Submission: Independent Review into the February-March 2023 fish deaths in the Darling-Baaka River, Menindee

July 2023

Executive Summary

WaterNSW welcomes the opportunity to provide a submission to the *Independent Review into the February-March 2023 fish deaths in the Darling-Baaka River, Menindee*.

In responding to the review terms of reference, the central components of this submission have been structured in the following format:

1. WaterNSW operations at Menindee Lakes - how WaterNSW functions at Menindee Lakes as a normal course of business.
2. WaterNSW actions during February/March 2023 - how WaterNSW exercised its functions during February/March 2023 (before and during the event) *(Chief Scientist and Engineer Terms of References s2)*.
3. Timeline - a timeline of WaterNSW's major operational activities in Menindee Lakes in the lead up to the event *(Terms of References s2)*.
4. Observations - matters relevant for consideration of recommendations *(Terms of References s3)*.

Note: The majority of references to flows or releases in this document are referred to in megalitres per day (ML/day). Where appropriate, volumes are referred to in gigalitres (GL) (One GL is 1,000 ML).

Introduction

Firstly, WaterNSW acknowledges the stress of this event on the Menindee community, particularly on those who rely so heavily on the river. We also acknowledge the impact on First Nations communities given their deep connection to the river and country.

The tragic fish death event of March 2023 followed a prolonged series of floods statewide, and associated water quality challenges in the Menindee region, which commenced in late 2021. Over this period the Menindee Lakes received the equivalent floodwaters and inflows of six times the lakes' capacity, more than 12,000 gigalitres (GL) of water, equating to more than five times what would normally be received in a year.

The Menindee Lakes – as the terminal lake system at the end of the northern flood plains and river tributaries – ultimately received all this water, organic debris, and fish populations. These floods brought with them not only vast volumes of water, but also an

incredible amount of organic matter like leaves, grass, trees, and brush from the floodplain, which supported conditions that proved ideal for the accumulation of algae.

WaterNSW submits that these prevailing conditions, combined with the extreme hot weather, large numbers of fish in the river as floodwater receded, and physical barriers to fish passage, likely all contributed to the conditions leading into this large-scale fish death event.

The Hypoxic Blackwater Working Group

In the months leading up to this event, a significant number of NSW and Federal Government agencies, including WaterNSW, worked closely together to mitigate these challenges to the natural environment at Menindee Lakes.

These coordinated management efforts were driven by a multi-agency State Government initiative known as the Hypoxic Blackwater Working Group (HBWG) (chaired by DPE-Water) designed to provide advice on management options and actions during a hypoxic water quality event. The working group tracked water quality impacts resulting from the prolonged flooding in New South Wales and coordinated actions across a wide range of agencies, based on consensus decision making.

WaterNSW's role in Menindee Lakes

The role of WaterNSW is set out in legislation, regulations, and its operating licence. With regard to the Menindee Lakes, this means WaterNSW performs its functions in relation to the lakes system under its statutory obligations and regulatory framework, including the Murray-Darling Basin Agreement.

During the period leading to the fish deaths, WaterNSW managed releases as per these operating rules at the recession (decreasing rate of flow) of the flood, noting that:

- The Menindee Lakes storages had been surcharged above full supply level (FSL, 100% capacity) since mid-February 2022, only returning to FSL again at the end of February 2023.
- All releases made over and above those required under WaterNSW operating rules (Work Approval) were made:
    - Following the advice, based on a consensus of agencies from the HBWG,

and in accordance with directions or requests from the HBWG;[1] or

- Following directions and water orders placed by environmental water (e-water) holders, the NSW and Australian Governments, following the consensus advice of the HBWG.[2]

During this time, WaterNSW ensured information was available to aid other agencies and the HBWG to determine the best approach to manage water quality and environmental outcomes. During this period, WaterNSW, as stated above, followed directions[3] and delivered e-water orders as required. Significant coordination and resources were allocated by multiple agencies to the working group to investigate potential management options and interventions.

There were inherent limitations in intervening and managing the conditions preceding the event. Notably, these limitations include:

- The absence of dams or other major assets along the extensive length of the Barwon-Darling upstream of Menindee means there are no measures that can control floodwaters making their way into the lakes.
- The inlet, outlet and storage capacity of the various lakes and assets (for example, regulators) in the Menindee Lakes System and WaterNSW's responsibility to ensure that storages are managed safely and in line with dam safety regulations.
- The physical barriers to fish passage on weirs that cannot be addressed through operational measures (such as releasing water).
- That the impact of releases from dams do not have immediate impacts. For example, it can take around nine days for dissolved oxygen (DO) to show a change (if any) at the river section of Weir 32 and downstream of Menindee outlet after a flow change has been made at Pamamaroo outlet.
- The defined nature of the current legal and regulatory framework which limits the discretion in which WaterNSW operates the Menindee Lakes infrastructure. For

[1] Initially, this included a total of 30 GL of additional releases from the Lower Darling-Baaka Environmental Water Allowance (EWA), which is sometimes referred to as the "Water Quality Allowance".

[2] As the MDBA can call on water when the storages are below FSL, the MDBA facilitated the requests for WaterNSW to release water to meet order requirements (It should be noted that WaterNSW has no discretion to refuse a Ministerial direction or to reject a legitimate water order.)

[3] These EWA releases were made from mid-February to mid-March at the direction of DPE-W as the Minister's delegate (following the consensus advice of the HBWG).

example, WaterNSW does not have its own water allocation to release, but rather must release water when it is ordered by customers, including environmental water holders, or under a Ministerial direction.

Releases into the Lower Darling-Baaka River

In the period 6 to 14 March 2023 (leading up the fish deaths), in managing the flood recession WaterNSW was releasing, at a declining rate, between 4,000 and 2,000 ML a day from the Menindee Lakes into the Lower Darling-Baaka River. No change to the release strategy was recorded on 14 March 2023.

The releases into the Lower Darling-Baaka River during this period comprised:

- Over 95% of releases sourced from the 'better quality' water at Lake Pamamaroo.
- Only minimal (less than ~5%) water from Lake Wetherell – which contained the poorest quality water in the Lakes – through minimal water passing through fish baffles installed on the Pamamaroo Inlet Regulator (at the request of DPI Fisheries via the HBWG) or minor leakage from the Wetherell Outlet Regulator[4] (due to accumulation of debris and silt during the floods), rather than active releases.

WaterNSW refers the Chief Scientist to research conducted by Charles Sturt University expert freshwater ecologist Professor Darren Baldwin. His opinion is that this minimal release rate of (lower DO) water to be far below what would be required to significantly impact DO levels downstream. Specifically, Professor Baldwin in his report, "*if there were any inflows into Lake Pamamaroo from Lake Wetherell immediately prior to the fish deaths, they would be best described as trivial*[5]".

Concluding comments

WaterNSW is happy to provide the Chief Scientist & Engineer with any further information that helps with the Review, including relevant monitoring and operational data.

We hope that our submission, and in turn the report of the Chief Scientist & Engineer, provides clarity for the communities of Menindee and those across NSW, including recommendations to ensure that agencies have available all possible avenues to ensure fish deaths are prevented in the future.

---

[4] Leaking at 65ML/day.

[5] A critical evaluation of Williams and Schulz (2023) Professor Darren Baldwin, *Rivers and Wetlands.*

About WaterNSW

Purpose: *Water, delivered when and where it matters.*

Vision: *To support the resilience of NSW communities through our leadership in delivering water services, for generations to come.*

WaterNSW is a State-Owned Corporation (SOC) established under the *Water NSW Act 2014* (NSW) and operates under an Operating Licence issued and monitored by the NSW Independent Pricing and Regulatory Tribunal (IPART). The services provided by WaterNSW are subject to economic regulation by IPART.

As a SOC, and subject to Government directions, WaterNSW is bound by the objectives outlined in the *Water NSW Act 2014* (NSW), including to operate at least as efficiently as any comparable business and to maximise the net worth of the State's investment in WaterNSW.[6]

WaterNSW is responsible for supplying the state's bulk water needs, operating the state's regulated river systems and the bulk water supply system for Greater Sydney and providing services to its customers with respect to licensing and approvals, water allocation trades, water licence trades and water resource information.[7] With more than 40 dams across the state, WaterNSW supplies two-thirds of water used in NSW to regional towns, irrigators, Sydney Water Corporation, environmental water holders and local water utilities. Through its hundreds of employees located across the state, WaterNSW provides services daily to over 40,000 customers and manages its extensive operational assets, water monitoring and metering networks.

[6] *Water NSW Act 2014* (NSW), section 6(2).
[7] *Water NSW Act 2014* (NSW), section 6.

Figure 1- WaterNSW Map of Operations

WaterNSW delivers five main functions:

- Source water protection – protection of the Greater Sydney drinking water catchment.
- Bulk water supply – supplying raw water from our storages to benefit customers, communities and the environment.
- System operator – managing water storages, operating the state's regulated river systems and bulk water supply systems. This includes working with the MDBA for the River Murray and Lower Darling-Baaka systems.
- Infrastructure planning, delivery and operation - projects to increase the security and reliability of water supplies to customers and the communities of NSW.
- Customer water transactions and information services - providing our customers with the highest level of service and support for water licensing and approvals, water trades, billing and to meet their water resource information needs for surface and groundwater quantity and quality.

WaterNSW operations at Menindee Lakes

WaterNSW operations are set out in legislation, regulations, and our operating licence. With regard to the Menindee Lakes, WaterNSW performs its functions under its statutory obligations and regulatory framework, including the Murray-Darling Basin Agreement. WaterNSW operates the infrastructure within the operational envelope, defined by the rules.

Menindee Lakes are owned by the NSW Government, but since 1963, NSW has agreed to share water from the lakes with the Commonwealth, Victorian and South Australian Governments. These arrangements now form part of the Murray Darling Basin Agreement, which can be found in the *Water Act 2007 (Cwlth)*. Under the Basin Agreement, the Murray Darling Basin Authority (MDBA) leases Menindee Lakes from the NSW Government and pays for three-quarters of the costs of operating and maintaining the storages.

Water Supply Infrastructure

In terms of releases from storages at Menindee Lakes, WaterNSW is bound by strict regulatory rules that govern how releases are made. When the volume of water stored in the lakes is greater than 640 Gigalitres (GL), the MDBA can call on water to be released from the lakes.[8] Whenever the lakes' volume falls below 480 GL, however, New South Wales may use the stored water as it requires until such time as the volume next exceeds 640 GL. This is the so-called "640/480 rule".

When the storages exceed full supply level (1,731 GL) the MDBA hands responsibility for operational decisions back to New South Wales. WaterNSW performs flood operations as per its Works Approval issued by Department of Planning and Environment – Water (DPE-W).

In times of flood, our legislative and regulatory instruments set out the need for WaterNSW to (in order of priority) maintain the safety of the dam infrastructure, ensure water security, and minimise impacts on downstream communities. The lakes can typically capture reasonable inflows during a flood, if there is enough airspace, however at certain levels water can't be captured and stored and will be passed as floodwater downstream. To do

[8] Water accessed by the MDBA is on behalf of the joint governments of South Australia, Victoria and New South Wales and is used to support entitlements in the river Murray.

otherwise under flood operations could risk damage to the scheme's structures with potential consequences for downstream lives, environment, and property.

Therefore, for the lakes system, this results in operating the lakes and assets within tight parameters during and after the floods, to make sure as to:

- Not over-fill the lakes, risking structural damage;
- Avoid inundation of cultural heritage sites; and
- Where possible, lesson impacts of flooding on people and property.

All increases to water releases are also subject to agreement with the State Emergency Service (SES), as per the State Flood Plan, and communicated with all relevant stakeholders.[9]

In managing a flood recession, WaterNSW is also required to safely balance the water levels in each of the storages. This is, among other things, to ensure the integrity of the structures is maintained. Certain asset limitations exist, such as the head differential that is permissible between Lakes Wetherell and Pamamaroo on either side of the Pamamaroo Inlet Regulator.[10]

The Menindee Lakes can temporarily hold up to 120% of Full Supply (~2,050 GL at maximum surcharge) and are typically drawn down to full supply level after a flooding event where the management of shared water resources reverts back to the MDBA. As per WaterNSW's regulatory framework, reducing the storages to full capacity is critical for maintaining the integrity and safety of the structures and is a normal part of flood operations.[11]

---

[9] WaterNSW also works together with other flood response agencies when managing floods. Agency roles and responsibilities are outlined in the NSW State Flood Sub-Plan 2018.

[10] This means that at no time, for example, can the level of Lake Wetherell be any more than 1.8 metres higher than the level of Lake Pamamaroo to meet Dam Safety requirements. To exceed this head difference could result in failure of the Pamamaroo Inlet Regulator with significant or catastrophic consequences. In practical terms, what this means is that during the flood recession, the Pamamaroo Inlet Regulator can be closed for certain periods of time; however, whilst ever the Lake Wetherell storage level is rising (e.g. due to inflows) and/or the Lake Pamamaroo storage level is falling (e.g. due to releases through the Pamamaroo Outlet regulator to the Darling-Baaka River) this configuration cannot be maintained indefinitely.

[11] Under its operating rules (Work Approval), WaterNSW is required to manage the recession of a flood to ensure that the shape of the flood hydrograph maintained downstream of the lakes is of similar shape to that of a natural flood event. This, in effect, means that releases must continue from the storages to not only ensure that the integrity and safety of the structures is maintained, but to provide additional environmental protection and benefits downstream. The rates of changes in the recession releases are strictly prescribed in the Works Approval to ensure that there are no rapid changes (or cessation) in overall releases to prevent issues such as bank slumping and erosion or other environmental harm.

Outside of flood releases, WaterNSW can only release water from a water account or from an allocation of water set aside under the rules, such as the Water Quality Allowance established by the Water Sharing Plan for the New South Wales Murray and Lower Darling-Baaka Regulated Rivers Water Sources.[12] Any water above the normal operating requirement must be accounted for. WaterNSW has no mechanism to reject a valid water order from a customer.

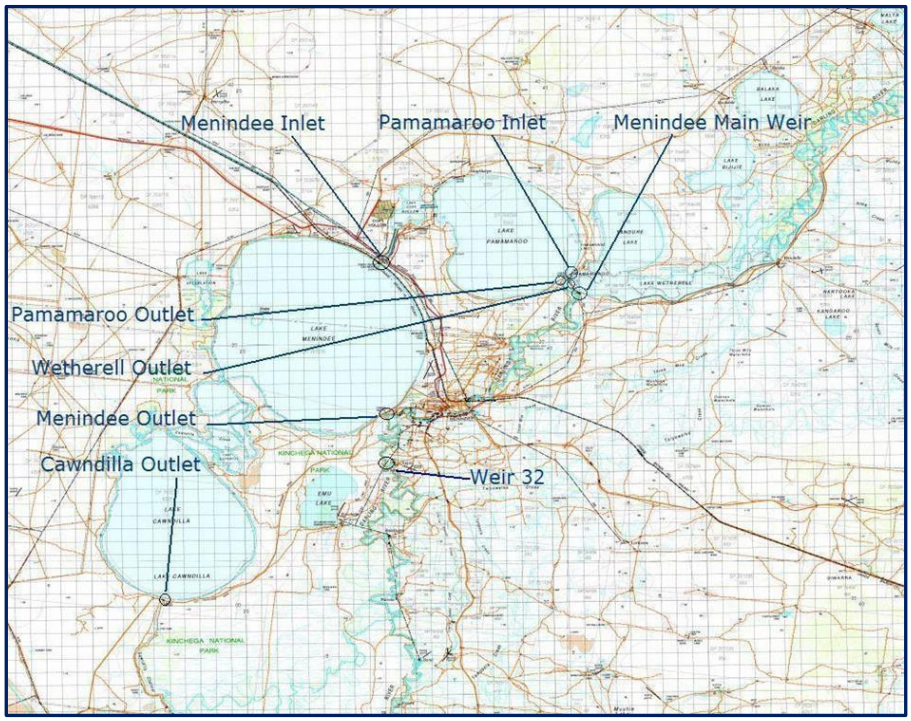

Figure 2- Menindee Lakes Storage Scheme

Water Quality Monitoring

Although WaterNSW has no specific responsibility for regional water quality (see **Observations**), we own a large network of river gauges state-wide, some of which record water quality information in near-to-real-time. This network of gauges has been developed over time to fulfil the information needs of WaterNSW as well as a variety of stakeholders such as the Department of Planning and Environment – Water (DPE-W), the

[12] Water Sharing Plan for the New South Wales Murray and Lower Darling-Baaka Regulated Rivers Water Sources 2016.

Murray Darling Basin Authority (MDBA) and local councils to help them perform their roles.[13]

WaterNSW is not the sole gauge owner and operator in NSW – there are hundreds of gauges owned by multiple groups, for example DPE Environment and Heritage Group, local councils, the MDBA and the Manly Hydraulics Laboratory.

The Barwon-Darling system has a comprehensive network of monitoring sites. Within the area between Wilcannia and Wentworth on the Darling-Baaka River and Great Darling Anabranch (downstream of Lake Cawndilla), there are 19 water monitoring sites (excluding the Menindee Lakes system storage gauges). This includes three sites upstream of the Menindee Lake system storages on the Darling-Baaka River and on the Talyawalka Creek.

Water Quality Monitoring Sites

Primarily, information obtained from the monitoring network is used by WaterNSW to plan the management of dam releases and river flows (that is, not for water quality). However, a smaller number of sites also have co-located instrumentation to collect water quality data (e.g. dissolved oxygen, salinity and water temperature) for use by other agencies, such as DPE-W, MDBA and local councils – to help them perform their roles.

WaterNSW Water Quality Monitoring activities in the Barwon-Darling includes:

- The maintenance of two permanent dissolved oxygen (DO) sensors at level gauge sites at Moorabin (Wilcannia) and Burtundy (several hundred kilometres downstream of Menindee) on the Darling-Baaka River.
- Programmed and ad hoc requested sampling for algae (analysed in a laboratory) and DO at multiple sites along the Darling-Baaka River and within the Menindee Lakes System.

WaterNSW has also maintained temporary DO sensors at Nellia Gaarie (upstream of Lake Wetherell) and Weir 32 since January 2022.

[13] A number of WaterNSW's gauges are also used by the State Emergency Service (SES) and the Bureau of Meteorology (BoM) in undertaking their roles in relation to flood planning, forecasting and emergency response.

WaterNSW actions during February/March 2023

Water Supply Infrastructure

Introduction

In the period leading up to the fish deaths, WaterNSW managed the recession of the flooding event, to safely pass the Darling-Baaka River floodwaters and return the Menindee Lakes below the surcharge level (to their full capacity). The combined Menindee Lakes Scheme storages were continuously above full supply level (in surcharge) for more than 12 months from mid-February 2022 to the end of February 2023.

Throughout this process, WaterNSW worked in close consultation with, and acted on consensus advice provided by, the Hypoxic Blackwater Working Group (chaired by DPE-Water). The agencies on the HBWG include (but are not limited to):

- The Department of Planning and Environment Water (DPE-W), which sets the rules and policies relating to water management in NSW and serves as Chair of the HBWG (under some circumstances DPE-W can direct WaterNSW to take certain actions on behalf of the Minister).
- DPI Fisheries, which provides advice on critical fish refuges, thresholds, locations, and requirements, and provide advice on fish population management measures.
- The Murray Darling Basin Authority (MDBA), which manages the shared water resources and can call upon water to be released from the Menindee Lakes outside of drought.
- The Commonwealth and NSW Environmental Water Holders (CEWH and EHG), which decide when to order environmental water held in the lakes, to be released for environmental benefit.
- WaterNSW, which as the operator of water infrastructure and water monitoring assets, provides data, information and advice and implements operational responses to meet the needs of the HBWG.

Water released in the period was delivered either as:

1. Releases required as per WaterNSW's Work Approval pertaining to flood operations and the flood recession (as noted above).

2. Water directed to be released under the Lower Darling-Baaka Environmental Water Allowance. This is sometimes referred to (and referred forthwith in this document) as the 'Water Quality Allowance' and is an allocation of 30,000 ML of water held in the lakes as specified in the Water Sharing Plan. To release this water, under its Work Approval, WaterNSW must receive a Ministerial direction (from DPE-Water as the Minister's delegate). This water was used to ensure releases to the Lower Darling-Baaka were made over and above the minimum releases required (as per the works approval) during the flood recession.

3. Customer Water Orders (from Commonwealth or NSW Environmental Water Holders) to deliver held environmental water releases into the Lower Darling-Baaka over and above the minimum releases required during the flood recession and thereafter. WaterNSW has no mechanism to reject a valid water order from a customer.

*Note: Full details of the form of these releases during the event is available in **Timeline**.*

Management 31 December 2022- 23 February 2023

From 1 January 2022 to 28 February 2023, inflows to the Menindee Lakes were >12,200 GL. This volume of water was managed through the Menindee Lake System via releases from regulators (including Main Weir continuously) from 27 April 2022 to 17 February 2023 as part of WaterNSW's airspace and flood operations.

The Lake Wetherell storage level peaked on 31 December 2022 with the Wetherell storage surcharged to 170.9% of full supply capacity at that time. This involved releasing water through the Main Weir gates, with maximum releases of 75,000 ML/d occurring on 1 January 2023 (compared with maximum inflows of >106,000 ML/d).

Throughout January and February 2023, WaterNSW managed the recession under specified parameters to bring the storages back to full supply level[14] and to ensure the releases maintained a hydrograph in the downstream Lower Darling-Baaka River of a shape similar to that of a natural flood, as per the Work Approval conditions. Releasing water either directly into the Lower Darling-Baaka River or into Lake Pamamaroo was therefore inevitable so as not to exceed the safe storage limits during this period.[15] The

[14] At full supply level, Lake Wetherell has a capacity to store ~193 GL of water. Inflows to Lake Wetherell during January were >2018 GL, which is a substantial volume of water and in excess of the storage capacity of the entire Menindee Lakes System (~1731 GL).

[15] During February and March 2023 alone, on the recession of the flood, inflows to Lake Wetherell totalled more than 394 GL, which is more than twice the volume able to be stored in the lake.

Main Weir was closed on 17 February 2023 and the combined storages returned to FSL on 28 February 2023.

Management 24 February- 16 March 2023

Water released above the required recession flows (from 24 February onwards) was initially made up of 30 GL of water held in the lakes under clause 64 of the Water Sharing Plan as the Water Quality Allowance. The Water Quality Allowance was exhausted by 16 March 2023. Therefore, releases above the minimum recession requirements were thereafter made for environmental water (e-water) holders who placed orders with WaterNSW for that water.[16]

During this period, WaterNSW continued to release water from Pamamaroo outlet regulator – which contained water of a better (although still relatively poor) quality – into the Lower Darling-Baaka River. The Pamamaroo inlet regulator, which receives water from Lake Wetherell into Lake Pamamaroo, was closed on 27-28 February and remained substantively closed until 20 March, with the exception of 30 ML/d released from 9 March onwards due to the installation of fish baffles[17] to enable fish passage between the two lakes. The baffles were installed at the request of DPI Fisheries via the HBWG.

In the period of 6 to 14 March, WaterNSW was releasing, on a declining basis, between 4,000 and 2,000 ML a day, with over 95% of this 'better quality' water from Lake Pamamaroo. These release rates continued during the time of the major fish death events on 15 and 16 March 2023.

Separately, the Wetherell outlet regulator was closed by 28 February. From this date, WaterNSW was not actively making releases from Lake Wetherell, but there was minor leaking which was caused by an accumulation of silt and organic matter around the gate seals of the Wetherell outlet regulator.[18]

Following the fish deaths, DPE Water and the MDBA requested independent advice from Professor Darren Baldwin, an expert in freshwater ecology with rivers and wetlands on hypoxic blackwater events, including the fish death event in 2022-23. As indicated by

[16] These e-water holders include the Commonwealth Environmental Water Holder (CEWH) and NSW DPE Environment and Heritage (EHG). Decisions by the e-water holders to place orders were made in consultation with the HBWG.

[17] A temporary structure installed on the face of a regulator to support fish passageway .

[18] Such minor leakage is a normal and expected outcome associated with gate seals on the inlet/outlet regulators, as is in place in the Menindee Lakes, particularly after a year of significant flooding.

Professor Baldwin, "*if there were any inflows into Lake Pamamaroo from Lake Wetherell immediately prior to the fish deaths, they would be best described as trivial*[19]".

Notably, the flood conditions were ideal for the accumulation and growth of large amounts of algae[20], reflected in algae biovolumes in the February/March period (see **Figure 3** below)along with dissolved oxygen measured at the Menindee town gauge.[21]

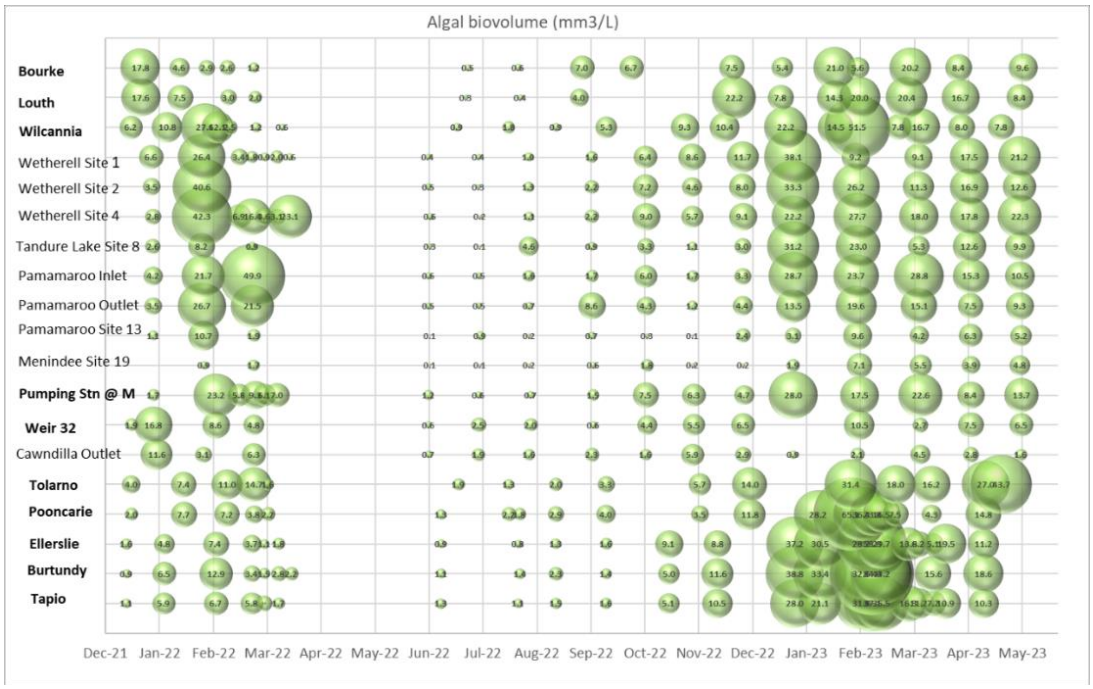

Figure 3-Bubble graph of the total algae (algae + cyanobacteria) biovolumes of the Darling River system from December 2021 to May 2023. Bubble size indicates concentration level while the sampled sites are located form upstream (top) to downstream (bottom).

[19] 'A critical evaluation of Williams and Schulz (2023)' Professor Darren Baldwin, *Rivers and Wetlands*

[20] Algae production along with the high flows would have meant that algae biomass would have been much higher than under most normal conditions. As algae are primary producers, they would have the potential to increase productivity of bacteria, protozoa, macroinvertebrate and ultimately, fish in the system. All of these consume oxygen.

[21] Dissolved Oxygen - Field (mg/L) of 1.3 on 27 February 2023, 2.55 on 8 March 2023, and 1.39 on 14 March 2023.

Release Images

Figure 4- Release volumes, 27 February 2023

Figure 5- Release volumes, 6 March 2023

Figure 6- Release volumes, 9 March 2023

Figure 7- Release volumes, 13 March 2023

Figure 8- Release volumes, 14 March 2023

Figure 9- Release volumes, 15 March 2023

Figure 10- Release volumes, 16 March 2023

Water Quality Monitoring

As part of our role in providing water quality monitoring services for other agencies in Menindee Lakes, WaterNSW collects and shares data for a range of water quality analytes at various sites within the lakes and Darling-Baaka River. WaterNSW also completed additional monitoring on request of the HBWG in February, March 2023 and onwards. For example, dissolved oxygen testing was undertaken by WaterNSW throughout the event, made available online as NSW Murray-Darling Basin dissolved oxygen water quality updates.

Work done following the fish deaths onwards included collection of water samples for testing by the EPA, deployment of additional temporary DO monitoring sensors and daily monitoring of dissolved oxygen along the reach between Lake Pamamaroo Outlet and Weir 32. WaterNSW also completed 18 longitudinal profile runs and 13 days of vertical profiles between 22 March and 27 June 2023.

Communications

WaterNSW utilised a suite of engagement and communication tools during the event to keep the community updated:

- Operations updates **-** *An outline of key decisions and changes which was widely distributed to the community and internal and external stakeholders and published on the WaterInsights portal.*
- Community engagement - *Ongoing engagement including attendance at community and stakeholder meetings and responding to public enquiries.*
- Government relations/engagement- *Ongoing engagement with local/regional mayors and representatives. Providing regular updates to the Minister and responding to ministerial requests and enquiries.*
- Media **-** *Ongoing liaison, interviews, and release of key information to media agencies.*
- Early Warning Notification (EWN) - *57 x Early Warning Notifications (for flood notifications) were issued to customer and stakeholders registered to the Murray & Lower Darling-Baaka Customer Notices Group between 23 May 2022 and 10 February 2023.*
- WaterInsights **-** *Customers/stakeholders who signed up for notifications via WaterInsights were notified via email/text when an update was made to WaterInsights.*
- Menindee daily operations emails **-** *Distribution of daily Menindee Lakes water readings to an extensive internal/external email list.*

Timeline

Below is a timeline of WaterNSW's major operational activities in Menindee Lakes from November 2021 to March 2023.

Disclaimer: Operational release changes are noted on the day a direction/order/request is submitted (depending on when operators make the change, flow rate may not reflect the date of change).

Date	Activity	Nature of Release:
December 2021 – September 2022	• On the back of flows from the Northern Basin of the State, the Menindee Lakes storages were about 110% (~1900 GL) full at the beginning of December 2021. • Throughout 2022, rainfall events continued to occur frequently across NSW, resulting in regular increases at Menindee Lakes and the inflow forecast. • During this period, WaterNSW managed releases from Menindee Lakes in line with its regulatory and statutory obligations, particularly to manage flooding in Menindee Town. • On request from the HBWG, WaterNSW installed dissolved oxygen sensors at two surface water sites – within the permanent site at Weir 32 and a temporary site at Nelia Gaari, upstream of Lake Wetherell.	WaterNSW Works Approval
October – November 2022	• On the 10th of October the HBWG is reactivated (after meeting through summer of 2021/22). • WaterNSW began additional DO monitoring and reporting on behalf of the HBWG for the Menindee Lakes and the Darling-Baaka River.	WaterNSW Works Approval

Date	Activity	Nature of Release:
	• While floodwaters had been entering the Menindee Lakes for months, larger flows – originating from rainfall events in the northern Murray-Darling basin, as far away as Queensland in the months prior – started to enter the Menindee Lakes system. WaterNSW increased releases from the Menindee main weir to pass these flows and support generation of additional airspace in the lakes. • Floodwater continued to arrive into the Darling-Baaka River below Weir 32 via the Tallywalka Creek, causing some backwater impacts to the bottom end of the weir pool (near Weir 32). • The approx. release rate was 30,000 ML/d from the system at Weir 32 by end of November 2022 to create airspace in the storages. • WaterNSW continued to maintain surface water monitoring sites, as well as collecting routine and additional requested water samples for algal analysis.	
Late November – mid December 2022	• With larger volumes forecast to enter the Lakes, the main weir gates were fully raised in the last week of November. This allowed upstream inflows to safely pass through, enabling WaterNSW to release the maximum amount of water possible. This created over 300 GL of airspace, while also providing the added benefit of enabling fish migration upstream. • The main gates were then reinstated on 20 December 2022 as flood water started to arrive from upstream and releases had to be scaled	WaterNSW Works Approval

Date	Activity	Nature of Release:
	back to help minimise flooding impacts. These measures aimed to restrict those larger inflows from passing directly through the Menindee Lakes and causing larger and earlier flooding in the town.	
End of December 2022	• Flows greater than forecast started entering the Lakes system on the back of higher-than expected flows returning from the floodplain via the Talyawalka Creek, which had branched out across the floodplain and re-joined the main channel of the Darling-Baaka River upstream of the lakes. The sheer volume of water entering the system reduced all the available airspace within the Lakes, however, WaterNSW was able to 'surcharge' Lake Wetherell and make releases through the main gates to temporarily hold back some of the flood. • While these actions effectively reduced the height of the flood at the Menindee town gauge (from an estimated 10.7 m down to 10.2 m), excess water flooded some parts of the Menindee township. • On 31 December, the combined volumes of the Menindee Lakes almost reached their maximum surcharge level (2,049 GL). • Releases varied during this period totalling a flow at Weir 32 between 30,000 and 40,000 ML/d until higher flows arrived at the end of December. • WaterNSW continued to maintain surface water monitoring sites, as well as collecting routine and additional requested water samples for algal	WaterNSW Works Approval

Date	Activity	Nature of Release:
	analysis and DO. Water Monitoring teams completed additional flow gauging activities.	
1-13 January 2023	• The release from Main Weir peaked on 1 January 2023 with a flow around 79,000 ML/d. From then, high releases continued until 13 January 2023 (more than 70,000 ML/d). • These rates continued for a week to ensure the protection of the dam structures and alleviate some of the flooding impacts. • Flooding at Menindee town reached a peak of 10.26 m on 6 January 2023. WaterNSW continued to maintain surface water monitoring sites, as well as collecting routine and additional requested water samples for algal analysis and DO. These continued throughout the following months. • Water monitoring teams completed additional flow gauging activities. These continued throughout the following months.	WaterNSW Works Approval
14 January	• The recession in flood waters started to occur and releases from the storages gradually dropped. *Note: The recession releases made by WaterNSW followed rules set out in our works approval.*	WaterNSW Works Approval
10 February	• Menindee town reached below 8.5 m which is below minor flood level.	WaterNSW Works Approval
17 February	• Main weir closed as per standard procedural requirements as main weir releases were no longer required for flood operations.	N/A

Date	Activity	Nature of Release:
24 February	• Given the DO levels, a direction was given from DPE following consensus advice by the HBWG for WaterNSW to: 1. Close Pamamaroo inlet regulator, except the Pamamaroo inlet gate with the fishway baffles installed (request by NSW Fisheries to reduce low DO water entering Lake and support fish passage). *WaterNSW action: Pamamaroo Inlet Regulator fully closed by 28 February (Fishway baffles* which *required machinery and resources for reinstalling were installed on 8 March).* 2. If possible (noting the constraint at the regulator between lakes Wetherell and Pamamaroo), increase flows from Lake Pamamaroo outlet (into Pamamaroo Creek) so they are maintained above current levels (3,200 ML/day). *WaterNSW action: Increased outlet releases to 4300 ML/d in steps - achieved 28 February.* 3. Reduce or cease releases from Lake Wetherell to ensure no low DO water enters the river downstream. *WaterNSW action: Flows reduced from 2430 ML/d to 0 ML/d by 5 March.* 4. Reduce releases from Lake Menindee outlet by 500 – 1000 ML/day to prevent water backing up into the river channel upstream.	Beginning the use of 30 GL of water from Water Quality Allowance by DPE-Water as instructed by the HBWG. WQA (30 GL) releases started 24 February and were completed on 16 March 2023.

Date	Activity	Nature of Release:
	WaterNSW action: Starting on 25 February at 3800 ML/d, reducing down to 3000 ML/d by 2 March. • The HPWG also requested WaterNSW to undertake monitoring in the Darling-Baaka River between Main Weir and Weir 32, so it could assess this management action. *WaterNSW action: Collected additional dissolved oxygen data at sites suggested by the HBWG.*	
28 February	• Menindee Lakes return to Full Supply Level.	
3 March	• Direction from DPE following consensus advice by the HBWG for WaterNSW to continue the release volumes from Lake Pamamaroo and Lake Menindee on 6 March, then commence the recession at the rate of 250 ML/day. This was in order to reduce fish deaths in the weir pool and impact DO. *WaterNSW Action: Actioned.*	Water Quality Allowance
8 March	• As per a formal request by HBWG on 24 February, WaterNSW reinstalled fishway baffles to allow fish passage through Pamamaroo inlet. This meant a minor flow from Pamamaroo inlet into Lake Pamamaroo of ~30 ML/day.	Water Quality Allowance
13 March	• Direction from DPE following consensus advice by the HBWG for WaterNSW to decrease Pamamaroo outlet flow by 500 ML/d and	Water Quality Allowance

Date	Activity	Nature of Release:
	increase Menindee outlet flow by 250 ML/d until further notice. *WaterNSW Action: Actioned.*	
15 March	• Direction from DPE following consensus advice by the HBWG for WaterNSW to increase Pamamaroo outlet flow from 750ML/d to 1250ML/d)(achieve a 30:70 ratio of water between Pamamaroo and Menindee outlets). *WaterNSW Action: Actioned.* • The Lower Darling-Baaka Technical Advisory Group (TAG) meets, and reports fish have died in the Menindee town weir pool overnight. Major heatwave commenced.	Water Quality Allowance
16 March	• Direction from DPE following consensus advice by the HBWG for WaterNSW to increase Pamamaroo outlet flow to 1500 ML/d and decrease Menindee outlet to 3500 ML/d. *WaterNSW action: Actioned*	Held Environmental Water- 'The Living Murray' (as WQA has run out)
19 March	• Direction from DPE following consensus advice by the HBWG for WaterNSW to increase releases from 2900 ML/day to 4000 ML/day at Lake Menindee (near maximum capacity). *WaterNSW action: Actioned.*	Held Environmental Water- 'The Living Murray'
20 March	• WaterNSW maintains 1350 ML/day release from Pamamaroo and Menindee at 4000 ML/day.	Held Environmental Water- 'The Living Murray'

Date	Activity	Nature of Release:
22 March	• WaterNSW Water Monitoring team collected water samples on behalf of the EPA. Samples handed to EPA for transport and analysis. • WaterNSW Water Monitoring team commenced daily vertical and longitudinal profiling. This continued for several months, at a frequency and at locations determined by the HBWG.	Held Environmental Water- 'The Living Murray'
23 March	• WaterNSW Water Monitoring team installed DO sensors at two additional locations in Darling-Baaka River – Menindee town and Menindee water treatment plant intake. Data available on public-facing websites.	Held Environmental Water- 'The Living Murray'

Observations

In response to this Review, WaterNSW raises the following matters for consideration by the Chief Scientist & Engineer:

a) Responsibility for Regional NSW Water Quality and Catchment Protection

There is currently no legislative requirement for any agency or organisation to monitor and respond to hypoxic blackwater risks. WaterNSW, despite the common misconception, does not have a role in managing water quality in regional areas (it does perform this role in Greater Sydney) with the exception of monitoring cyanobacteria (blue-green algae) and issuing associated alerts. Despite this, DPE-Water has taken the lead on establishing the HBWG to help fill this gap, and the agencies who sit on the working group have worked collaboratively to achieve outcomes for the benefit of the environment, water users and the public, in the absence of any statutory framework.

WaterNSW also observes a disparity in the management of water quality through catchment protection programs between that in our Greater Sydney operations (for which we have a statutory function and objective), and for regional NSW where there is no equivalent. Catchment protection programs in Greater Sydney, where WaterNSW works in partnership with landholders adjacent to the declared catchments and related waterways, has been shown to improve water quality outcomes.

WaterNSW recommends that the legislative oversight of monitoring and responding to hypoxic blackwater events, and the opportunity for a catchment protection objective focussed on water quality outcomes in regional NSW, are reviewed.

b) Water Quality Monitoring Sites Coverage

WaterNSW would – noting our role *"carrying out water monitoring… to meet the needs of DPE Water and NRAR"*[22], and not the agency with responsibility for funding or determining locations of permanent monitoring instruments – be willing to work with other government agencies to explore the installation of permanent DO sensors at agreed locations on the Barwon-Darling River.

[22] Roles and Responsibilities Agreement, clause 2.4 (iii)
https://water.dpie.nsw.gov.au/__data/assets/pdf_file/0003/389100/roles-and-responsibilities-agreement.pdf

However, it is worth acknowledging that any placement of sensors must be understood in the context of:

- The complexity, length, and varying hydrology of the ~40 km stretch of river between Main Weir and Weir 32.
- The limitations of DO sensors, such as depth of monitoring and limitation during events such as drought.

WaterNSW recommends that a detailed assessment is undertaken to scope locations of new sites that would contribute additional data points for dissolved oxygen monitoring to inform community and operational outcomes.

Further, similar to WaterNSW's Early Warning Network for water releases or Blue Green Algae monitoring, a system of better warning systems of low DO levels could also be explored.

c) Fishways

As the lack of fish passage at Main Weir and at the Lake Wetherell and Lake Pamamaroo outlets prevented the passage of fish, one potential solution to address this is accelerating the provision of fishways in the Menindee Lakes system.

While WaterNSW acknowledges solutions have been explored as part of the Menindee Lakes Sustainable Diversion Limit Adjustment Mechanism (SDLAM) project, options to investigate accelerating fish passage around the structures at the Main Weir, Pamamaroo outlet and Wetherell outlet would provide an ability for fish to migrate further upstream. This could help prevent a massive congregation of fish below Main Weir, as occurred in the lead up to this fish death event.

d) Infrastructure Options

Given the possible 'mixing' of flows into Lake Pamamaroo following releases from Lake Wetherell through the Pamamaroo Inlet Regulator, there is the option to assess infrastructure options (such as a curtain 'diversion' structure) to separate inflows.

e) Fish Health Strategies

While outside of its functions and responsibilities in the Menindee region, in recent years WaterNSW has supported the work of other agencies and organisations in exploring solutions to predicting and responding to fish death events. This includes operational responses on WaterNSW assets, scientific research into new methods and the development of predictive tools.

Most of these responses have been deployed on an ad hoc basis and their full deployment is contingent on additional funding and clarity on roles and responsibilities between agencies.

Information on this work is provided in **Appendix C** for the Chief Scientist & Engineer's consideration. WaterNSW would be pleased to provide further information on these projects if required.

f) Communications

Over the course of the successive flooding events and subsequent fish deaths, WaterNSW (along with other agencies) regularly communicated with customers and the public (see **Communications**).

The communication provided in the months before the fish deaths event emphasised the high likelihood of the event, but not the scale due to factors such as the time available and ideal conditions for some species to multiply in number. Despite this, in WaterNSW's opinion the risks associated with hypoxic blackwater and the efforts by the HBWG were not fully understood by the community at the time.

To address this, WaterNSW recommends that alternative communications tools are explored, including:

- Development of a communications protocol for the HBWG.
- Development of a new communications channel, for example a standalone website, and other engagement channels.
- Consideration of utilising more diverse and potentially less conventional channels to capture a wider audience.

Appendix A- The Menindee Lakes System

The present-day Menindee Lakes Scheme consists of four large, shallow lakes - Wetherell, Pamamaroo, Menindee and Cawndilla - along with several smaller interconnected lakes. The lakes are located near the town of Menindee in far-west NSW, 100 km south-east of Broken Hill. The lakes cover an area of 457 km^2 at full supply level (FSL) which, combined with the semi-arid climate, can result in losses to evaporation of between 400 and 800 GL per annum.

The combined storage capacity of the lakes is 1,731,000 ML (1,731 GL) at FSL. The lakes can be surcharged to a maximum of 2,050 GL (Table 1). However, each lake has its own characteristics, including storage at FSL, and maximum induced surcharge level (MISL). Additionally, there are limits on the rates at which water can pass through and/or be released through the various inlet and outlet regulators between and out of the lakes, as described below.

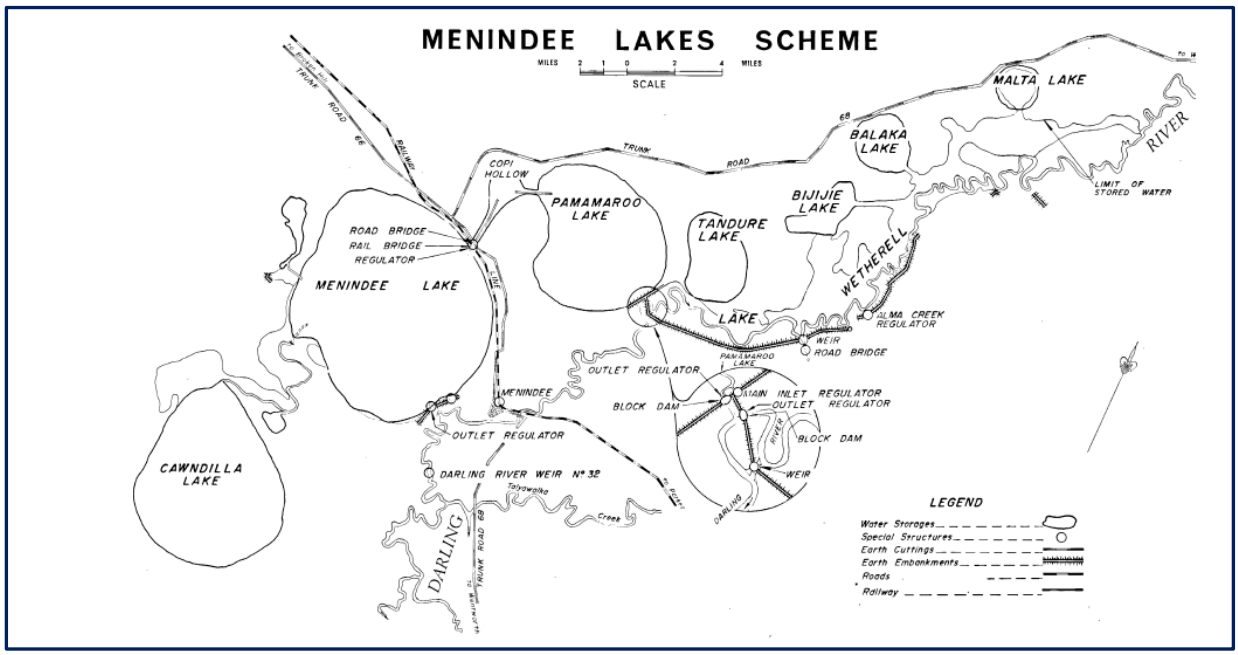

Figure 11- Plan of the Menindee Lakes Scheme. Source Menindee Lakes Storage Operation and Maintenance Manual, Figure 1, DOC13/13246

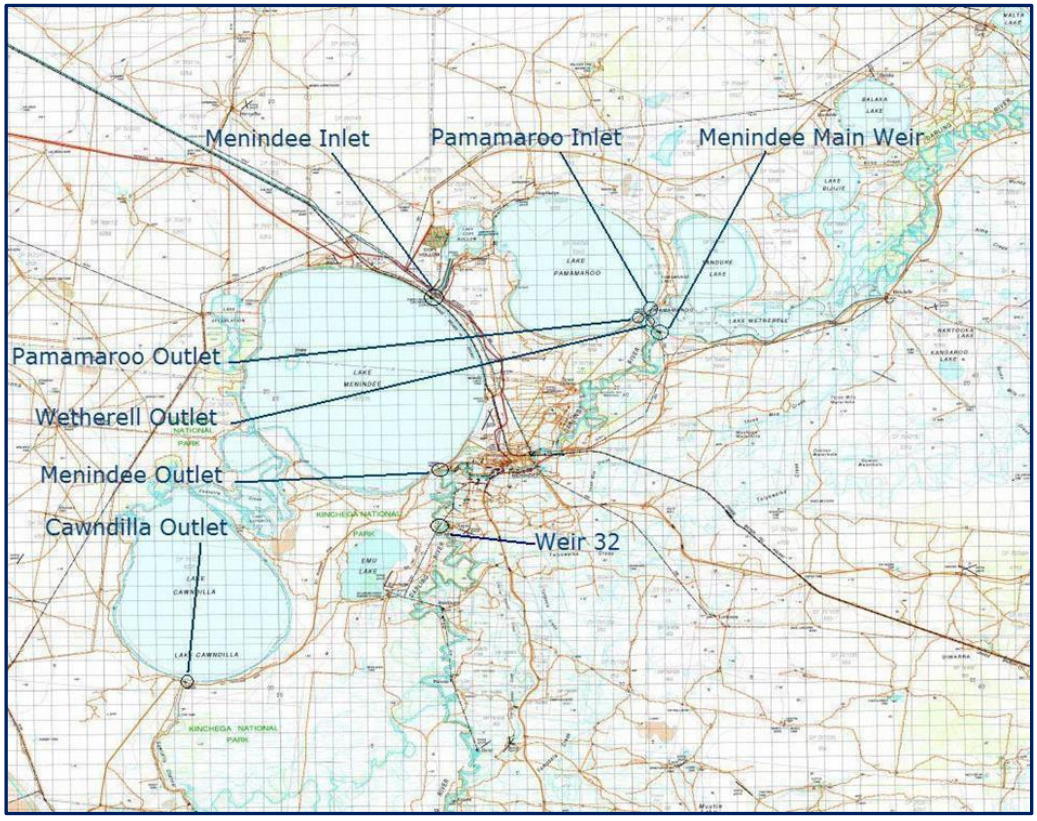

Figure 12- The main structures of the Menindee Lakes scheme. Source - Menindee Lakes Storage Operation and Maintenance Manual, Figure 2, DOC13/1324

Storage levels in the lakes' are summarised in the table below. The full supply level (FSL) for the various lakes is tabulated under 'Normal Conservation' level, also known as 'restricted levels'. Storage up to these levels can occur at any time. Operation over the years has allowed some surcharging of the lakes above these levels, to varying extents.

Summary of Menindee Lakes storage levels and capacities

Lake	Normal Conservation (Full Supply Level)		Maximum Surcharged	
	Storage Level (AHD)	Storage Capacity (ML)	Storage Level m AHD	Storage Capacity (ML)
Wetherell	61.67	192,950	62.30	262,150
Pamamaroo	60.45	277,724	61.50	353,060

Menindee and Cawndilla[1]	59.84	1,260,542	60.45[2]	1,434,760
Total		**1,731,216**		**2,049,970**

[1] *At full supply level, Menindee and Cawndilla storages are connected.*

[2] *The maximum approved surcharged level for Lakes Menindee and Cawndilla was restricted in ~1994 to protect sites of cultural significance.*

The main weir on the Lower Darling-Baaka River raises the water to 12 metres above riverbed level and forms Lake Wetherell. Water can then flow under gravity, even during low flow conditions, from Lake Wetherell downstream into Lakes Pamamaroo, Menindee and Cawndilla via two inlet regulators. Water can also be released from the Main Weir into the Lower Darling-Baaka River.

Releases can be made from Lake Menindee, Lake Pamamaroo and Lake Wetherell into the Lower Darling-Baaka River via outlet regulators. A gauge downstream of Menindee at Weir 32 is used to measure the total release into the lower Darling-Baaka River. Releases can also be made from Lake Cawndilla for supplying environmental flows along the Great Darling Anabranch.

The Cawndilla outlet can only release ~2 gigalitres per day, a small volume that is comparable to the combined daily summer evaporation rate from Lakes Cawndilla and Menindee.

WaterNSW keeps as much water as possible in the upper lakes (Lakes Wetherell and Lake Pamamaroo) to provide for drought security for when the lakes return to NSW control at 480 GL. The upper lakes primarily supply water to the local community and the lower Darling-Baaka.

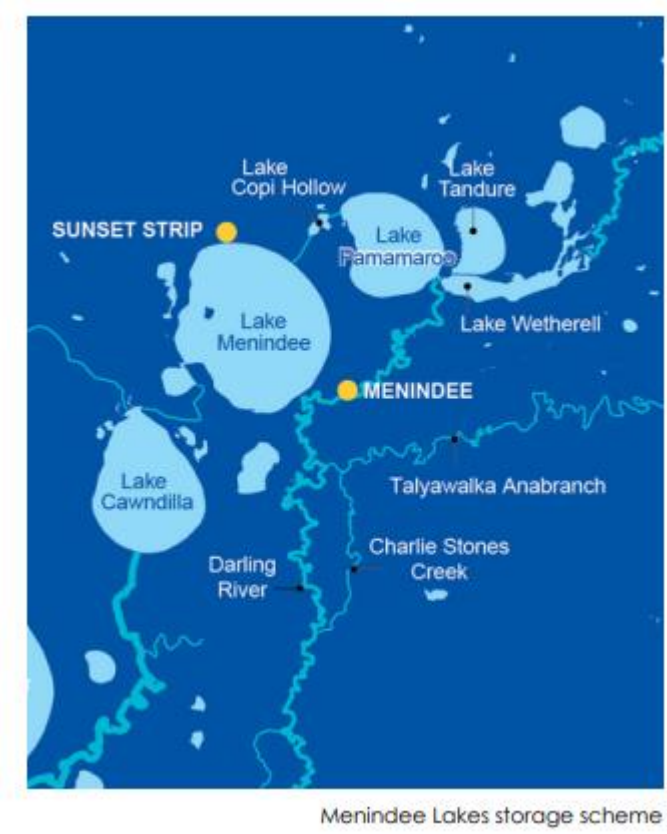

Figure 13- Menindee Lakes Storage Scheme

Main Weir and Lake Wetherell

Lake Wetherell is the river diversion storage formed upstream of the other lakes by a block dam in the river, Main Weir and a series of levees, mostly on the eastern side of the river, some 32 km long. The main block dam across the Lower Darling-Baaka River diverts the river flow through Main Weir and the Pamamaroo Inlet Regulator. Water can be released directly back into the river through Wetherell Outlet Regulator or through the Main Weir.

The Main Weir that creates Lake Wetherell is the largest concrete and steel structure in the Menindee Lakes Storage Scheme. The weir has been constructed in a bend of the river and is fitted with six electrically operated vertical lift steel gates, each 12.2 m wide by 4.9 m high, to discharge high river flows to the lower part of the Darling-Baaka River. The Main Weir can store water to a level approximately 8.7 m above the bed level, or up to 62.30 m AHD. The elevated level also diverts flows into Lakes Malta, Balaka, Bijijie and Tandure. Water also flows through Pamamaroo Inlet Regulator into Lake Pamamaroo and through Lake Pamamaroo into Lake Menindee and Lake Cawndilla.

The levee between Lake Pamamaroo and the Main Weir is called the West Levee (1.3 km long). The Wetherell Outlet Regulator was constructed in a channel beside the Lower Darling-Baaka River and pierces the West Levee to discharge water into the original riverbed. This structure has a maximum discharge capacity of 4,500 ML/d. The gate tower contains two radial gates.

Figure 14- Lake Wetherell upstream of Main Weir, 1 February 2023)

The levee extending from the Main Weir to sand hills at Windalle Homestead is called the East Levee and is 16 km long. A major feature of the East Levee is a fuse plug spillway designed to be intentionally failed in the event of very large floods, to prevent overtopping of the levees downstream, and possible failure of the Main Weir. The design flood of the current fuse plug spillway is 220,000 ML/d. The Main Weir capacity is 110,000 ML/d, requiring a fuse plug discharge of 110,000 ML/d. Details of the activation orders and relative heights are set out in the Dam Safety Emergency Plan (DSEP). There is also a small uncontrolled spillway (sheet piles and rockfill) located through the East Levee at Three Mile Creek. Flood waters can flow through the Three Mile Creek spillway and the fuse plug spillway into the Talyawalka Creek and then join the Lower Darling-Baaka River downstream of Menindee township.

Figure 15-Main Weir, 1 February 2023 releasing ~25,000 ML/d.

Lake Pamamaroo

Lake Pamamaroo adjoins Lake Wetherell for a short distance near Pamamaroo Inlet Regulator. This regulator allows water to flow from Lake Wetherell to Lake Pamamaroo through 15 steel radial gates, 3.66m wide x 2.81m high (Figure 15). The maximum capacity of Pamamaroo Inlet Regulator is 33,000 ML/d.

The Pamamaroo Outlet Regulator is located in an excavated channel beside the bed of Pamamaroo Creek. It discharges into Pamamaroo Creek and then into the Lower Darling-Baaka River. This structure has a maximum capacity of 4,500 ML/d. The gate tower contains two radial gates.

The Interconnecting Channel connects Lake Pamamaroo with Lake Menindee. Water leaves Lake Pamamaroo near its western end, and after flowing through Copi Hollow, which is a natural depression, passes along the Interconnecting Channel to the Menindee Inlet Regulator. The Menindee Inlet Regulator allows water to be stored in Lake Pamamaroo at a higher level than in Lake Menindee and controls the flow rate into Lake Menindee.

Figure 16- Pamamaroo Inlet Regulator, 1 February 2023 .

Lake Menindee

Lake Menindee is the largest of the Lakes in the Menindee Lakes Storage Scheme and is situated west of the township. Water enters through the Menindee Inlet Regulator (Figure 16), which comprises 15 radial gates, 3.66 m wide x 2.81 m high. The Menindee Inlet Regulator has a maximum capacity of 25,000 ML/d.

Figure 17-Menindee Inlet Regulator, 1 February 2023.

The lake has a substantial levee along its south-eastern side, passing over Menindee and Little Menindee Creeks. The Menindee Outlet Regulator is located in an excavated channel under the levee beside Menindee Creek, which joins the Lower Darling-Baaka River downstream of the township of Menindee. This structure has an intake tower, a gate tower, and two radial gates. The outlet's maximum capacity is 4,500 ML/d.

Lake Cawndilla

Cawndilla is the southern-most lake. It is connected to Lake Menindee by Cawndilla Creek, which allows water to flow in either direction depending on the head difference. Above a storage level of 55.5 m, Lakes Cawndilla and Menindee retain water to the same storage level.

Water from Lake Cawndilla can be released through the Cawndilla Outlet Regulator (Figure 11) which is located in sandhills at its southern side. This regulator has an excavated channel leading to Tandou/Redbank Creek and then to The Great Anabranch of the Darling-Baaka River. It has an intake tower, and a gate tower with a single radial gate. The Cawndilla Outlet Regulator has a maximum capacity of 2,000 ML/d.

Water can also be released from Lake Cawndilla back to the Lower Darling-Baaka River through Cawndilla Creek and Lake Menindee and then through the Menindee Outlet Regulator until Lake Cawndilla falls to the bed level of Cawndilla Creek. At this stage water ceases to flow back into Lake Menindee.

Structure	Capacity ML/d	Comments
Main Weir	110,000	Under flood conditions
Wetherell outlet	5,000	
Pamamaroo outlet	4,500	Reduces as lake falls
Menindee outlet	4,500	Reduces, with backwater from other outlets, and as lake falls
Cawndilla outlet	2,000	
Pamamaroo inlet	33,000	
Menindee inlet	25,000	

Main structures and operating capacities in the Menindee Lakes Scheme

Appendix B- WaterNSW meetings

In addition to fora mentioned in this document, WaterNSW also holds regular meetings with key stakeholders including:

- Bureau of Meteorology (BoM)
- State Emergency Service (SES)
- Murray Darling Basin Authority (MDBA)

  The aforementioned agencies met regularly to share information. The frequency of these meetings varied depending on urgency. The meetings were an opportunity for WaterNSW to gain weather and forecasting advice from BoM, while the SES provided flood emergency and on-the-ground advice. These meetings were key to providing WaterNSW with information to make operational decisions.

- Department of Planning & Environment – Water (DPE)

  WaterNSW works with the DPE and MDBA in undertaking water quality monitoring in Menindee Lakes and Darling-Baaka River. These relate to DO and algae. There is heightened engagement during floods to manage hypoxic blackwater events which could lead to fish deaths. WaterNSW provides any additional monitoring identified by the Hypoxic Water Group led by DPE.

- Local Emergency Management Committee (LEMC)

  WaterNSW participated in the Local Emergency Management Committee (LEMC). The committee is responsible for the prevention of, preparation for, response to and recovery from emergencies and disasters within the local government area. These responsibilities include activities such as the development of emergency management plans, emergency risk management, multi-agency training and exercises, and supporting combat agency public education programs.

  The LEMC membership includes local representatives from NSW Police, NSW Rural Fire Service, State Emergency Service, Fire and Rescue NSW and other support agencies. The Chair of the LEMC is a council appointed staff member who also sits on the Regional Emergency Management Committee.

WaterNSW also held and/or participated in the following meetings:

- WaterNSW - Murray-Lower Darling-Baaka Customer Advisory Group (CAG) meetings

  Held with WaterNSW and key customer stakeholders. During the event, two meetings were held (20 July 2022 and 2 November 2022). Due to the flooding events in November, the usual face to face meeting was changed to a 30-minute operations discussion held via MS Teams with CAG members to update on current flood actions.

- WaterNSW - Menindee Lakes Airspace Reference Panel Meeting

  A meeting between WaterNSW and Menindee Lakes stakeholders and key agencies to discuss rain forecast and airspace targets.

- WaterNSW - Murray ROSCCo (River Operations Stakeholder Consultation Committee)

  An open meeting with WaterNSW and Murray River stakeholders and interested parties to discuss operations and gain feedback.

- WaterNSW – Lower Darling-Baaka ROSCCo (River Operations Stakeholder Consultation Committee)

  An open meeting with WaterNSW and Murray River stakeholders and interested parties to discuss operations and gain feedback.

- SES – Menindee Community/Town Hall Meeting

  A community meeting organised by SES and attended by WaterNSW staff, NSW Police, local councils and other key agencies and stakeholders to discuss emergency issues relating to Menindee Lakes.

Appendix C-Fish health strategies previously assessed by WaterNSW

Previous research undertake by WaterNSW in fish health includes:

i. **Development of the Fish Health Risk Indicator**

In response to the fish death event that occurred in Menindee in December 2018 and January 2019, WaterNSW's science team developed a new modelling approach to predict areas where fish populations may be at risk.[23]

WaterNSW developed a Fish Health Risk Indicator – a geographic information system (GIS)-based tool that combines meteorological forecasts with river flow and algal biomass datasets to identify river reaches where additional stresses on fish health may produce an increased risk of mass fish deaths.

Despite the tool being in its development stage, the decision support tool has the potential to provide natural resource managers with a rapid way to understand and communicate risks to fish health, supporting improved water management options across the Murray–Darling Basin that may ultimately help reduce the frequency and severity of large-scale fish death events.

To develop the tool further, additional datasets and funding is required (noting that WaterNSW is not currently funded to undertake this work).

ii. Installation of aerators to destratify storages

During the most recent drought, WaterNSW's regional storages in many cases were close to empty (including Burrendong Dam which reached as 2%). This presented water quality risks associated with stratification, with low oxygen and fish deaths occurring in inaccessible water (or 'dead storage') and downstream refuge pools once flows ceased.

In consultation with DPI Fisheries, WaterNSW identified destratification using aeration as the main management action available to prevent and mitigate these water quality issues.

The following solutions were trailed during the 2019/20 summer:

---

[23] Davie AC, Pera J B. 2001. 'The Fish Health Risk Indicator: linking water quality and river flow data with fish health to improve our predictive capacity around fish death events.' Marine and Freshwater Research.

- Solair solar aerators – Macquarie and Peel River refuge pools (aerator).
- Diesel-electric powered bubble plume mixer – Lake Burrendong and Keepit Dam dead storage (aerator).
- Xylem buoy and telemetered oxygen loggers – Peel River refuge pools (oxygen monitoring equipment).

In general, the solar aerators and bubble plume mixers were effective in mixing stratified pools and lakes and maintaining DO levels to support fish survival.[24] The solar aerators were removed prior to heavy rainfall and flooding.

The diesel-powered aerators in the lakes did prevent fish kills from blackwater inflows by creating a layer of well oxygenated water that fish could use as a refuge from the event. However, these aerators were expensive to run, due to their reliance on significant volumes of fuel.

The xylem buoy systems performed well but were vulnerable to damage by inflow events.

Overall, the trials indicate that while aerators may play a role in emergency responses to hypoxic fish deaths, they have limitations regarding their area of influence and river flows (at best thousands of square metres) and their cost to deploy and operate.[25] WaterNSW is however, investigating whether alternative power sources may prove more effective.

WaterNSW is not funded to operate aerators on any permanent basis. Any further consideration of regular deployment would be contingent on funding being made available.

iii. Cyanobacteria management approaches

As an alternative to aeration, which can be expensive to operate (particularly in remote locations without a direct power source), WaterNSW's science team trialled several treatment products on the market that may offer an alternative approach to cyanobacteria bloom prevention by manipulating the microbial ecology of a lake.[26]

---

[24] Boys CA, Baldwin DS, Ellis I, Pera J, Cheshire K. 2021. 'Review of options for creating and maintaining oxygen refuges for fish during destratification-driven hypoxia in rivers.'

[25] Baldwin DS, Boys CA, Rohlfs A, Ellis I, Pera J. 2021. 'Field trials to determine the efficacy of aerators to mitigate hypoxia in inland waterways. Marine and Freshwater Research.'

[26] Baldwin DS, Boys CA, Rohlfs A, Ellis I, Pera J. 2021. 'Alternative cyanobacteria management approaches.' x Water e-Journal Vol 6 No 2 2021.

The trials assessed how well the products controlled cyanobacterial growth, and their potential for adverse effects on water quality, treatability, and ecological health.

The laboratory trials provided some evidence to support the effectiveness and mode of action for specific treatments. However, the field trial found that destratification still had the strongest influence on cyanobacterial growth relative to other tested treatments. The trials provided many useful learnings regarding the effectiveness and safety of the treatment products, the circumstances where specific treatments might best be suited for deployment and the design of any future trials. The outcomes of this work will be used to evaluate the potential of these products for future use in managing cyanobacterial blooms in WaterNSW's supply storages.

iv. Hydro-carbon blocks

WaterNSW has also explored the use of a hydro-carbon block placed in water bodies which fights cyanobacteria, as has been proposed by some companies. From the trial conducted by WaterNSW in the Macquarie River in the 2019/2020 summer, WaterNSW found that:

- The product did not have a significant effect on cyanobacteria relative to controls.
- The strongest influence on cyanobacterial growth was oxygen stratification driven by high temperatures, which would not be altered by application of the hydro-carbon block.
- Application of the product at the recommended dosage rate would not be cost effective for large water bodies (such as Menindee Lakes and Barwon-Darling River).
- While the product may be effective against cyanobacterial growth in some circumstances, a flood-driven blackwater (lack of oxygen) event would override any impact of the TWC product on lake water quality.