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Towards a scientific evaluation of environmental water offsetting in the Murray–Darling Basin, Australia

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ABSTRACT

Context. Increasing water scarcity creates the major challenge of how to achieve environmental outcomes while meeting human water demands. In the Murray–Darling Basin, Australia, this challenge is being addressed by the Murray–Darling Basin Plan and the 'Sustainable Diversion Limit Adjustment Mechanism' (SDLAM), an offsetting program seeking to achieve environmental outcomes using less water. **Aims.** We provide a critique of the legislated method for evaluation of the SDLAM and the suitability of the process for evaluating whether equivalent environmental outcomes have been achieved. **Methods.** Four project case studies, project documentation, external reviews and relevant legislation were used to assess the implementation of the SDLAM and the evaluation method. **Key results.** The SDLAM evaluation method is not scientifically rigorous. It excludes residual risks, Basin-wide impacts and climate change. The evaluation timeline is biased towards measuring infrastructure outputs rather than environmental outcomes and impacts. **Conclusions.** Flaws in the SDLAM evaluation processes mean that environmental benefits are likely to be overstated, risking further reductions in allocations of water for the environment, contrary to the objectives of the Basin Plan. **Implications.** Improved evaluation, including empirical data on outputs, outcomes and impacts, is needed to ensure that conservation objectives can be met for wetlands subject to SDLAM projects.

Keywords: biodiversity, catchment management, conservation, environmental monitoring, floodplains, Murray–Darling system, water reform policy, wetlands.

Introduction

Increases in human population pressure, economic growth and irrigated agriculture have caused high levels of water diversions, resulting in increasing water scarcity in many parts of the world, exacerbated by climate change (Vörösmarty *et al.* 2010; Greve *et al.* 2018). High diversions have led to greater water scarcity for consumptive use, altered flow and flood regimes, and compromised environmental water requirements of rivers, wetlands and their biota (Pittock and Finlayson 2011; Grafton *et al.* 2013; Pokhrel *et al.* 2018). The Murray–Darling Basin (hereafter 'the Basin') in south-eastern Australia provides an example of these issues. According to the 2021 State of the Environment report, 'In much of southern Australia, the greatest threat to freshwater ecosystems and biodiversity is the modification of water processes that has occurred as a result of changes to river and stream flow, surface water and groundwater extraction (primarily for agriculture), and land-use change' (Cresswell *et al.* 2021, p. 47).

Major policy reforms since the mid-1990s aimed at restoring rivers and wetlands (Grafton 2019) led to the Murray–Darling Basin Plan (Commonwealth of Australia 2012; hereafter 'the Basin Plan'). It was to be implemented by the Murray–Darling Basin Authority (MDBA), a Commonwealth Government agency, in partnership with the Basin States and Territory (Queensland, South Australia, New South Wales, Victoria and the Australian Capital Territory) under the *Water Act* (Commonwealth of Australia 2007). Progress on implementing the Basin Plan was to be monitored and audited by the National Water Commission (NWC), an independent statutory body who reported to the

Council of Australian Governments (Loynes 2014). However, the NWC was abolished through the *National Water Commission (Abolition) Act* 2015 (Commonwealth), with key functions relating to Basin Plan evaluation being passed to the more economically focused Productivity Commission. The 2021 State of the Environment report criticised some aspects of current monitoring and reporting on the Plan, particularly relating to threatened species, stating that current assessments are 'largely inadequate to assess whether the Basin Plan is achieving its environmental objectives' (Cresswell *et al*. 2021, p. 48).

Under the Basin Plan, the volume of annual surface-water diversions was to be reduced by 2750 GL year^{-1}, which is 20% of the average baseline diversion limit (the volume used for irrigation and other consumptive purposes; Murray–Darling Basin Authority 2020*a*). This reduction was to be achieved by a Basin-wide sustainable diversion limit (SDL). SDLs are limits on the volume of water that can be sustainably diverted in each catchment and across the Basin (Murray–Darling Basin Authority 2017*a*, p. 1). The Basin-wide SDL was intended to achieve the environmental objective of the Basin Plan, namely 'the restoration and protection of water-dependent ecosystems and ecosystem functions in the Murray–Darling Basin with strengthened resilience to a changing climate' (Commonwealth of Australia 2012, S5.03(2)). However, the volume of water to be returned to the environment under the Basin Plan has been widely regarded as inadequate to achieve this stated environmental objective (Young *et al*. 2011; Prosser *et al*. 2012; Grafton 2019). Furthermore, there has been a steady reduction in the volume of water to be returned from irrigators to the environment, referred to as 'the step-down effect' (Fig. 1; Colloff and Pittock 2022).

The *Guide to the Basin Plan* (Murray–Darling Basin Authority 2010, pp. 110, 212) states that a range of 3000–7600 GL of additional environmental water per year was required to restore wetlands and rivers. However, the MDBA considered only scenarios of 3000–4000 GL because

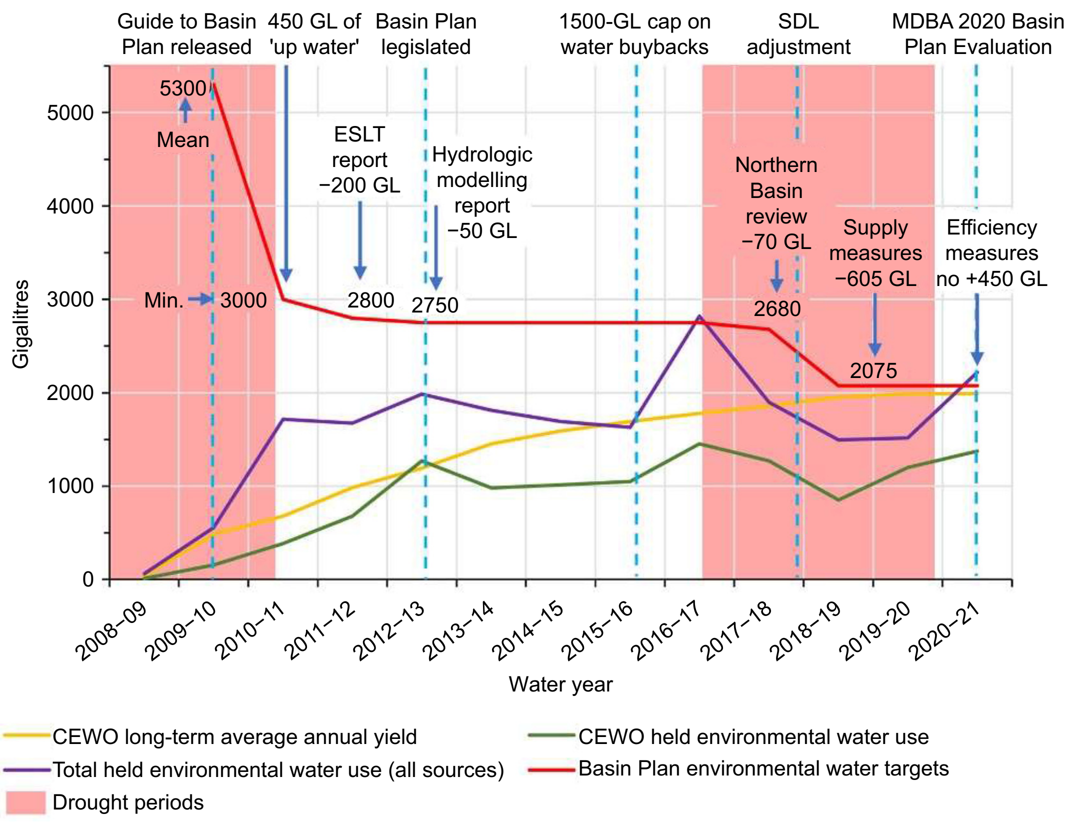

Fig. 1. The step-down effect: continual adjustments to targets for environmental water in relation to environmental water recovery and use in the Murray–Darling Basin. Environmental water entitlements do not represent the actual volume recovered, but what the Commonwealth could use were it available. Some entitlements are for low-security water, unlikely to be available except during very wet periods. CEWO, Commonwealth Environmental Water Holder; ESLT, ecologically sustainable limit of take; MDBA, Murray–Darling Basin Authority; SDL, sustainable diversion limit. Data on CEWO water entitlements from Department of Agriculture, Water and the Environment (2021*a*); data on environmental water use from Colloff and Pittock (2022, table S1 therein).

'the Authority [felt] that escalating social and economic effects [were] likely to outweigh the additional environmental benefits' (Murray–Darling Basin Authority 2010, p. 110). In 2011, the volume was further reduced to 2800 GL without justification (Walker 2019). A further 50-GL reduction followed revised modelling by the MDBA, and another 70-GL reduction after the northern Basin review (Murray–Darling Basin Authority 2016). In September 2015, the Australian Government legislated a cap on water buybacks from irrigators of 1500 GL year^{-1} (Department of Agriculture, Water and the Environment 2021*b*), requiring the remaining water for the environment to be acquired by other means. The volume of water to be recovered was further reduced through the Sustainable Diversion Limit Adjustment Mechanism (SDLAM).

The SDLAM was added to the Basin Plan to allow for an adjustment of SDLs in the southern Basin (Fig. 2). The SDLAM operates as a form of offset, whereby negative environmental impacts from water diversions are 'offset' by improving the effectiveness of environmental water in achieving environmental outcomes. The SDLAM is based on the concept of 'equivalent environmental outcomes'; that is, the idea that through various programs, environmental outcomes equivalent to the 2750-GL environmental water recovery target can be achieved with less water. The SDLAM sets a maximum adjustment of ±5% (544 GL) of the Basin-wide SDL for surface water. In 2017, the MDBA determined that implementing a series of supply measures and projects under the SDLAM, required to be operational by 30 June 2024, could allow an increase in the SDL, making an additional 605 GL (so-called 'downwater') available for consumptive use (Murray–Darling Basin Authority 2017*a*). Supply projects are designed to achieve environmental outcomes with less water. For example, by building levee banks, regulators and channels, less water is required to flood a wetland than would be required under conditions without such infrastructure (i.e. by overbank flows from the main river channel).

There are three types of supply projects (Murray–Darling Basin Authority 2017*a*, 2022), namely, 'environmental works and measures' involving building environmental infrastructure, 'constraints management/relaxation measures' that are intended to allow flows onto the floodplain while mitigating any adverse effects of flooding on private property and landholders (Murray–Darling Basin Authority 2015; Kahan *et al*. 2021) and 'operational rules changes/system enhancements' projects. On-farm efficiency measures form the other main component of the SDLAM. Efficiency measures are intended to allow recovery of 450 GL of additional water for the environment (so-called 'upwater') with neutral or positive socio-economic outcomes (Murray–Darling Basin Authority 2022). The SDLAM is financed through contributions from Basin States, in addition to A$1.3 billion from the Commonwealth Government for

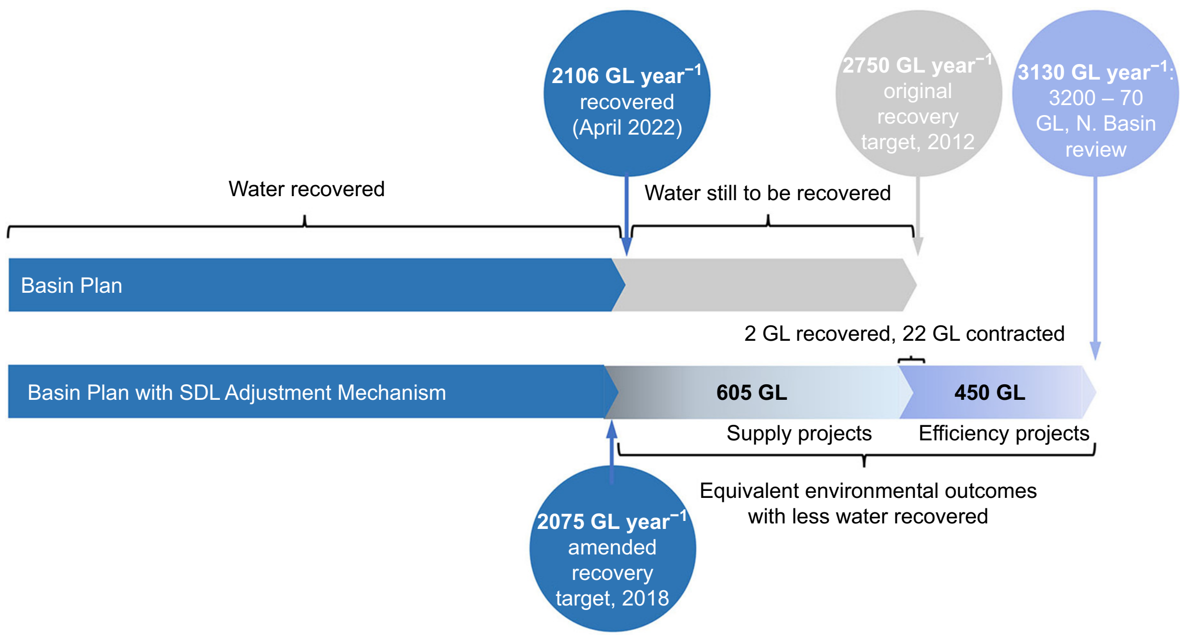

Fig. 2. The Sustainable Diversion Limit Adjustment Mechanism (SDLAM). Supply measures and projects are intended to save 605 GL year^{-1} of water and efficiency measures 450 GL year^{-1}. The Basin Plan with SDLAM thus involves 2075 GL year^{-1} of water to be delivered to the environment: 2750 GL minus 605 GL from supply projects offsets, minus a 70-GL reduction in environmental water in the northern Basin following the northern Basin review. Based on Murray–Darling Basin Authority 2017*a*, p. 2).

supply measures, and A$1.7 billion from the Water for the Environment Special Account for constraints and efficiency measures (Department of Agriculture, Water and the Environment 2022).

In January 2018, amendments to the Basin Plan were passed by the Australian parliament, effectively reducing the target volume for environmental water recovery from 2680 to 2075 GL, plus 450 GL year^{-1} from efficiency projects. To remain within the 5% limit, the increase in SDLs was capped at 544 GL, pending recovery of at least 62 GL of upwater from efficiency projects (Murray–Darling Basin Authority 2019*a*). By September 2021, only 1.9 GL of upwater had been recovered, with 18.5 GL under contract (Murray–Darling Basin Authority 2021*a*). The second review of the Water for the Environment Special Account (WESA) stated that '[i]t is not possible to reach the 450-GL target through the current efficiency measures program – even if the WESA time and budget limits were removed' and that, at best, an additional 60 GL could be recovered through the current efficiency program by 30 June 2024 (Australian Government 2021, p. 8). This has led to increasing discussions about the possibility of resuming voluntary buybacks, with the Federal minister for water stating she is 'not ruling things in or out' in regard to buybacks (Shepherd 2022; Sullivan 2022).

It is also unlikely that the downwater target will be met by 2024, with substantial delays and several supply projects deemed 'at risk' (Indec 2021; Murray–Darling Basin Authority 2021*b*). In June 2021, then MDBA Chief Executive Philip Glyde stated that unless things changed markedly, neither the 605 GL of offsets from supply measures nor the 450-GL savings from efficiency measures were likely to be delivered (Hannam 2021). Furthermore, Bender *et al.* (2022) found little or no alignment between the principles of the *Water Act* 2007 (Commonwealth) and the purpose of the SDLAM projects, highlighting the disconnect between the objectives that shape high-level water-policy reforms and management actions at local and regional scales.

To our knowledge, no water offset similar to the SDLAM, where environmental outcomes are the currency of the offset, has been implemented elsewhere. The SDLAM approach remains untested, lacks on-ground validation and is based on ecological modelling that relies on generalised and hypothetical assumptions. The premise that scarce environmental water can be traded off while conserving the environment *and* maintaining irrigated agricultural production has been described as 'beguiling and risky' (Pittock *et al.* 2013).

The MDBA has been undertaking assurance assessments since 2019 to determine whether SDLAM projects can deliver expected water-recovery volumes and equivalent environmental outcomes by the June 2024 deadline (Murray–Darling Basin Authority 2021*c*). Under the Basin Plan, the MDBA must undertake a reconciliation if a new SDL determination at 30 June 2024, including SDLAM measures, would produce a result different from the 2017 determination (Murray–Darling Basin Authority 2019*b*). A reconciliation involves calculating the difference between predicted *v.* achieved offset volumes and re-adjusting SDLs to reflect the new modelled offset. It is essential that the assurance and reconciliation process is rigorous and supported by best available science (Ryder *et al.* 2010). These processes will influence the environmental condition of the Basin and can provide important lessons for water management globally.

In this paper, we provide a critique of the legislated method for evaluation of the SDLAM and consider its suitability for assessing the achievement of equivalent environmental outcomes with less environmental water. We consider four SDLAM projects, including two environmental-works supply measures, one rule-change supply measure and one constraints-relaxation supply measure. These case studies provide context to enable an understanding of the operation of the SDLAM. We focus on how the SDLAM can be evaluated with sufficient rigour to ensure that water offset volumes reflect the reality of what environmental outcomes the SDLAM projects can deliver. In doing so, we consider the legislated requirements for assurance and reconciliation of the SDLAM in the Basin Plan (Schedule 6). We highlight major flaws in the method, with examples drawn from the four case studies, and provide policy options for how the processes of assurance and reconciliation can be improved.

Methods

We undertook an evaluation of the SDLAM assurance and reconciliation processes as follows: (1) a review of four case-study projects, using the business cases to provide details about each project at the time of planning, and subsequent documentation where available; (2) the collation and review of reports on the three main types of SDLAM supply projects; (3) a review of other reports on the functioning of the SDLAM, including SDLAM model reports, the reconciliation framework and status reports of projects; (4) a review of the MDBA evaluation reports to inform a critique of the proposed evaluation methods.

We selected the four case-study projects from the 36 approved SDLAM projects (Table 1) on the basis of the following criteria: (1) they represent a range of different types of supply project, with two being the most common type (environmental works); (2) business cases and other documentation for each project are publicly available; (3) the projects have been assessed for their operational status and progress towards implementation through annual assurance reporting by the MDBA (since 2019); (4) the projects have a range of risk assessments; and (5) the projects exemplify a broad range of issues and concerns, as raised in the introduction, regarding objectives, design, assumptions and implementation.

Table 1. Details of the SDLAM supply measures and projects used as case studies herein.

Name	Type of project	Target water savings (GL year^{-1})	Risks and risk status	States responsible	Implementation cost (A$)	References
Nyah Floodplain Management Project	Environmental works	2.5	Moderate risk: lack of stakeholder support may prevent statutory development approval	VIC	$11 million	Mallee Catchment Management Authority (2014); Wentworth Group (2017); Murray–Darling Basin Authority (2017*b*, 2020*b*, 2022); Indec (2021)
Koondrook–Perricoota Flood Enhancement Works	Environmental works	25	'In operation' (i.e. infrastructure completed), but not functioning as planned	NSW, Vic., SA	$80 million[A]	Department of Water and Energy (2009); Murray–Darling Basin Authority (2019*c*, 2020*b*, 2021*b*); Dind and Sim (2018); Cunningham *et al.* (2013); Wentworth Group (2017, 2018)
Yarrawonga to Wakool Junction Reach Constraints Management Strategy	Constraints relaxation	21	Strategy unlikely to deliver planned outcomes by June 2024. **At risk**	NSW	$262 million for 35 GL day^{-1}; $306 million for 50 GL day^{-1}	Department of Primary Industries (2016); Murray–Darling Basin Authority (2020*b*, 2021*b*); Wentworth Group (2017, 2018); Indec (2021); Kahan *et al.* (2021)
Enhanced Environmental Water Delivery (hydro-cues)	Operational rule changes and system enhancements	21	Technically, legally and operationally complex. Not likely to be completed by June 2024. **At risk**	NSW, Vic., SA	Costings redacted from business case, but ~$150 million	Murray–Darling Basin Authority (2017*c*, 2020*b*, 2022); Wentworth Group (2017, 2018); Indec (2021)

The operational date is 30 June 2024 except for Koondrook–Perricoota Flood Enhancement Works (part-commissioned in 2013). '**At risk**' indicates that projects are unlikely to be delivered by 30 June 2024 without major intervention (Indec 2021, pp. 14–16; Murray–Darling Basin Authority 2020*b*). Implementation costs are as stated in each business case; however, actual current costs, which are not publicly available, are likely to have increased markedly.
[A]A more recent cost estimate is more than A$120 million (Hannam 2020).

Throughout the paper, we refer to the concept of 'risk(s)' in different contexts. Each case study contains a summary of the risk analysis from the relevant business case. Business case risk assessments are typically structured as per the AS/NZS ISO 31000:2009 risk standard (the business cases for Nyah Floodplain Management Project and Enhanced Environmental Water Delivery make direct reference to the standards, and the risk assessments of other two cases are structured in a similar manner). In this approach, threats are identified and then assigned a risk rating (Table 2) based on the likelihood of the event occurring and the severity of the outcome if it eventuated (Mallee Catchment Management Authority 2014). The risk rating is then recalculated assuming that planned mitigation measures (actions to reduce the likelihood or consequence of the event) are implemented. The outcome of this is an assessment of 'residual risk' (i.e. the risk that remains after mitigation measures are applied).

Elsewhere, we refer to projects or the SDLAM mechanism being 'at risk'. This wording is consistent with the Indec (2021) review, where 'at risk' means unlikely to be delivered by 30 June 2024. Outside of the specific 'risk assessment' and 'at risk' categorisation, the term 'risk' is used in its general sense, as per the Oxford English Dictionary, namely 'exposure to the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility.'

Table 2. Risk rating categories used in risk assessments as per AS/NZS ISO 31000:2009, after Mallee Catchment Management Authority 2014, table 7-4 therein).

Risk rating	Definition
Very low	There is no reasonable prospect the project objectives will be affected by the event
Low	The event is a low priority for management but risk management measures should be considered
Moderate–medium	The risk is a moderate priority for management. Risk management measures should be undertaken
High	The risk is a high priority for management. There is a reasonable likelihood it will occur and will have harmful consequences. Risk management is essential
Very high	The risk is a very high priority for management. It is likely to occur and will have very harmful consequences. Risk management is essential

These risk ratings are based on the likelihood of occurrence and the severity of the consequence if the event occurs.

Results

Below, we outline the background, objectives, operation, risk assessments and current status of each of the following four SDLAM projects: Nyah Floodplain Management Project (environmental-works supply project); Koondrook–Perricoota Flood Enhancement Works (environmental-works supply project); Yarrawonga to Wakool Junction Reach

Constraints Management Strategy (constraints-relaxation supply measure); and Enhanced Environmental Water Delivery (operational rule-changes supply measure).

Nyah Floodplain Management Project

Background

The Nyah Floodplain, 30 km north of Swan Hill (Victoria), covers 913 ha of wetland, forest and woodland (Fig. 3; Mallee Catchment Management Authority 2014). Prior to river regulation and water resource development, the floodplain was usually inundated in spring with flows of more than 25 000 ML day^{-1} (Mallee Catchment Management Authority 2014). Increased diversions have reduced flood frequency, duration and extent, causing declines in tree density, condition and extent of wetland habitat (Mallee Catchment Management Authority 2014). The Nyah Floodplain Management Project is one of the nine Victorian Murray Floodplain Restoration Projects, and is estimated to contribute 2.5 GL in offsets (Murray–Darling Basin Authority 2020*b*).

In 2017, the Wentworth Group of Concerned Scientists provided a submission to the MDBA about the SDLAM, which included a set of 12 'conditions for approval' that were considered to be required for supply measures to be consistent with the Basin Plan and for projects to deliver equivalent environmental outcomes with less water (Wentworth Group 2017, pp. 1–2). Each SDLAM project was assessed against the relevant conditions for approval. This project met only two of eight relevant conditions (Wentworth Group 2018).

Objectives and operation

The objective of this project is to protect and restore key species, habitats and ecosystem functions through installation of five regulators and spillways and construction of a 1.7-km-long levee bank at the downstream end of the

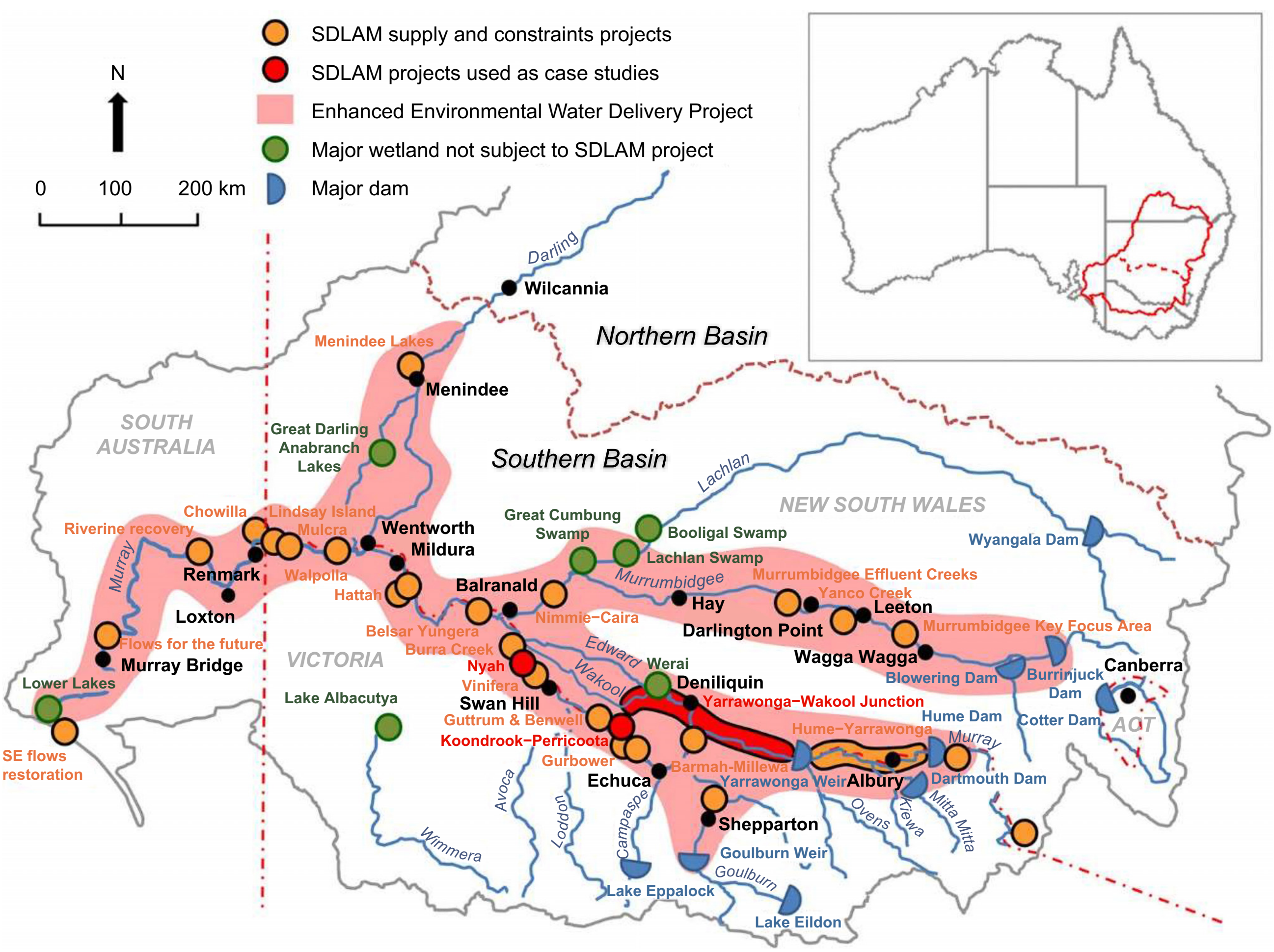

Fig. 3. Location of Sustainable Diversion Limit Adjustment Mechanism (SDLAM) supply and constraints projects in the southern Murray–Darling Basin (based on Murray–Darling Basin Authority 2017*a*, Fig. 4). Note that the Enhanced Environmental Water Delivery Project is one of the SDLAM operational rule changes and system-enhancement projects included as a case study herein but was not listed among the projects agreed by the Murray–Darling Basin Ministerial Council on 16 June 2017 (Murray–Darling Basin Authority 2022).

forest (Mallee Catchment Management Authority 2014; Murray–Darling Basin Authority 2017b; Indec 2021). Modelling has indicated that this infrastructure would allow flooding of ~488 ha (53%) of the floodplain with flows of just 5000 ML day^{-1}. This flood extent would otherwise require flows of 25 000 ML day^{-1} (Mallee Catchment Management Authority 2014).

The project has five broad environmental objectives, linked to those of the Basin Plan, each with quantitative targets and achievement dates between 2025 and 2035 (Mallee Catchment Management Authority 2014). Objectives include restoring a more natural watering regime to river red gum and black box woodlands and providing refugia and breeding habitat for aquatic fauna and waterbirds (Mallee Catchment Management Authority 2014).

Risk assessment

Seventeen threats were identified across the following four categories: salinity and water quality; pest species; ecological function and connectivity; and the conservation of some species to the detriment of others (Mallee Catchment Management Authority 2014). Following mitigation measures, all threats were downgraded to a moderate or low residual risk rating, with hypoxic blackwater events, carp and exotic weeds, habitat disturbance during construction and bushfires all being considered 'moderate' residual risk. In the business case, the Mallee Catchment Management Authority, (2014) considered these residual risk levels to be manageable because the threats were considered well understood and similar risks had been managed in the past. However, the MCMA received SDLAM funding and were thus potentially incentivised to downgrade risk ratings and overstate capacity for their mitigation.

Current status

In 2021, the project was still undergoing environmental approval processes, with construction expected to begin around December 2022 (depending on funding and legislative approvals), and be completed within 6–9 months (Victorian Murray Floodplain Restoration Project 2021).

The 2021 independent review of the SDLAM classed the satus of this project as 'medium risk' (i.e. facing 'normal' risks and likely to be delivered before June 2024 without major intervention; Indec 2021, p. 46). The MDBA noted that the 'physical structures described in the Indec report slightly differ from those that informed the 2017 modelling' and that the significance of changes will be monitored (Murray–Darling Basin Authority 2021b, p. 29).

Koondrook–Perricoota Flood Enhancement Works

Background

Koondrook–Perricoota Forest is located downstream of Torrumbarry Weir on the New South Wales side of the River Murray (Fig. 3). In 2012, 73% of the forest area was assessed as moderately to severely degraded (Cunningham et al. 2013) due to inadequate water availability, particularly during the Millennium Drought (1997–2010). No flooding occurred between 1993 and 2010.

The Koondrook–Perricoota Flood Enhancement Works is one of six projects from The Living Murray program (TLM) carried forward as SDLAM projects (Murray–Darling Basin Authority 2011). Environmental works under TLM were first used in January 2015 (Murray–Darling Basin Authority 2018a, p. 15). Although some outcomes on ecological condition have been reported, a detailed project evaluation has not been published (Dind and Sim 2018).

To our knowledge, no changes were made to these projects for their inclusion in the SDLAM and no environmental monitoring data from them were used to estimate ecological offsets under the SDLAM. This project met only three of eight relevant 'conditions for approval' (Wentworth Group 2018).

Objectives and operation

The flood enhancement works were intended to improve ecosystem condition of the vegetation complex of river red gum forest, black box woodland and floodplain marsh communities (Murray–Darling Basin Authority 2012). The ecological objectives were as follows: 80% of wetlands and 30% of river red gum forest in a healthy condition; successful breeding of colony-nesting waterbirds in at least 30% of years; and healthy populations of native fish (Murray–Darling Basin Authority 2012). The project commenced in 2003 and involved construction of 4 km of channels to divert flows of up to 6000 ML day^{-1} into the forest from Torrumbarry Weir, as well as building 60 km of levee banks and 11 regulators to manage outflows (Department of Water and Energy 2009). These works were proposed to enable flooding of up to half the forest area (16 900 ha) for 3 months (Murray–Darling Basin Authority 2017b, 2021b).

Risk assessment

There are several threats to the operation of this project. In the business case, residual risk levels were classed as 'medium' for the threats of blackwater events, negative effects on hydrology and downstream impacts of erosion (Murray–Darling Basin Authority 2012). Since the business case was published, other threats to successful operation have been identified. Notably, landholder consent for flooding of private land was not secured prior to construction and was subsequently refused (Wentworth Group 2017), resulting in maximum releases of only 250 ML day^{-1}: 20 times less than the planned maximum flows (Hannam 2020; Murray–Darling Basin Authority 2021b). At the time of writing, there is still no workable arrangement among environmental water managers, landowners and New South Wales forests managers for use of the infrastructure. Furthermore, the modelled environmental outcomes for this project contained the assumption that constraints-relaxation measures for

Yarrawonga to Wakool Junction would be fully operational (Murray–Darling Basin Authority 2021*b*, p. 18). This assumption is unlikely to be justified, as this constraints-relaxation measure is deemed 'at risk' (Indec 2021, pp. 14–16).

Current status

This project is classed as 'in operation' because the works have been constructed. However, the works have been operated only twice. In 2015, 26 GL of water was delivered to test the newly constructed works (Murray–Darling Basin Authority 2018*a*). The next operation did not occur until 2019, and delivered only 30 GL, flooding just 11% of the forest area (Murray–Darling Basin Authority 2019*c*). Since the 2017 determination, less than a quarter of ecological objectives for the Koondrook–Perricoota forest have been met each year (Murray–Darling Basin Authority 2019*c*). The infrastructure works have been reported as over-engineered and much larger than required, but are still unable to be used because of planning flaws (Hannam 2020).

In the 2021 SDLAM assurance report, the MDBA acknowledged that the current physical structures are unlikely to deliver the modelled environmental outcomes because of operating constraints (Murray–Darling Basin Authority 2021*b*, p. 19).

Yarrawonga to Wakool Junction Reach Constraints Management Strategy

Background

This reach includes the central Murray and the anabranch system containing the Edward, Wakool and Niemur rivers and their floodplain wetlands, creeks and flood runners (Fig. 3). This area supports ~300 000 ha of irrigated agriculture and contains the towns of Swan Hill, Deniliquin and Echuca (Murray–Darling Basin Authority 2015; Department of Primary Industries 2016). The reach contains the Ramsar wetlands of Barmah and Millewa forests and also the Barmah Choke, where the River Murray narrows and restricts flows to 7000–9000 ML day^{-1} (Murray–Darling Basin Authority 2021*d*). This project met only 4 of 11 relevant conditions for approval (Wentworth Group 2018, p. 9).

Objectives and operation

The main objective of the Yarrawonga to Wakool Junction Reach Constraints Management Strategy is to use environmental flows to reconnect rivers with floodplains and to improve environmental benefits through more effective use of environmental water (Department of Primary Industries 2016, p. iii; Murray–Darling Basin Authority 2021*b*, p. 10). Maximum operating flows downstream of Yarrawonga Weir at the time of the proposal (2015) were set at 15 000 ML day^{-1} to limit flooding of private land (Department of Primary Industries 2016). Constraints management includes negotiation with landholders for flood easements, protection or relocation of infrastructure, maintaining access and preventing damage to assets (Kahan *et al.* 2021). The goal of this project was a maximum regulated flow limit of 30 000 ML day^{-1} below Yarrawonga, with a buffer up to 50 000 ML day^{-1} (Department of Primary Industries 2016, p. 6). Increased flow limits would provide enhanced growth and reproduction of vegetation, waterbirds and fishes, increased biotic diversity and carbon and nutrient transfer between the floodplain and channel (Department of Primary Industries 2016, p. 9). The targeted 30 000 ML day^{-1} would flood 22 900 ha of private land, requiring negotiation of 1513 flood easements (Kahan *et al.* 2021). However, according to the Wentworth Group (2017, p. 14), for this project to be consistent with the Basin-wide Constraints Management Strategy (Murray–Darling Basin Authority 2013*a*) and achieve Basin Plan Schedule 5 outcomes, flow rates downstream of Yarrawonga Weir would need to be relaxed to 50 000 ML day^{-1}, with a buffer of 70 000 ML day^{-1}.

Risk assessment

Constraints-management projects are typically considered to be overwhelmingly beneficial for the environment and have been assumed to have no long-term environmental risks (Wentworth Group 2017). However, in the business case, residual risk was rated 'high' for unintended environmental outcomes from managed environmental flows. Other threats were identified too, with residual risk ratings being 'medium' for reduced land value owing to flooding, insufficient funding for mitigation and compensation for flooding, structural failure preventing delivery of managed flows and inability to deliver the project within the budget (Department of Primary Industries 2016, appendix 10). Furthermore, the likelihood of the project achieving Basin Plan objectives is low, given that the goal of 30 000 ML day^{-1} (Department of Primary Industries 2016) is 20 000 ML day^{-1} below the flow rates recommended by the Wentworth Group (2018).

Current status

The delivery of the project is considered 'at risk' because the threat of major negative effects on private and public lands and infrastructure means that stakeholder agreement on mitigation and compensation is unlikely, and there is little or no incentive for landholders to reach agreement voluntarily. The project is unlikely to be completed within the time available (Murray–Darling Basin Authority 2020*b*, p. 14; Indec 2021, p. 14). Failure 'may have flow-on effects to the capability of other measures to operate as envisaged', including the Koondrook–Perricoota Flood Enhancement Works, as mentioned above (Murray–Darling Basin Authority 2021*b*, p. 25).

Enhanced Environmental Water Delivery (the 'Hydro-cues' project)

Background

This project focuses on improving efficiency of environmental water delivery across the Murray, Murrumbidgee, lower Darling and Goulburn rivers (Fig. 3; Murray–Darling Basin Authority 2017*c*). The basis of the project is that ecological cues for growth of aquatic vegetation, fish spawning and waterbird nesting are triggered by a series of threshold exceedances of flow rates, flood depths and durations, water temperature, carbon and nutrient inputs (Murray–Darling Basin Authority 2017*c*). In anthropogenically modified river basins, these thresholds may never be reached or can be interrupted. For example, a flood may trigger breeding of colony-nesting waterbirds, but breeding can subsequently fail because flood depth and duration is shortened by upstream diversions and hatchlings do not survive long enough to become fully fledged (Arthur *et al.* 2012). This project met only one of four relevant conditions for approval in the Wentworth Group's assessment (Wentworth Group 2018, p. 3).

Objectives and operation

The objective of the Enhanced Environmental Water Delivery project is to improve environmental water delivery by linking environmental water management to ecological outcomes through a 'hydro-cues' delivery strategy (Murray–Darling Basin Authority 2017*a*, p. 36). The project aims to enhance planning and coordination of environmental water use to maximise connectivity and environmental benefits (Murray–Darling Basin Authority 2022). In practice, this means making releases of environmental water from storages to 'piggy-back' on unregulated flows caused by rainfall to increase the magnitude and duration of a flow event (Murray–Darling Basin Authority 2017*c*, p. 1). Modelled flow ranges and anticipated ecological benefits are specific to each river reach (Murray–Darling Basin Authority 2017*c*, table 7 therein), generally including watering of wetlands, with benefits to vegetation, fishes and waterbirds.

Combining constraints relaxation with hydro-cues would enable flows of greater magnitude and duration. This is particularly important for wetlands in the South Australian Murray where frequency of flooding flows has declined markedly, being dependent on combined high flows from across the Basin. Regulated flows of up to 80 000 ML day^{-1} at the South Australian border would offer 'significant environmental, cultural and social benefits' (Murray–Darling Basin Authority 2013*a*, p. 63).

Risk assessment

A detailed risk assessment has not yet been undertaken for this project, but in the business case, threats were identified for the following three categories: governance and project management, operationalising the project and adverse ecological impacts (Murray–Darling Basin Authority 2017*c*, table 14 therein). Residual risk levels were high for 'critical dependencies', including failure to implement the constraints management strategy (CMS) and pre-requisite policy measures (PPMs), and the breakdown of co-operation between project proponents.

The 'critical dependency' on the delivery of the CMS and PPMs is very important. The success of the project is predicated, in part, on the assumption that high flows (at least 80 000 ML day^{-1}) are achievable at the South Australian border. However, this target is based on hydrological modelling and is not grounded in the reality of river operations (Murray–Darling Basin Authority 2013*b*). Limits on flows imposed by river operators from different State jurisdictions are likely to severely constrain such high flows without agreement on, and implementation of, constraints relaxation throughout the region covered by the project. The CMS is considered unlikely to be delivered by June 2024, and without it, this project cannot function as designed (Wilson *et al.* 2019; Murray–Darling Basin Authority 2020*b*).

PPMs are specific State water policies that were determined by governments in 2012 as being necessary to ensure effective use of environmental water. Implementation of PPMs addresses two (unspecified) issues important to this project, but these have not been fully implemented (Slattery and Campbell 2018). Modelled assessments of supply-measure offsets need to be adjusted for PPMs. If models assume that PPMs have been implemented to ensure environmental water is used effectively, but they have not, then more water is required to achieve the same environmental outcomes and adjustment calculations will be incorrect (Slattery and Campbell 2018).

Furthermore, even if the CMS and PPMs were fully implemented, environmental flows may still be inadequate to achieve ecologically effective floods (Chen *et al.* 2021; Colloff and Pittock 2022). Because of the dependency of the project on occasional high natural flow events, a hydro-cues approach cannot operate as a routine, regular basis for environmental water delivery (Wentworth Group 2017, p. 23). Environmental watering of priority wetlands and refugia will still be required during dry years, which are likely to become more frequent under climate change.

Current status

This project in still in its early planning phase. A modelling assessment of the project has been conducted (Murray–Darling Basin Authority 2017*b*, pp. 38–45), but issues yet to be resolved include: (1) detailed planning and operationalisation, including specific risk-mitigation plans; (2) development of a detailed monitoring and evaluation plan; (3) stakeholder engagement processes; (4) ensuring knowledge uptake, transfer and complementarities; and (5) changes to inter-jurisdictional environmental watering planning, management and governance (Murray–Darling Basin Authority 2022).

The project is to be delivered in stages, with Stage 1A intended to define how the project will work, what it can achieve, and how much it will cost. Funding arrangements have not yet been agreed, despite the very short timeframe remaining for delivery of Stage 1A (Murray–Darling Basin Authority 2020*b*, p. 11). A Project Implementation Plan that will scope out Stages 1B and 2 is due in 2022 (Indec 2021).

The delivery of this project is considered 'at risk' because it is technically, legally and operationally complex, with numerous threats that have not been addressed in sufficient detail (Indec 2021, p. 2), including major unresolved issues over long-term, inter-jurisdictional governance arrangements (Wentworth Group 2018).

Discussion

Progress of the SDLAM projects is patchy. In 2021, 30 of the 36 projects were considered 'on track' to be in operation by 30 June 2024, accounting for 74% (445 GL year^{-1}) of the modelled SDLAM offset (Indec 2021, p. 1). Two of our four case studies were considered 'at risk', that is, unlikely to be delivered by June 2024 (Murray–Darling Basin Authority 2020*b*, p. 3, 2021*b*). Furthermore, the 2021 WESA review found that the total funds available for all SDLAM projects (including efficiency, constraints and supply measures) are unlikely to cover the total cost of successfully delivering these projects (Australian Government 2021). This highlights that the entire SDLAM program is under threat, both in terms of time and funding.

Where project delivery differs from agreed proposals, the MDBA must undertake a reconciliation to align water-offset calculations with the delivered package of projects. The process for assurance and reconciliation must be credible and legitimate because the SDLAM assumes that equivalent environmental outcomes can be achieved with less water. This assumption is yet to be demonstrated. Furthermore, the objectives of the *Water Act* 2007 (Commonwealth) and the A$3.1 billion in Commonwealth contributions create a responsibility for scientific rigour. We argue that the reconciliation must account not only for changes to the delivery of SDLAM projects by the due date (as required under the Basin Plan), but must also address problems in the SDL-adjustment calculation method. This will ensure that any SDL adjustment reflects a credible assessment of the environmental outcomes that can be achieved.

The SDL reconciliation modelling process

The Basin Plan details the initial process for adjustment to surface-water SDLs (Commonwealth of Australia 2012, Chapter 7, Part 2, Division 4) and the default method (Schedule 6) for calculating the supply contribution. The reconciliation determination must be based on the same concept of 'equivalent environmental outcomes' as the original determination, comparing modelled environmental outcomes under benchmark conditions to those under the SDLAM. The default method for this comparison is the Ecological Elements Method (EEM), developed by the CSIRO (Overton *et al.* 2014). The EEM assesses environmental equivalence at 'indicator sites' across the Basin (Fig. 4). Preference curves are used to score an outcome for an 'ecological element' (e.g. fishes, waterbirds or vegetation) on the basis of its likely response to flow or flood characteristics. Combined scores from multiple preference curves at indicator sites are then added to obtain composite scores for catchments or regions (Overton *et al.* 2014, p. 5).

There are significant flaws in the assurance and reconciliation processes that endanger the validity of any new SDL determination made under these reconciliation processes, as outlined below. In the monitoring and assessment of ecological outcomes of environmental flows, there are considerable pressures of time and resources on government agencies to undertake simple, desktop-based assessments of complex ecological and hydrological events and outcomes, based on untested assumptions, and to generate aggregated, quantitative scores for ecological processes that may, in reality, be incommensurate and hard to quantify in any ecologically meaningful way. Arthington *et al.* (2006, p. 1311) stated that 'there is a growing temptation to ignore natural system complexity in favour of simplistic, static, environmental flow 'rules' to resolve pressing river management issues'. With any environmental assessment process based predominantly on models that have not been verified empirically, there is a high risk that assumptions based on subjective judgements will lead to biased assessments (Kloprogge *et al.* 2011).

Reconciliation timeline and lack of empirical data use

Rigorous assurance requires that the achievement of 'equivalent environmental outcomes' be demonstrated with empirical evidence. However, the reconciliation timeline precludes such an assessment for many projects. The Indec (2021) review showed variation in the status of SDLAM projects; 15 are 'in operation', two are in the 'works stage' (i.e. under construction), and 19 remain in 'early' or 'design' stages (Indec 2021, p. 25). SDLAM projects are required to be operational by 30 June 2024, the same date that any adjustments to the SDLs under a reconciliation must be announced. Assurance of projects to determine whether a reconciliation is needed has been occurring since 2021, and a new SDL determination would be decided between 31 December 2023 and 30 June 2024 (Murray–Darling Basin Authority 2021*c*). Under this timeline, both assurance and the new determination must occur before the

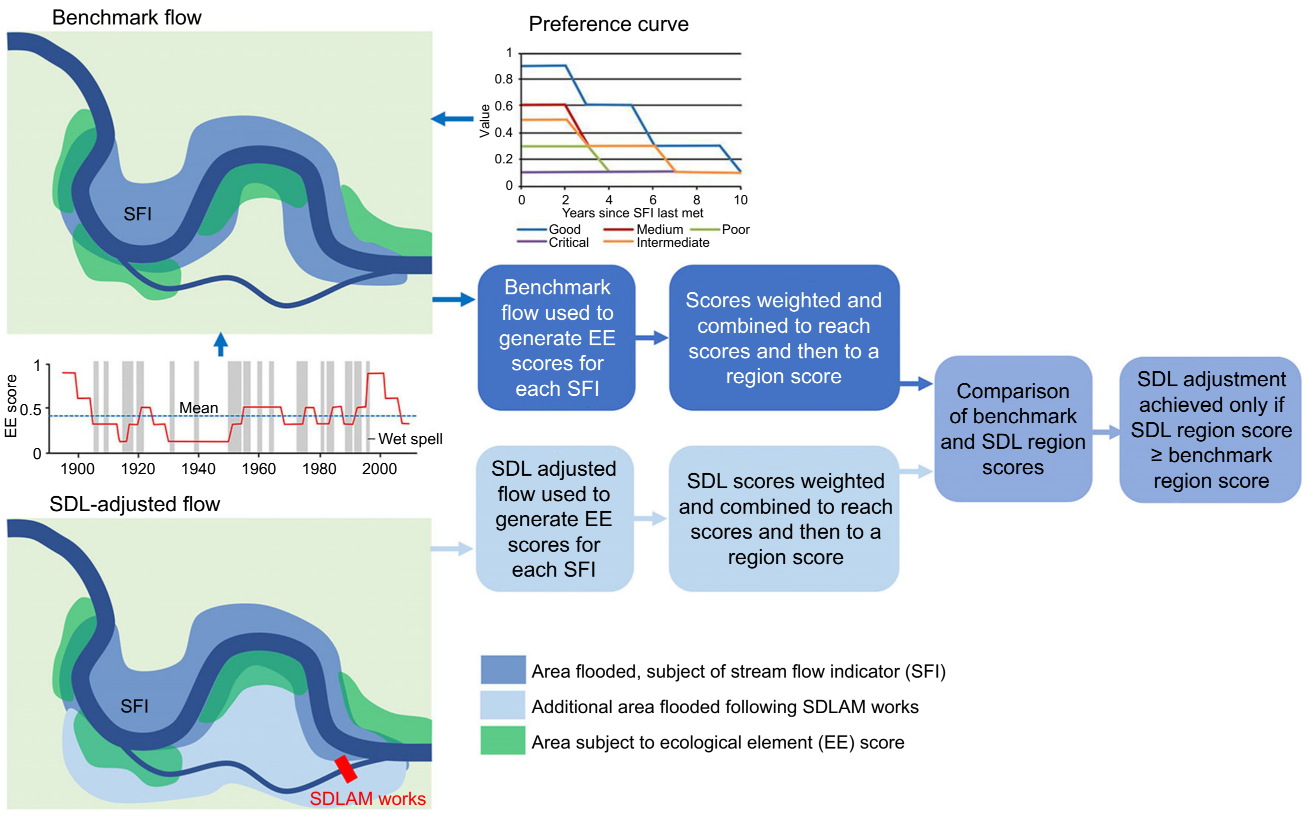

Fig. 4. The Ecological Elements Method. Benchmark scores for each Ecological Element (EE; eight in total for ecological classes of vegetation, fishes and waterbirds) are based on preference curves: simple models of whether water requirements for a particular EE have been met. Scores are calculated within the reach for which a stream flow indicator (SFI) applies, on the basis of flow metrics for a time series (from 1895), according to whether the SFI was met. Scores are weighted by area for which the EE applies and normalised to total area per reach. The three ecological-class scores per reach are averaged to give a reach and region score. The process is repeated to assess the effect of changes in flooding caused by construction of SDLAM environmental works. If the SDL-adjusted region score is lower than the benchmark score, equivalent environmental outcomes have not been achieved and there is no SDL adjustment. See Overton *et al.* (2014) for more detail.

date that the projects are required to be in operation. With so many projects still in the early or design stages, rigorous assurance within the 2021–2023 window is extremely difficult. The Enhanced Environmental Water Delivery project is still at Stage 1A, lacking such basic details as funding arrangements and detailed risk-mitigation strategies (Murray–Darling Basin Authority 2022). The Nyah Floodplain Management Project and the Yarrawonga to Wakool Junction Reach CMS also remain at the 'design stage'. For projects still in their initial phases, rather than using empirical data on the achievement of environmental objectives, the MDBA must make a judgement of the degree of project operationality and use this to inform their decisions of whether a reconciliation is needed and to assess the supply contributions.

Even for 'in operation' projects, there is limited evidence of empirical data being used for assurance. The Koondrook–Perricoota Flood Enhancement Works have been 'in operation' since 2015, allowing collection of extensive data on environmental outcomes, including the response of flora and fauna to flooding events (Murray–Darling Basin Authority 2018*b*, 2020*a*). The most recent MDBA assurance report (Murray–Darling Basin Authority 2021*b*), included a specific case study of the Koondrook–Perricoota Flood Enhancement Works. However, the available empirical data on environmental outcomes were not mentioned. Instead, the assurance report relied on flow-rate data and use of existing models to make a judgement that the limited inflows meant that this measure 'is not currently capable of supporting the ... environmental outcomes on which the 2017 SDLAM determination was based' (Murray–Darling Basin Authority 2021*b*, p. 19). The announcement of new 'flow enabling works' to address the inflow problems at this site demonstrates an assumption that the delivery of the modelled water volume will guarantee achievement of the envisaged environmental outcomes. This assumption has not been demonstrated with any empirical evidence.

Residual risks not accounted for

A further challenge to the validity of SDL adjustment calculations is that assessment of environmental equivalence under the Basin Plan does not account for the residual risks of SDLAM projects. For environmental outcomes to be 'equivalent', the risks and benefits of the SDLAM projects must be comparable with the risks and benefits of delivering the full 2750 GL of environmental water. The default method based on EEM assesses equivalence of benefits but not risks (Fig. 4), with no penalties for heightened risks in projects (Wentworth Group 2017). Across the four case studies, there are 14 threats with ecological consequences classed as having a medium or moderate residual risk and one with a high residual-risk rating (Department of Primary Industries 2016; Murray–Darling Basin Authority 2017*c*). These include ecological threats directly caused by the SDLAM measures such as blackwater events (Murray–Darling Basin Authority 2012, 2017*c*).

The authors of the EEM were clear about this limitation: environmental equivalence is calculated 'under the assumption that supply measures will be operated under best practice. Outcomes of limited fish passage, limited carbon exchange, prolonged inundation causing drowning and blackwater events etc, would reduce the ecological score but are not represented in the method' (Overton *et al.* 2014, p. 145). This lack of representation of negative outcomes is a significant problem that prevents rigorous assessment of environmental equivalence, invalidating offset calculations made under this method.

Limitations of the EEM – uncertainty in ecological requirements

The EEM is a 'highly modified construct and does not attempt to model actual health of ecological elements . . . in the field' (Overton *et al.* 2014, p. iii). It uses stream-flow indicator metrics to assess whether water requirements for biota have been met. Knowledge of such water requirements is incomplete and preference curves may be based on 'expert opinion'.

The extent and composition of vegetation communities differ among wetlands subject to SDLAM projects, yet the EEM uses generalised categories of ecological elements, such as 'tall grasslands, sedgelands and rushlands' to assess whether water requirements have been met (Fig. 4). However, aquatic grasses such as spiny mud grass (*Pseudoraphis spinescens*) and water couch (*Paspalum distichum*) have completely different water requirements from sedges such as common spikerush (*Eleocharis acuta*), which are different again from those for cumbungi (*Typha* spp.) and common reed (*Phragmites australis*; Roberts and Marston 2011). This approach is a typical example of overlooking ecosystem complexity in favour of simplistic assumptions and generalisations.

Furthermore, stream-flow indicators cannot reflect the detail of the flood regime (frequency, duration, depth, extent and magnitude) required to ensure maintenance in condition as well as reproduction and recruitment (Overton *et al.* 2014, p. 47). Preference curves cannot be used to account for ecological responses of all life-cycle stages of a species or group of organisms, or to assess ecological processes of flow-dependent ecosystems because 'the method is a highly simplified hydro-ecological model' (Overton *et al.* 2014, p. 144). Therefore, the delivery of modelled water volumes may fail to achieve the expected environmental outcomes, leading to an over-estimation of the environmental offsets achieved.

Cumulative and indirect effects not considered

The default method requires assessment at 'indicator sites', which means environmental equivalence is modelled without accounting for cumulative and indirect effects of the SDLAM as a whole. Such an assessment would include careful and explicit consideration of whether PPMs had been fully and effectively implemented. Reducing environmental water by 605 GL creates effects across the entire southern Basin that cannot be adequately assessed by a small number of individual sites. Although it might be argued the indicator sites are representative of expected outcomes at a broader scale, this assumption has not been tested and a rigorous evaluation of the effects of SDLAM projects at the scale of the entire southern Basin is lacking. The project-by-project nature of SDLAM offset calculations and assurance allows for exclusion of these broader impacts. There are particular concerns about the detrimental effects of reduced flows to the Coorong, Lower Lakes and Murray Mouth, as observed river flows were significantly lower than expected flows modelled by the MDBA (Wentworth Group 2020; Environmental Justice Australia, Environmental Defenders Office and Wentworth Group of Concerned Scientists 2021).

Climate change excluded from modelling

Offset calculations under the SDLAM do not account for climate change, despite the MDBA claiming that the Basin Plan 'currently addresses the risks of climate change' (Murray–Darling Basin Authority 2019*d*, p. 3). Under the Basin Plan (Commonwealth of Australia 2012; S7.15, 1(a)), modelling for SDL determination must be based on 'a repeat of historical climate conditions' (defined as 1895–2009), despite clear evidence that climate change is having significant impacts within the Basin (Prosser *et al.* 2021; Whetton and Chiew 2021; Colloff and Pittock 2022) and discussion of these impacts by the MDBA (notably Murray–Darling Basin Authority 2019*d*). Failure to consider climate change in setting the SDLs for the Basin Plan was found to be unlawful under the *Water Act* 2007 (Commonwealth) (Walker 2019, p. 56). The 2020 Basin Plan Evaluation report stated that annual inflows to the River Murray have declined by 39% in the last two decades, and are expected to continue to decline (Murray–Darling Basin Authority 2020*c*, p. 21). Climate-change impacts are likely to create a variety of barriers to the achievement of environmental outcomes under SDLAM projects. For example, reduced river inflows and more frequent droughts pose a large threat to the operation of the Enhanced Environmental Water Delivery project. With more dry years predicted under climate change, natural flow events suitable for 'piggy-backing' will be less frequent, reducing the opportunities to apply the hydro-cues strategy. Excluding climate change from SDL adjustment volumes makes achievement of the envisaged environmental outcomes unlikely and further invalidates the calculated offset volumes.

Towards a scientific evaluation: policy options from results-based management

One option for addressing the above concerns is to apply the results-based management framework. This framework was developed for assessment of complex, results-based public policy implementation and has been widely applied in evaluation of international development projects by the Organisation for Economic Co-operation and Development (OECD; Mayne 2007; Zwart 2017; Vähämäki and Verger 2019). This framework is particularly useful in the context of SDLAM assurance and reconciliation because it provides simple categories, namely outputs, outcomes and impacts, which align very closely with the three assurance criteria already set by the MDBA (Table 3). Therefore, it provides an opportunity for the MDBA to conduct a more credible evaluation of the SDLAM without requiring a total redesign of the approach to evaluation. The extended monitoring period would also provide the necessary data and time to allow modelling outcomes to be independently audited. The incoming Government has promised to establish a new National Water Commission (Butler 2022), who would be well suited to conduct such an audit.

Table 3 contrasts the types of indicator that the MDBA is likely to rely on for a 2024 reconciliation with the types of indicator that would be used under a results-based management framework. This framework requires long-term collection and use of empirical data, well beyond the current reconciliation timeline. Data on environmental outcomes over this time would inherently reflect the impacts of climate change and residual risks, while also allowing for ecological water requirement models and estimates to be ground-truthed. Careful application of this framework would address the concerns we have raised with the existing methodology, and allow the MDBA to rigorously evaluate whether equivalent environmental outcomes can be achieved under the SDLAM.

Conclusions

The SDLAM is an attempt to address a challenge shared by many river basins worldwide: how to improve environmental outcomes while water resources face increasing pressure from consumptive users and climate change. It is essential that the evaluation of this program is able to accurately represent the environmental outcomes achieved.

Table 3. SDLAM assurance criteria within the respective OECD result categories.

Type of result	OECD definition	Stated SDLAM assurance criteria	Expected MDBA indicators of success	Suggested indicators under result-based management	Timeframe for assessment of results-based indicators
Outputs	Products, capital goods and services from interventions	Will the SDLAM projects be in operation by 30 June 2024?	Infrastructure is built. Required rules changes have implemented	All works and measures completed. Rule changes in use	At completion (June 2024)
Outcomes	Likely or actual short- to medium-term change and effects on outputs of an intervention	Will the SDLAM projects deliver the expected adjustment volumes?	Infrastructure functions as intended and positive project interactions are achieved 2750-GL equivalent achieved through buybacks and offsets	Proposed flow regimes achieved. Short-term ecological outcomes met (e.g. breeding events of birds and fishes)	2–5 years (2026–2029)
Impacts	Positive and negative, primary and secondary, long-term effects of interventions	Will the SDLAM projects deliver expected environmental outcomes?[A]	Environmental benefits likely to be achieved (based on modelling). Area inundated meets expectations (modelled)	Empirical evidence of long-term ecological outcomes at SDLAM project sites and Basin-scale. Ongoing stakeholder support for SDLAM projects	10+ years (2034 and beyond)

Expected MDBA indicators for assurance (based on previous actions and assurance reports) are compared with authors' suggestions for best-practice indicators. Sources: Organisation for Economic Co-Operation and Development (2002, pp. 24, 28); Murray–Darling Basin Authority (2021*b*, Table 3); Murray–Darling Basin Authority (2021*c*, p. 7).

[A]Note that the MDBA's 'environmental outcomes' (as defined in the Basin Plan) are best understood as 'impacts' in the OECD framework.

Current evaluation methods contain an assumption that delivery of outputs (i.e. SDLAM projects are in operation) guarantee the achievement of equivalent environmental outcomes. This assumption is unlikely to be true for the reasons we have discussed, namely environmental outcomes are not being proven with empirical evidence, residual risks are not accounted for in offset calculations, ecological water requirements are not sufficiently understood or represented in modelling, cumulative and indirect effects of the SDLAM across the Basin are not considered in offset calculations, and climate change effects are not considered.

A reconciliation conducted using the default method outlined in Schedule 6 of the Basin Plan carries a very high level of uncertainty because it requires inputs of incomplete data to a flawed model, which is then treated as a reliable indication of the environmental results of the SDLAM projects. Environmental outcomes and, subsequently, offset volumes are likely to be overestimated. We consider that the set methods for assurance and reconciliation are not capable of producing a credible and legitimate assessment of the achievement of environmental equivalence under the SDLAM.

However, we do not support delaying a new determination. The 2024 reconciliation should occur so that incomplete projects are removed from the SDLAM offset volumes. However, the 2024 reconciliation should implement improved models that account for residual risks, climate change and Basin-wide effects. For those projects where it is available, empirical data must be used to demonstrate equivalence of environmental outcomes.

After the 2024 reconciliation, the results-based management framework should be applied, with ongoing environmental monitoring of outcomes and impacts used to regularly confirm or adjust offset volume calculations and SDLs. This empirical data can also be used to calibrate existing models, allowing for more accurate prediction of environmental results in situations where direct monitoring is not feasible. SDLs need to reflect the changing reality of human use, climate and SDLAM projects within the Basin. A once-off adjustment under a 2024 reconciliation is insufficient; ongoing flexibility and careful use of results-based information is needed.

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