Attachment A

Enhanced environmental water delivery

A BUSINESS CASE FOR THE SUSTAINABLE DIVERSION LIMIT ADJUSTMENT MECHANISM

To be submitted by Victoria, New South Wales and South Australia

Drafted by the MDBA on behalf of the governments of Victoria, New South Wales and South Australia

DISCLAIMER

This is a preliminary business case, used to inform decision-making by the Murray-Darling Basin Ministerial Council and Basin Officials' Committee on sustainable diversion limit adjustment mechanism projects. The documents represent the business case for each of these projects at the date they were submitted for assessment by Basin governments, which for this project was 2017. Detailed costings and personal information have been redacted from the original business cases to protect privacy and future tenders that will be undertaken to deliver these projects.

Version control

Date updated	Updated by	Comment
7/04/2017	MDBA	Preliminary draft for state comment
13/04/2017	MDBA	Draft incorporating preliminary state comments
3/05/2017	MDBA	Draft incorporating additional state comments
8/05/2017	MDBA	Draft incorporating multi-lateral workshop comments
9/05/2017	MDBA	Incorporating final state comments

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Acronyms

BOC	Basin Officials Committee
BOM	Bureau of Meteorology
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CLLMM	Coorong, Lower Lakes and Murray Mouth
EEWD	Enhanced Environmental Water Delivery
EWR	MDBA Environmental Water Requirement reports
HEW	Held environmental water
IGA	Inter-Governmental Agreement
IRORG	Independent River Operator Review Group
MDBA	Murray-Darling Basin Authority
MINCo	Ministerial Council
NSW	New South Wales
O&O	Objectives and Outcomes for River Operations in the River Murray System
PEW	Planned environmental water
PPM's	Pre-requisite Policy Measures
RMIF	River Murray Increased Flows
RMOC	River Murray Operations Committee
SA	South Australia
SCBEWC	Southern Connected Basin Environmental Watering Committee
SDL	Sustainable Diversion Limit
SDLAAC	Sustainable Diversion Limit Adjustment Assessment Committee
SFI	Site-specific Flow Indicator
the Agreement	the Murray-Darling Basin Agreement
the Proposal	Enhanced Environmental Water Delivery – a business case for the sustainable diversion limit adjustment mechanism
VIC	Victoria
WLWG	Water Liaison Working Group

Key terms and linkages

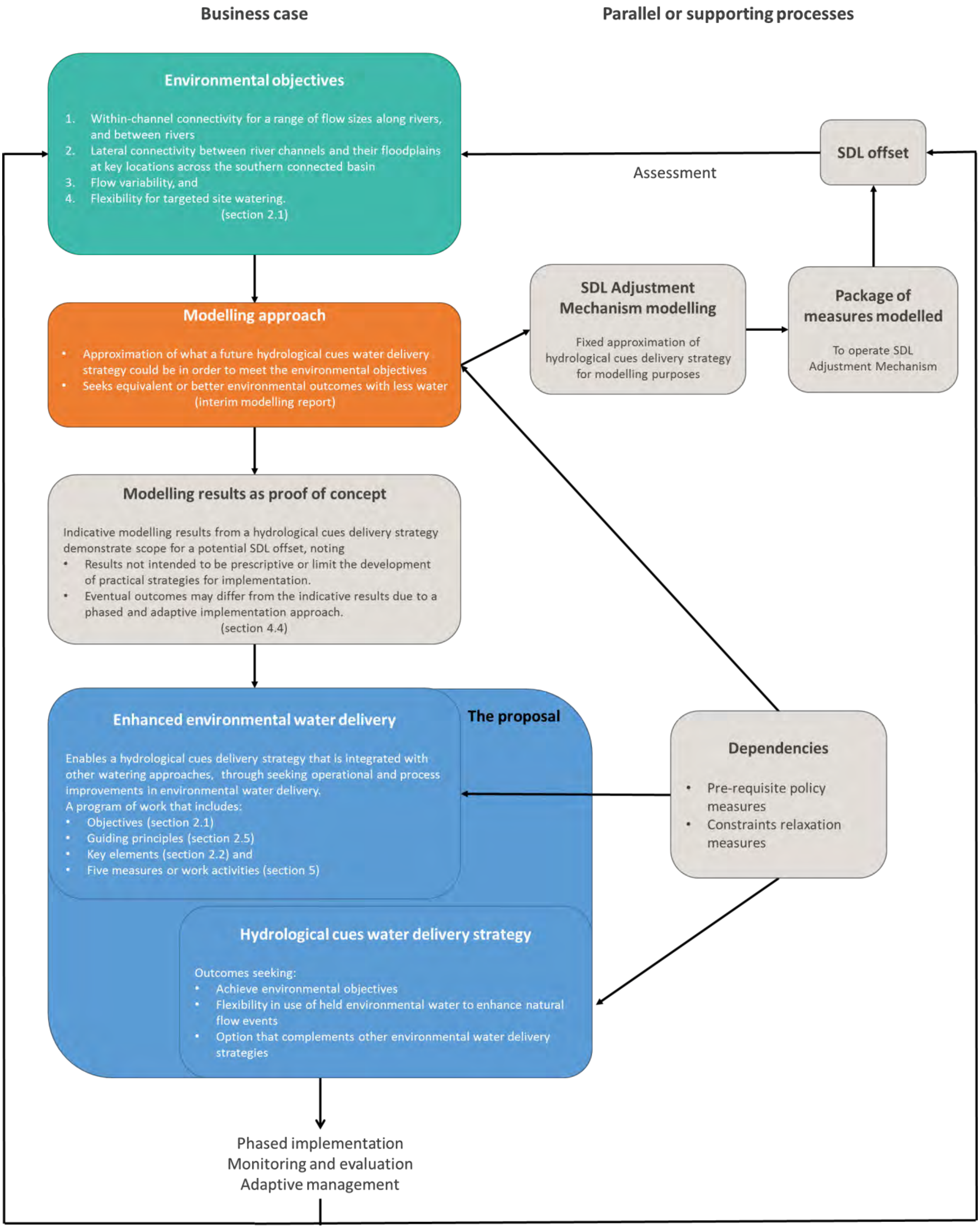
As part of the SDL adjustment mechanism, this proposal seeks equivalent or better environmental outcomes with less water. It does this through developing a hydrological cues delivery strategy which is enabled by a program of works to enhance environmental water delivery.

Hydrological cues delivery strategy:
At the request of environmental water holders, river operators will make regulated releases from storages to coincide with unregulated flows caused by rainfall. This is a structured approach for initiating managed environmental water releases from storages to increase the peak and/or duration of a flow event, and so reinstate some of the freshes, inner-floodplain flows, connectivity and end of system flows that have been intercepted and stored by dams. This type of managed watering would mainly occur in moderate to wet years to achieve environmental objectives, but could occur in any year if the hydrological conditions exist.

Enhanced environmental water delivery:
This proposal enables a hydrological cues delivery strategy, through seeking operational improvements in environmental water delivery in three key areas:

1. Aligning the release of held environmental water with unregulated flows to shape the peak and or duration of a flow event, in order to create a stronger biological stimulus in synch with natural climate signals.
2. Making efficient use of channel capacity through the implementation of Constraints Measures to allow increased managed flows up to higher regulated limits in order to improve in-channel, floodplain and wetland outcomes and may improve end of system outcomes.
3. Coordinating environmental water releases across tributaries of the southern basin to maximise downstream and system-wide connectivity outcomes.

Overview of linkages:



Executive Summary

This business case describes the Enhanced Environmental Water Delivery proposal for the Sustainable Diversion Limit (SDL) adjustment mechanism. The adjustment mechanism seeks to deliver environmental outcomes more efficiently, with neutral or improved social and economic effects.

The Enhanced Environmental Water Delivery proposal achieves environmental outcomes while using less water in the SDL adjustment modelling framework by establishing arrangements to develop a hydrological cues delivery strategy for environmental water holders, river operators and site managers to:

- Accurately align the release of held environmental water with unregulated flows to shape the peak and/or duration of a flow event, in order to create a stronger biological stimulus in synch with natural climate signals.
- Make efficient use of channel capacity through the implementation of Constraint Measures to allow higher managed flows up to new regulated limits in order to improve in-channel, floodplain and wetland outcomes and may improve end of system outcomes.
- Coordinate environmental water releases across tributaries of the southern basin to maximise downstream and system-wide connectivity outcomes.

This business case sets out the measures needed to enhance environmental water delivery across the southern connected basin and enable a hydrological cues delivery strategy. A hydrological cues delivery strategy is recognised as one of a number of water delivery strategies (options or tools), available for environmental water holders to use. The development of a hydrological cues delivery strategy with greater scope than what is currently possible, is intended to integrate into relevant water planning, delivery, practices and communications. This proposal is about improving the operational system to allow environmental water managers enhanced choice and flexibility in how their water holdings are used, by creating opportunities for more efficient and effective environmental watering.

This business case also identifies the environmental benefit of the proposal and the current and proposed hydrology (sections 3 and 4). Objectives, principles, critical dependencies and a phased approach have been defined to guide how the work program is undertaken (section 2). The Enhanced Environmental Water Delivery (EEWD) program measures are listed below and explored in more detailed in section 5. A table that identifies where in the business case the Phase 2 Assessment guidelines criteria are addressed is included at Appendix 1.

	EEWD measure
1	Investigative work to understand and trial the new delivery and operational environment for river management. This includes exploring a range of flows that are scientifically sound and operationally achievable, for release of environmental water at headwater storages across the southern connected basin under a hydrological cues delivery strategy.
2	Enhanced environmental water delivery administration and coordination processes.
3	Identification and removal of current accounting limitations to efficient environmental water delivery across the southern connected basin.
4	Establishment of clear and enduring mandate for governments and river operators to order and deliver environmental water aligned with un-regulated flows, up to agreed constraints relaxation levels. To be reflected in the River Murray Operations framework, and relevant state legislation as necessary.
5	Develop a monitoring and evaluation framework to assess the operationalization and effectiveness of a hydrological cues delivery strategy and the broader enhanced environmental water delivery (including EEWD measures 1-4).

1 Introduction

The Enhanced Environmental Water Delivery (EEWD) SDL proposal seeks to improve the efficiency of environmental water delivery by more closely linking environmental water management and river operations to achieve environmental outcomes through a hydrological cues delivery strategy. This proposal is about improving the operational system to allow environmental water managers to do more, not about restricting what environmental water managers currently do (Figure 1).

Environmental outcomes such as fish spawning or migration and waterbird nesting are typically triggered by a range of cues. These include changes in water levels, river flows, water temperature or carbon and nutrient input resulting from local rainfall or flows upstream. River regulation, water abstraction, and in-stream and floodplain structures are well known to interrupt or alter natural cues and reduce the success of these ecological triggers. Sometimes a partial cue occurs—such as when a rain event is largely captured in a dam upstream, but some tributary inflows still occur. This proposal is about strengthening partial cues to trigger and sustain biological responses and improve environmental outcomes.

A key way to ensure that environmental watering is effective and creates favourable environmental conditions is to work in harmony with natural hydrological cues. In doing so the intent through relaxed constraints is to build on unregulated river flows to get water to an extended range of areas in the landscape, and for environmental water holders to enhance the range of environmental outcomes possible from use of their portfolios.

The management of environmental water in response to hydrological cues does not exclude the need for targeted asset watering or to sometimes provide flows in areas or at times without a natural trigger (particularly when the watering purpose is to avoid environmental damage).

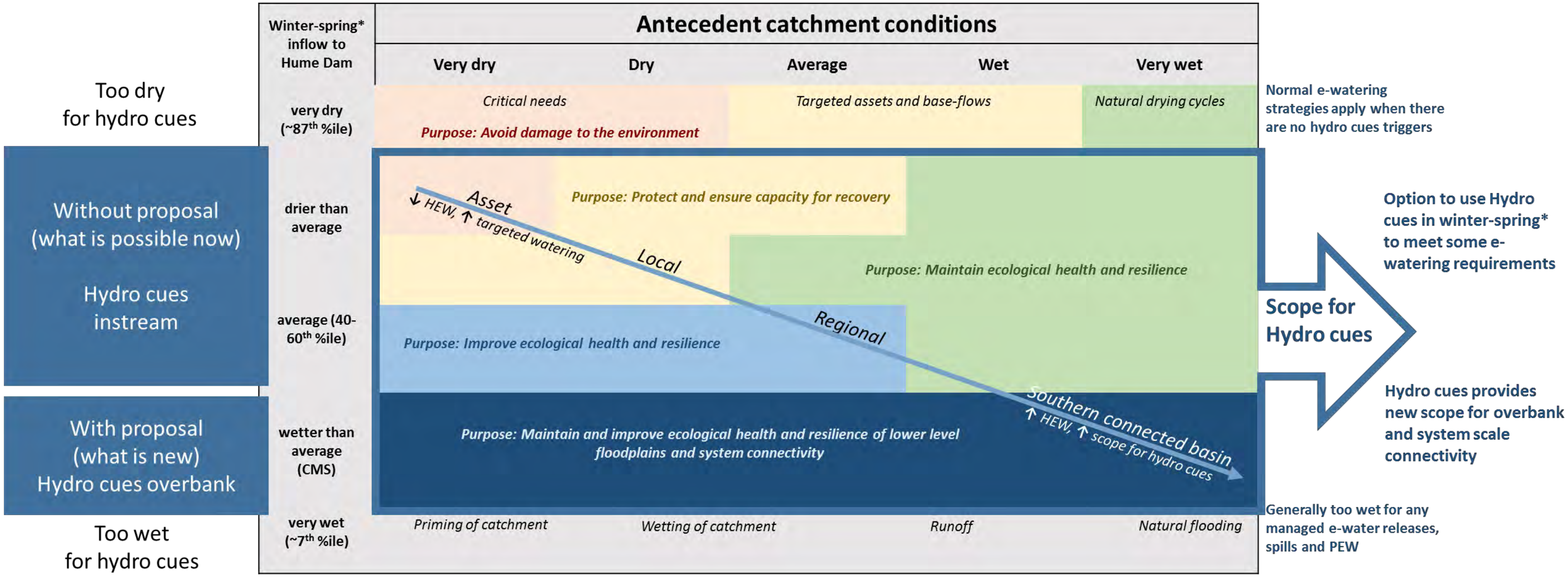
In the context of this business case, a "hydrological cues delivery strategy" is defined as the ability for river operators, at the request of environmental water holders, to make regulated releases from storages to coincide with unregulated flows caused by rainfall. This is a structured approach for initiating managed environmental water releases from storages to increase the peak and/or duration of a flow event, and so reinstate some of the freshes, inner-floodplain flows, connectivity and end of system flows that have been intercepted and stored by dams. This type of managed watering would mainly occur in moderate to wet years to achieve environmental objectives, but could occur in any yeah if the hydrological conditions exist.

Held water entitlements are unlikely to be large enough to deliver a range of fresh and over-bank flows solely from storage. Thus the focus of this proposal is on how to increase the efficiency and timing of delivering environmental water by:

- topping up unregulated flow events (‘piggybacking’ on hydrologic cues)
- best using the available channel capacity (assuming a level of relaxed constraints)
- coordinating flows across tributaries.

The concept of topping up natural inflows is not new. Environmental water managers and river operators are already trialling ‘hydrological cues’ in an operational sense, through multi-site environmental watering trials and actively coordinating use of environmental water along multiple river systems through the Southern Connected Basin Environmental Watering Committee (SCBEWC) and the Water Liaison Working Group (WLWG). This proposal recognises these recent advancements in environmental watering, and that they will continue with or without this proposal progressing past the feasibility stage (phase I).

This proposal builds on these measures by setting out a program of additional work (phase II), over and above core business. This program of work will enable more efficient delivery of environmental water on-top of unregulated flows, to allow the managed delivery of freshes and floodplain flows across the southern connected basin. Evaluating whether or not measures are successfully in place to allow this type of water delivery to occur, and early assessment of the relative effectiveness of this type of water delivery strategy for environmental outcomes, are part of the evaluation that will be guided by ongoing adaptive management (phase III).



* Hydro cues is an option mostly during winter and spring. This coincides with periods where higher flows tend to be captured in storage and irrigation demand for channel capacity is lower

Figure 1: Environmental Water Portfolio Management. Matrix of Commonwealth Environmental Water Holder behaviour overlaid with the scope for implementing a hydrological cues delivery strategy using held environmental water (HEW).

Areas where this proposal enhances what can currently be achieved with environmental watering are highlighted as 'what is new'.

2 Measure details

2.1 Proposal objectives

Consistent with the Basin Plan objectives, the overall objective of the EEWD proposal is to improve flow regimes and river and floodplain connectivity in order to:

- Protect and restore water-dependent ecosystems of the Murray-Darling Basin
- Protect and restore the ecosystem functions of water-dependent ecosystems
- Ensure that water-dependent ecosystems are resilient to climate change and other risks and threats

The outcome that will be achieved by the EEWD proposal is to allow regulated environmental water releases to be made from storages to coincide with natural flows caused by rainfall. Importantly the scale of outcomes possible from the proposal depend on the levels of constraints relaxation that are ultimately achieved (critical dependency), together with the appropriate legislative and policy changes needed to allow river operators to execute delivery orders contemplated under a hydrological cues delivery option. The final outcome of this project will depend on progressive steps over time as to what can practically be achieved with constraints relaxation as part of an adaptive implementation approach.

To achieve the overall outcome of enhanced ability to add regulated water to natural flows for the controlled shaping and alignment of flow events, the proposal has both water delivery objectives and specific outcomes.

Water delivery objectives

Ecological objectives are dealt with in more detail in section 3.2 but the water delivery objectives for a hydrological cues delivery strategy can be summarised as working to improve:

1. Within-channel connectivity for a range of flow sizes along rivers, and between rivers
2. Lateral connectivity between river channels and their floodplains at key locations across the southern connected basin (in conjunction with relaxing constraints)
3. Flow variability
4. Flexibility for targeted site watering

Specific outcomes

The specific outcomes being sought, and supporting rationale, for enhanced environmental water delivery include:

1. **A hydrological cues delivery strategy will allow held environmental water to be used in a number of ways to enhance a natural flow event (e.g. timing, peak, rates of rise and fall, and duration)**

   - Provides efficiency of delivery (less environmental water required to deliver the same, or better environmental outcomes as we are adding to an existing pulse of water).
   - Supports better environmental outcomes as many of the climatic and water quality conditions that accompany a natural increase in flow are important in driving ecological response.
   - Provides ecological benefits such as triggers for fish movement and breeding, low level floodplain vegetation condition and recruitment, movement of carbon and nutrients to/from the river channel, and connectivity for biota.

- Provides a sound underpinning to interventions as they are in synch with natural climate conditions, particularly in circumstances of limited or imperfect ecological data and knowledge currently available to guide management actions.

2. **Decisions to release water can be made quickly, to enable a timely action in response to a natural flow event**

    - To maximize the efficiency of hydrological cues, and accurately align releases with unregulated flows, the ability to respond to natural flow events in a timely manner is critical.

3. **Water planning and flow delivery can be efficiently and effectively coordinated across the southern connected basin for site-based and system scale outcomes**

    - Creates more opportunities to provide flows of sufficient size and duration to deliver whole of system ecological outcomes: including along the River Murray and its tributaries, floodplain, and Coorong, Lower Lakes and Murray Mouth.

2.2 What does success look like?

The proposal involves the development of a range of decision support tools and new water delivery and accounting mechanisms that will provide the means to make repeatable decisions about how and when to release environmental water to most effectively supplement natural inflow events. This is to be done through methods proposed within the Enhanced Environmental Water Delivery work measures (section 5.2). Jurisdictions will have joint responsibility for management and approvals of the development of supporting tools or mechanisms. These decisions will be based on rigorous analysis of system behaviour, inflow patterns and environmental water needs so that they have a high probability of generating positive environmental outcomes.

Successful implementation of a hydrological cues delivery strategy is likely to have a number of key steps:

1. Water holders take a decision, based on advice from operators that seasonal climate and catchment conditions are appropriate for hydrological cues planning in the coming season
2. The volumes of water available, the priority environmental assets for watering and the inflow triggers that will initiate releases are agreed by water holders
3. An authorisation for watering action is developed and approved by the water holders
4. River Operators have the ability to implement, or not, the strategy and monitor and report to water holders
5. Water holders and relevant agencies monitor and report on environmental outcomes
6. Parties involved reflect on the delivery and outcomes, learn from what worked, and identify what could be improved next time.

A hypothetical example of an authorisation for a hydrological cues watering action has been worked up. This is to help demonstrate proof of concept and be clear about what this type of water delivery could look like in the future (Appendix 2). The hypothetical authorisation includes information about what is needed to initiate and manage the hydrological cues watering action from start to end, including instructions about:

- Volumes available
- The time period that the authorisation applies for – when it starts, when it expires, what circumstances may result in a cancellation or suspension of the authorisation
- Assets being targeted and ecological objectives

- Delivery and accounting arrangements
- Describes the range of operating strategies that can be used under different conditions
- Reporting arrangements and consultation processes during releases
- Roles and responsibilities
- Risks, complementary projects and additional considerations.

Importantly implementation of the natural cues approach to water delivery would occur through a staged commissioning process. The natural cues trials already occurring would be gradually expanded as constraints management actions are implemented. Any change to regulated flow limits will be tested incrementally and monitored in an adaptive management process.

There is a strong probability that modelled outcomes as part of the SDL adjustment mechanism (4.4) will be achieved even with the adaptive approach to implementation. The Commonwealth Environmental Water Holder, as the largest of the Basin's environmental water holders, uses the objectives of the Basin Plan and Watering Strategy as mandated targets when managing portfolio use decisions. A proposal that seeks to make it easier for water holders to work with river operators across state boundaries to achieve mandated targets (environmental objectives and outcomes) is likely to be strongly supported throughout development and implementation.

Implementation of administrative efficiencies and enhanced river operating tools to support decisions that maximise the efficiency and effectiveness of use of held environmental water will also be critical to gain the support of river operators because of the changing methods of water delivery and the risk operators are bearing on behalf of the water holders.

2.3 Key elements of the work program

Key elements of the proposal:

This proposal aims to establish arrangements to support a hydrological cues delivery strategy integrated with other watering approaches by 2024. This strategy will complement other environmental water delivery strategies, and will provide environmental water managers with additional options and flexibility to achieve more environmental objectives.

To enable hydrological cues delivery strategy, the proposal includes the following key elements to enhance environmental water delivery (linked to measures in Table 1):

- Investigative and research work to inform development of a hydrological cues delivery strategy
- Development of improved forecasting, decision support tools and models
- Enhanced river operations and accounting arrangements, including changes to the River Murray Operations Framework
- Enhanced environmental water planning, delivery, administration and coordination processes
- Integration of hydrological cues strategy into relevant water planning, delivery, practices and communications
- Policy and system operational frameworks aligned to provide a clear mandate for the delivery strategy
- Community and stakeholder engagement (coordinated with complementary activities and programs such as constraints)
- Monitoring and evaluation strategy to support continuous improvement of watering using this strategy, delivering on program objectives and outcomes, and integrated with other relevant reporting and activities

Key activities that are critical to the success of this proposal but which are delivered through other projects include:

- Relaxation of constraints (potential projects in Hume to Yarrawonga, Yarrawonga to Wakool, Murrumbidgee, Lower Darling, Goulburn, and SA Murray)
- Implementation of pre-requisite policy measures to address policy constraints to the delivery of environmental water
- Implementation of other SDL adjustment measures such as Hume Dam Airspace and River Murray Increased Flows
- Annual environmental watering trials.

The proposal achieves more efficient use of environmental water through a multi-year program of work across the southern connected basin. The program of work will require actions across all the relevant jurisdictions in South Australia, New South Wales, and Victoria and at a Commonwealth government level. Some of the measures proposed incorporate processes that are already underway or proposed (e.g. PPMs, Constraint Measures), as well as some additional work activities (Figure 2). This business case ensures the broad suite of actions to enhance environmental water delivery are coordinated and implemented to a level able to be operationalised by the relevant stakeholders, and underpinned by the principles (section 2.5) and objectives (section 2.1) if a hydrological cues operating approach is to be selected for any given environmental watering event. It will not replace existing state Government policies.

The proposal identifies actions required across the environmental water delivery process, and across different water management agencies. This includes reviews and changes that need to be implemented at the planning, delivery, site, evaluation and accounting stages of environmental water delivery (Figure 3). These reviews and changes will require a collaborative approach from all stakeholders including river operators, environmental water holders, site managers, water planners and community across the jurisdictions. A summary of the proposed actions is at Table 1, while more detail is provided in section 5.

It is recognised that a number of the measures proposed will assist with more efficient, effective and coordinated environmental watering in general, in addition to supporting a hydrological cues delivery strategy. This highlights an additional benefit from this proposal in that it will provide additional impetus to more rapidly progress the coordination and development of emerging basin environmental watering arrangements in order to optimise the benefits from available water.

Figure 2: This proposal ensures coordination across a number of parallel strands of work, some of which are already in progress, in order to enhance environmental water delivery processes and environmental outcomes.

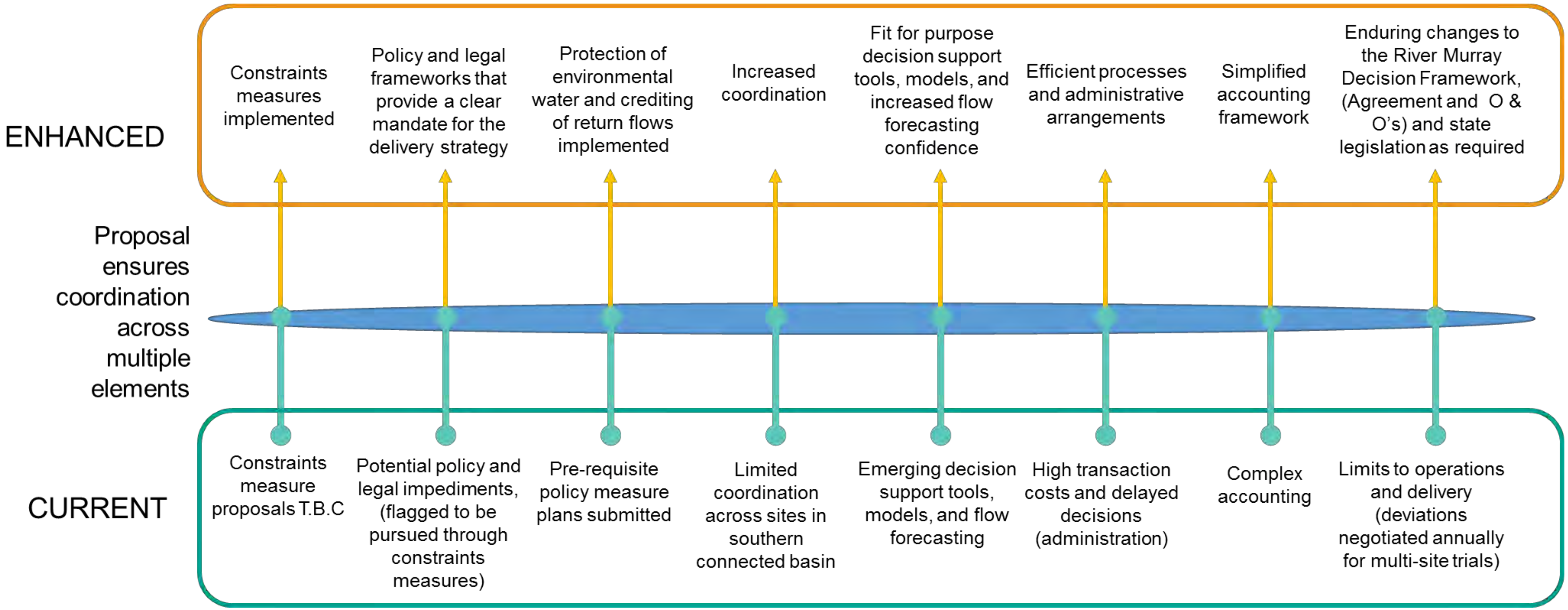


Table 1: Summary description of the measures including benefits, progress to date, action required and roles.

No.	EEWD measure	Benefits	Progress to date (Phase I)	Action required (Phase II and III)	Roles
1	**Investigative work to understand and trial the new delivery and operational environment for river management. This includes exploring a range of flows that are scientifically sound and operationally achievable, for release of environmental water at headwater storages across the southern connected basin under a hydrological cues delivery strategy.** Links to enabling all outcomes	Planning and delivery: This measure builds the technical knowledge and understanding required to enable the delivery of regulated flows on top of a range of un-regulated flows, in order to achieve environmental outcomes more efficiently. Investigating a range of flows will not be codified as 'rules', but will act as a general guide to better understand how to build and shape a variety of system flows to support environmental outcomes. This is especially important under a level of constraints relaxation, as this will be a new area for river operations to move into which will take careful testing. Site outcomes: Effective watering of downstream assets and a range of in-channel and floodplain environmental outcomes will be achieved due to the improved accuracy in being able to align regulated releases with unregulated flows arising from new investigations and knowledge.	MDBA has conducted early investigations into possible tributary and storage flow triggers required to deliver 80,000 ML/d at SA border (MDBA) EWRs and other documents currently inform ecological flow requirements but do not prescribe specific flows for delivery (MDBA) Investigations in early stages as part of long term water planning by jurisdictions (e.g. modelling project by NSW OEH) Southern connected basin multi-site natural cues trial Working closely with BOM, starting investigations into improved forecasting tools for river operators and environmental water holders (additional work TBC, proposed as part of Constraint Measures)	Phase IIa (2017-20): Integrated research and investigation process with river operators, environmental water holders and site managers. Develop, hydrological cues delivery strategy Phase IIb (2020-22): Implement changes to river operating rules and procedures to facilitate delivery actions as part of reform package with EEWD measures 2, 3 and 4. Develop improved tools, models, etc as required. Trial and evaluate hydrological cues delivery strategy Phase III (2022-2024): Evaluation (see EEWD measure 5 noting that relevant evaluation information will be collected throughout the whole implementation process). Trial and adapt hydrological cues delivery strategy	MDBA to facilitate: jurisdictional environmental water holders in partnership with river operators, and asset/site managers.

No.	EEWD measure	Benefits	Progress to date (Phase I)	Action required (Phase II and III)	Roles
2	**Enhanced environmental water delivery administration and coordination processes.** Links to enabling outcomes 2 and 3	Planning and delivery: Reduce administrative burdens of current processes and streamline approvals for delivery of environmental water to facilitate coordination and timely decision-making. Site Outcomes: Allow timely releases of held water to achieve target flows downstream for environmental outcomes. Coordination of the operation of works and measures to align water delivery with environmental cues and unregulated flows.	Scoping of project with SCBEWC (July 2017) Southern connected basin multi-site natural cues trial Early BOM investigations into improved forecasting tools for river operators and environmental water holders	Phase IIa (2017-18): Review of current planning, governance and coordination process to identify efficiencies and actions required to enable timely release of flows. Scope the need for decision support tools and models as required. Phase IIb (2018-22): Implement changes to governance, administration and coordination as required as part of reform package with EEWD measures 1, 3 and 4. Develop decision support tools and models as required. Phase III (2022-2024): Evaluation.	MDBA to facilitate: Jurisdictional environmental water holders in partnership with river operators and environmental asset/site managers.
3	**Identification and removal of current accounting limitations to efficient environmental water delivery across the southern connected basin.** Links to enabling outcome 2	Planning and delivery: Enhanced flexibility in portfolio management, simplifies accounting complexity, enables crediting and real-time protection of returned flows, builds confidence in decision-making and portfolio management, and supports EEWD 2 as streamlines administrative processes. Site outcomes: appropriate simplified accounting mechanisms enable environmental water holder flexibility to use water most efficiently and flexibly to achieve overbank outcomes and water multiple sites.	Independent River Operator Review Group (IRORG) recommendation to conduct a strategic review of accounting Broad scoping paper has been noted by RMOC PPM implementation plans developed	Phase IIa (2017-19): Strategic review of current accounting approaches for environmental water delivery. Phase IIb (2019-22): Implement identified recommendations as part of reform package with EEWD measures 1, 2 and 4. Phase III (2022-2024): Evaluation.	MDBA to facilitate on behalf of jurisdictions. Specific implementation roles to be identified after scoping the role of relevant jurisdictions identified.

No.	EEWD measure	Benefits	Progress to date (Phase I)	Action required (Phase II and III)	Roles
4	**Establishment of clear and enduring mandate for governments and river operators to order and deliver environmental water aligned with un-regulated flows, up to agreed constraints relaxation levels. To be reflected in the River Murray Operations framework, and relevant state legislation as necessary.** Links to enabling outcomes 1 and 2	Planning and delivery: Allows river operators to deliver on behalf of environmental water managers and state partners, the environmental water required to achieve in-channel and floodplain outcomes, with appropriate indemnities and protection. Site outcomes: Improvements to ability to order and deliver water in an adaptive manner to achieve floodplain outcomes.	PPM implementation plans developed ('piggy-backing') Constraint Measures proposed at priority reaches Inventory of SDLAM projects requiring changes to River Murray Operations Documentation (MDBA)	Phase IIa (2017-18): Review of the River Murray operations framework to provide for hydrological cues operations. Review to identify potential legal impediments. Phase IIb (2018-22): Implement required changes in the Agreement, O&Os and state legislation as necessary, as part of reform package with EEWD measures 1, 2 and 3 and other SDLAM projects. Phase III (2022-2024): Evaluation.	MDBA to facilitate on behalf of Basin Governments. Lead: MDBA with support from consultant(s), action required by BOC/MinCo.

No.	EEWD measure	Benefits	Progress to date (Phase I)	Action required (Phase II and III)	Roles
5	**Develop a monitoring and evaluation framework to assess the operationalization and effectiveness of a hydrological cues delivery strategy (including EEWD measures 1-4).** Links to enabling all outcomes	Planning and delivery: Allows for ongoing adaptive management and learnings from implementing EEWD measures 1 – 4 and evaluating early lessons in relative effectiveness of this type of water delivery strategy. Site outcomes: Transparent and accountable assessment that is evidence based and used to enable improved environmental outcomes into the long term.	Various monitoring and evaluation occurring at a site level (ecological outcomes) MDBA conducting evaluation of implementation of Basin Plan IRORG reviews	Phase IIa (2017-18): Develop a monitoring and evaluation framework to assess effectiveness of EEWD measures 1 – 4 individually and as a package. Phase IIb (2018- 2022): Collect information and interim evaluation of progress as part of evaluation framework Phase III (2022-2024): Conduct evaluation of hydrological cues approach and document outcomes and learnings for ongoing adaptive management.	MDBA in partnership with jurisdictional environmental water holders, asset/site managers and river operators.

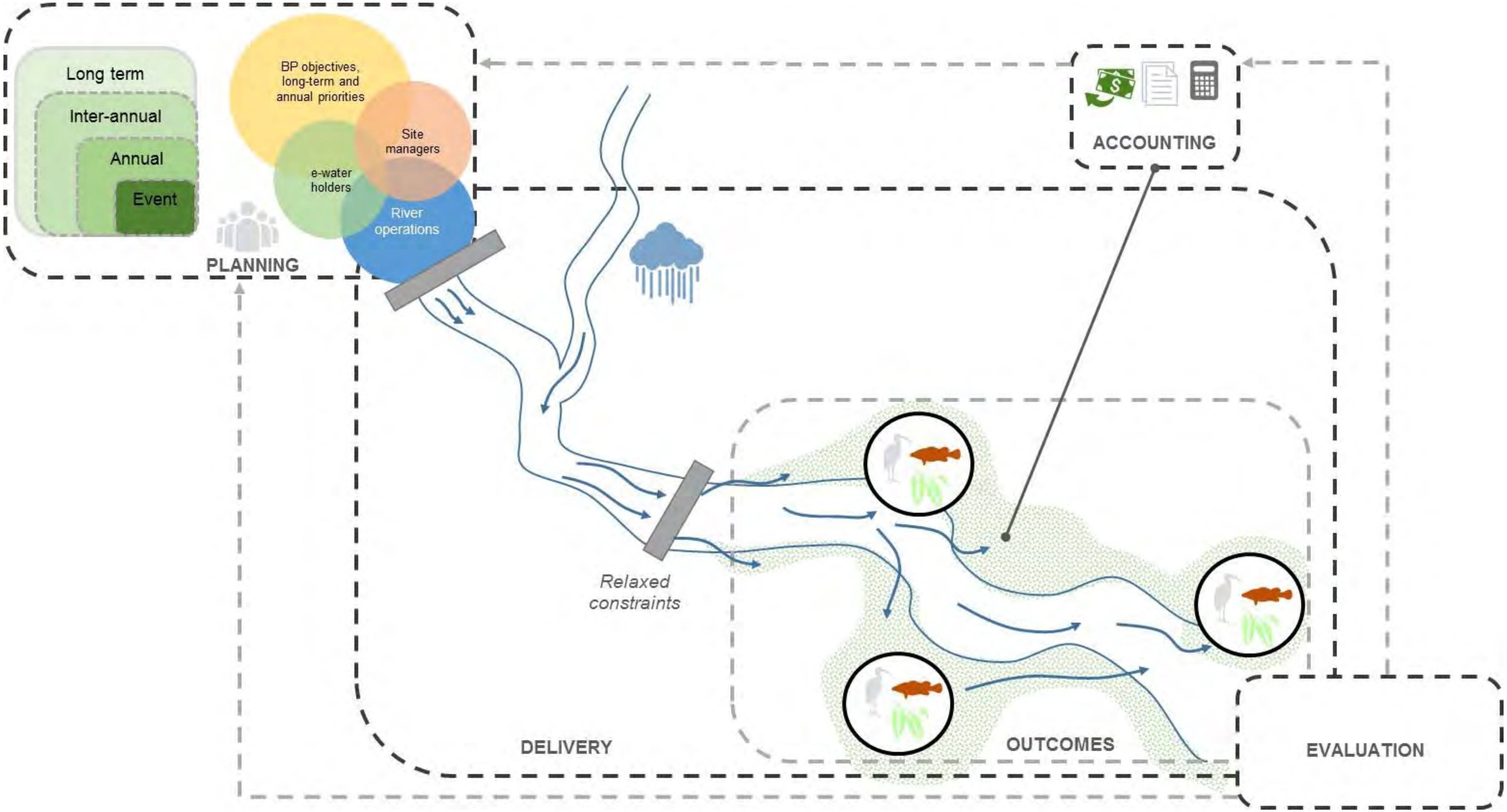


Figure 3: Generalised model of the environmental water delivery process, highlighting five key areas where improvements or changes could be made (planning, delivery, outcomes, accounting and evaluation).

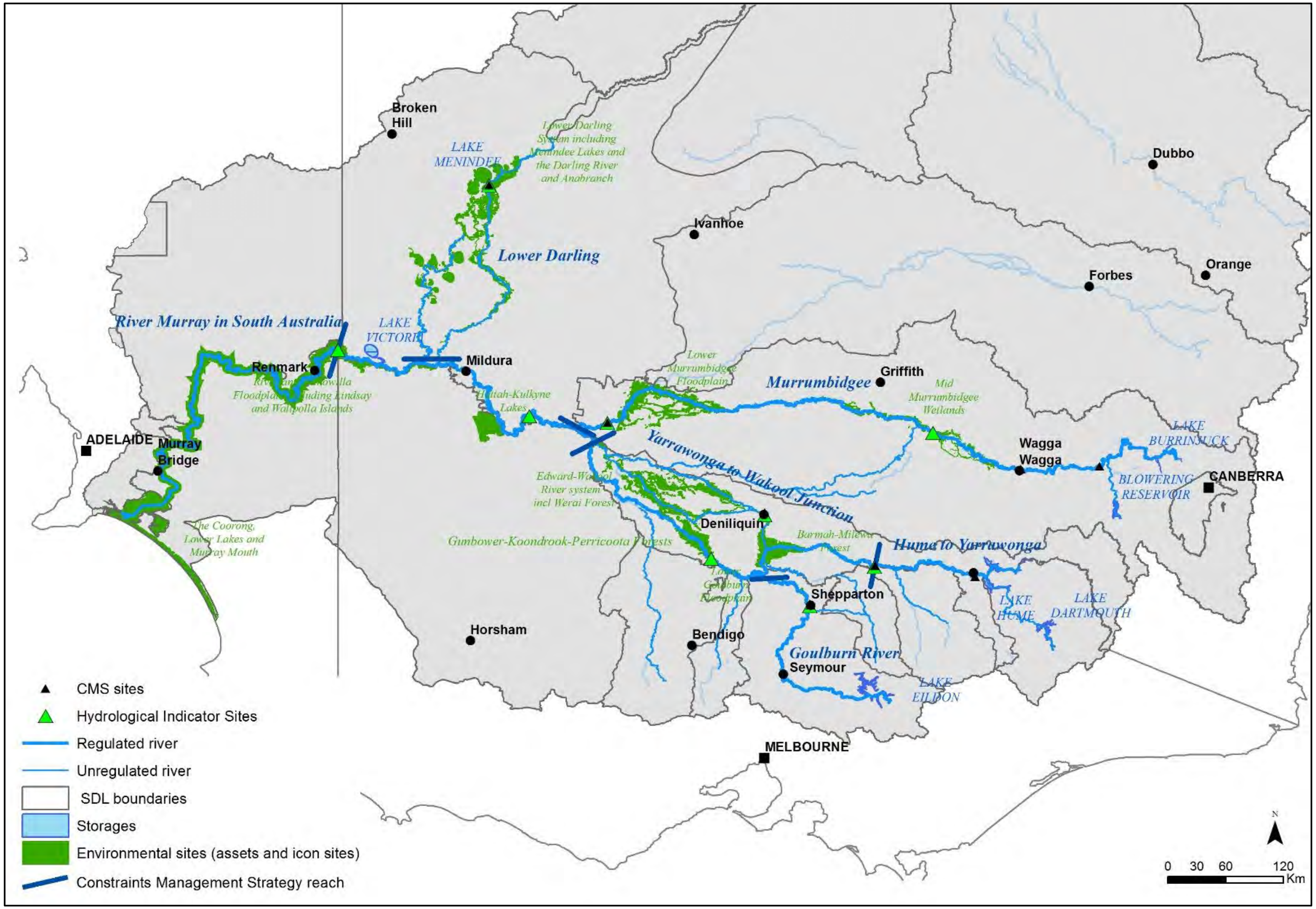


Figure 4: Map of the major storages and environmental assets and constraint reaches of the southern connected basin

2.4 Location of the measure

The EEWD proposal involves changes to the planning, delivery, site management and evaluation stages of environmental water management across the southern connected basin. The southern connected basin is identified in Figure 4 and includes the following SDL resource units:

- Victorian Murray (SS2)
- New South Wales Murray (SS14)
- Murrumbidgee (SS15)
- Lower Darling (SS18)
- Goulburn (SS6)
- South Australian Murray (SS11)

The major rivers and a description of their operating structures and current physical constraints be found in the Preliminary overview of constraints to environmental water delivery in the Murray-Darling Basin (MDBA, 2013).

This proposal, and the associated environmental outcomes, are linked to delivering environmental water and operating the southern connected basin in a coordinated way. This is because floodplain outcomes along the River Murray, and particularly flows that water the Chowilla-Lindsay-Wallpolla floodplain in the Lower Murray, are more readily achieved when there are flow contributions from several of the major tributaries in the upstream section of the Murray (i.e. Goulburn, Murrumbidgee, and Upper-Murray), rather than a single event originating in one valley (MDBA, 2012b). The Upper Murray (including unregulated flows from the Kiewa and Ovens) is the major contributor of flow in the Lower Murray, followed by the Goulburn, the Murrumbidgee and then the Darling.

Including the major regulated tributaries of the southern connected basin is critical as they add flexibility to which storage to call environmental water from. This helps optimise being able to shape hydrographs effectively, as well as being able to coordinate flows across tributaries for system connectivity outcomes.

2.4.1 Works and measure sites in the southern connected basin

The implementation of the EEWD proposal interacts with the operation of floodplain regulators, weirs, wetland watering infrastructure, and barrages in Lake Alexandrina and Albert. The need for environmental site managers (that include works and measures sites) to be closely involved in the development of the hydrological cues watering strategy and works program has been identified in EEWD measures 1, 2 and 5. These structures, and potential interactions are identified in (MDBA, 2013).

2.5 Critical Dependencies

There are a number of critical dependencies relevant to this proposal. It is assumed the components listed below (Table 2) will be implemented to appropriate levels in order to facilitate environmental outcomes sufficient to generate an SDL offset (dependent on additional modelling). These components will be progressed independent of the EEWD proposal and therefore have unique project plans and engagement strategies. The EEWD proposal will contribute to and integrate with, not duplicate, existing and proposed processes.

Table 2: Critical components and dependencies.

Dependency	Risks to this proposal	Status
Constraint Measures implementation • Hume to Yarrawonga • Yarrawonga to Wakool Reach • River Murray in South Australia • Goulburn River • Murrumbidgee • Lower Darling (integrated into the Menindee Lakes draft proposal)	Operationalising higher regulated flow limits (e.g. to achieve floodplain outcomes) requires a level of constraints relaxation Under current constraints in the southern basin, a hydrological cues delivery strategy on its own will not deliver the key outcomes sought. This business case assumes a level of constraints relaxation is in place.	Constraint Measures are proposed to be addressed through a staged program and be subject to assessment and significant progress test under the Basin Plan in 2024. Over this period reviews will be undertaken to assess progress, derive learnings and continuously improve the program. Business cases for constraints relaxation in a number or priority reaches have been prepared by the MDBA and Basin states. These business cases detail the level of constraints relaxation being sought and the associated risks, costs and community engagement required. The Constraint Measures may be implemented in a staged approach (i.e. Murray Main stem constraints relaxed initially, and tributaries following completion of the main stem). This will dictate when, where, and to what extent enhanced environmental water delivery is operationalised in the southern connected basin. Decisions to proceed with removing constraints will be made by Basin governments with investment being decided by the Commonwealth on the collective advice of governments. The scale of outcomes possible from the proposal depend on the levels of constraints relaxation that are ultimately achieved. The final outcome of this project will depend on progressive steps over time as to what can practically be achieved with constraints relaxation as part of an adaptive implementation approach.

Dependency	Risks to this proposal	Status
PPM implementation: s7.15 of the Basin Plan defines PPMs (unimplemented policy measures) as an anticipated measure consisting of a policy to: • credit environmental return flows for downstream environmental use; or • allow the call of held environmental water from storage during un-regulated flow events.	Adequate protection of environmental water is required for environmental water holders to confidently manager their portfolios using a range of flows and hydrological cues (EEWD1). PPM plans need to have adequate measures in place to ensure tributary flows are adequately protected from being re-regulated when they enter the Murray; and that tributary flows are not prevented from being re-used on downstream sites.	PPM implementation plans are in active development. The PPMs are due to be implemented by 30 June 2019. An implementation management process has been agreed by SDLAAC, with jurisdictions providing quarterly implementation process updates to SDLAAC between July 2017 and June 2019. Jurisdictions will also prepare an annual written implementation progress report that will be reviewed by IRORG and tabled at BOC.

Dependency	Risks to this proposal	Status
Annual environmental watering trials	Annual environmental watering trials are an integral part of adaptive management of river operations in the southern connected basin. It is critical that these continue and lessons learnt (i.e. annual deviations from standard operating procedures) are made enduring. The EEWD proposal is complementary to the environmental watering trial process. Changes required to standard operations as a result of implementation of the EEWD proposal can be trialed using the annual environmental watering trial process.	The 2017-18 Annual Environmental Watering Trial includes the following proposed actions relevant to this proposal (in particular testing PPM implementation): • Directed releases from headwater storages, including during periods of unregulated flow, from Hume, Menindee and Lake Victoria • Accounting methods for directed releases from headwater storages • 'Bulk' entitlement delivery provisions to ensure environmental water flows through the length of the river (NSW only) • Protection of environmental water from re-regulation or extraction • Delivery of residual flows to downstream sites
Other SDLAM supply measure proposals	Interaction with other supply measures remains to be determined to ensure consistency across proposals.	The full suite of supply measure proposals is yet to be confirmed. Further investigation will be needed to assess interactions between other proposals including those listed below and the EEWD proposal. • Hume Dam Airspace • RMIF (Snowy Water Licence Schedule 4 NSW)

2.6 Guiding principles

Hydrological cues is recognised as one environmental water delivery strategy. Other delivery strategies such as targeted watering and contingency planning are equally important for optimising ecological outcomes and providing flexibility to water a range of environmental assets.

It is recognised that the system is no longer a natural system and the volume of held environmental water is limited. It is not possible or desirable to enhance all natural flow events. In such a modified system there is a need to target the delivery of environmental water to meet specific environmental objectives or biotic requirements which may not be achieved with a hydrological cues delivery strategy (e.g. water quality mitigation, low flow objectives, etc).

How the EEWD proposal program of work sets out to achieve the objectives in section 2.1 will be guided by a range of principles. These are in addition to the 4 principles for Basin Plan implementation, and 11 principles for planning and delivering environmental water (Chapter 8 of the Basin Plan) (Appendix 3).

PRINCIPLES SPECIFIC TO THIS PROPOSAL:

Ensure flexibility in how environmental objectives are achieved

1. Requires an options based approach to allow environmental water holders the flexibility to manage their portfolio for best effect under changing seasonal conditions, water availability and environmental needs.
2. Requires a proportion of held environmental water to be used to implement a hydrological cues delivery strategy, subject to environmental water holder decisions, seasonal conditions, allocations and the scale of the watering being planned (ranging from relatively small at the individual asset level up to a larger proportion at the scale of the southern connected system in moderate to wet years).
3. Requires that the use of available environmental water under a hydrological cues delivery strategy be guided by reinstating wetting and drying regimes at multi-year scales to reflect natural processes and functions, whilst seeking, wherever possible, event-based outcomes.
4. Flexibility to include targeted watering and specific demands will be required at some sites and in some years to avoid unintentional adverse ecological impacts. Development of specific strategies for some sites are likely to be required e.g. CLLMM, Basin wide icon sites the and lower Murray floodplain.

Enhance and coordinate environmental water delivery arrangements

5. Environmental water and river operations policy, accounting and operational arrangements will reflect and enable planning, coordination and delivery of a hydrological cues approach.
6. Requires arrangements to integrate and support a hydrological cues delivery strategy within the environmental water management framework (relevant plans, processes and operations).
7. Requires no detrimental environmental impacts or any third party impacts due to the implementation of the EEWD proposal.
8. Requires that the use of held environmental water, as part of implementation of the EEWD proposal, does not substitute for planned environmental water.
9. Successful delivery of EEWD may require changes to relevant river operations management frameworks such as the MDB agreement and objectives and outcomes documents. It may also require changes to relevant legal frameworks.

Apply best available science

10. Modelling, expert knowledge, science and field trials will inform the development of the hydrological cues delivery strategy.
11. The hydrological cues delivery strategy will be scientifically sound and operationally achievable.

Adaptive Management

12. Monitoring and evaluation arrangements will be required, that align with Basin Plan monitoring and evaluation frameworks at a Basin and state level, to support an effective adaptive management approach.
13. Requires arrangements to ensure that a phased implementation approach to hydrological cues monitors for and avoids unintentional adverse ecological impacts.

Collaboration

14. In agreeing to this proposal, Basin governments and statutory authorities agree to work together in good faith to implement priority recommendations that arise from the five measures identified in this proposal.
15. Governments will act to implement the hydrological cues delivery strategy as developed by this proposal. This will include assessing actions on the basis of transparent criteria agreed by jurisdictions; managing risk; and working collaboratively to meet the requirements of all jurisdictions.
16. Affected communities, including land holders and managers, water entitlement holders, Traditional Owners, management agencies and local governments need to be involved from the beginning to identify potential impacts and solutions (predominantly through the Constraint Measures engagement process).
17. Potential changes should be worked through with relevant Basin governments and relevant stakeholders to resolve issues before changes to existing policies and arrangements are made.

DEPENDENCIES:

Constraints relaxation

1. Requires relaxation of operational and policy constraints in a number of priority reaches in order to allow higher regulated flow limits and progressive implementation towards being able to inundate low to mid-level floodplain areas.

Effective implementation of pre-requisite policy measures

2. Requires implementation of a policy to credit environmental return flows for downstream environmental use. Measures will be implemented to address key policy barriers.
3. Requires a clear and enduring mandate for governments and river operators to order and deliver environmental water aligned with unregulated flow events.

Mitigation of third party impacts

4. In pursuing enhanced environmental outcomes, arrangements will need to:
    - recognise and respect the property rights of landholders and water entitlements holders
    - mitigate any new risks to the reliability of entitlements
    - be identified in consultation with affected parties to appropriately address and mitigate negative impacts where possible
    - identify and aim to achieve positive impacts for the environment, stakeholders and communities wherever possible
    - work with stakeholders in a transparent and equitable way
    - work within the boundaries defined by the Water Act, the Basin Plan and relevant state water laws and policies.

2.7 Costs

Proponents can confirm that this is a new project, additional to those already included in the benchmark assumptions under the Basin Plan. Pending a final plan to proceed with this project, its implementation is expected to:

- Allow environmental water to be used more effectively,
- Be designed, implemented and operational within agreed timeframes.

This project is not part of a 'pre-existing' Commonwealth funded project and has not already been approved for funding by another organisation with in full or in part. Where there is overlap in project work between existing core business of proponents and the Commonwealth, funding has not been sought. Project work beyond core business has been identified and budgeted accordingly. Funding is being sought from Commonwealth supply measure funding.

The costs to implement this work is projected to be [redacted] over seven years (Appendix 5 – Detailed Cost Summary). The identified costs are for works and measures over and above the core business of state agencies.

The value of this proposal lies in integrating and building on a number of parallel areas of work (see Figure 2). Supporting an effective program management and coordination process (this proposal), will guarantee that all components of the work will be adequately progressed, in order to achieve the scale of the environmental and SDL outcome described by the interim SDL modelling work. Outcomes of the Constraints management projects will involve significant outlays that a hydrologic cues delivery option has significant dependency on.

It is proposed that there will be an independent project management team that will coordinate the delivery of the proposal on behalf of the states and provide oversight and ensure project milestones are met, as outlined in section 8. Effective coordination and integration will also involve the commitment of staff time and resources from Commonwealth and state government agencies. Where this aligns with these agencies core business, existing budgets may already cover this participation. However, given the large potential SDL offset being considered through this proposal, the scale of measures proposed, and timeframes for implementation, additional funds are needed to implement the full work program. Additional resources will be required for state proponents to:

- Add value to existing policies and programs already in progress
- Deliver a systematic approach to integrating a number of improvements across environmental water delivery and river operations
- Achieve a greater level of stakeholder engagement and coordination.

The costs outlined in Table 3 represent an estimated budget for work over and above existing commitments and core business including:

- Ecological and hydrological research and investigations (linked to river operations)
- Strategy development
- Technical and modelling work
- Development of new forecasting, modelling, decision support and risk mitigation tools
- Stakeholder and community engagement
- Program evaluation and assessment, and
- Potential increased monitoring and gauging requirements.

There will be extensive stakeholder engagement, led by respective jurisdictions, with a focus on jurisdictional entities involved in environmental watering and those affected by changes to river operations outside of Constraint Measures e.g. catchment management authorities etc. The program will also require a level of broader community engagement which will be coordinated with/complementary to engagement planned for the Constraint Measures projects. Coordination will prevent duplication and provide considerable efficiencies.

In this proposal it is assumed that asset-scale condition and intervention monitoring and basin-wide condition monitoring will continue via joint venture funding and Commonwealth funding. This includes The Living Murray icon site monitoring, and the Commonwealth Environmental Water Holder's long term intervention monitoring program. However, there will be a need to evaluate delivery of this proposal and to specifically assess the ecological outcomes from a hydrological cues delivery strategy and an additional [redacted] of monitoring, investigations and research funds would be required.

The later phases of the work program may require the investment in physical and technological upgrades to help facilitate enhanced environmental water delivery. Methods to improve streamflow gauging and forecasting will enable environmental water managers and river operators to have increased confidence and accuracy in delivering flows on top of unregulated events. There may be an additional cost associated with overbank flows delivery on top of existing monitoring networks. Research and development and infrastructure costs could be shared between Constraints Management Measures proposals and enhanced environmental water delivery, where this issue is partially addressed. Constraints business cases currently contain infrastructure development costs.

Table 3 provides a breakdown of costs according to the phases of each measure. There are significant aspects of this work already being undertaken by state organisations. Table 4 provides a breakdown of in-kind contributions. For a detailed cost summary, including deliverables of each activity, please refer to Appendix 5 – Detailed Cost Summary.

Table 3: Summary of program costs

Timelines	Phase	Activity	EEWD 1	EEWD 2	EEWD 3	EEWD 4	EEWD 5
2017-2018	Phase I	Review	Business as usual	Business as usual	Business as usual	Business as usual	Business as usual
	Phase IIa	Consultation and reviews	[redacted]	Business as usual	Business as usual	Business as usual	Business as usual
2018-2020		Research and Investigation	[redacted]	[redacted]	[redacted]	[redacted]	Business as usual
		Evaluation					[redacted]
2020-2023	Phase IIb	Implementation of review recommendations, report outcomes	[redacted]	[redacted]	Business as usual	[redacted]	[redacted]
		Evaluation Implementation					[redacted]
2023	Phase III	Evaluation	Business as usual	Business as usual	Business as usual	Business as usual	Business as usual
		Sub Totals	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Subtotal of work measures							[redacted]
Communications and Engagement							[redacted]
Program Delivery							[redacted]
Ongoing Program Management							[redacted]
Subtotal Project Management							[redacted]

Contingency [redacted]	[redacted]
Grand Total (incl. contingency)	[redacted]

Table 4: Jurisdiction in-kind contributions

Timelines	Phase	Activity	EEWD 1	EEWD 2	EEWD 3	EEWD 4	EEWD 5
2018-2020	Phase IIa	Research and Investigation & Consultation and Review	[redacted]	[redacted]	[redacted]	[redacted]	
			[redacted]	[redacted]	[redacted]	[redacted]	
2020-2023	Phase IIb	**Implementation of review recommendations, report outcomes**	[redacted]			[redacted]	[redacted]
			[redacted]			[redacted]	[redacted]
States Total			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
MDBA Total			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*FTE – Full Time Equivalent

2.8 Eligibility

The activities identified as being above core business have not received funding from any other source. The measure is a new measure.

This measure will achieve equivalent environmental outcomes with a lower volume of held environmental water than would otherwise be required and without detrimental impacts on reliability of supply of water to holders of water access rights. Modelling conducted to date provides evidence that the EEWD proposal has the potential to be a supply measure. The proposal links to three SDL project categories, operating rules changes with clear dependencies on physical constrain measures, and operational and management constraint measures.

The governance and project management plan identified in section 8 provides evidence that it is able to be operationalised by 30 June 2024. The measures outlined in this proposal were not in the benchmark conditions of development. Therefore this proposal is eligible as an SDL adjustment supply measure.

2.9 Proponents

The proponents for this proposal are the Governments of Victoria, New South Wales and South Australia. Project implementation and governance will be jointly managed by the MDBA and the proponents. Further detail is identified in the governance and project management in section 8.

In agreeing to this proposal, Basin governments and statutory authorities commit to working together in good faith to implement priority recommendations that arise from the five measures identified in this proposal. Governments will act to implement the hydrological cues delivery strategy as developed by this proposal. This will include assessing actions on the basis of transparent criteria agreed by jurisdictions; managing risk; and working collaboratively to meet the requirements of all jurisdictions.

3 Environmental benefits of the EEWD proposal

3.1 Ecological values of the southern connected Murray Darling Basin.

The EEWD proposal is expected to deliver greater connection along rivers, and between river channels and their floodplains across the southern connected basin, as well as more efficient use of environmental water for targeted site watering as illustrated in a recent trial by CEWH (Campbell, Coote, Foster, Johnson, & Sloane, 2016). Accordingly, both instream and floodplain ecological values, objectives, benefits and potential adverse effects, are noted here. The measure includes the major regulated rivers and key environmental assets of the southern connected Murray-Darling Basin: the Murray, Goulburn, Murrumbidgee and Lower Murray as outlined in Table 5 and shown in Figure 4.

In addition to the large number of individual site assets, and wetlands of national and international importance, the southern connected basin should also be considered in its entirety. In NSW, the Lower River Murray aquatic ecological community is listed as an endangered ecological community. The Lower Murray Endangered Ecological Community includes all native fish species and aquatic biota within all natural creeks, rivers and associated lagoons, billabongs and lakes of the regulated portions of the Murray, Murrumbidgee and Tumut rivers, as well as their tributaries and branches (NSW DPI, 2007). The Lower River Murray and associated wetlands, floodplains and groundwater system from the junction of the Darling River to the Sea is recognised as a highly dynamic and connected system. Appropriate hydrological connectivity within this system is essential to its long-term health (Department of Environment, Heritage and Water, 2013)

Table 5: Summary of ecological values of the southern connected basin as described in the assessments of environmental water requirements.

Location	Description
River Murray	
River Murray Channel. Further details and the environmental water requirements (EWRs) are outlined in MDBA (2012i) and (DEWNR, 2015)	The River Murray Channel is the main artery of the river. Extending over 2,000 km from the Hume Dam in Victoria to Wellington in South Australia, the channel links the forests, floodplains, wetlands and estuaries along the River Murray. It provides habitat for many native plants, fish and animals, while its banks support river red gum forests of high natural and cultural value.
Barmah–Millewa Forest. Details and EWRs refer MDBA (2012c).	The Barmah–Millewa Forest icon site is the largest river red gum forest in Australia. Located in New South Wales and Victoria, the forest covers 66,000 ha of wetlands, and is a significant breeding site for waterbirds and an important native fish habitat.
Gunbower–Koondrook– Perricoota Forest. Details and EWRs refer MDBA (2012e).	Gunbower–Koondrook–Perricoota Forest icon site consists of two forests that together comprise Australia's second largest river red gum forest (~50,000 ha). It is home to many threatened native plants and animals, and its wetlands are important breeding places for waterbirds and native fish.
Hattah Lakes. Details and EWRs refer MDBA (2012f)	The Hattah Lakes icon site forms part of the 48,000 ha Hattah–Kulkyne National Park. Located in Victoria, this icon site includes over 20 semi-permanent freshwater lakes that support river red gum communities, waterbird breeding habitat and a variety of native plants and animals.
Chowilla Floodplain and Lindsay– Wallpolla Islands. Details and EWRs refer MDBA (2012k)	The Chowilla Floodplain component of this icon site covers over 17,000 ha across New South Wales, Victoria and South Australia. Because of its remote location, Chowilla retains much of its natural character. Included in this icon site are the Lindsay–Wallpolla Islands, including Mulcra Island, and their floodplains. Together this part of the icon site covers almost 20,000 ha and supports many threatened native plants, animals and fish species.
South Australian River Murray floodplains (DEWNR, 2015)	The floodplains of the lower Murray River include two Ramsar-listed Wetlands; the Riverland Ramsar Site and Banrock Station Wetland Complex. Inundated at flows of between 40,000 and 80,000 ML/day, the floodplains include 40 plant species that are state-listed, and 50 protected fauna species, including frogs, fish and waterbirds.
Lower Lakes, the Coorong and Murray Mouth. Details and EWRs refer MDBA (2012j)	The CLLMM is in South Australia and is where River Murray meets the Southern Ocean. Covering over 140,000 ha, it includes 23 different wetland types that range from very fresh water to saltier than the sea. As a complex estuarine environment, this site is one of 10 major Australian havens for large concentrations of wading birds and is recognised internationally as a breeding ground for many species of waterbirds and native fish. The site is listed under Ramsar and it also an icon site under The Living Murray program.
Goulburn River Lower Goulburn River (in-channel flows and associated floodplains)/ Details and EWRs refer MDBA (2012h)	The Goulburn River is the largest Victorian tributary of the River Murray. Detailed ecological values are in the Goulburn Constraint Measure Business Case – Phase 2 Investigations (DELWP 2016). The Lower Goulburn River from downstream of Goulburn Weir to the confluence with the Murray includes about 13,000 ha of DIWA listed floodplains supporting a range of flood-dependent vegetation communities while the river and floodplain support significant fauna species including nine fish species listed under the FFG Act (1998) and/or the EPBC Act (1999).

Location	Description
Lower Murrumbidgee River Mid-Murrumbidgee wetlands Details and EWRs refer MDBA (2012l; Wallace, et al., 2011). Lower Murrumbidgee River Floodplain. Details and EWRs refer MDBA (Assessment of environmental water requirements for the proposed Basin Plan: Lower Murrumbidgee River Floodplains, 2012m)	The Murrumbidgee catchment is home to two wetlands of national importance, the Mid-Murrumbidgee Wetlands and the Lower Murrumbidgee Floodplain. The lower Murrumbidgee River downstream of Wagga Wagga, and in particular the lower reaches around Balranald support the most intact native fish populations compared to other elements of the system (MDBA, 2012n). The Mid-Murrumbidgee Wetlands include an assemblage of lagoons and billabongs with a total area of wetlands periodically connected to the main channel is around 5,000 ha. This area includes habitats critical to several fish species in the Murrumbidgee (Gilligan, 2005). Around 200,000 ha of the Lowbidgee floodplain wetlands are listed in the Directory of Important Wetlands in Australia (DIWA).
Lower Darling River System. Details and EWRs refer MDBA (Assessment of environmental water requirements for the proposed Basin plan: Lower Darling River System, 2012o)	The Lower Darling River system encompasses Menindee Lakes, the Darling River anabranch and the Lower Darling River as well as Kinchega National Park. Menindee and Cawndilla lakes are considered important waterbird habitat are listed in DIWA (MDBA, 2015). The Great Darling Anabranch and its associated lakes is an important ecological asset, is listed in DIWA and are highly significant in terms of their contribution to terrestrial and biodiversity value.

3.2 Ecological objectives and targets

A natural cue may be a change in water level (including natural drying sequences), river flow (including velocity, volume, and duration), water temperature or carbon and nutrient input as a result of local rainfall or inflows. Natural cues are more likely to trigger ecological processes such as fish spawning, waterbird nesting or frog breeding (Department of the Environment and Energy, 2016). In this proposal, the hydrological cues component of the enhanced environmental water delivery refers to the timing of flow releases to coincide with natural increases in flow. In conjunction with relaxing constraints to improve connectivity within channel, and with low to middle level floodplains and habitats, there is a much greater chance of meeting the objectives and targets under the 2012 Basin Plan (Table 6). These are linked to the Basin Plan's Environmental Watering Plan objectives and the system-wide environmental water requirements targets as well as the site specific ecological targets for each site, and site or reach based environmental flow plans. It is recognised that these targets will be, or have been, updated as more information becomes available through a process of adaptive management (and are included in measures 1 and 5 of this proposal).

Table 6: Basin Plan targets and outcomes.

Source	Relevant target or outcome
Basin Plan, Schedule 7: Long term targets for flow regime and hydrological connectivity including:	
2a	flow regimes which include relevant flow components set out in paragraph 8.521(1)(b) (III) high-flow-season baseflows (v) high-flow-season freshes (vi) bank-full flows (vii) over-bank flows and in particular 8.51 (1) (d) be within the range of natural flow variability and seasonality.
2b	hydrological connectivity between the river and floodplain and between hydrologically connected valleys.
By improving these flow regimes and connectivity, improvements in ecological Basin Plan targets including:	
2c	river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions
2d	condition of the Coorong and Lower Lakes ecosystems and Murray Mouth opening regime
2e	condition, diversity, extent and contiguousness of native water-dependent vegetation
2f	recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates
2g	the community structure of water-depended ecosystems
Basin Plan, Schedule 5 enhanced environmental outcomes	
2a-e	A range of outcomes related to the CLLMM including (in summary) a) Reducing salinity levels b) Meeting water level targets for the Lower Lakes c) Meeting opening targets for the Murray Mouth d) Meeting salt export targets from the MDB e) Increasing barrage flows for fish migration
2f	providing opportunities for environmental watering of an additional 35,000 ha of floodplain in South Australia, New South Wales and Victoria, improving the health of forests and fish and bird habitat, improving the connection to the river, and replenishing groundwater; and
2g	Achieving enhanced in-stream outcomes and improved connections with low to middle level floodplain and habitats adjacent to rivers in the southern Murray-Darling Basin.

The Basin-wide Environmental Watering Strategy (BWS) identifies maintaining vegetation, wetlands and waterbirds as important outcomes; and identifies overbank flows, with water volumes greater than the channel capacity, as important to "recharge wetlands and important for floodplain vegetation, fish and waterbirds, as well as productivity." In addition, the BWS identifies the importance of using environmental water to mimic natural patterns as this is "most likely to produce desired environmental responses" (MDBA, 2014). The proposal aligns with the river flows and connectivity outcome of "improved connectivity with bank-full and/or low floodplain flows by 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne." (MDBA, 2014). Better coordinated and aligned flows have the potential to provide higher peak flows to the lower River Murray with the same amount of environmental water (MDBA, 2016).

The EEWD proposal with relaxed constraints aims to restore ecosystem connectivity between the Murray River, its tributaries, its surrounding floodplains, and through to the sea, which has been identified as one of the 2014-15 environmental watering priorities. “Connectivity in the River Murray System: improve riparian, littoral and aquatic vegetation (e.g. *Ruppia tuberosa*) and native fish populations by increasing ecosystem connectivity through coordinating water delivery in the River Murray system.” (MDBA, 2014h).

The BWS identifies that ‘environmental water managers must and do consider their impact on water quality for other downstream uses. They must have regard to water quality targets for dissolved oxygen, cyanobacteria and salinity levels when making decisions about the use of environmental water’ (MDBA, 2014). Over time, delivering higher flow pulses in a more natural watering regime may also help to deliver on the water quality objectives of the Basin Plan.

3.3 Anticipated ecological benefits

Ecological benefits from a hydrological cues delivery approach have already been demonstrated from watering trials and natural events. From June to October 2015 hydrological cues were used to inform the delivery of Commonwealth environmental water in the River Murray (Department of the Environment and Energy, 2016) as part of multi-site trials seeking continuous improvements in river operations. Environmental water releases from Hume Dam were triggered by rainfall events and local runoff with the aim to pass a proportion of what the natural flow downstream would have been if the dam was not present. Releases were managed below existing delivery constraints (regulated flow limits) to ensure there were no third party impacts. The flows contributed to growth of Moira grass and other aquatic vegetation, supported breeding of water birds and provided opportunity for fish spawning (Campbell, Coote, Foster, Johnson, & Sloane, 2016). The flows also provided further downstream benefits supporting outcomes including fish movement along the length of the River Murray, restoration of flow seasonality and mimicking the natural flow variability. The use of hydrological cues for the delivery of Commonwealth environmental water resulted in greater automation and efficiency of the delivery of environmental flows with less need for an exchange of information or negotiation between the CEWO and MDBA’s river operators (Campbell, Coote, Foster, Johnson, & Sloane, 2016).

These examples build on other translucency and transparency rules that have been used in a range of systems in Australia (Growns & Reinfelds, I, 2014) and overseas. The purpose of these types of flows are to (re)create environmental flow regimes that seek to protect or restore the natural range of low flows, flow pulses and moderate flows on the ecological basis that riverine biota are adapted to the historical flow regimes. A direct translucency approach has been criticized as it may fail to provide threshold events, particularly small to moderate size flood events, necessary for ecological functioning (Poff, et al., 1997). Furthermore, it has been suggested that the reliance on quantified flow targets alone cannot account for the high level of dynamics, heterogeneity and ecosystem modification in the Murray Darling Basin (Capon & Capon, 2017). Despite this, there are some clear thresholds such as water depths for *R. tuberosa* reproduction in the Coorong or for particular colonial nesting waterbirds in wetland habitats that are well documented. Hence a combination of a hydrological cues approach, as well as targeted watering and relaxed constraints to allow for small to moderate size flood events, is likely to provide the greatest benefit to a highly modified system.

Overall, better coordinated and aligned flows from a number of upstream tributaries can result in higher peak flows to the lower Murray River channel with the same amount of environmental water (MDBA, 2016). Throughout the southern basin, key environmental assets downstream of target reaches benefit from increased flows, and from the connectivity between the Murray and its major tributaries. Increased flows and connectivity benefit riparian vegetation, wetlands and low lying floodplain habitats, fish populations, and productivity (Table 7). The expected outcomes are based on best available information, proof of concept modelling and with respect to draft proposals under the Constraint Measures business cases. An update may be required following resolution of constraint relaxation issues and final modelling has been completed. There is also a body of research and review identified in this business case (measure 1) that assesses and builds on our current knowledge, and in measure 5 through monitoring and evaluation frameworks and throughout all measures as a process of adaptive management.

Monitoring and evaluation principles and responsibilities are outlined in Chapter 13 of the Basin Plan. The key evaluation questions that are relevant to this proposal are the extent to which the objectives, targets and outcomes set out in the Basin Plan have been achieved (Table 6) and what, if any, unanticipated outcomes have resulted from the implementation of the Basin Plan. Schedule 12 of the Basin Plan outlines the responsibilities of reporting including Matter 7 (the achievement of environmental outcomes at a Basin scale) which are the MDBA and CEWH, and Matter 8 (the achievement of environmental outcomes at an asset scale) which is the Basin States. Matter 9 (identification of environmental water and the monitoring of its use) is also relevant and responsibility is with all jurisdictions (MDBA, CEWH and the Basin States). This proposal requires a review of the information collected, and may require further monitoring effort in relation to the environmental outcomes at basin or asset scales specifically related to the hydrological cues delivery strategy within enhanced environmental water delivery. This monitoring is beyond existing monitoring coordinated via joint venture funding and Commonwealth funding. In particular hydrological and ecological outcomes from a hydrological cues delivery strategy may be required to be specifically assessed, in which case additional monitoring effort may be required (costs identified in section 2.7).

Table 7: Summary of key anticipated benefits of enhanced environmental water at the reach scale (MDBA, 2014i; MDBA, 2015; NSW DPI, 2016; NSW DPI, 2016; MDBA, 2012o; DEWNR, 2015). This table was prepared using proof of concept modelling and with respect to draft Constraint Management proposals. An update may be required following resolution of constraint relaxation issues and final modelling has been completed.

Reach	Benefits at reach scale
Hume to Yarrawonga	Increased inundation of river red gum, black box and identified wetlands. Improved flow variability.
Yarrawonga to Wakool (includes Barmah-Millewa Forest, Gunbower-Koondrook-Perricoota Forest and Werai Forest plus over 3000 wetland and creek systems)	Enhanced growth and reproduction of vegetation communities, increased support for bird and fish breeding, more effective transfer of carbon and nutrients, more frequent flushing out of sediments, salts and alkaline water from deeper holes in the river systems.
Goulburn River downstream Goulburn Weir	Increased regulated flow limits would water almost 12,000 ha of Goulburn floodplain. This includes almost all of the wetlands and a significant area of floodplain forest in the Lower Goulburn National park. Anticipated benefits include improved watering outcomes for 2,075 ha of wetlands and 7,700 ha of native vegetation on the lower Goulburn floodplain. The Constraint Measures would also contribute to improved ecological outcomes for fish and birds.
Murrumbidgee (including Lowbidgee)	At flows of 40,000 ML/d at Wagga Wagga, approximately 10,000 ha of wetland and approximately 44,000 ha of floodplain vegetation (including river red gum, black box and shrublands including lignum) could be watered. Flow pulses can also stimulate longitudinal as well as river-floodplain movement of adult and juvenile fish for spawning, dispersal and access to habitat. Vegetation communities also provide habitat and food for waterbirds and other fauna.
Lower Darling	The Lower Darling is expected to benefit with increased environmental flows to the Lower Darling as well as the Darling Anabranch. An increase in the frequency of SFIs for this system are significant and likely to support native riparian, floodplain and wetland vegetation, waterbird habitat and recruitment opportunities for a range of native aquatic species.

Reach	Benefits at reach scale
South Australian Murray The Floodplain priority environmental asset (Priority Environmental Asset) The Channel PEA	Increased duration and frequency of flows in the 10,000 to 40,000 ML/day range to meet a range of targets for the Channel PEA. This is expected to support ecosystem processes; restore the distribution of native fish including resilient population of Murray cod, golden perch and silver perch, freshwater catfish and foraging generalist fish species; and improve flood dependent and macrophyte communities in wetlands inundated by flows up to 40,000 ML/day. An increase in flows in the range of 40,000 to 80,000 ML/day is required to provide for ecosystem processes on the floodplain PEA and maintain viable river red gum, black box, river cooba and lignum populations; as well as establishing and maintain diverse water dependent vegetation in aquatic zones and on the floodplains inundated by these flows. These flows will help to restore fish communities and provide frog and waterbird habitats. Proof of concept modelling suggest that EEWD using hydrological cues alone may not provide increased flows for the floodplain PEA. This requires further investigation and assessment in EEWD measures 1 and 5, and may require further demands to meet these outcomes.
Coorong, Lower Lakes and Murray Mouth	The LTWP identifies that increased flows would provide better water quality and habitat conditions for foraging generalists and diadromous species of fish which are present in the lower lakes and Coorong, as well as the recruitment of flow dependent specialists in the lower lakes. Connectivity with the Murray Mouth are important for estuarine dependent species which are widespread and abundant in Coorong. Flow dependent specialists common in lakes and recruitment will occur. Improved water levels in the south Lagoon can assist water-dependent vegetation including *R. tuberosa*. *R. tuberosa* will germinate in late autumn and will replenish the propagule bank if flows persist until spring/summer. Improved flows is also expected to reduce salinities and weaken the salinity gradient. Proof of concept modelling indicates that EEWD using hydrological cues does not breach the limits of change for the Coorong if used in combination with targeted site watering in dry years. However, more work is required through EEWD measure 1 and 5 to ensure better outcomes are achieved (e.g. water level targets, both water height and seasonality, are sufficient for *R. tuberosa* recovery).

3.4 Potential adverse ecological effects

This section outlines the risks associated with accurately understanding, predicting and delivering ecological objectives at the site, within the reach and to downstream locations. (see also Appendix 4).

The CEWH has set out a Framework for Determining Commonwealth Environmental Water Use. Under the framework environmental watering should have regard to the potential environmental risks, including downstream environmental risks, which may result from applying environmental water; and measures that may be taken to minimize those risks (Commonwealth Environmental Water Office, 2013). Potential environmental risks include things like the possibility of hypoxic blackwater events, salinity, and the spread of pest flora and fauna. These risks and issues are considered for all environmental watering, but are especially important to consider for overbank environmental watering events, as higher flows could exacerbate some of these risks. The risks of adverse environmental effects from higher flows are described in detail in the Constraint Measures business cases, and therefore are not described here.

A shift to using more environmental water in the winter/spring months could have an effect on water availability for those ecological elements that rely on flows outside this period. Modelling has indicated that this is unlikely to eventuate given the natural variability of flows and that not all water will be used by the hydrological cues delivery strategy. Further, this proposal provides one option for environmental water delivery. It will remain the discretion of environmental water holders to use their water using a hydrological cues delivery strategy or to use it for specific or targeted events (such as pumping to wetlands) or for late season watering. There is also a need to consider drying phases and operation of weirs and other structures for specific asset sites. In weighing up all water use decisions, environmental water holders consider the opportunity cost of using water and the need to maintain reserves for different uses. Measure 1 is expected to further explore any risk of adverse environmental outcomes, and identify mitigation strategies, from providing an enhanced ability to use hydrological cues for watering.

Modelling has been undertaken to test the environmental outcomes that could be achieved from the hydrological cues delivery strategy (MDBA draft modelling report, in prep). The 'proof of concept' modelling provides an estimate of what outcomes are possible and are only indicative. Real hydrological outcomes are a product of climatic conditions and the decisions of environmental water holders in the future. The modelling has examined the environmental outcomes as changes to the average ecological elements scores (Overton IC, 2015) and the Site-specific Flow Indicators (SFIs) as well as determining if the proposal compromises any of the limits of acceptable change outlined in Schedule 6 of the Basin Plan. More details on the model assumptions are in section 4.4.

Any SDL adjustments are based on achieving equivalent environmental outcomes as defined by the Basin Plan using less environmental water. The Ecological Elements method compares any SDL proposal model run with the benchmark model to demonstrate equivalence. In the most recent 'proof of concept' modelling of the EEWD scenario (using Yarrawonga 50,000 ML constraint relaxation and including Murrumbidgee, Lower Darling and Goulburn Rivers), the ecological elements score increased slightly over both the benchmark score, and the 19-pack model option. SFIs have been determined for 60 sites throughout the southern connected basin that are relevant to this proposal. Modelling has shown that overall there is a small increase from 38 targets met in the benchmark model to 40 in the EEWD scenario.

In early investigations there were some adverse impacts for SFIs in the Lower Lakes. Basin Plan modelling is largely driven by environmental demand placed at SFIs sites. Environmental outcomes along the length of the river Murray, including the Lower Lakes depend on these demands (pattern, peak, period and frequency). Basin Plan target frequency and duration of flows at SA border for Chowilla SFI. As per the targets, environmental demand for the Chowilla floodplains provides environmental flow to SA ranging from 70-80% of years at 20,000 ML/day to 5% of years for flows of 125,000 Ml/day. This means the driest 20% of years are not targeted specifically by the hydrological cues delivery strategy alone. These dry years are the ones that require targeted environmental water if the target frequency for Lower Lakes of 95% to 100% of years is to be achieved as per the Basin Plan. This application of targeted watering in some of the drier years applies to many of the icon and asset sites and is current practice for environmental water managers and is expected to continue into the future.

With this context, additional environmental demand is included in the latest EEWD scenario modelling for the Lower Lakes in the driest 15% of the years (excluding some extremely dry years). This is a low flow demand and not limited to any season, winter-spring or summer-autumn. The demand triggers based on the probability of three-monthly rolling without development flow to SA and may range from 5,000 to 18,000 ML/d at SA border depending on the without development flow conditions. As part of measure 1 these demands will be further explored and refined and management strategies developed as part of the overall EEWD approach.

Despite the availability of held environmental water (HEW), the majority of environmental water is planned environmental water (PEW) including account based, which may have some of the characteristics of HEW, and passive environmental water. Passive planned environmental water 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 (compared to PEW that delivers, for example, minimum daily flow targets in regulated systems). Much of this passive component of PEW occurs as unregulated flow via spills from storages or from tributaries downstream of storages. PEW is important in terms of the environmental outcomes achieved for higher floodplains and as a source of streamflow variability. Enhanced environmental water delivery modelling does indicate that there may be a reduction in the frequency of spills from Hume Dam and Lake Eildon compared to benchmark while there may be a slight increase in the frequency of spills from Menindee Lakes System and the Murrumbidgee storages however there is a reduction in the average annual spill volume for all storages. Reduced spills (frequency and volume) can be an adverse outcome for higher level floodplain ecosystems (beyond the managed floodplain areas under relaxed constraints) and possibly for volume based outcomes such as those required for the Coorong and Murray Mouth. This is a potential ecological trade-off between supporting more frequent managed watering of inner floodplain habitats to improve their resilience and health, versus relying on unpredictable episodic spills to water these lower level floodplains as well as the mid- and outer floodplain habitats. This trade-off needs to be better understood (this will be an important part of measure 1) with mitigation strategies put in place to manage any adverse ecological outcomes, particularly for sites of ecological significance.

As a result it is proposed that these issues outlined above are actively examined as part of EEWD measure 1 and development of the hydrological cues delivery strategy to determine what real world cues or management approach is needed to address any adverse effects and to support environmental outcomes.

This proposal includes a number of measures which provide an adaptive framework to build on current knowledge. It is anticipated that the measures will be implemented over a period of time. Conducting further multi-site trials will increase the knowledge and understanding of operating the southern connected system using hydrological cues delivery strategy with relaxed constraints. This gradual implementation will also help identify, and ameliorate possible adverse ecological effects.

4 Current hydrology and proposed changes to the hydrology

4.1 Hydrology of the southern connected basin

The hydrology of each component of the southern connected basin is outlined in detail in relevant Constraint Measures business cases. Below is a brief summary of the hydrological characteristics of the system.

The upper Murray is a major contributor of the flow in the Lower Murray. Prior to river regulation, the Hume-Yarrawonga stretch of the River Murray would have experienced peak flows in winter and early spring, and low flows in summer. Hume Dam now captures high flows in winter and spring, with peak irrigation demand causing high releases downstream during summer and autumn to supply irrigation water locally and further downstream (MDBA, 2014d).

From Yarrawonga to Wakool junction, the hydrology is complex and higher flow and flood events are highly variable (NSW DPI, 2016). Variability is related to the number of large tributaries that can provide inflows to the reach and the complex interactions between the connected creeks, flood runners and vast floodplains within the Edward-Wakool River systems.

The Goulburn River is a major regulated tributary of the Murray, joining the Murray upstream of Echuca, and downstream of Barmah-Millewa Forest. Flow in the Goulburn River is highly modified by Lake Eildon and Goulburn Weir. Lake Eildon fully regulates downstream flows in all but very wet years and the frequency of overbank flows is now less that what is needed to maintain the health of the lower Goulburn floodplain and river channel (DELWP, 2016). Immediately downstream of Lake Eildon, higher flows predominately occur in summer and autumn due to releases to meet irrigation and other consumptive demands. Downstream of Goulburn Weir and major irrigation diversions, the river has lower summer flows and retains some natural seasonal flow pattern due to influence of its tributaries.

The Murrumbidgee is a major regulated tributary of the River Murray, joining downstream of the return flows from the Edward-Wakool system. This area supports the Junction Wetlands which are an extensive area of distributary creeks and other wetlands. The headwaters of the Murrumbidgee are regulated by a number of dams including Burrinjuck and Tantangara, and Blowering on the Tumut River (NSW DPI, 2016). Similar to the Goulburn and Murray itself, flows are highly modified, with reversed seasonality of flow and reduced variability below the dams.

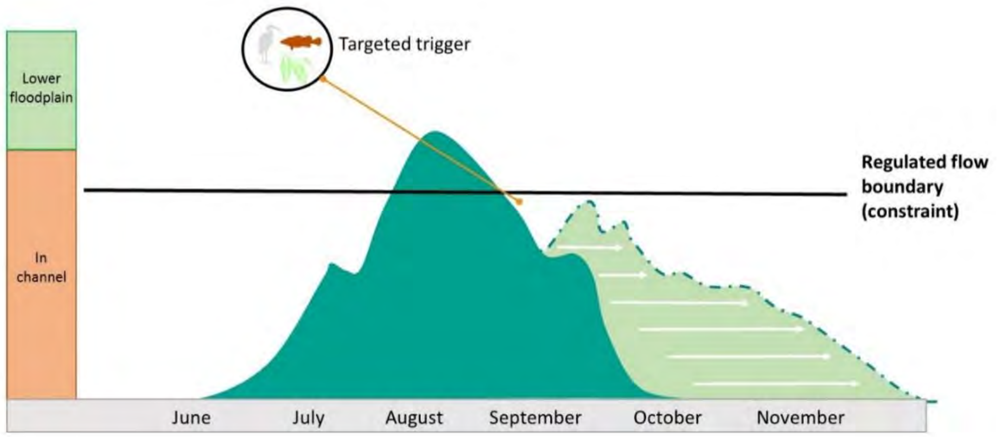
The Darling River enters the River Murray near Wentworth and is the major tributary of the River Murray downstream of the Murrumbidgee. The water that flows into the Menindee Lakes system comes from the rivers that flow south from southern Queensland and northern NSW. Flows in the Darling are driven by episodic and variable rainfall events, as well as summer storms (MDBA, 2014c). The Menindee Lakes storage scheme has reduced the flows to the Lower Darling, all but eliminating small floods and reducing the frequency and duration of moderate floods. The results of regulation and abstractions throughout the system have reduced mean annual flows in the Darling River by more than 40% and changed both the seasonality and variability of flows.

The cumulative effects of river regulation in the southern connected basin has significantly reduced the occurrence and magnitude of medium and small flows to South Australian River Murray. The CSIRO (2008a) found that as a result of water resource development, the average period between beneficial spring-summer overbank flows has more than tripled from 2.4 years to 9.3 years. On average, flows through the system to the Murray Mouth have been reduced by 75%.

In 2012 an analysis of the key attributes of high flows in the southern connected basin was undertaken. Significant inflows are required from at least 3 of the 4 major valleys (Upper Murray, Goulburn, Murrumbidgee, and Lower Darling) to target events (ie 50,000 to 80,000 ML/day) to occur downstream of Euston. These larger events tend to be the culmination of multiple events (or peaks) across multiple valleys. The initial events pre-wet the upstream wetlands, forests and floodplains, so that subsequent events pass through more quickly and with less “loss”. Environmental water delivery can only achieve higher targets when topping up existing (or forecast) moderate to high flows in the major valleys. Currently the major storages are generally in filling/storing mode in winter/spring when natural events would otherwise have occurred, removing significant volumes of inflows from the missing events. Hence there is a focus to both relax constraints to allow larger flows where environmental water can build on natural events, and to target flows when natural events typically occur, that is mostly in the winter/spring period.

4.2 River flows with enhanced environmental water delivery

Natural flow regime is understood to be critical in maintaining ecosystem integrity and services (Poff et al., 1997). The hydrological cues approach attempts to re-establish some elements of the flow regime that have been reduced or lost due to regulation of river flows for consumptive uses. This proposal has a particular focus on allowing rivers to connect with their floodplains by allowing higher regulated flows (Figure 5).



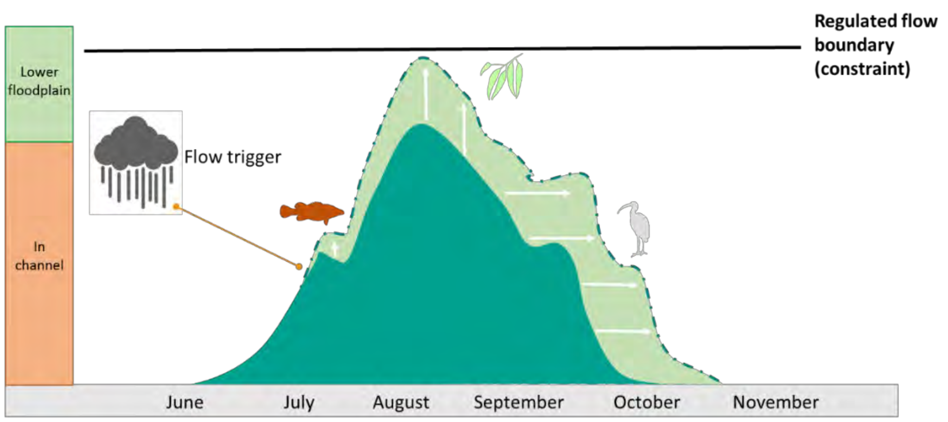


Figure 5: Conceptual diagrams of current environmental water delivery with regulated flow boundaries (constraints) (top) and proposed environmental water delivery with relaxed flow boundaries and ability to deliver on top of the peak of the hydrograph (bottom). Dark green indicates flow without environmental water, while the light green indicates environmental water.

The approach can also reconnect the southern connected basin, as well as water key environmental assets, as environmental flow releases can be triggered from multiple tributaries in response to hydrological cues. By reconnecting the southern connected basin and relaxing constraints, there are a number of potential benefits during moderate flow events. These include increased travel times, cumulative flow and environmental benefits (demonstrated through a number of trials and the 2012 river operators workshop) (Figure 6).

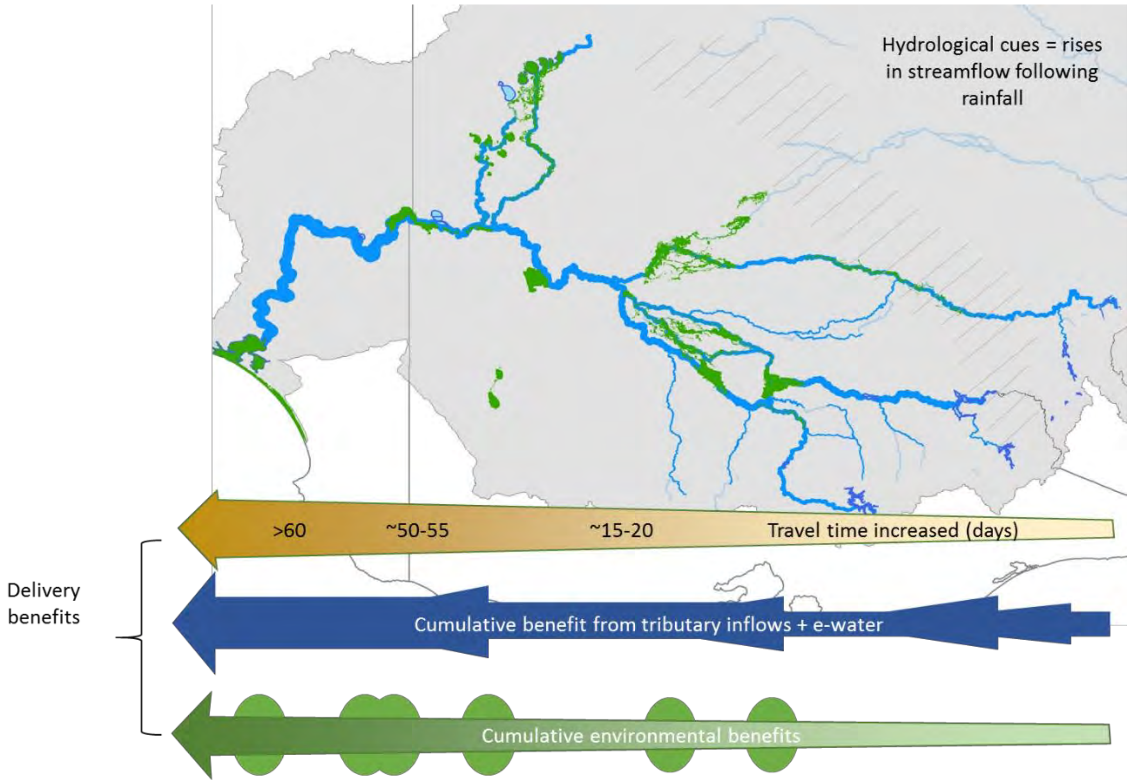


Figure 6: Benefits of operating a southern connected basin system in sync with hydrological cues

In planning for releases using enhanced environmental water deliveries, consideration is given to the seasonal conditions (Figure 1). Large environmental flows are not required every year, and particularly not in very dry years as the priorities for environmental watering will be very different under dry conditions. Similarly decisions are likely to be different in very wet years as environmental needs may be met naturally.

Modelling has been undertaken to investigate the EEWD concept and its capacity for an SDL adjustment. This modelling represents a "proof of concept" and it is recognised that the operational approach will need to be refined and this is the focus of the measures outlined in this proposal. The model is not an operational tool, but provides some guidance as to the climatic and flow conditions in which EEWD is one of the options available for environmental water holders.

The final model report (MDBA in prep) outlines the assumptions about the specific hydrological condition in which the EEWD is modelled and how the flow demands are calculated in the model environment. The Constraint Measures specifically target wetter than average years but not the wettest 5-10% of years (depending on the system) as this is where small overbank flows will typically occur. The EEWD proposal provides environmental water holders with the option to additionally target moderate dry to moderately wet years using the hydrological cues delivery strategy, but does not propose applying the hydrological cues delivery strategy in the driest 10-20% of years. In EEWD, the hydrological cues targeted are also seasonal, mid-June to mid-November at Yarrawonga, July to November at Torrumbarry and Euston and between August and the end of November at the South Australian border (MDBA, 2016), with some additional targeted environmental demands in other seasons or in drier years.

The enhanced environmental water delivery with relaxed constraints scenario modelling (see section 4.4 for model assumptions and limitation) results in overall increase in the frequency of site-specific flow indicators (SFIs) compared to the benchmark model for a 600 GL SDL offset and a more variable flow regime for overbank flows. Full results are detailed in the modelling report (MDBA in prep) and in appendix 6. The modelling is indicative only and does not necessarily reflect the range of options that managers delivering water for the environment might choose given climatic conditions and continued learning through adaptive management. The relaxed constraints in the model are also at the upper end of the range and implementation is likely to be staged over a number of years. Indicative changes indicted by the modelling include:

- Potential of approximately 600 GL SDL offset for the EEWD scenario compared to approximately 400 GL for the 19-pack scenario.
- An increase in the average ecological elements score (compared to the benchmark) of 132 for the EEWD scenario compared to the 70 for the 19-pack scenario.
- An additional one SFI basin plan target met compared to 19-pack and two compared to benchmark model.
- More flow events in the 25 – 30, 30-35 and 35-40 GL/d ranges at Doctors Point compared to the Benchmark and 19-pack scenarios with less days between 20-25 GL/d and over 40 GL/d. A similar pattern is found downstream of Yarrawonga.
- At Deniliquin there is an increase in flow days between 15-20, 20-25 and 25-30 GL/d with a reduction in days over 30 GL/d.
- A slight change in frequency of events (as per the Basin Plan SFI target flow rates and duration) at the South Australia border compared to the benchmark. In most cases this a redistribution of flow components into a higher flow rate but still demonstrated equivalency.

The Constraint Measures business case for the River Murray at the SA border (DEWNR and MDBA, 2016) indicates that larger flow events are most likely between June and November each year. This is when natural tributary flow events occur, noting that flows in South Australia may arrive in late spring and early summer given upstream travel times. In ideal circumstances, the occurrence of higher flows between June and November poses the least risk to recreation and tourism activities and is the most beneficial to wetlands and floodplains in advance of the drier seasons. This timing would also minimise competition for upstream channel capacity by avoiding the peak irrigation demands typically in late spring and summer.

4.3 Storage behaviour with enhanced environmental water delivery

Compared to the benchmark model, EEWD modelling indicates that the frequency and volume of spills could change under this proposal. These model results are indicative only and reflect a higher level of relaxed constraints which may take a number of years to implement.

- Hume Dam spills are reduced in frequency and in annual spill volume.
- Menindee Lakes spill slightly more frequently compared to the Benchmark, however the average annual spill volume is slightly reduced.

- Spills in the Murrumbidgee occur only slightly less frequently (ie 1%) but there is a reduced average annual volume of over 160GL compared to benchmark
- Lake Eildon spills slightly less frequently and with a lower average annual volume compared to benchmark.
- Overall in the southern basin, the spill volume is reduced by about 460 GL/yr under the enhanced environmental water delivery scenario.

This reduced spill volume occurs because under a hydrological cues delivery strategy in the EEWD model, larger managed environmental releases are made in the winter/spring coinciding with natural inflows, which creates significant environmental benefits, whilst also creating more airspace in the reservoir and reducing the frequency of unmanaged spills. The peak flows generated downstream of storages under hydrological cues releases will be within the capacity of the mitigation measures implemented as part of the Constraints Measures.

4.4 Model assumptions and limitations

Current modelling work is indicative of what is possible, but is not final as it is dependent on modelling of all SDL adjustment proposals together. Indicative results are included to demonstrate proof of context and scope for a potential SDL offset. Indicative results and modelling assumptions are not intended to be prescriptive, or to limit the development of practical strategies for implementation through adaptive management processes.

Similar to prior Basin Plan modelling, the current version of the hydrological cues delivery strategy model also has a prior hydro-climatic knowledge of the system. The model currently has a foresight of one month and environmental water is used whenever the opportunity arises and is limited only by the water available in the environmental account. It is acknowledged this may not correctly reflect the behaviour of environmental water managers. The focus of the model is on long-term policy development and planning rather than day-to-day river operations. The model provides an estimation of the changes in river flows if environmental water is delivered using a hydrological cues delivery strategy.

The main point of comparison between the 19-pack model and the inclusion of the hydrological cues delivery strategy is how the demand series for key ecological assets (KEA) is generated. The 19-pack used the pick-a-box method which specifically releases against SFI targets (flow and duration). In contrast the hydrological cues delivery strategy targets the SFI flows (daily flow volume), but is not constrained to the duration of the target (MDBA, 2016), rather the duration is similar to a natural flow event.

The modelling of EEWD is representative of potential operating strategies and is consistent with the southern connected Basin constraints projects. However, it is recognised that final flow rates will depend on the flow rates determined through extensive consultation with all potentially affected land holders, industries and communities, as part of relevant constraint measures implementation. Constraint relaxation may take a number of years to implement and are likely to be the product of adaptive management through a phased approach. The model assumes the following upper limits:

- Hume to Yarrawonga key focus area - up to 40,000 megalitres per day from Hume Dam (MDBA 2014d)
- Lower Darling key focus area - up to 14,000 megalitres per day at Weir 32 (MDBA 2015)
- Murrumbidgee key focus area - up to 40,000 megalitres per day at Wagga Wagga (NSW DPI 2016)
- South Australian Murray key focus area - up to 80,000 megalitres per day at the South Australian border (DEWNR and MDBA 2016)

- Yarrawonga to Wakool junction key focus area - to 30,000 megalitres per day downstream of Yarrawonga Weir, with a buffer for flows up to 50,000 megalitres per day (NSW DPI 2016)
- New Goulburn key focus area - up to 20,000 megalitres per day at Shepparton for flows to the Murray [and to be represented by the Benchmark approach].

Other key elements of the EEWD model scenario include:

- Hydrological cues delivery strategy generates demand that essentially replaces Basin Plan KEA demand (key ecological assets) that 19-pack uses from Pick-a-Box.
- Other demands (Freshes and Base flows) in the EEWD scenario are same as 19-pack Basin Plan environmental demand.
- In addition to the above Basin Plan environmental demand, there may be other environmental water uses from TLM portfolio which has its own operating rules. TLM may use its water concurrently or in other periods as triggered by its rules. Since the BP and TLM draw water from the same single account, the account is debited if TLM use occurs regardless of the Basin Plan water use.
- Other environmental watering such as RMIF, Barmah-Millewa Forest environmental water allocations and uses are same as in the 19-pack.
- Drier season watering for CLLMM targets are also included.
- Note that use of one environmental portfolio, particularly if it is a large scale watering, may change system dynamics including storage behaviour and this in turn may affect ‘triggering’ of other environmental water account affecting the volume and frequency of water use.

The method used in the modelling is conceptually sound and robust. It represents high and low flow cycles in the system and is generic in terms of its application to the different hydro-climatic conditions across the southern connected basin. The final outcome of SDL adjustment will also depend on a whole range of measures that are yet to be finalised.

5 Proposed operating environment

5.1 Current operations and limitations on the delivery of environmental water

The MDBA coordinates the operation of the River Murray system to provide water to the states of New South Wales, Victoria and South Australia in accordance with the Water Act 2007 (Cth.), and the Murray–Darling Basin Agreement ('the Agreement') which is a schedule to the Act. The Murrumbidgee and Goulburn Rivers are managed by Water NSW and Goulburn-Murray Water respectively.

River Murray system operators apply a set of guiding principles which involve exercising judgement and consideration of numerous opportunities, risks, uncertainties and options while maintaining the flexibility to effectively respond to conditions and system drivers. The following guiding principles provide the foundation for operations in the River Murray system:

I. Apply adaptive management to find better ways to operate the River Murray system. Applying adaptive management gives a framework for evaluating and documenting lessons learnt, so that they can be applied in the future. The Independent River Operations Review Group (IRORG) process is a key part of the adaptive management framework.

II. Contribute to environmental outcomes. This principle applies to demand driven system conditions, however it may become increasingly relevant to inflow driven conditions in the future as operational constraints to managing higher flows are relieved or resolved. River regulation has had significant impacts on both the in-stream, riparian and floodplain environment in the River Murray System. River operations have been changing over time to try and reduce these impacts. These changes are supported by major reforms, such as The Living Murray program, the Basin Plan and the recovery of water for the environment. River operations in the River Murray system contribute to environmental water management and delivery in a range of ways, such as providing information to help inform annual environmental watering priorities and helping to identify opportunities to coordinate environmental watering.

III. Coordinate River Murray System operations with tributary inflows. This principle supports the achievement of the general objectives and outcomes for water storage and delivery and accounting, River Murray Operations' assets and environment. It applies in both demand and inflow driven conditions. Coordinating River Murray System operations with tributary inflows provides for efficient and effective operation of the River Murray system by conserving water and minimising undesirable losses or unnecessary transfers between storages while maximising water available to the States.

IV. Meet water orders, as far as possible. This principle applies during demand driven conditions. This principle requires water orders and water entitlements along the River Murray system to be met, as far as possible, by river operators making appropriate dam releases. A water order may be for consumptive or environmental water use.

V. Other principles. Other principles that guide River Murray operations include: passing floods safely; anticipating problems and exercise judgment; releasing water from downstream storages first; avoiding unnecessary big changes to river conditions; using historic data, information and modelling to guide operations; monitoring and considering relevant climate outlooks and weather forecasts; and maintaining open communications.

Environmental water coordination and delivery

Current environmental water delivery requires a multifaceted approach reliant on coordination and collaboration. The MDBA sets the planning framework which includes the Basin Plan (Chapter 8), the Basin-wide Watering Strategy and the Basin Annual Environmental Watering Priorities. The environmental water holders from each jurisdiction manage their respective portfolios of environmental water to protect and restore the environment in line with relevant statutory obligations. The CEWO and state water holders make water available and deliver water together with river operators, state environmental water managers, non-government organisations and their local delivery partners (MDBA, 2017).

Environmental water management to date, includes and will continue to build on many years of knowledge, testing, trialling and adaptive management. Collaboration and collective actions of existing environmental watering is a growing strength and the testing and trialling of different environmental watering actions is building trust to enable these collaborations to work more effectively. The adoption of a hydrological cues delivery strategy will require further research and investigation, strong collaboration and coordination as well as shared understanding of environmental water targets and outcomes. Environmental watering trials are recognised as contributing to this outcome.

Since 2010-11, annual Southern connected basin multisite natural cues trials have been coordinated by the jurisdictions, the CEWO, the MDBA and the Water Liaison Working Group (WLWG). Trials have focussed on a mix of wet and dry years whilst attempting to build resilience. From 2013-16 the focus was also on works commissioning throughout ecological sites along the River Murray. The trials have allowed releases of environmental water from headwater storages on top of unregulated flows, and also attempted to provide certainty that the volume released can be delivered throughout the length of the River Murray. This ensures the most efficient use of environmental water, thus maximising environmental benefit from the available water. The context for the trials are partially focussed on testing PPM arrangements and do not yet consider possible changes required to support SDL supply measure proposals. This may need to be addressed in the lead up to final assessment of SDL relative progress.

The planning and delivery of designed hydrographs or events using environmental water entitlements to single asset or site for specific outcomes is considered to be well developed. There are strengths in annual planning, particularly in relatively dry conditions. The ability to use pumps to get water into difficult sites has been adopted in some areas and adding e-water to the recession at the end of an event is operational.

River operators are willing to take on environmental water delivery as a new challenge; to adapt and improve; and to be cooperative and collaborative in approach. This positive cultural change is occurring at all levels in river management.

Limitations of current environmental water delivery

Under water recovery as part of the Basin Plan, developing the ability to undertake large-scale environmental water delivery will increase in significance. Some of the main issues are discussed below including where adopting a hydrologic cues delivery strategy could assist in addressing these issues and/or where the issues would need to be addressed to enable a hydrologic cues delivery strategy.

The amount of water available for environmental purposes is increasing and its timing and location of use is expected to vary greatly between years depending on needs and resource availability. As a result, , adaptive management and policy will need to be in place to ensure desired outcomes are not only achievable but developed in a timely manner to support environmental demands. It has become increasingly apparent that the current operating and management arrangements under the MDB Agreement do not always provide for delivery of these new demands in the most effective and efficient manner. At various locations in the River Murray system there are flow constraints, which may apply during periods of regulated release and which, if breached, may have significant social, economic, cultural and environmental impacts depending on timing. Addressing constraints is an important element of more efficient and effective water use.

Flow constraints include physical operational and management, or policy constraints including the current operations Outcomes and Objectives document restricting flow downstream of the Yarrawonga weir to maximum flow rates of 15,000ML and 18,000 ML per day. While the level of constraints relaxation will be determined by Constraint Measures business cases, Enhanced Environmental Water Delivery will provide an option for the operating environment to do so. As such, there is still a need for consideration of the constraints impacts on this proposal. River operations are expected to change in the longer term as constraints to the delivery of environmental water are reviewed and lifted.

The current accounting rules are not designed primarily for environmental water with many temporary solutions used to alleviate the issues including:

- Requirement for 50/50 use of environmental entitlements between Vic and NSW
- Upfront assumed use
- River operations data needs (significant issues, no mandate to collect data for environmental use, floodplain complex models, need data agreements)

For the majority of environmental watering currently undertaken, decisions to commit a particular volume of environmental water are made based on antecedent conditions (natural and recent environmental watering history), water resource availability and a range of demand factors (such as particular river flow targets, vegetation watering requirements, a species' lifecycle needs, etc). Increasingly this is done to provide designed cues, rather than in response to hydrological cues. Decision making that is inadvertently biased towards a particular process, function, species of taxonomic group may risk long term outcomes for the asset or ecosystem as a whole and may also see trade-offs made which compromise a greater range of outcomes at the asset, reach or system scale. A singular focus on managing for a narrow set of ecosystem components may present a longer term risk of achieving perverse ecological outcomes.

The communication, collaboration and coordination is generally identified as a successful part of environmental water delivery. However, outcomes from the Enhanced Environmental Water Delivery Workshop suggest there is a potential for improvement, particularly in integration between various environmental water delivery agencies in the commonwealth and the states. Currently this can slow down the approvals process, hindering the ability to respond to hydrological cues with timely releases. An example is the 15 decision and approval steps needed to deliver just one water order, which is too complex and cumbersome to be timely. There is a need to have overarching support for environmental water holders and river operators to make real time decisions (to respond to hydrological and other natural cues in a timely fashion).

Channel capacity limitations are a major influence on the system's operating approach, and require extra attention to understand and anticipate downstream demands well ahead of time. There is further work being conducted on channel capacity as current sharing arrangements may not accommodate environmental delivery patterns in all scenarios when considered in conjunction with consumptive demands and critical human water needs requirements. A hydrological cues delivery strategy may provide some benefit to this issue as the timing of demands may differ as it is likely that environmental demand is going to be earlier and outside peak irrigation season.

There is a likelihood that operating under a hydrologic cues based option can have some impact upon reliability both positively and negatively. This is not confined solely to hydrologic cues operating strategies, and it will be relevant to some extent, for all major environmental water release directed form storages. Historically, the supply of entitlements was met first from flows already in the river, then the closest tributary or storage, with releases from headwater storage last. Changing practice to make directed releases from headwater storage to meet entitlement demand may present a practical challenge in terms of the scale and scope of potential releases. The impacts could be positive or negative, depending on several factors, including the timing of the releases and whether the storage subsequently refills. If directed releases from a headwater storage occur early in the season or at times when the dam is filling, as occurs in an unregulated event, there is likely to be more water available to other users later in the year. This issue will need further understanding in context of all environmental water delivery, not just using a hydrologic cues approach.

The need for the measure

River regulation has diminished sources of natural streamflow variability by capturing small to medium flows and floods 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).

Synchronising operations of all the southern connected basin sites to hydrological cues is complex in the current administrative and operational frameworks. The river operating frameworks are not designed to deal with large volumes of environmental water (to multiple sites from multiple water holders). One subsequent impact is that operations management of environmental water is operationally challenging and resource intensive. The history of delivering water for consumptive use can be analysed to assist with the development of forecasts under different scenarios. In comparison, at this point in time there is a limited history of environmental water delivery to assist in forecasting the use of recently acquired environmental water as conditions can vary significantly if inflows below storages meet environment objectives. The proposed hydrological cues delivery strategy is designed to build on existing knowledge to improve information gaps and increase the forecasting abilities of environmental water managers and river operators.

Environmental water released in conjunction with a natural event has increased effectiveness when targeting floodplain inundation as less water is needed to achieve the desired flow and ecological responses. Such releases have potential to increase the capacity for triggering ecological outcomes for flora and fauna (see section 3.3 Anticipated ecological benefits). They can also make better use of productivity gains from upstream flooding. These productivity gains result from inundation of floodplain soils and plant material; and can include plant and invertebrate propagules, increased carbon and nutrients, and the eggs and larvae of fish and other organisms spawned at upstream sites (Wallace, et al., 2011; Baldwin, Wilson, Gigney, & Boulding, 2010).

The measures outlined in Section 5.2 are designed to build upon previous work conducted by the various parties involved in environmental water management and delivery. In doing so, they will identify and address the limitations mentioned above through the identified work plan.

5.2 Proposed operating environment and facilitating measures

The proposal aims to use environmental water through a multi-year program of work across the southern connected basin. The program of work will require actions across all the relevant jurisdictions in South Australia, New South Wales, Victoria and at a Commonwealth government level. Some of the measures proposed are dependent on processes that are already underway (e.g. PPMs), risks to project delivery from these dependent processes are identified in the section 9 Risk assessment. This business case ensures the broad suite of actions to enhance environmental water delivery are aligned and implemented to a level that enables the hydrological cues delivery strategy to be operationalised by the relevant stakeholders, and which is underpinned by the key principles outlined in section 2.

The proposal identifies actions required across the environmental water delivery process, and across different watering stakeholders. This includes reviews and changes that need to be implemented at the planning, delivery, site, evaluation and accounting stages of environmental water delivery (see Figure 3) These reviews and changes will required a collaborative approach from all stakeholders including river operators, environmental water holders, water planners and community across the jurisdictions. Specific risks to project development and delivery are identified for each measure, risks that apply to the proposal as a whole are identified in section 9.

This proposal has three phases of activity:

Phase I. Provides a stocktake of recent developments and the current situation for work supporting hydrologic cues and environmental watering development. Given the evolution of environmental watering, this phase recognises that the way we currently operate is different to the assumptions of the benchmark model. To allow more efficient delivery of environmental water there are a number of administrative and governance processes that have already been identified and whose relative progress could be built on and reviewed in Phase IIa and implemented through Phase IIb (EEWD measures 2 and 3). In addition past environmental watering activities, monitoring and evaluation, provides a large amount of information that will underpin further work in phases IIa, IIb and III (EEWD measures 1 and 5).

Phase IIa. Develops the details of proposed changes, operational practise, policies and decision support tools required. This phase includes a range of reviews and research investigations to ensure implementation is based on best practice and is flexible and adaptive. This includes EEWD measure 1 actions - research and investigation to better understand system delivery opportunities, review and update models, explore a range of flow options etc. It also includes reviews of administration, accounting and evaluation mechanisms, in many cases these are in train already or have clear pathways.

Phase IIb. Implements the required policy and operational changes to allow implementation of Phase IIa findings.

Phase III. Development of an evaluation framework to assess the operationalization and effectiveness of a hydrological cues delivery strategy (EEWD measure 5)

The phase II assessment guidelines require technical feasibility and fitness for purpose of projects to be identified. This proposal builds on considerable system operational planning and management expertise available in the MDBA and jurisdictions. Modelling has provided proof of concept, and a strong indication that the process is both feasible and achievable.

5.2.1 EEWD 1: Investigative work to trial and understand the new delivery and operational environment for river management. This includes exploring a range of flows that are scientifically sound and operationally achievable, for release of environmental water at headwater storages across southern connected basin under a hydrological cues delivery strategy.

Background to measure

Environmental flow management needs to be able to deliver water from headworks storages to multiple environmental assets spread over large distances along multiple rivers. Understanding the timing constraints and opportunities is a crucial part of actively managing the shaping of upstream and downstream hydrographs.

This measure builds the technical knowledge and understanding required to enable the delivery of regulated flows on top of a range of un-regulated flows, in order to achieve environmental outcomes more efficiently. Investigating a range of flows will not be codified as 'rules', but will act as a general guide to better understand how to build and shape a variety of system flows to support environmental outcomes. This is especially important under a level of constraints relaxation, as new regulated flow boundaries will be a new area for river operations to move into which will take careful testing.

To achieve target flows using a hydrological cues delivery strategy, operators will need to be able to effectively time releases of environmental water from storages to ensure that they coincide with inflows from one or a number of other valleys (objective 2, and EEWD measure1).

The key purpose of this measure is to coordinate input from water managers, operators and water holders as well as other experts and to undertake hydrological, ecological and operational research and trials, as required, to define the best suite of cues and flow management options to maximise watering outcomes under a range of conditions.

The second purpose is to understand the types of cues and flow management options that can be operated with current (or improved) levels of climate and river flow forecasting (the two studies to date assuming perfect knowledge of the future climate and river flows).

To date, environmental watering has largely been driven by ecological demands linked to life cycle needs of particular plants and animals. A range of hydrological variability will need to be described which can then be considered as a surrogate for a range of other cues such as vegetation germination, fish/bird breeding, etc. This will help determine the scale of operations and options for environmental water use based on the actual seasonal conditions as they unfold.

This measure must also consider alignment with objectives and outcomes under the Basin Plan, including the Science Plan (under development), Basin-wide Environmental Water Strategy, Water Resource Plans, Long-term Watering plans and other legislative requirements.

MEASURE DESCRIPTION:

WORKPLAN:

Phase I (2009-2017)

Actions:

Understand the development of environmental watering and ensure that the evolution and learnings of environmental watering is incorporated into reviews and actions in Phase IIa and IIb. The review should include, but is not limited to, the following.

- Outcomes from environmental water delivery that occurred in the Basin prior to 2009. Often the delivery was aimed at specific outcomes such as maintaining a water level to allow the completion of a bird breeding event.
- Review the history of targeted watering actions and the increasing level of understanding of flow triggers and ecological response that is reported both through internal jurisdictional technical reports and in peer-reviewed literature.
- Outcomes from preliminary modelling work conducted in 2012 as part of the Experienced River Operators forum which looked at the frequency of larger flow events (i.e. between 50,000 to 80,000 ML/day) at the South Australian border and considered how to 'top up' existing flow events to increase the frequencies of these types of flows (focussed on releases in the Murray and Murrumbidgee rivers). It found events need flows from at least 3 of the 4 major sources – the upper Murray, the Goulburn, the Murrumbidgee and the Darling Rivers. The flows were also not one single event, but multiple flows over several months. Given the flow travel times, it tested triggers for Lake Hume and Lake Eildon based on flows in the Murrumbidgee River at Wagga Wagga, achieving good increases of flow in the target range.
- Outcomes from the Commonwealth Environmental Water Office trials in 2015/16 of a natural cues approach for releasing predominantly in-bank environmental flows in the River Murray (due to existing system constraints), with triggers based on inflows to the upstream storage.
- Outcomes from MDBA in 2016 which looked at a similar natural cues approach including the Murrumbidgee and the Murray River and showed an increase in successful watering of floodplains at the South Australian border.

Roles:

Much of this work has been undertaken by the MDBA, jurisdiction water managers and, more recently, environmental water holders. In recent years there has been coordination through SCBEWC supported by MDBA.

Outcomes:

- Ensure that Phase IIa builds on existing knowledge and development of environmental watering, as well as moving forward to investigate new areas.

Products/Deliverables:

- Stocktake report on current delivery and operation trials of environmental water

Phase IIa Planning, investigate, reviews: (2018-19):

Actions:

Research and investigation project including ecological literature review, hydrological modelling and scenario planning/workshops with river operators, environmental water managers and environmental water holders and relevant scientific/e-watering experts to identify the types of flows and document location of triggers required under a hydrological cues delivery strategy.

- Undertake a study of the unregulated flow losses (and return flows) and travel times for the Murray, Goulburn, Murrumbidgee and Darling Rivers. This would involve both examining the behaviour of current unregulated flow events, and interrogating the existing hydraulic models of rivers and floodplains.
- Review the environmental demands, including targets outlined in long-term watering plans, along the Murray, Goulburn, Murrumbidgee and Darling Rivers and operation of works and measures projects to understand the likely target events that would have to be delivered.
- Undertake a study to review existing information and further analyse historic high flow events to define the nature and timing of target events to be added to. It should also define the nature of basin wide flow events. This should then define how, when and from where water added could increase flows to desirable levels. Possible indicators of these events (or cues for releases) need to be developed, identifying seasons for possible release and the timing to commence releases (and to abandon releases). The occurrence of overbank flow events after the targeted events should also be assessed (to identify the potential for exacerbating these events).
- Improve current hydrology models (especially on the Goulburn and Murrumbidgee) to allow testing of various hydrological cues delivery strategy options, incorporating environmental water accounting, realistic climatic and flow forecasting, and variable river loss/travel time allowances.
- Use the models to test and refine various hydrologic cue options and water release options to identify the most effective options.
- Use the models to test implications of key options on other water supply system issues, such as the Lake Victoria Operating Strategy and the potential Menindee Lakes decommissioning.
- Ensure compatibility with all environmental watering strategies (including flows outside of the hydrological cues range and timing such as targeted watering during dry periods and planned drying sequences). This includes long-term watering plan targets for sites such as the Lower Murray floodplains and CLLMM.
- Establish how to deal with known system constraints.
- Investigate the suitability of the existing gauging network to assist in developing hydrologic cues delivery options
- Assess:
    - the interaction with consumptive water use rules and availability
    - the impact on flooding downstream of major dams
    - the operation of environmental works and measures
    - changes needed to ensure efficient achievement of all objectives
    - environmental trade-offs

Roles:

Coordinated by jurisdictional environmental water holders (MDBA to assist with facilitation) in collaboration with river operators, and asset managers

Outcomes:

- Understand the incremental changes in losses and travel times and hydrograph shape associated with incremental increases in river flows. The impact of antecedent conditions also needs to be assessed (ie floodplain wet, partially wet, or dry). This should also consider how to monitor important antecedent condition status.
- Understand the likely target events that would have to be delivered under different resource availability scenarios for the Murray River and its tributaries.

- Better understanding of hydrology, particularly overbank inundation, losses and return flows, throughout the SCB.
- Hydrology and forecasting models to enable fit for purpose scenario testing.
- Common/shared understanding of flow and inundation behaviour and all environmental demands through the system.
- An increased understanding of the suitability and capability of the existing gauging network in a hydrologic cues context.
- An understanding of the suitability of the existing gauging network

Deliverables:

- Technical Report: literature review of flows and inundation, return flows, travel times, losses of SCB in relation to operating under EEWD.
- Coordinated workshops and workshop outcomes report
- Tools: improved hydrology model for EEWD scenario testing and operations.

Phase IIb Implementation and Commissioning (2018-22):

Actions:

Implement required policy and operational changes (links to EEWD 4) and operationalise the EEWD strategy. Conduct trials to gradually 'commission' and test the strategy. Iterate, implement and refine other policy changes as required. Trials using held environmental water will be as directed by environmental water holders.

Roles:

MDBA and jurisdictions to implement policy changes. River operations to operationalise the strategy. SCEWBC to continue to coordinate trials and testing. This measure will also inform other EEWD measures and be implemented through a variety of policy and operations changes (measures 2-4).

Outcomes:

- Incremental testing and improvement in ability to deliver water for the environment using EEWD strategies

Deliverables:

- Annual reports detailing implementation of policy changes. Should be incorporated in existing reporting structures but some additional work required to report against EEWD specifically
- Annual reports detailing operational testing highlights and outcomes. Should be incorporated in existing reporting structures but some additional work required to report against EEWD specifically
- Decision and systems support tools

Phase III - Evaluation (2022-2024)

Action:

Evaluation of this measure will be undertaken to determine in the first instance whether it was successfully delivered and operationalised. As far as possible existing processes, particularly matter 9.3 reporting on the use of environmental water and through existing monitoring, evaluation and reporting frameworks on ecological outcomes (CEWO, TLM, MDBA, States), will be used to support the evaluation Refer to section 5.2.5 for more detail on evaluation.

Roles:

Coordination through existing processes by MDBA on behalf of jurisdictions, TLM, CEWO, States.

Outcomes:

- Appropriate reporting questions in existing reporting structures – refer to 5.2.5
- Ability to adaptively update knowledge and identify further policy changes as required

Deliverables:

- Annual reports as per Phase IIb and overall evaluation as outlined in measure 5.

Environmental benefits

- Increased ability of river operators and governments to deliver water both in channel and overbank to key wetland and floodplain assets, guided by hydrological cues for timing and duration
- More environmental assets watered using less held environmental water in moderate to wet years
- Increased ability to coordinate environmental water delivery to provide system scale outcomes in wetter years.

Risks and third party impacts

- The EEWD project has the potential to increase flooding of private land, both during the event and in a subsequent natural event, as a consequence of constraint relaxation. The Constraint Measures project is assessing this risk and considering appropriate mitigation measures.
- The use of large volumes of environmental water early in the water year could potentially change water availability to the environment and to other water supply system users. This task assesses this reliability impact and considers appropriate changes to mitigate impacts.
- For example, the current modelling incorporated specific targeted watering for CLLMM year round in the driest 5-15% of years. Ensuring watering requirements at this site, and other significant sites, need to be reflected in real world outcomes. This measure will evaluate the hydrological impacts throughout the system and refine options to assist all environmental water delivery as required as part of an adaptive management framework.
- Using hydrological cues delivery strategy to deliver environmental water does not replace other targeted watering requirements. Specific targeted watering will still be required for some sites and situations.

Complementary actions and interdependencies

This measure assumes that there is a level of relaxed constraints, implementation of PPMs and implementation of EEWD measure 2-4.

Interaction with other supply measure proposals

- The measure aims to deliver overbank flows which rely on the Constraints Measures business cases to define allowable levels of inundation and the associated risk management (including flow forecasting, river operations and buffers).
- Many supply measure proposals use engineering works to provide lower level inundation of floodplains and creek lines. This project includes using information and hydraulic models from

these proposals to better understand losses and travel time, and considers the interaction (both positive and negative) of operation of these measures with hydrological cues delivery strategy.

Stakeholder management considerations

- This measure should be undertaken as a cooperative project through key jurisdictional stakeholders. This will require extensive coordination and stakeholder engagement.
- Triggers, benefits, and mitigation options for impacts, need to be clearly articulated and communicated to community stakeholders through existing processes.

5.2.2 EEWD 2: Enhanced environmental watering delivery administration and coordination processes

Background to measure

- The volumes of water available for environmental watering have increased and in doing so have increased the potential for bigger/broader outcomes.
- Existing administrative arrangements (e.g. water transfer and water use accounting) do not provide the necessary flexibility in the management of the environmental water portfolio to respond to real time events. Arrangements proposed for the environmental water trial in 2017-18 are set to investigate the value of the early season use of environmental allocations
- Current administration and coordination processes require reform in order to deliver environmental water in the most efficient and effective way in order to operationalise a hydrological cues delivery strategy (refer to core principles).
- Environmental water managers and operators currently use a range of 'Band-Aid' solutions to deliver water for environmental outcomes. The annual deviations from standard operating procedures (environmental watering trials) are an attempt to use environmental water in the most effective and efficient way, within the current operating and governance framework.
- There is now general agreement among environmental water managers and operators that there are opportunities to strengthen administration and coordination of e water including:
    - Achieving southern connected basin system-scale environmental outcomes maximised by effective planning and coordinating all water sources and tributaries,
    - Clear/efficient alignment of committee functions
    - Collaborations in e water and river operations
- Current administration and coordination arrangements can be time consuming and place administrative burden on River Operators, for example the IRORG report 'Review of River Operations 2015-16' identified that "River Murray Operations staff participated in 170 Operational Advisory Group meetings in 2015/16 (230 in 2014/15) the Authority is urged to continue to look for efficiencies in these processes" (IRORG Report). Further "IRORG recognises that the increasing complexity of river operations and environmental water deliveries requires significant consultation and liaison by MDBA staff with many stakeholders. This has resourcing implications."
- Implementing environmental watering trials over the past seven years has allowed changes from historic river operations practices to be gradually tested and refined, including administration and coordination.
- Current practice of implementing annual trials has been effective at providing short-term solutions to issues associated with environmental water delivery. However, the short-term nature of trials impedes their effectiveness at addressing any significant policy changes required.

- IRORG recommendation 2016.02 recommends that the MDBA undertakes a review of the roles of Basin Officials Council and Ministerial Council in relation to river operations and water sharing decision making, with a view to determining the most appropriate balance between responsive decision making and appropriate levels of accountability.
- This measure requires a high level of coordination between governments, environmental water holders, and river operators, as there are many parties involved with the planning, delivery and use of environmental water.

MEASURE DESCRIPTION:

- This measure involves reviewing existing administration and coordination processes to identify issues and potential changes. Effective delivery of this measure will enable the subsequent measures to be implemented.
- Delivering on a hydrological cues delivery strategy will require timely decision making to capitalise on episodic natural flow events – arrangements to enable this to occur are critical to delivering this project successfully. Timeliness of delivery is required for alignment accuracy so that releases from storages coincide accurately with natural flows to boost peak duration.
- Environmental water delivery administration and coordination needs to be a streamlined decision making process that can be implemented quickly and effectively in response to stream flow planning, forecasts, and observations. It is imperative that local input from on-ground environmental, resource and water managers into this process maintains a strong presence.
- Any reform to administration and coordination processes must be fit for purpose, enduring and have the support of environmental water holders and river operators, as well as asset or site managers.
- Explicit consideration must be given to provide site managers and river operators with the ability not to select a hydrological cues delivery scenario. Having the power to say no forms part of their work in balancing environmental and social outcomes.
- The use of a committee (e.g. SCBEWC) would be beneficial in coordinating releases and streamlining the approvals process for water delivery. These have been used in the past and may help reduce the administrative time demands of environmental water delivery. This would involve providing an existing committee with this mandate rather than creating a new committee.

WORKPLAN:

Phase I (2009-2017)

Action:

The aim of phase I is to establish a stocktake of work to date or in progress. This will build the foundation for the body of work outlined in phase II. The intention of this is to recognise previous efforts to progress work in environmental water management, clarify material issues and determine an approach to review of current water delivery administration and coordination processes on all levels including interactions between state and commonwealth environmental water holders and Operations.

Roles:

The MDBA has responsibility for leading the review process within this phase, acting as agent on behalf of partner governments and agencies. Input and guidance will be sought from partner organisations.

Outcomes:

- A shared understanding of the current administration and coordination process involved in the management and delivery of environmental water.
- A documented process for undertaking the further research and investigative work to improve the administration and coordination process (phase II).

Deliverables:

- Stocktake of current administration and coordination processes involved in the management and delivery of environmental water.
- Consultation with environmental water holders, site managers, river operators, and others involved in event based operating committees to inform the stocktake process.

Phase IIa Planning, investigate, reviews: (2018-19):

Actions:

Review current administration and coordination process described as part of the stocktake process to identify impediments (including understanding the conditions where not to proceed with a hydrological cue delivery strategy) and potential actions required to enable timely release of flows. Environmental water delivery agencies and river operators workshop to identify key focus areas for review.

- Review and document learnings from environmental watering trial reviews conducted by the MDBA and CEWO to understand potential improvements from the previous 7 years of watering trials.
- Identify and articulate the need to align all water delivery agencies: consistency in approach across states is needed to simplify administrative and accounting processes (links to measure 3).
    - Environmental water administration and coordination process at a system scale
    - Identifying how different processes in jurisdictions will be linked and integrated to provide a fit for purpose administrative and coordination approach.
- Clarify material issues and determine an approach to review of current water delivery administration and coordination processes on all levels including interactions between state and commonwealth environmental water holders and Operations.
- Clarification of roles and responsibilities and the efficiency of decision making in coordination and approvals is required to help facilitate delivery of a changed inundation frequency.
    - Ownership and coordination of watering committees
    - Planning and collaboration with site managers – identify protocols for communication between agencies.
- Determine requirements for increased resourcing and improved rainfall and stream-flow forecasting systems.
- Investigate decisions making processes and tools to enhance decision making abilities and timeliness.

Roles:

The MDBA will coordinate the body of work and seek collaboration with environmental water delivery agencies, river operators and site managers. Existing committees such as SCBEWC, WLWG and Environmental Watering Working Group (EWWG) will be approached for guidance as required, as well as oversight provided by the jurisdictional steering committee. River operators from all delivery agencies will be required to provide input in steering and participating in the work associated with this measure.

Outcomes:

- Demonstrated streamlined process for enabling a hydrological cues delivery strategy.
- Specific committee identified with responsibility for hydrological cues delivery strategy that require coordination (potentially SCBEWC)
- Recommendations for jurisdictional steering committee and other relevant
- A comprehensive understanding of the resource implications of delivery under a hydrological cues delivery strategy committees to consider
- Articulation of the linkages between this measure and EEWD measures 3 and 4.

Deliverables:

- Workshop/s to identify review requirements and associated consultation activities.
- Update protocols for communication between agencies for the ordering and delivery of environmental water documented.
- Report detailing the environmental water administration and coordination process at a system scale.
- Options paper based on proposed changes
- Specific Terms of Reference developed for providing appropriate administration and coordination to enact an enhanced environmental water delivery option.
- Review report articulating the findings of environmental water trials and identifying recommendations.

Phase IIb Implementation and Commissioning (2018-22):

Action

- Implement recommendations from Phase IIa under the oversight of the jurisdictional steering committee.
- Commissioning phase and implement changes to administration and coordination as required as part of reform package with measure 1, 3 and 4.

Roles: MDBA to help coordinate and facilitate actions by Jurisdictional water delivery agencies, environmental water holders and site managers.

Outcomes:

- The measure will facilitate a process to work with states, MDBA and water holders to make changes to relevant agreements, governance structures, policies and plans
    - Possible changes may include:
        - Participatory planning processes (scenario planning similar to ‘flood ops’ protocols)
        - Online environmental water and ops coordination and planning tools (environmental water ‘portal’)
- Changes to Terms of Reference for committee (TBD) to include hydrological cues delivery strategy oversight where coordination across agencies is required.

Deliverables:

- Consultation, particularly a number of technical workshops, of scenario planning to develop protocols.

- Hydrological modelling work to support development of scenario planning and ops protocols.
- Technical work to create data management systems and user coordination tools to assist with real time environmental water delivery integrated with river operations.
- Decision support tools: create data management system/environmental water management portal

Phase III - evaluation of planning outcomes (2022-2024)

Action

- Evaluate success of environmental water delivery administration and coordination. Test for reduced administrative burden and increased speed of decision making. Also test adequacy of processes for accurately aligning water released from storage with natural flows for targeted hydrograph outcomes.

Roles

The MDBA will lead and facilitate the evaluation with oversight from the jurisdictional steering committee, with input from other relevant committees such as SCBEWC.

Outcomes:

- Appropriate reporting questions in existing reporting structures – refer to 5.2.5
- Ability to adaptively update knowledge and identify further policy changes as required

Deliverables:

- Annual reports as per Phase IIb and overall evaluation as outlined in measure 5.

Risks and impacts of the measure

- A perverse outcome could be adding another bureaucratic step to environmental water delivery

Complementary actions and interdependencies

- Improved forecasting tools required to integrate environmental water delivery and management across southern connected basin
- Constraint Measures – the level constraints are relaxed to impacts on water planning processes and may require additional agreements from landholders to release certain flows.
- The IRORG annually reviews the MDBA's performance in operating the River Murray System and provides recommendations for improvement. It is anticipated that any of the proposed changes discussed in this business case will support the implementation of recommendations that:
    - E2012:08 *the MDBA develop a strategic roadmap that identifies agreed timelines and priorities for resolving operational and water accounting processes that represent barriers to effective environmental water delivery.*
    - E2014:06 *the MDBA builds upon the Constraint Measures and develops a prioritised work program that identifies:*
        - *the tasks required to resolve key operational and water accounting issues associated with environmental water delivery;*
        - *the process for developing/operationalising new delivery practices that have already been sufficiently tested; and*

        - *the timing and resources that will be committed to addressing each task.*
    - E2015:03 *the MDBA and jurisdictions continue to work collaboratively on the PPM implementation program, and ensure that sufficient resources are made available in a timely manner to support the planned work program.*
    - E2015:07 *the Authority* (MDBA) *progressively develop environmental water delivery guidelines to capture good practice in the planning, co-ordination, implementation and accounting for environmental events, and that these guidelines should form part of the framework for river operations in the River Murray system* (sic).

5.2.3 EEWD 3: Identify and remove current accounting constraints to efficient environmental water delivery across southern connected basin.

Background to measure

- Water accounting in the River Murray system is complex and has been developed over time to account for the efficient and sustainable sharing of water between the River Murray states and for allocation to entitlement holders. Traditionally, water was for consumptive use and water used did not generally return to the river system.
- Over time, large volumes of entitlements have been moved from consumptive to environmental use. Water is now used and managed across multiple sites with flow traveling from the top to bottom of a system via a series of ecological sites. Situations are arising where water accounting principles are no longer fit-for purpose, resulting in increasingly complex water accounting issues as new water delivery techniques are developed and trialled.
- There are a number of levels of water accounting involved and important interfaces between these levels: MDBA wholesale accounting, state shares and retail accounts.

Measure description:

- This measure is an operational and management constraint measure that seeks to facilitate a more fit-for-purpose (and enduring) method of accounting for environmental water. To ensure environmental water can be used through the length of the river and achieve outcomes at multiple sites, through to the CLLMM.
- This may include consideration of the following themes (as per RMOC 11, AI 5.2):
    - What provisions may need to be changed, what are the new accounting challenges that will emerge and what are the most appropriate solutions that should be applied?
    - What systems may be needed to support future accounting, and how and by whom will data collection, validation and exchange be done?
    - How can we best maintain alignment between wholesale and retail accounting to support efficient and timely accounting at all levels?
    - What are the feasible stages in a manageable transition from where we are now to where we need to be to achieve the agreed vision?

Workplan:

Phase I (2009 – 2017)

Action:

- The aim of phase I is to identify the complex water accounting issues that are increasingly arising as new water delivery techniques are developed and trailed. As well as scope the work required to develop a shared vision for water accounting in the River Murray system. This will build the foundation for the body of work outlined in phase II.

Roles:

The MDBA has responsibility for leading the review process within this phase. Input and guidance has been sought from supporting committees including IRORG, WLWG and RMOC.

Outcomes:

- Draft scope of work required to develop a vision for water accounting in the River Murray system (RMOC 11 AI 5).

Deliverables:

- o Stocktake report including detail on required outcomes for accounting and recommendations for work to deliver the outcomes.

Phase IIa – investigate and review (2017 – 2019)

Action:

A strategic review of current accounting approaches for environmental water delivery with aim to identify actions to ensure the accounting framework is fit for purpose.

- Identify the desired future state of the River Murray accounting system, to ensure it meets the needs of all parties.
- Develop water accounting rules to support above outcome.
- Modelling will be required to support the development of new water accounting rules.

Roles:

The MDBA to initially scope the review, with responsibilities being redefined once the full scope of work is identified.

It is understood external expertise may be difficult to acquire in a leading capacity, but an external facilitator may assist with enabling discussions. Existing committees are expected to be utilised in progressing this measure as well as oversight provided by the jurisdictional steering committee. .

Outcomes:

- A shared vision of the future River Murray accounting system.
- Demonstrated commitment across jurisdictions to facilitate changes in water accounting across the River Murray system.

Deliverables:

- Workshop/s to develop a shared vision of the River Murray accounting system.
- Review report articulating the required accounting changes to support the new vision and including a set of recommendations.
- Modelling report supporting the necessary accounting rule changes.
- Develop new accounting support system

Phase IIb – implementation (2019 – 2022)

Action:

- Implement recommendations from phase IIa under the oversight of the jurisdictional steering committee.
- A commissioning phase to implement changes in the accounting approach as required as part of the reform package with EEWD measures 1, 2 and 4.

Roles:

The MDBA to assist with the coordination and facilitation of actions by the jurisdictions. Jurisdictions to implement reform as per recommendations. Additional support will be provided through existing committees.

Outcomes:

- This measure will facilitate a process for the MDBA and the States to make necessary changes to relevant agreements, policies, operating procedures and rules.

Deliverables:

- Modelling work to support the implementation of rule changes
- Implement changes to relevant documentation to demonstrate River Murray accounting system

Phase III – evaluation (2022 – 2024)

- 2022 – 2024) evaluation of this EEWD measure.

Action:

- Evaluate the success of the accounting approach reform for environmental water delivery.
- Test for reduced administration and operating burden.
- Assess if the accounting framework for environmental water delivery is 'fit for purpose', with environmental water able to be used along the length of the river and achieve outcomes at multiple sites.

Roles:

The MDBA will lead and facilitate the evaluation with oversight from the jurisdictions steering committee. Input from other relevant committees will also be sought.

Outcomes:

- Appropriate reporting questions in existing reporting structures – refer to 5.2.5
- Ability to adaptively update knowledge and identify further policy changes as required

Deliverables:

- Annual reports as per Phase IIb and overall evaluation as outlined in measure 5.

Environmental benefits:

- Appropriate accounting mechanisms will enable environmental water holders' the flexibility to use their entitlements more efficiently and effectively to achieve overbank outcomes and to water multiple sites through return to system flows.
- Allows timely release of flows to align with identified hydrological cues

Other benefits

- Enhanced flexibility in portfolio management
- Enable crediting and real-time protection of returned flows
- Builds confidence in decision-making and portfolio management
- Streamlines administrative processes (EEWD 2).

Risks and impacts of the measure

- Any changes to accounting frameworks need to consider the CEWH's obligations under the PGPA act, ensuring environment entitlements retain their value.
- As per clause 5.2 of the IGA on Implementing Water Reform in the Murray-Darling Basin, implementation of this measure requires agreement between the Commonwealth and the relevant State(s) to facilitate any changes to accounting frameworks required to improve environmental watering.

Third party impacts and benefits

- May be impacts on third parties from a change to accounting frameworks. Actions will be designed in consultation with affected parties to ensure there are no unintentional third party impacts or unmitigated new risks to the reliability of entitlements.

Complementary actions and interdependencies

- PPM implementation
- Flexible Trade Adjustments, currently being undertaken by the MDBA's Water Markets Section
- Southern connected basin multi-site natural cues trial

Stakeholder management considerations

- **Jurisdictional:** Exploring these questions in detail to reach consensus between all relevant parties would be a considerable undertaking. Water accounting is complex and the roles of both the MDBA and the jurisdictions in all levels of water accounting would need to be explored, requiring the support of all parties to undertake such a review.
- **Community:** Any changes that may affect retail accounting will require the jurisdictions to consult with communities and entitlement holders. The required level of engagement will be identified in phase IIa during the strategic review of current accounting approaches.

Legal and regulatory requirements

- Legal and regulatory requirements of the EEWD proposal are outlined in section 7.

5.2.4 EEWD 4: Establish clear and enduring mandate for governments and river operators to order and deliver environmental water on-top of natural flows, up to agreed constraints relaxation level, reflected in the O&Os and legislation as necessary

Background to measure

- To achieve Basin Plan outcomes, portions of the floodplain need to be inundated in order to achieve effective environmental outcomes. However, there are concerns about liability and claims for damages arising from unintentional and intentional inundation of private lands and floodplain infrastructure are a limiting factor.

- Creating a mandate that is enduring and fit for purpose for delivery of environmental water in the present and into the future is integral to the success of environmental watering but also critical for sustaining environmental health.
- The changes to the inundation frequency of the identified reaches are at rates not previously delivered and require further exploration to enable environmental water holder and operational confidence.
- It is essential that the organisations responsible for river operations (river operators, Environmental water holders etc.) communicate with communities and other stakeholders about the ordering and delivery of environmental water, particularly in the context of constraints relaxation. Clarification of the fact that river operators enact the decisions of others rather than decide what environmental flows to deliver is required.
- Water released from storages within MDBA's control needs to be managed in conjunction with other regulated and unregulated inflows to the system in order to optimise outcomes. Understanding and expressing clarity of roles in regard to the actual delivery of flow and the coordination involved in doing so to build on outcomes of measure 2 is important.

MEASURE DESCRIPTION:

- This measure aims to ensure that, in conjunction with the three proceeding measures, once there is an option of a hydrological cues delivery strategy, governments and river operators have the ability to take responsibility for ordering and delivering the required water.
- Once in place, this measure will also provide operators with the right to act upon or veto a hydrological cues water order if necessary.
- The measure will build upon constraints relaxation outcomes, EEWD 2, and learnings from the annual environmental water trials
- Objective and Outcomes clauses may be amended to allow for the ability to order and deliver flows associated with a hydrological cues delivery strategy.

WORKPLAN:

Phase I (2009-2017)

Action
The aim of phase I is to identify all current and previous work that enables river operators and environmental water managers to carry out the ordering and delivery processes involved in environmental water management. This measure is designed to illustrate progress, work to date and highlight any positives and limitations in the ordering and delivery of environmental water. Identifying any links with EEWD measure 2 and describing what the proposed mandate may look like forms part of the measure.

Roles
The MDBA has responsibility for leading the review process within this phase, acting as agent on behalf of partner governments and agencies. Input and guidance will be sought from partner organisations.

Outcomes:

- A shared understanding of the work conducted to enable the ordering and delivery process of environmental water.
- A documented process for undertaking the further research and investigative work to address limitations to developing a mandate (phase II).

Deliverables:

- Stocktake of current work enabling the ordering and delivery of environmental water.

Phase IIa Planning, investigate, reviews: (2018-19):

Actions:

- Legal review: understanding the implications for water delivered from one storage into another system requires further understanding. This will need to be aligned with the constraints relaxation work.
- Legal review of liabilities to provide understanding of what needs to be addressed
- In conjunction with EEWD measure 2, reviewing how administration and coordination processes contribute to ordering and delivery, needs improved understanding.
- Documenting lessons learned from watering trials will provide a significant knowledge base.
- The Objectives and Outcomes will be reviewed with relevant clauses identified in terms of how they contribute to the proposed mandate.
- Review regulatory and River Murray Framework as appropriate.
- Assess gauging networks for current suitability to measure the changes of flow regimes. Increasing the network or upgrading the current network may contribute to more 'comfort' in aligning contributions of inflows between reaches. This is linked with measure 1.

Roles:

- The MDBA will coordinate the body of work and seek collaboration with environmental water delivery agencies and state partners. Existing committees (TBD) will be approached for guidance as required. There will be specific roles for all operations staff from the MDBA, Goulburn-Murray Water and Water NSW.

Outcomes:

- Agreement on what responsibility for ordering and delivery means for all water management and delivery agencies.
- Articulation of the ordering and delivery process
- Building on existing work, a detailed understanding of all liabilities arising from environmental water delivery will be developed.
- Specific Terms of Reference will be developed for enacting the option of enhanced environmental water delivery under a hydrological cues delivery strategy (linked to measure 2)
- Ability to add to EEWD measure 2's documentation of the hydrological cues water ordering and delivery process
- Describe direct links between this measure and EEWD measures 2 and 3

Deliverables:

- Documented strategy for creating the mandate for ordering and delivery.

- Suitability assessment of Objectives and outcomes and River Murray Operations framework
- Report detailed operations mandate for delivery based on aligning flows between tributaries and suitability of existing gauging network.
- Document how learnings from environmental water trials can be adopted for a hydrologic cues delivery option

Phase IIb Implementation and Commissioning (2018-22):

Action

- Commissioning phase and implement changes to administration and coordination as required as part of reform package with measure 1, 2 and 3.
- Amendment of the Objectives and Outcomes by BOC to appropriately direct and guide MDBA river operators.
- Research opportunities to address legal liabilities review outcomes
- Implement appropriate facilitation and coordination strategy. MDBA to act as 'environmental watering facilitator/coordinator', operators to enact outcomes of shared process.
- Implement any legislative changes required to enhance indemnities. Also, changes/additions to State water sharing plans may be required for environmental water management and delivery to operate most efficiently and effectively across the southern connected system.

Roles:

The MDBA will act as a facilitator of the measure and seek input from jurisdictional water delivery agencies and environmental water holders. Further responsibility for individual components and bodies of work will emerge during phase IIa.

Outcomes:

- A clear and enduring mandate for environmental water managers and river operators to deliver water using a hydrological cues delivery strategy.
- Recommendations and outcomes of the previous 2 phases will progress to commissioning and implementation

Deliverables:

- Amended Outcomes and Objectives and/or other relevant legislation or documentation

Phase III - evaluation of planning outcomes (2022-2024)

Action

- Evaluate success of creating the ability for governments and operators to be able to deliver water under a hydrological cues delivery strategy.

Roles

The MDBA will be required to lead and facilitate the evaluation with oversight from a committee such as SCBEWC or IRORG.

Outcomes:

- Appropriate reporting questions in existing reporting structures – refer to 5.2.5

- Ability to adaptively update knowledge and identify further policy changes as required

Deliverables:

- Annual reports as per Phase IIb and overall evaluation as outlined in measure 5.

Risks and impacts of the measure

- There is considerable concern within floodplain communities that allowing the delivery of environmental water on top of regular and/or natural flows will exacerbated the flood risk. It is felt that the increased volumes, will increase the antecedent condition, posing the risk that if further water is added there is significant risk of a flooding event. This detail is largely covered within the Constraint Measures business cases however will receive considerable attention.
- The water ordering process (through State water agencies) needs careful attention, as that is part of how relevant parties work together. Water orders are required for MDBA river operators to then issues instructions for appropriate water releases.

Third party impacts and benefits

- Projects such as this one, which may have implications for operating Hume Dam and other major storages, will inevitably give rise to a range of concerns about the potential for such changes to create third party impacts.
- A key area of concern identified so far relates to inundation of private property.
- Impact to third parties is further detailed in the Constraint Measures business cases. It is expected that the majority of these issues will be addressed through this. Key identified impacts include inundation of private land and landholder crossings potentially impeding access to sections of properties, and damage to other private infrastructure.

Complementary actions and interdependencies

- This measure aims to allow for the ordering and delivery of environmental water to contribute to overbank flows to levels which will be defined within the relaxation of system constraints.
- The Hume Dam airspace proposal will see a change in dam release patterns which will be conducive to the hydrological cues delivery strategy.

5.2.5 EEWD 5 Develop a modelling and evaluation framework to assess the outcomes and operationalisation of enhanced environmental water delivery including the hydrological cues delivery strategy (including EEWD measures 1-4).

Background to measure

This measure is designed to ensure that the implementation of EEWD measures 1 – 4, along with critical components and dependencies, result in the outcomes expected of this proposal as a whole and in the context of the Basin Plan and Science Plan (under development). The ability to deliver environmental water under the enhanced environmental water delivery strategy, as guided by the underlying principles and objectives of the proposal, will be evaluated. Under this proposal's adaptive management principle and because of the progressive and phased implementation approach, it is recognised that ultimate proposal outcomes will be influenced by lessons learnt along the way.

This measure will also provide specific recommendations for assessment of the SDL adjustment mechanism. In 2024, MDBA assesses whether the implemented adjustment measures delivered the supply outcomes as determined in 2017. MDBA undertakes a final adjustment of the SDLs to account for any difference between planned and actual supply contribution. This also takes into account any additional efficiency measures proposed and implemented between 1 July 2017 and 31 December 2023. The process for final SDL assessment is under development.

MEASURE DESCRIPTION:

Monitoring and evaluation of the EEWD proposal seeks to

1. Evaluation the success of each individual measure (EEWD 1 – 4)
2. Evaluate the overall outcomes of the strategy as a whole in regards to:
    a. Hydrological outcomes
    b. Ecological outcomes
    c. SDL adjustments (2024)
3. Provide mechanism for continuous improvement of the measures to deliver the overall outcomes.

Existing O&O document already incorporate provisions for an annual independent review of the MDBA's performance in river operations activities and that their compliance with the general and specific outcomes and objectives for river operations practices has regard to any matters that are relevant. This measure does not replace this function.

A monitoring and evaluation plan will be developed to assess impacts and outcomes of delivering environmental water using enhanced environmental water delivery including the hydrological cues delivery strategy.

More broadly, the final monitoring and evaluation plan (MEP) for this proposal will be informed by broader intergovernmental arrangements for Basin-wide monitoring and evaluation under the Basin Plan. This includes aligning objectives and outcomes that will arise from the Science Plan (under development), Water Resource Plans, Basin-wide Environmental Watering Strategy, Long-term Watering Plans and Water Quality and Salinity Plans. This measure is expected to contribute to the achievement of outcomes under two key Chapters of the Plan, namely:

- The delivery of ecological outcomes under Chapter 8; and
- Under Chapter 10, meeting the relevant sustainable diversion limit/s, which must be complied with under the states' relevant water resource plans.

Under current Basin Plan Evaluation& Reporting framework, the implementation of improved water management mechanisms, as well as environmental outcomes, will be reviewed.

WORKPLAN:

Phase I (2012-2017)

Current evaluation frameworks and processes are in place as outlined in Chapter 13 and schedule 12 of the Basin Plan. The matters to be evaluated include environmental outcomes at both Basin and Asset scales, the identification of environmental water and the monitoring of its use and various matters under water resource planning including compliance, accountability and transparency for water sharing. These matters are the responsibility of the Authority, CEWH and Basin States.

Independent River Operators Reference Group currently reviews objectives and outcomes, and reports annually incorporating feedback from the jurisdictions. Similarly the existing matter 9.3 annual reporting from environmental water holders can provide a structure for reporting the delivery of held environmental water under the EEWD option.

Existing frameworks and processes will be reviewed to inform development of the plans for this proposal to ensure coordination and integration and avoid duplication.

Phase IIa: Design appropriate evaluation mechanisms: (2018-19):

Actions:

Review and design appropriate evaluation for the enhanced environmental water delivery mechanism. First the question ‘what does success look like’ will have to be clearly articulated in line with SMART principles; in consultation with the commonwealth, states, environmental water holders and river operations; and in consideration of the objectives and outcomes from planning instruments under the Basin Plan. The EEWD ‘proof of concept’ modelling work provides underlying assumptions required to deliver both environmental benefits and the SDL offset, while EEWD measures 1 – 4 provide a range of mechanisms to operationalise the proposal. The review and design should build on this knowledge to ensure the correct information is collected from all stakeholders through processes already in place where possible.

There may be a requirement to increase the Monitoring and Evaluation effort across the southern connected basin to address particular elements of environmental watering and outcomes under EEWD. The review and design should also align the objectives and outcomes that will arise from the Science Plan (under development), Water Resource Plans, Basin-wide Environmental Watering Strategy, Long-term Watering Plans and Water Quality and Salinity Plans as they become available.

It will also be necessarily to provide specific recommendations for assessment of the SDL adjustment mechanism. This will be conducted as part of the ongoing work undertaken by the MDBA in consultation with relevant organisations.

There are four distinct parts to the evaluation (Figure 7). Each part should include evaluation of the outcomes, efficiency (ie value for money/water) and appropriateness in relation to the overall objectives of the business case. Evaluation is the critical underpinning of adaptive management.

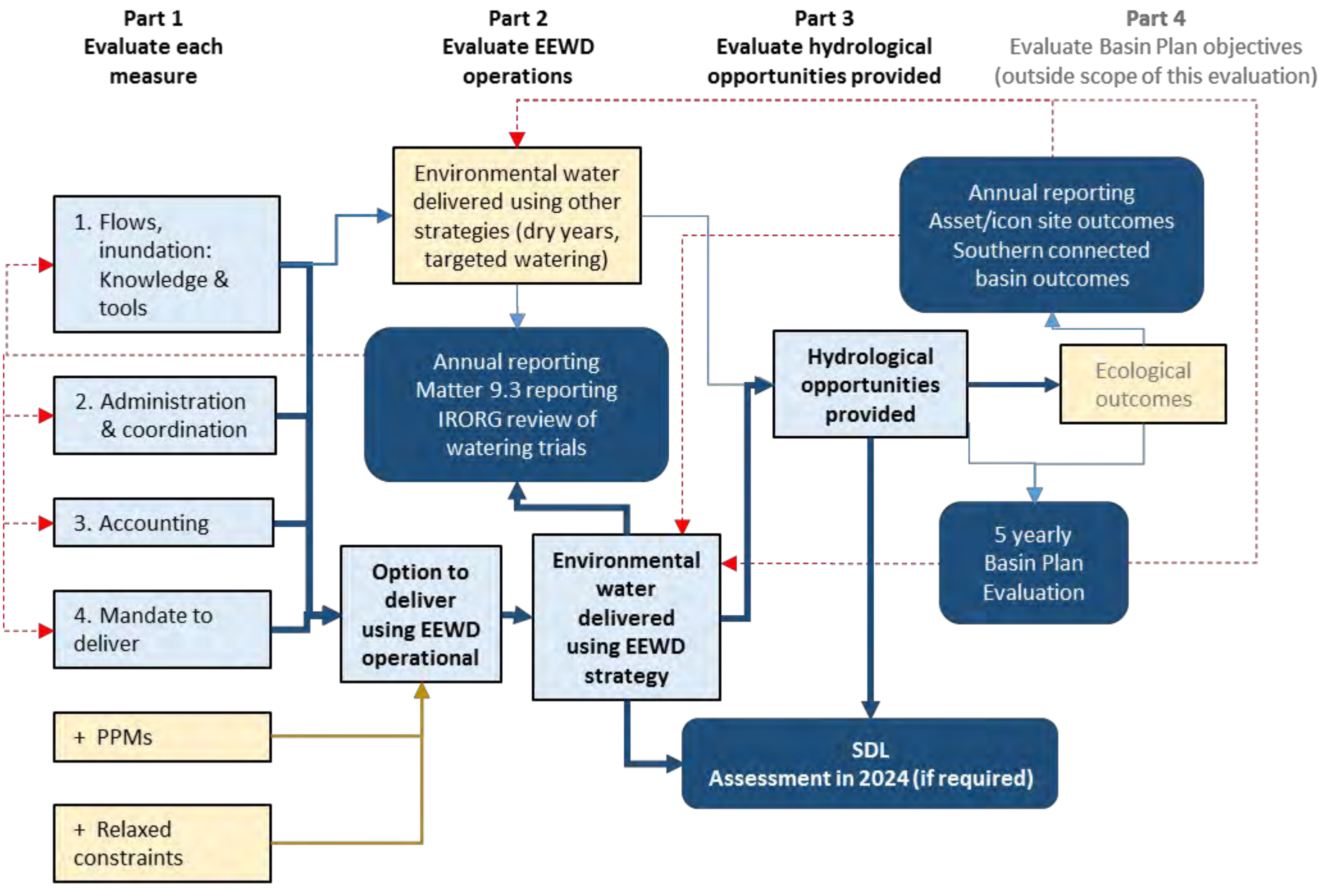


Figure 7: Evaluation of Enhanced Environmental Water Delivery.

Shown in red are the feedback loops that support adaptive management. It is expected that learnings from annual water use reporting (Matter 9.3) and watering trials will inform adaptive management of each measure, and annual reporting and basin plan evaluation processes will inform emerging environmental watering practice and outcomes.

Part 1: Evaluation of each measure

Table 8: Evaluation of each measure. These evaluation questions are in draft and may be further refined with iterations of the evaluation as measures are progressively implemented.

Measure	Description	Outcome	Evaluation
1	Flow & inundation (triggers)	Knowledge (tools) of how/when to delivery flows in sync with hydrological cues Aligns to objective 1	Have information and tools been developed that are fit for purpose and adaptable? Do environmental water holders and river operators use the information and tools?
2	Administration & coordination	The ability to coordinate between e-water holders, states and river operations to deliver flow – timely, common vision, reduced administrative burden Aligns to objectives 2 and 3	Is there evidence of greater coordination between water holders for delivering water for southern connected basin outcomes? Has the complexity and administrative burden of the processes that surround environmental water management been simplified and minimized? Do environmental water management processes enable environmental water delivery to accurately align with unregulated flows?
3	Remove accounting limitations	The ability to efficiently use e-water across the southern connect basin. Aligns to objective 3	Has the complexity of accounting for environmental water use been simplified?
4	Mandate for delivery	"Permission" to deliver the flow Aligns to objective 1	Can river operators and environmental water holders deliver a greater range of environmental flows, including overbank flows to new regulated limits? (linking to the critical dependency of constraint measures and PPM implementation)
Critical dependency	Constraint Measures (constraint relaxation)	Allows larger flows to be delivered to inundate priority low-lying floodplain areas	What level of relaxation achieved has been achieved? (Separate process)
Critical dependency	PPMs	Allows call on water from storage, protect e-water through system	Were the PPMs implemented as planned? (Separate process)

Part 2: Is the enhanced environmental water delivery mechanism implemented?

Matter 9.3 reporting. Consider specific reporting in conjunction with the review of Schedule 12 reporting requirements (MDBA). Matter 9.3 is reported annually by all environmental water holders and is a useful mechanism to allow continual assessment and adaptive management of each of the measures and the overall enhanced environmental water delivery mechanism over time. Some examples of the sort of evaluation questions include:

- How often were hydrological cues delivery strategy options triggered?
- What spatial scale were they available at/for?
- How often were they used, and by whom?
- What impediments were there to using them more often? (ie climate, targeted watering requirements, site operations, coordination between environmental water holders and/or river operations, accounting limitations).

Part 3: Did the measures and dependencies together deliver the hydrological opportunities and ecological outcomes sought. Were potential adverse impacts avoided or managed?

For the EEWD strategy to be successful there should be no change, or an increase in, the frequency and/or duration of target flows as measured by SFI and Ecological Elements scores compared to benchmark. Although this is modelled comparison, this should be translated to real world outcomes. There is a component of Basin Plan evaluation (2017, 2020, 2025) which encompasses the hydrological indicators and the extent to which the Basin Plan has influenced river flows and connectivity. This part is also essential towards final SDL assessment in 2024.

The monitoring and evaluation plan for this element will consider any additional monitoring and evaluation required to specifically understand the benefits and impacts of the delivery of a hydrological cues delivery strategy. This will include consideration of monitoring and evaluation for sites where they may be risk of adverse impacts and where strategies will be required to address these impacts that are outside of core business.

Part 4: Were the overarching Basin Plan Objectives met?

This is beyond the scope of this business case but is part of the Basin Plan Evaluations in 2017, 2020 and 2025.

Roles:

- MDBA to lead the development of the evaluation framework.

Outcomes:

- A clear understanding of how to evaluate each part of the measure
- Updated mechanisms to collect and report appropriate information
- Clear articulation of the roles of jurisdictions with regards to evaluation of EEWD
- A gap analysis to highlight additional M&E requirements to adaptively manage EEWD

Deliverables:

- Updated reporting templates
- Report outlining the evaluation requirements for EEWD

Phase IIb Implementation (2018-24):

Actions:

Implement the Monitoring and Evaluation Plan, commencing 2018/19, as outlined in Phase IIa. This will also lead to any assessment required as part of the SDL adjustment process in 2024.

Roles:

MDBA to lead implementation. Jurisdictions and environmental water holders/managers to undertake additional M&E and reporting as outlined in Phase IIa, according to their responsibilities under the Basin Plan (Schedule 12).

Outcomes:

- As outlined in table 7 for each measure
- As outlined in Phase IIa, parts 1-4

Deliverables:

- Annual reporting (ie matter 9.3)
- Annual and longer term reports for sites/assets across the southern connected basin
- Additional reports identified in phase IIa

Phase III - evaluation of planning outcomes (2024 -)

Action:

Evaluation of enhanced environmental water delivery in 2024. Refine and continue monitoring and evaluation as required for adaptive management and to meet reporting obligations beyond 2024 as required with regular review and reporting timeframes.

Roles:

MDBA to coordinate in partnership with Jurisdictions and environmental water holders/managers. Jurisdictions and environmental water holders/managers to undertake additional M&E and reporting as outlined in Phase IIa, according to their responsibilities under the Basin Plan (Schedule 12).

Outcomes:

- Ongoing adaptive management as Constraint Measures and other measures are implemented beyond 2024

Deliverable:

- Evaluation and reporting as outlined in Basin Plan (Schedule 12)

Environmental benefits

As outlined in section 3.3, this proposal has a range of anticipated environmental benefits linked to the changes in river flows (section 4.2). This measure does not provide additional benefits, but rather will provide an evaluation of the success of the proposal in providing those river flow and ecological outcomes and contribute to the adaptive management framework to support environmental flow management.

Risks and impacts of the measure

There is a risk that the review and design phase can introduce more complexity in an already overly complex structure for environmental watering and reporting. It is important the existing structures are used wherever possible, and that effort should be streamlined as much a practical.

Third party impacts and benefits

There is a potential benefit in aligning evaluation frameworks at different scales and levels to give a broader, clearer picture of outcomes of Basin Plan implementation.

This measure will be used to address risks and potential impacts on specific sites that have been identified and will be further identified as part of Measure 1, and will required specific actions to mitigate against those risks.

6 Stakeholder engagement strategy

There will be extensive stakeholder engagement, led by respective jurisdictions, with a focus on jurisdictional entities involved in environmental watering and those affected by changes to river operations outside of those addressed in the Constraint Measures e.g. catchment management authorities etc. Implementation of the program of work will also require a level of broader community engagement which will be coordinated with/complementary to engagement planned for the Constraint Measures projects. Coordination will prevent duplication and provide considerable efficiencies.

This project spans three states (Victoria, New South Wales and South Australia) with multiple other parties involved in planning and management of environmental water. This includes agencies and organisations responsible for river operations (MDBA, Water NSW and Goulburn-Murray Water), those responsible for asset and icon site management (e.g. Victorian catchment management authorities, Forests NSW, National Parks, etc), and environmental water holders and coordinators (CEWO, OEH, VEWH, SA, MDBA). There will be considerable stakeholder management and engagement over and above core business. As a result, engagement will be complex and will require detailed planning, structure and strategies and budget. It will also need to complement and integrate with Constraint Measures engagement strategies

Summary of engagement to date:

In developing this proposal, a multilateral workshop involving relevant jurisdictional agencies was held to identify the key issues of concern and potential benefit in February 2017. In addition, a number of bilateral meetings in late 2016 and in 2017 identified potential limitations, risks, or further work required as well benefits and complementary work planned or in progress.

Direct engagement with the broader community has not been undertaken by MDBA as we have respected the desire of jurisdictions to lead community engagement within their respective jurisdictions.

Identifying the next steps for developing a stakeholder engagement strategy:

This section outlines consultation approaches for key stakeholder groups during the project development and implementation phases. It is recognised that states will continue to lead community consultation processes within their jurisdictions. It has been identified that there are two levels of engagement required for this proposal. The broad groups required within these levels are outlined below (Table 9: Local and regional stakeholder groups). One level will require government level stakeholder engagement. This is aimed at river operations, environmental water accounting, site management, monitoring and evaluation and environmental water holders. The second level will be aimed at broader community level stakeholders and will be closely aligned with constraints management engagement planning. Detailed stakeholder engagement plans are intended to be constructed in phase 3 of the below SDL implementation engagement activities.

A phased approach to stakeholder engagement is outlined, that will need to be integrated with other relevant SDL adjustment proposals, as well as being considerate of other state and Basin Plan implementation engagement activities:

- **Phase 1:** Business case development and stakeholders identified
- **Phase 2**: Activities and outcomes from proposal matched to relevant stakeholders, identify any overlap between other proposals and other planned engagement activities
- **Phase 3:** Design of consultation plan and production of supporting materials. This will include a process for managing media enquiries.

- **Phase 4**: Delivery of the consultation plan including stakeholder workshops and other engagement mechanisms. If required, states to conduct a range of community engagement meetings, as appropriate to the audience and engagement purpose. The number of meetings required will depend on the final form of the proposed changes and how wider consultation processes on other SDL adjustments and Basin plan implementation issues are managed.
- **Phase 5:** Evaluating the effectiveness of the engagement process.

The various phases of the project will require different approaches to engagement with various stakeholder groups. There will be some overlap as the project moves into different phases and adaptive management will need to be adopted in order to respond to stakeholders needs.

For broader the community engagement strategy, a simple community engagement plan will be developed that involves the use of jurisdictional and local agency communications networks in close communication with the MDBA. This will be done in a way that is complementary to and does not duplicate constraints management engagement by the states.

Table 9: Local and regional stakeholder groups

Stakeholder group	Details
Group 1: Agencies	• Department of Agriculture and Water Resources (Commonwealth) • Commonwealth Environmental Water Office • MDBA • SA Water • NSW DPI Water • Goulburn-Murray Water • Victorian Department of Environment, Land, Water and Planning • SA Department of Environment, Water and Natural Resources • Water NSW • NSW Office of Environment & Heritage • Victorian Environmental Water Holder
Group 2: other river management organisations	• CMAs / NRM Boards • Water authorities • Indigenous groups
Group 3: Landholders and directly impacted stakeholders	• Landholders and local community members • Broader NSW/Vic/SA Aboriginal community • Local Land Services • Shire councils

Table 10: Consultation strategy for the implementation phase

Stakeholder Group	Consultation approach
Group 1 & 2: Agencies/ other river management organisations	• Intensive engagement with technical experts through Steering Committees • Design planning and operation meetings, identifying milestones and outcomes.
Group 2: Landholders and directly impacted stakeholders	• Individual meetings as required • Notifications – email, mail or phone

	• Information packages via website (e.g. fact sheets, photos, contact information)

7 Legal and regulatory requirements

Implementation of the EEWD proposal interacts with a range of policy documents and legislative instruments. The exact detail of any changes to these documents will be scoped as part of Phase IIa of the work program for each EEWD measure (see section 5). In many instances this will build on Phase I which represents the evolving environmental water management to date including watering trials. Any changes to legislation or policy documents identified in Phase IIa will be implemented in Phase IIb by the relevant jurisdiction. The below list includes some of the relevant legal and regulatory instruments that may need review as part of the EEWD measure, noting a more formal assessment will be complete as part of Phase IIa. The final evaluation of each measure, are phase III of the proposal.

Implementation of EEWD 4 specifically requires changes to the river operations frameworks to enable the delivery of environmental water up to agreed constraints levels. Without specific and defined powers, the bodies responsible for delivering environmental water could be found liable to pay compensation for negligence or nuisance and may also void their current immunities, or alternatively may not be prepared to operate rivers effectively. Therefore, review of legal and regulatory requirements is particularly urgent in this area. Note, a number of policy and legislative changes are required to relax constraints in priority reaches, these are listed but not explored in detail here. Implementation of the Constraint Measures and related legal and regulatory changes is critical to being able to effectively deliver this SDL proposal.

Note: the below list does not constitute formal legal advice and is indicative only

Table 11: Legal and regulatory instruments that may influence the EEWD proposal.

Legal and regulatory instrument		EEWD Measure	Jurisdiction
Legislation	*Water Act 2007* (Cth)	EEWD 1-4	Commonwealth
Agreement	The Murray-Darling Basin Agreement (Joint Venture arrangement)	EEWD 2, EEWD 3, EEEW 4	Ministerial Council
Policy Document	Objectives and Outcomes for the river operations in the River Murray System	EEWD 1 - 5	Basin Officials Committee
Internal Document	Guidance on whole of River Murray System operations	EEWD 1, 2, 4	The MDBA
Internal Document	River Murray System operations reference manual	EEWD 1, 2, 4	The MDBA
Internal Document	Flood operations manuals	EEWD 1, 2, 4	The MDBA
Internal Document	Environmental guidelines	EEWD 1, 2, 4	The MDBA
Legislation	*NSW Environmental Planning and Assessment Act 1979*	TBC	NSW
Legislation	*NSW Water Management Act 2000*	TBC	NSW
Legislation	*NSW Fisheries Management Act 1994*	TBC	NSW
Legislation	*Water Act 1989* (Vic)	TBC	Victoria
Policy Document	Integrated Waterway Management Strategy	TBC	Victoria
Legislation	*Murray-Darling Basin Act 1993* (Vic)	TBC	Victoria

Common law	Common law – negligence or nuisance considerations	TBC	All
Legislation	*River Murray Act 2003* (SA)	TBC	SA
Legislation	*Murray-Darling Basin Act 2008* (SA)	TBC	SA
Legislation	*Natural Resources Management Act 2004* (SA).	TBC	SA
Policy Document	Basin Plan water trading rules	EEWD 3	The MDBA
Policy Document	CEWH Water trading framework (including consistency with PGPA Act and Commonwealth Procurement Rules 2014)	EEWD 3	CEWO

7.1 Proposed management strategy:

All relevant jurisdictional legal and regulatory instruments will be assessed and reviewed as part of EEWD measure 2 and 4. If any changes are required, a strategy will be developed including the process required, roles and responsibilities, risks and timeframes.

A process has been agreed with SDLAAC for making changes to the general framework for River Murray System operations, to give effect to a range of constraint and supply measure proposals. As part of this, an independent expert is being engaged to document the proposed changes to the framework for in-principle agreement. Changes already identified in Phase I, and new changes identified as part of Phase IIa, can be incorporated into a broader reform package in Phase IIb. This can occur concurrently with other changes required as part of the broader SDLAM process. Phase III will evaluate each of the EEWD measures and provide a framework for assessing outcomes as part of the SDL adjustment mechanism.

8 Governance, program management and assessment

This proposal has been developed on behalf of southern basin jurisdictions and as such will be jointly governed by the Commonwealth, New South Wates, Victorian and South Australian governments. All jurisdictions are required to deliver project objectives and outcomes, and as such project risks will be shared (see implementation principles and supporting context, section 2.5). Program oversight will be provided through BOC supported by the oversight of the relevant SDL Adjustment Implementation committee.

A brief governance structure for the program of works is outlined below (Figure 8).

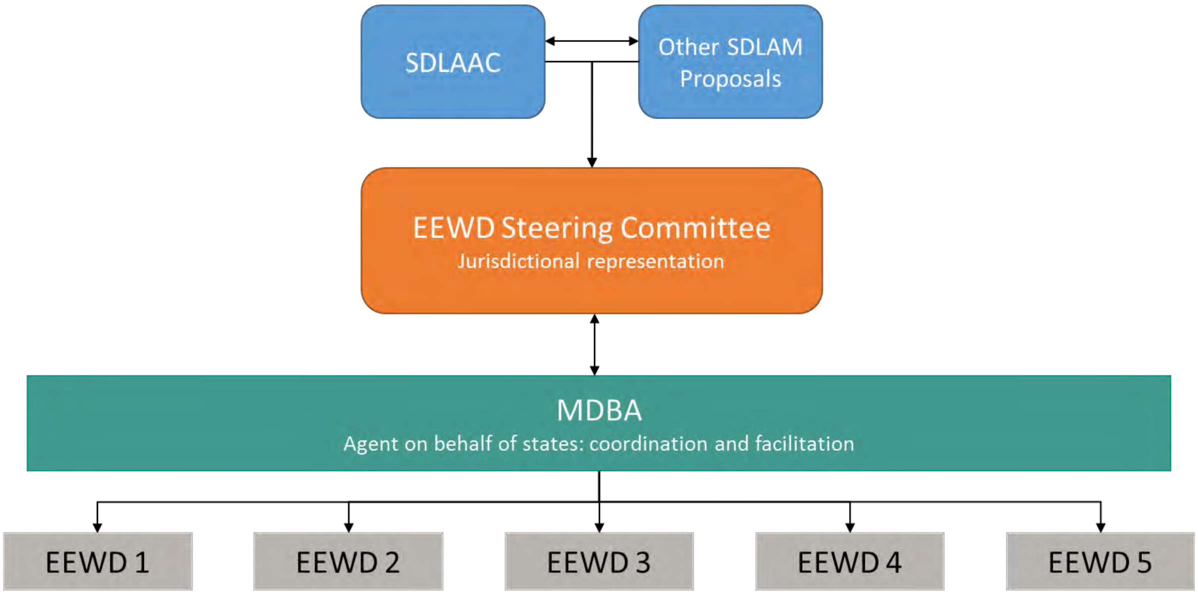


Figure 8 Schematic of proposed governance structure

Implementation of this proposal will require the establishment of an overarching project management team to undertake the necessary facilitation and coordination tasks. The state proponents have suggested that the MDBA could undertake a role in doing so, acting as agent on behalf of the states. The successful implementation of this proposal will require the identification clear leads and partners for each EEWD measure across a number of jurisdictions and agencies (noting the potential for leads and partners to alter slightly during the different phases of implementation). The identified leads for each EEWD measure would be required to report back to the EEWD Steering Committee through the project management team. Further detail on the indicative governance of each EEWD measure can be found in section 5.2.

The project managers for progressing each EEWD measure will be required to report back to a steering committee of jurisdictional representatives that provides overarching guidance and control to the phased implementation of the EEWD proposal. The detail of the steering committee and its terms of reference will be developed once the proposal is approved including whether any existing groups could play this role. Targeted input and advice will be sought from existing committees as appropriate, including SCBEWC, EWWG, RMOC and IRORG. Working groups may also be established where appropriate.

A detailed program management plan will be developed once the proposal is approved. This includes developing a detailed stakeholder engagement strategy and an overview of governance for operationalising the hydrological cues delivery strategy. Governance includes developing more detail around various roles and responsibility during implementation, as well as demonstrating capacity for jurisdictions and site managers to exercise the option to say no to a hydrological cues delivery opportunity.

An indicative timeline has been developed to show the phasing of each EEWD measure and the relationship to inter-dependencies (see Figure 9). The three phases include:

- **Phase I**: recognises work already underway and in development.
- **Phase IIa**: scoping and planning the work to be conducted through the measures. Often this phase includes a detailed review of current operational procedures.
- **Phase IIb**: phased implementation of the measure. In many instances this will be reliant on the concurrent implementation of other EEWD measures and inter-dependent processes such as PPM's and the Constraint Measures.
- **Phase III**: evaluation of the implementation of the measures and the overall project.

Note timing of specific components could vary from the projected timeline. This is because different SDL adjustment projects will be realised over different time frames to 2024, and because implementation progress is staged in a number of dependent proposals (notably constraints relaxation).

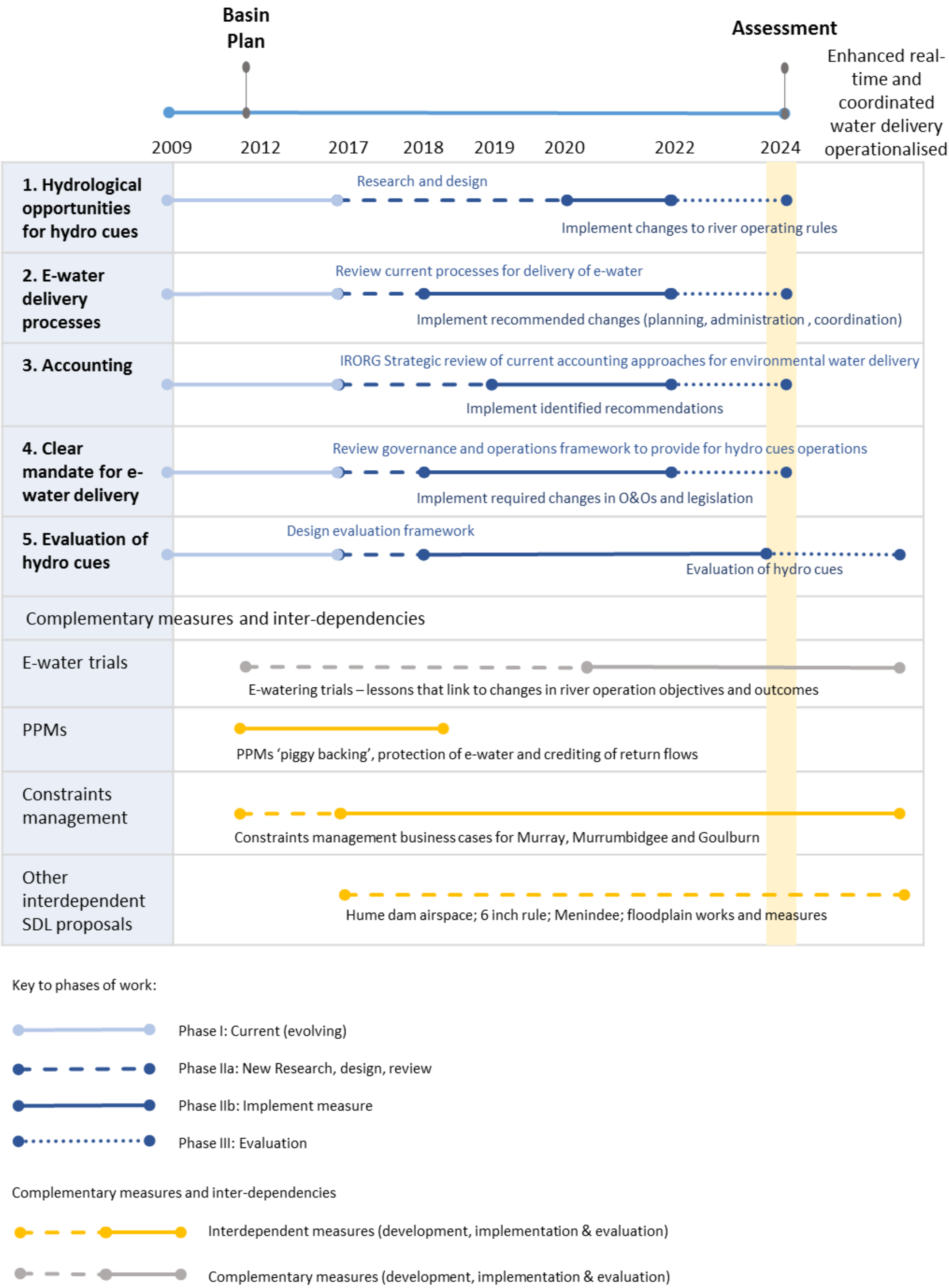


Figure 9: EEWD implementation timeline.

9 Risk assessment

This section considers project development and operational risks that could impact the proposal delivery and utilisation. The identified potential adverse ecological effects (see section 3.4) have also been considered in this risk assessment.

Identified risks have been broadly grouped into the following categories:

- Governance and project management
- Operationalising EEWD
- Adverse ecological impacts
- EEWD measure specific risks

This risk assessment was completed in line with the AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines (Standards Australia, 2009). This methodology assesses both the likelihood of an event occurring and the severity of the outcome if it occurred. The framework used in this assessment has been outlined below in Table 12 and Table 13.

It is recognised that overall this is a relatively high risk proposal, but a proposal with high environmental benefit and low cost.

The listing of risks, their severity and potential mitigation strategies are listed below in Table 14. We believe this to be a fair and encompassing list of potential risks to the proposal, however a best endeavours approach was utilised. It is possible that further risks may be identified or risk severity altered during the scoping of the different EEWD measures (phase IIa of the proposed work plan).

Table 12: Risk matrix.

	Consequence			
Likelihood	Minor	Moderate	Major	Extreme
Rare	Low	Low	Low	Moderate
Unlikely	Low	Low	Moderate	High
Possible	Low	Moderate	High	High
Likely	Low	Moderate	High	Very high
Almost certain	Moderate	High	Very high	Very high

Table 13: Definitions of risk levels.

Low	Risk has a low likelihood and/or consequence of occurring. Risk is a minimal concern and risk management may be considered.
Moderate	Risk has a moderate likelihood with reasonable consequence. Risk management should be undertaken.
High	Risk is likely to occur and will have harmful consequences. Risk is of a large concern and risk management is essential.
Very high	Risk is likely to occur and will have very harmful consequences. Risk is of high concern and risk management is essential.

Table 14: Risk assessment and proposed mitigation.

Risk No.	Description of risk	Likelihood	Consequence	Initial risk	Mitigation	Residual risk
Governance and project management						
1	Failure to fully implement the Constraint Measures SDLAM consequence	Possible	Extreme	High	Adequately identify dependencies with Constraint Measures in this Business Case to ensure high-level buy-in for agreed constraints levels prior to confirmation of this proposal. Establish an agreed implementation management process that requires jurisdictions to provide quarterly progress updates on the implementation process. Regular communication and coordination with Constraint Measures implementing jurisdictions via SDLAAC and Constraint Measures Working Group (or other relevant governance groups) to occur. Project delivery risks for the Constraint Measures are identified and mitigated in the relevant business cases.	High
2	Failure to fully implement the Constraint Measures Ecological consequence	Possible	Major	High	Adequately identify dependencies with Constraint Measures in this Business Case to ensure high-level buy-in for agreed constraints levels prior to confirmation of this proposal. Establish an agreed implementation management process that requires jurisdictions to provide quarterly progress updates on the implementation process. Regular communication and coordination with Constraint Measures implementing jurisdictions via SDLAAC and Constraints Measures Working Group (or other relevant governance groups) to occur. Project delivery risks for the Constraint Measures are identified and mitigated in the relevant business cases.	Moderate
3	Failure to implement PPMs in their entirety by 30 June 2019	Possible	Extreme	High	To maximise the SDL adjustment potential, the Basin Plan requires the implementation of PPM's by June 2019.	High

	Proposal consequence				An implementation management process has been agreed by SDLAAC. The process will involve jurisdictions providing quarterly implementation progress updates to the SDLAAC between July 2017 and June 2019. In addition, jurisdictions will prepare an annual written implementation progress report that will be reviewed by IRORG and tabled at BOC. Annual environmental watering trial process provides vehicle to continue to test implementation of PPMs, with multi-jurisdictional oversight and agreement via RMOC and BOC.	
4	Failure to deliver all EEWD measures to a useable standard Proposal consequence	Possible	Extreme	High	An effective program management structure and detailed project plan to be developed to ensure measures implemented to a useable standard by agreed dates. Project management and coordination to be overseen by the MDBA via multi-jurisdictional committees (e.g. SDL implementation committee and/or SCBEWC). Evaluation framework designed as part of EEWD measure 5 to ensure objectives of proposal are clearly defined and measurable, with a clear measure of success. Review and evaluation periods identified in project plan to ensure delays or issues identified and mitigated early.	Moderate
5	Insufficient commitment of time and resources from all jurisdictions during implementation Proposal consequence	Possible	Major	High	Project plan (including roles, responsibilities and resourcing) developed in partnership with jurisdictions. Processes for project implementation to be identified and streamlined to ensure efficient and effective project delivery. Interim inter-governmental working group established to provide advice and oversight for the business case design and development. SDL implementation committee to provide jurisdictional oversight and guidance for implementation.	Moderate
6	Breakdown of cooperation and	Possible	Major	High	Implementation principles and project plan identified in the business case to be agreed between all relevant agencies, including roles and	High

	relationships between proponents Proposal consequence			High	responsibilities for the development and implementation of the Proposal. Project plans include strategies to engage and maintain relationships between proponents. The mutual benefit and importance of the Proposal is clearly communicated to all jurisdictions regularly.	
7	Unwillingness to commit to implementing changes, including in the water accounting framework, required to enhance environmental water delivery in an enduring way Proposal consequence	Likely	Major	High	Implementation principles identified in business case to be agreed by all jurisdictions via SDLAAC. SDL assessment and evaluation framework to ensure any changes are implemented in an enduring way or SDL adjustment not granted.	Moderate
8	Insufficient funding and resources to implement the proposal Proposal consequence	Possible	Extreme	High	Costings and resources identified in business case to be approved and agreed by jurisdictions via SDLAAC prior to implementation of proposal. Review costings during implementation and seek further funding if required. Implementation of the Constraint Measures has its own funding attached.	Moderate
9	Unable to adequately mitigate third party impacts (i.e. new effects on reliability) Proposal consequence	Possible	Major	High	Relevant stakeholders will be consulted throughout the implementation of the proposal to ensure third party impacts are identified and mitigated, additional modelling and investigation will be conducted as required to build understanding. Ongoing engagement with landholders regarding planned watering events and outcomes (as a component of Constraint Measures engagement).	Moderate

10	Unforeseen inability to test approach due to inadequate climatic conditions (i.e. too dry or too wet) Proposal consequence	Possible	Moderate	Moderate	Implementation of the approach will be phased allowing for discrete trials. A communication strategy between proponents and other stakeholders to be developed to communicate the progress of the trails and to manage expectations.	Low
11	Unforeseen changes in the level of political support for the proposal and associated work Proposal consequence	Possible	Major	High	All governments have committed to Basin Plan implementation. The SDL adjustment mechanism is a component of the Basin Plan. Changes to support for this proposal will be considered in the SDL adjustment at assessment in 2024. The mutual benefit and importance of the Proposal is clearly communicated to all jurisdictions regularly.	Moderate
12	Unforeseen delays due to delays in interdependent processes, approval processes or conflict with stakeholders Proposal consequence	Possible	Moderate	Moderate	Establish effective joint governance and coordination mechanisms, with streamlined processes to ensure efficient and effective project delivery. Communication strategies adopted to manage expectations and dispel misunderstandings. Clear project planning and review points will be developed to ensure delivery of this proposal by 2024.	Low
Operationalising Enhanced Environmental Water Delivery						
13	Implementation of the proposal does not achieve intended ecological response SDLAM consequence	Possible	Extreme	High	Hydrological cues delivery strategy based on sound science and expertise. Models predicting ecological outcomes developed using the best available information. Ecological objectives are aligned with other relevant objectives (e.g. in LTWPs) to create efficiencies and shared vision and goals for environmental water management. Implementation of the proposal will be phased to allow finessing of the operation and the use of adaptive management strategies. On ground outcomes to be monitored and the approach modified as new understanding is generated. A communication strategy to be	Low

					developed to ensure the incorporation of site manager feedback and review workshops.	
14	Increased third party impacts SDLAM consequence	Possible	Major	High	Ongoing engagement with landholders regarding planned watering events and outcomes (refer to Constraint Measures business case). Implementation of the proposal will be phased to assess any potential impacts and mitigate prior to full implementation. This will also allow the finessing of operation. This will be completed to reflect to Constraint Measures consultation and implementation processes. Feedback loop developed with the Constraint Measures implementation process to efficiently and effectively manage third party impacts.	Moderate
15	River operators unable to operate using the EEWD approach due to insufficient constraints relaxation and legal protection Proposal consequence	Likely	Extreme	Very High	Regular communication and coordination with Constraint Measures implementing jurisdictions via SDL implementation committee and Constraints Measures Working Group. River operators will be consulted throughout the development of the proposal and operating approach. Secure a mandate for the operation of EEWD for the River Murray and its tributaries through BOC. Provide support for the legal process of PPM implementation. Implementation of the approach will be phased allowing for trials and gradual commissioning.	Moderate
16	Environmental water holders unwilling to utilise the EEWD approach due to lack of confidence in ecological outcomes or social impacts or lack of allocations	Likely	Extreme	Very High	Environmental water holders will be consulted during the development and implementation of the proposal and involved in the development of the hydrological cues delivery strategy to ensure it is fit for their purpose. Implementation of the proposal will take a phased approach to build confidence, including conducting environmental watering trials and adaptive management principles will be applied. On ground outcomes to be monitored and the approach modified as new understanding is generated.	Moderate

	Ecological consequence					
17	Identified flow triggers are shown to be unsuitable and unable to be operationalised Proposal consequence	Possible	Extreme	High	Flow triggers to be based on best available evidence, and trialled through extensive collaboration and consultation with environmental water holders, modellers, proponent governments and river operators. Implementation of the use of triggers will be phased to allow finessing and flexibility within the triggers and the use of adaptive management strategies.	Moderate
18	Inadequate technology available to confidently implement the EEWD approach (i.e. forecasting) Proposal consequence	Likely	Major	High	Project plan allows for comprehensive review of technology required to operationalise EEWD (in partnership with Constraint Measures). Continue to build on the knowledge and experience of Commonwealth and State river operations.	Moderate
19	Lack of community confidence and social licence to operate the EEWD approach Proposal consequence	Likely	Major	High	Implementation of the proposal will be phased to build community confidence. Ongoing stakeholder engagement will occur (early and often) guided by a stakeholder engagement plan, in partnership with Constraint Measures. Targeted engagement to address identified concerns.	Moderate
20	Unforeseen legal challenges raised by the community or lobby groups Proposal consequence	Possible	Moderate	Moderate	Early and ongoing consultation with stakeholders (see Constraint Measures). Transparent development and operationalisation of the Proposal.	Low
Adverse ecological impacts						
21	Reduction of spill events effects outer floodplain ecological outcomes (SFI)	Likely	Major	High	Identify key floodplain dependent ecosystem that may be effected and look for alternative options to manage these areas.	Moderate

	Ecological consequence				Implementation of the proposal will be phased to assess any potential impacts and mitigate prior to full implementation.	
22	Potential negative impacts on the CLLMM (i.e. in drought scenarios) Ecological consequence	Possible	Extreme	High	Implementation of the proposal will be phased to assess any potential impacts and mitigate prior to full implementation. Delivery of environmental water remains the decision of the environmental water holders in line with their objectives for ecological outcomes. Build in a hydrological trigger(s) to support delivery to this site and ensure complementary targeted delivery of environmental water in line with the long term environmental watering plans.	Low
23	Frequency and severity of Blackwater events, and other adverse water quality events, may be impacted	Possible	Extreme	High	Implementation of the proposal will be phased to assess any potential impacts and mitigate prior to full implementation. Triggers will be flexible to account for preceding, current and forecasted flows. Delivery of environmental water remains the decision of the environmental water holders in line with their objectives for ecological outcomes.	Low

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

The following table lists the requirements as specified by the Phase 2 Assessment Guidelines and identifies where each criteria is addressed in the business case.

Table 14: Links between the Enhanced Environmental Water Delivery SDL Adjustment Proposal and the Phase 2 Assessment Guidelines.

Guidelines Section	Description	Business Case Section
3.1.1	Supply measure definition	2.8, 4.2
3.1.2	Measures not included in the benchmark conditions of development	0, 5.2
3.2.1	Constraint measure requirements	2.4.1, 2.5
3.2.2	Alignment with the Constraint Measures	2.4.1, 2.5
3.3	Operational by 30 June 2024	2.8, 5.2, 8
3.4.1	The measure is a ‘new measure’	2.8
3.4.2	Compliance with the purposes of the Water for the Environment Special Account	Not applicable
4.1	Project details	2, 8
4.2	Ecological values of the site	3.1
4.3	Ecological objectives and targets	3.2, 3.4
4.4.1	Anticipated ecological benefits	3.3, 5.2
4.4.2	Potential adverse ecological impacts	3.4, 9, Appendix 4
4.5.1	Current hydrology and proposed changes to the hydrology	4
4.5.2	Environmental water requirements	3
4.6	Operating regime	4.1, 4.2, 4.3, 5.2
4.7	Assessment of risks and impacts of the operation of the measure	3.4, 5.2, 9
4.8	Technical feasibility and fitness for purpose	2.2, 5.2, 8, Appendix 2
4.9	Complementary actions and interdependencies	2.4.1, 2.5, 5.2
4.10.1	Projects seeking Commonwealth Supply or Constraint Measure Funding	2.7
4.10.2	Projects not seeking Commonwealth Supply or Constraint Measure Funding	2.7
4.11.1	Stakeholder management strategy	5.2, 6
4.11.2	Legal and regulatory requirements	5.2, 7
4.11.3	Governance and project management	5.2, 8
4.11.4	Risk assessment of Project Development and Delivery	3.4, 5.2, 9
Appendix 6	Summary of key evaluation criteria	Appendix 1
Appendix 8	Categories of risk and impact that should be considered in business case development	9

Appendix 2 – Hypothetical hydrological cues delivery plan

The following table has been modified from a real CEWO delivery plan. In particular CEWO's delivery plan for their 2015-16 hydrological cues operations in the River Murray.

Note that this proposal's use and adaptation of a real delivery plan is a mock-up to assist with demonstrating proof of concept for the approach. It should not be interpreted as CEWO's support or endorsement for any altered content within. This adaptation is merely an early imagination and adaptation of what a hydrological cues delivery plan in 2024 could look like.

Item No.	Description	Details
	Authorisation signature block	This plan has been approved by: *Insert each environmental water holder as appropriate – to sign and date their explicit approval of the plan*
1	**Action summary**	Agreement between Environmental Water Holders has made available up to Z GL of environmental water to support winter-spring river flows within the River Murray. The planned flow regime aims to provide whole of system benefits from Hume Dam through to the Coorong, Lower Lakes and Murray Mouth. Environmental water delivery will be managed by the MDBA RMO to coordinate system operations and in response to seasonal conditions. Local expert advice will be used to support operational decisions on the use of environmental water. The releases of environmental water from storage will be guided by natural hydrological cues. This is expected to result in environmental water being predominately delivered during the winter-spring period. These hydrological cues will also guide the complementary operation of floodplain infrastructure, weir pools, wetland regulators and lake barrages to maximize the environmental outcomes. The planned use of held environmental water aims to support in-channel, wetland and low elevation floodplain habitat for improving the condition, movement and recruitment of native fish, improve riparian and wetland vegetation condition and the managed export of salt from the River Murray system.
2	**Catchment**	River Murray Valley - WUM: 10031
3	**Duration**	1 June 2024 to 31 January 2025
4	**Environmental assets being targeted**	River Murray channel and low elevation floodplain from Hume Dam to the Lower Lakes, Coorong and Murray Mouth.
5	**Environmental water proposed for use**	Volume: Z ML subject to environmental need and water availability. This total volume includes: Y ML of Commonwealth held NSW and Victorian Murray allocation X ML Commonwealth's held South Australian allocation W ML of MDBA The Living Murray allocation V ML of Victorian Environmental Water Holder (VEWH) allocation U ML of NSW Office of Environment and Heritage (OEH) allocation

<table>
<tr><th>Item No.</th><th>Description</th><th>Details</th></tr>
<tr><td></td><td></td><td>The proportion of allocations accessed from accounts will be determined by the Portfolio Management Section of each water holder throughout the year and communicated to the MDBA RMO.</td></tr>
<tr><td>5</td><td>Other potential water volumes contributing to this event</td><td>The above volume will be coordinated with:
Environmental water return flows from upstream catchments
Other volumes of environmental water delivered across the southern connected basin
River Murray unregulated flows
River Murray Increased flows
Other river operations and consumptive water deliveries.</td></tr>
<tr><td>6</td><td colspan="2">Proposed watering actions</td></tr>
<tr><td>a.</td><td colspan="2">Location: River Murray valley</td></tr>
<tr><td></td><td colspan="2">Management objectives (relevant to the environmental outcomes within the Basin-wide environmental watering strategy)
<u>Ecological objectives</u>:
▪ Maintaining current species diversity, extend distributions, improve breeding success and numbers of short, moderate and long-lived native fish species by:
– Increasing the presence of fast flowing fish habitat along the River Murray and, where feasible, increased lateral connectivity with anabranches and low elevation floodplain wetlands.
– Supporting primary and secondary production along the River Murray through the mobilisation and longitudinal transport of nutrients, carbon cycling and biotic dispersal.
– Maintaining sufficient flows through the barrage fishways to maintain connectivity between the Lower Lakes and Coorong enabling the seasonal movement of diadromous fish species.
– Maintaining suitable habitat conditions (salinity and water levels) for estuarine fish species within the Coorong North Lagoon
– Providing opportunities for fish spawning, subject to appropriate seasonal conditions.
▪ Maintaining the extent and condition of riparian and in-channel vegetation by:
– Increasing periods of growth for non-woody vegetation communities that closely fringe or occur within the River Murray channel, anabranches and low elevation floodplain wetlands.
– Maintaining the current extent of Ruppia tuberosa by supporting suitable habitat conditions within the Coorong South Lagoon to promote growth and survival.
– Maintaining the diversity, condition and extent of aquatic and littoral vegetation in the Lower Lakes.
– Maintaining the extent and condition of inundation dependent river red gum, black box, lignum and non-woody vegetation within low-lying areas of floodplain, subject to appropriate seasonal conditions.
▪ Supporting suitable habitat conditions and food resources for water bird growth and survival, maintenance of population condition and diversity, along the River Murray valley and within the Coorong lagoons, subject to appropriate seasonal conditions.
▪ Supporting the managed transport and export of salt and nutrients from the River Murray system.
<u>Hydrological objectives for River Murray flow</u> (subject to seasonal conditions, water availability and operational feasibility):
▪ Base flows targeting:
– X ML/d variable flow rate (+/- X ML/d), up to Y days duration, measured d/s Yarrawonga Weir during the period July to November.
– median flow of X ML/d with +/-Y ML/d variability for a period of up to 90 days duration measured at the South Australian border during the period August to November.</td></tr>
</table>

Item No.	Description	Details
		– minimum barrage flows of X ML/d barrage flows during the period of August to January 2016. – approx X ML/d continuous flow through the barrage fishways during the period August 2015 to January 2016. ▪ Fresh(es) during September-November targeting: – X ML/d for minimum Ydays, measured at the South Australian border, in coordination with unregulated flows and/or tributary inflows ▪ Overbank flows during August-November (subject to natural hydrological cues): – maximum X ML/d, measured d/s Yarrawonga Weir, up to Y days following the recession of a natural high flow event (refer to operational limits below). – X ML/d, measured at the South Australia border, up to Y days duration.
		Delivery arrangements General arrangements General arrangements are outlined in *Operating arrangements for the delivery of Commonwealth environmental water (Appendix 1).* Commonwealth held South Australian allocation will be accessed within South Australia for use in discrete South Australian wetlands, water level management within the Lower Lakes, and barrage flow into Coorong. The delivery of the Commonwealth's South Australian access entitlement to the South Australian border will be in accordance with the monthly entitlement flow. During regulated flow conditions, Commonwealth environmental water will be delivered as a water order to an agreed location or for diversion from the river. E During unregulated flow conditions environmental water delivery will be managed in accordance with the agreed hydrological cues delivery strategy. MDBA RMO will provide updated hydrographs for the River Murray demonstrating the expected use of environmental water. The MDBA's Operational Advisory Group will be consulted to provide advice on the expected hydrograph and operating strategies to maximise environmental outcomes. The participating environmental water holders, relevant state government agencies, water authorities and regional agencies will participate as members on these groups. River Murray flows will be coordinated with other sources of environmental water, and consumptive water orders. The delivery of environmental water should be managed complementarily with standard river operations and not substitute for water managed to the effect of other operational requirements, rules or past practices.
		Operating strategies and accounting arrangements The following broad suite of operating strategies and the associated specific delivery arrangements are proposed for the use of Commonwealth environmental water (NSW and Victorian Murray allocation) during 2024-25. The implementation of any strategy will be determined with regard to seasonal conditions and natural hydrological cues. *Environmental water delivery during regulated river conditions* Environmental water will be managed either as a direct order at Hume Dam, to the South Australian border or to other works within the River Murray as predetermined in agreement between the participating environmental water holders, the MDBA RMO and relevant state authorities as required. The delivery of environmental water will be guided by the modeled natural flow (based on seasonal conditions) as determined for d/s Yarrawonga Weir and /or the South Australian Border. *Releases from Hume Dam in response to natural hydrological cues during unregulated river conditions:* The directed release of Commonwealth environmental water from Hume Dam will be guided by the modelled natural flow (based on seasonal conditions) as determined for d/s Yarrawonga Weir and /or the South Australian Border. Where the modeled natural flow exceeds the MDBA RMO's planned/expected operational outlook environmental water, up to the volume limits agreed, will be released from storage to increase river flows targeting a rate downstream of Yarrawonga Weir proportionate to the modeled natural but not resulting in flow rates at Doctor's Point exceeding existing operational limits or maximum flow rates defined below. This will result in a translucent flow from Hume Dam.

Item No.	Description	Details
		• If there are strong tributary inflows in the Ovens or other downstream tributary flows, but only moderate inflows to Hume, an increased portion of the Hume inflows may be called upon in order to create the hydrologic regime needed to achieve intended environmental outcomes. Based on the total volume of environmental water available for use across water holders, maximum monthly volumes have been determined to guide the distribution of environmental water delivery through winter and into spring. The monthly range in volumes for delivery as a River Murray flow, up to a total volume of X GL, are as follows:

une	July	Aug.	Sept.	Oct.	Nov.	Dec.
' - Z GL	Y - Z GL	Y - Z GL	Y - Z GL	Y - Z GL	Y - Z GL	tbd

The rate of recession for the environmental release should be managed to follow the modeled natural however, subject to the advice of the MDBA's Operational Advisory Group and seasonal outlooks, environmental releases may be extended to target the hydrological objectives listed above to maximise the environmental outcomes.

The release of environmental water will be determined as the volume released in excess of other operational releases, including pre-releases for flood mitigation or bulk water transfers. *Updated accounting arrangements would be inserted here*

Directed releases from Hume Dam will assume the following use rates in determining the volume delivered into South Australia:

Any updates to accounting arrangements for losses would go here for in-channel and overbank components of deliveries

Releases from Lake Victoria to augment River Murray flows during unregulated river conditions

XXX

Operation of floodplain regulators

XXX

Weir pool manipulation

XXX

Wetland watering using pumping infrastructure

XXX

Barrage operations and management of water levels within Lakes Alexandrina and Albert

XXX

Operating limits for river flows

- *Any updates to relaxed constraints levels and new regulated flow limits would go in here*
- In addition to standard operating limits, the following maximum flows rates will apply to the use of environmental water:
    - X ML/day measured downstream Yarrawonga Weir
    - XML/day measured at the South Australian border avoid third party impacts on privately owned floodplain properties.

Item No.	Description	Details
7	**Proposed hydrograph required**	☒ Yes Hydrographs for the planned delivery of environmental water will be discussed by the MDBA's Operational Advisory Group and be provided to the environmental water holders on a monthly basis, or as required.

<table>
<tr><th>Item No.</th><th>Description</th><th colspan="2">Details</th></tr>
<tr><td>8</td><td>Role of Environmental water holders</td><td colspan="2">Oversight of the use of environmental water as per this Delivery Plan, including the management of water transfers for delivery and participation in operational advisory groups.
Liaising between water holders, state government agencies and site managers to agree arrangements required for the site specific operational use of environmental water. Support monitoring and evaluation of watering actions where appropriate.</td></tr>
<tr><td rowspan="4">9</td><td rowspan="4">Role of key delivery partners</td><td>MDBA RMO</td><td>Implementation of water delivery and River Murray infrastructure operations, including liaising with the state water authorities and coordinating the management and delivery of environmental water with consumptive water in the River Murray system.
Convening or participating in operational advisory groups, providing river flow forecasts and advising on environmental water delivery and river operations.
Notifying the public of relevant operations, as required.</td></tr>
<tr><td>Goulburn-Murray Water, Lower Murray Water, Water NSW, SA Water</td><td>Enabling use and transfer of entitlements in accordance with state retail and legislative frameworks.
Liaising with MDBA RMO on the coordination and management of site infrastructure, accounting for the use of consumptive and environmental water in the River Murray and provide public notification where relevant.
Working with regional catchment management authorities and local land services to manage relevant on-ground operations.</td></tr>
<tr><td>Catchment Management Authorities (Victoria), Local Land Services (NSW), Natural Resources SA, NGO's</td><td>Working with the MDBA, state government agencies and water authorities to develop and implement operational plans, including the operation of infrastructure (where appropriate), consulting with local communities and providing public notifications, obtain any necessary approvals, monitor on-ground operations and report, as necessary, to inform operational advisory group discussions.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>10</td><td>Risk assessment summary</td><td colspan="2">Risk assessment and mitigation has been discussed with the MDBA RMO and is at <u>Attachment X</u>:
☒ Yes ☐ No
Summary rating:
☒ Low ☐ Medium ☐ High ☐ Other
Comment:
Overall risks are rated as low.
Detailed operating plans and risk assessments for site specific operations will be provided as the basis for agreement on the use of environmental water. Key risks will be noted in the relevant Watering Schedules with the delivery partners.</td></tr>
<tr><td>11</td><td>Reporting and monitoring</td><td colspan="2">This section outlines requirements for participating environmental water holders and MDBA RMO
Monthly operational updates
MDBA River Murray Operations will provide monthly operational information on water delivery, noting figures are subject to amendment. Operational updates may be required more frequently, such as to align with Operational Advisory Group discussions during large scale events.
The relevant state government agency will report on site specific use of environmental water where agreed through the relevant Watering Schedules.</td></tr>
</table>

Item No.	Description	Details
		Issues arising updates – as required • For matters which may significantly affect the other party. **Final operational monitoring reports** Developed by participating environmental water holders and state jurisdictions
12	**Dates and triggers for reviewing the watering actions**	**Date:** 29 August 2024, or in relation to the triggers listed below. **Triggers:** ☒ Significant change in climate requiring a change to the watering regime, e.g. Shifting to extremely dry or wet conditions ☒ Increase/decrease in water availability ☒ Negative environmental outcomes ☒ Unanticipated significant operational constraints ☒ Changes to risk status or asset, including due to new information ☒ New information/review of supporting documentation ☒ A significant new proposal for alternative use is received by collaborating water holders
13	**Complementary projects and additional considerations or requirements**	*Specific arrangements will be communicated here.*

Appendix 3 – Basin Plan principles

The principles for implementation of the Basin Plan apply to this proposal:

1. All parties commit to the collaborative implementation of the measures, including making the necessary changes to state water management frameworks that are necessary to facilitate enhanced environmental water delivery
2. The implementation is grounded in common understandings including:
   - many Basin Plan obligations are delivered through state water management frameworks;
   - meeting social, economic and environmental outcomes requires a balanced approach;
   - measures need to be undertaken on a cost effective basis;
   - innovative approaches are needed, which may be consistent with existing water resource management frameworks or may require changes to these.
3. Community engagement is an integral part of progressing the proposal. The Parties will make their processes and decisions as transparent as possible and to collaborate on public communication among themselves and with the MDBA. Responsibility for community engagement in the implementation of measures rests with the jurisdictions identified in each measure.
4. Risks of implementation of the measures will be shared amongst the states

The principles for planning and delivering environmental water set out in Chapter 8 of the Basin Plan also apply to the implementation of this proposal:

1. Environmental watering to be undertaken having regard to the Basin annual environmental watering priorities
2. Consistency with the objectives for water-dependent ecosystems
3. Maximising environmental benefits
4. Risks
5. Cost of environmental watering
6. Apply the precautionary principle
7. Working effectively with local communities
8. Adaptive management
9. Relevant international agreements
10. Other management and operational practices
11. Management of water for consumptive use

Appendix 4 – Risk of adverse ecological outcomes

This is based on existing work, including work by the Commonwealth Environmental Water Office

Risk	Geographical scope	Description	Mitigation/control
Hypoxic blackwater	Whole of system	Given that the measure intends to increase the frequency of overbank flows, this should reduce both the frequency and severity of blackwater events over time. However, without considering program controls, blackwater events could still occur in the short-term given that organic matter can build up over only one season.	Watering may be designed to specifically avoid high risk periods, such as warm weather in late spring and summer, in order to reduce the potential for hypoxic blackwater. Where possible and where natural dilution flows are not available, dilution flows may be provided to provide aquatic refuge habitat in the main river channel during blackwater events and provide localised dilution of incoming blackwater from the floodplain. Additional monitoring activities may include testing of dissolved oxygen levels to assist in the active management of the watering action and for adaptive management.
Blue-green algae	Limited to weir pool lowering only	Blooms that may occur at the same time as environmental watering events cannot be attributed solely to river flows and environmental watering is not considered to amplify most of the individual risk factors, but without controls it could potentially help create stable water levels through the use of weir pool lowering, which could amplify the risk of blooms under certain conditions.	Watering may be designed with specific flow variability provisions to avoid stable water levels for prolonged durations: for example, while the weir pool is lowered the water levels are fluctuated around a mean to prevent stratification. A follow-up flow may be incorporated to encourage mixing of water layers following weir pool lowering and provide flushing to reduce potential impacts associated with blue-green algae.
Geomorphic impacts	Whole of system	By providing more variable and overbank flows, the measure should help mitigate the risk factors that contribute to scouring, notching and other erosion impacts in the long term. However, without controls, higher environmental flows could potentially contribute to individual cases of accelerated erosion that might have localised impact in the short term. Also, river banks are more	Manage the rate of recession of the flow tail to most effectively manage the risk of erosion and bank slumping. Ongoing monitoring and a commitment to help address potential impacts. Detrimental geomorphic impacts in this reach are currently being monitored and mitigated through the implementation of the Hume-Yarrawonga River works program.

Risk	Geographical scope	Description	Mitigation/control
		susceptible to erosion under current conditions so unless the rates of recession associated with flow events are managed, environmental watering may amplify the risk of bank slumping as well as associated turbidity impacts.	
Inundation of cultural heritage	Whole of system	By increasing the frequency of small to medium floods, the Program may amplify the risk of inundation-related impacts to cultural heritage. Potential hotspots have been identified where extra care would need to be taken to minimise erosion and other impacts.	Consent for enhanced protection of at risk heritage could be sought from landholders and Indigenous cultural groups.
Salinity and groundwater recharge	Whole of system	If spikes in salt concentrations associated with individual watering events are not mitigated by the provision of dilution flows, environmental watering could potentially amplify the risk of salinity spikes during watering actions on a short-term basis. In addition, given that post-watering spikes are a product of multiple factors that affect groundwater salinity, by providing additional river flows and weir pool manipulations environmental watering may amplify the risk of post-watering salinity spikes.	Application of *The Living Murray* framework for salinity spike management to help ensure that environmental watering is undertaken with regard to the Basin Plan salinity targets. Dilution flows may be provided, where possible and where natural dilution flows are not available, to reduce the concentration of mobilised salt. Communication materials may be provided to affected communities where relevant. This includes media releases by the delivery partner/s and river operators.
Spread of disease (particularly chytrid fungus)	Whole of system	Environmental watering is likely to reduce the overall risk of mosquitoes by changing the seasonality and variability of flow events. Psittacine Circoviral (beak and feather) disease is not water-borne and water flows are only one of a number of factors that may contribute to the spread of infected parrot species. River flows are only one of a number of factors that can spread root-rot fungus. However, by increasing the frequency of small to medium flows that promote hydrologic	The peak flow of the watering action would be designed to most effectively manage inundation of risk areas. This may include avoidance of the area altogether (where possible and appropriate).

Risk	Geographical scope	Description	Mitigation/control
		connectivity, the measure may increase the frequency with which frog species are exposed to the chytrid fungus.	
Spread of pest flora species	Whole of system	By increasing the frequency of small to medium flows that promote hydrologic connectivity and seeking to provide flows during potential risk periods such as spring, the measure may amplify the risk of spread or population increase of pest flora spread by flows. A more natural flow regime would also help to benefit establishment of native species and provide non-beneficial conditions for the spread of some non-native species.	As this is an exacerbation of an existing risk, existing weed control programs may help to manage it. Easement agreements may also include a recognition of the greater need for weed management to help supplement existing weed management on private land.
Spread or population increase of pest fauna species	Whole of system	By increasing the frequency of small to medium flows that promote hydrologic connectivity and seeking to provide flows during potential risk periods such as spring, the measure may amplify the risk of spread or population increase of aquatic and amphibious pest fauna.	Site managers may be requested to use existing exclusion devices, such as carp screens, to minimise the additional contribution to the spread of pest fauna. Regulatory structures may be used to complement the watering action and help mitigate pest fauna impacts. For example, a wetland system may be watered to support vegetation outcomes and once watering has concluded regulating structures may be closed to prevent further inflows. This allows the wetland to be dried out to kill invasive fauna, while vegetation condition is maintained through soil moisture as a result of the watering action.

Appendix 5 – Detailed Cost Summary

EEWD 1	category	Outputs and Deliverables	Costs
Phase I	Review	Stocktake report on current delivery and operation trials for environmental water Coordinated and delivered by an independent reviewer in consultation with relevant jurisdictional agencies	Nil – covered by project management costs
Phase IIa	Consultation and reviews	1. Scenario planning/workshops with river operators, environmental water managers and environmental water holders and relevant scientific/e-watering experts to identify the types of flows and document location of triggers for 'hydrological cues' operation. Coordinated and delivered by an independent facilitator	Nil – covered by project management costs
		Outputs:	
		- Workshop outcomes report	
		- Review document of forecasting capability and feasibility - what is required moving forward	
	Consultation and reviews	2. Ecological literature review of managed river systems with a focus on the southern connected basin (building on existing work; incorporating broader system scale and floodplain connectivity) Coordinated and delivered by an independent facilitator	Independent specialist expert advice - hydrological, ecological or modelling expertise: [redacted]
	Research and Investigation	- Technical Report: literature review of flows and inundation, return flows, losses of the SCB	
		- document policy and procedures for implementation	
	Consultation and reviews	3. Undertake specific research and investigative recommendations by relevant jurisdictional agencies expediting BAU Coordinated through existing governance arrangements with additional independent support including MDBA modelling advice	[redacted] To be provided by relevant contractors
	Research and Investigation	- Technical Report: Engage technical support to conduct modelling support Testing and confirm the hydrological basis, improved understanding of ecological response to timing and duration	[redacted]

		- Enhanced hydrological and inundation modelling (applied specifically to delivering regulated flows on top of unregulated flows and understanding of system hydrological responses)	
		- Investigate, develop and document decision support tools: assessing hydrology and timeliness	
		- Tools: improved hydrology model for EEWD scenario testing and operations	
		- Investigate and document suitability of gauging network and any associated recommendations for improvements	
Phase IIb	Implementation of review recommendations, report outcomes	1. Decisions support tool: develop procedures for scenario planning outcomes	[redacted] Provided by relevant contractors
		- Commissioning and implementation of forecasting tools	Independent specialist expert advice - hydrological, ecological or modelling... [redacted]
		2. Future adaptive development and improvements to models and system support tools	
			[redacted]
Phase III	**Evaluation**	Annual reports as per phase IIb and evaluation outlined in measure 5.	nil - BAU/ covered by measure 5
		sub total	[redacted]

EEWD 2	category	Outputs and Deliverables	Costs
Phase I	Review	Stocktake report on current environmental watering delivery administration and coordination processes Coordinated and delivered by an independent reviewer in consultation with relevant jurisdictional agencies	Nil – covered by project management costs

Phase IIa	Consultation and review	1. Administration and Coordination Workshop with independent facilitator	Business as usual
		- workshop outcomes report	
		- explore development of specific TOR's for EEWD administration and governance.	
		- identification of key focus areas for review and revision	
	Research and Investigation	2. Investigate Decision support tools: administration and coordination	
		- Investigate decision support framework	
	Research and Investigation	3. Independent Review: Engage consultant to report on all administration and coordination at a SCB system scale	Independent specialist expert advice [redacted]
		- administration and coordination review report	
		- Investigate data management systems, environmental water management portal	[redacted]
Phase IIb	Implementation of review recommendations, report outcomes	1. Explore and implement workshop report outcomes	[redacted] Provided by relevant contractors
		2. Technical work: create decision support tools, scenarios planning and develop protocols	[redacted]
		3. Apply administration and coordination framework to southern connected basin	
		- Technical work: create data management systems	
Phase III	Evaluation	Evaluate success of environment water delivery arrangements under EEWD scenarios.	nil - BAU/ covered by measure 5
		sub total	[redacted]

EEWD 3	category	Outputs and Deliverables	Costs
Phase I	Review	Stocktake report on current environmental watering accounting Coordinated and delivered by an independent reviewer in consultation with relevant jurisdictional agencies	Nil - covered by project management
Phase IIa	Consultation and review	1. Workshop to develop a shared vision of the River Murray accounting system.	[redacted]
		- workshop outcomes report	
	Research and Investigation	2. Review report articulating the required accounting changes to support the new vision and including a set of recommendations	[redacted] Provided by relevant contractors
		- Modelling report supporting the necessary accounting rule changes.	[redacted]
		- Review accounts and supporting infrastructure	
		- Develop new accounting support system	
Phase IIb	Implementation of review recommendations, report outcomes	1. Implement changes to relevant documentation to demonstrate River Murray accounting system	BAU
Phase III	**Evaluation**	Evaluate the success of accounting approach reform	nil - BAU/ covered by measure 5
		sub total	[redacted]

Timelines	EEWD 4	category	Outputs and Deliverables	Costs
2017-18	Phase I	review	Stocktake report on current river operations for environmental watering Coordinated and delivered by an independent reviewer in consultation with relevant jurisdictional agencies	Nil - covered by project management
2018-20	Phase IIa	Consultation and review	1. River operators' workshop with independent facilitator.	nil - Project management and delivery costs
			- workshop outcomes report	
			- identify hydrologic cues delivery scenarios for testing	[redacted]
			- documented strategy for creating the mandate for ordering and delivery.	[redacted]
			2. Legal and Legislative reviews	[redacted]
		Research and Investigation	- Legal review report	
			- Legislative review report	
			3. Operating procedural documentation review conducted by independent consultant	BAU - IRORG
			- Suitability assessment of Objectives and outcomes and River Murray Operations framework	
			4. Conduct trial and document learnings from Environmental water trials to deliver identified EEWD scenarios	[redacted] Provided by relevant contractors
			- detail relevant learnings and how they can be applied to hydrologic cues delivery option	
2020-23	Phase IIb	Implementation of review recommendations, report outcomes	1. Codify required changes to develop delivery mandate	[redacted] Provided by relevant contractors
			2. Legal and legislative changes identified and implemented	
			- Amend documentation and provide stakeholder information	
			- Update regulatory framework	
			3. Amend Objectives and Outcomes document and/or River Murray Operations framework	[redacted]
			4. Implement as required	
Annual	Phase III		Evaluate ability of governments and operators to order and deliver using a hydrologic cues approach.	nil - BAU/ covered by measure 5

Timelines	EEWD 5	category	Outputs and Deliverables	Costs
2017-18	Phase I	Review	Stocktake report on current evaluation frameworks Coordinated and delivered by an independent reviewer in consultation with relevant jurisdictional agencies	Nil - covered by project management
2018-20	Phase IIa	Evaluation	1. Project planning	
			- identify project governance	[redacted] Provided by relevant contractors
			- determine project deliverability	
			2. Monitoring and Evaluation plan	
			- outline and document M & E requirements	
			- identify matter 9.3 reporting requirements	
2020-23	Phase IIb	Implementation	1. Reporting	[redacted] Provided by relevant contractors
			- annual and longer terms reports for sites/assets across the southern connected basin	[redacted]
			Monitoring and Data collection for new data	[redacted] Provided by relevant contractors
Annual	Phase III		Evaluation and reporting as outlined in the basin plan.	nil - BAU
			sub total	[redacted]

	Activity	Item	Costs
	Program Management	Program management team	[redacted]
		Program Delivery	[redacted]
		- Annual workshop costs: - Program design, planning, early stage reviews, Workshops, facilitation, coordination	[redacted]
		Overarching communication and engagement strategy - strategy documents for government agencies (i.e. NRM, CMAs…) and public costs for strategy development [redacted] costs for consultation over 6.5 years [redacted]	[redacted]
		Gauge board management contingency ongoing [redacted] ([redacted])	[redacted]
		Subtotal Project Management	[redacted]
		Subtotal Work program	[redacted]
		Contingency ([redacted])	[redacted]
		Grand Total	[redacted]

Appendix 6 – Interim modelling results for Basin Plan SFIs

Frequency of Basin Plan SFIs for the southern connected basin (19-pack scenarios). The results presented below were correct as at the 12th May 2017 using the 19-pack SDL modelling as described. The results may change as modelling is updated.

SFI sites	SFI		BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
	Environmental watering strategy			pick-a-box		pick-a-box	Hydrological cues
	Model foresight (month)			12		12	1
	Water recovery (GL/y)			2,750		2,350	2,150
	Potential SDL adjustment (GL/y)					~ 400	~ 600
Barmah-Millewa Forest	1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70-80%	78%	70%	73%	83%
	2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40-50%	52%	47%	49%	54%
	3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40-50%	46%	41%	45%	53%
	4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33-40%	35%	33%	34%	36%
	5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25-30%	18%	18%	18%	19%
	6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20-25%	13%	13%	15%	11%
	7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	36%	32%	33%	32%
Gunbower-Koondrook-Perricoota	1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70-80%	68%	61%	62%	65%
	2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60-70%	67%	60%	60%	60%
	3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33-50%	39%	35%	37%	38%
	4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25-33%	22%	20%	23%	22%
	5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	28%	25%	25%	25%
Hattah-Kulkyne Lakes	1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40-50%	44%	40%	42%	45%
	2	50,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	30-40%	31%	30%	29%	36%
	3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20-33%	19%	17%	18%	23%
	4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20-30%	11%	10%	12%	16%
	5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14-20%	9%	8%	8%	8%
	6	150,000 ML/d for a total duration of 7 days (with min duration of 7 consecutive days) between Jun & May	10-13%	6%	5%	7%	6%

SFI sites		SFI	BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
		Environmental watering strategy		pick-a-box		pick-a-box	natural hydro cues
		Model foresight (month)		12		12	1
		Water recovery (GL/y)		2,750		2,350	2,150
		Potential SDL adjustment (GL/y)				~400	~600
Riverland Chowilla Floodplain	1	20,000 ML/d for 60 consecutive days between Aug & Dec	71-80%	71%	71%	71%	77%
Riverland Chowilla Floodplain	2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50-70%	59%	53%	54%	56%
Riverland Chowilla Floodplain	3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33-50%	39%	35%	36%	40%
Riverland Chowilla Floodplain	4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25-33%	26%	25%	26%	25%
Riverland Chowilla Floodplain	5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17-25%	13%	11%	13%	15%
Riverland Chowilla Floodplain	6	100,000 ML/d for a total duration of 21 days (with min duration of 1 day) between Jun & May	13-17%	8%	7%	7%	7%
Riverland Chowilla Floodplain	7	125,000 ML/d for a total duration of 7 days (with min duration of 1 day) between Jun & May	10-13%	5%	4%	6%	5%
Edward Wakool River System	1	1,500 ML/d for a total duration of 180 days (with min duration of 1 day) between Jun & Mar	99-100%	94%	94%	96%	97%
Edward Wakool River System	2	5,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	60-70%	67%	60%	60%	63%
Edward Wakool River System	3	5,000 ML/d for a total duration of 120 days (with min duration of 7 consecutive days) between Jun & Dec	35-40%	33%	30%	36%	38%
Edward Wakool River System	4	18,000 ML/d for a total duration of 28 days (with min duration of 5 consecutive days) between Jun & Dec	25-30%	17%	15%	18%	18%
Edward Wakool River System	5	30,000 ML/d for a total duration of 21 days (with min duration of 6 consecutive days) between Jun & Dec	17-20%	12%	12%	15%	11%
Lower Darling Floodplain	1	7,000 ML/d for 10 consecutive days between Jun & May	70-90%	58%	58%	60%	65%
Lower Darling Floodplain	2	17,000 ML/d for 18 consecutive days between Jun & May	20-40%	22%	20%	18%	17%
Lower Darling Floodplain	3	20,000 ML/d for 30 consecutive days between Jun & May	14-20%	11%	10%	15%	15%
Lower Darling Floodplain	4	25,000 ML/d for 45 consecutive days between Jun & May	8-10%	8%	8%	9%	9%
Lower Darling Floodplain	5	45,000 ML/d for 2 consecutive days between Jun & May	7-10%	7%	7%	8%	8%
Coorong Lower lakes and Murray Mouth	1	Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,500 EC	100%	100%	100%	100%	100%
Coorong Lower lakes and Murray Mouth	1	Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,000 EC	95%	95%	95%	96%	96%
Coorong Lower lakes and Murray Mouth	2	Barrage flows: Percentage of years that barrage flows are greater than 2,000 GL/yr (measured on a three year rolling average) with a minimum of 650 GL/yr	95%	95%	95%	96%	96%
Coorong Lower lakes and Murray Mouth	3	Barrage flows: Percentage of years that barrage flows are greater than 600 GL for any two year period	100%	100%	100%	100%	100%
Coorong Lower lakes and Murray Mouth	4	Coorong Salinity: Percentage of days South Lagoon average daily salinity is less than 100 grams per litre.	96%	96%	96%	100%	99%
Coorong Lower lakes and Murray Mouth	5	Mouth Openness: Percentage of years mouth open to an average annual depth of 1.0 meters (-1.0 m AHD) or more	90%	90%	90%	93%	94%
Coorong Lower lakes and Murray Mouth	5	Mouth Openness: Percentage of years mouth open to an average annual depth of 0.7 metres (-0.7 m AHD) or more	95%	95%	95%	97%	97%

SFI sites		SFI	BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
		Environmental watering strategy		pick-a-box		pick-a-box	natural hydro cues
		Model foresight (month)		12		12	1
		Water recovery (GL/y)		2,750		2,350	2,150
		Potential SDL adjustment (GL/y)				~ 400	~ 600
Goulburn River at Shepparton	1	Two events annually of 2,500 ML/d for 4 consecutive days (with min duration of 30 days between events) between Dec & Apr	36 - 48 %	54%	54%	54%	57%
	2	5,000 ML/d for 14 consecutive days between Oct & Nov	49 - 66 %	55%	55%	55%	64%
	3	25,000 ML/d for a median duration of 5 days between Jun & Nov	70 - 80 %	82%	74%	80%	82%
	4	40,000 ML/d for a median duration of 4 days between Jun & Nov	40 - 60 %	58%	52%	54%	67%
Mid - Bidgee (Narrandera flow)	1	26,850 ML/d for a total duration of 45 days (with min duration of 1 day) between Jul & Nov	20 - 25 %	11%	11%	12%	19%
	2	26,850 ML/d for 5 consecutive days between Jun & Nov	50 - 60 %	61%	55%	59%	58%
	3	34,650 ML/d for 5 consecutive days between Jun & Nov	35 - 40 %	46%	41%	42%	44%
	4	44,000 ML/d for 3 consecutive days between Jun & Nov	30 - 35 %	31%	30%	32%	28%
	5	63,250 ML/d for 3 consecutive days between Jun & Nov	11 - 15 %	10%	10%	11%	11%
Low - Bidgee (Maude flow)	1	Total volume of 175 GL (flow > 5,000 ML/d) between Jul & Sep	70 - 75 %	94%	85%	86%	88%
	2	Total volume of 270 GL (flow > 5,000 ML/d) between Jul & Sep	60 - 70 %	88%	79%	79%	82%
	3	Total volume of 400 GL (flow > 5,000 ML/d) between Jul & Oct	55 - 60 %	81%	73%	73%	77%
	4	Total volume of 800 GL (flow > 5,000 ML/d) between Jul & Oct	40 - 50 %	60%	54%	54%	54%
	5	Total volume of 1,700 GL (flow > 5,000 ML/d) between Jul & Nov	20 - 25 %	28%	25%	28%	35%
	6	Total volume of 2,700 GL (flow > 5,000 ML/d) between May & Feb	10 - 15 %	17%	15%	16%	17%
BIDG Freshes (Balranald	1	1,100 ML/d for 25 consecutive days between Dec & May	58 - 77 %	67%	67%	67%	68%
	2	4,500 ML/d for 20 consecutive days between Oct & Dec	54 - 72 %	73%	73%	74%	72%
	3	3,100 ML/d for 30 consecutive days between Oct & Mar	55 - 73 %	73%	73%	74%	75%

Ecological element scores for the southern connected basin (19-pack scenarios)

Basin Plan sites	**Ecological Elements Scores**		
	Benchmark #1094	**19-pack #1116**	**EEWD Y50**
Environmental watering strategy	pick-a-box	pick-a-box	natural hydro cues
Model foresight (month)	12	12	1
Water recovery (GL/y)	2,750	2,350	2,150
Potential SDL adjustment (GL/y)		~ 400	~ 600
River Murray system			
Barmah-Millewa Forest	5193	5161	5333
Gunbower-Koondrook-Perricoota	5569	6336	5992
Hattah-Kulkyne Lakes	3536	3602	4009
Riverland Chowilla Floodplain	4046	4074	4210
Edward Wakool River System	4126	4391	4036
Lower Darling Floodplain	2942	2857	2779
Murrumbidgee			
Mid-Bidgee	4762	4775	4961
Low-Bidgee	6539	6298	6373
Lower Goulburn	8176	8024	8385
Overall Southern Basin	**4988**	**5057**	**5120**

Attachment B

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MURRAY–DARLING BASIN AUTHORITY

Environmental water delivery following natural flow cues and relaxing constraints in the Southern Basin

- potential options for SDL adjustment

[redacted]

Water Resources Group, River Management Division

Murray-Darling Basin Authority

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EXECUTIVE SUMMARY

An alternative way of delivering environmental water was explored that led to the development of a Natural Flow Cues method (the method). The method uses natural inflows to the storage to define seasonal hydrologic condition (wet, medium or dry). Based on the seasonal condition, delivery of environmental water is designed to mimic the natural flow regime reflecting elements of natural variability, seasonality and drying-wetting cycles while providing environmental flows.

The method differs from the Basin Plan *Pick-a-Box* method (*Environmental Event Selection Tool*) as to how the *high* environmental flows are delivered. In the planning stage, seasonal conditions are assessed as wet or dry using historical winter-spring inflows to the storages. This has a foresight of up to six months and is used as a trigger for an environmental watering event. Based on the seasonal condition, peak environmental flow rates are determined at each of the eight Site-specific Flow Indicators (SFI) sites in the Southern Basin. The peak environmental flow rate targets for the wet years are set higher compared to the dry years, but are restricted by the specified channel capacity constraints. During the wet years, water availability would be greater and with the higher flow targets the extra channel capacity available due to constraints relaxation would be effectively utilised.

To restore part of the natural high flows in the system, environmental flow demands are estimated using the modelled without development flows between June and November and included in the model. Estimates of environmental flow demand are calculated monthly at each SFI site as a sub-set (or fraction) of the local without development (WoD) flows. The fraction represents a coefficient of flow efficiency, which is higher for the wetter months than for the dry months. During extremely wet and dry years, particularly the wettest 5% - 10% and the driest 10% - 20% of the years, no high environmental flows are targeted.

The method was initially applied in the Southern Basin to model hydrology changes due to constraints relaxation in 2015-16 with 2,750 GL/y of environmental water recovery under the Basin Plan (MDBA, 2016). The efficient delivery of environmental flows and improved environmental outcomes in that study indicated that the natural flow cues approach with constraints relaxation would have an SDL adjustment potential, which led to this study where the approach is applied to the 15-pack SDL adjustment scenario exploring potential options for additional SDL adjustments.

The 15-pack SDL adjustment scenario assumes environmental water delivery as per the *Pick-a-Box* approach with the delivery constraints that existed at the time of setting the Basin Plan. It shows a 370 GL/y SDL offset. The natural flow cues scenarios are compared to this to determine the additional SDL offset.

The natural flow cues scenarios investigated for additional SDL adjustments are:

- ***Natural flow cues scenario***: This is a 500 GL/y SDL offset scenario built on the 15-pack model with the constraints that existed at the time of setting the Basin Plan (*40,000 ML/d downstream of Yarrawonga among others as per Table 1*), with environmental water delivery as per the natural flow cues approach (the approach).
- ***Natural flow cues constraints relaxed scenario Y50***: This is a 600 GL/y SDL offset scenario built on the 15-pack model with constraints relaxed (*to 50,000 ML/d downstream of Yarrawonga among others as per Table 1*) and environmental water delivery as per the approach.
- ***Natural flow cues constraints relaxed scenario Y65***: This is a 600 GL/y SDL offset built on the 15-pack model with constraints relaxed (*to 65,000 ML/d downstream of Yarrawonga among others as per Table 1*) and environmental water delivery as per the approach.

To date, initial modelling in the natural flow cues framework has been completed for the Murrumbidgee and the River Murray. Some key observations from the modelling results to date for the above three scenarios compared to the 15-pack are:

Natural flow cues scenario (*40,000 ML/d downstream of Yarrawonga*):

1. possibly an additional SDL offset of about 100 GL through delivery of less environmental water more efficiently;
2. improved environmental outcomes with less water;
3. efficient use of available channel capacity and environmental water through better alignment and co-ordination of environmental releases and tributary inflows providing increased opportunities to deliver more managed high flows to the lower Murray; and
4. effective use of water providing more watering of target floodplains throughout the system.

***Natural flow cues constraints relaxed* scenario Y50 (*50,000 ML/d downstream of Yarrawonga*):**

1. possibly an additional SDL offset of about 200 GL through delivery of less environmental water more efficiently;
2. significantly improved environmental outcomes with less water;
3. fewer spills due to more airspace in the storages;
4. lower risk of flooding in the upper Murray due to reduction of unmanaged spills later in the season; and
5. additional watering of target floodplains in the lower Murray.

***Natural flow cues constraints relaxed* scenario Y65 (*65,000 ML/d downstream of Yarrawonga*):**

1. further improved environmental outcomes, but only slightly with similar SDL offset potential to the Y50 scenario.

Note these observations are from a model, which is still a work in progress, in which the Goulburn and Lower Darling system are yet to be included in the natural flow cues framework. The results may differ when an integrated Southern Basin natural flow cues scenario is completed.

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Table of Contents

1. INTRODUCTION

An alternative way of delivering environmental water has been explored which led to the development of a Natural Flow Cues method (the method). This is a plausible method of environmental water delivery and was developed by building on existing modelling frameworks at the Murray-Darling Basin Authority (MDBA).

The method uses available environmental water and channel capacity efficiently by mimicking the 'natural flow regime' through the coordination and alignment of water releases and tributary flows. By doing this, the method better reflects the potential hydrologic opportunities to deliver higher flows and provides a more realistic hydrologic regime to inform an assessment of benefits of environmental water use as well as the implications of relaxing system constraints in the Southern Basin.

This method differs from the Basin Plan *Pick-a-Box* method (*Environmental Event Selection Tool*) as to how high environmental flow events are delivered. It uses natural inflows to the storages to define seasonal hydrologic conditions (wet, medium or dry). Based on the seasonal condition, environmental water is delivered by mimicking the natural flow regime. The idea is to reflect elements of natural variability, seasonality and drying-wetting cycles while providing environmental flows.

The method was initially developed and applied in the Southern Basin to undertake a hydrology modelling study by relaxing constraints in 2015-16 (MDBA, 2016). This study investigated what environmental flows would be hydrologically feasible, when applying the natural flow cues to use the specified volume of environmental water to be recovered under the Basin Plan (2,750 GL/y). The study informed the constraints business cases that were being developed by Basin governments. The modelling results in the study showed:

- improved environmental outcomes;
- reduced spills and consequently reduced risk of flooding in the upper Murray as environmental water use early in the season creates more airspace in the storages;
- efficient use of additional channel capacity available due to constraints relaxation providing opportunities for more managed releases; and
- better coordination and alignment of flows from tributaries, resulting in improved high flow events to the lower Murray.

These results indicated that the natural flow cues approach with constraints relaxation would have an SDL adjustment potential and led to a new study where the natural flow cues approach has been applied to the 15-pack SDL adjustment mechanisms scenario, exploring options for potential SDL adjustments.

2. SCOPE AND PURPOSE OF THE STUDY

The scope of the work involved applying the natural flow cues approach, including constraints relaxation to the 15-pack model and investigating possible additional SDL adjustment options in the Southern Basin.

The purpose of the study was to inform SDL adjustment mechanisms and associated technical work, particularly to assess the plausibility of additional SDL adjustment potential when the Southern Basin was modelled with the approach and constraints relaxation.

The following three natural flow cues scenarios are discussed in this report:

- ***Natural flow cues scenario***: This is a modelled representation of the flows that would occur with 500 GL/y SDL offset with the delivery constraints that existed at the time of setting the Basin Plan (*40,000 ML/d downstream of Yarrawonga among others as per Table 1*) with environmental water delivery as per the approach. Comparing this scenario with the 15-pack, the effects solely attributable to environmental water delivery method can be assessed (noting, however the requirement for a minmum of 40,000 ML/day flow limit downstream of Yarrawonga).
- ***Natural flow cues constraints relaxed scenario Y50***: This is a modelled representation of the flows that would occur with 600 GL/y SDL offset with delivery constraints downstream of Yarrawonga relaxed to 50,000 ML/d with environmental water delivery as per the approach. Constraints are also relaxed at Doctors Point (*from 25,000 to 40,000 ML/d for the Murray*), and at Gundagai (*from 30,000 to 33,000 ML/d*) and Balranald (*from 9,000 to 12,000 ML/d*) for the Murrumbidgee.
- ***Natural flow cues constraints relaxed scenario Y65***: This is a modelled representation of the flows that would occur with 600 GL/y SDL offset with delivery constraints downstream of Yarrawonga relaxed further to 65,000 ML/d with environmental water delivery as per the approach. Constraints at the other locations are the same as the Y50 scenario.

Apart from the above three scenarios, this report also refers to the following scenarios where appropriate:

- ***15-pack scenario***: This is a modelled representation of the flows that would occur with 370 GL/y SDL adjustment and the constraints that existed at the time of setting the Basin Plan with the environmental water delivery as per the *Pick-a-Box* approach.
- ***Benchmark***: This is a modelled representation of the flows that would occur with 2750 GL/y water recovery and used with the constraints that existed at the time of setting the Basin Plan (*25,000 ML/d at Doctors Point and 40,000 ML/d downstream of Yarrawonga*) with the environmental water delivery as per the *Pick-a-Box* approach. It provides a "reference" for SDL adjustment mechanisms against which the scenarios are assessed for potential SDL adjustment.

- ***Baseline:*** This scenario represents water sharing arrangements and levels of infrastructure development as per June 2009 with no Basin Plan.
- ***Without Development:*** This scenario represents a near-natural condition with no water resources development, no water sharing arrangements and no infrastructure development in the basin.

The approach proposed in this study does not aim to prescribe a future flow regime but rather is intended to provide a flexible framework where environmental watering plans can be adapted to suit needs as per hydro-climatic conditions in the future. The approach was applied to investigate whether more efficient delivery of environmental water would have any potential for SDL adjustment. Both the constraints at benchmark levels and constraints relaxed scenarios were investigated.

3. KEY MODELLING ASSUMPTIONS

3.1. Model versions

A benchmark version of the model (run #1062) for the SDL adjustment mechanisms in the Southern Basin forms the basis of this study, in which delivery of environmental water (high flows, freshes and base flows) is simulated using the *Pick-a-Box* method. A variation of the benchmark with 15 SDL adjustment options having a total of 370 GL/y SDL offset is used as a starting point.

3.2. Natural flow cues scenario

The high flow component of environmental water is delivered through the natural flow cues approach in the Murrumbidgee and River Murray. The Goulburn and Lower Darling system are the same as the 15-pack.

Other assumptions are unchanged. The environmental water releases in the model are subjected to States' water sharing rules, operational constraints, and water availability in the environmental account.

3.3. Natural flow cues constraints relaxed scenarios Y50 and Y65

The high flow component of environmental water is delivered through the natural flow cues approach in the Murrumbidgee and River Murray with system constraints relaxed to the flow rates provided in Table 1.

River Murray system:

- Downstream of Albury at Doctors Point from 25,000 ML/d to 40,000 ML/d,
- Downstream of Yarrawonga from 40,000 ML/d to 50,000 ML/d (*Y50 scenario*), and
- Downstream of Yarrawonga from 40,000 ML/d to 65,000 ML/d (*Y65 scenario*).

Murrumbidgee system:

- Gundagai from 30,000 ML/d to 33,000 ML/d, and
- When constraints are relaxed, environmental flow at Balranald is allowed to increase from 9,000 ML/d to 12,000 ML/d.

The rates in Table 1 reflect the outcomes of consultations and discussions between the MDBA's hydrological modelling team and the States' modellers during the 2015-16 constraints modelling study (MDBA, 2016).

Table 1 - Physical constraints applied in the Southern Connected System (ML/d)

	Baseline	Benchmark	15-pack	Natural flow cues Y40	Natural flow cues constraints relaxed	
					Y50	Y65
Murrumbidgee						
Gundagai	30,000	30,000	30,000	30,000	33,000	33,000
Wagga Wagga	~ 37,000	~ 37,000	~ 37,000	~ 37,000	~ 40,000	~ 40,000
Goulburn						
Eildon	12,000	12,000	12,000	12,000	12,000	12,000
Molesworth	-	-	-	-	-	-
Seymour	12,000	12,000	12,000	12,000	12,000	12,000
Murchison	-	-	-	-	-	-
River Murray						
Doctors Point	25,000	25,000	25,000	25,000	40,000	40,000
Yarrawonga	~18,000	40,000	40,000	40,000	50,000	65,000
Lower Darling ^						
Menindee Outlet ^	9,300	9,300	14,000	14,000	14,000	14,000
Weir 32 ^	9,300	9,300	14,000	14,000	14,000	14,000
Anabranch offtake	9,300	9,300	14,000	14,000	14,000	14,000

Maximum environmental flow rates that were targeted at the SFI sites are provided in Table 2. Other assumptions are unchanged. The environmental water releases in the model are subjected to States' water sharing rules, operational constraints, and water availability in the environmental account.

Table 2 - Maximum flow rate limit applied to environmental flow demand (ML/d)

	Benchmark	15-pack	Natural flow cues Y40	Natural flow cues constraints relaxed	
				Y50	Y65
Murrumbidgee					
Narrandera	44,000	44,000	44,000	44,000	44,000
Maude	20,000	20,000	20,000	20,000	20,000
Balranald	9,000	9,000	9,000	12,000	12,000
Goulburn					
Shepparton	40,000	40,000	-	-	-
McCoys Bridge	-	-	-	-	-
River Murray					
Yarrawonga	40,000	40,000	40,000	50,000	65,000
Torrumbarry	40,000	40,000	40,000	40,000	40,000
Euston	85,000	85,000	85,000	85,000	85,000
SA Border	80,000	80,000	80,000	80,000	80,000
Lower Darling ^^					
Weir 32 / Burtundy	-	-	-	-	-

4. METHODOLOGY

The Natural Flow Cues method aims to mimic the natural flow regimes so that elements of natural variability, seasonality and drying-wetting cycles are reflected when environmental water is delivered.

With river regulation and infrastructure development, winter-spring high flows are captured in Dams and released later to meet irrigation demands in the summer-autumn period. This has substantially altered the natural flow regime. Representing dry and wet seasonal conditions of the natural system, a natural flow cues approach targets environmental flows in the winter-spring period so a proportion of the natural flow regime can be reinstated when opportunities arise. During this period more channel capacity may also be available for environmental releases as the capacity would be constrained more during the summer-autumn period due to high irrigation demand.

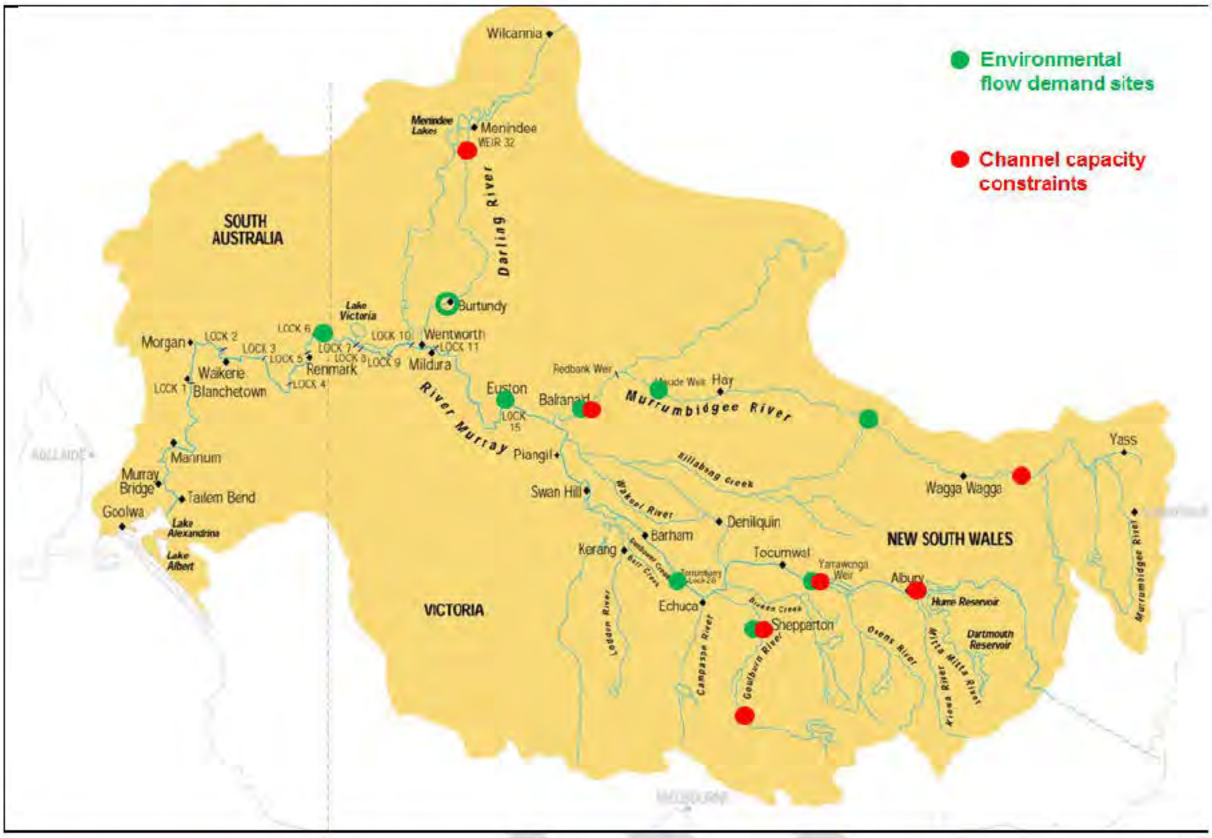
Strategically, the use of environmental water early in the season results in more airspace in headwater storages, which is expected to reduce the risk of major flooding due to unmanaged spills later in the season. Also, coordination of regulated releases from storages (e.g. Hume Dam) with peak flows from the tributaries (e.g. Oven and Goulburn inflows to the Murray) plays a crucial role in boosting the peaks in the lower Murray. If releases were well coordinated, peaks would be better aligned and there would be increased opportunities to deliver even higher peak flows to the lower Murray with the same amount of environmental water. Conceptually, the approach is designed to provide better coordinated and aligned flows, which will ensure efficient delivery and effective use of environmental water resulting in optimal environmental outcomes system-wide.

The method is generic and involves following three steps:

- Analyse natural inflows to assess seasonal hydrologic conditions to decide whether to use environmental water in the season. The probabilities of the occurrence of inflows are used as clues to identify dry or wet seasons. During extremely wet and dry years, *high* flow events are not attempted.
- Decide which peak environmental flow rate to target based on the hydrologic condition from step 1 above. These peak flow targets are subject to channel capacity constraints and other operational constraints.
- Analyse local 'without development' (WoD) flows to determine the coefficient of flow efficiency and estimate the environmental flow sequence, which is limited by the peak flow rates from step 2, and the channel capacity constraints. This sequence is used as the environmental flow demand in the model.

There are nine SFI sites in the Southern Basin, as shown in Figure 1. Based on the seasonal hydrologic condition, the peak environmental flow rates at each SFI site are determined. The wetter years are expected to effectively utilise the extra channel capacity available due to constraints relaxation. Therefore, the peak environmental flow rates that would be targeted for wet years are higher compared to those for dry years.

Figure 1 - Southern Basin with SFI sites and channel capacity constraints



4.1. River Murray

4.1.1. *Assessment of hydrologic condition to identify wet and dry periods*

In the planning stage, wet or dry seasonal conditions are assessed using historical winter-spring inflows to storages (*e.g. Hume Dam in the upper Murray, Eildon Dam in the Goulburn, and Burrinjuck Dam in the upper Murrumbidgee*) with a foresight of six months (i.e. June to November). It is important to identify wet or dry seasons so that environmental watering can be varied annually to suit the seasonal condition. High environmental flows are not required every year, particularly not during the dry period, because the purpose and priorities of environmental watering under drier conditions will be different to those under wetter conditions. The delivery of high environmental flows during extremely wet years may also not be needed as environmental requirements are met naturally.

To identify dry and wet seasons, inflows to storage were used. In this study, they were accumulated over the winter-spring season and analysed to determine their probability of occurrences using a plotting position formula given in equation 1 bvelow (Cunnane, 1978).

$$p = 1 - \frac{(R-0.4)}{(N+0.2)} \quad (1)$$

where,

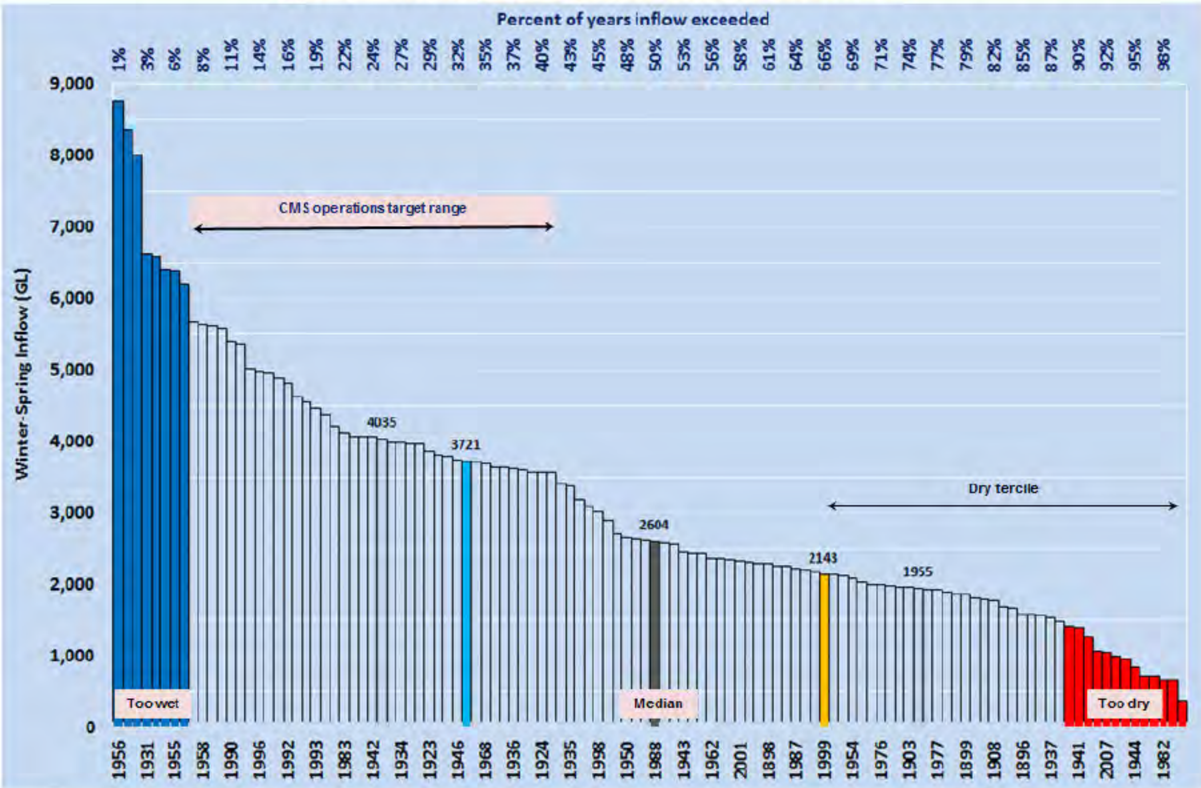
p = probability that the specified flow is exceeded

R = ranks of inflows or flows in ascending order

N = total number of data points (e.g. 114 years)

Figure 2 shows winter-spring (1 June to 30 November) inflows to Hume Dam (exclusive of net snowy transfer) for 114 years (1895 - 2009) and are ranked from the wettest to the driest. These inflows can vary from less than 1,000 GL in extreme dry years to more than 8,000 GL in extreme wet years during the winter-spring season. The wettest 25% of years (wet quartile) have inflows in excess of ~ 4,000 GL while the driest 25% of years (dry quartile) have less than ~ 2,000 GL.

Figure 2 – Winter-spring inflows to the Hume Dam



4.1.2. *Maximum environmental flow limit (E_{max})*

In the River Murray, there are four SFI sites, where the Basin Plan specifies a range of flow rates for the environmental watering targets. They are:

- Downstream of Yarrawonga (*flow target range 12,500 to 40,000, 50,000 or 65,000 ML/d depending on the Yarrawonga constraints relaxation*);
- Downstream of Torrumbarry (*flow target range 16,000 to 40,000 ML/d*);
- Downstream of Euston (*flow target range 40,000 to 85,000 ML/d*); and
- South Australia border (*flow target range 20,000 to 80,000 ML/d*).

Based on the seasonal hydrologic condition, peak environmental flow rate targets are determined for each site. These are the maximum allowable limits for environmental releases and are determined from a limit curve constructed for each site based on the probabilities of inflows. Figure 3a shows, as an example, maximum environmental flow limits applied at Yarrawonga downstream (*i.e. flow indicator site for Barmah-Millewa Forest*) for various constraints scenarios. It is intended to represent variance of natural peaks in the environmental flow sequence. It varies with hydrologic conditions, from a lower threshold for drier years to a higher threshold for wetter years and is constrained by channel capacity. To apply the concept, the lower or upper limits and stepping are set based on the SFIs specified for each site in the Basin Plan (Table A.1 in Appendix A) and channel capacity constraints, where applicable.

Figure 3a – Maximum environmental flow limit: downstream of Yarrawonga

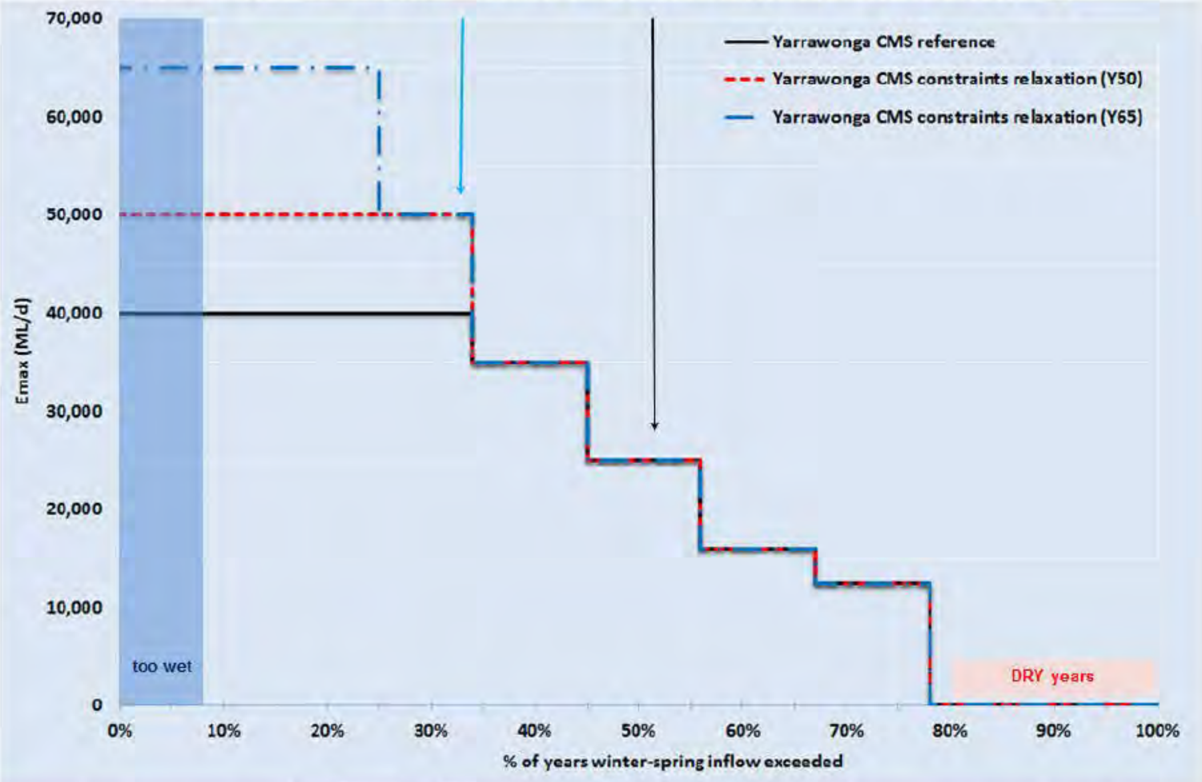
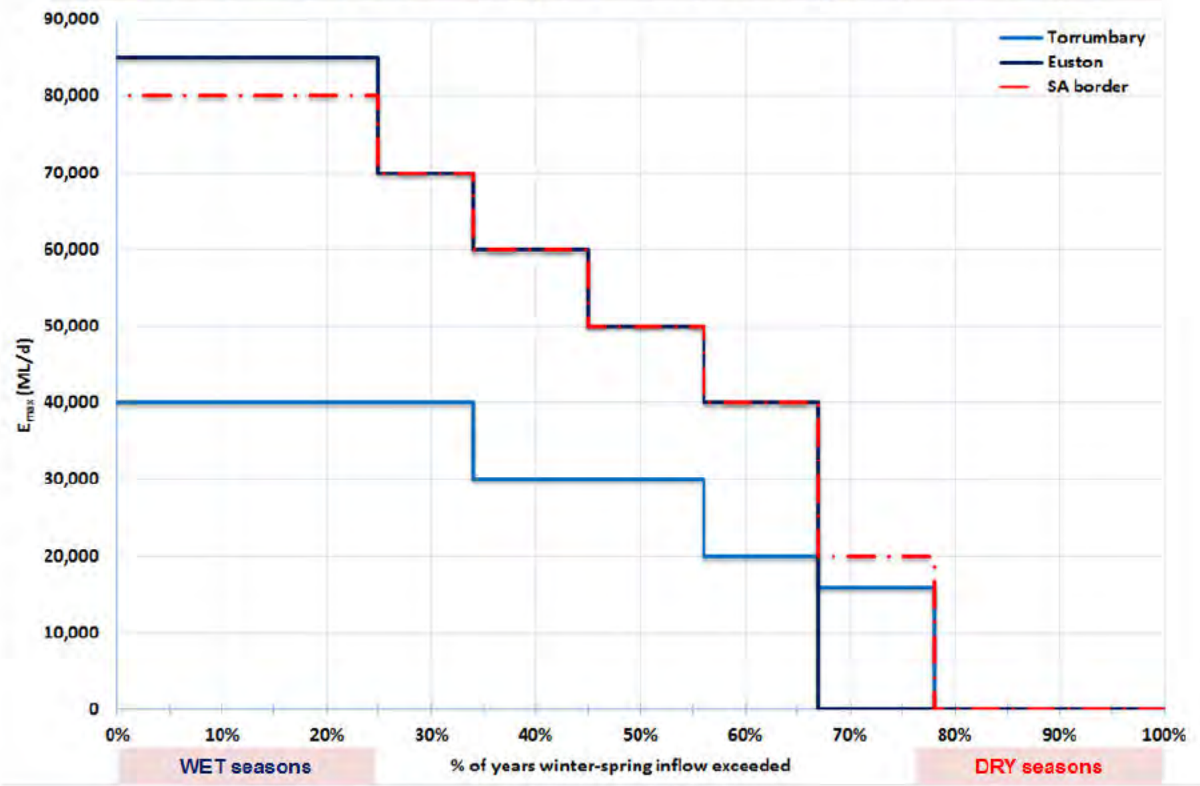


Figure 3a shows a range of peak environmental flow thresholds being investigated in this part of the Murray reach, where peak flows from 40,000 to 65,000 ML/d downstream of Yarrawonga were modelled by coordinating maximum flow of 40,000 ML/d at Doctors Point with unregulated flows from the Ovens River. It is noted that the higher flow limits were used only during the wet period (the wettest tercile, i.e. 33% of years) matching the relaxed capacity constraint downstream of Yarrawonga. Currently, flows downstream of Yarrawonga during the winter/spring period are managed to less than ~ 18,000 ML/d and are regulated by the maximum flow limit of 25,000 ML/d at Doctors Point. The actual flows for the dry period are much lower than the current channel capacity constraints. Peak flows during the dry period are naturally smaller and therefore, it is logical to apply lower limits for dry years so the environmental flow regime appropriate for the dry conditions can be targeted.

Similarly, Figure 3b shows maximum environmental flow limits applied at Torrumbarry (i.e. flow indicator site for Koondrook-Perricoota Forest), Euston (i.e. flow indicator site for Hattah Floodplains) and SA border (i.e. flow indicator site for Chowilla Floodplains), which are again consistently high for the wet period and low for the dry period.The maximum limits of 40,000 ML/d at Torrumbarry, 85,000 ML/d at Euston and 80,000 ML/d at SA border are applied as the maximum targeted flow rates for the environment. Note that higher flow indicators (e.g. 150,000 ML/d at Euston and 125,000 ML/d at the SA border) are specified in the Basin Plan

(2012) but these flows are not targeted or actively managed. They happen due to spills from the Hume Dam and unregulated flows from tributaries.

Figure 3b –Maximum environmental flow limit: Torrumbary, Euston and SA border



4.1.3. *Estimation of Environmental Flow Demand*

Environmental flow demand at each of the four sites is estimated using equation 2. This generates an environmental flow demand sequence as a sub-set of local 'without development' flows with the peaks constrained by the maximum environmental flow limit described above.

$$Q_E = \min\,(E_{max},\ f(p) \times Q_W) \qquad (2)$$

where,

$Q_E =$ *environmental flow demand (ML/d),*

$E_{max} =$ *maximum environmental flow limit (ML/d),*

$f(p) = coefficient\ of\ flow\ efficiency,$

$Q_W = local$ *without development flow* $at\ the\ site$ *(ML/d)*.

The environmental flow demands calculated above are included between mid-June and mid-November at Yarrawonga, between July and the end of November at Torrumbarry and Euston for the mid Murray, and between August and the end of November at SA border for the lower Murray.

The environmental flow demands are then filtered to ensure they meet (but are not limited to) requirement of the SFI sites specified in the Basin Plan. For example, if the target flow rates at a SFI site are 25,000 ML/d and 35,000 ML/d, and the calculated demand happens to be somewhere in between the two flow thresholds (e.g. 28,000 ML/d), then the demand estimate is scaled down to the 25,000 ML/d target, as it would not be achieving the upper 35,000 ML/d target. Similarly, if the minimum duration of an event required is, for example seven days and the calculated demand has an event lasting only for five days, this event is filtered out from the demand estimates because it would not be contributing to achieving the target outcomes.

Coefficient of flow efficiency, $f(p)$:

The coefficient of flow efficiency, $f(p)$ required in equation 2 was calculated monthly using equation 3.

$$f(p) = \begin{cases} 0.9, & \mathrm{p} < 0.25 \\ -1.2658p^2 + 0.4249p + 0.8653, & 0.25 \le \mathrm{p} \le 0.90 \\ 0, & \mathrm{p} > 0.90 \end{cases} \qquad (3)$$

where,

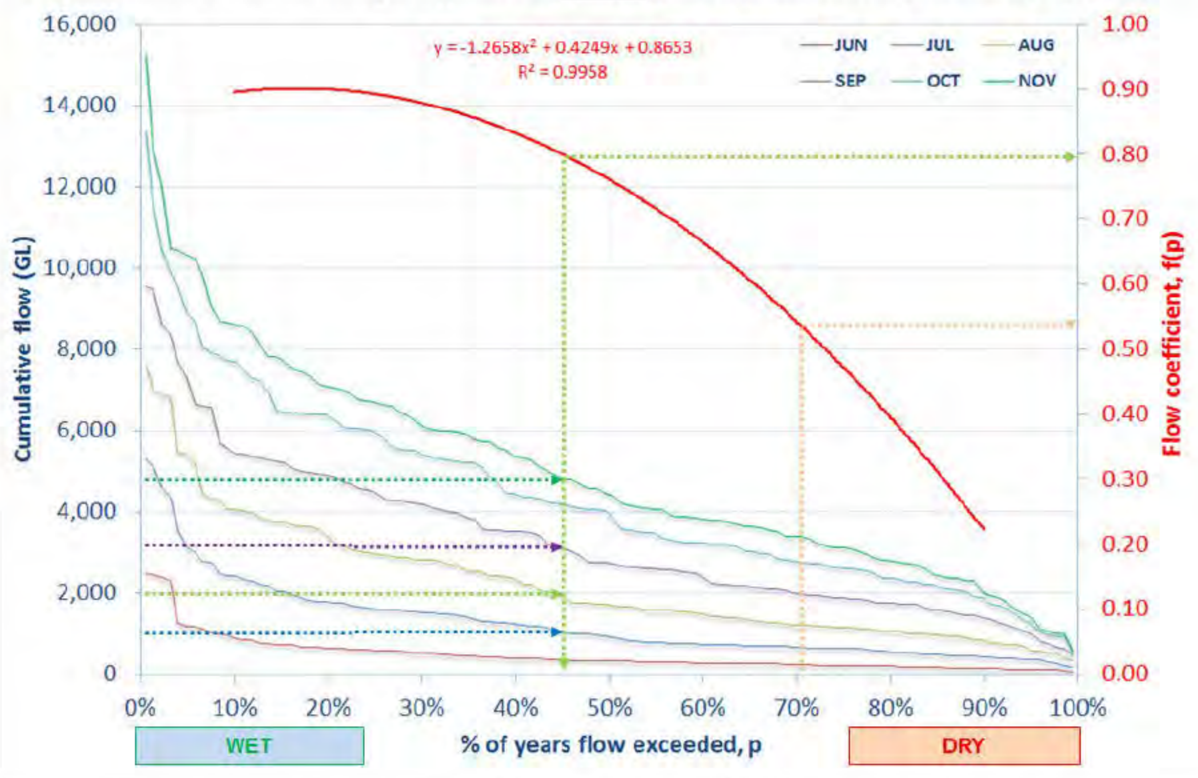
$p =$ probability of occurrence of flows for the specified month

Probability, p is obtained for each month from the equation 1 above using accumulated WoD flows for the specified month assuming a June - May water year for the period of 114 years (1895 to 2009). Accumulation of WoD flows commences from 1st June and ends in 30th November. For the month of July, as an example, the cumulative flow will be a total of June and July, while for the month of September it will be a total of June to September, etc.

Initially, a simple linear relation such as *f(p) = 1 – p* was used to calculate the coefficient values, then the empirical relationship provided in equation 3 was developed through an iterative process to achieve the appropriate SDL targets while minimising the *Limit of Change* breaches.

To demonstrate the concept, Figure 4 shows how the coefficient values are calculated for different months at a site downstream of Yarrawonga. Figure 4 shows cumulative WoD flows downstream of Yarrawonga for each month between June and November. From this relation, coefficient values for any month of any year can be determined. For example, November of 1969 has a cumulative flow of ~ 4,800 GL with 46% probability of recurrence, which corresponds to the coefficient value of 0.79. Similarly, the coefficients for other months in the modelling period are calculated using the same method. Note that the flows with 46% probability of recurrence are different for the different months but all the months with 46% probability of recurrence are assigned the same coefficient value of 0.79. These different months may fall in different years but are assumed to have similar flow conditions in terms of wetness or dryness. To be generic, the same equation 3 is applied for all months in winter and spring seasons.

Figure 4 – Determination of coefficient of flow efficiency: Yarrawonga, Murray system



Similarly, the coefficient is calculated at the other SFI sites using the same method.

The value of the coefficient will be higher for wet seasons, compared to dry seasons, representing the variable efficiency of flow propagation and movement under different hydrologic conditions. During extremely dry years (i.e. probability > 90%), the coefficient value is set to zero (including 6-7% of extremely wet years), meaning there will be no high environmental flow demand in extreme years. For the wet years (probability < 20%), the coefficient value is set to a maximum of 0.9. For the rest of the years, the value varies from relatively low in dry to high in wet conditions.

Conceptually, the coefficient of flow efficiency broadly reflects antecedent conditions of the system prior to the commencement of a flow event. As shown in Figure 4, it is the inverse of the loss component and represents the excess flow component (net of system losses) that contributes to propagation of flows by creating ripples / waves and peaks. During the dry season, the system is disconnected and parched and most of the available water resources are lost or absorbed by evaporation, infiltration, canopy, filling channels / depressions etc. Only a small component of the total is available for flow propagation, hence the low or close to zero flow coefficient in extreme dry conditions. Conversely during the wet season, the system is close to saturation, the loss component is small, and more water resources are available for flow propagation, hence the coefficient is expected to be high, or close to one, in extreme wet conditions. Therefore, the coefficient of flow efficiency should not be interpreted as the fractional ratio of environmental flow to the WoD flow. This is because the actual fraction would be much smaller as the water supplied to meet these environmental demands is limited by the volume in the environmental account and other operational constraints, including channel capacity constraints.

4.1.4. *Checking model results against the SDL targets*

Table 3 provides a summary of potential SDL offsets modelled in this study. In the baseline condition, before the Basin Plan, average annual diversions in the Murray system are reported to be 4,015 GL each year. From this consumptive use, the Basin Plan recovers ~ 1,160 GL for the environment from the River Murray system.

Table 3 – Potential SDL offsets in the Southern Basin based on 15-pack model (GL/y)

Valley	Baseline	BP Water recovery	SDL offsets			
			15-pack	Natural flow cues Y40	Natural flow cues CR Y50	Natural flow cues CR Y65
Murray system	4,015	1,163	-187.9	-273.3	-338.9	-338.9
Lower Darling	55	16	-2.6	-3.8	-4.7	-4.7
Murrumbidgee	2,107	592	-95.8	-139.3	-172.7	-172.7
Goulburn	1,784	519	-83.8	-83.8	-83.8	-83.8
Southern Basin	**7,961**	**2,290**	**-370**	**-500**	**600**	**600**

From the model output, long-term average annual diversions for the Murray valley are assessed to confirm that the total consumptive use for the valley matches the SDL targets with the specified SDL offsets provided in Table 3. If the average diversion is different from the SDL targets with the specified SDL offsets, the environmental flow estimates are adjusted up or down as required with the process repeated until the average diversions similar to the SDL targets are achieved.

Adjustment to environmental flow demands is an iterative procedure where the parameters associated with the calculation of environmental flow demands are refined. The parameters that can be adjusted to recompute environmental flow demand (individually or in combination) are:

- re-set the probability range for having environmental flow demands. The purpose is to increase or decrease as necessary the number of years with the demand;
- review the maximum environmental flow limit by re-setting limit curves in terms of shape and gradient; and
- review the relationship curve in terms of shape and gradient for the coefficient of flow efficiency.

The wet years that are selected for environmental watering have their environmental flow demands predominantly in winter-spring periods. Additionally some low flow demands may need to be provided at the SA border during the summer-autumn drought period, if hydrologically plausible, to maintain or improve water quality in the Lower Lakes and to enhance flow over Barrages, particularly when the *Limit of Change* is breached in the Coorong, Lower Lakes and Murray Mouth.

With the final set of environmental flow demands, further checks are carried out to ensure the average diversions in the sub-reaches are also similar to the corresponding SDL targets. Consideration is also given to the *Limit of Change* breaches of the SFIs. If necessary, any small difference between the modelled diversions and the SDL targets is fine-tuned by scaling utilisation factors or irrigation areas, as appropriate, to the sub-reaches in the valley.

4.2. The Murrumbidgee

4.2.1. *Assessment of hydrologic condition to identify wet and dry periods*

Figure 5 shows the winter-spring (1 June to 30 November) inflows to Burrinjuck Dam of the Murrumbidgee system. Inflows range from less than 400 GL to more than 4,000 GL for the period 1895 to 2009. The probability of occurrence of these inflows are used to identify dry and wet years.

The inflows can be less than ~ 400 GL/y for the 10 percent of extreme dry years and more than ~ 2100 GL for the extreme 10% of wet years with a median inflow of ~ 1,000 GL. The figure shows that the wettest 25% of years (wet quartile) have a total winter-spring inflow in excess of ~ 1,500 GL while the driest 25% of years (dry quartile) have less than ~ 600 GL.

4.2.2. *Maximum environmental flow limit (E_{max})*

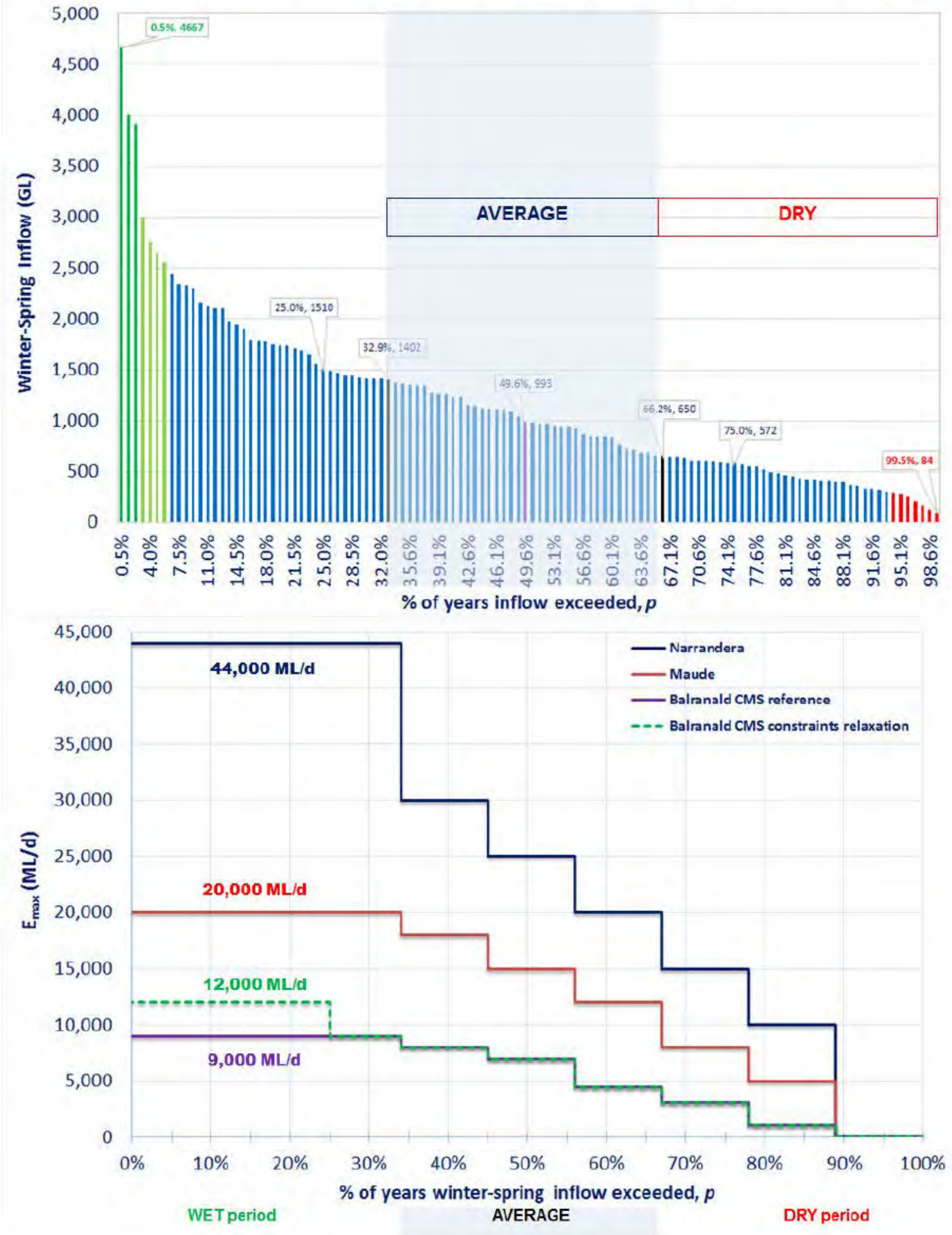
In the Murrumbidgee system, there are three SFI sites. The Basin Plan specifies a range of flow rates and volumes for the environmental watering targets at these sites. They are:

- Narrandera (*flow target range 26,850 to 44,000 ML/d*),
- Maude (*flow target range 175 to 2,700 GL*), and
- Balranald (*flow target range 1,100 to 9,000 or 12,000 ML/d depending on the constraints relaxed or not*). Note that the flow target specified in the Basin Plan for this SFI site is only upto 4,500 ML/d to meet the local environmental needs but since this site is at the end of system, higher flow is also targeted to contribute toward the River Murray targets downstream.

The maximum environmental flow limit (E_{max}) for these sites is determined from the probability of occurrence of winter-spring inflows to the Burrinjuck Dam, as shown in Figure 5 (*lower graph*). Similar to the Murray system, the maximum flow peaks are higher for the wet years and lower for the dry years and limited by the constraints.

During the wet seasons when constraints are relaxed, higher maximum environmental flow limits are applied to allow for higher peak flow (e.g. 12,000 ML/d at Balranald for a 'constraints relaxed' scenario versus 9,000 ML/d in the benchmark). The lower or upper limits and the steppings at each site are initially set based on the SFIs specified in the Basin Plan (Table A.2 in Appendix A) and channel capacity constraints where applicable.

Figure 5 –Inflows to Burrinjuck Dam and environmental flow limit curve: Murrumbidgee



4.2.3. *Estimation of Environmental Flow Demand*

Similar to the River Murray System, the environmental flow demands at each of the three sites are estimated using equation 2 above.

The environmental flow demands calculated above are provided predominantly during the winter-spring period. They are provided between July and the end of November at Narrandera and Maude for the mid and lower Murrumbidgee, and between October and May at Balranald for the end of the system as per the Murrumbidgee SFIs.

Coefficient of flow efficiency, $f(p)$:

The coefficient of flow efficiency, $f(p)$ required in equation 2 for the Murrumbidgee sites was calculated using equation 4.

$$f(p) = \begin{cases} 0.9, & \mathrm{p} < 0.25 \\ -1.2468p^2 + 0.4186p + 0.8524, & 0.25 \le \mathrm{p} \le 0.90 \\ 0, & \mathrm{p} > 0.90 \end{cases} \quad (4)$$

where,

p = probability of occurrence of local WOD flows for the specified month.

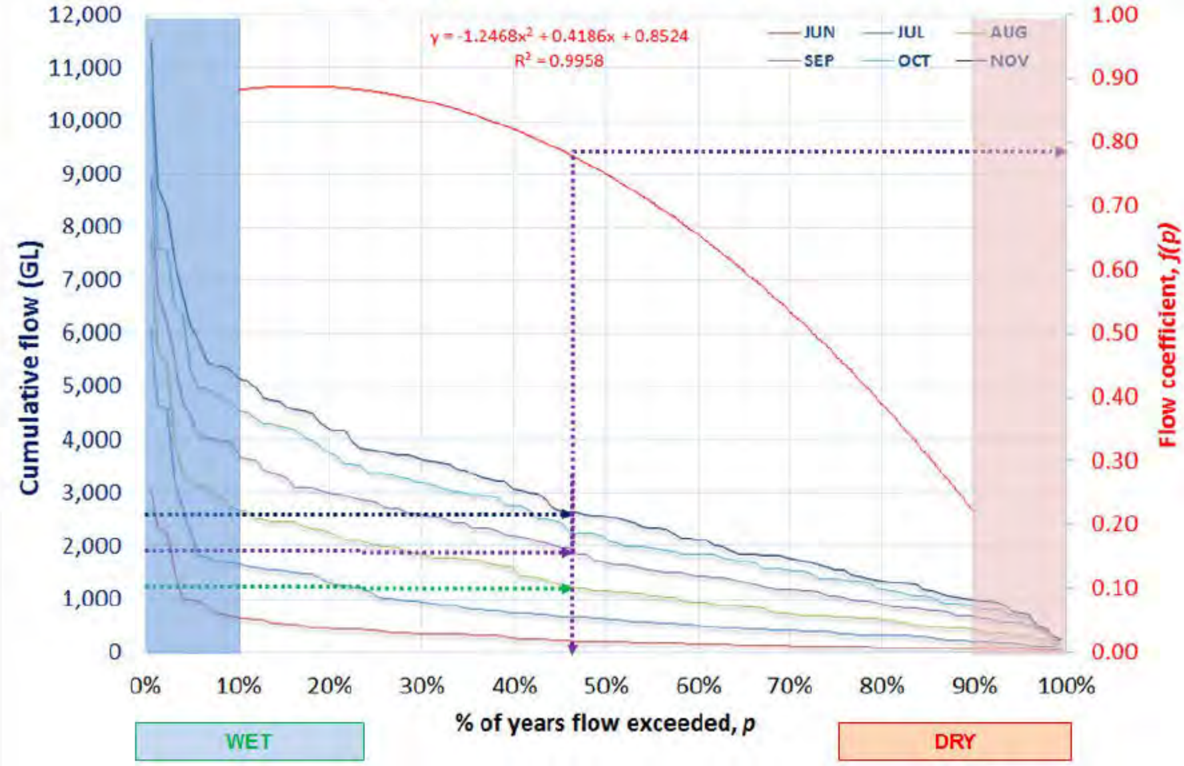
During extremely dry years, there will be no high environmental flow demand as the coefficient of flow efficiency in such dry conditions is assumed to be very low. The value is set to zero for these years. Similarly, the value is set to zero for extremely wet years. For other wetter years (i.e. probability < 25%), the coefficient is set to a maximum of 0.9 which reflects high flow efficiency under the wetter conditions. For the rest of the years, the coefficient varies from relatively low in dry years to high in wet years.

Figure 6 demonstrates how the coefficient of flow efficiency is related to the cumulative WoD flow and its probability of occurrence for a given month. Accumulation of flows commences from June and ends in November for the entire winter-spring period. As an example, Figure 6 shows the Narrandera cumulative WoD flow for the months between June and September.

To demonstrate the concept, the years 1961 and 1980 out of 114 years (1895 – 2009) are used as an example. September of 1961 has a cumulative flow of ~ 1,960 GL with ~ 46% probability of recurrence, while the September of 1980 has a cumulative flow of ~ 1,150 GL with ~ 72% probability of recurrence. The September of 1961 is wetter and will have a higher coefficient of flow efficiency value (0.78) compared to the coefficient value (0.50) of the September of 1980. Similarly, coefficient values are calculated for all months for the period from 1895 to 2009. To be generic, the same equation 4 is applied to get the coefficient values for all months.

Similarly, the coefficient is calculated at other SFI sites (i.e. Maude and Balranald).

Figure 6 – Determination of coefficient of flow efficiency: Narrandera, Murrumbidgee



4.2.4. *Checking model results against the SDL targets*

Similar to the Murray valley, long-term average annual diversions for the Murrumbidgee are assessed and checked to confirm that the total consumptive use for the valley matches the SDL targets with the specified SDL offsets provided in Table 3. If the average diversion is different from the SDL targets with the specified SDL offsets, the environmental flow estimates are scaled up or down as required and the process is repeated until the average diversions similar to the SDL targets are achieved.

4.3. Goulburn System

The Goulburn model included in this report is the same as the 15-pack.

It will be included in the natural flow cues framework and assessed for any possible additional SDL offset compared to the 15-pack. More information will be provided when the modelling is completed.

4.4. Operability of the natural flow cues approach

This sub-section describes the strengths and limitations of the approach and further work needed to translate the theoretical concept into operational practice.

4.4.1. *Strengths of the approach*

The natural flow regime is understood to be critical in maintaining ecosystem integrity and services (Poff et al., 1997). The approach applied in this study attempts to re-establish some of those elements of the flow regime that have been lost due to regulation of river flows for consumptive uses.

The method is conceptually sound, robust and viable. It represents high and low flow cycles in the system and is generic in terms of its application to the valleys and regions with different hydro-climatic conditions.

The constraints applied for the 'constraints relaxed' scenarios are aspirational. If the operational constraints are to be changed, the method can be easily customised to reflect the change as necessary.

If climate and flow forecasts are available (e.g. seasonal flow forecasts of Bureau of Meteorology (BoM)) and current decision making criteria of environmental water use is known, they can be easily incorporated in to the modelling framework, which can then be used to plan environmental watering events in advance.

The approach provides a flexible framework that can be adapted to hydrologic conditions at the time to guide in operating the rivers in real world situations for more efficient delivery of environmental water.

4.4.2. *Limitations of the approach*

Similar to the 'previous Basin Plan' modelling, the current version of the natural flow cues model has prior hydro-climatic knowledge of the system because the focus in these studies has been on long-term policy development and planning rather than day-to-day river operations.

In the current model, environmental water use is assumed to commence from early in the season (from mid-June untill the end of November) whenever opportunities arise with no limit on the amount of water being released as long as there is water in the environmental account. This pattern of environmental water use may not correctly reflect the current behaviour of environmental water holders.

The model currently has a foresight of one to six months and is only a proof-of-concept in the context of long-term policy development and water use planning. The method is still evolving and further refinement is required to reduce the foresight to shorter period. As such it can not be applied for planning and operation in real world situations.

When the model is ready to put in practice, it needs to rely on seasonal flow forecasts and the reliability of the modelling results will depend on the quality of the forecasts.

4.4.3. *Further work*

Further work is needed to include the Goulburn-Broken system into the natural flow cues framework. Further refinement of the method is also necessary to operationalise the concept in a real world situations.

The following summarises the required additional work:

1. Apply natural flow cues to the Goulburn-Broken system and model the integrated southern connected system as one hydrologic unit.
2. Apply natural flow cues to the Lower Darling system as well. This is likely to address some of the *Limit of Change* breaches during the dry years, particularly in the Lower Lakes and Coorong.
3. Incorporate CEWH's current water use decision making criteria in the modelling as appropriately as possible so the modelled pattern of environmental water use reflects the current practice of environmental water holders.
4. Currently the method has a foresight of a month to six months and uses the flows accumulated for one to six months. The method needs further refinement to be able to work with a reduced foresight of one to three months so environmental watering plan options can be explored in advance using the BoM's flow forecast.
5. Currently wet or dry conditions are represented by probability of flows accumulated from one to six months. It is not known yet what variable (e.g. probability or median ratio, etc) and period of accumulation is more appropriate to represent hydrologic variability in the system for the purpose of this modelling. This needs to be explored further so the non-linearity of the system is better represented in the model.
6. In the final package, *Limit of Change* breaches, if there are any, need to be addressed. Current modelling indicates that the breaches are likely during the extreme dry years because in this study the focus, to date, has been on wet years providing high flows during the winter-spring season. This may be addressed by including a drought management strategy in the natural flow cues framework for dry years.

5. RESULTS AND DISCUSSION

The current modelling is a work-in-progress and the results are preliminary meaning some key points are only briefly discussed for the Murray and the Murrumbidgee. The discussion of results are structured as follows:

- potential SDL offset and *Limit of Change (LoC)*;
- environmental benefits: ecological element scores and SFIs;
- system dynamics: storage and spill behaviours of the system; and
- hydrologic changes: flows at key locations including some hydrographs.

5.1. Potential SDL offset and Limit of Change

The SDL offset scenarios explored in this study are provided in Table 3 above.

5.1.1. *Potential SDL offset*

Table 3 provides a summary on additional SDL offsets that can be achieved in the Southern Basin over the 15-pack if environmental water is delivered more efficiently. Preliminary results indicate a SDL offset of about 100 GL may be possible if the environmental water is delivered following natural flow cues. This assumes a constraint of 40,000 ML/day downstream of Yarrawonga. A further 100 GL SDL offset may be possible if physical constraints in the Southern Basin are relaxed, including raising the Yarrawonga constraint to 50,000 ML/day, to deliver higher peak environmental flows. That is, there is potentially a total of nearly 200 GL offset available if environmental water is delivered differently by relaxing constraints. About two-third of this additional offset is in the River Murray and the remaining one-third is in the Murrumbidgee. The Goulburn system is yet to be included in the natural flow cues framework.

5.1.1. *Limits of Change (LoC)*

Figure 9 shows the number of indicators that have breached LoC criteria for SDL adjustment mechanisms specified under the Basin Plan. In the figure, four scenarios are included: (i) 15-pack SDL offset 370 GL (top-left), (ii) Natural flow cues SDL offset 500 GL (top-right), (iii) Natural flow cues constraints relaxed Y50 SDL offset 600 GL (bottom-left), and (iv) Natural flow cues constraints relaxed Y65 SDL offset 600 GL (bottom-right). For each scenario, the y-axis represents change in frequency from the benchmark and the x-axis represents the 60 SFIs in the Southern Basin. The positive value indicates that the frequency of the SFI has increased by that value compared to the benchmark and the negative value indicates a decrease. As can be seen, the frequency of some SFIs increased while others decreased compared to the benchmark. However, there are greater frequency increases for the natural flow cues scenarios for some SFIs despite less environmental water being available as compared to the 15-pack.

The SFIs in the blue have passed the LoC criteria while those in the red have breached.

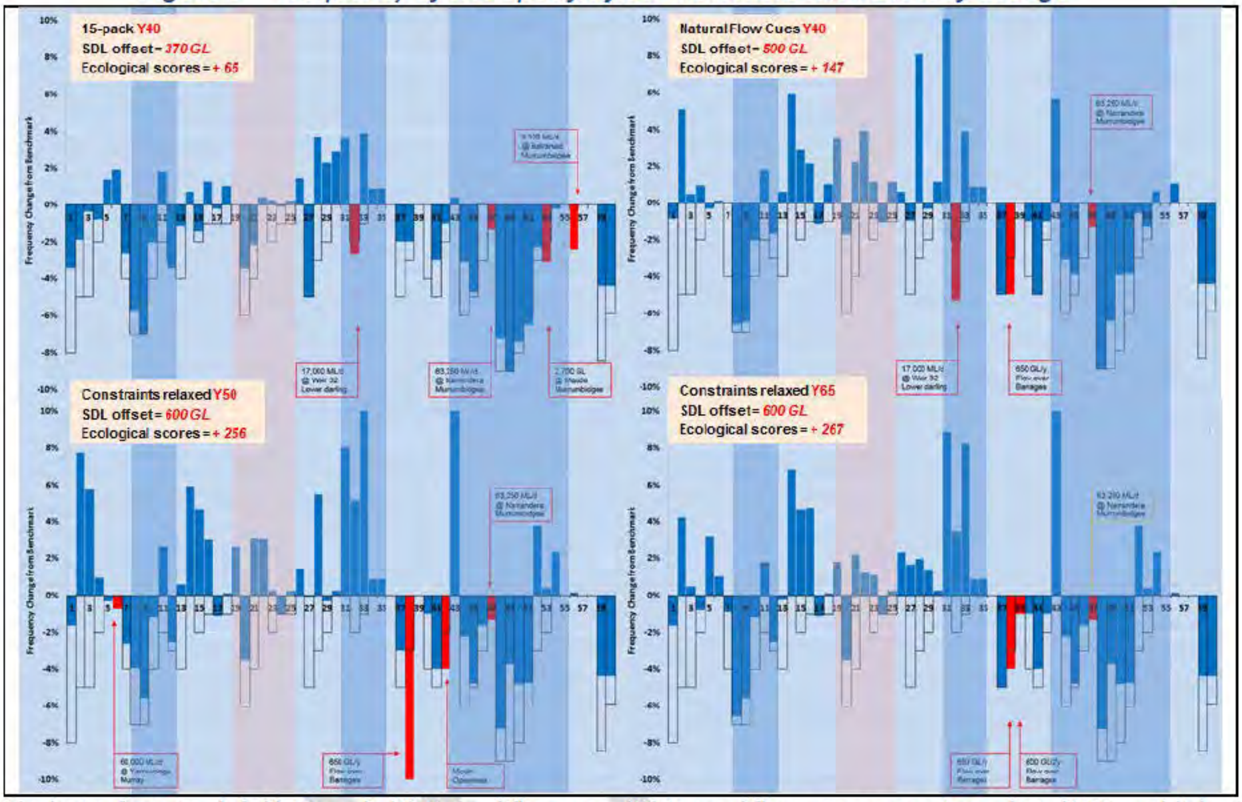
15-pack scenario (SDL offset = 370 GL/y): LoC breached by four SFIs. They are: (i) 17,000 ML/d flow at Weir 32 in Lower Darling, (ii) 63,250 ML/d flow at Narrandera in mid Murrumbidgee, (iii) 2,700 GL flow at Maude in lower Murrumbidgee, and (iv) 3,100 ML/d flow at Balranald. The first two SFIs are not directly targeted by actively managing environmental water use, but are expected to meet by unmanaged spills.

Natural flow cues scenario (SDL offset = 500 GL/y): LoC breached by three SFIs. They are: (i) 17,000 ML/d flow at Weir 32 in Lower Darling, (ii) 63,250 ML/d flow at Narrandera in Murrumbidgee, and (iii) 650 GL/y flow over Barrages in the Lower Lakes. The first two SFIs are not directly targeted, but are expected to be met by unmanaged spills. LoC breach by the third SFI was during the drought and may be managed by including low flow environmental demand at SA border during dry years.

Natural flow cues constraints relaxed scenario Y50 (SDL offset = 600 GL/y): LoC breached by four SFIs. They are: (i) 60,000 ML/d flow downstream of Yarrawonga in the River Murray, (ii) 650 GL/y flow over Barrages in the Lower Lakes, (iii) Murray mouth openness, and (iv) 63,250 ML/d flow at Narrandera in Murrumbidgee. The first and the last SFIs are not directly targeted, but are expected to be met by unmanaged spills. The LoC breach by the two SFIs in the Lower Lakes and the Murray Mouth is during the drought and may be managed by including low flow environmental demand at the SA border during dry years.

Natural flow cues constraints relaxed scenario Y65 (SDL offset = 600 GL/y): LoC breached by three SFIs. They are: (i) 650 GL/y flow over Barrages in the Lower Lakes, (ii) 600 GL/2y flow over Barrages in the Lower Lakes, and (iii) 63,250 ML/d flow at Narrandera in Murrumbidgee. LoC breach by the first two SFIs is during the drought and may be managed by including low flow environmental demand at the SA border during dry years. The last SFI is not directly targeted, but is expected to be met by unmanaged spills.

Figure 9 – Frequency of site-specific flow indicators with Limit of change



Clockwise from top left (i) 15-pack, (ii) Natural flow cues, (iii) Natural flow cues constraints relaxed Y65, and (iv) Natural flow cues constraints relaxed Y50. The empty bars with negative value represent LoC allowed for the SFIs. SFIs in the red indicate a breach of LoC criteria.

5.2. Environmental Benefits

5.2.1. *Ecological Elements Score*

The ecological elements scores have been estimated for each valley. A summary is provided in Table 4. How these scores are estimated is described by Overton et al. (2015).

For the natural flow cues scenario with about 100 GL less environmental water, the score is improved by about 80 points compared to 15-pack.

The ecological scores improved further by 190 – 200 points with about 200 GL less environmental water when the constraints are relaxed .

Relaxing constraints further to 65,000 from 50,000 ML/d downstream of Yarrawonga improves the score slightly.

Table 4 - Ecological elements scores by valleys

Sites / Valleys	Benchmark	15-pack	Difference from 15-pack		
			Natural flow cues Y40	Constraints relaxed Y50	Constraints relaxed Y65
Murray and Lower Darling	4,198	4,425	+60	+148	+164
Murrumbidgee	5,581	5,281	+187	+416	+416
Goulburn*	8,176	7,998	0	0	0
Southern Basin average	***4,947***	***5,012***	***+82***	***+191***	***+202***

* Note the Goulburn system is yet to be included in the natural flow cues framework.

5.2.2. *Site-specific Flow Indicators*

The Natural Flow Cues method does not actively seek to achieve SFI targets, but rather it attempts to provide environmental flows of high magnitude whenever opportunities arise to better utilise the available channel capacity depending on the hydrologic condition in the season.

The modelling results however, have been analysed to see how the natural flow cues method compares against the SFIs prescribed in the Basin Plan. A summary of the analysis is provided in Table 5.

Under the benchmark, a total of 38 SFIs out of the 60 in the Southern Basin achieve the requirements of the lower frequency targets. With the 15-pack scenario, one less SFI achieves the target. Compared to the 15-pack, three additional SFIs achieve the target in the Southern Basin with the natural flow cues scenario.

Similarly, with natural flow cues and constraints relaxation, four additional SFIs achieve the target in the Southern Basin. However, with natural flow cues and constraints relaxation, one to two SFIs at the Coorong, Lower Lakes and Murray Mouth (CLLMM) site fail to achieve the target. This may be addressed when the Goulburn and Lower Darling are included in the natural flow cues framework. Drought management strategies may need to be included to prevent this from happening, particularly in the dry years when the method is operationalised.

Except the CLLMM site, frequencies of SFIs at other sites across the Southern Basin are *mostly* improved as shown in Figure 10 through to Figure 12. These figures show a comparison of frequencies of all 60 SFIs between the 15-pack and the natural flow cues scenarios including the constraints relaxed scenarios. The zero line represents the frequency of the 15-pack scenario and a positive value for a SFI means the frequency of that SFI has increased by that amount compared to the 15-pack and vice-versa.

More information on SFIs is provided in Appendix B.

Table 5 – Number of SFIs achieving the SFIs targets

SFI sites	Benchmark	15-pack	Difference from 15-pack		
			Natural flow cues Y40	Constraints relaxed Y50	Constraints relaxed Y65
River Murray (30)	13	12	+ 4	+ 4	+ 4
Lower Darling (5)	2	3	0	+ 1	+ 1
Coorong, Lower Lakes and Murray Mouth (7)	7	7	-1	-2	-2
Murrumbidgee (14)	12	11	0	+ 1	+ 1
Lower Goulburn Floodplains (4)	4	4	0	0	0
Total (60)	**38**	**37**	**+ 3**	**+ 4**	**+ 4**

Figure 10 - Natural flow cues frequency of SFIs (expressed as a difference from the 15-pack)

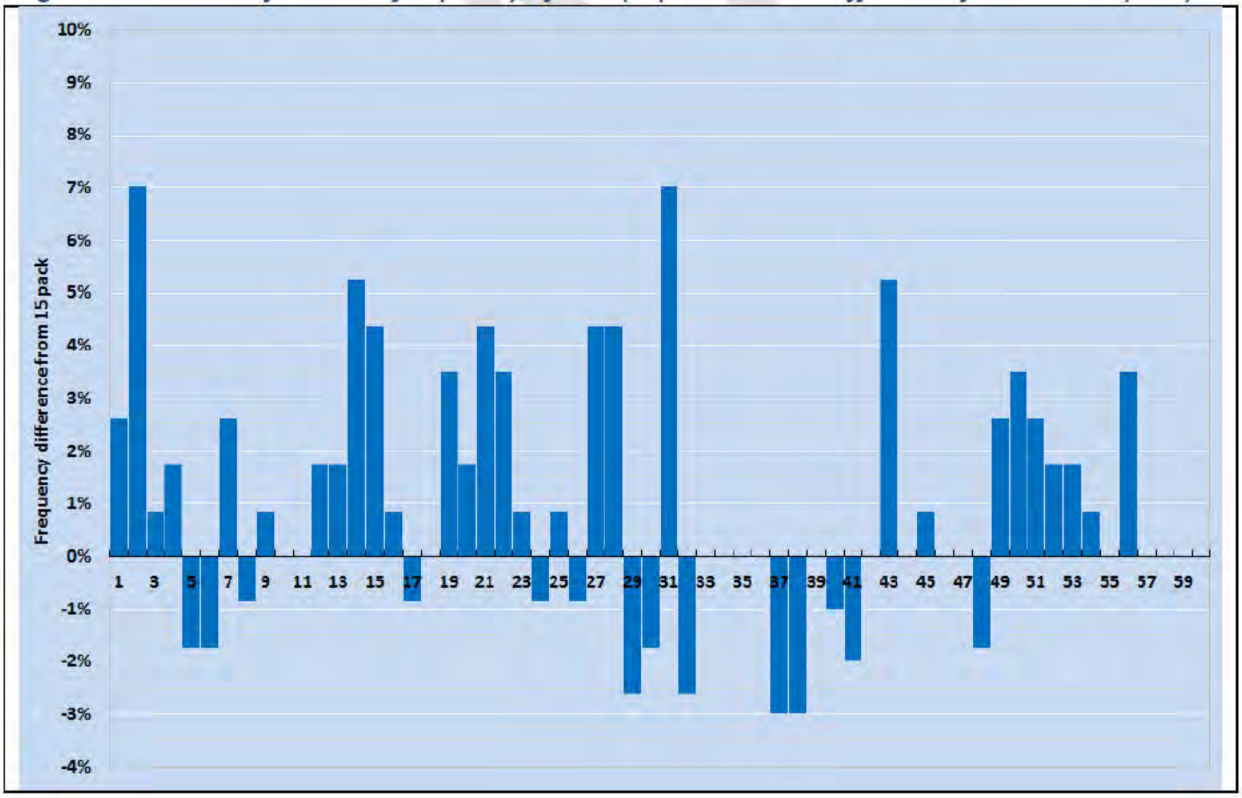


Figure 11 - Frequency of SFIs (difference from the 15-pack): constraints relaxed Y50 scenario

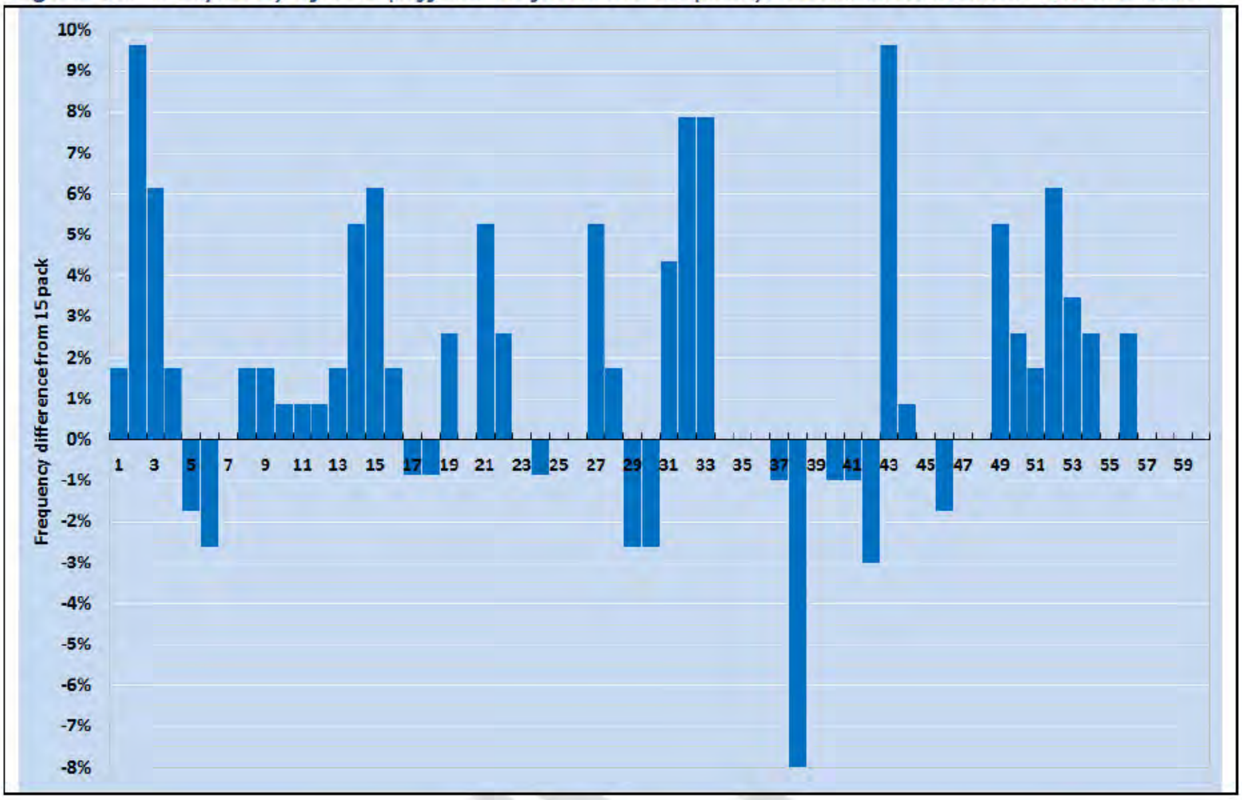
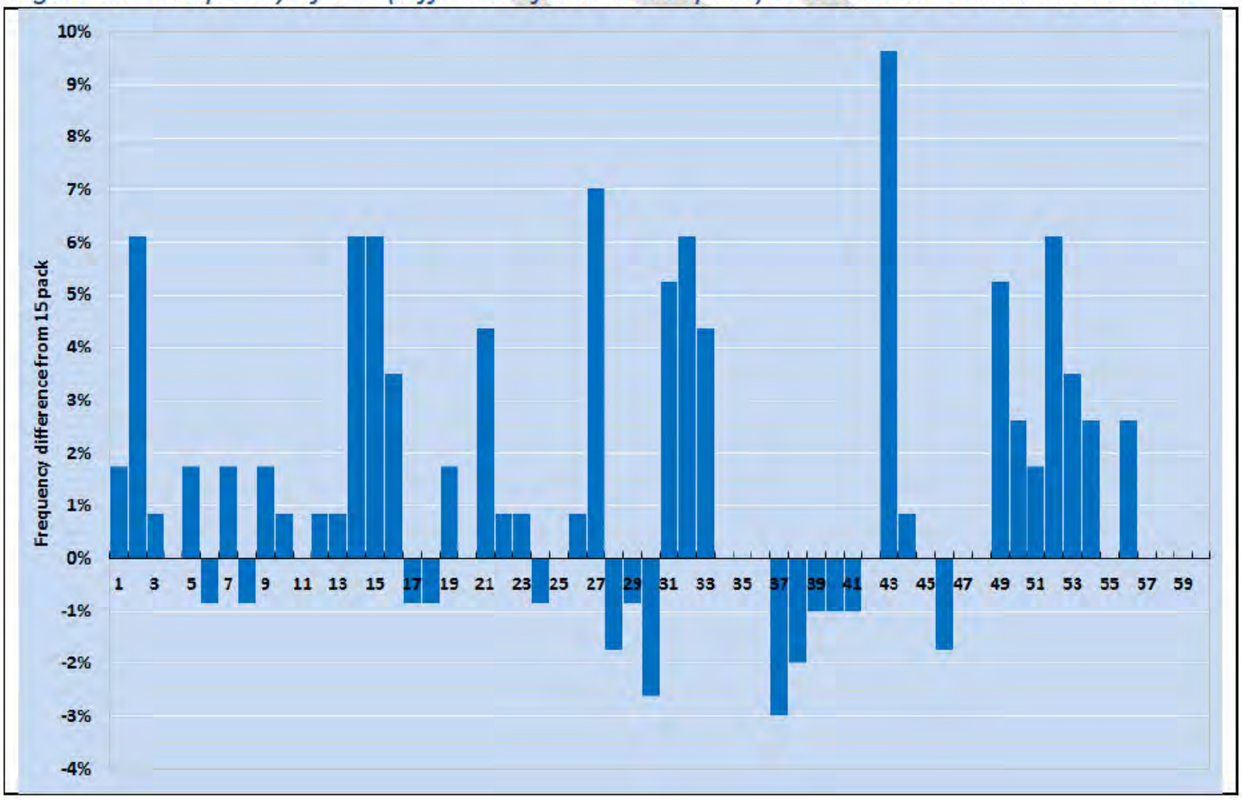


Figure 12 - Frequency of SFIs (difference from the 15-pack): constraints relaxed Y65 scenario



5.3. Spill from Storages

Table 6 shows the number of years of spilling and average annual spill volume from major storages in the Southern Basin. Note that the Goulburn system is yet to be included in the natural flow cues modelling framework.

Compared to the 15-pack, Hume Dam spills in fewer years and annual spill volume is also reduced on average. The reduction is greater when the constraints are relaxed. Changes are small when the constraint at Yarrawonga is relaxed further to 65,000 ML/d from 50,000.

With the natural flow cues approach, Menindee Lakes spill for a similar number of years as the 15-pack but with a higher spill volume. This indicates that the years that are spilling under the 15-pack scenario are spilling longer under the natural flow cues scenario. This may be partly due to its interaction with Hume Dam and the Lake Victoria harmony rules, and partly due to the Goulburn and Lower Darling system not yet being in the natural flow cues framework. This provides an opportunity to investigate further if the application of a natural flow cues approach to the Goulburn and Lower Darling changes Menindee spill behaviour.

Compared to the 15-pack, the spill in the Murrumbidgee increases slightly, both in frequency of years and magnitude, on average, under the natural flow cues scenario. However, the magnitude of spill is reduced by about 200 GL/y when constraints are relaxed.

Overall in the Southern Basin, the spill volume is reduced by about 400 GL/y under the natural flow cues constraints relaxed scenarios compared to the 15-pack.

Table 6 - Spill behaviour of storages: number of years spilling and volume of spill

Valley	Baseline	Benchmark	15-pack	Difference from 15-pack		
				Natural flow cues Y40	Constraints relaxed Y50	Constraints relaxed Y65
Number of years spilling						
Hume Dam in River Murray	58	59	68	-10	- 18	- 17
Menindee Lakes System	36	45	49	0	- 1	+ 2
Burrinjuck + Blowering in Murrumbidgee	81	76	77	+ 5	0	0
Eildon in Goulburn	21	35	35	yet to be completed		
Average Annual Spill Volume (GL/y)						
Hume Dam in River Murray	1,152	1,048	1,145	- 116	- 288	- 263
Menindee Lakes System	937	948	918	+ 71	+ 64	+ 73
Burrinjuck + Blowering in Murrumbidgee	723	654	623	+ 28	- 209	- 209
Eildon in Goulburn	159	254	232	yet to be completed		
Southern Basin total (GL/y)	**2,971**	**2,904**	**2,918**	**- 17**	**- 433**	**- 399**

5.4. Hydrology

In this section potential hydrology changes due to environmental water delivery following the natural flow cues approach and constraints relaxation is discussed, focussing particularly on the high flow range at key locations in the Southern Basin.

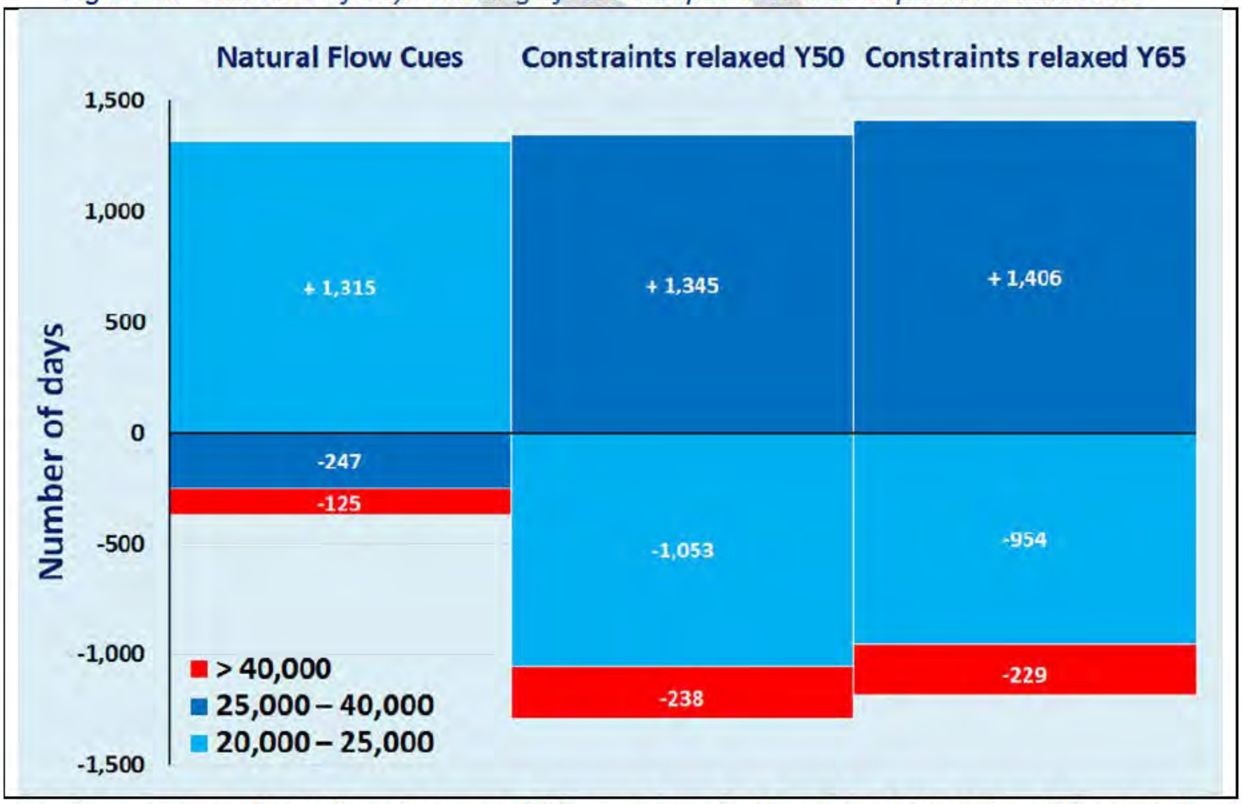
5.4.1. *Flow at Doctors Point*

Figure 13 shows total number of days (as a difference from the 15-pack) the flow at Doctors Point is over 20,000 ML/d for the 114-year modelling period (1895 – 2009) for different flow ranges. For the natural flow cues scenario, the period of flows in the 20,000 – 25,000 ML/d range are increased by about 1,300 days (i.e. 11-12 days per year on average) compared to the 15-pack. At the same time, the number of days that the flow exceeds the current channel capacity of 25,000 ML/d is reduced.

When the constraints are relaxed, flows in the 20,000 – 25,000 ML/d range are boosted up, which increases the occurance of flows in the 25,000 – 40,000 ML/d range by about 1,350 days (i.e. 11-12 days per year on average). Relaxing constraints downstream of Yarrawonga further to 65,000 from 50,000 ML/d has small changes with the flows at Doctors Point.

These results suggest that the managed flows can be increased with a smarter delivery of less environmental water (about 100 GL less for a natural flow cues scenario). Additionally, if constraints are relaxed, there would be further opportunities to supply more regulated high flows in the moderately wet years with even less environmental water (about 200 GL less for the constraints relaxed scenarios).

Figure 13 – Number of days with high flows compared to the 15-pack: Doctors Point



The plus and minus values indicate incremental difference from the 15-pack for 1895-2009 modelling period.

Unmanaged flows: For the natural flow cues scenario, the unmanaged flows in the Hume to Yarrawonga reach are those that exceed 25,000 ML/d at Doctors Point. Compared to the 15-

pack, the occurance of flows that exceed 25,000 ML/d is reduced by about 370 days. Similarly, the period of flows that exceed 40,000 ML/d is reduced by about 125 days on average.

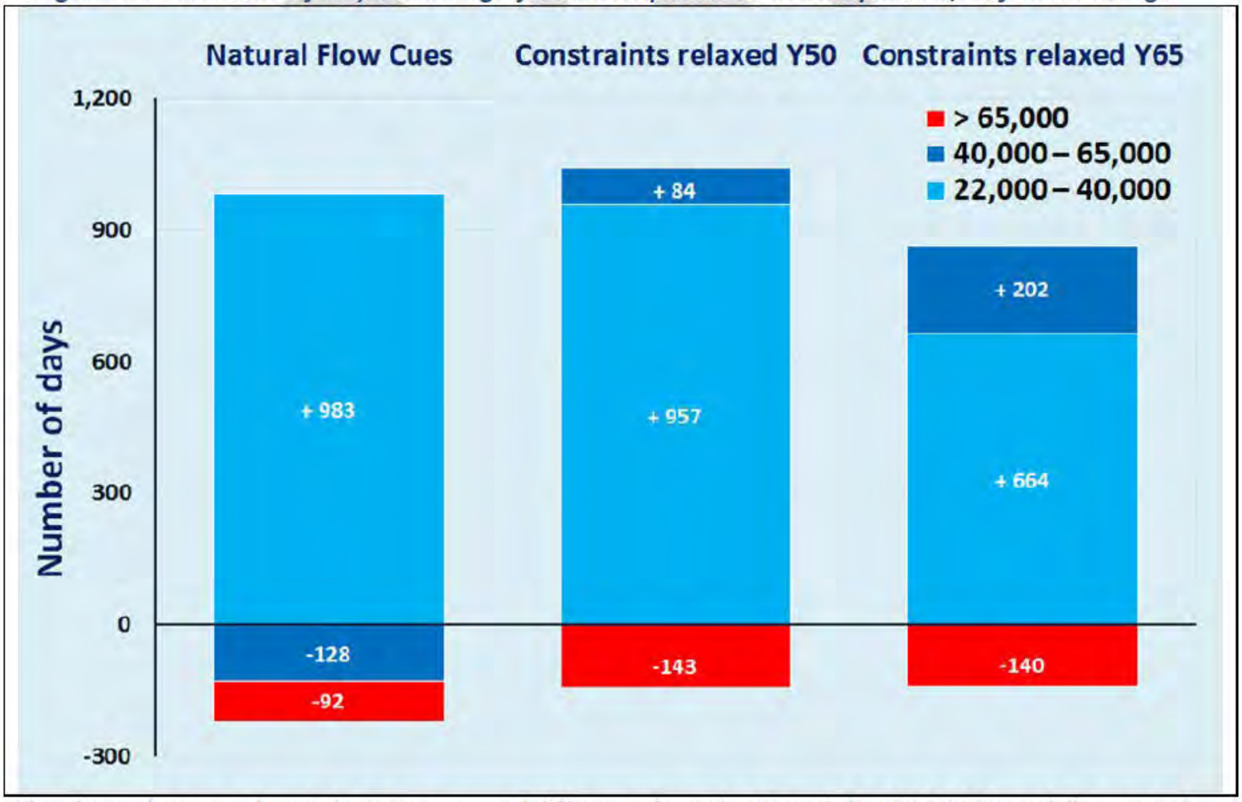
For the constraints relaxed scenarios, the unmanaged flows in Hume to Yarrawonga reach are those that exceed 40,000 ML/d at Doctors Point. The occurance of unmanaged flows is reduced by about 230 days, on average, when the constraints are relaxed.

These results suggest that the smarter delivery of environmental water would reduce unmanaged flows in Hume to Yarrawonga reach, thereby minimising the potential risk of flooding. Additionally, if constraints are relaxed, there would be a greater reduction of unmanaged flows in moderately wet years, which would further minimise the potential risk of flooding in the reach.

5.4.2. *Flow downstream of Yarrawonga*

Figure 14 shows the total number of days (as a difference from the 15-pack) the flow downstream of Yarrawonga is over 22,000 ML/d for the 114-year modelling period (1895 – 2009) for different flow ranges. For the natural flow cues scenario, the occurance of flows in the 22,000 – 40,000 ML/d range is increased by about 980 days (i.e. 8-9 days per year on average) compared to the 15-pack. At the same time, the number of days that the flow exceeds the assumed channel capacity of 40,000 ML/d are reduced.

Figure 14 - Number of days with high flows compared to the 15-pack: d/s of Yarrawonga



The plus and minus values indicate incremental difference from the 15-pack for 1895-2009 modelling period.

When the constraints are relaxed, including to 50,000 ML/d downstream of Yarrawonga, some of the flows in the 22,000 – 40,000 ML/d range are boosted up to increase the occurance of flows in the 40,000 – 65,000 ML/d range by about 80 days, on average.

When the constraint downstream of Yarrawonga is relaxed further to 65,000 ML/d, more flows from the 22,000 – 40,000 ML/d range are boosted up, which further increases the occurance of flows in the 40,000 – 65,000 ML/d range by about 200 days, on average.

Similar to the Hume to Yarrawonga reach, these results suggest that managed flows downstream of Yarrawonga can be increased in the 22,000 – 40,000 ML/d range with a smarter delivery of less environmental water (about 100 GL less for natural flow cues scenario). Additionally if constraints were relaxed, there would be further opportunities to supply more regulated high flows in the moderately wet years with even less environmental water (about 200 GL less for the constraints relaxed scenarios).

Unmanaged flows: For the natural flow cues scenario, the unmanaged flows downstream of Yarrawonga are those that exceed 40,000 ML/d. Compared to the 15-pack, the occurance of flows that exceed 40,000 ML/d is reduced by about 130 days. Similarly, the occurance of flows that exceed 65,000 ML/d is reduced by about 90 days, on average.

For the constraints relaxed scenarios, the unmanaged flows downstream of Yarrawonga are those that exceed 50,000 ML/d for the Y50 scenario and 65,000 ML/d for the Y65 scenario. For both the Y50 and Y65 constraints relaxed scenarios, the occurance of unmanaged flows exceeding 65,000 ML/d is reduced by about 140 days, on average, compared to the 15-pack.

These results suggest that the smarter delivery of environmental water would reduce unmanaged flows downstream of Yarrawonga, thereby minimising the potential risk of flooding. Additionally, if constraints were relaxed, there would be a greater reduction of unmanaged flows in the moderately wet years, which would further minimise the potential risk of flooding downstream of Yarrawonga.

5.4.3. *Flow at Deniliquin*

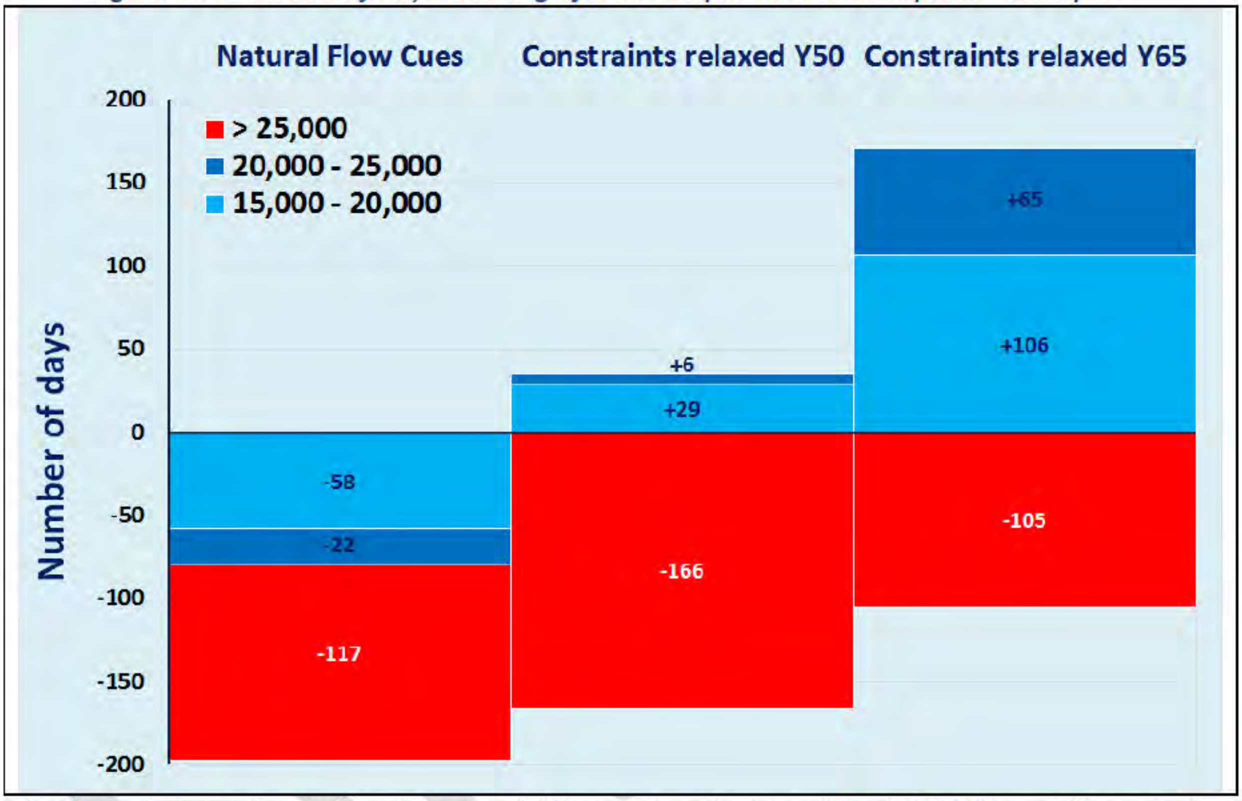
Figure 15 shows the total number of days (as a difference from the 15-pack) the flow at Deniliquin is over 15,000 ML/d for the 114-year modelling period (1895 – 2009) for different flow ranges. For the natural flow cues scenario, the flows over 15,000 ML/d is decreased by about 200 days compared to the 15-pack.

When the constraints are relaxed, including to 50,000 ML/d downstream of Yarrawonga, the occurance of flows in the 15,000 – 25,000 ML/d range is increased by about 35 days where as the occurance of flows over 25,000 ML/d is reduced by about 160 days, on average.

When the constraint downstream of Yarrawonga is relaxed further to 65,000 ML/d, the occurance of flows in the 15,000 – 25,000 ML/d range is increased by about 170 days but the occurance of flows over 25,000 ML/d is reduced by about 105 days, on average.

These results suggest that the flows at Deniliquin that are higher than 25,000 ML/d will decrease if environmental water is delivered following natural flow cues approach compared to the 15-pack, whether constraints relaxed or not.

Figure 15 - Number of days with high flows compared to the 15-pack: Deniliquin



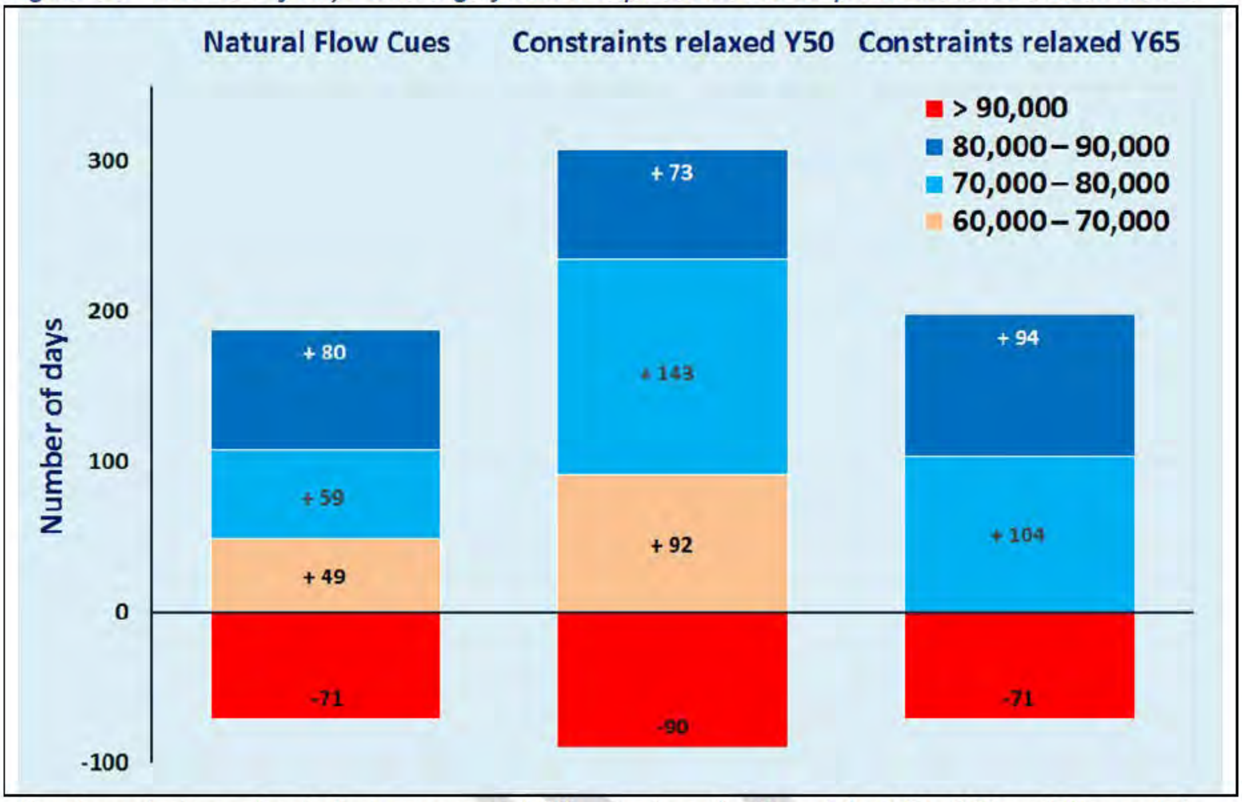
The plus and minus values indicate incremental difference from the 15-pack for 1895–2009 modelling period.

5.4.4. *Flow to South Australia*

Figure 16 shows the total number of days (as a difference from the 15-pack) the flow to South Australia is over 60,000 ML/d for the 114-year modelling period (1895 – 2009) for different flow ranges. For the natural flow cues scenario, the occurance of flows in the 60,000 – 80,000 ML/d range are increased by about 110 days compared to the 15-pack. The occurance of flows in the 80,000 – 90,000 ML/d range are increased by about 80 days as the unmanaged flow exceeding 90,000 ML/d is reduced to a lower range by about 70 days.

When the constraints are relaxed, including to 50,000 ML/d downstream of Yarrawonga, the occurance of flows in the 60,000 – 80,000 ML/d range are increased by over 230 days compared to the 15-pack. The occurance of flows in the 80,000 – 90,000 ML/d range are also increased because the unmanaged flow exceeding 90,000 ML/d is decreased to a lower range with a reduced period of about 90 days, on average.

Figure 16 - Number of days with high flows compared to the 15-pack: South Australia border



The plus and minus values indicate incremental difference from the 15-pack for 1895-2009 modelling period.

When the constraint downstream of Yarrawonga is relaxed further to 65,000 ML/d, the flows in the 70,000 – 80,000 ML/d range are boosted up so the occurance of flows in the 80,000 – 90,000 ML/d range is increased by over 90 days, on average. The unmanaged flow exceeding 90,000 ML/d is reduced by about 70 days.

These results suggest that the managed flows to South Australia in the 60,000 – 80,000 ML/d range can be increased with the smarter delivery of less environmental water (about 100 GL less for the natural flow cues scenario with a constraint of 40,000 ML/d downstream of Yarrawonga). Additionally, if constraints were relaxed, including to 50,000 ML/d downstream of Yarrawonga, there would be further opportunities to supply more regulated high flows in the 60,000 – 80,000 ML/d range in the moderately wet years with even less environmental water (about 200 GL less for the constraints relaxed scenarios).

Relaxing constraints further to 65,000 ML/d downstream of Yarrawonga tends to push flows up from the 70,000 – 80,000 ML/d range to the 80,000 – 90,000 ML/d.

For more information on flows, some example hydrographs are provided in Appendix C.

Dry spell: Table 7 provides a summary of maximum dry period between the flow events to South Australia, as an example. Results indicate that it may be possible to maintan maximum dry spell between the SA flow events, in general, even with 100 - 200 GL less environmental water as compared to the 15-pack if constraints are relaxed to appropriate level and environmental water is delivered more efficiently.

Table 7 – Maximum dry spell between the flow events longer than 7 days to SA (years)

Flow threshold (ML/d)	WoD	Bench mark	15-pack (offset = 370 GL)	Natural flow cues difference from 15-pack		
				Y40 (offset = 500 GL)	Constraints relaxed Y50 (offset = 600 GL)	Constraints relaxed Y65 (offset = 600 GL)
20,000	3	3	4	-1	-1	0
40,000	4	9	9	0	-3	0
50,000	4	9	9	0	0	0
60,000	4	9	10	+1	+1	+1
70,000	9	18	13	0	0	0
80,000	9	21	21	-3	0	0
100,000	13	21	21	0	+3	+3
120,000	13	24	34	-6	-10	-10

6. CONCLUSION

An alternative way of Basin Plan environmental water delivery, called the Natural Flow Cues method, was applied to the 15-pack SDL adjustment mechanisms for a proof of concept study. Possible SDL adjustment options were investigated by delivering less environmental water more efficiently and still achieving similar or better environmental outcomes.

Preliminary natural flow cues modelling has been completed for the Murrumbidgee and the River Murray and work is progressing for the inclusion of the Goulburn and (possibly the Lower Darling) in to the natural flow cues framework. The results may be slightly different when an integrated scenario for the southern connected system is completed with the natural flow cues approach, however some key points from the modelling completed to date are summarised below as compared to the 15-pack scenario:

Natural flow cues scenario (40,000 ML/d downstream of Yarrawonga):

1. An additional SDL offset of about 100 GL can be possible through more effective delivery of environmental water;
2. Increased ecological benefits and improved environmental outcomes with less water;

3. Effective use of water providing more watering of target floodplains throughout the system;
4. Efficient use of available channel capacity and environmental water through better alignment and co-ordination of environmental releases and tributary inflows delivering more managed high flows to the lower Murray; and
5. More airspace in storages, providing improved capacity to mitigate the risk of flooding due to unmanaged spills later in the season in moderately wet years.

Natural flow cues constraints relaxed Y50 (50,000 ML/d downstream of Yarrawonga):

1. An additional SDL offset of about 200 GL can be possible through delivery of less environmental water more efficiently;
2. Significantly improved ecological benefits and environmental outcomes with less water;
3. Relaxing constraints and delivering environmental water early in the season jointly lead to increased airspace in storages, reduced spills and increased opportunities for more actively managed environmental releases;
4. Substantial additional airspace becomes available in the Southern Basin with an annual reduction of spills by about 400 GL. As a consequence, this may reduce the risk of flooding due to unmanaged spills later in the season; and
5. With constraints relaxation, the number of days high flows are regulated within channel capacity is increased in moderately wet years, resulting in higher peak flows in the lower Murray from managed environmental releases.

Natural flow cues constraints relaxed Y65 (65,000 ML/d downstream of Yarrawonga):

1. Further relaxation of constraints at Yarrawonga to 65,000 ML/d further improves the outcomes, but only slightly, with similar SDL offset potential.

7. REFERENCES

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8. APPENDIX A

Table A.1 – Site-specific Flow Indicators for the River Murray system

Location	Site Specific Flow Indicator
Yarrawonga	1) 12,500 ML/d for a total duration of 70 days (with a minimum duration of 7 consecutive days) between June & November for 70% of years; 2) 16,000 ML/d for a total duration of 98 days (with a minimum duration of 7 consecutive days) between June & November for 40% of years; 3) 25,000 ML/d for a total duration of 42 days (with a minimum duration of 7 consecutive days) between June & November for 40% of years; 4) 35,000 ML/d for a total duration of 30 days (with a minimum duration of 7 consecutive days) between June & May for 33% of years; 5) 50,000 ML/d for a total duration of 21 days (with a minimum duration of 7 consecutive days) between June & May for 25% of years; 6) 60,000 ML/d for a total duration of 14 days (with a minimum duration of 7 consecutive days) between June & May for 20% of years; and 7) 15,000 ML/d for a total duration of 150 days (with a minimum duration of 7 consecutive days) between June & December for 30% of years
Torrumbarry	1) 16,000 ML/d for a total duration of 90 days (with a minimum duration of 7 consecutive days) between June & November for 70% of years; 2) 20,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & November for 60% of years; 3) 30,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & May for 33% of years; 4) 40,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & May for 25% of years; and 5) 20,000 ML/d for a total duration of 150 days (with a minimum duration of 7 consecutive days) between June & December for 30% of years
Euston	1) 40,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & December for 40% of years; 2) 50,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & December for 30% of years; 3) 70,000 ML/d for a total duration of 42 days (with a minimum duration of 7 consecutive days) between June & December for 20% of years; 4) 85,000 ML/d for a total duration of 30 days anytime in the water year (with a minimum duration of 7 consecutive days) for 20% of years; 5) 120,000 ML/d for a total duration of 14 days anytime in the water year (with a minimum duration of 7 consecutive days) for 14% of years; and 6) 150,000 ML/d for 7 consecutive days anytime in the water year for 10% of years
SA Border	1) 20,000 ML/d for 60 consecutive days between August & December for 72% of years; 2) 40,000 ML/d for a total duration of 30 days (with a minimum duration of 7 consecutive days) between June & December for 50% of years; 3) 40,000 ML/d for a total duration of 90 days (with a minimum duration of 7 consecutive days) between June & December for 33% of years; 4) 60,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & December for 25% of years; 5) 80,000 ML/d for a total duration of 30 days (with a minimum duration of 7 consecutive days) anytime in the water year for 17% of years; 6) 100,000 ML/d for a total duration of 21 days anytime in the water year for 13% of years and 7) 125,000 ML/d for a total duration of days anytime in the water year for 10% of years

Table A.2 - Site Specific Flow Indicators for the Murrumbidgee River

Location	Site Specific Flow Indicator
Narrandera	1) 26,850 ML/d for a total duration of 45 days between July & November for 20%; of years; 2) 26,850 ML/d for 5 consecutive days between June & November for 50% of years; 3) 34,650 ML/d for 5 consecutive days between June & November for 35% of years; 4) 44,000 ML/d for 3 consecutive days between June & November for 30% of years; and 5) 63,250 ML/d for 3 consecutive days between June & November for 12% of years.
Maude	1) A total in-flow volume of 175 GL above a minimum flow threshold of 5,000 ML/d during July & September for 70% of years; 2) A total in-flow volume of 270 GL above a minimum flow threshold of 5,000 ML/d during July & September for 60% of years; 3) A total in-flow volume of 400 GL above a minimum flow threshold of 5,000 ML/d during July & October for 55% of years; 4) A total in-flow volume of 800 GL above a minimum flow threshold of 5,000 ML/d during July & October for 40% of years; 5) A total in-flow volume of 1,700 GL above a minimum flow threshold of 5,000 ML/d during July & November for 20% of years; and 6) A total in-flow volume of 2,700 GL above a minimum flow threshold of 5,000 ML/d during May & February for 10% of years.
Balranald	1) 1,100 ML/d for 25 consecutive days between December & May for 58% of years; 2) 4,500 ML/d for 20 consecutive days between October & December for 54% of years; and 3) 3,100 ML/d for 30 consecutive days between October & March for 55% of years.

Table A.3 - Site Specific Flow Indicators for the Goulburn River at Shepparton

Location	Site Specific Flow Indicator
Shepparton	1) Two events annually of 2,500 ML/d for 4 consecutive days between December & April for 36% of years; 2) 5,000 ML/d for 14 consecutive days between October & November for 49% of years; 3) 25,000 ML/d for a median duration of 5 days between June & November for 70% of years and 4) 40,000 ML/d for a median duration of 4 days between June & November for 40% of years

Table A.4 - Site Specific Flow Indicators for Edward Wakool and Lower Darling

Location	Site Specific Flow Indicator
Edward Wakool	1) 1,500 ML/d for a total duration of 180 days (with min duration of 1 day) between Jun & Mar 2) 5,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec 3) 5,000 ML/d for a total duration of 120 days (with min duration of 7 consecutive days) between Jun & Dec 4) 18,000 ML/d for a total duration of 28 days (with min duration of 5 consecutive days) between Jun & Dec 5) 30,000 ML/d for a total duration of 21 days (with min duration of 6 consecutive days) between Jun & Dec
Lower Darling	1) 7,000 ML/d for 10 consecutive days between Jun & May 2) 17,000 ML/d for 18 consecutive days between Jun & May 3) 20,000 ML/d for 30 consecutive days between Jun & May 4) 25,000 ML/d for 45 consecutive days between Jun & May 5) 45,000 ML/d for 2 consecutive days between Jun & May

Table A.5 - Site Specific Flow Indicators for Coorong, Lower Lakes, and Murray Mouth

Location	Site Specific Flow Indicator
CLLAMM	1) Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,500 EC 2) Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,000 EC 3) Barrage flows: Percentage of years that barrage flows are greater than 2,000 GL/yr (measured on a three year rolling average) with a minimum of 650 GL/yr 4) Barrage flows: Percentage of years that barrage flows are greater than 600 GL for any two year period 5) Coorong Salinity: Percentage of days South Lagoon average daily salinity is less than 100 grams per litre. 6) Mouth Openness: Percentage of years mouth open to an average annual depth of 1.0 meters (-1.0 m AHD) or more 7) Mouth Openness: Percentage of years mouth open to an average annual depth of 0.7 metres (-0.7 m AHD) or more

Further information on SFIs can be found in the MDBA's report on the methods and outcomes on the proposed 'Environmentally Sustainable Level of Take' for surface water of the Murray-Darling Basin (MDBA, 2011).

9. APPENDIX B

Proportion of years achieving environmental targets at the Basin Plan SFI sites

Valley	SFI Sites	Flow indicators	Target range	WoD	Benchmark	15-pack	Natural flow cues Y40	Natural flow cues constraints relaxed	
								Y50	Y65
River Murray	Barmah-Millewa Forest	12,500 ML/d for 70 days	70-80%	87%	78%	75%	77%	76%	76%
		16,000 ML/d for 98 days	40-50%	66%	51%	49%	56%	59%	55%
		25,000 ML/d for 42 days	40-50%	66%	46%	46%	46%	52%	46%
		35,000 ML/d for 30 days	33-40%	53%	35%	34%	36%	36%	34%
		50,000 ML/d for 21 days	25-30%	39%	17%	18%	17%	17%	20%
		60,000 ML/d for 14 days	20-25%	33%	13%	15%	13%	12%	14%
		15,000 ML/d for 150 days	30%	44%	36%	33%	36%	33%	35%
	Gunbower-Koondrook-	16,000 ML/d for 90 days	70-80%	86%	68%	62%	61%	64%	61%
		20,000 ML/d for 60 days	60-70%	87%	67%	60%	61%	61%	61%
		30,000 ML/d for 60 days	33-50%	60%	38%	36%	36%	37%	37%
		40,000 ML/d for 60 days	25-33%	39%	21%	23%	23%	24%	23%
		20,000 ML/d for 150 days	30%	43%	28%	25%	26%	25%	25%
	Hattah-Kulkyne Lakes	40,000 ML/d for 60 days	40-50%	67%	45%	44%	46%	46%	45%
		50,000 ML/d for 60 days	30-40%	47%	30%	31%	36%	36%	37%
		70,000 ML/d for 42 days	20-33%	38%	19%	18%	22%	24%	24%
		85,000 ML/d for 30 days	20-30%	33%	11%	12%	13%	14%	16%
		120,000 ML/d for 14 days	14-20%	23%	9%	9%	8%	8%	8%
		150,000 ML/d for 7 days	10-13%	17%	6%	7%	7%	6%	6%
	Riverland Chowilla Floodplain	20,000 ML/d for 60 days	72-80%	89%	71%	71%	75%	74%	73%
		40,000 ML/d for 30 days	50-70%	80%	57%	54%	55%	54%	54%
		40,000 ML/d for 90 days	33-50%	58%	39%	37%	41%	42%	41%
		60,000 ML/d for 60 days	25-33%	41%	25%	25%	29%	28%	26%
		80,000 ML/d for 30 days	17-25%	34%	12%	12%	13%	12%	13%
		100,000 ML/d for 21 days	13-17%	19%	8%	8%	7%	7%	7%
		125,000 ML/d for 7 days	10-13%	17%	5%	5%	6%	5%	5%
	Edward Wakool River System	1,500 ML/d for 180 days	99-100%	75%	95%	96%	96%	96%	97%
		5,000 ML/d for 60 days	60-70%	82%	65%	60%	64%	65%	67%
		5,000 ML/d for 120 days	35-40%	52%	34%	38%	42%	39%	36%
		18,000 ML/d for 28 days	25-30%	39%	17%	19%	17%	17%	18%
		30,000 ML/d for 21 days	17-20%	28%	12%	15%	13%	12%	12%
Lower Darling	Lower Darling Floodplain	7,000 ML/d for 10 days	70-90%	95%	56%	60%	67%	64%	65%
		17,000 ML/d for 18 days	20-40%	47%	22%	19%	17%	27%	25%
		20,000 ML/d for 30 days	14-20%	27%	11%	15%	15%	23%	19%
		25,000 ML/d for 45 days	8-10%	14%	8%	9%	9%	9%	9%
		45,000 ML/d for 2 days	7-10%	10%	7%	8%	8%	8%	8%
Lower Lakes	Coorong Lower lakes and Murray Mouth	% days Lake Alexandrina salinity < 1,500 EC	100%		100%	100%	100%	100%	100%
		% days Lake Alexandrina salinity < 1,000 EC	95%		100%	98%	95%	97%	95%
		Barrage flows: % years > 650 GL/y (> 2,000 GL /3 yrs)	95%		98%	96%	93%	88%	94%
		Barrage flows: % years > 600 GL/ 2 yrs)	100%		100%	100%	100%	100%	99%
		South Lagoon Salinity: % days < 100 g/l	96%		100%	100%	99%	99%	99%
		Mouth Openness: % years average annual depth < = -1.0 m AHD	90%		95%	92%	90%	91%	91%
		Mouth Openness: % years average annual depth < = -0.7 m AHD	95%		97%	96%	96%	93%	96%

Murrumbidgee	Mid - Bidgee	26,850 ML/d for 45 days	20 - 25 %	28%	11%	11%	17%	21%	21%
		26,850 ML/d for 5 days	50 - 60 %	67%	61%	58%	58%	59%	59%
		34,650 ML/d for 5 days	35 - 40 %	57%	46%	41%	42%	41%	41%
		44,000 ML/d for 3 days	30 - 35 %	44%	28%	28%	28%	26%	26%
		63,250 ML/d for 3 days	11 - 15 %	21%	11%	10%	10%	10%	10%
	Low - Bidgee	5,000 ML/d for 92 days (Total Volume 175,000 ML)	70 - 75 %	94%	95%	88%	86%	88%	88%
		5,000 ML/d for 92 days (Total Volume 270,000 ML)	60 - 70 %	92%	88%	79%	82%	84%	84%
		5,000 ML/d for 123 days (Total Volume 400,000 ML)	55 - 60 %	92%	82%	75%	78%	77%	77%
		5,000 ML/d for 123 days (Total Volume 800,000 ML)	40 - 50 %	78%	60%	54%	56%	55%	55%
		5,000 ML/d for 153 days (Total Volume 1,700,000 ML)	20 - 25 %	56%	26%	24%	25%	30%	30%
		5,000 ML/d for 303 days (Total Volume 2,700,000 ML)	10 - 15 %	44%	18%	15%	17%	18%	18%
	Freshes	1,100 ML/d for 25 days	58 - 77 %	96%	66%	66%	67%	68%	68%
		4,500 ML/d for 20 days	54 - 72 %	90%	71%	71%	71%	71%	71%
		3,100 ML/d for 30 days	55 - 73 %	91%	70%	68%	71%	70%	70%
Goulburn	Lower Goulburn	2,500 ML/d for 4 days	36 - 48 %	60%	54%	54%	54%	54%	54%
		5,000 ML/d for 14 days	49 - 66 %	82%	55%	55%	55%	55%	55%
		25,000 ML/d for 5 days	70 - 80 %	90%	82%	78%	78%	78%	78%
		40,000 ML/d for 4 days	40 - 60 %	72%	58%	54%	54%	54%	54%

(dark green)	Low uncertainty or better frequency range
(light green)	Low to high uncertainty frequency range
(yellow)	Below high uncertainty frequency; improvement relative to baseline
(grey)	No environmental demands specified in the model

10. APPENDIX C

Just to provide a flavor of the sort of flow regime the Natural Flow Cues method with constraints relaxtion would result compared to the 15-pack, example hydrographs include only two scenarios and flows at two locations in the River Murray system.

Figure C.1 – Example hydrograph: 1906

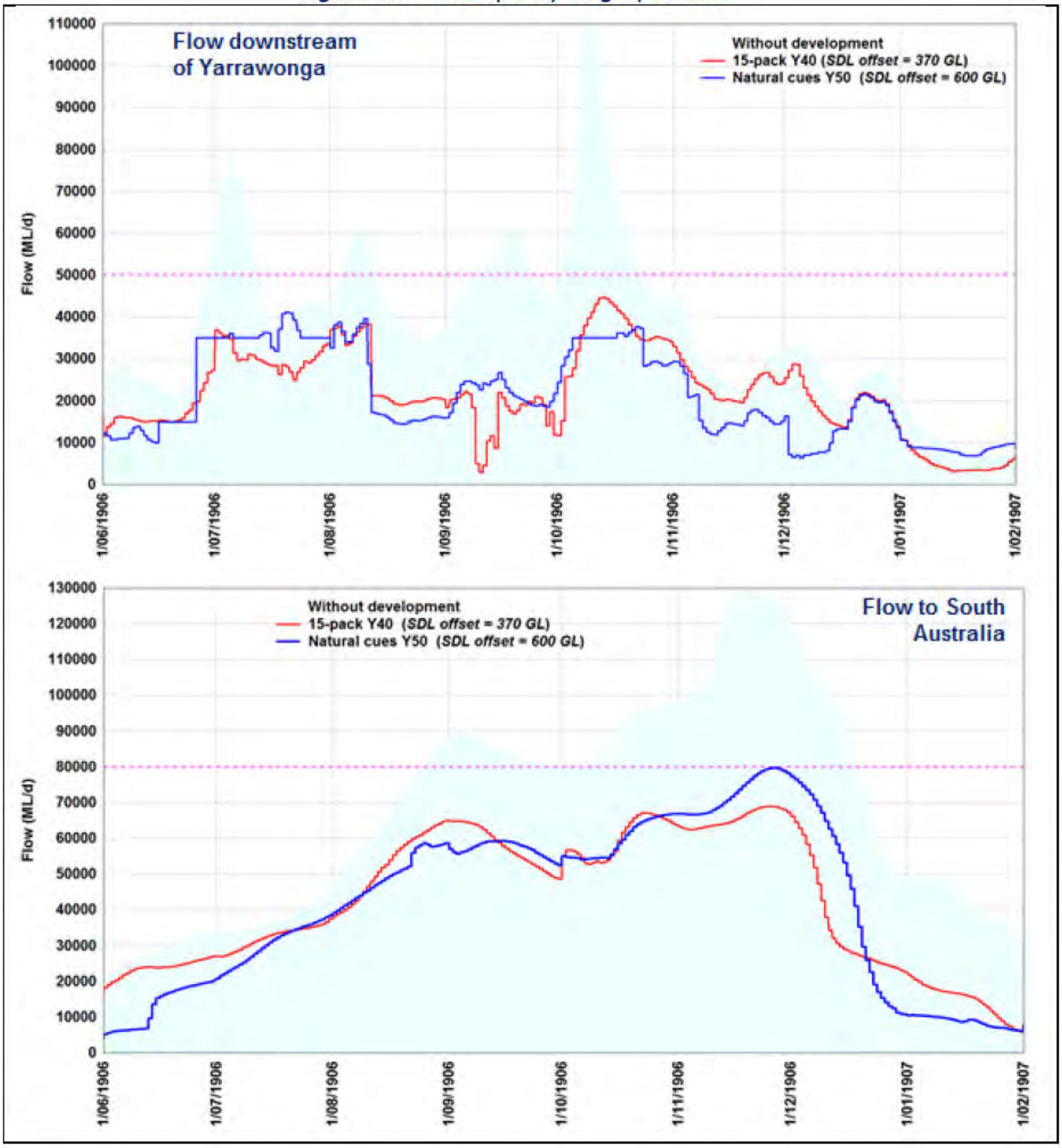

Figure C.2 – Example hydrograph: 1916

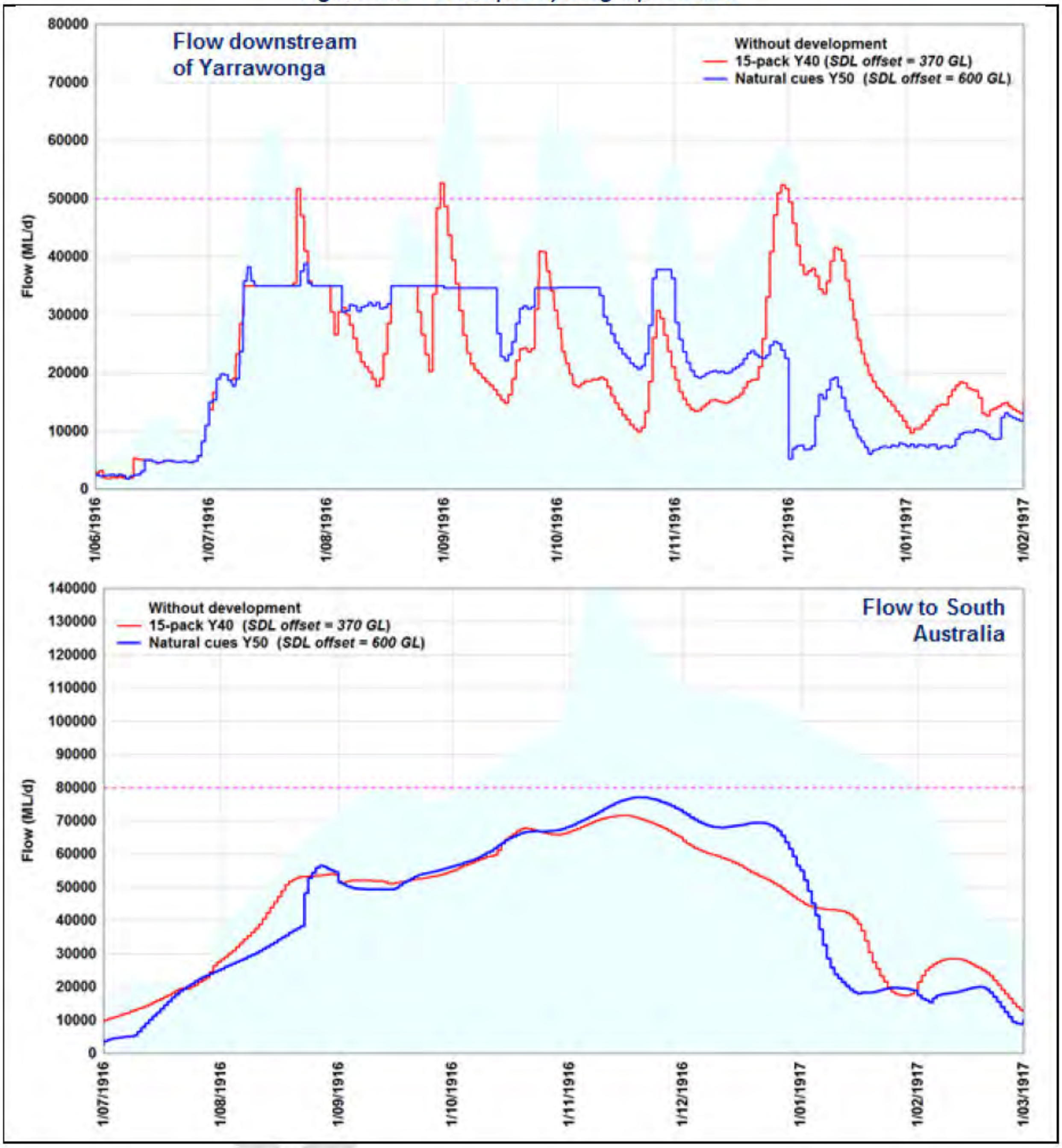

Figure C.3 – Example hydrograph: 1921

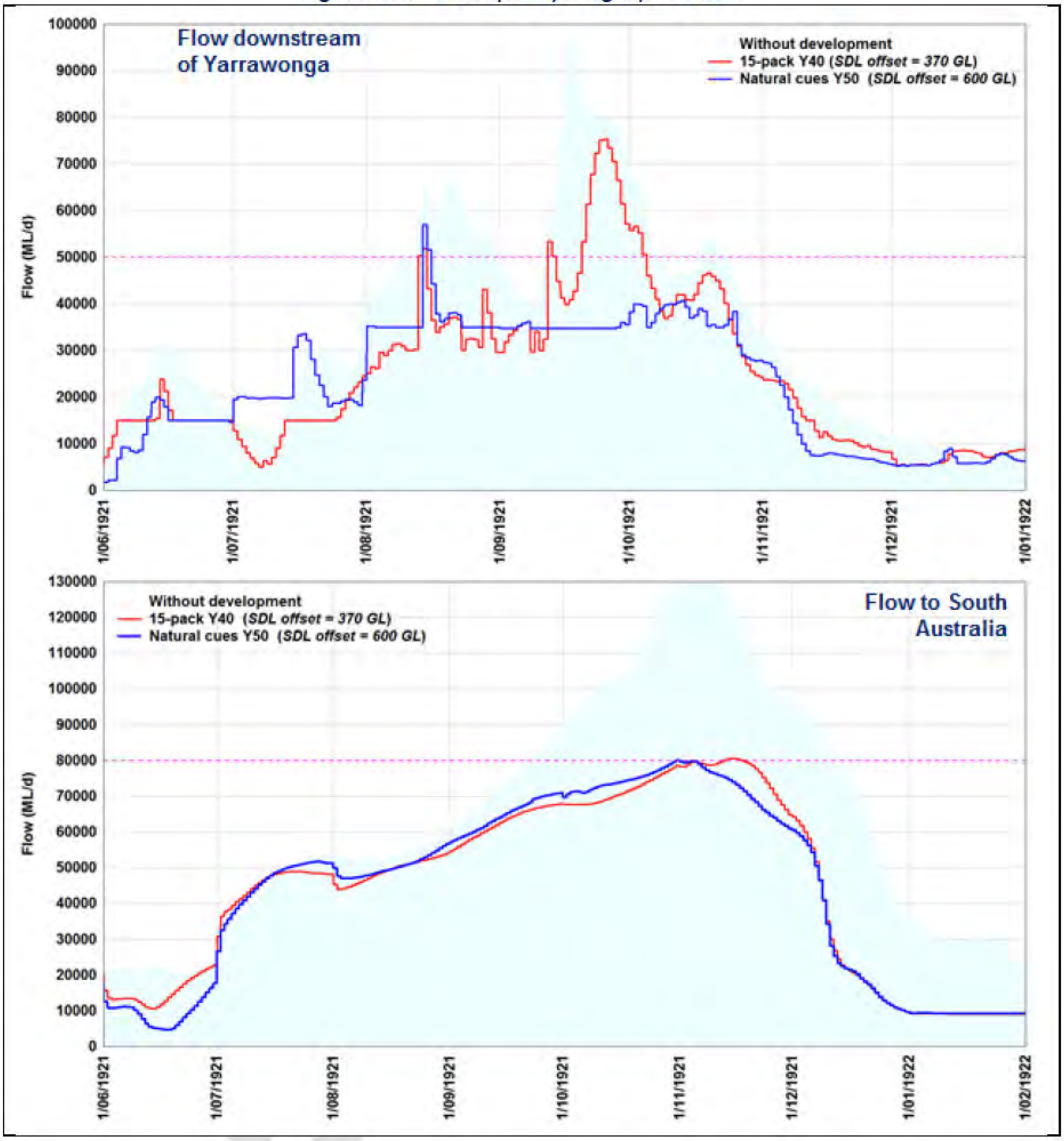

Figure C.4 – Example hydrograph: 1931

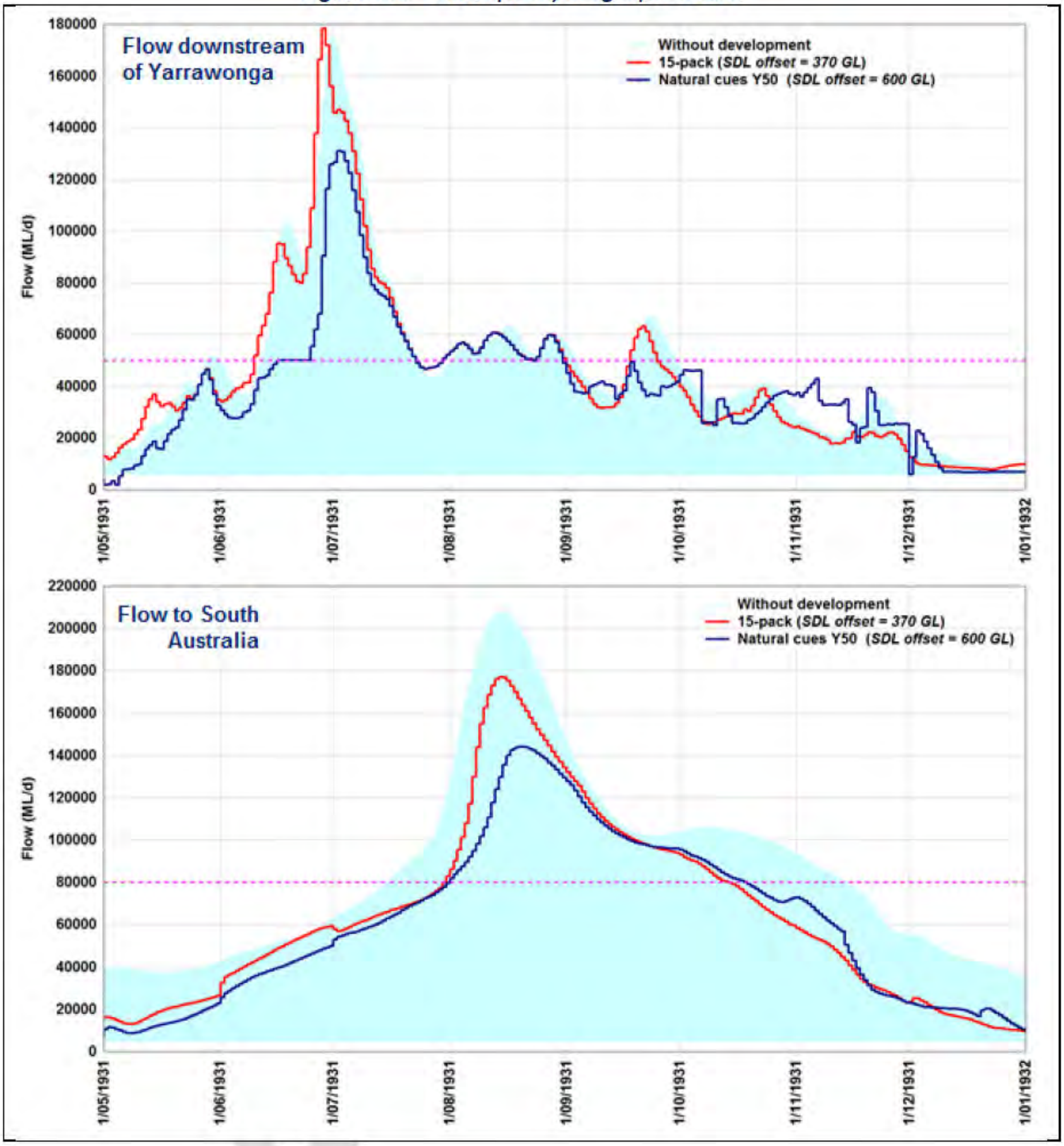

Figure C.5 – Example hydrograph: 1939

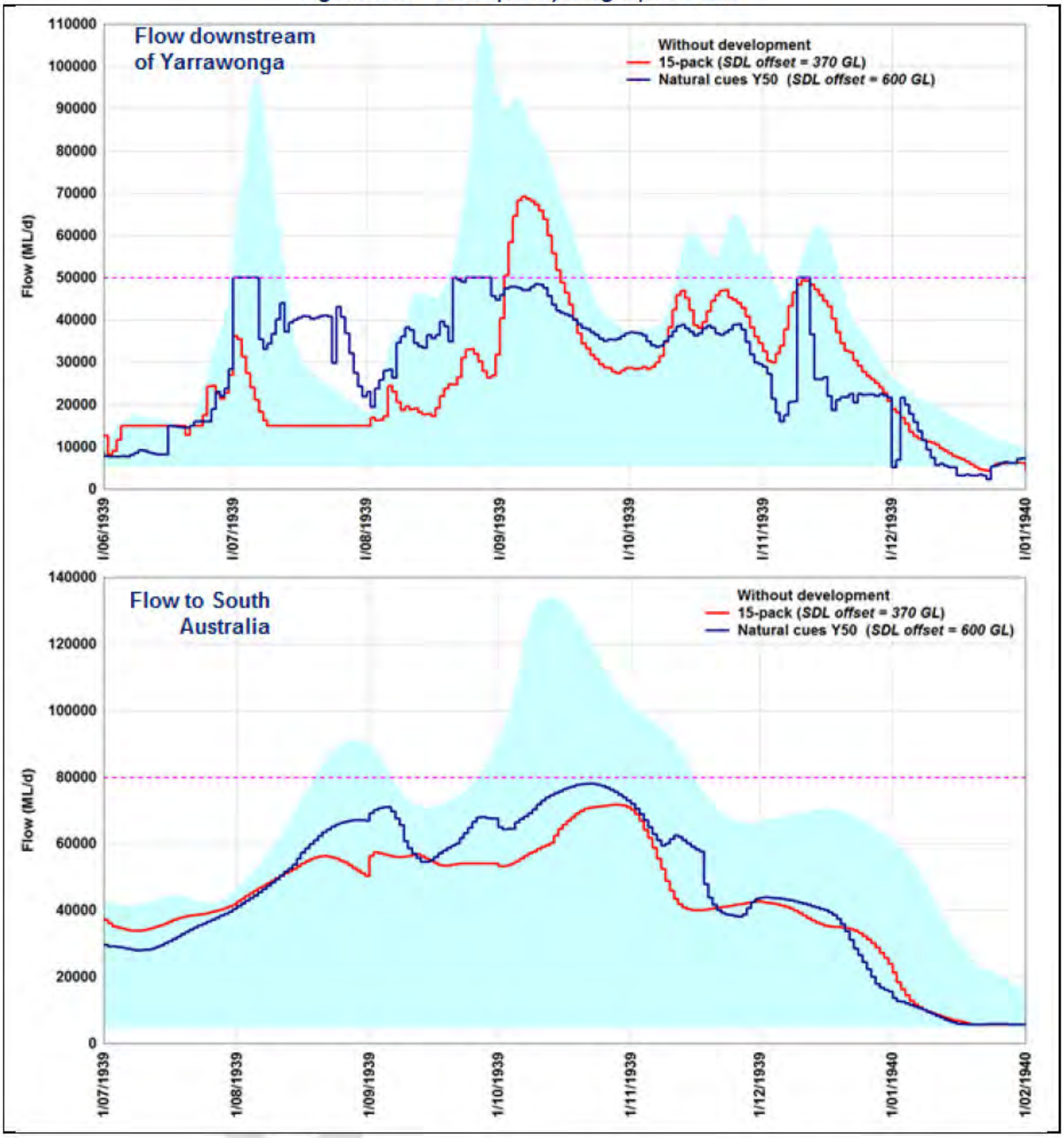

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Figure C.6 – Example hydrograph: 1958

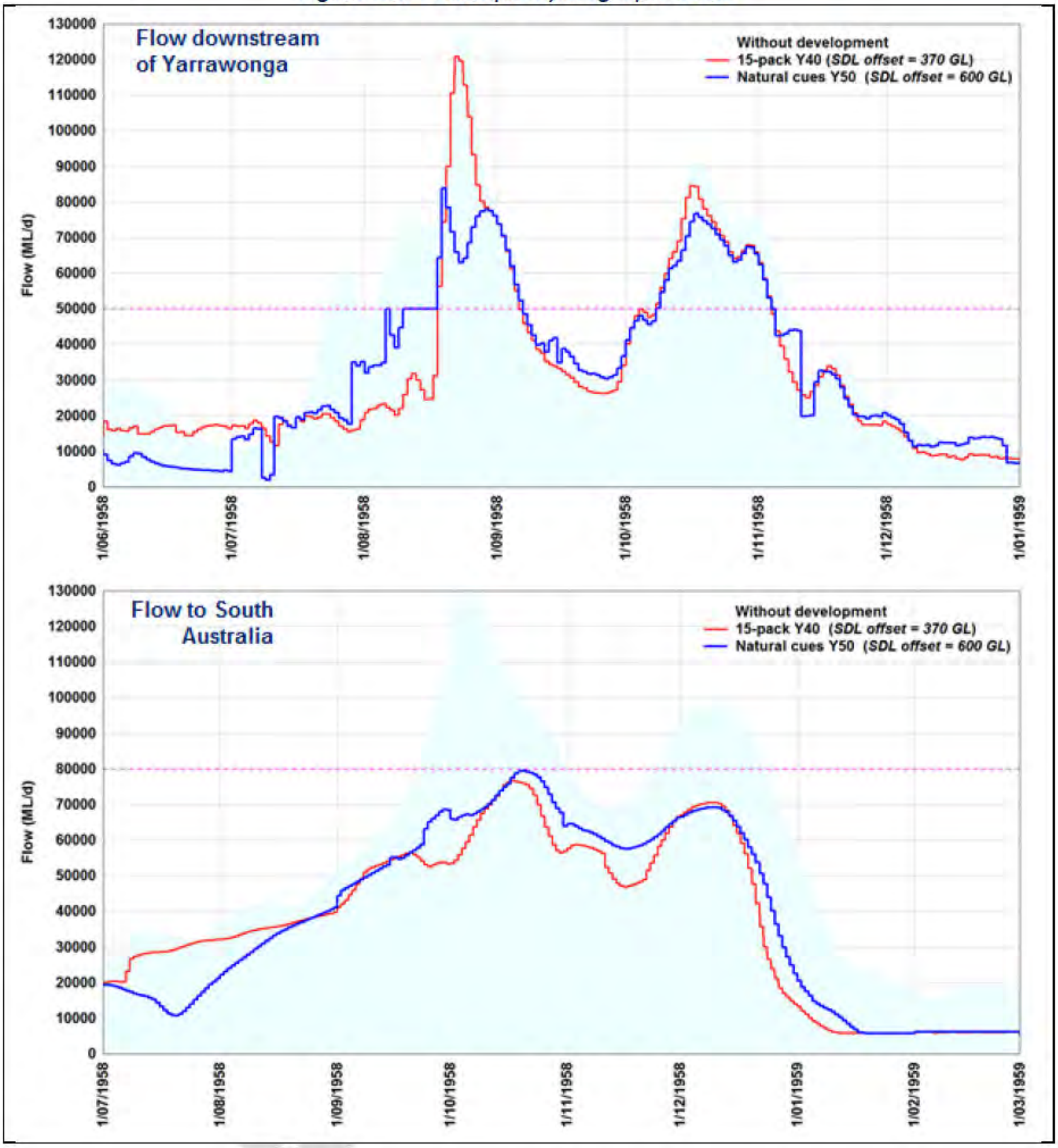


Figure C.7 – Example hydrograph: 1960

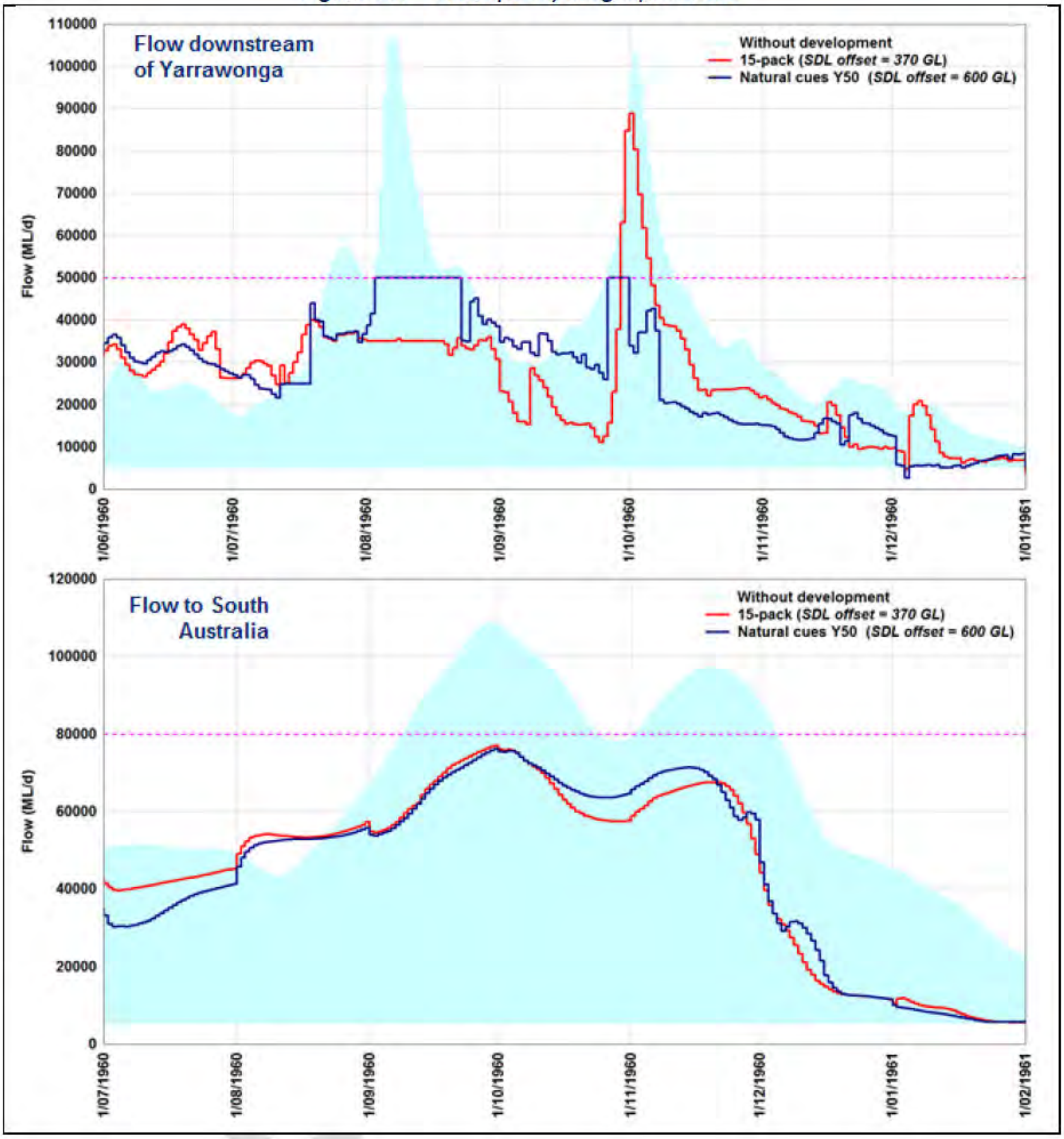


Figure C.8 – Example hydrograph: 1964

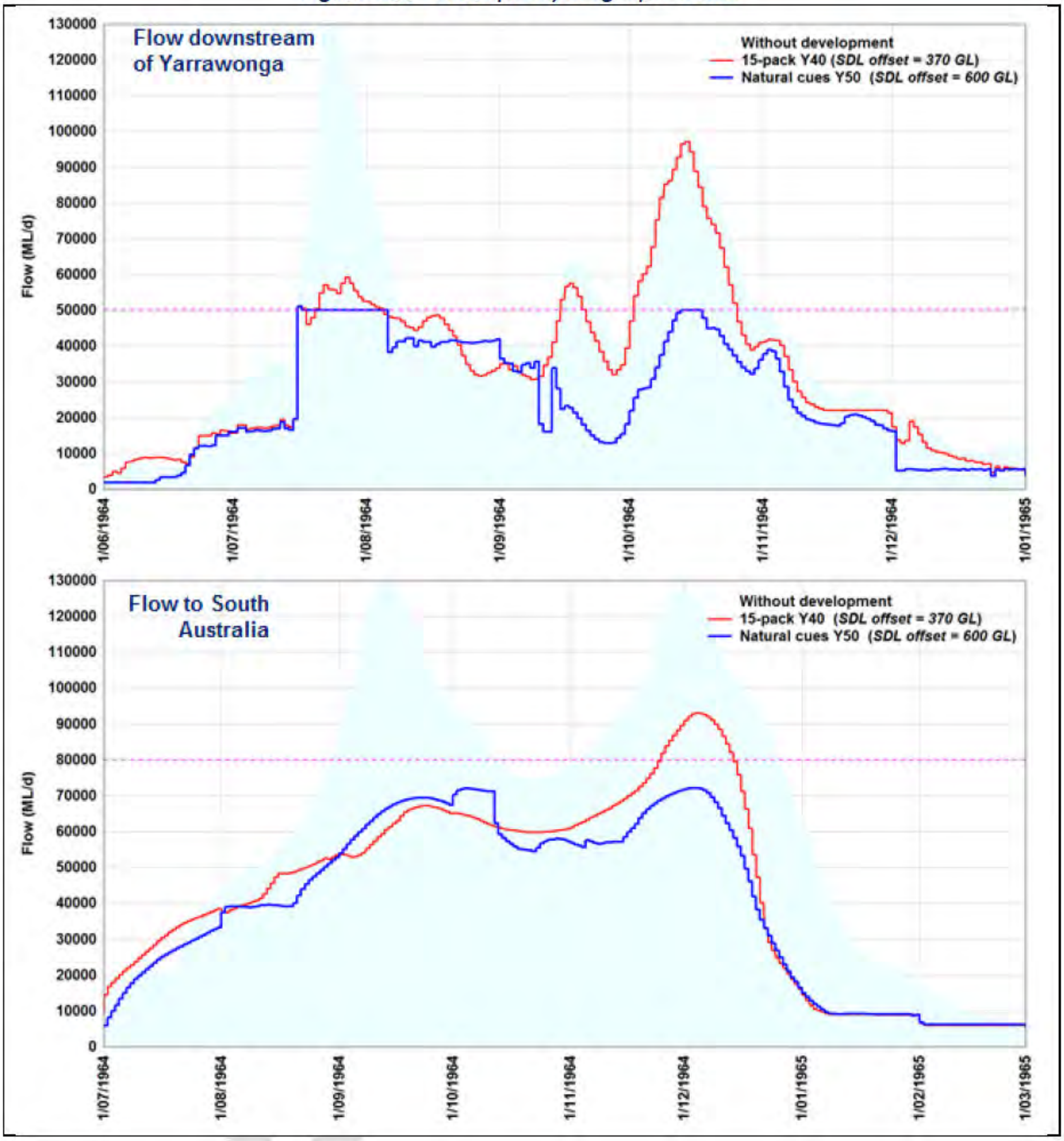


Figure C.9 – Example hydrograph: 1973

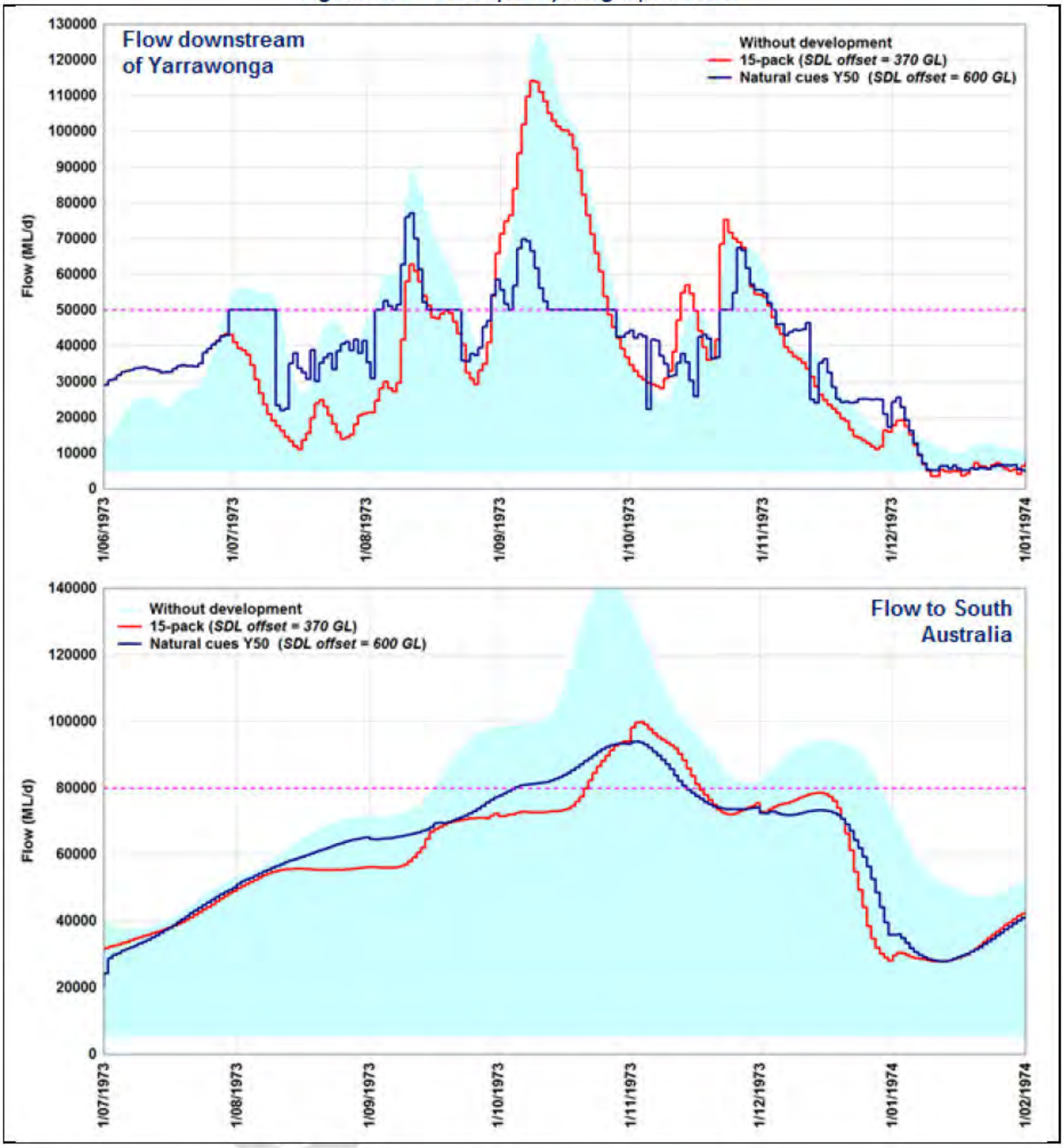


Figure C.10 – Example hydrograph: 1978

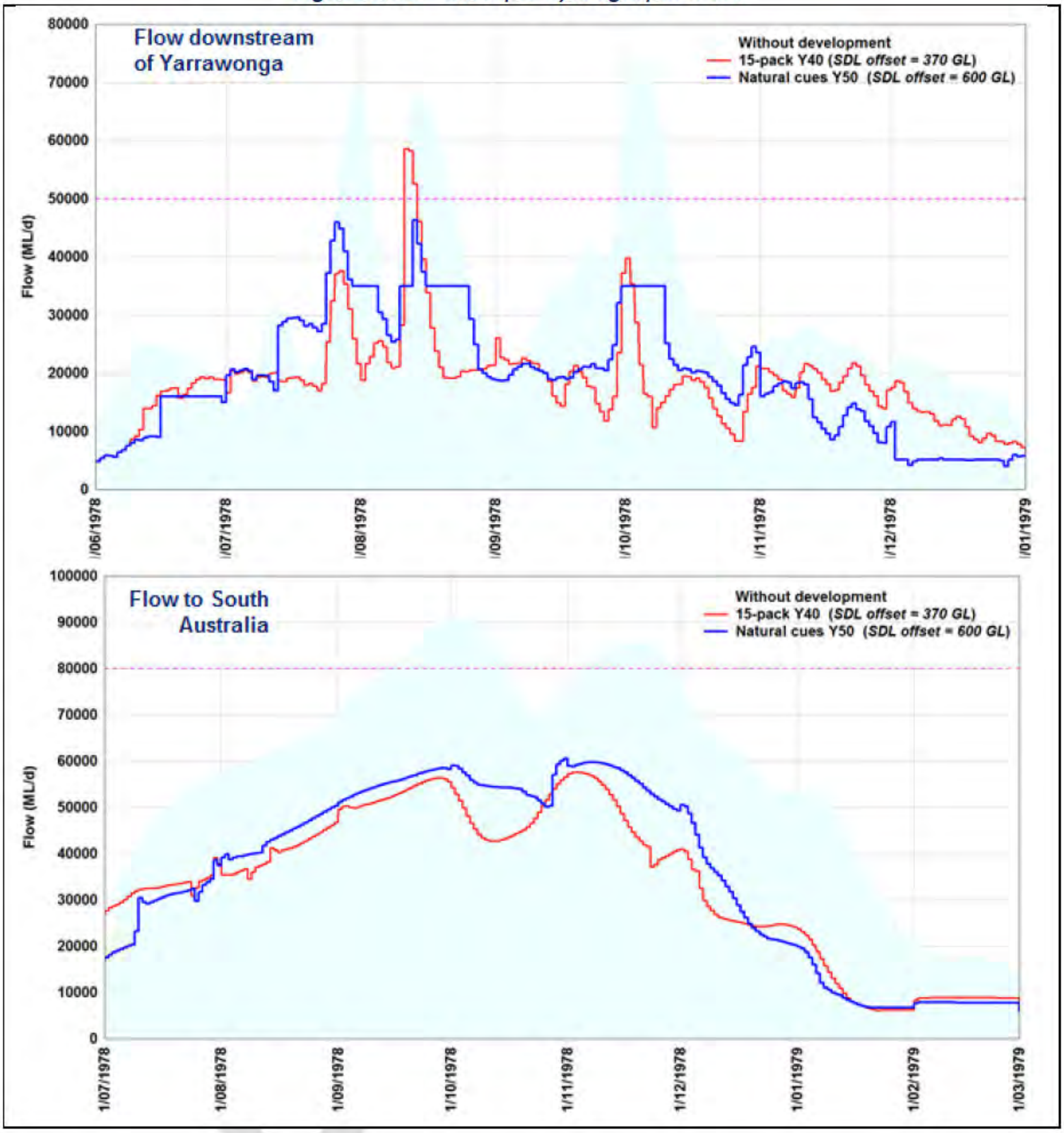
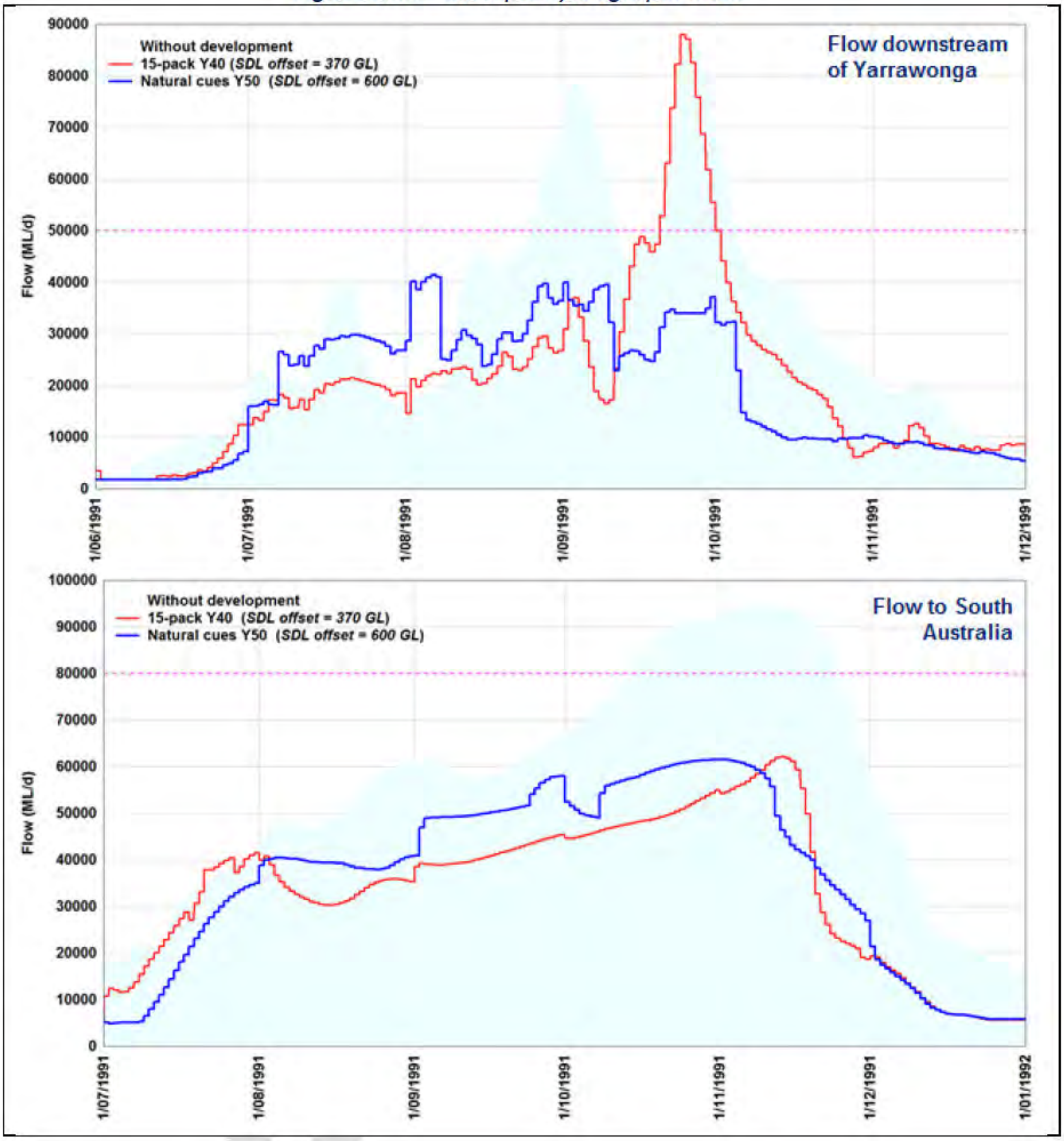


Figure C.11 – Example hydrograph: 1991



Attachment C

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Environmental water delivery following natural flow cues and relaxing constraints in the Southern Basin:

Part 2 methodology applied to Goulburn system

[redacted]

Water Resources, River Management Division

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Table of Contents

1. INTRODUCTION

This is a part 2 of the earlier natural flow cues modelling study (MDBA, 2016) that has been progressed to include Goulburn system in to the natural flow cues framework. This report describes how natural flow cues method for Goulburn system was developed and apllied to 19-pack SDL adjustment mechanism. Constraints in Goulburn are assumed same as the benchmark while that in other valleys are relaxed as shown in Table 1.

Hydrology conditions are assessed as wet or dry using historical inflows to Eildon storage. Cumulative inflow was used as a trigger for environmental watering events in moderately dry to moderately wet years. In extremely wet or dry years, environmental flows are not targeted with natural flow cues.

During the wet years, relatively more water is available so higher peak environmental flow is targeted to more effectively utilise the channel capacity available. Cumulative without development flow at Shepparton is used as a guide to determine peak flow rate targets at the site-specific flow indicators site.

The other changes made in the natural hydro cues modelling with the inclusion of Goulburn system include:

1. *Reduction of model foresight from six month to one*: Three monthly rolling flows (last two months plus current month) are used to assess wet / dry hydrology conditions. Earlier six-monthly total winter-spring flows were used (MDBA, 2016).

2. *Additional environmental demand at SA border targeting CLLMM outcomes*: Modelled environmental outcomes along the length of the river Murray, including the Lower Lakes depend on the environmental demand (peak, period and frequency) placed at the SFIs sites (Yarrawonga, Torrumbarry, Euston and SA border). The pattern of demand at SA border is particularly important for Coorong, Lower Lakes and Murray Mouth (CLLMM) outcomes associated with a range of flows in the lower Murray. Frequency of Basin Plan target flows at SA border for Chowilla SFI site (20,000 – 80,000 ML/d) ranges between ~20% and ~80% of the years. As per the target, the model attempts to provide environmental flow to SA only for a maximum of 80% of the years. This means the driest 20% of years are left out when natural hydrology cues was initially applied. These dry years require some environmental flow to achieve lower Lakes outcomes for 95% to 100% of years as per the Basin Plan. With this context, additional environmental demand is included in the recent modelling for ~15% of the dry years. This is a low flow demand and not limited to any season.

Table 1 – Constraints assumed in the Southern Connected System modelling (ML/d)

	Benchmark	19-pack	Natural flow cues Y50
SDL offset (GL/y)		**~ 400**	**~ 600**
Murrumbidgee			
Gundagai	30,000	30,000	33,000
Wagga Wagga	~ 37,000	~ 37,000	~ 40,000
Narrandera ^	44,000	44,000	44,000
Maude ^	20,000	20,000	20,000
Balranald	9,000	9,000	12,000
Goulburn			
Eildon	12,000	12,000	12,000
Seymour	12,000	12,000	12,000
Shepparton ^	40,000	40,000	40,000
River Murray			
Doctors Point	25,000	25,000	40,000
Yarrawonga	40,000	40,000	50,000
Torrumbarry ^	40,000	40,000	40,000
Euston ^	85,000	85,000	85,000
SA border ^	80,000	80,000	80,000
Lower Darling			
Menindee Outlet	9,300	14,000	14,000
Weir 32	9,300	14,000	14,000
Anabranch offtake	9,300	14,000	14,000

^ Maximum limit applied to environmental flow demand

2. Goulburn System: application of natural hydrology cues

Goulburn System, where flows exhibit a very high level of natural variability and at times can be very flashy (particularly in winter), is modelled using a benchmark version of REALM model at a monthly time step. Given the monthly time step and flashy nature of the system, calculation of environmental flow demand for Goulburn is slightly different to that for the Murray or Murrumbidgee as described in MDBA (2016). However the method is conceptually the same.

Probability and median ratio of natural inflows to Eildon Dam is analysed to assess hydrologic conditions of Goulburn system as wet, average or dry. Median ratio analysis is particularly useful to identify flashy extreme wet events.

The Upper limit for environmental flow, which is limited to the maximum of 40,000 ML/d (Table 1), is derived from probability of occurrence of without development flows at Shepparton. Median ratio of flows at Shepparton is also used, considering the flashy nature of the system, to identify extreme events. Daily incremental estimates of environmental flow demand are calculated as a difference between the derived daily timeseries of modelled baseline and without development flows as shown in equation 1 below. This provides an estimate of how much can be potentially provided as environmental flows on top of the baseline flows, and is constrainted by channel capacity and the maximum environmental flow limit. Note daily demand pattern for Murray and Murrumbidgee is calculated using coefficient of flow efficiency, which is not applicalble for monthly time-step Goulburn model.

The daily incremental estimates are aggregated to monthly estimates. Sum of these monthly estimates and the monthly baseline flows are used as monthly environmental demand. After the model is simulated, the monthly results are disaggregated to daily flows as a post-processing step outside of the REALM model using a disaggregation scheme based on daily pattern derived from the daily baseline flows and the daily environmental demand increments.

In summary, the steps involved in modelling Goulburn system with natural flow cues are:

(i) determine daily environmental flow increments that can be added to the daily baseline flow (if hydrologically plausible with the given constraints, E_{max} and without development flow),
(ii) agreegate daily increments to get monthly estimates for each year in the modelling period, and
(iii) add monthly estimates to monthly baseline flows. This sum total is then used as the monthly environmental flow demand that REALM model uses to simulate flows at the monthly time step.
(iv) after the model simulation is completed, daily environmental flow increments are added to the daily baseline flows to create a daily pattern that is used to convert the modelled monthly flows (ML/m) to the daily flows (ML/d).

2.1. Assessment of hydrologic condition to identify wet and dry periods

Three-monthly rolling inflows to Eildon Dam are calculated for each month as shown in Figure 1. The three months include last two months and the current month so the model has a foresight of a month. Based on this analysis, the months in the winter-spring season are identified as wet, average or dry. The environmental watering event is triggered in those months that are neither extremely wet nor extremely dry.

2.2. Environmental flow limit

In the Goulburn system, there is only one SFIs site, ie Shepparton. The environmental flow limit is derived for each month from probability distribution of without development flows at the site and is limited to the system constraint. In this case, the constraint assumed at Shepparton is 40,000 ML/d as provided in Table 1. The limit for peak environmental flows is relatively higher for the wet years and lower for the dry years. These limits and the steppings in between as shown in Figure 2 are initially set based on the SFIs specified in the Basin Plan (Appendix A).

2.3. Estimation of Environmental Flow Demand

Environmental flow demand at Shepparton was calculated using equation 1.

$$Q_{Em} = Q_{Bm} + \sum_{i=1}^{i=31}\{min(E_{max}\ ,\ Q_W)_i - Q_{Bi}\} \quad (1)$$

where,

Q_{Em} = *monthly environmental flow demand (ML/m)*

Q_{Bm} = *monthly baseline flow (ML/m)*

$Q_{Bi} = daily\ baseline\ flow\ (ML/d)$
$E_{max} = Environmental\ flow\ limit\ (ML/d)$
$Q_W = daily\ without\ development\ flow\ (ML/d)$

The monthly environmental increments are added to the monthly baseline flows to calculate the monthly environmental flow demand, which is disaggregated to daily environmental flow estimates such that the daily values remain within the environmental flow limit (E_{max}) as shown in Figure 2.

Figure 1 – Probability and median ratio of inflows to Eildon Dam

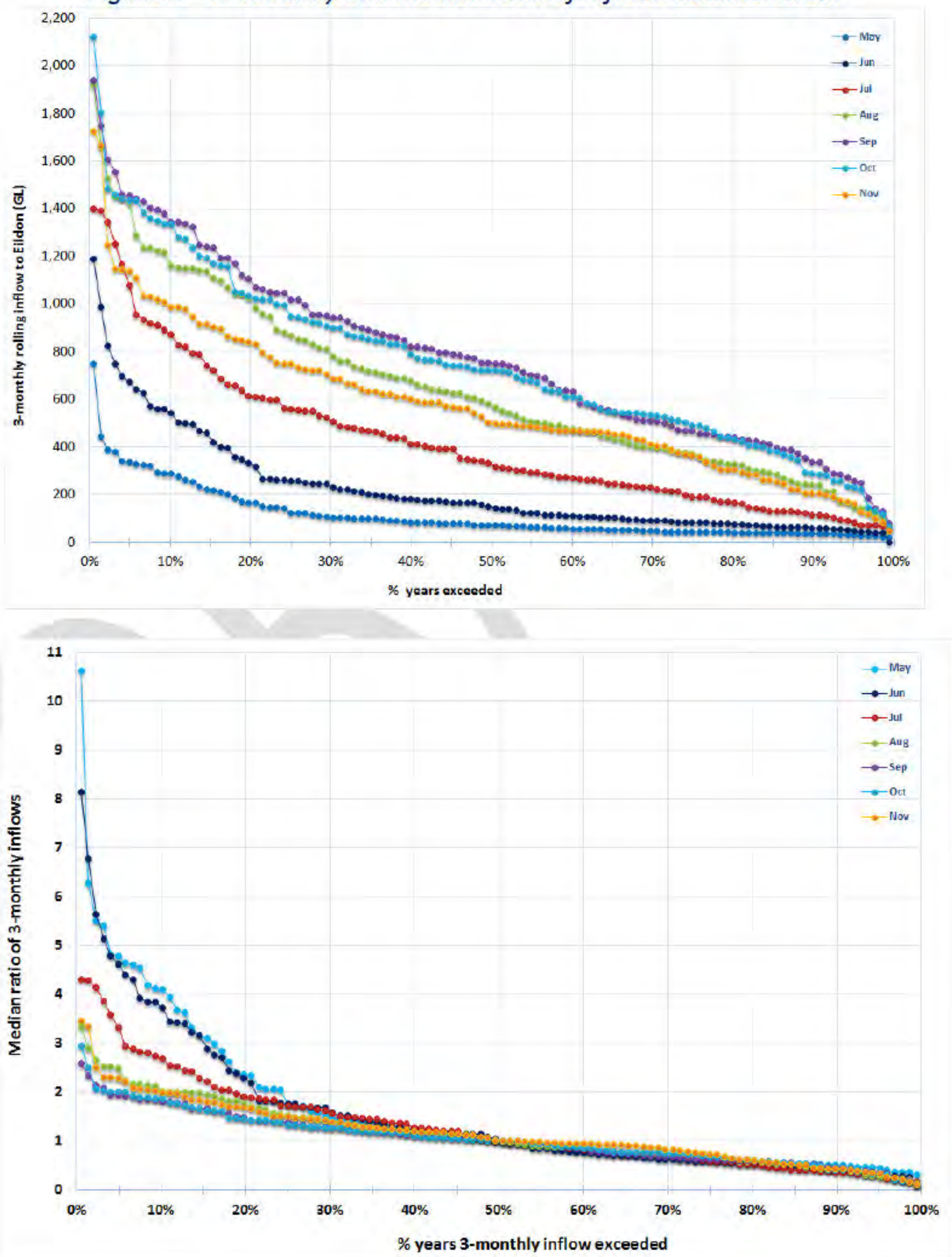
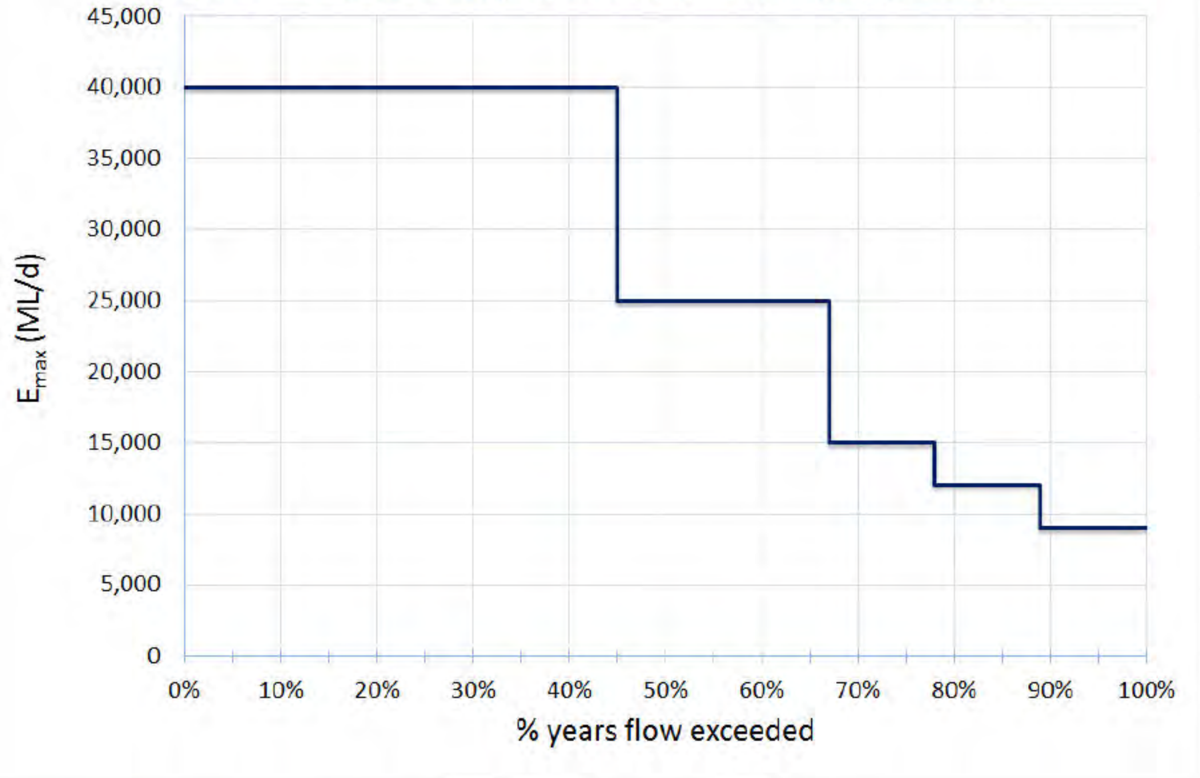


Figure 2 – Environmental flow limit curve: Shepparton, Goulburn



2.4. Checking model results against the SDL targets

The periods identified as the wettest (~10% of years) and driest (~20% of years) are not targeted with 'natural hydrology cues' environmental flows. That is, only about 70% of years in moderately dry to moderately wet period are targeted. Environmental flow is predominantly sought in winter-spring season (July - November). Note an exception that a minimum translucency flow of 2,500 ML/d is provided in summer-autumn (ie between December and April) where feasible, as per the environmental water requirement at Shepparton SFIs site specified under the Basin Plan.

Long-tem average annual diversions for the Goulburn valley are assessed to confirm total consumptive use for the valley matches the SDL targets with the specified SDL offsets provided in Table 2. If the average diversion is different from the SDL targets with the specified SDL offsets, the environmental flow estimates are adjusted as required and the process is repeated until the average diversions similar to the SDL targets are achieved.

Table 2 – Potential SDL offsets in the Southern Basin based on 19-pack model (GL/y)

Valley	Benchmark Water recovery (19-pack)	Potential SDL adjustment	
		19-pack	Natural flow cues Y50
Murray system	1,162	197	306
Lower Darling	15	2	2
Murrumbidgee	592	106	155
Goulburn	519	99	136
Southern Basin	**2,290**	**404**	**599**

3. RESULTS

A summary of an analysis of preliminary results is provided below in Tables 3 to 6 and Figures 3 to 5. Details on reach-by-reach ecological scores and frequency of Basin Plan SFIs in the southern basin are provided in **Appendix B.**

Table 3 – Average ecological scores (19-pack scenarios)

Valley	Benchmark ^	Change from benchmark	
		19-pack *(SDL offset ~400 GL)*	EEWD Y50 *(SDL offset ~600 GL)*
Murray and Lower Darling	4,235	+ 168	+ 158
Murrumbidgee	5,651	- 114	+ 16
Goulburn	8,176	- 152	+ 210
Southern Basin	**4,988**	**+ 70**	**+ 132**

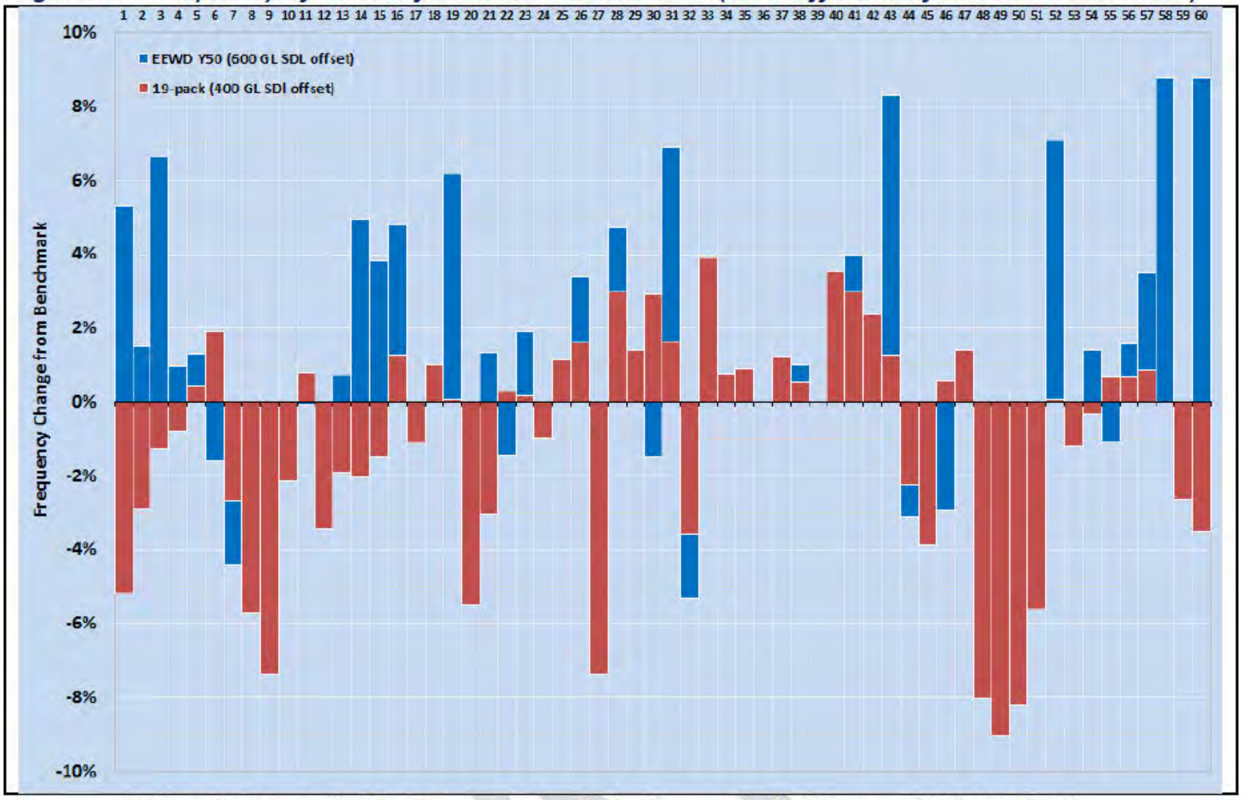
^ the statistics for the 19-pack benchmark may have slightly changed from the previous 15-pack due to new version of MSM-Bigmod models for Murray and Lower darling, and IQQM model for Murrumbidgee.

Table 4 – Number of SFIs (out of 60) achieving Basin Plan targets (19-pack scenarios)

Valley	Benchmark ^	Change from benchmark	
		19-pack *(SDL offset ~400 GL)*	EEWD Y50 *(SDL offset ~600 GL)*
Murray and Lower Darling (*42 SFIs*)			
Low uncertainty targets	1	- 1	+ 2
High uncertainty targets	21	+ 1	0
Murrumbidgee (*14 SFIs*)			
Low uncertainty targets	10	- 1	- 2
High uncertainty targets	2	+ 2	+ 2
Goulburn (*4 SFIs*)			
Low uncertainty targets	2	- 1	+ 1
High uncertainty targets	2	+ 1	- 1
Southern Basin (*60 SFIs*)			
Low uncertainty targets	13	- 3	+ 1
High uncertainty targets	25	+ 4	+ 1
Overall total	***38***	***+ 1***	***+ 2***

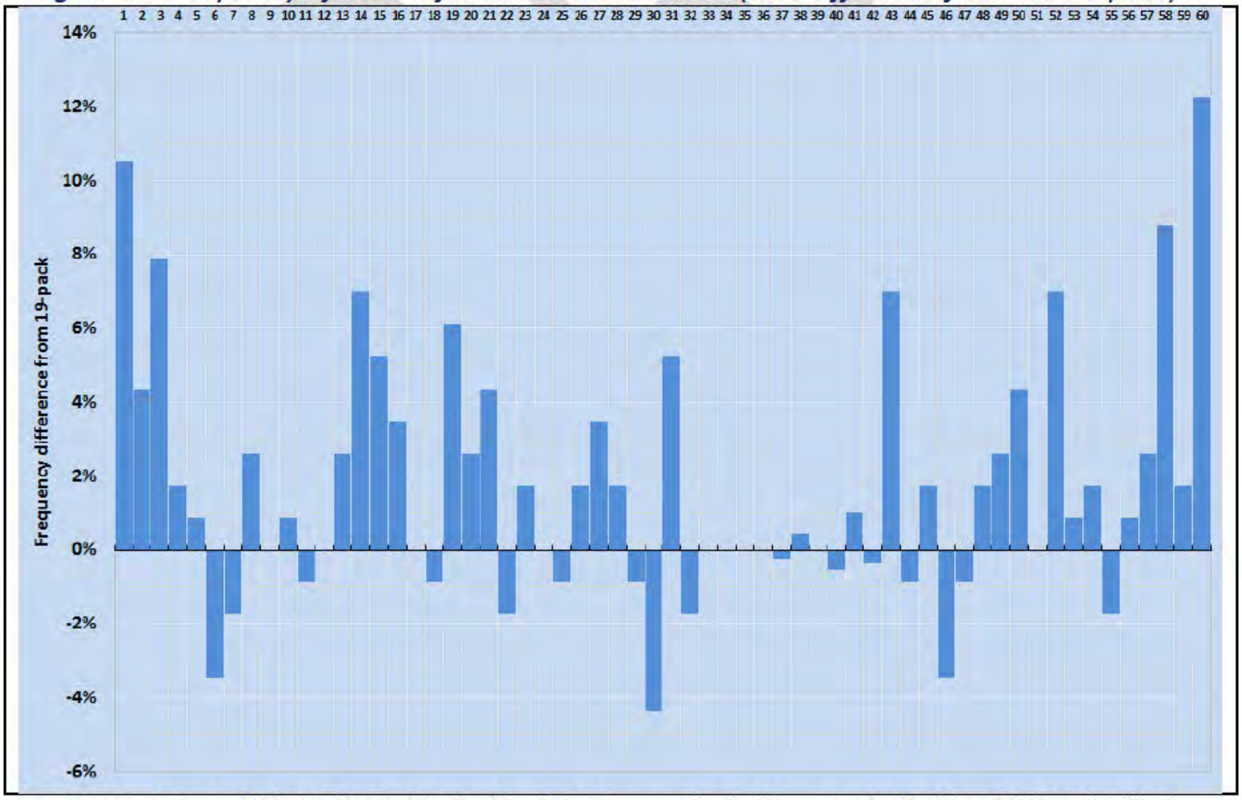
^ the statistics for the 19-pack benchmark may have slightly changed from the previous 15-pack due to new version of MSM-Bigmod models for Murray and Lower darling, and IQQM model for Murrumbidgee.

Figure 3 – Frequency of 60 SFIs for EEWD Y50 scenario (as a difference from the benchmark)



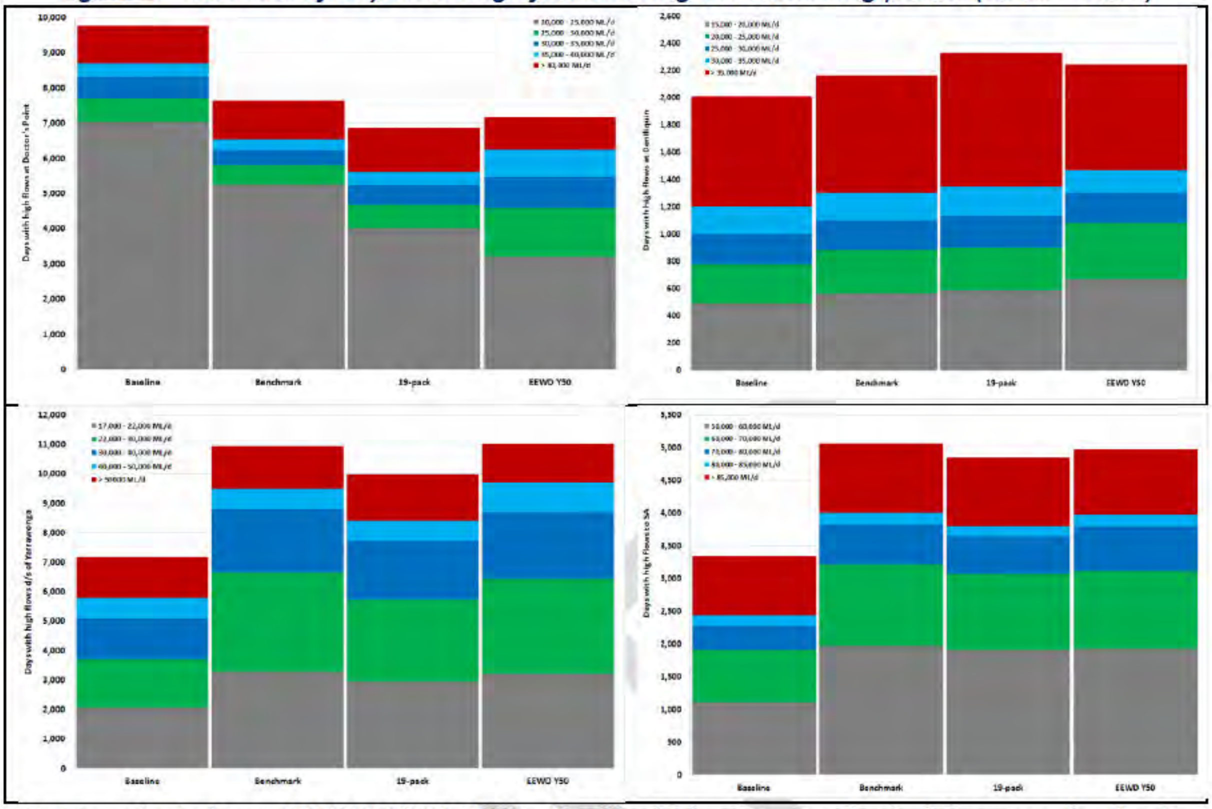
Positive value indicates the SDL offset scenarios have higher frequency for the SFI compared to the benchmark.

Figure 4 – Frequency of 60 SFIs for EEWD Y50 scenario (as a difference from the 19-pack)



Positive value indicates EEWD Y50 (600 GL SDL offset) has higher frequency for the SFI compared to the 15-pack (400 GL SDL offset).

Figure 5 – Number of days with high flows during the modelling period (1895 – 2009)



Positive value indicates EEWD Y50 (600 GL SDL offset) has higher frequency for the SFI compared to the 15-pack (400 GL SDL offset).

Table 5 – Number of days with high flows during the modelling period (1895 – 2009)

SFI sites		Benchmark	Change from benchmark	
			19-pack (SDL offset ~400 GL)	EEWD Y50 (SDL offset ~600 GL)
Doctor's Point flow (ML/d)				
	20,000 - 25,000	5,261	- 1,235	- 2,054
	25,000 - 30,000	543	+ 100	+ 860
	30,000 - 40,000	723	+ 223	+ 916
	> 40,000	1,099	+ 159	- 171
Flow d/s of Yarrawonga (ML/d)				
	17,000 - 30,000	3,715	- 891	- 211
	30,000 - 40,000	1,381	- 220	+ 109
	40,000 - 50,000	691	+ 47	+ 331
	> 50000	1,400	+ 125	- 165
Deniliquin flow (ML/d)				
	15,000 - 20,000	561	+ 22	+ 108
	20,000 - 25,000	322	- 1	+ 93
	25,000 - 30,000	216	+ 11	+ 2
	> 30,000	1,064	+ 133	- 122
Flow to SA (ML/d)				
	50,000 - 60,000	1,974	- 66	- 39
	60,000 - 70,000	1,249	- 81	- 67
	70,000 - 80,000	602	- 28	+ 76
	> 80,000	1,238	- 44	- 58

Table 6 - Spill from storages: frequency of years (%) and average volume of spill (GL/y)

	Baseline	Benchmark	Change from benchmark	
			19-pack (offset ~400 GL)	EEWD Y50 (offset ~600 GL)
Frequency of years spilling (%)				
Hume Dam in River Murray	51%	50%	+ 10%	- 10%
Menindee Lakes System	32%	39%	+ 6%	+ 4%
Burrinjuck + Blowering in Murrumbidgee	71%	60%	+ 1%	+ 1%
Eildon in Goulburn	18%	31%	- 1%	- 3%
Average Annual Spill Volume (GL/y)				
Hume Dam in River Murray	1,152	1,052	+ 108	- 237
Menindee Lakes System	937	940	- 24	- 33
Burrinjuck + Blowering in Murrumbidgee	723	573	- 80	- 161
Eildon in Goulburn	159	254	- 29	- 35
Southern basin total	**2,971**	**2,904**	**- 25**	**- 466**

4. CONCLUSION

Natural Flow Cues method for Goulburn system was developed and applied to the SDL adjustment mechanism assuming Goulburn constraints as per benchmark.

Model foresight is reduced to one month.

Additional environmental demand at SA border incuded for dry years considering Coorong, Lower Lakes and Murray Mouth (CLLMM) outcomes.

A summary of an analysis of preliminary results is provided.

5. REFERENCES

- MDBA (2016). Environmental water delivery following natural flow cues and relaxing constraints in the Southern Basin: potential options for SDL adjustment, MDBA Technical Report no 2016/27. November 2016.

6. APPENDIX A

Table A1 - Site Specific Flow Indicators for the Goulburn River at Shepparton

Location	Site Specific Flow Indicator
Shepparton	1) Two events annually of 2,500 ML/d for 4 consecutive days between December & April for 36% of years; 2) 5,000 ML/d for 14 consecutive days between October & November for 49% of years; 3) 25,000 ML/d for a median duration of 5 days between June & November for 70% of years and 4) 40,000 ML/d for a median duration of 4 days between June & November for 40% of years

7. APPENDIX B

Table B1 – Ecological element scores for the southern connected basin (19-pack scenarios)

Basin Plan sites	**Ecological Elements Scores**		
	Benchmark #1094	**19-pack #1116**	**EEWD Y50**
Environmental watering strategy	pick-a-box	pick-a-box	natural hydro cues
Model foresight (month)	12	12	1
Water recovery (GL/y)	2,750	2,350	2,150
Potential SDL adjustment (GL/y)		~ 400	~ 600
River Murray system			
Barmah-Millewa Forest	5193	5161	5333
Gunbower-Koondrook-Perricoota	5569	6336	5992
Hattah-Kulkyne Lakes	3536	3602	4009
Riverland Chowilla Floodplain	4046	4074	4210
Edward Wakool River System	4126	4391	4036
Lower Darling Floodplain	2942	2857	2779
Murrumbidgee			
Mid-Bidgee	4762	4775	4961
Low-Bidgee	6539	6298	6373
Lower Goulburn	8176	8024	8385
Overall Southern Basin	**4988**	**5057**	**5120**

Table B2 – Frequency of Basin Plan Site Specific Flow Indicators (19-pack scenarios)

SFI sites	SFI		BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
	Environmental watering strategy			pick-a-box		pick-a-box	Hydrological cues
	Model foresight (month)			12		12	1
	Water recovery (GL/y)			2,750		2,350	2,150
	Potential SDL adjustment (GL/y)					~ 400	~ 600
Barmah-Millewa Forest	1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70-80%	78%	70%	73%	83%
Barmah-Millewa Forest	2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40-50%	52%	47%	49%	54%
Barmah-Millewa Forest	3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40-50%	46%	41%	45%	53%
Barmah-Millewa Forest	4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33-40%	35%	33%	34%	36%
Barmah-Millewa Forest	5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25-30%	18%	18%	18%	19%
Barmah-Millewa Forest	6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20-25%	13%	13%	15%	11%
Barmah-Millewa Forest	7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	36%	32%	33%	32%
Gunbower-Koondrook-Perricoota	1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70-80%	68%	61%	62%	65%
Gunbower-Koondrook-Perricoota	2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60-70%	67%	60%	60%	60%
Gunbower-Koondrook-Perricoota	3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33-50%	39%	35%	37%	38%
Gunbower-Koondrook-Perricoota	4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25-33%	22%	20%	23%	22%
Gunbower-Koondrook-Perricoota	5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	28%	25%	25%	25%
Hattah-Kulkyne Lakes	1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40-50%	44%	40%	42%	45%
Hattah-Kulkyne Lakes	2	50,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	30-40%	31%	30%	29%	36%
Hattah-Kulkyne Lakes	3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20-33%	19%	17%	18%	23%
Hattah-Kulkyne Lakes	4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20-30%	11%	10%	12%	16%
Hattah-Kulkyne Lakes	5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14-20%	9%	8%	8%	8%
Hattah-Kulkyne Lakes	6	150,000 ML/d for a total duration of 7 days (with min duration of 7 consecutive days) between Jun & May	10-13%	6%	5%	7%	6%

SFI sites	SFI		BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
	Environmental watering strategy			pick-a-box		pick-a-box	natural hydro cues
	Model foresight (month)			12		12	1
	Water recovery (GL/y)			2,750		2,350	2,150
	Potential SDL adjustment (GL/y)					~ 400	~ 600
Riverland Chowilla Floodplain	1	20,000 ML/d for 60 consecutive days between Aug & Dec	71-80%	71%	71%	71%	77%
Riverland Chowilla Floodplain	2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50-70%	59%	53%	54%	56%
Riverland Chowilla Floodplain	3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33-50%	39%	35%	36%	40%
Riverland Chowilla Floodplain	4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25-33%	26%	25%	26%	25%
Riverland Chowilla Floodplain	5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17-25%	13%	11%	13%	15%
Riverland Chowilla Floodplain	6	100,000 ML/d for a total duration of 21 days (with min duration of 1 day) between Jun & May	13-17%	8%	7%	7%	7%
Riverland Chowilla Floodplain	7	125,000 ML/d for a total duration of 7 days (with min duration of 1 day) between Jun & May	10-13%	5%	4%	6%	5%
Edward Wakool River System	1	1,500 ML/d for a total duration of 180 days (with min duration of 1 day) between Jun & Mar	99-100%	94%	94%	96%	97%
Edward Wakool River System	2	5,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	60-70%	67%	60%	60%	63%
Edward Wakool River System	3	5,000 ML/d for a total duration of 120 days (with min duration of 7 consecutive days) between Jun & Dec	35-40%	33%	30%	36%	38%
Edward Wakool River System	4	18,000 ML/d for a total duration of 28 days (with min duration of 5 consecutive days) between Jun & Dec	25-30%	17%	15%	18%	18%
Edward Wakool River System	5	30,000 ML/d for a total duration of 21 days (with min duration of 6 consecutive days) between Jun & Dec	17-20%	12%	12%	15%	11%
Lower Darling Floodplain	1	7,000 ML/d for 10 consecutive days between Jun & May	70-90%	58%	58%	60%	65%
Lower Darling Floodplain	2	17,000 ML/d for 18 consecutive days between Jun & May	20-40%	22%	20%	18%	17%
Lower Darling Floodplain	3	20,000 ML/d for 30 consecutive days between Jun & May	14-20%	11%	10%	15%	15%
Lower Darling Floodplain	4	25,000 ML/d for 45 consecutive days between Jun & May	8-10%	8%	8%	9%	9%
Lower Darling Floodplain	5	45,000 ML/d for 2 consecutive days between Jun & May	7-10%	7%	7%	8%	8%
Coorong Lower lakes and Murray Mouth	1	Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,500 EC	100%	100%	100%	100%	100%
Coorong Lower lakes and Murray Mouth	1	Lake Alexandrina salinity: Percentage of days that Lake Alexandrina salinity is less than 1,000 EC	95%	95%	95%	96%	96%
Coorong Lower lakes and Murray Mouth	2	Barrage flows: Percentage of years that barrage flows are greater than 2,000 GL/yr (measured on a three year rolling average) with a minimum of 650 GL/yr	95%	95%	95%	96%	96%
Coorong Lower lakes and Murray Mouth	3	Barrage flows: Percentage of years that barrage flows are greater than 600 GL for any two year period	100%	100%	100%	100%	100%
Coorong Lower lakes and Murray Mouth	4	Coorong Salinity: Percentage of days South Lagoon average daily salinity is less than 100 grams per litre.	96%	96%	96%	100%	99%
Coorong Lower lakes and Murray Mouth	5	Mouth Openness: Percentage of years mouth open to an average annual depth of 1.0 meters (-1.0 m AHD) or more	90%	90%	90%	93%	94%
Coorong Lower lakes and Murray Mouth	5	Mouth Openness: Percentage of years mouth open to an average annual depth of 0.7 metres (-0.7 m AHD) or more	95%	95%	95%	97%	97%

SFI sites		SFI	BP target (%)	Benchmark #1094	LOC	19-pack #1116	EEWD Y50
		Environmental watering strategy		pick-a-box		pick-a-box	natural hydro cues
		Model foresight (month)		12		12	1
		Water recovery (GL/y)		2,750		2,350	2,150
		Potential SDL adjustment (GL/y)				~ 400	~ 600
Goulburn River at Shepparton	1	Two events annually of 2,500 ML/d for 4 consecutive days (with min duration of 30 days between events) between Dec & Apr	36 - 48 %	54%	54%	54%	57%
	2	5,000 ML/d for 14 consecutive days between Oct & Nov	49 - 66 %	55%	55%	55%	64%
	3	25,000 ML/d for a median duration of 5 days between Jun & Nov	70 - 80 %	82%	74%	80%	82%
	4	40,000 ML/d for a median duration of 4 days between Jun & Nov	40 - 60 %	58%	52%	54%	67%
Mid - Bidgee (Narrandera flow)	1	26,850 ML/d for a total duration of 45 days (with min duration of 1 day) between Jul & Nov	20 - 25 %	11%	11%	12%	19%
	2	26,850 ML/d for 5 consecutive days between Jun & Nov	50 - 60 %	61%	55%	59%	58%
	3	34,650 ML/d for 5 consecutive days between Jun & Nov	35 - 40 %	46%	41%	42%	44%
	4	44,000 ML/d for 3 consecutive days between Jun & Nov	30 - 35 %	31%	30%	32%	28%
	5	63,250 ML/d for 3 consecutive days between Jun & Nov	11 - 15 %	10%	10%	11%	11%
Low - Bidgee (Maude flow)	1	Total volume of 175 GL (flow > 5,000 ML/d) between Jul & Sep	70 - 75 %	94%	85%	86%	88%
	2	Total volume of 270 GL (flow > 5,000 ML/d) between Jul & Sep	60 - 70 %	88%	79%	79%	82%
	3	Total volume of 400 GL (flow > 5,000 ML/d) between Jul & Oct	55 - 60 %	81%	73%	73%	77%
	4	Total volume of 800 GL (flow > 5,000 ML/d) between Jul & Oct	40 - 50 %	60%	54%	54%	54%
	5	Total volume of 1,700 GL (flow > 5,000 ML/d) between Jul & Nov	20 - 25 %	28%	25%	28%	35%
	6	Total volume of 2,700 GL (flow > 5,000 ML/d) between May & Feb	10 - 15 %	17%	15%	16%	17%
BIDG Freshes (Balranald	1	1,100 ML/d for 25 consecutive days between Dec & May	58 - 77 %	67%	67%	67%	68%
	2	4,500 ML/d for 20 consecutive days between Oct & Dec	54 - 72 %	73%	73%	74%	72%
	3	3,100 ML/d for 30 consecutive days between Oct & Mar	55 - 73 %	73%	73%	74%	75%

Attachment D: Representation of the each operating strategy in the MDBA modelling framework

While the environmental demands for the Goulburn are modelled in the same way as the benchmark, using the EEST, environmental flow demand for specific flow indicator sites on the Murray and Murrumbidgee are developed using the new approach. The logic for calculating the environmental demand is summarised in Figure 1. Each site has a pre-defined start and end date, orders are prevented outside of these dates. If a site is active, each rule at the site is then checked to see if they are active. If the rule is in progress, then it is continued until it is completed. If a rule is active but not in progress, the antecedent conditions are checked to see if a new event should be triggered (Figure 2). This involves the following checks:

- The rule has not been yet delivered in current season.
- The rule is in the target season.
- There is sufficient time left in the target season to deliver the rule.
- Storage inflows are in the target range for an event.

The specific parameters for each of the specific flow indicator sites implemented in the model are listed in Table 1. The start and end date for each site define the target window for generating environmental demands at the site. No demands are generated outside this target window. The inflows to the storage are used to characterise how wet the season is based on an exceedance probability. Wetter conditions (lower exceedance probability) will target higher flow rules, while drier conditions (as indicated by high exceedance probability) will only trigger the low flow rules. The gauge represents the reference site, or gauge, where without development flows are referenced to trigger environmental demands. A constant value for the coefficient of efficiency is adopted for each site (Table 1). A forecast window of seven days is adopted for the Murray and five days adopted for the Murrumbidgee. The forecast represents how far into the future without development flows can be analysed to determine if it is appropriate to trigger an environmental demand.

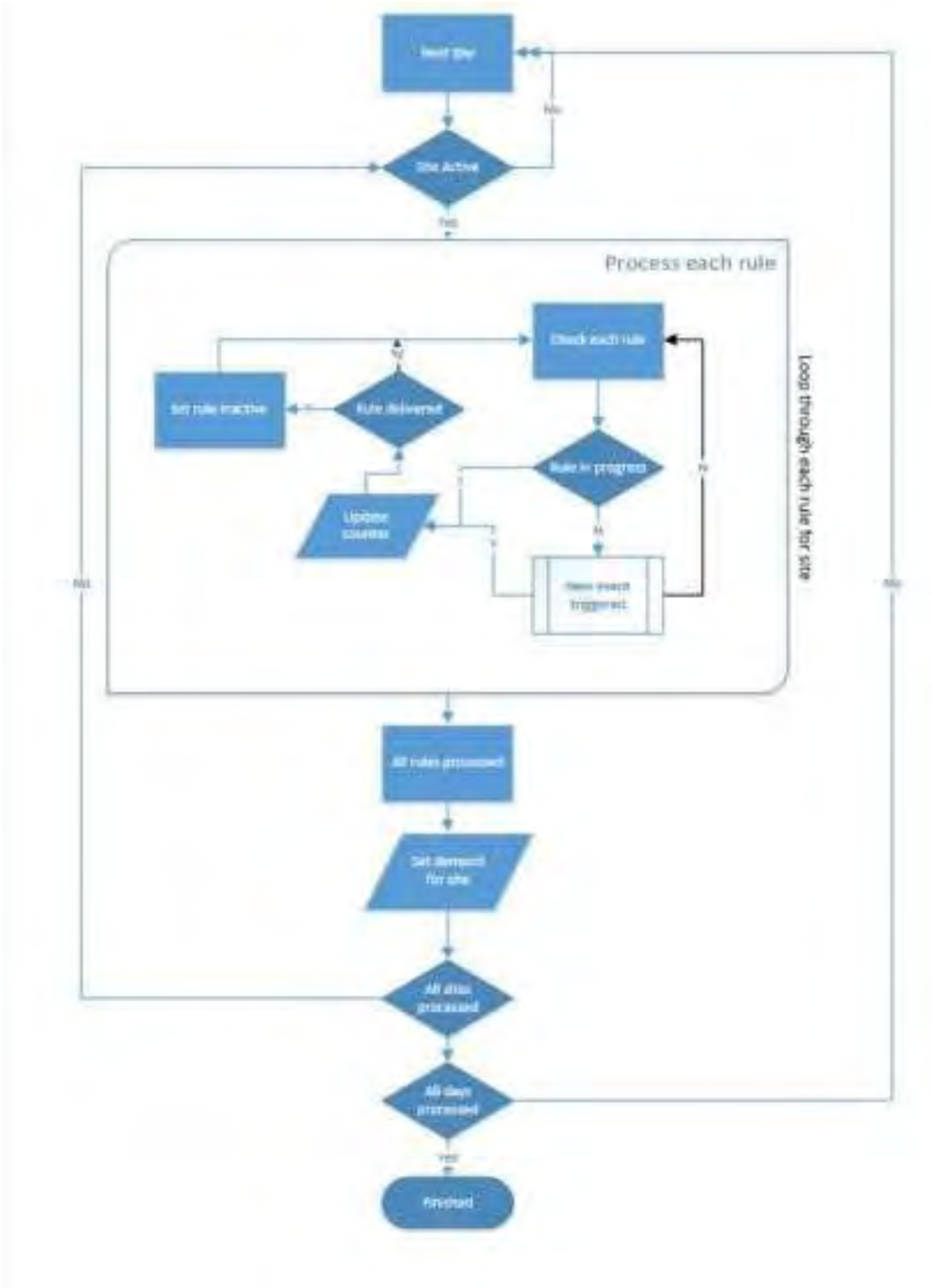


Figure 1 Method for calculating if a demand is generated at a site.

The Coorong, Lower Lakes and Murray Mouth demands are only targeted during very dry periods on the Murray. Demands from both the Murrumbidgee and Murray will be attempted, based on exceedance probability of inflows to Hume. As the indicators include a three-yearly rolling total annual barrage flow, the exceedance probability of Hume inflows are assessed for the July to December period at the end of December. If the inflows are drier than a threshold exceedance probability, an additional order is generated over the summer and autumn period of the current water year and the next to achieve three-yearly rolling total barrage flow target (Table 2). The 88% exceedance probability of Hume inflows is used as a threshold for Murrumbidgee to generate an additional order at Balranald. No additional order is generated for the Murray during extremely dry years (exceedance probability > 92%) so as to avoid triggering of special accounting and potential impact on South Australian reliability.

Table 1 Parameters for each site

	Barmah	Gunbower	Hattah	Chowilla	Narran	Maude	Balranald
Start Date	6.01	6.15	7.01	8.01	7.01	7.01	12.01
End Date	11.30	11.30	12.31	12.31	11.30	2.28	5.31
Storage	Hume	Hume	Hume	Hume	Burrinjuck	Burrinjuck	Burrinjuck
Gauge	Yarrawonga	Torrumbarry	Euston	SA Flow	Narrandera	Maude	Balranald
Max order	50,000	40,000	85,000	80,000	34,650	8,000	9,000
Coefficient of efficiency	0.7	0.7	0.7	0.7	1.1	0.8	1.0
Forecast days	7	7	7	7	5	5	5

Table 2: Indicative parameters for CLLAMM demand

	Balranald	Chowilla
Start Date	1.01	1.01
End Date	6.30	6.30
Storage	Hume	Hume
Gauge	Balranald	SA flow
Max order	9,000	20,000
Coefficient of efficiency	0.75	1.0
Forecast days	0	0

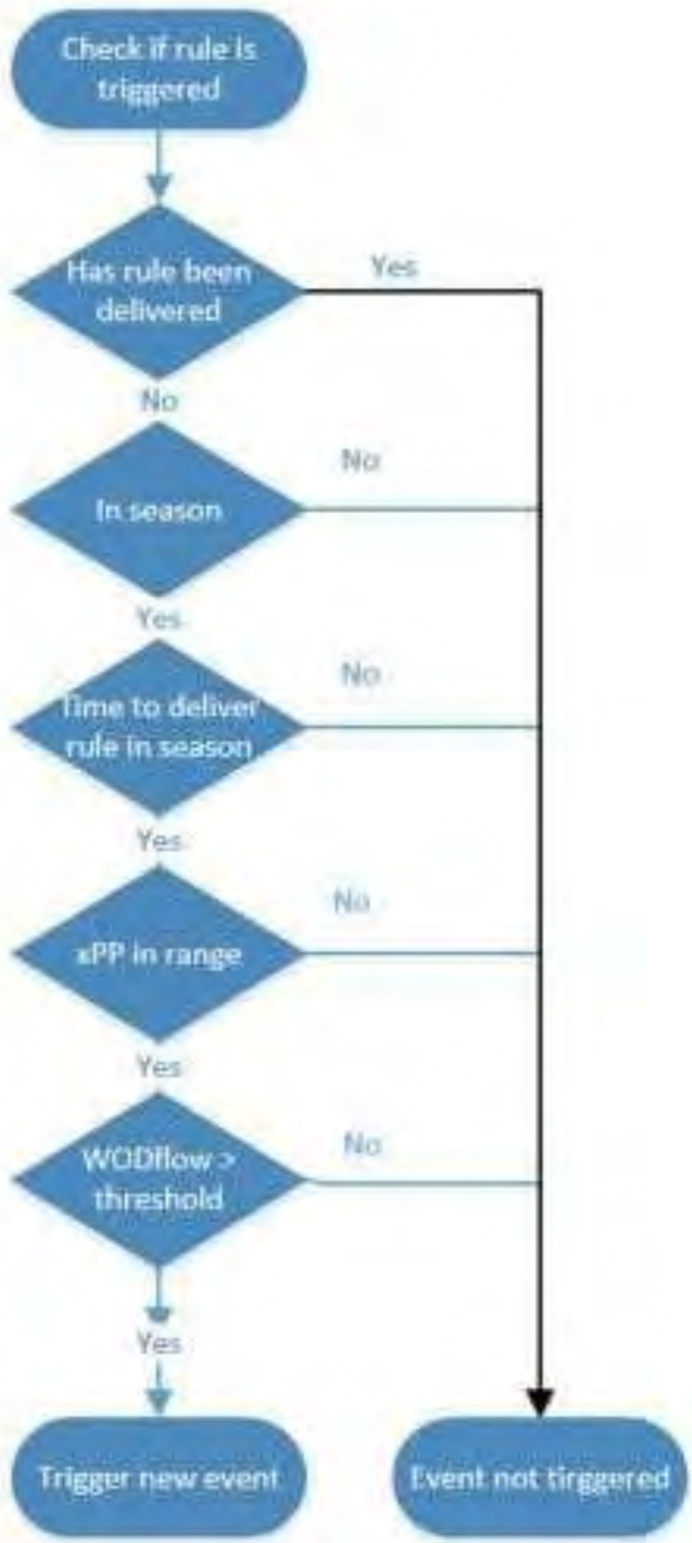


Figure 2 Logic for triggering a new flow event

At each site, there are a number of rules defining target flow rates. These rules are summarised in the tables below for each of the sites. For each rule, a minimum and maximum exceedance probably is defined. The minimum exceedance probability (xPPmin) sets the lower bound, or wettest conditions, that this rule will be targeted under. The maximum exceedance probability (xPPmax) defines the driest conditions the rule will be targeted under.

Site - Barmah-Millewa Forest

Rule	Description	xPP min	xPP max
1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	0%	5%
2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	0%	17%
3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	0%	15%
4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	0%	23%
5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	0%	2%
6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	0%	0%
7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	0%	23%

Site - Gunbower-Koondrook-Perricoota

Rule	Description	xPP min	xPP max
1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	0%	54%
2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	37%	63%
3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25%	37%
4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	0%	25%
5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	11%	33%

Site - Hattah-Kulkyne Lakes

Rule	Description	xPP min	xPP max
1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	0%	26%
2	50,000 ML/d for a total duration of 60 days (with a min duration of 7 consecutive days) between Jun & Dec	0%	21%
3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	0%	9%
4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	0%	0%
5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	0%	0%

Site - Riverland Chowilla Floodplain

Rule	Description	xPP min	xPP max
1	20,000 ML/d for 60 consecutive days between Aug & Dec	0%	72%
2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	0%	33%
3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	0%	5%
4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	0%	21%
5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	0%	20%
6	100,000 ML/d for a total duration of 21 days between Jun & May	0%	0%
7	125,000 ML/d for a total duration of 7 days between Jun & May	0%	0%

Site - Mid-Bidgee floodplain

Rule	Description	xPP min	xPP max
1	26,850 ML/d for a total duration of 45 days (with min duration of 1 day) between Jul & Nov	0%	0%
2	26,850 ML/d for 5 consecutive days between Jun & Nov	0%	0%
3	34,650 ML/d for 5 consecutive days between Jun & Nov	0%	61%
4	44,000 ML/d for 3 consecutive days between Jun & Nov	0%	0%
5	63,250 ML/d for 3 consecutive days between Jun & Nov	0%	0%

Site - Low-Bidgee floodplain

Rule	Description	xP P	xPP ma
1	Total volume of 175 GL (flow > 5,000 ML/d) between Jul & Sep	78%	84%
2	Total volume of 270 GL (flow > 5,000 ML/d) between Jul & Sep	75%	77%
3	Total volume of 400 GL (flow > 5,000 ML/d) between Jul & Oct	56%	75%
4	Total volume of 800 GL (flow > 5,000 ML/d) between Jul & Oct	29%	55%
5	Total volume of 1,700 GL (flow > 5,000 ML/d) between Jul & Nov	25%	28%
6	Total volume of 2,700 GL (flow > 5,000 ML/d) between May & Feb	13%	16%

Freshes - Balranald

Rule	Description	xPP min	xPP max
1	1,100 ML/d for 25 consecutive days between Dec & May	0%	95%
2	4,500 ML/d for 20 consecutive days between Oct & Dec	0%	53%
3	3,100 ML/d for 30 consecutive days between Oct & Mar	0%	42%

Coorong, Lower Lakes and Murray demand

Rule	Description	xPP min	xPP max
1	Additional demand at SA border on Murray (minimum of 20,000 ML/d and without development flow) between January and June (current water year and next year)	89%	92%
2	Additional demand at Balranald on Murrumbidgee (minimum of 9,000 ML/d and without development flow) between January and June (current water year and next year)	88%	100%