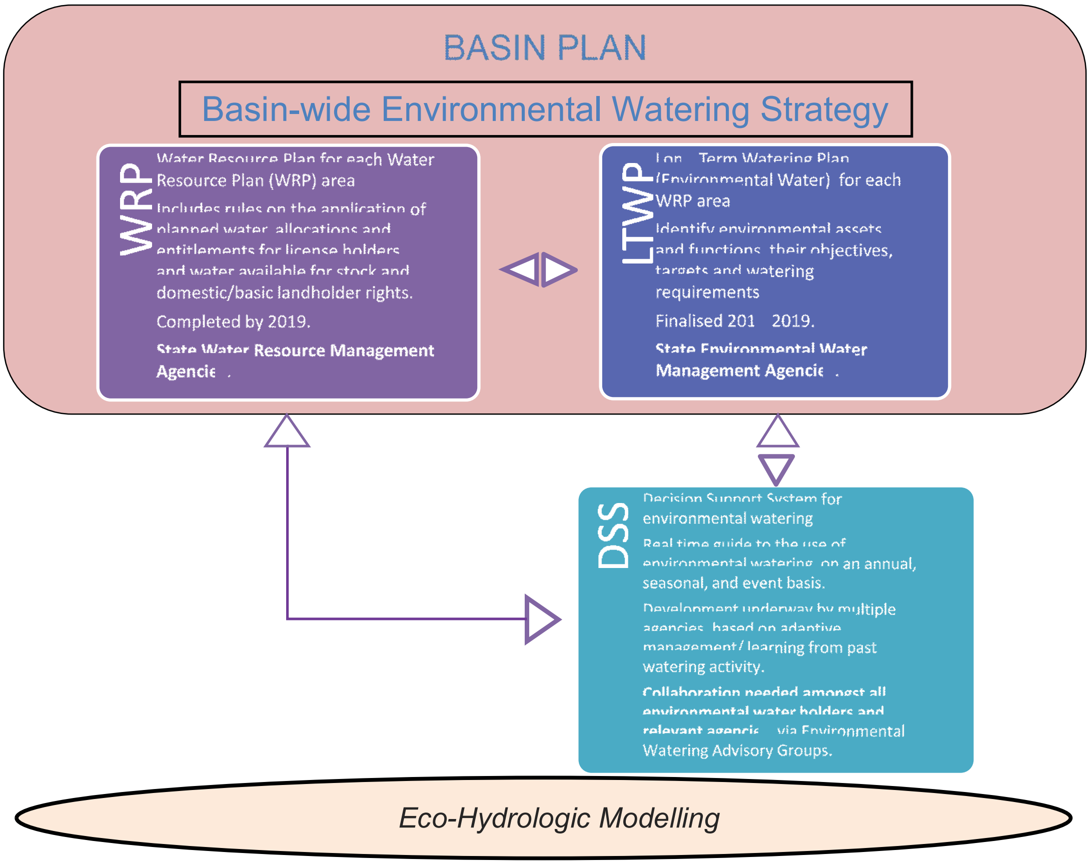

Figure 3 - Relationships between planning instruments required by the Basin Plan, and environmental watering DSS

Figure 3 also identifies that each of the component planning instruments are underpinned by hydrologic modelling (as is the Basin Plan itself). To achieve greatest accuracy, modelling for each of the key components should reflect the others, including the reflection of environmental watering DSS in modelling undertaken for WRPs and LTWPs. For environmental watering DSS to reach their potential to help to achieve the requirements of the LTWP including by supporting operations in near real-time (in response to hydrologic events, annually and intra-annually) they will benefit from further refinement through iterative model testing. However, given that DSS will both inform and be informed by the other instruments (in a feedback loop) for the first iterations of each of the two mandated instruments, it may be necessary to simplify the representation of environmental water DSS and allow for more thorough representation in future revisions.

The practical experience of the CEWH and partner agencies in developing DSS to date provides a caution against “locking in” environmental watering in any prescribed way, particularly in planning frameworks. The DSS developed to date have commenced as relatively simple strategies developed from planning and operational experience, which remains relatively limited in the context of the short history of held environmental water management, and have developed dynamically in response to further experience.

Conclusion:

Environmental watering Decision Support Systems are being developed and refined from practical implementation of environmental watering, which in most catchments in the Murray-Darling Basin is a relatively new activity. These DSS reflect adaptive management and represent contemporary best practice in an evolving area of work. Experience gained by the CEWH and other water holders to date shows that whilst some catchments could use similar DSS, some variation in approach will be needed. There are advantages in being able to adapt DSS quickly and regularly in response to emerging knowledge. DSS have the capacity to improve the accuracy of hydrologic modelling by better representing the anticipated behaviour of environmental water holders under a range of hydrologic conditions. In future, Long Term Watering Plans required by the Murray-Darling Basin Plan will inform long term ecological objectives and targets for each catchment. DSS have the potential to aid environmental water holders in achieving these objectives in near real-time. Whilst a LTWP may benefit from referring to the need for a DSS, to hardwire a DSS into planning documents would constrain adaptive management over shorter timeframes and risk compromising environmental outcomes.

Acknowledgments

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Appendix 1 - Flowchart or "Decision Tree"

This DSS approach has been developed to manage the Commonwealth's unregulated entitlements, including Supplementary entitlements (which allow access to unregulated flows in many regulated catchments) and water entitlements in unregulated streams such as the Darling River and Warrego River, especially where minor infrastructure exists that provides options to redirect flow between alternative environmental assets.

Case Study: Macquarie Supplementary Water Entitlements

The Macquarie-Castlereagh catchment is situated in central western NSW and is based around the Castlereagh, Macquarie and Bogan River valleys. Environmental assets in the catchment that can be targeted to varying degrees by environmental water include the Macquarie Marshes, Macquarie River channel, the lower Macquarie River and a series of effluent creeks to the west of the Marshes.

Key sources of environmental water in the Macquarie are HEW and PEW. This includes supplementary entitlements (held by both the CEWH and NSW) that allow access (subject to announcements) to unregulated flows (e.g. tributary inflows or spills from storage) that are in excess of those required to meet regulated demands and when the river flows exceed certain thresholds. Macquarie River flows are heavily influenced by large rainfall events in the upper catchment and flows in tributary systems. Supplementary flows are unpredictable with no access in some years and multiple events in others. The size and duration of events can also vary from one day to over a month. However, supplementary flows are less affected by regulation and can have significant environmental benefits by providing more natural flow variability, stimulating primary production and providing chemical cues important for biota. Therefore access to this type of water plays an important role in meeting environmental demands in the catchment.

A challenge for the CEWH is to use supplementary entitlements in such a way as to preserve the expected yield of these entitlements. As the CEWH is not reliant upon on-farm storage, there are circumstances where the CEWH could activate the Commonwealth's supplementary entitlements when irrigators may not normally access these flows (e.g. when on-farm storages are full or if they choose to use carryover). In such circumstances, the CEWH would be liable for fees and charges, yet the environmental outcome is not improved (given that the flows would have occurred regardless). Critically, decisions on the activation and use of the Commonwealth's supplementary entitlements in the Macquarie River system need to be made quickly in order to respond to announcements on supplementary water take.

To guide these decisions, the CEWO (in consultation with NSW OEH) has developed a Decision Support System (DSS) (**Figure 4**). The DSS identifies circumstances where Commonwealth supplementary water could be delivered to the Macquarie Marshes or distributary creek systems based on highest environmental demand, antecedent conditions, watering history, risks and operational feasibility of delivering the supplementary water to the asset. The DSS is not applied in isolation of decisions and priorities relating to other environmental water such as held (General Security) and planned environmental water in the Macquarie system. The DSS has not yet been tested in practice because of dry conditions and lack of supplementary access in the Macquarie valley since 2013. Nonetheless, the tool remains ready to be applied rapidly in response to supplementary flow events. Despite the fact that the DSS has not yet been implemented in practice, it has continued to be refined as it has been reconsidered as part of annual planning activity, to reflect improved information about assets, environmental demands and delivery feasibility (particularly for the distributary systems).

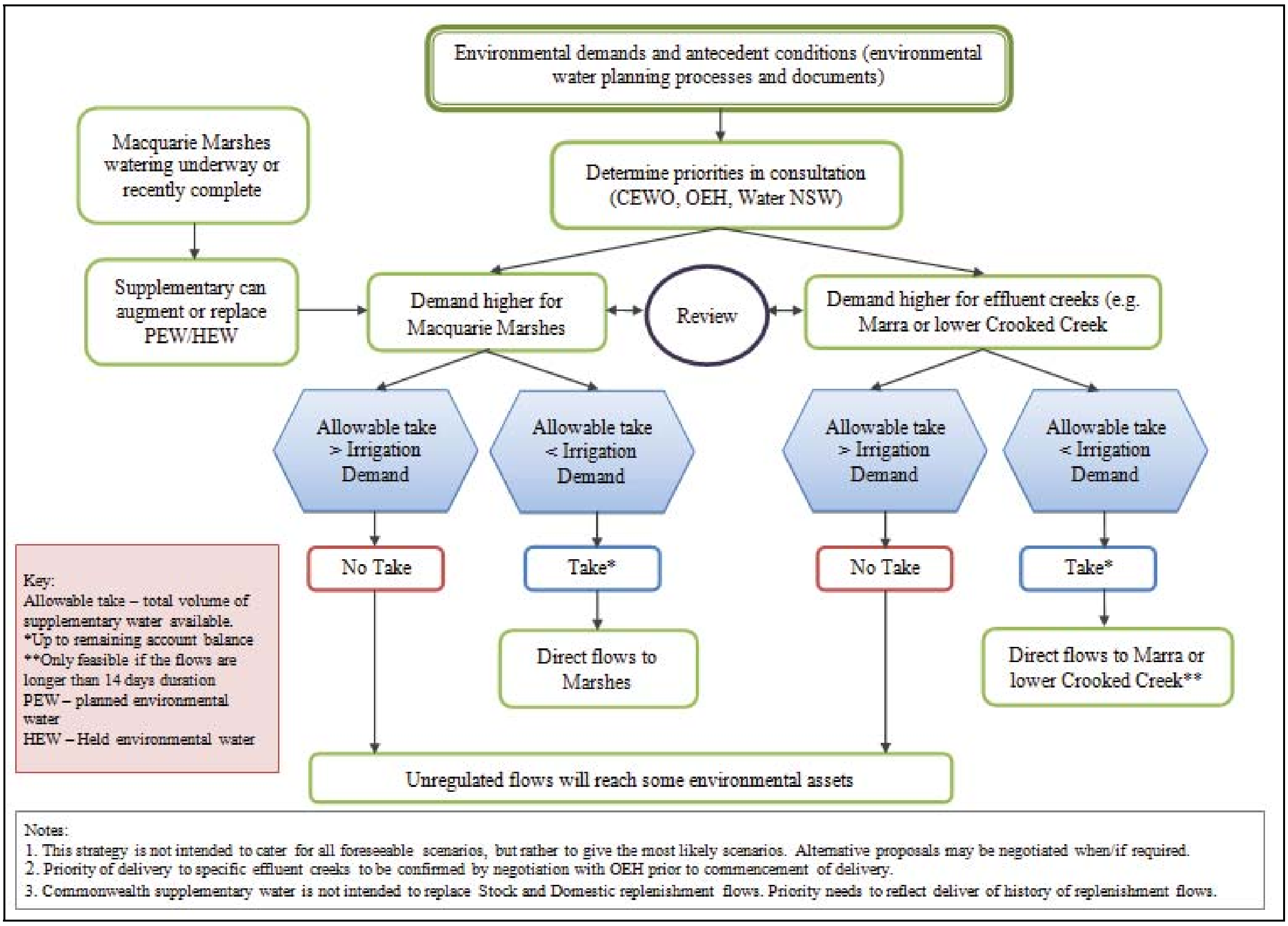

Figure 4 - Adaptive strategy for delivering Commonwealth supplementary entitlements in the Macquarie Catchment

Appendix 2 - "Natural Cue" In-stream Flow

This DSS approach has been developed to manage the Commonwealth's use of environmental water for a range of in-stream purposes. Examples include the River Murray (to reinstate a proportion of natural streamflow variability) and the Lachlan River (to preserve unregulated tributary inflows, and associated sources of nutrient and carbon, and to provide stimulus for migration and spawning of native fish).

Case Study: Following "Natural Cues" in the River Murray

River regulation has diminished sources of natural streamflow variability by capturing small to medium flows (at rates mainly within channel) within storages, or by using these flows to meet consumptive demands within the system. These effects are most pronounced in winter and spring, and have been recognised as a priority for environmental watering (MDBA 2014). In 2015–16, the CEWH implemented an innovative approach to delivering environmental water in the River Murray system, aimed at reinstating some streamflow variability. The approach saw environmental water delivered up to maximum rates within existing delivery constraints based on a calculation of natural flow that would have occurred at Yarrawonga Weir. The resulting environmental water component of the flow was then able to be used for priority environmental watering actions further downstream, less an allowance for losses (environmental use, via evapotranspiration and seepage). 420 GL was delivered between June and October 2015 under this watering action – the largest single action undertaken by the CEWH, and one of the largest environmental watering actions undertaken in the MDB – using flows guided by natural cues combined with specific releases to environmental assets.

Figure 5 shows a hydrograph for the River Murray downstream of Yarrawonga Weir for May-November 2015, and shows how the flow benefited from the application of the Natural Cue method between late June and late September. Not only has a proportion of the calculated natural flow (that would have occurred without flows being captured in upstream storages, or diverted for consumptive use) been re-instated, but the hydrograph generally follows the pattern of the calculated natural flow, at matching times. In comparison, the hydrograph shows that for the case without the additional environmental water provided under this action, the natural variability is mostly absent, and lengthy periods of constant flow would have occurred.

In terms of a DSS, the River Murray Natural Cues environmental watering action required the MDBA's river operations division (which is the agency responsible for the operation of the River Murray system) to calculate daily estimated natural flow at Yarrawonga, and where required regulated flows were less, to make up a proportion of the difference using Commonwealth environmental water to reflect the 'natural' pattern of in-stream flow variability (including timing). This resulted in greater automation of the delivery (at least as far as the CEWO was concerned), and despite the greater variation of flow, there was less need for an exchange of information or a negotiation between the CEWO and the MDBA's river operators.

This approach was deceptively simple. In the past, large environmental watering actions have generally been delivered based on (i) exceeding commence-to-flow thresholds for major wetland complexes, at times suited to vegetation growing season or to support conclusion of bird breeding events (that have usually commenced due to prior unregulated flows); (ii) meeting spawning requirements of large bodied native fish (which is biased to late spring-summer based on temperature thresholds); or (iii) geomorphologic outcomes such as supporting the maintenance of the Murray Mouth opening. These priorities are valid, however they have led to a bias to later season delivery and feature less natural flow variability. This has in turn led to the delivery of flows as a specific 'block' of water to a discrete asset rather than river systems flows, and does not represent an optimal hydrological response and therefore compromises environmental outcomes (by not fully considering the needs of multiple sites, and not based on natural timing). Rather than competing with these (previous) approaches, the 2015–16 Natural Cues approach is intended to compliment them as part of an overall strategy. For example, flows delivered following natural hydrological cues may at times need to be augmented where the requirements of specific assets take precedence.

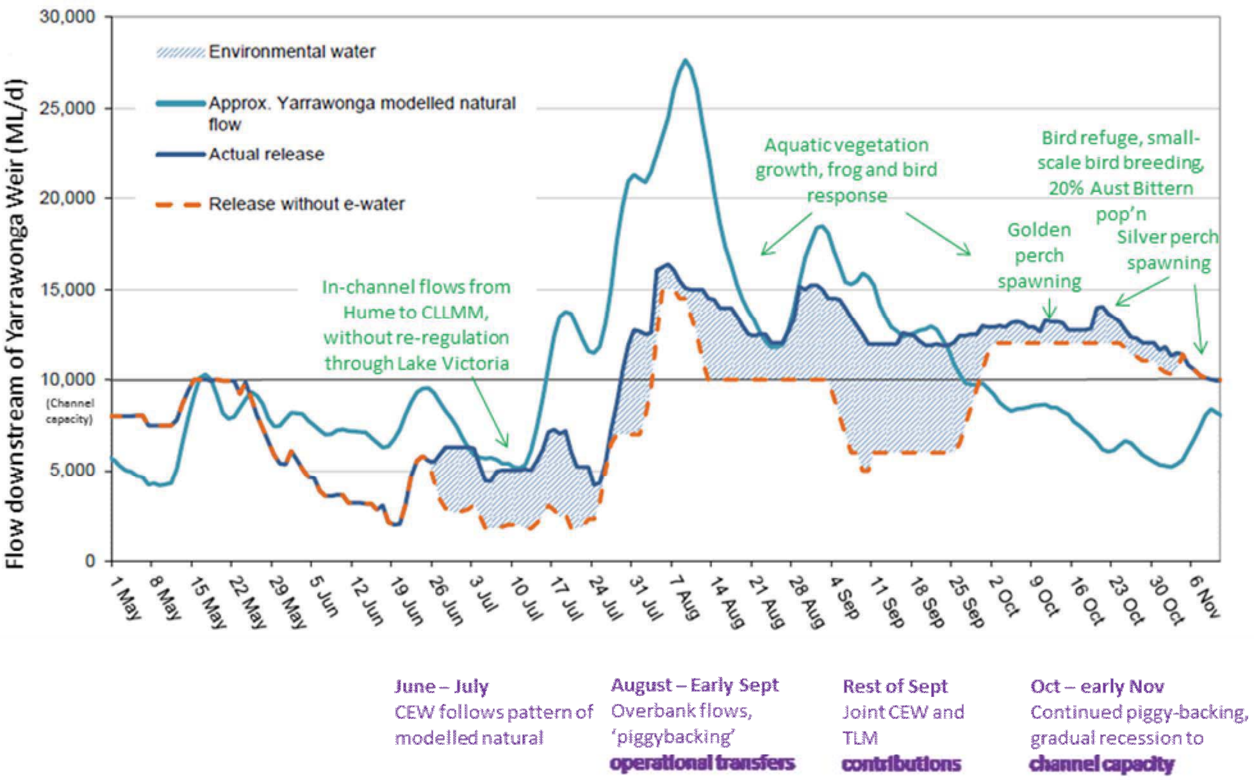

Figure 5 - River Murray "Natural Cues" delivery, winter-spring 2015

Appendix 3

This DSS approach has been developed to coordinate and balance environmental demands across multiple objectives and environmental assets, and to provide a better representation of HEW use to improve accuracy of existing eco-hydrologic models to benefit a range of planning instruments.

Case Study: Lachlan River System DSS

The Lachlan River is an infrequent tributary of the Murrumbidgee River, only connecting in flood events of approximately 1 in 10 year Average Recurrence Interval. At other times, the Lachlan River terminates in a large and ecologically significant wetland complex, the Great Cumbung Swamp. The Lachlan system also features a number of terminal distributary creek systems, such as Willandra Creek and Merrowie Creek. The distributary creeks differ in that they have been modified by water resource development in different ways—in the case of Willandra Creek, the offtake has been lowered and upstream reaches receive both regulated and unregulated flows more frequently than under natural conditions, whereas other creeks such as Merrowie Creek receive less frequent ecologically significant flows than pre-river regulation.

The geomorphology of the Lachlan River system is such that significant connection with the Murrumbidgee River will be achieved through planned environmental water rather than held environmental water, which can be expected to terminate in the Great Cumbung Swamp. The lack of connectivity simplifies the delivery of held environmental water, in that demands downstream of the catchment can largely be discounted[2].

The Commonwealth holds approximately 88 GL of (mainly general security) entitlement in the Lachlan system. NSW OEH holds a further 38 GL (also mainly general security), in addition to managing several other (smaller) planned environmental water accounts. There is no supplementary entitlement in the Lachlan system.

Since 2009, multiple environmental watering actions have been implemented in the Lachlan, with several similar actions being repeated. This repetition has given CEWO and NSW OEH cause to collaborate on the development of a (preliminary) DSS for a comprehensive suite of objectives: in-stream; multiple distributary creek systems; and terminal wetland complexes (**Figure 6**). The approach taken to date has been based on “expert” judgement (experienced practitioners with local knowledge) rather than a more rigorous environmental flow assessment methodology supported by eco-hydrologic modelling. A further and key driver has been the need to upgrade the Lachlan River hydrologic model to incorporate HEW. This model does not currently represent HEW in the form of environmental water delivery/demand patterns. The DSS has been further refined by CEWO and NSW OEH to provide advice to NSW Department of Primary Industries - Water for the purpose of upgrading the Lachlan hydrologic model to support the development of the Lachlan Water Resource Plan, and potentially to support the development of the Lachlan LTWP by NSW OEH. Whilst the DSS has not benefited from iterative model testing and refinement reflecting desired watering volume, frequency, duration and intervals between events required to satisfy ecological outcomes (and whether the combined environmental water portfolio is sufficient to meet them), it has been expressed in a form that could be easily refined based on such modelling. This is expected to be of benefit to future water planning.

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[2] An exception to this is where bird breeding events may be occurring simultaneously in the lower Lachlan and lower Murrumbidgee. Whilst hydraulic connectivity between these two systems cannot be achieved using HEW, some opportunities to align timing of environmental watering of nesting or foraging sites in both systems may be worth implementing.

The Lachlan DSS is not intended to be a rigid, rules based “set and forget” tool, but rather a guide to environmental water planning, with recommended watering actions subject to further review prior to implementation. Despite its interim form, the Lachlan DSS provides greater transparency about expected behaviour of environmental water holders to water resource managers, river operators, the local irrigation industry, riparian landowners and local communities. Whilst the Lachlan DSS should be considered interim, it has been trialled to guide annual environmental water planning and delivery over the last two years at a whole of catchment scale. These trials will further inform possible adoption of the DSS, or some refinement, in future planning. This form of DSS, developed by workshopping the experience of environmental water practitioners, could be developed for many other river systems within the MDB for similar advantage.

1. Large scale wetlands

Target sites

Lachlan Swamp (North side), and the Great Cumbung Swamp.

This requires overbank flows downstream of Whealbah to inundate Lake Waljeers and Peppermint Swamp. Flows would also benefit the in-channel system downstream of Lake Brewster and reach the Great Cumbung Swamp at the terminus of the system.

Objectives

- Provide flow variability and longitudinal connectivity to support refuge habitats; provide lateral connectivity and associated outcomes (i.e. fish migration, carbon inputs);
- Support vegetation communities within or closely fringing the river channel as well as some low lying areas of the floodplain;
- Improve the condition of emergent, submergent, semi-permanent wetland vegetation and riparian vegetation communities; and
- Provide foraging opportunities for a range of waterbird species and maintaining waterbird drought refuges.

Hydrology

In order to maximise the delivery volume, consideration would be given to delivery in conjunction with natural inflows, replenishment flows or other planned environmental water. This delivery could also be conducted in conjunction with other environmental deliveries (Strategy 2 or 3) to minimise transmission losses. In order to minimise carp breeding, the flow can be delivered in late winter. If wet conditions prevail, the demand for this action would be met through natural flows. The target frequency of watering these assets is 7 in 10 years, with the maximum duration between watering is considered to be 3 years, before vegetation would become drought stressed. Up to 25 GL would be considered to meet this demand, therefore over 45 GL should be held in accounts in order to fulfil other demands during the watering year.

2. Wetlands which provide habitat for waterbirds

Target sites

Muggabah Creek and Merrimajeel Creek (Booligal Wetlands), and Merrowie Creek.

Objectives

- Improve the condition of emergent, submergent, semi-permanent wetland vegetation and riparian vegetation communities; and
- Provide foraging opportunities for a range of waterbird species and maintaining drought refuges.

Hydrology

In order to maximise the delivery volume, consideration would be given to delivery in conjunction with natural flows, replenishment flows or other planned environmental water. The target frequency of watering these assets ranges from 2 in 10 years, to 7 in 10 years, as some sites are key breeding sites for waterbirds and require the vegetation to be maintained in event ready condition. If a waterbird breeding event occurs, a contingency volume (approximately 5 GL for Booligal wetlands and 12 GL for Merrowie Creek) would be triggered for use if existing flows are inadequate to meet the breeding requirements through to fledging. There is no specific maximum duration for breeding events, as it occurs opportunistically if conditions are suitable.

3. In-channel watering for native fish outcomes

Target sites

Lachlan River downstream of the Boorowa River confluence. *As the environmental water is maintained in-channel, an attenuated volume also contributes to the Great Cumbung Swamp asset.*

Objectives

- Improve the condition of emergent, submergent, semi-permanent wetland vegetation and riparian vegetation communities;
- Provide short-term, in-channel connectivity that maintains in-stream habitats and facilitate native fish movement; support native fish breeding opportunities; and
- Support small-scale recruitment, particularly for short-lived species.

Hydrology

Natural inflows are ideally the first option for consideration, as the flow maintains the natural chemical signature. In the event that unregulated tributary inflows are considered unlikely to occur in spring and there is an identified need for an action for specific species, a release from storage would be considered, with the caveat that tributary inflows would substitute for releases from storage. If other planned water is in the system, the dam is spilling, or a large scale wetland watering event has occurred (Strategy 1) this additional flow may fulfil this requirement.

The volume required depends on the desired hydrograph and other orders in the system, and timing of the delivery would most likely be in spring- early summer once water temperatures and other parameters are suitable for species to spawn. Between 30-35 GL should be available in accounts to proceed with this action. The target frequency would be most years (8 out of 10). The maximum duration between events and the target volume depends on the species targeted. Up to 20 GL would be considered for this strategy.

Figure 6 - Lachlan Decision Support System (abridged)