NSW GOVERNMENT Natural Resources Commission

Improving outcomes in the Lower Darling-Baaka River: advice to the Connectivity Expert Panel

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Enquiries

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Acknowledgement of Country

The Natural Resources Commission acknowledges and pays its respects to Aboriginal nations, communities, people and traditional owners, past and present and future, for whom the Lower Darling-Baaka River is significant. The Commission recognises and acknowledges that Aboriginal people have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. We value and respect their knowledge in natural resource management, and the contributions of many generations, including Elders, to this understanding and connection.

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Summary

Context

As part of the NSW Government's response to the Office of the NSW Chief Scientist and Engineer's (OCSE) report into the 2023 fish deaths at Menindee, the Minister for Water requested the Natural Resource Commission (the Commission) to undertake specific analysis of the water quality and environmental water needs of the Lower Darling-Baaka River as part of its review of the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources 2016.

The Connectivity Expert Panel requested that the Commission provide its initial analysis regarding these issues, including an approach for determining the volume of a priority storage reserve, which may be used to inform revisions to the Menindee Lakes trigger. This trigger seeks to increase inflow into the Menindee Lakes, when needed, by restricting the take of floodplain harvesting in upstream valleys of the northern Basin.

The Menindee Lakes trigger should be underpinned by latest information on environmental needs

- The 195 GL volume of the Menindee Lakes trigger reflects outdated minimum daily flow requirements that have been in place for over two decades. The existing minimum daily flows are not adequate for supporting the basic river health of the Lower Darling-Baaka River.
- Latest information regarding the environmental needs of the Lower Darling-Baaka should underpin revisions to the Menindee Lakes trigger i.e., the priority storage reserve in the lakes should include revised minimum daily flows and the Lower Darling Environmental Water Allowance (EWA). This allowance should be available when the lakes are under NSW control and when they are managed as a shared resource by the Murray-Darling Basin Authority (MDBA). For clarity the Lower Darling EWA should be relabelled as the Lower Darling-Baaka Water Quality Allowance to clearly indicate its purpose.
- Proposed minimum daily flows and Lower Darling EWA require a minimum of 204.4 GL/year (not including losses and potential top-ups of the EWA). This is an additional 108.8 GL/year more than existing minimum daily flow requirements when the lakes are under NSW control (additional 78.1 GL of minimum daily flow per year plus 30 GL EWA).
- Proposed minimum daily flows are informed by recent river operations aimed at mitigating persistent thermal stratification in the Menindee weir pool (upstream of Weir 32). For high risk periods, proposed minimum daily flow rules more than double the existing minimum (750 ML/day versus 350 ML/day) but remain within the baseflow environmental water requirement (EWR) flow categories for the Darling River upstream Weir 32, as described in the Murray-Lower Darling Long Term Water Plan (LTWP).
- There will be periods when proposed minimum daily flows cannot be met (as has been experienced during the term of the NSW Murray and Lower Darling Plan), particularly given climate change projections. The Minister for Water can exercise discretion over the minimum daily flow releases and could do so during drought periods when the lakes are approaching dead storage. A process should be established for these events which requires concurrence between the NSW Minister for Water and the NSW Minister for the Environment to determine the revised volume of water available for the environment, allowing for consideration of critical human needs. During these

events a Water Quality Working Group chaired by NSW DCCEEW-Water should advise on appropriate release rates.

- Under certain circumstances, such as dry conditions or when there are elevated risks of poor water quality events, consideration should be given to enabling top up of the Lower Darling EWA from inflows when the EWA has been depleted to a specified level. For instance, in some years additional pulses of water may be required beyond the 30 GL EWA to mitigate a water quality issue.

Giving effect to environmental provisions to support the Lower Darling-Baaka River requires changes to State and interjurisdictional instruments and agreements

- Operationalising the proposed rules to improve environmental outcomes in the Lower Darling-Baka River requires changes to NSW water sharing plans for the Murray-Lower Darling and upstream valleys, as well as the WaterNSW Work Approval for the NSW Murray and Lower Darling Regulated Rivers.
- Amendments to the Murray-Darling Basin Agreement and the Objectives and Outcomes for River Operations for the River Murray system document are also required to alter the arrangements for the shared water resource, and to operationalise proposed revised minimum daily flows when the lakes are being managed as a shared resource.
- Proposed provisions will require consultation with the Basin Officials Committee and the Ministerial Council given they will have implications for the management of the Menindee Lakes as a shared resource and require changes to interjurisdictional agreements. It is anticipated that these issues would be explored as part of a review of Menindee Lakes management that is being led by the MDBA.
- The revised environmental provisions require an increased volume of water to be stored and released from the upper lakes (lakes Wetherell, Pamamaroo). Reducing or removing lower priority demands from the upper lakes (such as demands from the shared resource) would assist in supporting environmental requirements in the Lower Darling-Baaka River, particularly the reach between the upper lakes and Weir 32. The upper lakes should be reserved for high priority commitments. Only minimum daily flow reuse and water in the lower lakes should be available to the shared resource.
- If interjurisdictional agreement is not achieved, NSW should encourage management of the shared resource to continue to maximise stored volumes in the upper lakes and expand the use of surcharging the upper lakes when appropriate. Further, NSW should encourage operational flexibility to allow the shared resource to be delivered from the upper lakes at a rate that achieves the revised minimum daily flows. For example, there could be scope to deliver the shared resource from Lake Cawndilla if infrastructure options allowed for connection to the Lower Darling-Baaka River.
- Between 29 May – 19 June 2024, around 45 GL of water was released to the Lower Darling-Baaka River from the upper lakes as a Northern Connectivity flow trial. This water was delivered when the lakes were being managed as a shared resource. In addition to providing for connectivity between the northern and southern Basin, it also helped flush high algal loads in the Lower Darling-Baaka River, which had triggered red alerts at several algal monitoring sites for a period of weeks. There is a need to codify this type of release and appropriate water quality triggers (based on condition of inflows) in the water sharing plan and to ensure it is protected under interjurisdictional agreements and not reregulated for other water users.

The volume of a priority storage reserve should be calculated based on a water balance equation. A range of scenarios should be developed to identify risks associated with priority needs supply shortfalls

- Priority storage reserves are the primary mechanism for providing for priority needs into the future. In other valleys, the volume of the reserve generally seeks to supply priority needs during severe drought over a two-year period. While other rule changes can improve deliverability of priority needs under certain circumstances, the use of the priority reserve seeks to improve deliverability under most foreseeable circumstances.
- The volume of a storage reserve for priority needs should be based on a water balance equation using principles from the NSW DCCEEW-Water resource assessment process.
- The volume of priority storage reserves are generally based on conservative principles to ensure the reserves can supply priority needs even during dry periods. However, when using these conservative principles to calculate the volume of the reserve for the Lower Darling-Baaka the volume required exceeds the total storage capacity of the upper lakes.
- The lower-risk profile associated with priory supply shortfalls used in other valleys is likely not able to be applied to the Lower Darling-Baaka. There will likely need to be a higher 'agreed level of risk' of supply shortfalls for priority needs.
- The ability to meet priority needs could be prolonged by maintaining the upper lakes as full as possible including potentially normalising the practice of surcharging, reducing or removing lower priority demands, infrastructure improvements and increasing inflow through trigger conditions.
- However, even with these steps implemented, the risk of being unable to provide for environmental needs in the Lower Darling-Baaka is likely considerably higher than in other valleys in the northern basin. An approach which relies more heavily on inflow based on a broader suite of water reforms across the northern basin would be required to reduce the risk of priority need supply shortfalls to levels that align with risks in other valleys.
- Hydrological models should be used to inform the volumes of a priority reserve. Model enhancements are required to better represent current conditions as well as proposed rule changes.

Considerations for evaluating potential social, cultural, and economic benefits and impacts

- Proposed rule changes seek to improve environmental outcomes by providing water for basic ecosystem needs. This is consistent with the principles of the *Water Management Act 2000,* which prioritise the water source and its dependent ecosystems, and basic landholder rights.
- Water quality improvements intended by proposed rule changes are expected to deliver broader benefits for the community, including Barkandji traditional owners. However, it is difficult to quantify potential social, cultural and economic benefits and impacts given a lack of data and access to updated hydrological modelling.
- Key areas for assessing benefits and impacts of proposed rules include:
    - Impacts associated with increased drawdown from the upper lakes and other changes to upper lake operations.
    - Implications of surcharging the upper lakes, including infrastructure safety constraints, protection of cultural values and sites of cultural significance as well as environmental values and water quality.
    - Potential economic impacts from changes to allocation reliability of the shared consumptive pool (including NSW and Victorian Murray general security licence holders) and water users in the Lower Darling-Baaka River.

1 Introduction

The Natural Resources Commission (the Commission) is reviewing the *Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources 2016* (the Plan) as required under Section 43A of the *Water Management Act 2000* (the Act) (see **Appendix A**). The review assesses the extent to which the Plan has achieved social, economic, environmental and cultural outcomes.

The Plan, which is due to expire on 30 June 2026, applies to two NSW regulated river water sources including:

- Lower Darling Regulated River Water Source[1]
- NSW Murray Regulated River Water Source.

Menindee Lakes and the Lower Darling-Baaka River form part of the Lower Darling Regulated River Water Source.

The Lower Darling-Baaka River has experienced multiple significant poor water quality events, algal blooms and mass fish deaths during the term of the Plan. Most notably, millions of native fish died in the summer of 2018-19, and in March 2023 an estimated 20 to 30 million fish perished in a mass fish death event. The March 2023 event at Menindee was the largest mass fish death event in recorded history in the Murray-Darling Basin, comprising largely native bony bream (*Nematalosa erebi*).[2]

Several reviews have examined the causal factors of the fish deaths including (but not limited to) the Office of the NSW Chief Scientist and Engineer's (OCSE) independent review of 2023 fish deaths,[3] and the Vertessy[4] and Australian Academy of Science[5] reviews of 2018-19 fish deaths. Water diversion in the northern Murray-Darling Basin, river regulation, operation of Menindee Lakes for water efficiency and barriers to fish movement were identified as contributing factors along with extremes in drought and flood conditions.

River regulation and water resource development in the northern Basin have fundamentally altered the flow regime of the river and impacted key environmental assets of the Lower Darling-Baaka River, particularly in the last two decades. The health of Lower Darling-Baaka river system and its dependent ecosystems has declined significantly as a result of these stressors. These impacts have also been felt by the community, including the Barkandji Traditional Owners.[6]

1.1 Expediting advice on the Lower Darling-Baaka River and Menindee Lakes

The OCSE fish deaths review recommended prioritisation of the review of the NSW Murray and Lower Darling Water Sharing Plan, particularly 'the adequacy of Plan provisions for

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1 The Lower Darling Regulated River Water Sources includes the Lower Darling-Baaka River and Menindee Lakes to the upper limit of Lake Wetherell.

2 ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.

3 ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.

4 Vertessy, R., D. Barma, L. Baumgartner, S. Mitrovic, F. Sheldon, and N. Bond. (2019) *Independent assessment of the 2018/19 fish kills in the lower Darling: final report*.

5 ..... Australian Academy of Science (2019) *Investigation of the causes of mass fish kills in the Menindee Region NSW over the summer of 2018–2019*

6 Ellis, I., Bates, B., Martin-Bates, S., McCrabb, G., Hardman, D., Heath, P., and Koehn, J. (2022) How fish kills affected traditional (Barkandji) and non-traditional communities on the Lower Darling Baaka River. *Marine and Freshwater Research* 73, 259-268.

meeting environmental and water quality objectives.'[7] The impacts of water quality issues can be far reaching and affect a broad range of values and stakeholders. As well as supporting water dependent ecosystems and ecosystem functions, the Plan's water quality objectives also relate to maintaining water quality within suitable ranges for:

- Aboriginal cultural use
- basic landholder rights
- town water supply
- licensed domestic and stock purposes
- recreational uses
- agriculture
- surface water dependent businesses.

The Commission is cognisant of the urgency to evaluate and address the existing water sharing plan provisions for managing water quality events and the health of the Lower Darling-Baaka River. Plan amendments are required before the Plan expires on 30 June 2026 to support improved outcomes, particularly in the Menindee weir pool (upstream of Weir 32).

The Commission engaged experts with knowledge of the Lower Darling-Baaka River and its water needs in the fields of water quality, algae and fish ecology to inform advice on provisions for the Lower Darling-Baaka River.[8] In addition, the Commission considered public submissions, reviewed literature, conducted targeted interviews, and considered relevant state-wide and regional policies and agreements in line with the Commission's evaluation framework for the review of water sharing plans.[9]

Changes to the Plan rules are critical but will not on their own result in improved environmental health of the Lower Darling-Baaka. Additional interventions including infrastructure upgrades and changes to water sharing arrangements in the northern Basin are required to improve system connectivity and environmental, social and cultural outcomes in the Lower Darling-Baaka River. It is anticipated that other initiatives occurring in parallel with the Commission's review of the Plan will provide a pathway towards addressing some of these issues, including the NSW Government's initial[10] and full response[11] to the OCSE fish deaths review report and advice from the Connectivity Expert Panel (see **Section 1.2**).

1.2 Provision of advice to the Connectivity Expert Panel

In September 2023, the NSW Minister for Water convened the Connectivity Expert Panel to provide advice on the adequacy and potential improvements to rules in northern Basin

[7] ..... Recommendation 1.3 of the OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.
[8] ..... The Commission engaged Dr Darren Baldwin, Rivers and Wetlands; Iain Ellis, Millewa Pumping; and Dr Simon Mitrovic, University of Technology, Sydney to inform its advice on the Lower Darling-Baaka River.
[9] ..... Natural Resources Commission (2022) *Evaluation framework for the review of water sharing plans under Section 43A of the Water Management Act 2000*, Sydney, D22/3364
[10] ..... NSW Department of Climate Change, Energy, the Environment and Water(2023) *NSW Government response: Office of Chief Scientist and Engineer independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee* (released November 2023)
[11] ..... NSW Department of Climate Change, Energy, the Environment and Water(2024) *NSW Government response: Office of Chief Scientist and Engineer independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee* (released June 2024)

water sharing plans that might improve hydrological connectivity.[12] This includes advice on the adequacy of a Menindee Lakes "critical dry conditions" trigger for restricting extraction in the northern Basin when the upper lakes falls below 195 GL.[13] The Panel's interim advice, which was published 18 April 2024, indicated further work was required on reviewing this trigger.[14]

The Panel sought advice from the Commission while it was reviewing the Plan on an evidence-based approach for specifying trigger conditions that restrict lower priority take in upstream valleys in order to provide for critical needs in the Lower Darling-Baaka River and support connectivity outcomes. Guidance on estimated volumes needed to be stored for critical needs in the Menindee Lakes was requested.

Advice provided by the Commission to the Panel relates to a subset of provisions within the scope of the Commission's Plan review. Specifically, these include provisions that require release of water from the upper lakes of the Menindee Lakes System to improve outcomes in the Menindee weir pool reach upstream of Weir 32 (particularly from Menindee Main Weir downstream to the junction with Menindee Creek) where recent mass fish death events have occurred. Typically, these releases would also result in improvements in conditions further downstream along the Lower Darling-Baaka River.

The Commission's advice is based on an understanding that critical needs vary along the length of the Lower Darling-Baaka River. Which of the lakes releases are made from, and the water quality of releases are important considerations in providing for critical environmental and human needs. For example, needs of the Lower Darling-Baaka River upstream of Menindee Creek junction can only be met via releases from lakes Pamamaroo and Wetherell outlets.

Advice to the Panel covered in this document includes:

- an overview of the Menindee Lakes System (MLS) and complexities in managing the lakes including interjurisdictional arrangements (see **Chapter 2**)
- inadequacies of existing Plan provisions (see **Chapter 3**)
- improvements to environmental provisions that require storage and release of water from the upper lakes (see **Chapter** [illegible])
- inadequacies of the 195 GL Menindee Lakes trigger for meeting priority needs of the Lower Darling-Baaka River (see **Chapter 0**)
- a transparent, evidence-based approach to identifying the volume of a priority storage reserve (**Chapter 0**)
- insights arising from the storage reserve scenario analysis (**Chapter 7**)
- the importance of updated modelling to underpin a reserve volume and trigger conditions (**Chapter 8**)
- considerations for evaluating potential social, cultural and economic impacts associated with proposed rule changes (**Chapter 9**).

[12] ..... NSW Department of Climate Change, Energy, the Environment and Water(2023) *Connectivity Expert Panel - Terms of Reference*.

[13] Part of the Panel's scope is to assess the adequacy of the Menindee Lakes trigger for restricting upstream supplementary, floodplain harvesting and A, B, and C licence extraction when the upper Menindee Lakes reaches 195 GL active storage. This volume currently represents what is needed for one year of minimum daily flow requirements plus 'average' evaporative losses. The Panel is seeking advice from the Commission as part of the Plan review on this volume and whether rules should differ based on best available evidence.

[14] ..... Connectivity Expert Panel (2024) *Connectivity Expert Panel Interim Report*

2 Menindee Lakes and Lower Darling-Baaka River

2.1 Overview of Menindee Lakes

The Menindee Lakes Storage in far western NSW comprises five main lakes (Wetherell, Tandure, Pamamaroo, Menindee and Cawndilla), several smaller lakes and an array of infrastructure including inlet and outlet regulators and weirs (see

No.	Name	No.	Name
1	Old Town weir	6	Pamamaroo outlet regulator
2	Menindee inlet regulator	7	Wetherell outlet regulator
3	Menindee outlet regulator	8	Main weir
4	Weir 32	9	Cawndilla outlet regulator
5	Pamamaroo inlet regulator		

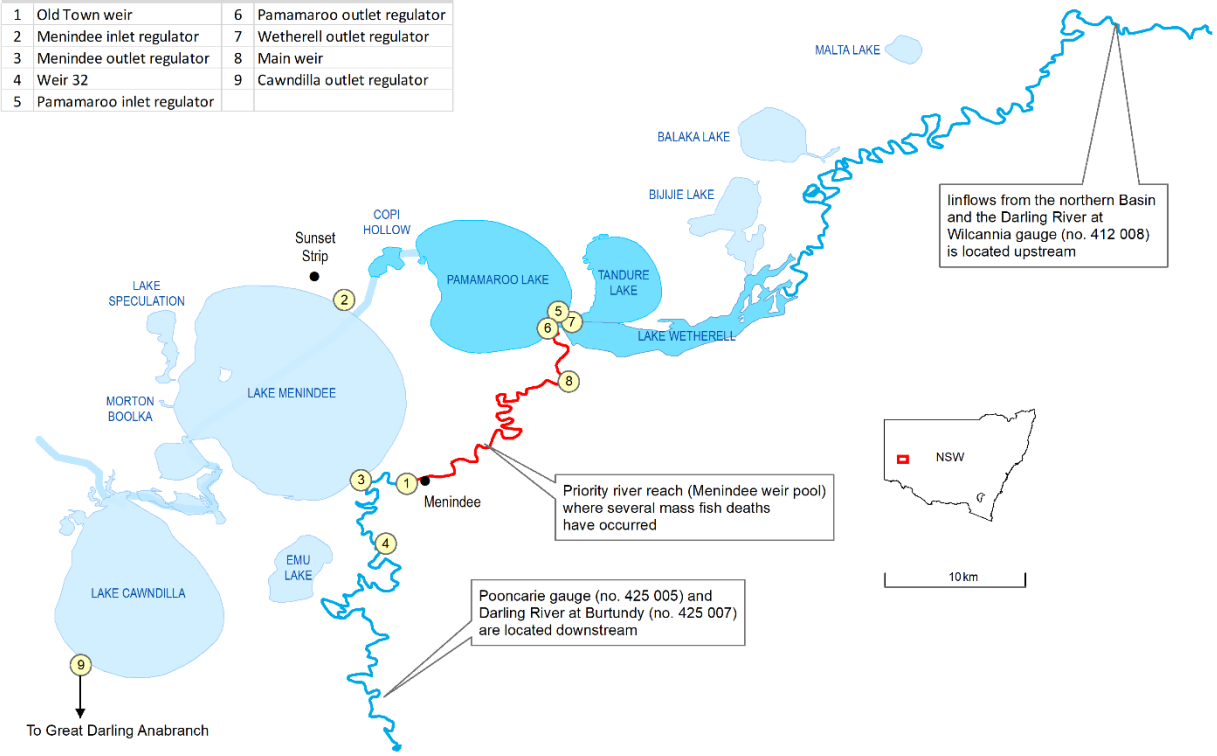

Figure *1*). These lakes have active storage (water that can be released via regulating structures) and dead storage (water remaining below the outlet point after the storage is drained). The combined lakes have a full storage capacity of 1,731 GL and maximum surcharge capacity of 2,050 GL.

The lakes incur substantial evaporative losses given their location in the semi-arid region of far western NSW. These losses depend on the surface to depth ratio and vary depending on lake levels. Lakes Menindee and Cawndilla have the highest evaporative losses given their large surface area to volume. At 100 percent capacity, the lakes can incur combined evaporative losses of around 783 GL per year, whilst at 50 percent storage capacity they can experience losses of 668 GL per year.[15]

Under certain conditions, the lakes are managed as a shared resource between NSW, Victoria and South Australia as required by the Murray-Darling Basin Agreement.[16] Consequently some operating requirements sit outside of the Plan (see **Section 2.2.1**). The Murray-Darling Basin Authority (MDBA) can call on the lakes for meeting downstream needs including South Australian and Victorian demands in addition to supplying the needs of the Lower Darling-Baaka and NSW Murray when the combined lakes storage volume exceeds 640 GL until the storage volume falls below 480 GL.[17] The lakes then revert to NSW control until they next exceed 640 GL.

[15] ..... Based on data provided by WaterNSW.
[16] ..... Schedule 1 of the Commonwealth *Water Act 2007*.
[17] ..... Clause 95 of the Murray-Darling Basin Agreement provides that if the volume in storage in lakes drops below 480 GL, control of the lakes transfers to NSW until the volume in storage next exceeds 640 GL.

Inflows to the Menindee Lakes enter via Lake Wetherell. Water can be delivered to Lake Pamamaroo or directly to the Lower Darling-Baaka River via Main Weir. Water enters Lake Menindee from Lake Pamamaroo via Copi Hollow. Water enters Lake Cawndilla from Lake Menindee via a natural connection called Morton Boolka.

Releases to the Lower Darling-Baaka River can be made via opening Main Weir (typically during a major flood) and the outlet regulators of lakes Pamamaroo, Wetherell and Menindee. Releases from Lake Menindee enter the Lower Darling-Baaka River around 30 river kilometres downstream of Main Weir via Menindee Creek. Flows into the Great Darling Anabranch can occur via releases from Lake Cawndilla into Tandou Creek, or from a natural offtake on the Lower Darling-Baaka River downstream from the Menindee Lakes when flows exceed 9,000 ML/day.

Only releases from the upper lakes (via lakes Wetherell and Pamamaroo outlets and Main Weir) can provide flows for managing water quality events, supporting river health and community needs in the weir pool reach between Menindee Main Weir and Menindee Creek junction. Releases made from Lake Menindee bypass the majority of the weir pool given the junction of Menindee Creek and the Lower Darling-Baaka is roughly 30 kilometres downstream of Main Weir, and therefore are not effective for managing water quality events in this reach.

The river reach between Main Weir and the Menindee Creek junction is at higher risk of poor water quality and mass fish deaths. Rule changes are required to upper lake operations to manage this increased risk. However, releasing additional water from the upper lakes conflicts with the historic operational preference whereby releases were made from Lake Menindee to maintain a drought reserve in the upper lakes and reduce evaporative losses (conserving water in the most efficient and accessible lakes).[18]

Broken Hill historically sourced its town water supply from the Lower Darling-Baaka. However, a Murray River to Broken Hill pipeline was commissioned in 2019 and Broken Hill no longer sources its water supply from the Menindee Lakes. Town water supply continues to be sourced from the Lower Darling Regulated River Water source for the communities of Menindee and Pooncarie.

Currently there are no fishways in place to support movement from the Darling-Baaka into lakes Menindee, Pamamaroo or Wetherell at their outlets, nor in the structures between these lakes (aside from recent trials of a temporary fishway structure by NSW DPI Fisheries). Effectively this prevents fish movement from the southern to northern basins except under rare occasions when Menindee Main Weir is fully opened. Lack of fish passage significantly contributes to aggregation of fish in the Menindee weir pool, particularly in response to flow events that prompt fish movement upstream, and following floods when the populations of some species boom (e.g. Bony herring and Carp).

Over the past 18-24 months the operation of the lakes has been revised in recognition of the importance of releasing water from the upper lakes (Pamamaroo and Wetherell) for managing water quality in the Menindee weir pool and mitigating fish deaths.

[18] ..... Clause 10.5 of the Murray-Darling Basin Officials Committee (2023) *Objectives and outcomes for river operations in the River Murray System*.

No.	Name	No.	Name
1	Old Town weir	6	Pamamaroo outlet regulator
2	Menindee inlet regulator	7	Wetherell outlet regulator
3	Menindee outlet regulator	8	Main weir
4	Weir 32	9	Cawndilla outlet regulator
5	Pamamaroo inlet regulator		

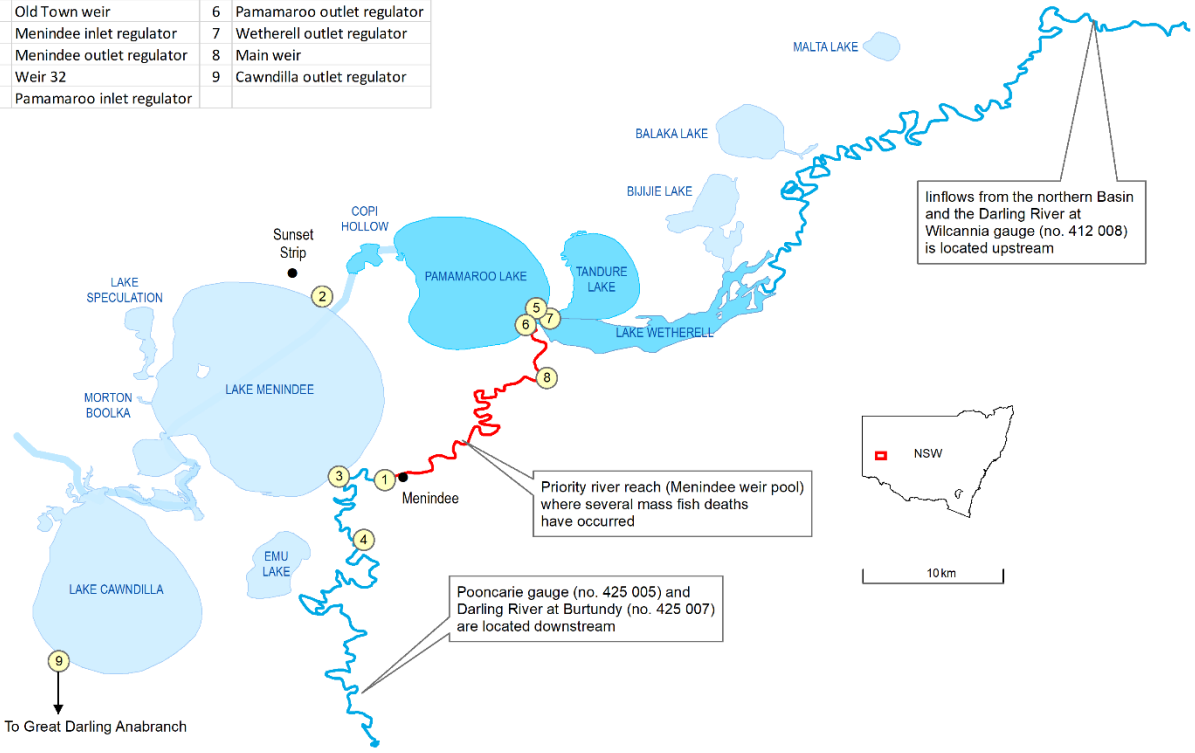

Figure 1: Menindee Lakes System including infrastructure and flow paths

2.2 Complexities with managing Menindee Lakes

2.2.1 Interjurisdictional agreements

Management of the Menindee Lakes System and provision of flows to the Lower Darling-Baaka is multifaceted. While the infrastructure is owned by the NSW Government and operated by WaterNSW, at times the lakes are operated as a shared resource and are governed by State-based planning instruments and interjurisdictional arrangements. The *Murray-Darling Basin Agreement* and *Objectives and Outcomes for river operations for the River Murray System* (O&O) document set out arrangements for when the lakes are operated as a shared resource.

Provisions in the Plan, the MDB Agreement and O&O document underpin how the lakes are operated. Some provisions do not align with what is recently considered required to support the health of the Lower Darling-Baaka, particularly to manage water quality issues and mitigate risks of algal events and fish deaths in the Menindee weir pool reach between Main Weir and Menindee Creek. Specifically, the preferential draining of Lake Menindee (via Lake Menindee outlet) to reduce evaporative losses across the lakes system and maintain a drought reserve in the upper lakes creates lentic conditions in the reach upstream of where Lake Menindee releases enter the Lower Darling-Baaka (Menindee Creek junction). This in turn supports the development of thermal stratification and algal blooms and increases the risk of mass fish deaths.

While it is not directly within the scope of the Commission's review, there is a clear need to review the MDB Agreement and the O&O document to improve outcomes for the Lower Darling-Baaka River. This was recognised in the OCSE fish deaths review which recommended exploring how Menindee Lakes as a shared resource "can be better

managed to mitigate water quality and fish deaths in the … weir pool".[19] Ultimately the lakes are a shared resource with other jurisdictions benefiting from the operation and supply from Menindee Lakes, therefore efforts to improve water quality and ecological outcomes should also be shared.

The Commission understands that the MDBA will shortly commence a review of these arrangements in consultation with the Basin Officials Committee, which is responsible for the O&O and the Ministerial Council, which is responsible for the MDB Agreement. It is anticipated that findings from the Commission's Plan review will be relevant to the MDBA's review including proposed changes to environmental provisions.

There may be opportunities as part of the MDBA's review to consider interjurisdictional arrangements including but not limited to:

- the appropriateness of 640/480 GL rule and how the needs of the Lower Darling-Baaka are considered.
- whether the upper lakes remain part of the shared resource given the importance of releases from the upper lakes for supporting the Lower Darling-Baaka, particularly the reach between Main Weir and Menindee Creek junction.
- prioritisation of environmental needs and water quality conditions when ordering releases from the lakes for meeting downstream needs.

2.2.2 Lack of permanent fishways for supporting fish passage

The regulatory structures in Menindee Lakes System do not have permanent fishways. A lack of fishways is one of the contributing factors to fish deaths in the Menindee weir pool. Under certain conditions, fish aggregate in the Menindee weir pool but are unable to escape when water quality declines.

Fishways exist at Weir 32, Pooncarie and Burtundy, but their design is not optimal. The Lower Darling Fish Passage program funded by the Commonwealth government was intended to refurbish fishways located at Weir 32, Pooncarie and Burtundy.[20] Phase 1 of the program was due for completion in 2023.[21] However, Weir 32 fishway was removed from the program and included in the Better Baaka program.[22]

In November 2023, the Australian Government announced $2.3 million in funding for a new business case for permanent fish passage in the Lower Darling-Baaka and Menindee Lakes.[23] This business case is intended to complement the NSW Government's response to the OCSE's independent review of fish deaths.

Advice on environmental provisions provided in **Chapter [redacted]** is based on existing infrastructure including lack of permanent fishways between the Lower Darling-Baaka River and lakes Pamamaroo and Wetherell. The proposed rules will need to be revisited once permanent fishways are in place, to ensure appropriate flows are provided to operate effectively.

[19] ..... Recommendation 1.5 from the OSCE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.
[20] ..... See Phase 1 Funding for the Lower Darling Fish Passage Program (Amended)
[21] ..... See Phase 1 Funding for the Lower Darling Fish Passage Program (Amended)
[22] ..... DCCEEW-Water factsheet (2021) *About the Better Baaka Program*
[23] ..... Media release. Minister for Environment and Water. *Giving native fish at Menindee Lakes and Lower Darling-Baaka a better chance*, 23 November 2023.

2.2.3 Capacity of the upper lakes

The proposed environmental provisions discussed in **Chapter 4** target the reach between Main Weir and Menindee Creek but will also have benefits in the Lower Darling-Baaka River further downstream of this reach. Providing for the needs of this reach requires that releases are made from the upper lakes. However, the upper lakes have a combined storage volume that may not be sufficient for meeting these needs, priority human needs and accommodating evaporative losses under all climate and inflow conditions. This issue is further discussed in **Section 6**.

2.2.4 Significant evaporative losses

Given their location in the semi-arid region of western NSW the Menindee Lakes experience substantial evaporative losses. Lakes Menindee and Cawndilla experience the greatest evaporative losses given their larger surface area relative to depth. This has underpinned how the lakes are managed for water efficiency, with drought reserves typically stored in the upper lakes.

Data provided by WaterNSW indicates that at 100 percent capacity, the lakes can incur combined evaporative losses of around 783 GL per year, whilst at 50 percent storage capacity they can experience losses of 668 GL per year.[24] The upper lakes which are the focus of advice to the Panel can incur losses ranging between 229 GL to 294 GL depending on storage levels.

2.2.5 Dead storage and disconnection with the Lower Darling-Baaka River

The majority of lakes that comprise the Menindee Lakes System have dead storage. This is water that is inaccessible without pumping as it is below the height of the outlet point. The combined dead storage is around 125 GL across the four main lakes (Wetherell, Pamamaroo, Cawndilla and Menindee).[25] In addition, Lake Cawndilla disconnects from Lake Menindee as storage levels fall. This can result in around 200 GL of water being isolated in Lake Cawndilla that is not accessible for supporting environmental and critical human needs in the Lower Darling-Baaka River.[26] The isolated water in Lake Cawndilla is able to be released to the Great Darling Anabranch. The Commission understands that options for connecting Lake Cawndilla with the Lower Darling-Baaka River are being explored.

2.3 Changes to the flow regime of the Lower Darling-Baaka

The flow regime of the Lower Darling-Baaka River has changed significantly since the commissioning of the Menindee Lakes System in the 1960s, but these changes are more pronounced in the past two decades specifically in relation to low flow and cease to flow conditions (see **Figure 2** and **3.** Flow rates of 15 ML/day or less are considered effectively cease to flow conditions).

Although historically the Darling River experienced occasional cease to flow events, they occurred within a broader flow regime that included regular in-channel flow pulses and

[24] ..... Based on data provided by WaterNSW.
[25] ..... NSW DoI (2019) *Measurement and comparison of evaporation in water storages*.
[26] ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*

overbank floods.[27, 28, 29] This differs substantially from the prevailing flow regime in the last two decades, which has been characterised by protracted periods of low flow punctuated by in-channel flow pulses and few overbank flow events aligned with natural system scale floods in 2011, 2012, and 2022.[30, 31, 32, 33]

The longest period of very low/cease to flow on record occurred during the term of the Plan:

- over 400 days at Weir 32 from Feb 2019 to March 2020
- over 550 days at Burtundy (noting block banks were in place from October 2018 to April 2020).

Changes in the flow regime of the Lower Darling-Baaka River reflect observed and modelled changes in streamflow in the Barwon-Darling River where there has been a marked reduction in streamflow between 2001-2019.[34] A recent study by the CSIRO attributed this change equally to climate variability and water resource development in the northern Basin. [35]

Changes in inflows from the northern Basin entering Menindee lakes have had implications for the health of the Lower Darling-Baaka and its contribution to flows in the Murray River. Given the dependence of the Menindee Lakes System, Lower Darling-Baaka and the Great Darling Anabranch on inflows from the northern Basin, the water sources of the Plan area cannot be considered in isolation of northern basin water sharing plans.

[27] ..... Thoms, M. and Sheldon, F. (2000) Water resource development and hydrological change in a large dryland river: the Barwon-Darling River, Australia. *Journal of Hydrology* 228, 10-21

[28] ..... Mallen-Cooper, M. and Zampatti, B. (2020) Restoring the ecological integrity of a dryland river: why low flows in the Barwon-Darling River must flow. *Ecological Management & Restoration*, 21(3), 218-228

[29] Vertessy, R., D. Barma, L. Baumgartner, S. Mitrovic, F. Sheldon, and N. Bond. (2019) *Independent assessment of the 2018/19 fish kills in the lower Darling: final report*.

[30] ..... Sheldon, F. (2017) *Characterising the ecological effects of changes in the 'low-flow hydrology' of the Barwon-Darling River*. Advice to the Commonwealth Environmental Water Holder Office.

[31] MDBA (2018) *Ecological needs of low flows in the Barwon-Darling*.

[32] ..... Sheldon, F. Barma, D., Baumgartner, L., Bond, N., Mitrovic, SW. and R. Vertessy (2021) Assessment of the causes and solutions to the significant 2018–19 fish deaths in the Lower Darling River, New South Wales, Australia. *Marine and Freshwater Research*

[33] Ellis, I., Townsend, A., Cheshire, K., Stocks, J., Thiem, J., Boys, C., Heath, P., Lay, C., Danaher, K. (2021). *NSW DPI Fisheries Lower Darling-Baaka River Drought Response and short-term recovery outcomes 2018-2020*. NSW DPI Technical report.

[34] ..... Chiew F.H.S, Weber T.R, Aryal S.K, Post D.A, Vaze J, Zheng H, Peña-Arancibia J.L. and Robertson D.E. (2022) *Evaluation of causes of reduced flow in the northern Murray–Darling Basin*. CSIRO Technical report for the Murray–Darling Basin Authority.

[35] ..... Chiew F.H.S, Weber T.R, Aryal S.K, Post D.A, Vaze J, Zheng H, Peña-Arancibia J.L. and Robertson D.E. (2022) *Evaluation of causes of reduced flow in the northern Murray–Darling Basin*. CSIRO Technical report for the Murray–Darling Basin Authority.

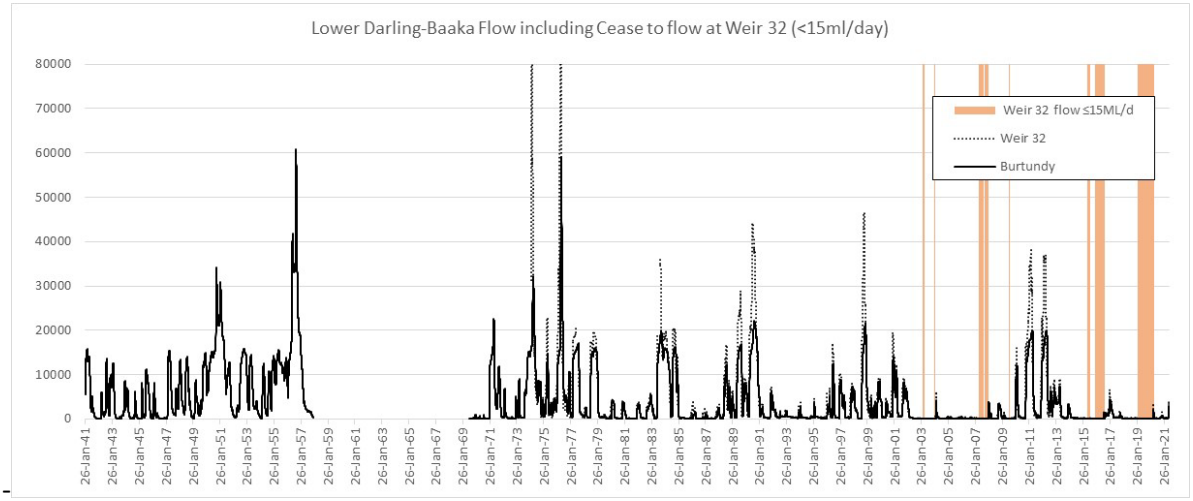

Figure 2: Flows at Weir 32 (gauge 425012) between 1941 and 2021 (data sourced from Water NSW)

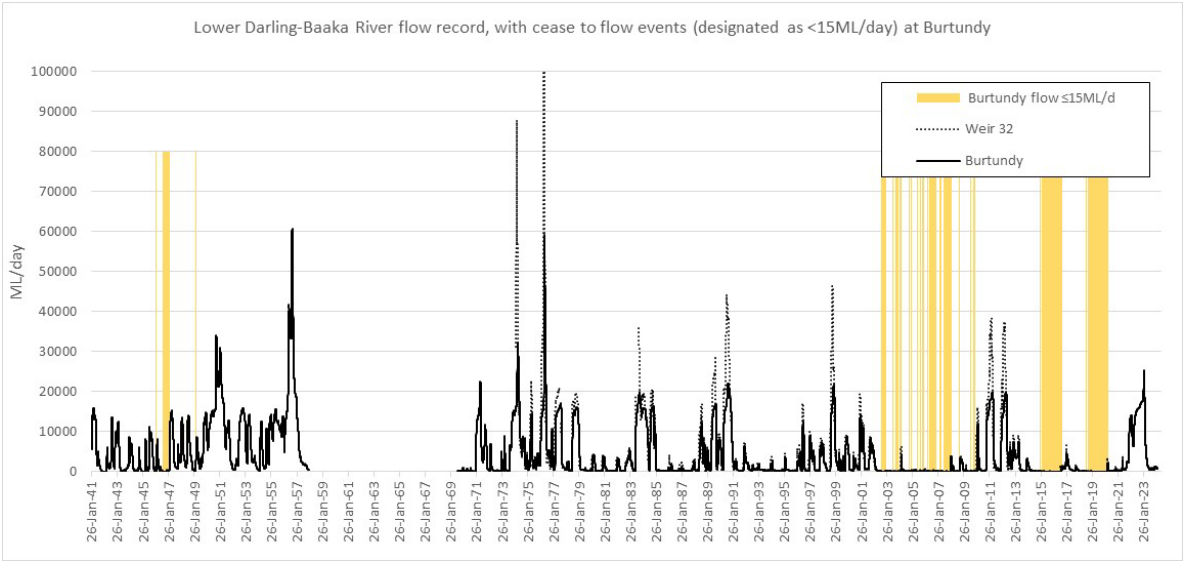

Figure 3: Flows at Burtundy (gauge 425007) between 1941 and 2023 (data sourced from Water NSW)

3 Environmental provisions are not achieving their intended purpose

This chapter examines the inadequacies of the existing provisions for supporting environmental outcomes in the Lower Darling-Baaka River. The Commission has reviewed multiple lines of evidence that demonstrate the Plan is not achieving its water quality and environmental objectives.

It is important to note that it is not only inadequacies in Plan provisions that are impacting achievement of Plan objectives. However, this chapter seeks to highlight examples where Plan provisions are a substantial contributing factor.

3.1 Water quality objectives are not being achieved

The Plan includes several water quality objectives that span the range of values and uses associated with the Lower Darling-Baaka River. These values and uses have target ranges for water quality that are set out in the Water Quality Management Plan for the Murray and Lower Darling Water Resource Plan Area.[36] The Water Quality Management Plan forms part of the NSW Murray and Lower Darling Water Resource Plan, which was accredited in May 2024.

Several papers and reports document the poor water quality in the Lower Darling-Baaka River, including but not limited to:

- Matter 12 reporting prepared as part of Basin Plan requirements
- independent reviews of fish deaths (OSCE, Vertessy et al, Academy of Science)
- water quality updates published by NSW DCCEEW-Water between 2021 - 2024[37]
- community updates published by NSW DCCEEW-Water.

Water Quality Index scores reported in Matter 12 reporting (2014-2019)[38] rated both Darling River at Weir 32 and Darling River at Burtundy as poor.[39] Results for some water quality indicators, particularly dissolved oxygen, have repeatedly been outside of target ranges for aquatic ecosystems, placing native fish and other aquatic biota in the Lower Darling-Baaka under stress and contributing towards an increased risk of mortality. Low dissolved oxygen was the primary cause of 2018-19 and 2023 mass fish deaths observed in the Lower Darling-Baaka River, albeit under different river conditions in each case.

WaterNSW has a responsibility to test and publish notifications regarding algal blooms in rivers and storages it manages and operates including the Menindee Lakes and the Lower Darling-Baaka River. This reporting is important given the risks that algal blooms pose to humans and livestock. There have been a high number of amber and red algal alerts at sites in Menindee Lakes and the Lower Darling-Baaka River during the term of the Plan, making water unsafe for community recreation activities, affecting cultural practices and use of water for domestic and stock purposes. In recent years, algal alerts have been recorded outside of their typical season of occurrence in the Lower Darling-Baaka River. For

[36] ..... Notes in the Water sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources 2016 refer to the Water Quality Management Plan for the Murray and Lower Darling Water Resource Plan Area.
[37] ..... NSW DCCEEW-Water (2024) *Dissolved oxygen water quality updates – Murray-Darling Basin*.
[38] NSW is required to report progress every five years against Matter 12, Schedule 12 of the Basin Plan. Matter 12 pertains to progress towards the water quality targets in Chapter 9 of the Basin Plan.
[39] ..... NSW DPIE (2020) *The Basin Plan 2012, schedule 12, Matter 12: NSW 2020 five-yearly Matter 12 report*, October 2020.

example, amber and red algal alerts were recorded in late autumn and winter of 2023 and 2024, likely associated with elevated nutrient loads in the river following the mass fish deaths of March 2023.

Whilst a 30 GL environmental water allowance (EWA) exists for managing water quality events and algal blooms in the Lower Darling-Baaka River, it is currently only available when the lakes are being managed as a shared resource (i.e. when combined storage has exceeded 640 GL and until the lakes fall below 480 GL). This is problematic given water quality deteriorates during protracted low flow conditions, which can occur when the lakes are under NSW control. This allowance was not available at the time of the 2018-2019 fish deaths given the lakes were under NSW control but was available (and fully utilised for the first time) in the lead up to the March 2023 fish deaths.

The OCSE fish death review report highlighted that the Lower Darling EWA was inadequate for managing water quality events in the Lower-Darling Baaka.[40] During the 2022-23 water year, the EWA was exhausted in around three weeks prior to the March 2023 fish deaths. At this time agencies utilised held environmental water and environmental water from The Living Murray (TLM) program to mitigate further fish deaths and help manage the water quality impacts of this event. It is worth stating for clarity, that the maintenance of suitable water quality is not the remit of held environmental water but should be provided through adequate water sharing plan provisions.

The Lower Darling EWA was exhausted for a second consecutive water year (2023-24) in February 2024. In 2023-24 the EWA was used to supplement minimum daily flows and provide for flow pulses to improve water quality in the Menindee weir pool. Exhaustion of the EWA again led to the use of held environmental water from The Living Murray program for managing water quality in the Lower Darling-Baaka River. In addition, under a trial arrangement, 45GL of protected environmental water inflows from the northern Basin was released from the upper lakes in winter 2024 to improve connectivity between the northern and southern basins, and with the added benefit of flushing algal blooms through the Lower Darling-Baaka River.[41]

3.2 Environmental objectives are not being realised

The Plan has not achieved its targeted environmental objective relating to protecting and enhancing water dependent ecological populations and communities. The Plan notes list several species including native fish that Plan provisions are intended to support including Murray cod (*Maccullochella peelii*), southern pygmy perch (*Nannoperca australis*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanusi)*.[42]

Native fish have been significantly negatively impacted by poor water quality in the Plan area. Increased organic matter after mass fish deaths in turn further impacts water quality. Decomposing fish elevate nutrient levels that support algal growth. While these impacts are not solely associated with the provisions of the Plan, provisions have been inadequate for mitigating the scale of impacts and the Lower Darling EWA has been inadequate to support the management of these events and recovery of affected populations.

[40] ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.
[41] ..... NSW DCCEEW-Water (2024) *Community update for Menindee and the Lower Darling-Baaka: Innovative trial of environmental water flush to boost river health, 29 May 2024.*
[42] ..... Noting that these species are known or predicted to occur in the Lower Darling Regulated River Water Source and/or the Murray Regulated River Water Source.

DPI Fisheries have completed analysis of the Basin Plan Environmental Outcomes Monitoring for Fish Program (BPEOM-Fish) from 2014/15 – 2023/24.[43] This analysis examines the population structure, relative abundance, health, and distribution of six key fish species across Water Source Areas and compares relative biomass and abundance across longer term data sets since the 1990s. This comparative analysis has highlighted a number of key points about the status of native fish in the Lower Darling-Baaka River, including:

- Fluctuations in relative abundance of Murray cod since the 1990s followed by a strong decline in recent years, which is lower when compared across the NSW Murray-Darling Basin; however relative biomass of Murray cod has been stable over the period.
- Relative abundance of Golden perch peaked in 2011/12 following significant recruitment; however, relative abundance has returned to pre-2000 levels, whilst relative biomass has declined since 2015, with both relative biomass and abundance approximately equal to overall levels in the NSW Murray-Darling Basin.
- Very strong variation in relative abundance and biomass of Carp across the time series, with a slight overall increase in biomass since the 1990s; however, relative abundance and biomass are generally similar to the overall NSW Murray-Darling Basin, although variation over time is higher in the Lower Darling-Baaka.
- A total of 14 fish listed as threatened under NSW legislation were sampled in the Lower Darling-Baaka over the last 10 years, including one Olive perchlet and 13 Silver perch.

Additionally, fish surveys conducted by DPI Fisheries between June 2019 and May 2023 (post March 2023 fish death event) provide a more current indication of the status of fish communities in the Lower Darling-Baaka River (upstream of Weir 32 and at Pooncarie).[44] While some species are recovering post the March 2023 fish deaths (e.g. golden perch), others are not (e.g. the iconic Murray cod). Due to their size, Murray cod can be more susceptible to water quality issues.

Low numbers of Murray cod were detected in sampling along the lower Darling-Baaka between 2019 and 2023. However, they were not recorded in the Menindee weir pool (upstream Weir 32) and were in much lower numbers (compared to previous years' sampling) upstream of Pooncarie in May 2023 sampling. This is concerning given the Murray cod population in the Lower Darling-Baaka River was considered one of the most robust populations in the Murray Darling Basin prior to 2018-19 fish deaths.[45] We note however that recreational fishers have recorded Murray cod in the Menindee Weir pool since March 2023.[46]

3.3 Plan rules do not adequately support connectivity

Plan provisions related to longitudinal and lateral connectivity are critical for supporting a range of ecological processes in the Lower Darling-Baaka River, with advancements in knowledge of critical connectivity aspects since the last revision of the plan, including

[43] ..... The latest published report for this program is Schilling, H. and Crook, D. (2023) *Basin Plan Environmental Outcomes Monitoring for Fish (2014/15 – 2019/20)*: Water Resource Planning Area Reports. NSW Department of Primary Industries. Fisheries NSW, Port Stephens Fisheries Institute. 517pp.
[44] ..... Stocks, J. and Ellis, I. (2023) *Native Fish Recovery Strategy Recovery Reach Program: Lower Darling- Baaka Recovery Reach fish community monitoring*
[45] ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*
[46] ..... Stocks, J. and Ellis, I. (2023) *Native Fish Recovery Strategy Recovery Reach Program: Lower Darling- Baaka Recovery Reach fish community monitoring*
[46] ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*

detailed aquatic habitat mapping, LiDAR mapping, refuge pool mapping and hydraulic assessment of river reaches. Both longitudinal and lateral connectivity have been impacted by river regulation and the current Plan provisions are inadequate for supporting connectivity along the length of the Lower Darling Water Source and with adjoining unregulated river water sources as described in the Murray-Lower Darling Long Term Water Plan.[47] In particular:

- **Loss of lateral connectivity** – changes in the flow regime have contributed to reduced lateral connectivity, with fewer high flow and overbank events occurring. Flood operations and measures taken to reduce damage to life and property (such as during recent flooding) further affect lateral connectivity. The Plan also places constraints on the rate of daily releases by limiting releases to within the river channel.
- **Changes in longitudinal connectivity** – while this is affected by regulating structures such as weirs, Plan provisions (including those in northern Basin water sharing plans) are also not considered adequate for supporting connectivity along the length of the Lower Darling-Baaka River. This is evident from the extended cease-to-flow events at Weir 32 and Burtundy (discussed in **Section 2.3**). Reduced inflows into Menindee Lakes in recent decades have compounded these issues.[48] The Plan also does not indicate how rules in the northern Basin water sharing plans interact with and contribute to inflows to the Lower Darling-Baaka River to support connectivity.

New knowledge and information should be used to inform changes in Plan provisions that provide for improved longitudinal and lateral connectivity.

4 Environmental provisions require improvement to support basic river health

The Commission's Plan review to date focuses on environmental provisions for the Lower Darling Regulated River Water Source, including the Menindee weir pool with an emphasis on the reach upstream of Menindee Creek junction. As outlined in **Chapter 3**, existing provisions are not adequate for achieving the Plan's water quality and environmental objectives, particularly for managing water quality events in the Menindee weir pool.

This section examines what changes to Plan provisions are needed to improve environmental outcomes in the Lower Darling-Baaka River based on the latest science and expert advice. It focuses on the subset of provisions considered relevant to the Connectivity Expert Panel, specifically provisions that relate to storage and release of water from the upper lakes.

Proposed rule changes outlined in this chapter, particularly revised minimum daily flow rules, will require more water to meet environmental needs. This water will either have to be drawn from the upper lakes, likely leading to more rapid drawdown of the upper lakes or provided through upstream rule changes that increase inflow.

4.1 Overview of proposed environmental provisions

There are several areas where Plan provisions can be improved to help support basic river health and mitigate perverse water quality events, algal blooms and mass fish deaths in the Lower Darling-Baaka River (see **Figure 4**).

[47] ..... NSW DPIE(2020) *Murray–Lower Darling Long Term Water Plan, Part A: Murray–Lower Darling catchment*
[48] ..... Chiew FHS, Weber TR, Aryal SK, Post DA, Vaze J, Zheng H, Peña-Arancibia JL and Robertson DE (2022) *Evaluation of causes of reduced flow in the northern Murray–Darling Basin*. CSIRO Technical report for the Murray–Darling Basin Authority.

Proposed provisions are colour coded to clarify which ones the Commission considers most relevant to the Panel's advice on the Menindee Lakes trigger i.e. those that require storage and releases from the upper lakes to achieve their intended purpose are darker blue. Specifically proposed amendments that are designed to manage water quality risks and mitigate algal blooms in the Menindee weir pool (upstream Menindee Creek junction) include:

- revised minimum daily flow rules and for their incorporation into the Plan (see **Section 4.2**)
- providing the Lower Darling Environmental Water Allowance (EWA) when the lakes are under NSW control and as a shared resource. Provisions to allow the EWA to be topped up under certain conditions when needed (see **Section 4.3**), to be used (for example) to flush algal blooms (noting the recent flush required around 45 GL).[49]

Not all of the Commission's proposed provisions would form part of the ongoing storage volume needs in the upper lakes e.g. the Lower Darling Restart Allowance may only require short-term storage for managing water quality and provisions for the Great Darling Anabranch do not require upper lake releases.

Figure 4: Proposed suite of provisions for improving environmental outcomes in the Lower Darling-Baaka River and Great Darling Anabranch

[49] ..... As part of its Plan review, the Commission will consider Ministerial discretion on the rates of rise and fall, where circumstance may require a pulse of water to mitigate a water quality issue, and where utilising the standard current recession of 250ML/day for smaller pulses requires too much water

While not directly relevant to the Panel's advice, the Commission acknowledges that improvements to governance arrangements for managing water quality events are also required. The Commission proposes enshrining the strategic role and functions of the Water Quality Working Group into the Plan. This is to support adaptive management of water quality events on an as needs basis based on monitoring. It is anticipated that the proposed suite of rules, particularly the revised minimum daily flow rules if adopted will alleviate some of the pressure this group has faced to date in managing water quality events on an almost daily basis over the past 18 months; however the use of the Working Group will still be needed to manage water quality and associated ecological risks on an as needs basis, primarily associated with extreme events. Consideration of funding arrangements for the functions of the Water Quality Working Group are also required.

4.2 Incorporate updated minimum daily flows into the Plan

Minimum daily flows are intended to maintain water quality and river health and minimise the occurrence of algal blooms.[50] Current minimum daily flow requirements[51] which are measured at the gauge directly upstream of Weir 32 (gauge 425012) have been in place for over two decades.[52] They were previously listed in the Plan (Appendix 3) but were removed in 2022.[53]

Requirements for minimum daily releases currently form part of the Work Approval for the NSW Murray and Lower Darling. Under condition DS8702-00001 of this approval the Minister for Water can direct alternative release rates. As of 1 June 2019, minimum flow requirements are also part of the O&O document that governs river operations when the lakes can be called upon as a shared resource by the MDBA.[54] However, this document specifies minimum daily releases of 500 ML/day when the lakes are at full capacity.

While they are not currently a provision of the Plan, minimum daily flows are considered within the scope of the Commission's Plan review as they are a key strategy for contributing towards the Plan's environmental, water quality and connectivity objectives. They are also considered an important mechanism, if appropriately designed, for managing the effects of climate change when combined with flow pulses.

The Commission is of the view that a revised suite of minimum daily flow rules should be incorporated into the Plan. These rules would support the health of the Lower Darling-Baaka, particularly the Menindee weir pool, if:

- higher daily flow rates based on latest knowledge are released during periods where there is elevated risk of persistent thermal stratification

[50] ..... Murray Lower Darling Community Reference Committee (2003) *Guide to the draft water sharing plan for the NSW Murray-Lower Darling Regulated River Water Source*, Appendix 1, unpublished.

[51] ..... Minimum daily releases from Menindee Lakes were approved by the Murray–Darling Basin Commission in November 1997 and formed part of the original water sharing plan for the Lower Darling Regulated River Water Source. These requirements are now part of the WaterNSW work approval and Objectives and Outcomes for river operations in the River Murray System document

[52] The minimum flow requirements were part of a package of rules recommended by the Murray Lower Darling Community Reference Committee (the Committee) which was appointed in January 1999 to develop environmental flow rules for the Murray-Lower Darling River system and again in March 2001 to assist with developing the water sharing plan.

[53] ..... Based on table of amendments in historical notes from the Water Sharing Plan for the for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2016

[54] ..... Section 10.4 of the Basin Officials Committee (2023) *Objectives and outcomes for river operations in the River Murray system*. Published by the Murray Darling Basin Authority.

- there is clarification that releases must be made from the upper lakes – where releases are made from is critical to their effectiveness as is the quality of releases to support basic river health, recovery and resilience in the Menindee weir pool.[55]
- there is adequate consideration of the ratio of releases from the upper lakes relative to Lake Menindee given the 'blocking' effect of Lake Menindee releases on flow through the Menindee weir pool, which can result in lentic conditions (standing water) in the river reach upstream of the junction with Menindee Creek.
- there is some flexibility in the delivery of proposed minimum daily flows including where releases are made from based on antecedent, climatic and water quality conditions and to support dispersal of native fish e.g. golden perch – this was raised by several agency staff and will be further explored in the WSP review report
- Plan rules incorporate seasonal and event-based triggers to better manage water quality and other risks including providing for flow pulses to respond to poor water quality conditions
- they are adaptively managed (and revisited) if/when new infrastructure such as permanent fishways are installed and/or new information is provided including real time water quality data.

Table 1 compares existing and proposed minimum daily flow requirements and the volumes required to deliver them. Revised minimum daily flows need a significant additional volume of water on top of existing requirements (78.1 GL per year not including evaporative losses). Revised minimum daily flows increase flow during high risk periods of persistent thermal stratification. This period has traditionally been December to March, but recent monitoring indicates this high risk period should be extended, hence a higher flow rate of 750 ML/day is proposed for November to March. The proposed Wilcannia baseflow target of 350 ML/day in the Connectivity Expert Panel's interim report is not adequate for ensuring sufficient inflows into the lakes to meet this increased need at all times.[56] Other provisions are likely needed to support the Commission's proposed revised minimum daily flows.

Further details regarding the rationale for the revised flow rates is provided in **Section 4.2.1.** While **Section 4.2.2** provides a comparison of proposed minimum daily flows with the environmental water requirements from the Murray-Lower Darling Long Term Water Plan.

[55] ..... Releases from Lake Menindee bypass the majority of the weir pool where water quality issues are more prevalent.
[56] ..... Connectivity Expert Panel (2024) *Connectivity Expert panel interim report*, March 2024.

Table 1: Comparison of current and proposed minimum daily flows (MDF) to improve environmental outcomes in the Lower Darling-Baaka River

Month	Current minimum daily flow[a]		Proposed minimum daily flow		Difference (ML)
	Current MDF (ML/day)	Volume (ML)	Proposed MDF (ML/day)	Volume (ML)	
January	350	10,850	750	23,250	12,400
February	350	9,800	750	21,100[b]	11,300
March	350	10,850	750	23,250	12,400
April	300	9,000	500	15,000	6,000
May	200	6,200	200	6,200	0
June	200	6,000	200	6,000	0
July	200	6,200	200	6,200	0
August	200	6,200	200	6,200	0
September	200	6,000	200	6,000	0
October	200	6,200	500	15,500	9,300
November	**300**	9,000	750	22,500	13,500
December	**300**	9,300	750	22,500	13,200
Total annual volume for MDF		**95,600**		**174.350**	**78,100**

Table notes:

a. Current requirements are set out in the NSW Murray and Lower Darling Work Approval and Objectives and Outcomes for River Operations in the River Murray System document. Clause 10.3 (d) of the Objectives and Outcomes document includes an additional requirement of 500 ML/day release when the Menindee Lakes storage is above full supply level.

b. Every four years an additional 750 ML of water will be required when February has a leap year (29 days).

4.2.1 Improved understanding of minimum daily flow requirements

Until recently, there have been limited scientific studies in the Lower Darling-Baaka River, particularly in relation to water quality.[57] Post the 2023 fish deaths the water quality monitoring network has been expanded in the Lower Darling-Baaka River to better understand river condition and response of water quality parameters to flow.

The basis of the current minimum daily flows is unclear as this was not detailed in the original Plan's background document, but an early work approval indicates they are for mitigating risk of algal blooms. The Commission is aware of a study of algal response to flows published in 2011 that indicated that flows greater than 300 ML/day (flow velocities above 0.03 m/s) were sufficient to prevent prolonged periods of thermal stratification (>7 days) in the Lower Darling-Baaka River and mitigate the formation of algal blooms (*Anabaena. circinalis* now named *Dolichspermum circinale*)).[58] This work was based on simple cross sectional area determinations, discharge at gauges and then mathematical determination of the average flow velocity.[59]

More recent data indicates that this flow rate is not sufficient for mitigating shorter periods of persistent thermal stratification in the Menindee weir pool. A recent investigation[60] has

[57] ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*
[58] ..... Mitrovic, S. M., Hardwick L, and Dorani, F. (2011) Use of flow management to mitigate cyanobacterial blooms in the Lower Darling River, Australia. *Journal of Plankton Research* 33, 229-241.
[59] ..... Facey, J., Balzer, M., Brooks, A., Westhorpe, D., Williamson, N., Mitrovic, S., (2021) *Minimising persistent thermal stratification and algal blooms using improved flow velocity and discharge targets*, NSW Department of Planning and Environment
[60] ..... Facey, J., Balzer, M., Brooks, A., Westhorpe, D., Williamson, N., Mitrovic, S., (2021) *Minimising persistent thermal stratification and algal blooms using improved flow velocity and discharge targets*, NSW Department of Planning and Environment

revised the required flow rate upward to 750 ML/day (based on a velocity of around 0.05 m/second) to mitigate prolonged thermal stratification and the risk of mass fish deaths. This is more than double the current minimum daily flow of 350 ML/day required during high risk periods. This new knowledge is informing the current management of releases to the Lower Darling-Baaka River.[61]

During the 2023/24 water year, flows in the Lower Darling Baaka River have been operated above minimum daily flows for much of the time to manage water quality issues post March 2023 fish deaths and mitigate the risk of further fish deaths.[62] Releases made above the existing minimum daily flow requirements have been supplemented with planned environmental water (Lower Darling EWA) and water from The Living Murray (TLM) program when the EWA account was exhausted on 16 February 2024.[63]

Data collected during these releases indicate this flow rate, when delivered from Lake Pamamaroo, is generally effective for limiting persistent thermal stratification in the Menindee weir pool. **Figure 5** presents water temperature at different depths below the surface (light blue: 0.75 metres; dark blue: 2 metres; and orange: 3 metres) during a period of time when releases of 750 ML/day were made from the upper lakes. While the surface layer (light blue) reflects the influence of ambient temperature, persistent stratification (identified when the minimum temperature difference between the surface and bottom water is greater than a specified temperature over a specified period[64]) was generally not observed in the weir pool. This is despite ambient temperature exceeding 40°C during this period.

Releases greater than the existing minimum flow requirements were made to manage water quality issues and mitigate the risk of fish deaths. Most notably, releases from Lake Pamamaroo were generally kept at 750 ML/day throughout most of January, February and March 2024, punctuated by some flow pulses (see **Figure 6).** Releases made during this time indicate that flow pulses remain important for managing water quality in the Menindee weir pool. The 750 ML/day release was maintained until 27 March 2024 when releases from Lake Pamamaroo fell to 500 ML/day.

[61] ..... DCCEEW-Water's incident response plan for managing stratification and fish deaths in the Menindee weir pool which recommends releases of 750 ML/day from the upper lakes to prevent stratification from forming.

[62] ..... Fish deaths were recorded in February 2024. The underlying cause was inconclusive but does not appear to be associated with low dissolved oxygen.

[63] ..... If the lakes were below 480 GL, the Lower Darling EWA would not have been available. Data collected during this period should inform the future management of the lakes.

[64] ..... Facey, J., Balzer, M., Brooks, A., Westhorpe, D., Williamson, N., Mitrovic, S., (2021) *Minimising persistent thermal stratification and algal blooms using improved flow velocity and discharge targets*, NSW Department of Planning and Environment

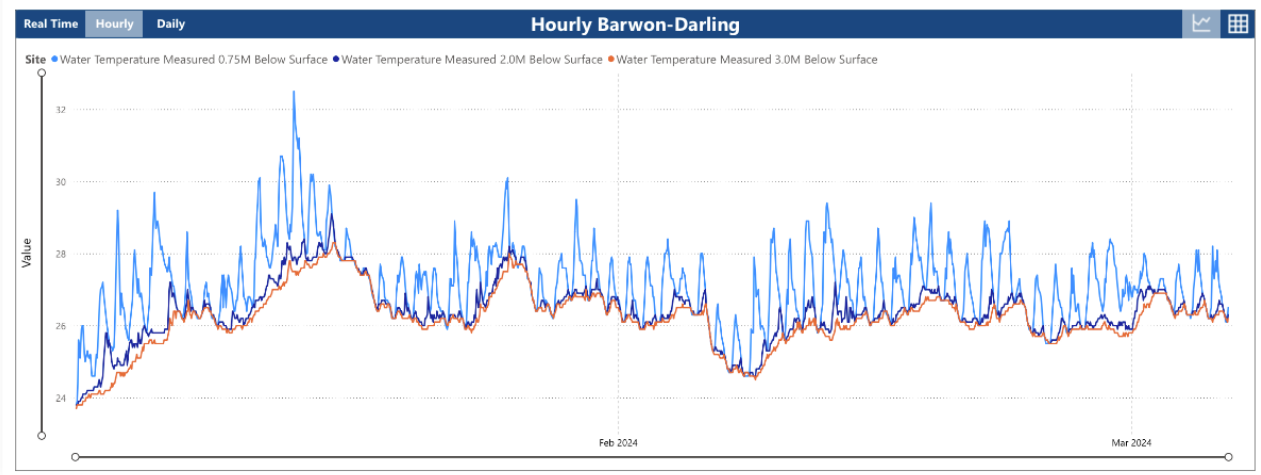

Figure 5: Water temperature at a site in Menindee weir pool (upstream of the junction with Menindee Creek (Menindee Lake outlet) from January to March 2024.[65]

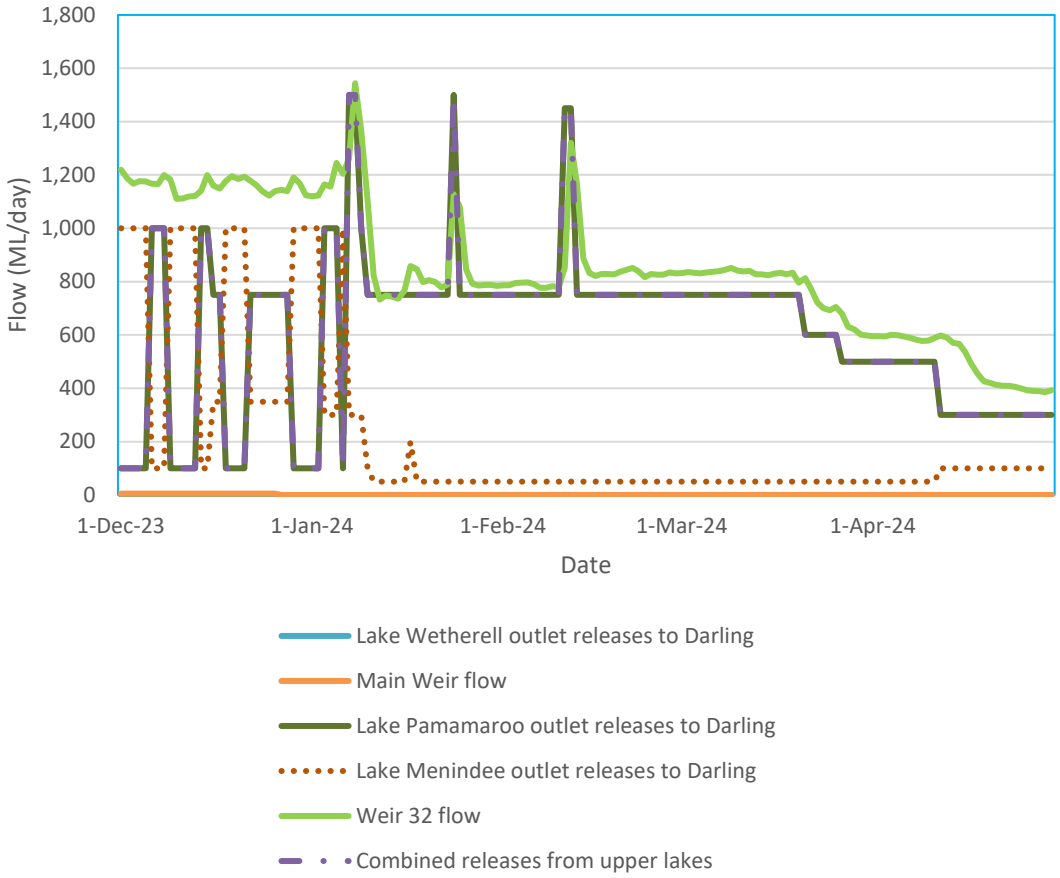

Figure 6: Releases made from Menindee Lakes storages between 1 December and 30 April 2024 (data provided by WaterNSW)

It is also important to consider end of system flow requirements at Burtundy (gauge 425007) that would assist in supporting ecosystem functions and connectivity along the length of the Lower Darling Water Source. These flows could be met by a combination of releases from the upper lakes and Lake Menindee.

[65] ..... Source: Graph provided by Dr Darren Baldwin from data collected by BCS.

While proposed minimum daily flows would likely contribute towards supporting ecosystem functions further downstream of Menindee weir pool, they may not provide for end of system flows in all months given losses and lower minimum daily releases outside of high risk periods. Further provisions for supporting connectivity along the length of the Lower Darling-Baaka may be required. Releases from Lake Menindee should be considered for meeting critical needs further downstream and are important for supporting the ecological values of Menindee Creek (between Lake Menindee outlet and the junction with the Lower Darling-Baaka River).

4.2.2 How proposed minimum daily flows compare to Long Term Water Plan

The Murray-Lower Darling Long Term Water Plan: Part B sets out environmental watering requirements (EWRs) for the Lower Darling-Baaka River including the Darling River upstream Weir 32 (gauge 425012) and Darling River at Burtundy (gauge 425007).[66] The Commission compared the proposed minimum daily flow rules with EWRs, recognising that the Connectivity Expert Panel has used EWRs from other Long Term Water Plans to inform its advice on proposed baseflow targets.

The baseflow range for Darling River upstream Weir 32 (425012) in the Murray-Lower Darling Long Term Water Plan ranges from a minimum of 250 ML/day (April to August) and 1,100 ML/day (December to February) to a maximum of 2,000 ML/day. Proposed minimum daily flows fall within the baseflow range for higher risk periods for stratification and the very low flow range for lower risk periods:

- **Lower risk period for stratification:** the proposed minimum daily flow of 200 ML/day for May to September, which is consistent with current minimum flow requirements for these months is in the very low flow range.
- **Higher risk period for persistent thermal stratification:** The proposed minimum daily flow of 750 ML/day for the period at greater risk of persistent thermal stratification (November to March) falls within the higher baseflow range for the Darling River upstream Weir 32. This contrast to the current minimum daily flow for this period (300 to 350 ML/day) which sits within the lower range of the baseflow EWR from January to March (300-2,000 ML/day September to March) but is on the cusp of very low flows in November to December.
- **Shoulder period and nesting of riverine specialists:** In consultation with experts, the Commission has proposed a shoulder period with a 500 ML/day minimum daily flow for April and October recognising that the window for persistent stratification can extend to these months, particularly with climate change. The proposed flow rate for October is also intended to help support Murray cod nesting in the Lower Darling-Baaka River.[67] The nesting EWR from the Long Term Water Plan seeks to protect nesting sites by avoiding rapid changes in water levels, which may cause adults to abandon nests or desiccation of nests.[68]

The Commission recognises that the proposed minimum daily flows, which are designed for mitigating persistent thermal stratification, may require flexibility in their delivery including to support flow variability. Provisions of flow variability is fundamental to ecosystem health as recognised in the Long Term Water Plan.[69] A variable flow regime is critical for supporting the life stages of organisms such as native fish that have evolved to function within a variable hydrological regime and is particularly important for breeding and

[66] ..... DPIE (2020) *Murray-Lower Darling Long Term Water Plan Part B: Murray-Lower Darling planning units*
[67] ..... It should be noted that other interventions may be required to support Murray cod nesting.
[68] ..... DPIE (2020) *Murray-Lower Darling Long Term Water Plan Part B: Murray-Lower Darling planning units*
[69] ..... DPIE (2020) *Murray-Lower Darling Long Term Water Plan Part A: Murray-Lower Darling catchment*

recruitment.[70, 71, 72] The Commission will further consider flow variability as part of its Plan review including operational considerations.

Proposed minimum daily flows on their own will contribute to protecting river health and providing opportunities for system recovery and resilience, however they may not be adequate to support all of the critical life stages of aquatic organisms or support riparian and floodplain vegetation communities. It is anticipated that flow pulses, natural events and informed environmental water deliveries will provide for some variability and contribute towards improved productivity and achievement of some of the EWRs from the Long Term Water Plan.

4.2.3 Managing for climate change

Climate change is anticipated to increase the occurrence of extreme water quality events and their severity.[73] It will likely contribute to extended periods of persistent thermal stratification and occurrence of algal blooms. It is highly probable that water quality events observed in the Lower Darling-Baaka River are already being influenced by climate change. Therefore, it is important to have Plan provisions in place that can help to manage these events and associated water quality risks.

Current rules do not consider climate change and do not adequately allow for adjustment of flows to manage or mitigate the effects of climate change. Proposed minimum daily flow rules and water quality flow pulses are intended to ameliorate the increased water quality risks by requiring higher flow rates for mitigating persistent stratification during high risk periods and extending the period that higher flow rates are to be released (given the expanded window of risk for persistent stratification). Minimum daily flows should be complemented by flow pulses that are based on decision trees underpinned by near real-time data, meaning that rules are not static and can support responses on an event basis in a timely manner.

The Commission acknowledges that it will be impractical to deliver revised minimum daily flow rules at all times. During extreme events, particularly where prolonged drought conditions result in lowering of the upper lakes stored volume to critical levels required for priority human need, it will not be possible to deliver the proposed minimum daily flows and flow pulses. A process for establishing the volume of water available for critical human water needs, minimum daily flows and associated release rates during these periods requires development. This should be based on advice from the Water Quality Working Group chaired by NSW DCCEEW-Water.

4.2.4 Other considerations

While revised minimum daily flows are important and should be released from the upper lakes, there are several issues that affect the intended benefits these releases can provide:

- **Available inflows:** The amount of water available within the Menindee Lakes System is linked to the upstream Barwon-Darling River and its tributaries. Management of inflows to Lake Wetherell and the Panel's proposed rules (including the Wilcannia

[70] ..... Ellis, I. Cheshire, K., Townsend, A., Danaher, K., Lone, R. (2022). *Fish and Flows in the Southern Murray-Darling Basin (condensed summary)*. NSW Department of Primary Industries, Buronga

[71] ..... Mallen Cooper, M. and Zampatti, B (2022) Restoring the ecological integrity of a dryland river: Why low flows in the Barwon-Darling River must flow, *Ecological Management & Restoration* 21(3), 218-228

[72] Thoms, M.C. and Sheldon, F. (2000). Water resource development and hydrological change in a large dryland river: the Barwon-Darling River, Australia. *Journal of Hydrology* 228, 10-21

[73] ..... Baldwin, D. S. (2021) Water quality in the Murray-Darling Basin: the potential impacts of climate change. In 'Murray–Darling Basin, Australia: Its Future Management' (Eds. B. T. Hart, N. R. Bond, N. Byron, C. A. Pollino, and M. J. Stewardson), Elsevier, New York, pp. 137–159

baseflow target) can influence the management of and outcomes in the Lower Darling-Baaka River.

- **Ratio of releases from the upper lakes and Lake Menindee:** The ratio of water released from the upper lakes (Wetherell and Pamamaroo outlets) compared to Lake Menindee is important. If releases from Lake Menindee are too high this can create a backwater effect (lentic water upstream of Menindee Creek junction). To avoid this it is important to maintain an adequate flow velocity through the Menindee weir pool upstream of Menindee Creek junction. Over the summer of 2024 the ratio between releases from Lake Menindee and the upper lakes varied between 1:15 to 1:7.5 (based on between 50 ML/day and 100 ML/day being released from Lake Menindee outlet when 750 ML/day was being released from the upper lakes). We acknowledge the post-flooding aggregation of fish in this reach (high biomass) also contributed to hypoxia and have assumed that proposed provision of suitable fish passage at lakes Pamamaroo/Wetherell outlets will allow for this ratio to be revisited. There may also be an opportunity to trial different ratios during non-critical times.
- **Quality of releases:** Risk of releasing poor quality water to the Lower Darling-Baaka River is an important issue to consider and manage when delivering minimum daily flows and making other releases. Ongoing monitoring of water quality in the lakes and along the length of the Lower Darling-Baaka River will be important.
- **Interventions to assist in management of water quality**: Interventions to manage the short circuiting of poor water quality through Lake Pamamaroo should be considered e.g. a breakwall between Pamamaroo inlet and outlet. Repair of the Lake Pamamaroo inlet regulator to address dam safety risk is also anticipated to assist with water quality management.
- **Historical operations and river gauges:** currently the river operator has discretion over where releases can be made to meet minimum daily flows. This flexibility is in part attributed to the location of the river gauge (425012) downstream of the upper lakes and Lake Menindee outlets. As a result there are risks associated with the Menindee weir pool (upstream Menindee Creek junction) being bypassed as releases are only required from the Lake Menindee outlet. This can be overcome by prescribing the volume of releases that must come from the upper lakes for meeting minimum daily flows, or by upgrading and referencing the Darling River at Menindee Town gauge (425001) once Old Town Weir is fully removed (scheduled for removal in winter 2024).

4.3 Extending provision of the Lower Darling EWA for flow pulses

The Lower Darling EWA (Clause 64 of the Plan) is intended for managing water quality in the Lower Darling-Baaka River. The current Plan rules specify it is only available when the lakes are being managed as a shared resource, not when under NSW control (when the lakes fall below 480 GL combined storage and until they exceed 640 GL).

The Plan is one of two regulated river plans with an allowance dedicated to managing water quality and blue-green algae. The other is the Lachlan valley.[74] However, there is a clear distinction between the two plans regarding the labelling of the allowance. The Lachlan plan is arguably clearer in its purpose given the allowance is termed a Water Quality Allowance. For clarity, the Lower Darling EWA could be renamed the Lower Darling-Baaka Water Quality Allowance to avoid any ambiguity regarding its purpose.

When the original Plan was being developed, the Murray-Lower Darling Community Reference Committee proposed a 60 GL algal contingency allowance for managing algal

[74] ..... Clause 56 of the Water Sharing Plan for the Lachlan Regulated River Water Source 2016 provides for a water quality allowance of 20,000 ML each water year.

events in the Lower Darling-Baaka River.[75] The Committee also proposed daily flow rates for this contingency of 5,000 ML/day for November to April and 2,000 ML/day for May to October. Only half of this volume was included in the Plan as the Lower Darling EWA.

The Commission understands that the Lower Darling EWA was examined during the water resource plan development process in 2018-19. At that time, the EWA had never been utilised, but a recommendation was made to:

- make it available when the lakes are under NSW control
- expand what the allowance could be used for to include any water quality management purpose, maintenance of aquatic ecosystem health and to support native fish and threatened species.

When the Plan was amended the purpose of the Lower Darling EWA was broadened with a focus on water quality and algal blooms. However, provisions were not updated to allow use of the EWA when the lakes are under NSW control.

As outlined in **Chapter 3**, the Lower Darling EWA has been called upon and exhausted in two consecutive water years (2022/23 and 2023/24). In both years these releases predominantly came from the upper lakes and were exhausted months before the end of the water year. The 30 GL allowance accounted for around 15 percent of environmental water delivered between February and 30 June 2023.[76] This occurred during a time of significant inflows to the lakes, but the inflows were not available under the Plan for managing water quality and fish deaths. In addition, fish that congregated below Main Weir were unable to migrate out of the weir pool due to a lack of fishways.

The Commission in consultation with experts agreed on the need for making the Lower Darling EWA available when the lakes are under NSW control recognising this option was examined in both development of the NSW Murray and Lower Darling Water Resource Plan and Western Regional Water Strategy. It was also agreed that the revised minimum daily flows outlined in **Section 4.2** would help to mitigate persistent stratification in the Menindee weir pool and reduce reliance on the EWA. Nonetheless, flow pulses may still be necessary when minimum daily flows are insufficient for managing water quality and the EWA should provide for these pulses.

To be effective in managing water quality events in the Menindee weir pool, the Lower Darling EWA would need to be stored and released from the upper lakes and flow pulses up to 1,500 ML/day would be required for up to three days. The EWA would therefore need to be included in the volume reserved in the upper lakes (see **Chapter** Error! Reference source not found.).

4.3.1 Decision trees for water quality flow pulses

As noted, there have been two water years where the Lower Darling EWA was ordered for managing water quality. The water quality monitoring network has improved since the first Lower Darling EWA release and has contributed to an improved understanding of the conditions in which a flow pulse may be required. This knowledge should underpin decision trees for the future management of releases above revised minimum daily flows to the Lower Darling-Baaka River.

Decision trees coupled with water quality monitoring provide greater transparency and clarity regarding river operations when water quality is at risk of deteriorating. They will help guide when EWA releases are to be made and can potentially be linked to the water

[75] ..... Murray Lower Darling Community Reference Committee (2003) *Guide to the draft water sharing plan for the NSW Murray-Lower Darling Regulated River Water Source*, Appendix 1, unpublished.
[76] ..... OCSE (2023) *Independent review into the 2023 fish deaths in the Darling-Baaka River at Menindee*.

quality dashboard that NSW DCCEEW-Water has established. Triggers in the decision trees should be based on risk of persistent thermal stratification developing (if minimum daily flows are inadequate for mitigating this risk) and potential for deterioration in dissolved oxygen in the water column which will pose a risk to aquatic biota.

4.3.2 Provisions to reduce risks around a depleted EWA

Based on expert advice, the Commission understands that the revised minimum daily flow rules combined with making the 30 GL Lower Darling EWA available when Menindee Lakes are under NSW control and managed as a shared resource would be adequate to mitigate water quality events in most instances. However, there may be circumstances where additional EWA is required.

Given the exhaustion of the Lower Darling EWA in two consecutive water years, the Commission is considering the merits of being able to carryover unused EWA from one water year to the next and topping up the EWA when nearing depletion. Further analysis is required outlining the risks and benefits associated with each option.

The rationale for carryover is to ensure that unused EWA water is not forfeited and is available for managing water quality events in years where the EWA may be insufficient for managing water quality events.

NSW DCCEEW-Water provided the Commission with outputs from hydrological analysis it had undertaken to inform the Western Regional Water Strategy. This included making the 30 GL Lower Darling EWA available under NSW control. The analysis indicates that there would be potential need for carrying over unused EWA for up to three years. However, it is important to note:

- this water would need to be stored in the upper lakes for the EWA to be effective in managing water quality events in the Menindee weir pool
- given the high evaporation rates associated with Menindee Lakes, any unused EWA that is carried over may incur additional evaporative losses.

Allowing for top ups of the Lower Darling EWA account during the water year could also address periods where the 30 GL EWA is insufficient. This would be triggered if the EWA is forecast to be exhausted within the water year. It is anticipated that additional inflows provided via rules proposed by the Connectivity Expert Panel could be used for topping up the Lower Darling EWA if their purpose was consistent with the flows protected in the northern Basin.

While this approach may help to mitigate some of the losses incurred from carryover of unused water, there are several issues with top-up of the Lower Darling EWA that require consideration, including:

- during dry years there may be a lack of inflow for topping up the EWA
- timing and quality of inflows i.e. it may not be practicable to top up towards the end of the water year
- impacts of top-ups on the shared resource including negotiation with other jurisdictions and changes to interjurisdictional agreements
- what happens with unused water that has been credited to the Lower Darling EWA account as a top-up, particularly if it has been made available as a result of restrictions on take in the northern Basin.

Further analysis of the arrangements of carryover provisions and top-ups are required to assess potential benefits and impacts.

4.4 Greater clarity is needed for implementation of the Lower Darling restart allowance

The Lower Darling Restart Allowance is an important addition to the Plan that was made in 2022.[77] It is intended to protect the first 60 GL of inflow to Menindee Lakes once the Darling River upstream Weir 32 (gauge 425012) has ceased to flow for ten consecutive days. This rule has not yet been triggered as the Lower Darling-Baaka River has not ceased to flow given wetter conditions over the past two years the rule has been in place.

The Commission considers the restart volume of 60 GL to be adequate based on previous river restarts (March 2020) and advice from experts. However, additional considerations related to drought management actions that may have been implemented (such as block banks that will need removal) as well as flow related guidance is needed for river operators on how the restart would be managed to mitigate perverse outcomes that could arise from a restart such as poor source water quality and potential for fish deaths in the Lower Darling-Baaka River.

There needs to be clarity over what the shape of the restart hydrograph should look like. Specifically the restart hydrograph requires a relatively sharp increase (especially if it occurs during summer) towards 3,500 ML/day to help flush and reconnect pools and then protracted flow recession back to the revised minimum daily flow required for the time of year (discussed in **Section 4.2**).

NSW Department of Primary Industries - Fisheries commissioned a report on guidance for restarting.[78] The Murray-Lower Darling Long Term Water Plan (part B) and March 2020 restart provide insights into a suitable restart hydrograph. Drawing on this information, the Water Quality Working Group should advise on the restart hydrograph, release locations and rates and risk management before the restart commences. Any restart will require adequate water of good quality to be available in active storage in the upper lakes for the restart hydrograph to be delivered.

There are also significant water quality risks with a river restart that need to be managed that are associated with the quality of inflows to Menindee Lakes. Managing these risks requires appropriate water quality triggers and water quality monitoring to mitigate fish deaths in the Lower Darling-Baaka River. Water quality monitoring of the flow front as it approaches and once it reaches the lakes is essential. Poor quality flow fronts may need to be diverted into the upper lakes before releases downstream for the restart commence. Water quality triggers based on dissolved oxygen and temperature should inform when it is suitable to commence the restart.

Unlike the revised minimum daily flows and Lower Darling EWA, the Commission does not anticipate the 60 GL Lower Darling restart allowance needs to be included in the volume required to be stored in the upper lakes. However, short-term storage may be required for managing water quality risks (to ensure poor quality inflows are not released directly downstream).

[77] ..... Clause 72 of the Water Sharing Plan for the Murray and Lower Darling Regulated Rivers Water Sources.
[78] ..... Baldwin DS, (2020) *Planning for restarting rivers to minimise harm to native fish in the Murray-Darling Basin*. A report prepared for the NSW Depart of Primary Industries - Fisheries.

5 Trigger conditions to prioritise the needs of the Lower Darling-Baaka River

5.1 The Menindee Lakes trigger is inadequate for meeting the priority needs of the Lower Darling-Baaka River

Recently issued floodplain harvesting licences in northern NSW regulated plan areas and the Barwon-Darling unregulated plan area are restricted from taking water when the volume in Menindee Lakes and flow rates at specific locations within each valley are below specified threshold triggers.

The Menindee trigger, as currently enacted, applies when the volume in the Menindee Lakes storage is below 195 GL.[79] The Western Regional Water Strategy clarified that in order to meet priority need the volume had to be 'active water'[80] held in the upper lakes and that around 250 GL was required to account for Pamamaroo inlet regulator safety concerns.[81] The Menindee trigger would also restrict releases of lower priority use from the upper lakes.[82] The Menindee trigger, as currently enacted, applies only to floodplain harvesting licences, which means that when this trigger is active, water can be extracted by other lower-priority entitlements.

In-valley triggers, as currently enacted, permit extractions through floodplain harvesting even when the Menindee trigger is active. In-valley trigger thresholds are valley-specific and generally represent small or large fresh flow categories. Connecting the Menindee 'restriction' trigger with in-valley 'relaxation' triggers compromises the Menindee trigger's effectiveness to enhance inflows to the Menindee Lakes, compared to if it were implemented independently. The Commission considers it would be more effective to separate the Menindee trigger from in-valley triggers and restructure them to establish independent restriction and relaxation conditions depending on local conditions as well as downstream priority needs.

To address these concerns, the Department proposed a set of "critical dry condition triggers" in the Western Regional Water Strategy.[83] The proposed triggers intend to override the in-valley floodplain harvesting relaxation triggers. They would restrict floodplain harvesting, supplementary and A, B and C class licences in the northern valleys if the upper lakes are forecast to drop below 195/250 GL of active storage. The proposed rules are vague on the criteria for relaxing the restrictions, with a clear trigger only for the case where the Lower Darling-Baaka River has stopped flowing. The Department's proposed "critical dry condition triggers" are inadequate to prioritise the needs of the Lower Darling-Baaka River particularly in light of the revised minimum daily flows required to reduce risk of poor water quality events.

The Menindee and in-valley triggers do not restrict lower priority take in unregulated plan areas outside of the Barwon-Darling. Entitlement holders in unregulated plan areas generally received a single entitlement that accounted for all forms of surface water extraction including overland flow, equivalent to floodplain harvesting in regulated valleys.

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79 ..... See Section 43B (3) of the *Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2021*.

80 ..... Note active water refers to the volume of water in the Menindee Lakes that can be accessed using gravity alone. Note that the Murray–Darling Basin Authority uses alternative active storage figures that assume that most of the water in the lakes (aside from 36 GL) can be accessed using pumps.

81 ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*

82 ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*

83 ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*

Without separate entitlements representing differing prioritisation it is more challenging to restricting only lower priority extraction in unregulated plan areas.

5.2 Impact of proposed connectivity provisions

The Connectivity Expert Panel proposed rule changes seeking to increase connectivity flows within each valley and at Wilcannia, likely increasing inflow into the Menindee Lakes under certain conditions. Updated modelling is required to calculate the volume of increased inflow these proposed rule changes could achieve. However, the proposed rule changes are unlikely to provide the increase in inflow required to achieve priority needs in the Lower Darling-Baaka River at all times. During high-risk periods, the minimum daily flow rate required is more than twice the flow rate of the Wilcannia baseflow target the Connectivity Expert Panel is proposing. Over a year, there is a shortfall of more than 50 GL between the Wilcannia trigger flow rate and the revised minimum daily flow rates. This gap is greater when accounting for flow pulses required to respond to water quality events, system losses, evaporation, and requirements for other priority needs.

6 Approach to identifying a storage volume to provide for priority needs

The Menindee Lakes System is unique among public storages in the Murray-Darling Basin in that it is characterised by low rainfall, high evaporation, highly variable inflow including sustained periods of low or zero flow, and occasional dry periods. The upper lakes, where the priority reserve is required to be stored, have a total storage capacity totalling around 445 GL (without surcharging). These factors likely necessitate a relatively large priority reserve for environmental needs, that may account for a larger proportion of total storage volume compared to reserves in other public storages.

The Commission calculated the volume of the reserve using the water balance approach applied in DCCEEW-Water's water resource assessment process that underpins the issuing of water allocations in NSW. Using parameters generally applied in other plan areas the Commission found that the storage reserve required would likely exceed the total storage capacity of the upper lakes. This indicates that an approach to securing the needs of the Lower Darling-Baaka requires changes to parameters assumed in the water balance and consideration of any increase in risk of supply shortfalls arising from these assumptions. The Commission explored these options through calculating the volume of priority reserve required with modified water balance parameters.

The process for calculating volumes for the priority reserve and assessing scenarios are discussed below. Ideally, hydrological modelling should be used to simulate these scenarios, refine the water balance parameters and calculate levels of supply shortfall risk.

6.1 Calculating the volume of the priority reserve

Resource assessments, fundamental to water allocations, calculate the volume of water that must be retained in a 'priority reserve' to satisfy future priority needs over a defined planning horizon. These assessments seek to maintain adequate reserves even during dry and drought periods. Water exceeding the reserve can be allocated for lower priority needs. This ensures that allocations for lower priority needs are made only when there is a surplus of water for priority needs, in line with the Act's requirements.

Priority reserves account for several water fluxes in the system over a specified planning horizon through the water balance equation:[84]

priority reserve = priority commitments + system overheads – minimum inflow **(1)**

These reserves are generally maintained at all times providing certainty that the water is available for future use. While maintaining these reserves reduces allocations and increase evaporation losses this approach ensures priority needs are available for an agreed planning horizon even if there is a rapid onset of dry or drought conditions.

Each parameter of the water balance equation is discussed below.

6.1.1 Planning horizon

The planning horizon establishes the duration over which priority commitments are sought to be secured, even under dry and drought conditions. Generally, planning horizons are described as the duration when the plan area is 'statistically likely to recover' from dry conditions based on long term modelling.[85] Planning horizons form part of the 'agreed level of risk' related to the reliability of supply for priority needs.[86]

Generally, three approaches are used for specifying planning horizons in NSW. In plan areas with reliable inflows and large public storages[87] a 12-month horizon is used for normal conditions with up to 24 months when dry conditions are expected. In plan areas with less reliable inflow and moderate-sized public storages[88] the horizon duration changes based on a cycle. The shortest cycle is 10 to 21 months while the longest is 24 to 36 months. Finally, in plan areas with less reliable inflow and smaller public storages[89] a fixed planning horizon of 24 months is used. Most planning horizons are around 24-months leading to the priority reserve being termed the 'second-year reserve.'

The planning horizon for the Lower Darling-Baaka River is identified in the water allocation methodology[90] and incidence response guide as 24 months.[91] Historically, an 18 to 24-month planning horizon was used. For example, the planning horizon for Broken Hill's priority supply, when sourced from the Menindee Lakes, was 18 months[92] and the Murray-Darling Basin Agreement trigger to transition to NSW control was generally considered to secure needs for 18 to 24 months.[93] However, the Western Regional Water Strategy[94] identifies 12 months for critical need and based on conversations with DCCEEW-Water Group the Commission understands that in practice a 12 month planning horizon is used.

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84 ..... Water allocation methodologies generally provide the water balance equation in the following form: *Available Water = Available Resource + Minimum Inflow – Commitments – Overheads.*

85 ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

86 ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

87 ..... Murray and Murrumbidgee.

88 ..... Macquarie (10 to 21 months), Hunter (24 to 36 months), Lachlan (19 to 30 months), and Belubula (24 to 36 months).

89 ..... Gwydir, Namoi, Border Rivers, Peel, and Lower Darling.

90 ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

91 ..... The Incidence Response Guide specifies a 24-month planning horizon; page 19: 'The critical planning period for the Lower Darling regulated river system is two years, consistent with the lowest inflow sequence experienced during the 2013 to 2016 period.'
NSW Department of Planning, Industry and Environment (2019) *BASIN PLAN 2012 NSW Murray and Lower Darling Surface Water Resource Plan Incident Response Guide Schedule G*

92 ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

93 ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

94 ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*

6.1.2 Commitments

Water commitments accounted for in the priority reserve are limited to the water needs prioritised in ss 5(3) and 58 of the Act. These priority commitments (**Table 23**) include water for basic human and environment need as well as regulated river (high security) entitlements. The volume of priority human commitments is relatively small totalling 9.5 GL/y.[95] Priority environmental commitments based on revised needs total 204 GL/y.

The priority reserve does not account for the needs of regulated river (general security) allocations totalling up to 79.5 GL[96] plus carryover,[97] any contribution to the shared resource, or any trade balance. The Commission notes that most of the regulated river (general security) entitlement is held by the Commonwealth Environmental Water Holder and The Living Murray.

Table 23: Volumes of priority water commitments identified in Plan and water allocation methodology[98] and revised environmental commitments.

Priority water commitments	Current volume (ML)[99]	Revised volume (ML)
Basic landholder rights	445#	No change (445#)
Domestic and stock licences (100%)	1,341	No change (1,341)
Local water utility (100%)	422	No change (422)
High security (100%)	7,771	No change (7,771)
Minimum daily flows	95,600	174,350
Lower Darling EWA	0 or 30,000*	30,000
Total	**105,579 or 135,579**	**213,884**

Basic landholder rights are considered to be achieved through minimum daily flows and are not considered a commitment as part of the resource assessment
* 0 ML when operated as a NSW resource and 30,000 ML when a shared resource

6.1.3 Overheads

System overheads account for losses to the surface water consumptive pool through evaporation, infiltration, conveyance, and system operations. Volumes lost to evaporation represent the largest overhead in the Lower Darling-Baaka and can reduce the volume of water stored in the lakes by up to 40% over a year.[100] Total evaporation varies based on physical and atmospheric factors and cannot be measured resulting in uncertainty and ranges of evaporation losses (Table 4).

Table 4: Summary of evaporative loss estimates for all lakes in the Menindee Lakes System.

Loss estimate	Lower range (GL/y)	Average (GL/y)	Upper range (GL/y)
WaterNSW[101]			783
Water allocation methodology[102]	450	600	730

[95] ..... Basic landholder rights are assumed to be supplied through minimum daily flow releases and are not included in this total.
[96] ..... Section 24(b) Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2016
[97] ..... Up to 50% of entitlement is permitted as per section 43(2b) Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2016
[98] ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*
[99] ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*
[100] ..... NSW Department of Planning and Environment (2022) *Regional Water Strategy Western December 2022*
[101] ..... WaterNSW information request
[102] ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*

Long-term modelling[103]		410	660
General purpose water accounting reports (2009-2022)[104]	85	442	790

Evaporation accounted for as part of the priority reserve are limited to evaporative losses from the upper lakes. Estimates provided to the Commission by WaterNSW for this loss ranged from 229 GL/y when the upper lakes were at 50% capacity to 294 GL/y when at 100% capacity.[105] A previous published estimate for the upper range of evaporation for the upper lakes was 252 GL/y.[106]

The Commission notes that evaporation during dry conditions may be substantially lower when there is less stored water with a smaller surface area. For example, over 2015-2016 evaporation was estimated at 85 GL[107] when the upper lakes held between 2% (around 40 GL) and 6% (around 100 GL) capacity.

6.1.4 Minimum inflow

As part of the resource assessment process, the volume of water stored in the priority reserve is reduced by the volume of inflow expected to occur over the planning horizon. Incorporating water that is not stored risks supply shortfalls if the assumed inflow does not eventuate. This risk is lowered by applying the lowest inflow simulated in the long-term modelled record representing very dry conditions.

Resource assessments for the Menindee Lakes assume zero inflow over a 12-month period[108] and would likely assume zero inflow for a 24-month period if including the Millenium Drought.[109] This is lower than inflows assumed in other plan areas which vary from around 5 GL in the Belubula to more than 700 GL in the Murrumbidgee.

7 Insights arising from storage reserve scenario analysis

The Commission's analysis found that the storage reserve required when applying the risk framework generally applied in other valleys (24-month planning horizon, modelled minimum inflow, revised commitments) exceeds the total storage capacity of the upper lakes. This is also the case when applying a 12-month planning horizon. The upper lakes cannot store enough water to reliably deliver revised priority needs during drought conditions.

The lower-risk profile associated with the generally conservative assumptions used in other valleys is likely not appropriate to be applied in the Lower Darling-Baaka. There will likely need to be a higher 'agreed level of risk' of supply shortfalls for priority needs.

Approaches which apply a higher level of risk have been explored in **Appendix B**. The scenario analysis calculated the volume of priority reserve required when modifying each of the input parameters separately. Combinations of parameter changes should be explored to determine the volume of a potential storage reserve and assess the risk profile those reserves provide. Insights from the scenario analysis include:

[103] ..... NSW Department of Planning, Industry and Environment (2019) *BASIN PLAN 2012 NSW Murray and Lower Darling Surface Water Resource Plan Incident Response Guide Schedule G*
[104] ..... GPWARs are available on SEED
[105] ..... WaterNSW information request
[106] ..... SEBAL: Evans, R. et al (2009) *Using satellite imagery to measure evaporation from storages–solving the great unknown in water accounting*
[107] ..... Burrell M., Moss P., Petrovic J., Ali A., (2017) General Purpose Water Accounting Report 2015-2016: Lower Darling Catchment, NSW Department of Primary Industries, Sydney
[108] ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*
[109] ..... WaterNSW information request

- Planning horizons have a substantial impact on the volume of the storage reserve. For a reserve to fit within the upper lakes storage capacity, the planning horizon for priority human need likely needs to be longer than that provided for environmental need. Environmental need may not be able to be provided for even if the planning horizon is shorter than that applied in other plan areas.
- The high rates of evaporation substantially increase the storage reserve volume even over shorter planning horizons. An approach which relies more heavily on inflow may be required to reduce the evaporative losses.
- Assuming higher inflows decreases the storage volume required but carries risks of shortfall if these inflows don't eventuate. These risks can be estimated using the historic and modelled records. For example, assuming an annual inflow of 84 GL/y leads to a reserve volume of around 360 GL for 12 months priority need. This is associated with a 25% chance of shortfall based on the flow at Wilcannia over the last 20 years.
- Finally, consideration should be given to improving arrangements for increasing the volume of water regularly held in the upper lakes as occurs during surcharge events. This approach likely requires infrastructure upgrades to the Pamamaroo regulator and may impact cultural heritage outcomes (discussed further in Section 9).

Generally, the scenario analysis indicates that providing for priority needs in the Lower Darling-Baaka likely requires the upper lakes to be kept as full as possible, potentially at a surcharged storage level, lower priority demands reduced or removed and a mechanism to increase the volume of inflow when needed to top up the lakes. However, even with this approach, the risk of shortfall for priority environmental needs will likely be higher than the risk profile established in other plan areas.

8 Importance of updated modelling to underpin a reserve volume and trigger conditions

A range of scenarios should be simulated using hydrological models to account for changes in extractions, inflows, stored volumes, and evaporation over the long-term climate. These scenarios should evaluate the benefits and impacts of possible rule changes and priority reserve assumptions. However, the Commission understands that a number of improvements to DCCEEW-Water and MDBA models would be needed to better reflect current conditions and proposed rule changes. These include improved representation of low and no-flow events, lake volumes during dry spells, the order of lake drawdown, revised minimum daily flow rates with specific release locations, updated EWA provisions, representation of drought restrictions, and inaccessible storage volumes.

9 Evaluating potential social, cultural, and economic impacts

The proposed rule changes seek to improve environmental outcomes by improving delivery of water for basic ecosystem needs including responding to poor water quality events. This focus aligns with the principles of the Act, specifically section 5(3), which requires water to be prioritised to protect the water source and its dependent ecosystems as well as for basic landholder rights. These water needs must be prioritised above and before other water sharing. After these priorities are met, the potential benefits for social, cultural and economic outcomes should be maximised and impacts minimised consistent with the general water management principles in Section 5(2).

The Commission is unable to quantify potential benefits and impacts on social, cultural and economic outcomes due to the lack of available data and resources. Hydrological model simulations are required to assess changes over the long term and the potential benefits and impacts on social, cultural and economic outcomes. These models are operated by the DCCEEW-Water and the MDBA and should be updated to better reflect current management conditions as well as proposed rule changes.

The Commission acknowledges several areas where potential benefits and impacts require further consideration including:

- Increased flows, enhanced ecosystem health and water quality along the Lower Darling-Baaka will likely provide benefit to and increase outcomes for social amenity values and wellbeing, cultural values and economic values in the Lower Darling-Baaka. It is anticipated that proposed provisions will help to ameliorate some of the impacts that the degradation of the Lower Darling-Baaka River have had on Barkandji Traditional Owners and their connection to Country and culture.
- Increased drawdown from the upper lakes and other changes to upper lake operations may impact the volume of drought reserves maintained in the upper lakes and require appropriate responses to ensure the reserve for critical human need is maintained. Increased drawdown of the upper lakes may also impact social amenity and wellbeing, as well as cultural values associated with the upper lakes during dry periods. Long term modelling would be required to identify the impact of rule changes on upper lake storage levels.
- Potential impacts on inflows to lakes Menindee and Cawndilla associated with increased drawdown of the upper lakes for meeting revised minimum daily flow requirements and EWA are possible but likely minimal given expected additional inflows to the lakes from proposed rules for the northern Basin. Hydrological modelling will help to assess these potential impacts.
- Surcharging the upper lakes may impact cultural heritage outcomes due to increased inundation including potential disturbance and damage to Aboriginal burial sites and associated objects. Further consideration of strategies and operations to protect cultural heritage are required.
- Potential economic impacts arising from changes to the long term allocation reliability to the shared consumptive pool (including NSW and Victorian Murray general security licence holders) and lower priority users in the Lower Darling-Baaka River. Any changes in allocation reliability need to account for any increased inflow arising from upstream valley rule changes. An assessment of potential changes in allocation reliability requires the use of long term modelling.

Appendix A: Water sharing plan reviews

1 The Commission's role in reviewing water sharing plans

The Commission has a role under Section 43A of the Act to review water sharing plans within five years of expiry, and report to the Minister on:

- the extent that a plan's water sharing provisions have materially contributed to the achievement of, or failure to achieve, environmental, social and economic outcomes
- if changes to plan provisions are warranted.

The Commission may recommend extending or replacing plans depending on its review findings. Section 43A(3A) of the Act requires the Commission to consider some potential compensation requirements resulting from recommended plan changes.[110] Under the Act, compensation is payable by the state to access licence holders only in certain circumstances[111] where water allocations under a water sharing plan are reduced.

The Commission's review must consider the water management principles,[112] including the water sharing principles, when reviewing plans. The Act is clear that water sharing is not about balancing uses and values – it is about first providing for the environment and second recognising basic landholder rights above other uses. It specifies that the:

a) sharing of water from a water source must protect the water source and its dependent ecosystems, and

b) sharing of water from a water source must protect basic landholder rights, and

c) sharing or extraction of water under any other right must not prejudice the principles set out in paragraphs (a) and (b).[113]

Further, the water management principles should be prioritised in the order that they are set out above.[114] Water sharing plans must be based on evidence to achieve these outcomes.

In reviewing the Plan, the Commission aims to contribute to improved and more transparent water management by evaluating the achievement of Plan environmental, social, cultural and economic outcomes through:

- evaluating key risks to Plan outcomes under current Plan provisions
- independently assessing Plan performance, and alignment with the objects, principles and priorities of the Act

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[110] ..... If a Commission report recommends changes to a plan that will reduce water allocations in relation to which compensation might be payable under Section 87AA of the Act, the Commission is to state in the report if the purpose of the proposed changes is: (a) to restore water to the environment because of natural reductions in inflow to the relevant water source, including changes from climate change or drought or (b) to provide additional water to the environment because of more accurate scientific knowledge demonstrating the amount previously allocated to the environment is inadequate.

[111] ..... As set out in sections 87 and 87AA of the Act. Section 87 states that compensation applies for certain reductions in water allocations arising during the initial (10-year) period of a water sharing plan, only where amendments are not already contemplated in that plan. Section 87AA makes clear that compensation applies to amendments to the Plan after its 10-year term. In addition, the Minister has an overriding discretion under Section 87 (but not under Section 87AA) to determine if compensation should be paid and, if so, the amount of any such compensation and the manner and timing of any payments.

[112] Section 5 of the Act.

[113] ..... Section 5(3) of the Act.

[114] ..... Section 9(1) of the Act.

- identifying areas where Plan provisions can be improved to better achieve outcomes
- identifying new evidence and good practices to improve Plan design and performance.

The Commission's full evaluation framework is published on the Commission's website.[115]

2 Relevant regional plans, policies, programs and agreements

In reviewing the Plan, the project team considered the following plans, policies and agreements in accordance with Section 43A(4)(b) of the Act:

- NSW Water Strategy
- Western Regional Water Strategy
- Murray Darling Basin Agreement and the Objectives and Outcomes for River Murray Operations document, as these affect the management of Menindee Lakes as a shared resource (O&O)
- Murray and Lower Darling Surface Water Resource Plan and other accompanying documentation, such as the Long-Term Water Plan (LTWP)
- programs that form part of the suite of projects under the Better Baaka program (formerly the Sustainable Diversion Limits Adjustment Mechanism (SDLAM) program), as these affect Menindee Lakes and the Lower Darling-Baaka River
- various Department policies as these impact water management in the Murray and Lower Darling regulated system including water allocation methodology[116] and the Extreme Events Policy.[117]

[115] ..... NSW NRC (2022) *Review approach*
[116] ..... NSW DPE (2022) *Water Allocation in the Regulated Lower Darling River*
[117] ..... DPE (2023) *Extreme Events Policy*

Appendix B: Scenario analysis

1 Scenario assumptions

Without access to modelled scenarios, static water balances have been calculated to illustrate the relative impact of changes to key water balance parameters. These scenarios make the following assumptions:

- Parameters are fixed (static) over the planning horizon.
- All priority commitments are drawn from the upper lakes. This assumption should be revised to exclude any priority commitments that do not need to be drawn from the upper lakes. Lower priority commitments including regulated river (general security), the shared consumptive pool (including annual dilution flows), or commitments arising from trade have not been included.
- Evaporative losses represent all system overheads and was generally assumed to be 230 GL/y based on the lakes being at 50% capacity. This assumption overestimates evaporation when storages have been depleted.
- All flow at the Wilcannia gauge enters Lake Wetherall without losses.

2 Modifying planning horizons

Modifications to the planning horizon parameter could include changing the duration (i.e., 6, 12, 18 or 24 months), applying fixed or variable durations, or applying different horizons for each priority need.

Error! Reference source not found. includes three scenario examples where the duration of the planning horizon has been modified. Applying a 12 month or longer planning horizon results in a storage reserve which exceeds the total accessible storage of the upper lakes, noting that assuming 230 GL/y evaporation overestimates evaporation when storages are low.

Table 5: Water balance scenarios modifying the planning horizon.

These scenarios provide for priority human and revised environmental commitments and assume zero inflow and 230 GL of evaporation per year.

Scenario modifications:
A. Applying a 12-month planning horizon
B. Priority human commitments for an 18-month planning horizon and environmental commitments for a 12-month planning horizon
C. Priority human commitments for a 24-month planning horizon and environmental commitments for a 12-month planning horizon

	A	B	C
Human (GL)	10	15	20
Environmental (GL)	204	204	204
Evaporation (GL)	230	345	460
Less **inflow (GL)**	0	0	0
Storage reserve (GL)	480*	564*	672*

* volume exceeds total accessible storage of the upper lakes

Reducing the duration of the planning horizon will increase risks of supply shortfalls for any dry period that exceeds the planning horizon duration. Applying shorter duration planning horizons for priority needs should consider the Act's principles and should only be implemented if satisfactory alternative water sources can provide for critical human needs during dry conditions.

3 Modifying commitments

Modifications to the commitment parameter reduce the assumed volume of priority human and/or environmental need. Scenario examples (**Error! Reference source not found.**) explore implications for the priority reserve if no priority environmental need was accounted for, if current minimum daily flows were used, and if priority commitments are reduced to represent 'critical' needs[118] when water restrictions are in place and minimum daily flows are reduced.[119] The Commission notes that providing a priority reserve to achieve only restricted commitments during drought conditions would be inconsistent with the approach applied in all other plan areas and may not comply with the Act's water sharing principles.

In practice there are options to reduce priority commitments from the upper lakes. For example, options to encourage licence holders to convert regulated river (high security) entitlement to regulated river (general security), trade limitations on works that draw water from the upper lakes and infrastructure improvements which may allow for lower minimum daily flows without increased risk of poor water quality and fish kill events.

Table 6: Water balance scenarios modifying commitments.

These scenarios assume 230 GL/y for evaporation and assume zero inflow for a 12-month planning horizon.

Scenario modifications:
A. Priority human commitments and zero environmental commitments
B. Priority human commitments and current environmental commitments (96 GL/y)
C. Restricted human and environmental commitments during drought conditions assuming lower evaporation at 180 GL/y

	A	B	C
Human (GL)	10	10	6
Environmental (GL)	0	96	63
Evaporation (GL)	230	230	180
Less **inflow (GL)**	0	0	0
Storage reserve (GL)	240	336	249

4 Modifying system overheads

Modifications to the system overheads parameter reduce volumes of assumed losses over the planning horizon. Scenario examples (**Error! Reference source not found.**) include reduced evaporation representing conditions when storage reserves are at critical levels over a 12- and 24-month planning horizon, evaporation at the upper end estimate over 12 months and the volume of evaporation assumed to occur over 12 months to keep the volume of the storage reserve less than 250 GL.

Risks related to evaporation assumptions can be calculated based on long-term modelling of historic and climate change conditions or estimates from the historic record. Assuming 230 GL/y evaporation from the upper lakes may reflect higher than actual evaporation from the upper lakes when stored water is low. Assuming higher evaporative losses may align with likely increased evaporation under climate change. In addition, due to the interlinked

[118] ..... The priority of distribution for the making of available water determinations changes during plan suspensions made using severe water shortages or extreme events to prioritise critical and essential human need, followed by environmental needs then regulated river (high security), basic landholder rights (stock) and stock licences before remaining lower-priority needs.

[119] ..... WaterNSW proposed in the incident response guide to reduce the current minimum daily flows (96 GL/y) to 63 GL/y during Stage 2 (emerging drought/water shortage) and suspend them during Stage 3 (severe drought) and Stage 4 (critical drought). NSW Department of Planning, Industry and Environment (2019) *BASIN PLAN 2012 NSW Murray and Lower Darling Surface Water Resource Plan Incident Response Guide Schedule G*

nature of the water balance, other parameter changes will also impact on evaporative losses.

There are limited options to reduce evaporation in practice. Evaporative losses are reduced when less water is stored but this conflicts with providing sufficient volumes of stored water for priority needs. Infrastructure improvements, particularly to the Pamamaroo inlet regulator, may allow more water to be held in Lake Wetherall and reduce evaporative losses from Lake Pamamaroo. Increased use of transparent or translucent flows may reduce evaporative losses.

Table 7: Water balance scenarios modifying overheads.

These scenarios apply priority human and revised environmental commitments and assume zero inflow.

Scenario modifications:

A. Lower evaporation (180 GL/y, representing 2018-2019 conditions) for a 12-month planning horizon
B. Lower evaporation (180 GL/y, representing 2018-2019 conditions) for a 24-month planning horizon
C. Higher evaporation (294 GL/y) for a 12-month planning horizon
D. Evaporation volume assumed for a 12-month planning horizon storage reserve to be less than 250 GL

	A	B	C	D
Human (GL)	10	20	10	10
Environmental (GL)	204	408	204	204
Evaporation (GL)	180	360	294	36
Less **inflow (GL)**	0	0	0	0
Storage reserve (GL)	394	788*	508*	250

* volume exceeds total accessible storage of the upper lakes

5 Modifying assumed inflow

Minimum inflows represent a conservative estimate of future inflow that is very likely to occur under all climate conditions. As inflows are subtracted from the water balance any increase to the assumed inflow decreases the storage volume with an associated increase in risk of supply shortfall. Scenario examples (**Error! Reference source not found.**) include:

- For a 12-month planning horizon, an inflow of 350 ML/d (Wilcannia baseflow; 127 GL/y) requires a storage reserve of 317 GL to meet priority needs. The risks of this inflow not occurring under a repeat of the last 20 and 40 years are 25% and 15% respectively.
- For a 12-month planning horizon, an inflow of 84 GL/y (230 ML/d) is required for a storage reserve to be 360 GL. The risks of this inflow not occurring under a repeat of the last 20 and 40 years are 22% and 13% respectively.
- For a 24-month planning horizon, an inflow of greater than 222 GL/y (608 ML/d) is required for a storage reserve to be less than 445 GL, the total accessible storage capacity of the upper lakes. The risks of this inflow not occurring under a repeat of the last 20 and 40 years are 52% and 39% respectively.
- No storage reserve is required if the average annual inflow over the last 20 years (greater than 1,500 GL/y) is assumed. However, assuming average inflow, which is disproportionately influenced by large flood events, poses a high risk of insufficient inflow as under a repeat of the last 20 and 40 years this occurred 69% and 60% respectively.

In practice, rule changes to increase the long term modelled minimum inflow to match the assumed inflow would require rule changes that increase inflow during severe drought conditions. These rule changes would likely have a substantial impact on upstream users and are unlikely to substantially increase inflows when there is limited water available.

Risks associated with changes to the inflow assumption can be calculated based on the frequency of time those inflows occurred in the historical record and/or climate change modelling. Assuming higher minimum inflows increases risk for priority needs and would require appropriate and timely management responses if inflows were lower than assumed otherwise the shortfall burden would be applied to priority users.

The Commission notes that low inflows are frequently grouped over consecutive years during drought conditions often exceeding a 12-month planning horizon. In addition, the frequency and duration of dry and drought conditions are likely to increase under climate change. Both factors should be considered further when assessing shortfall risks associated with assuming higher inflows.

Table 8: Water balance scenarios modifying inflow.

These scenarios apply priority human and revised environmental commitments and assume 230 GL/y of evaporation.

Scenario modifications:
A. 350 ML/d inflow assumed for a 12-month planning horizon
B. Inflow required for a 12-month planning horizon storage reserve to be less than 360 GL
C. Inflow required for a 24-month planning horizon storage reserve to be less than 445 GL (accessible storage volume of the upper lakes)

	A	B	C
Human (GL)	10	10	20
Environmental (GL)	204	204	408
Evaporation (GL)	230	230	460
Less **inflow (GL)**	127	84	444
Storage reserve (GL)	317	360	445
% of time inflow not achieved over last 20 years	25%	22%	52%
% of time inflow not achieved over last 40 years	15%	13%	39%

* volume exceeds total accessible storage of the upper lake